

# Welcome

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## How to Start

When reading this, you should have downloaded the ZIP file for this product.

Unzip it and you will get a folder containing tutorials and related files. Please start with this PDF tutorial.

- ! Unzip the ZIP file instead of opening the file in the ZIP file directly.
- ! Do not move, delete or rename files in the folder just unzipped.

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Encounter problems? Don't worry! Refer to "TroubleShooting.pdf" or contact us.

When there are packaging damage, quality problems, questions encountering in use, etc., just send us an email. We will reply to you within one working day and provide a solution.

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Pay attention to safety when using and storing this product:

- This product is not suitable for children under 12 years of age because of small parts and sharp parts.
- Minors should use this product under the supervision and guidance of adults.
- This product contains small and sharp parts. Do not swallow, prick and scratch to avoid injury.
- This product contains conductive parts. Do not hold them to touch power supply and other circuits.
- To avoid personal injury, do not touch parts rotating or moving while working.
- The wrong operation may cause overheat. Do not touch and disconnect the power supply immediately.
- Operate in accordance with the requirements of the tutorial. Fail to do so may damage the parts.
- Store this product in a dry and dark environment. Keep away from children.
- Turn off the power of the circuit before leaving.

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## About

Freenove provides open source electronic products and services.

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

- Kits for learning programming and electronics
- Kits compatible with Arduino®, Raspberry Pi®, micro:bit®, ESP32®, etc.
- Kits for robots, smart cars, drones, etc.
- Components, modules and tools
- Design and customization

To learn more about us or get our latest information, please visit our website:

<http://www.freenove.com>

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## Prepare

ESP32 is a micro control unit with integrated Wi-Fi launched by Espressif, which features strong properties and integrates rich peripherals. It can be designed and studied as an ordinary Single Chip Microcontroller(SCM) chip, or connected to the Internet and used as an Internet of Things device.

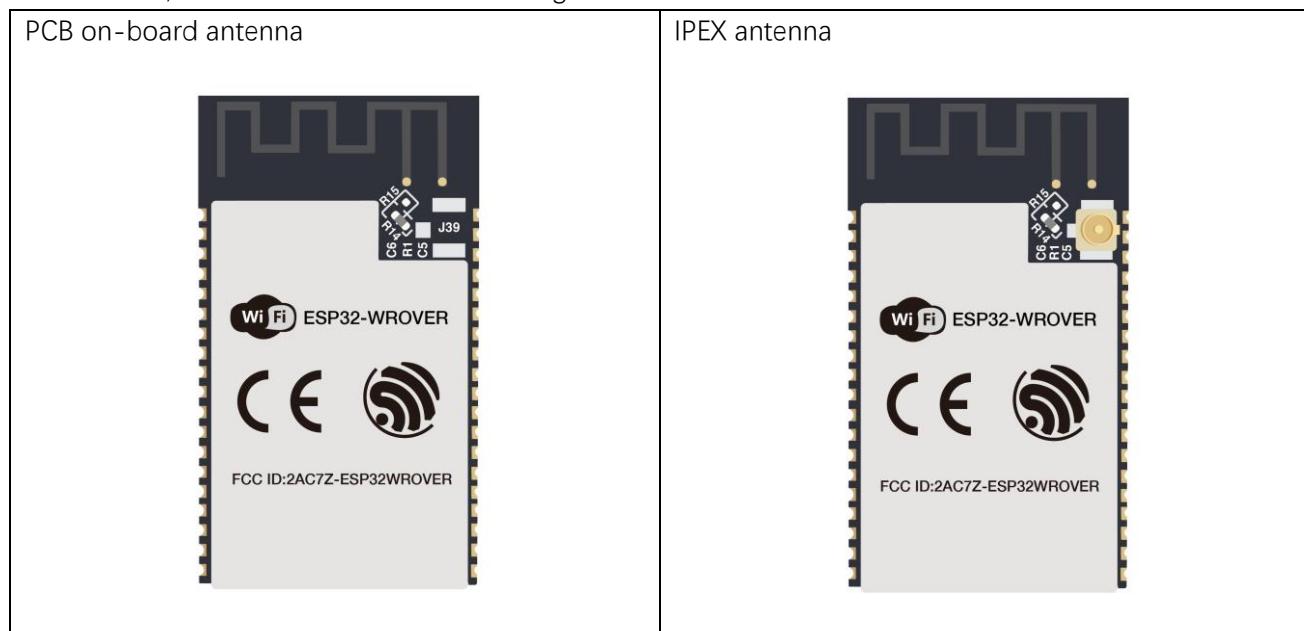
ESP32 can be developed both either with C/C++ language or micropython language. In this tutorial, we use micropython. With Micropython is as easy to learn as Python with little code, making it ideal for beginners. Moreover, the code of ESP32 is completely open-source, so beginners can quickly learn how to develop and design IOT smart household products including smart curtains, fans, lamps and clocks.

We divide each project into four parts, namely Component List, Component Knowledge, Circuit and Code. Component List helps you to prepare material for the experiment more quickly. Component Knowledge allows you to quickly understand new electronic modules or components, while Circuit helps you understand the operating principle of the circuit. And Code allows you to easily master the use of ESP32 and its accessory kit. After finishing all the projects in this tutorial, you can also use these components and modules to make products such as smart household, smart cars and robots to transform your creative ideas into prototypes and new and innovative products.

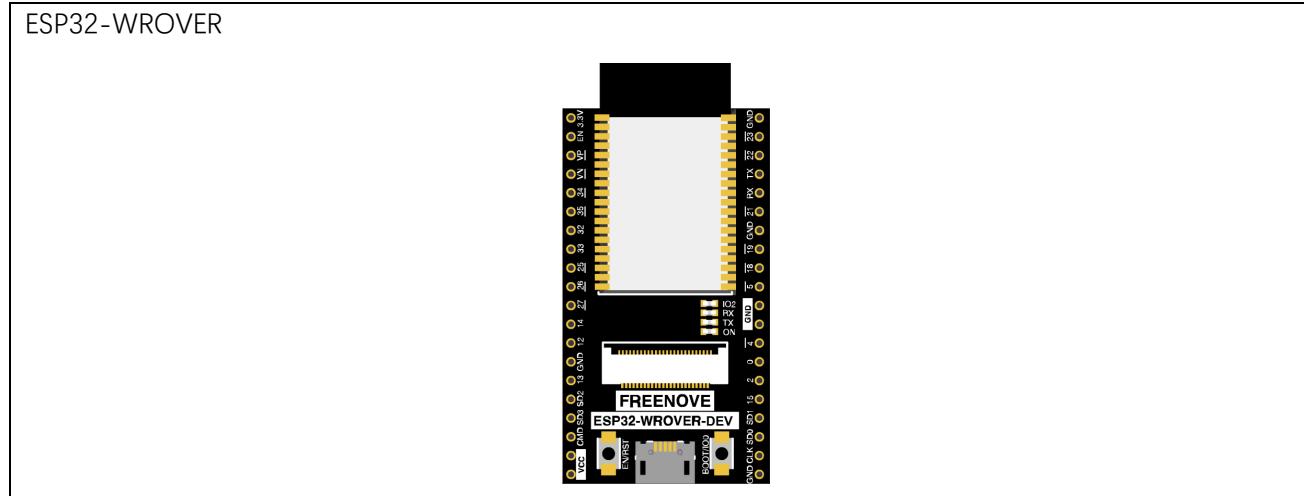
In addition, if you have any difficulties or questions with this tutorial or toolkit, feel free to ask for our quick and free technical support through [support@freenove.com](mailto:support@freenove.com)

## ESP32-WROVER

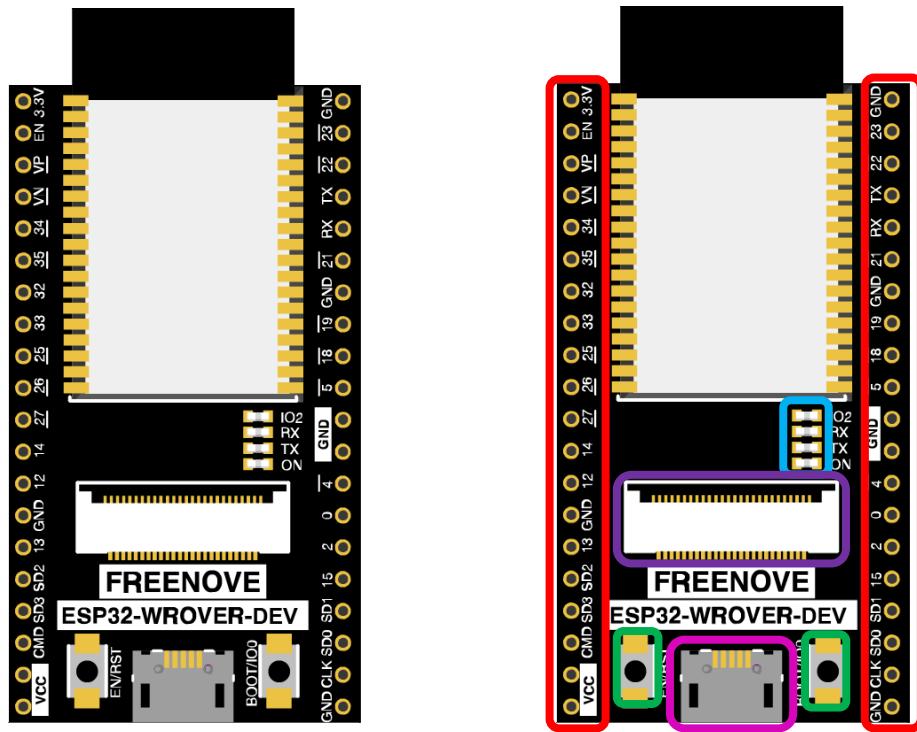
ESP32-WROVER has launched a total of two antenna packages, PCB on-board antenna and IPEX antenna respectively. The PCB on-board antenna is an integrated antenna in the chip module itself, so it is convenient to carry and design. The IPEX antenna is a metal antenna derived from the integrated antenna of the chip module itself, which is used to enhance the signal of the module.



In this tutorial, the ESP32-WROVER is designed based on the PCB on-board antenna package.



The hardware interfaces of ESP32-WROVER are distributed as follows:



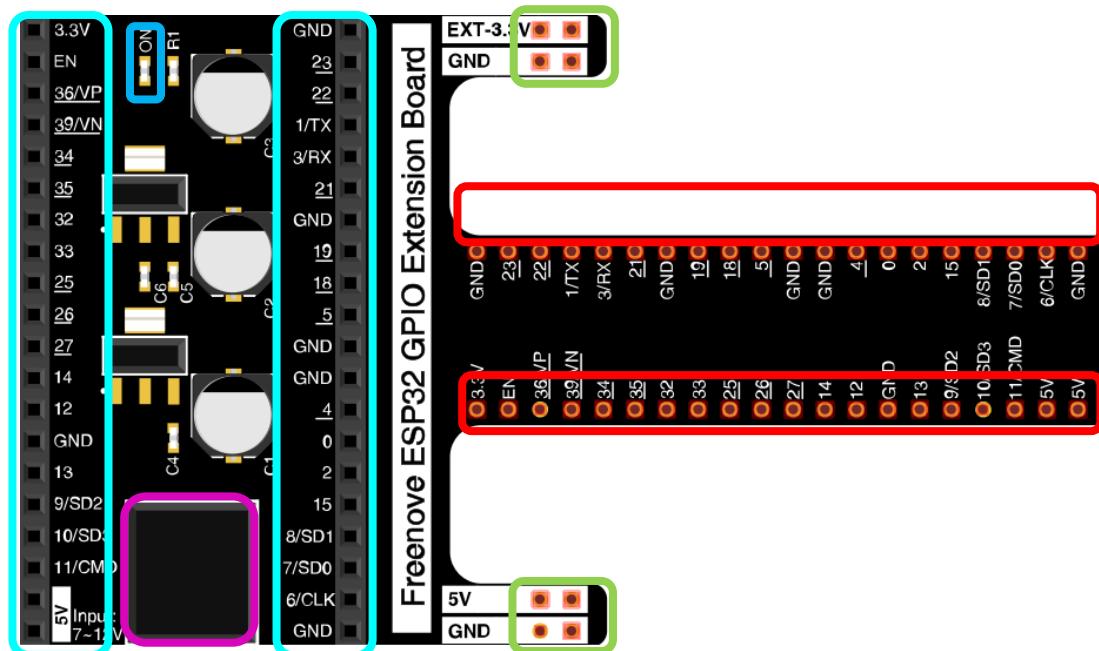
Compare the left and right images. We've boxed off the resources on the ESP32-WROVER in different colors to facilitate your understanding of the ESP32-WROVER.

Box color	Corresponding resources introduction
	<b>GPIO pin</b>
	<b>LED indicator</b>
	<b>Camera interface</b>
	<b>Reset button, Boot mode selection button</b>
	<b>USB port</b>

## Extension board of the ESP32-WROVER

And we also design an extension board, so that you can use the ESP32 more easily in accordance with the circuit diagram provided. The followings are their photos. All the projects in this tutorial are studied with this ESP32-WROVER.

The hardware interfaces of ESP32-WROVER are distributed as follows:



We've boxed off the resources on the ESP32-WROVER in different colors to facilitate your understanding of the ESP32-WROVER.

Box color	Corresponding resources introduction
	<b>GPIO pin</b>
	<b>LED indicator</b>
	<b>GPIO interface of development board</b>
	<b>Power supplied by the extension board</b>
	<b>External power supply</b>

In ESP32, GPIO is an interface to control peripheral circuit. For beginners, it is necessary to learn the functions of each GPIO. The following is an introduction to the GPIO resources of the ESP32-WROVER development board.

Later, we only use USB cable to power ESP32-WROVER in default.

In the whole tutorial, we don't use T extension to power ESP32-WROVER. So 5V and 3.3V (include EXT 3.3V) on the extension board are from ESP32-WROVER.

We can also use DC jack of extension board to power ESP32-WROVER. Then 5v and EXT 3.3v on extension board are from external power resource.

For more information, please visit:

[https://www.espressif.com/sites/default/files/documentation/esp32-wrover\\_datasheet\\_en.pdf](https://www.espressif.com/sites/default/files/documentation/esp32-wrover_datasheet_en.pdf)

# Chapter 0 Ready (Important)

Before starting building the projects, you need to make some preparation first, which is so crucial that you must not skip.

## 0.1 Installing Thonny (Important)

Thonny is a free, open-source software platform with compact size, simple interface, simple operation and rich functions, making it a Python IDE for beginners. In this tutorial, we use this IDE to develop ESP32 during the whole process.

Thonny supports various operating system, including Windows、Mac OS、Linux.

### Downloading Thonny

Official website of Thonny: <https://thonny.org>

Open-source code repositories of Thonny: <https://github.com/thonny/thonny>

Follow the instruction of official website to install Thonny or click the links below to download and install.  
(Select the appropriate one based on your operating system.)

Operating System	Download links/methods
Windows	<a href="https://github.com/thonny/thonny/releases/download/v3.2.7/thonny-3.2.7.exe">https://github.com/thonny/thonny/releases/download/v3.2.7/thonny-3.2.7.exe</a>
Mac OS	<a href="https://github.com/thonny/thonny/releases/download/v3.2.7/thonny-3.2.7.pkg">https://github.com/thonny/thonny/releases/download/v3.2.7/thonny-3.2.7.pkg</a>
Linux	<b>The latest version:</b> <b>Binary bundle for PC (Thonny+Python):</b> bash <(wget -O - https://thonny.org/installer-for-linux)  <b>With pip:</b> pip3 install thonny  <b>Distro packages (may not be the latest version):</b> <b>Debian, Raspbian, Ubuntu, Mint and others:</b> sudo apt install thonny  <b>Fedora:</b> sudo dnf install thonny

You can also open “**Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32/Python/Python\_Software**”, we have prepared it in advance.

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## Installing on Windows

The icon of Thonny after downloading is as below. Double click “thonny-3.2.7.exe”.



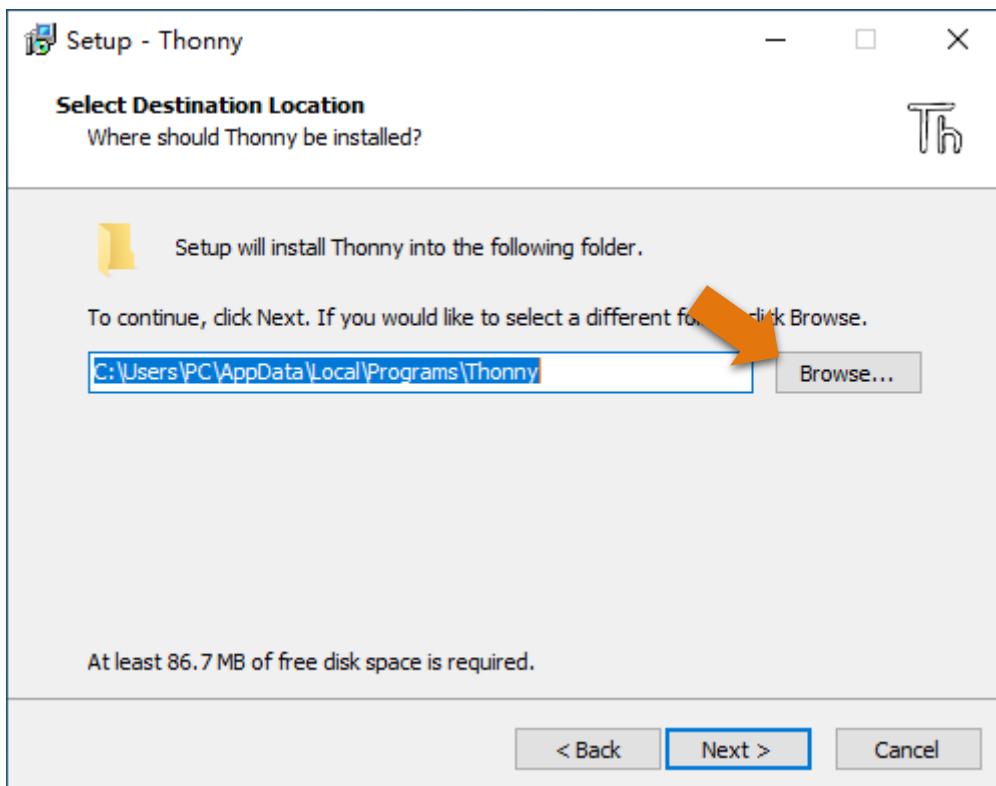


If you're not familiar with computer software installation, you can simply keep clicking "Next" until the installation completes.



If you want to change Thonny's installation path, you can click "Browse" to modify it. After selecting installation path, click "OK".

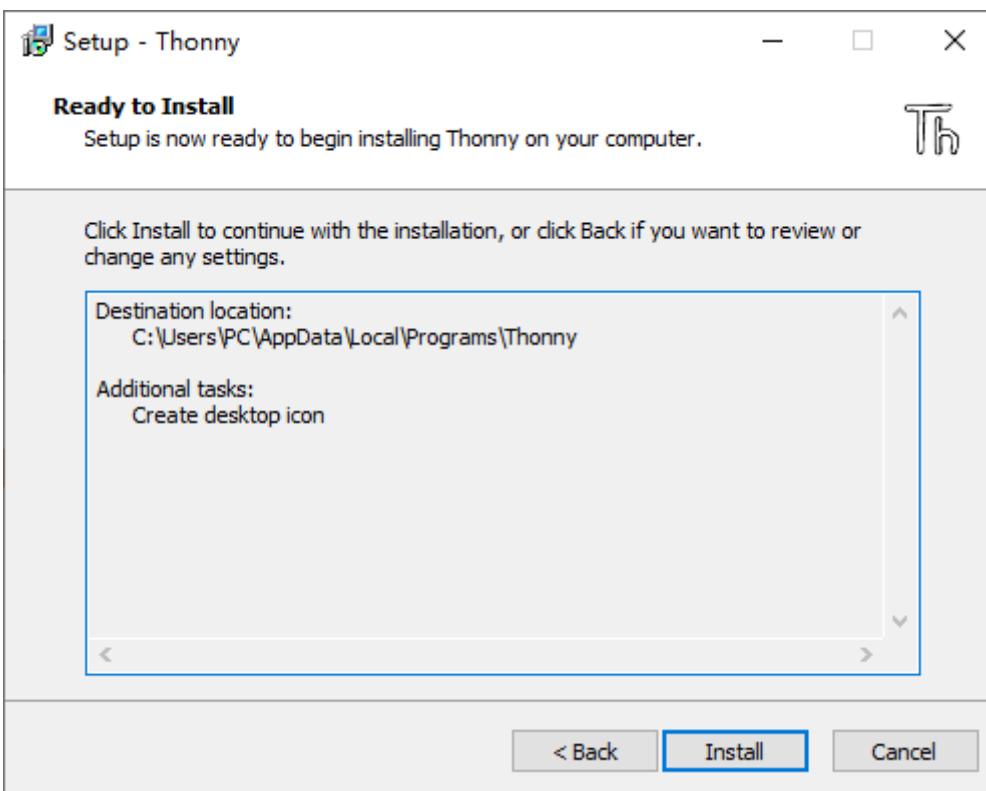
If you do not want to change it, just click "Next".



Check “Create desktop icon” and then it will generate a shortcut on your desktop to facilitate you to open Thonny later.

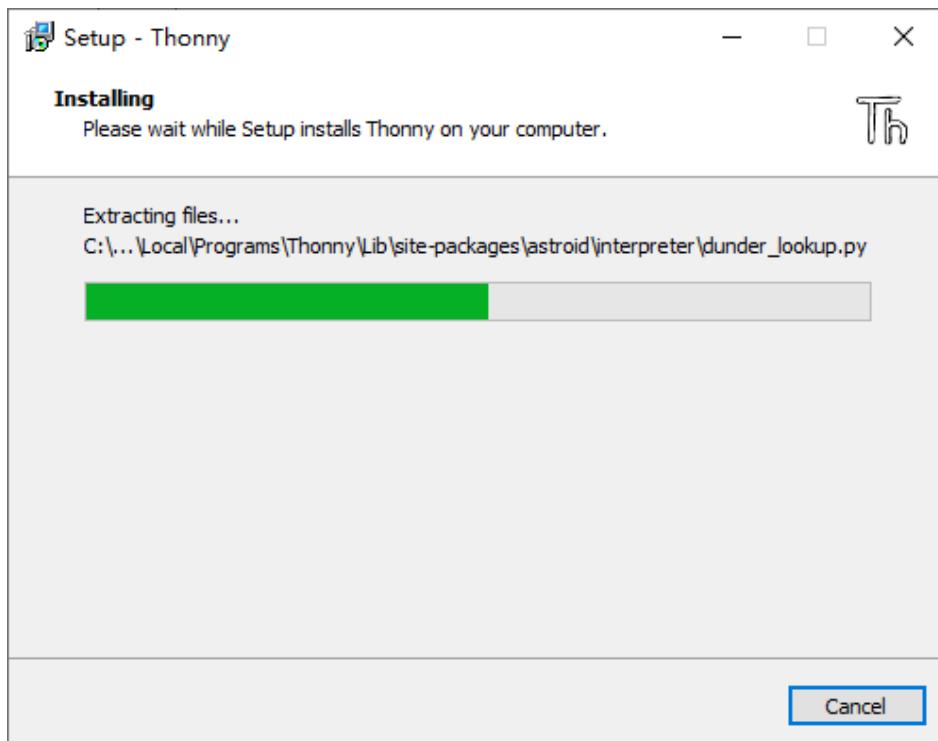


Click “install” to install the software.





During the installation process, you only need to wait for the installation to complete, and you must not click "Cancel", otherwise Thonny will fail to be installed.



Once you see the interface as below, Thonny has been installed successfully.



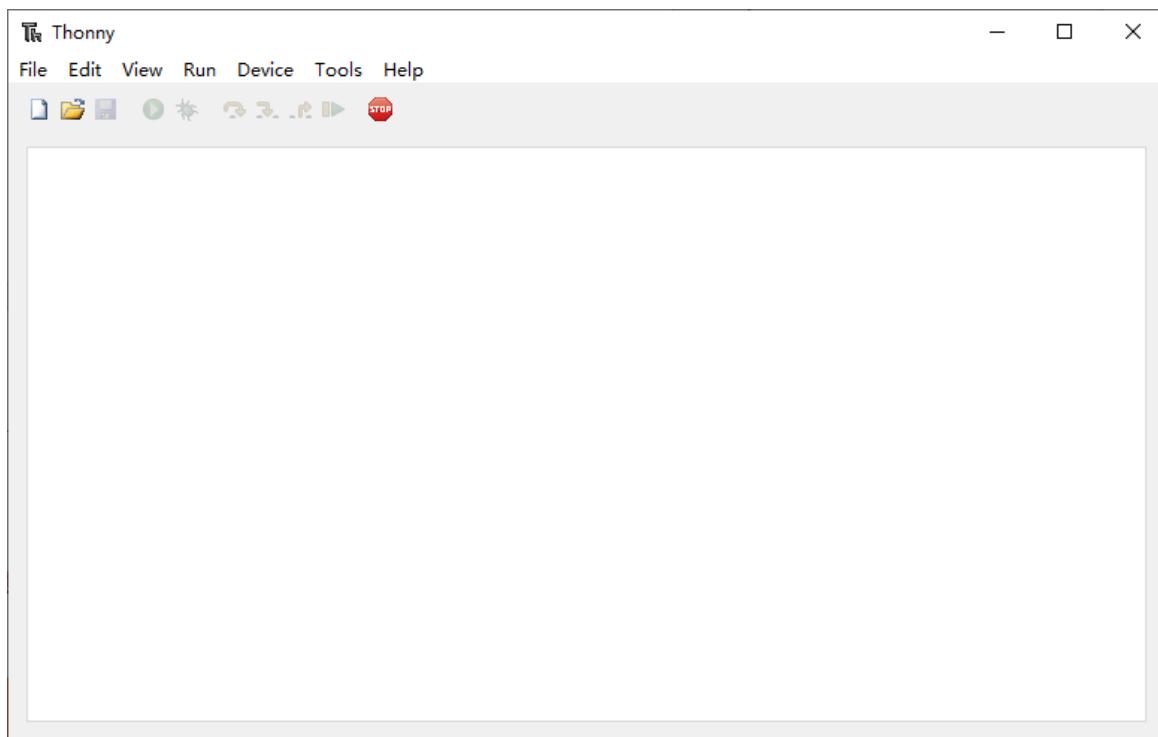
If you've checked "Create desktop icon" during the installation process, you can see the below icon on your desktop.



**Any concerns? [✉ support@freenove.com](mailto:support@freenove.com)**

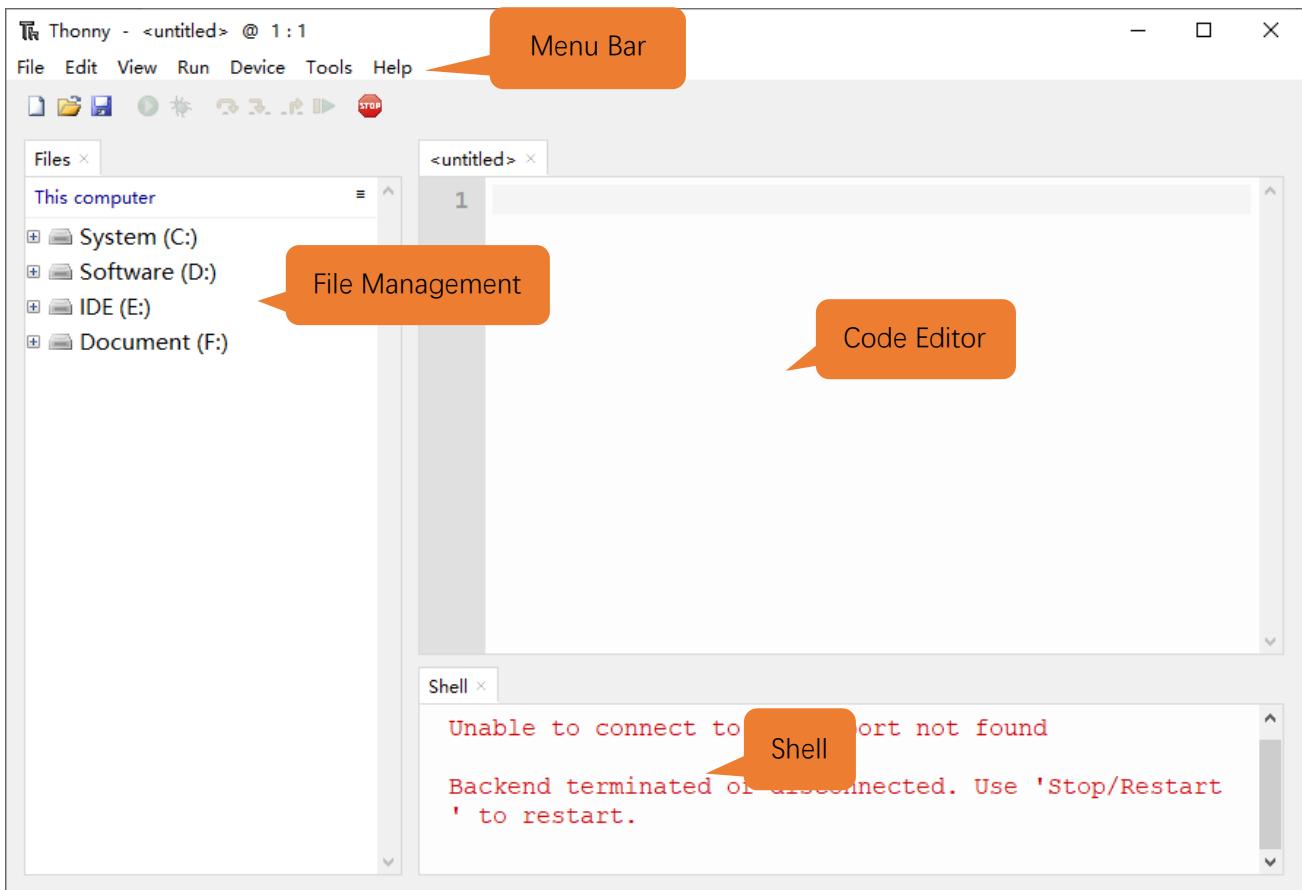
## 0.2 Basic Configuration of Thonny

Click the desktop icon of Thonny and you can see the interface of it as follows:



Select "View" → "Files" and "Shell".





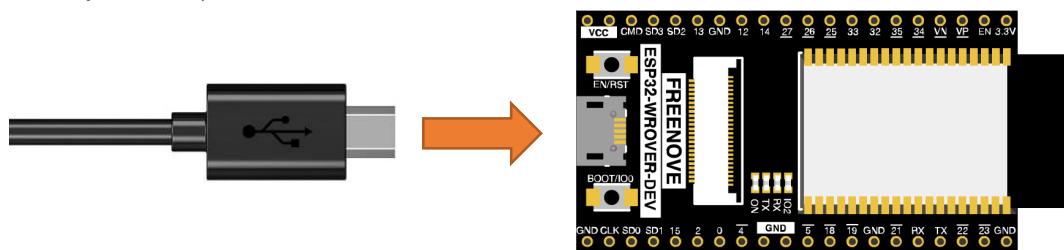
## 0.3 Installing CH340 (Important)

ESP32 uses CH340 to download codes. So before using it, we need to install CH340 driver in our computers.

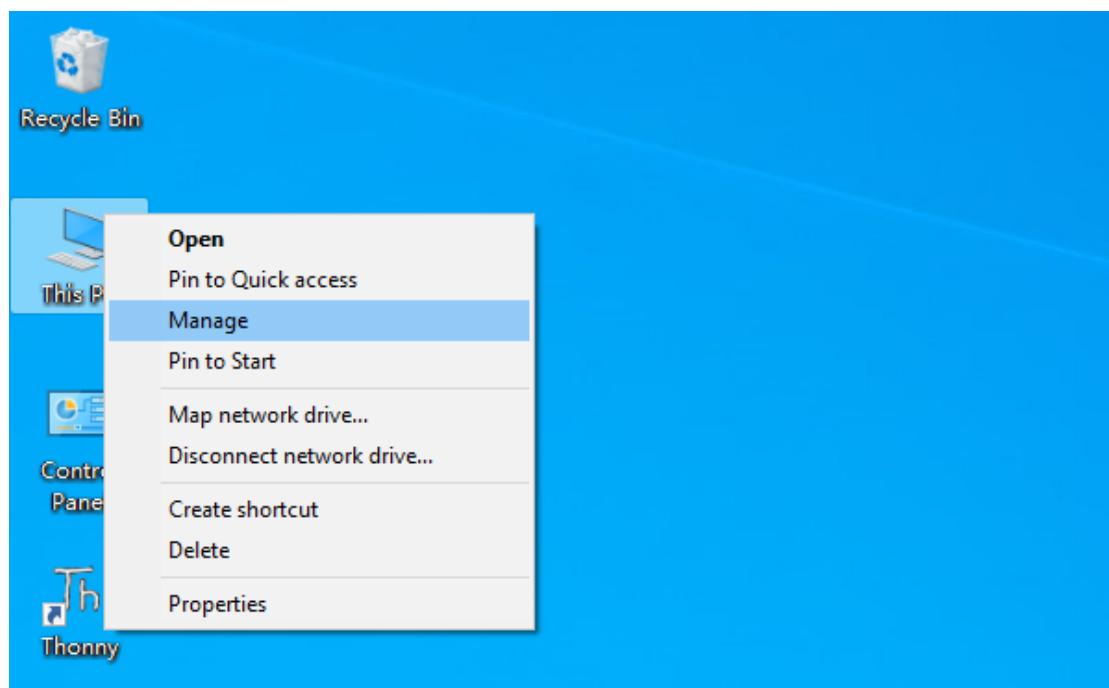
### Windows

Check whether CH340 has been installed

1. Connect your computer and ESP32 with a USB cable.

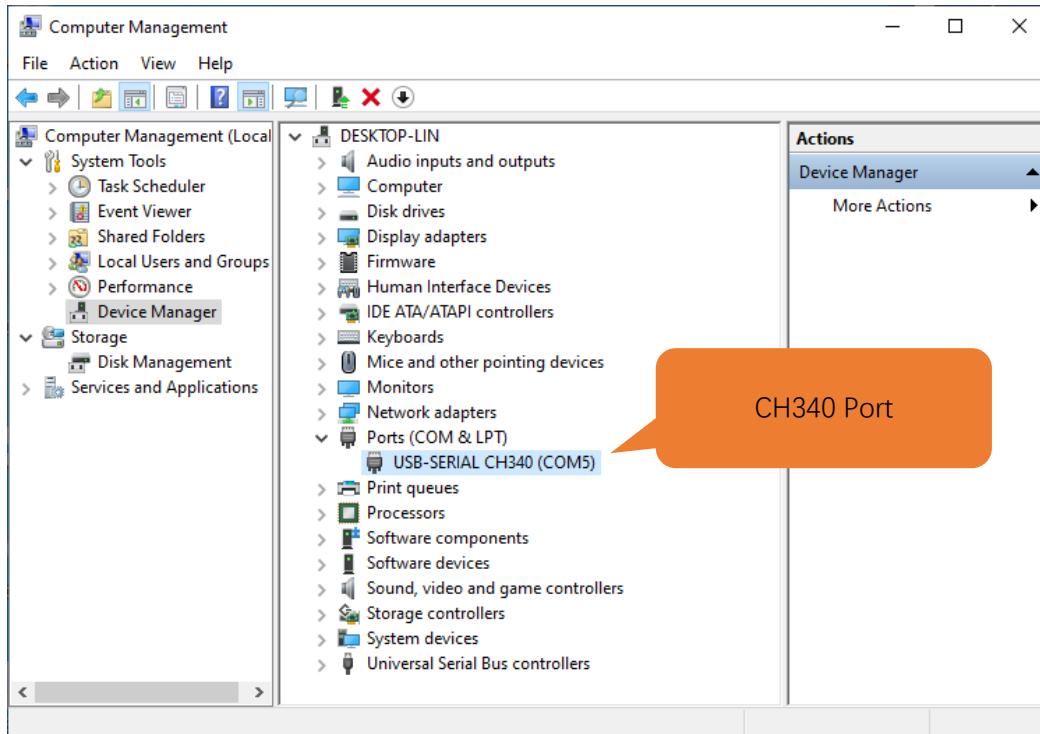


2. Turn to the main interface of your computer, select “This PC” and right-click to select “Manage”.





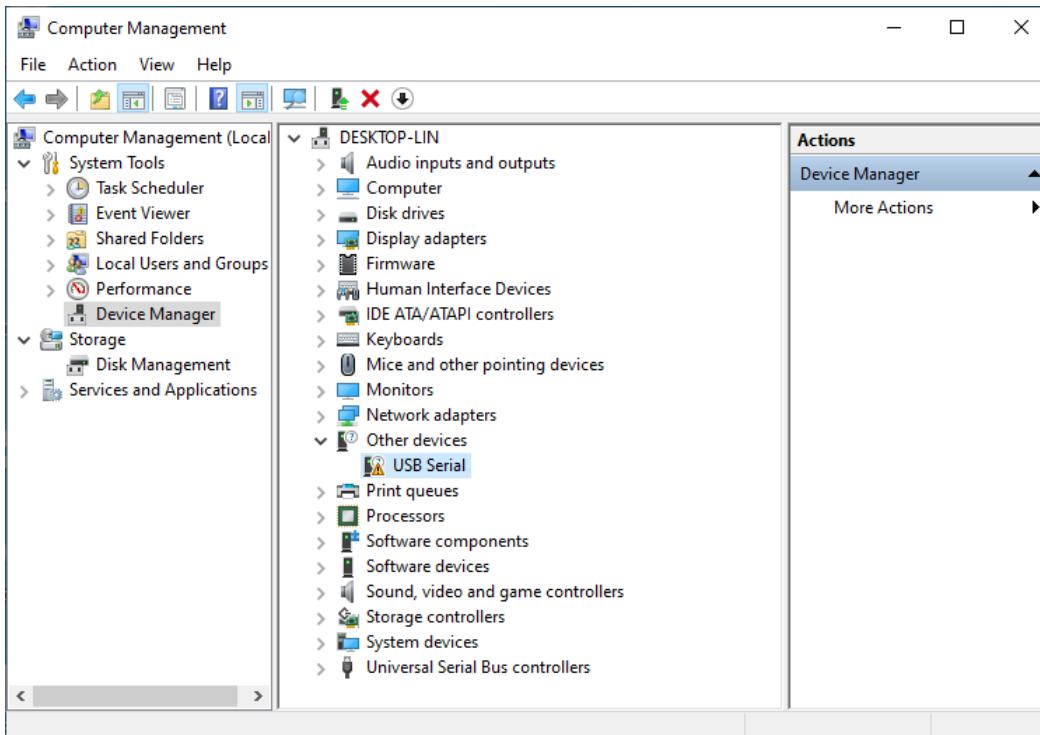
3. Click “Device Manager”. If your computer has installed CH340, you can see “USB-SERIAL CH340 (COMx)”. And you can click [here](#) to move to the next step.



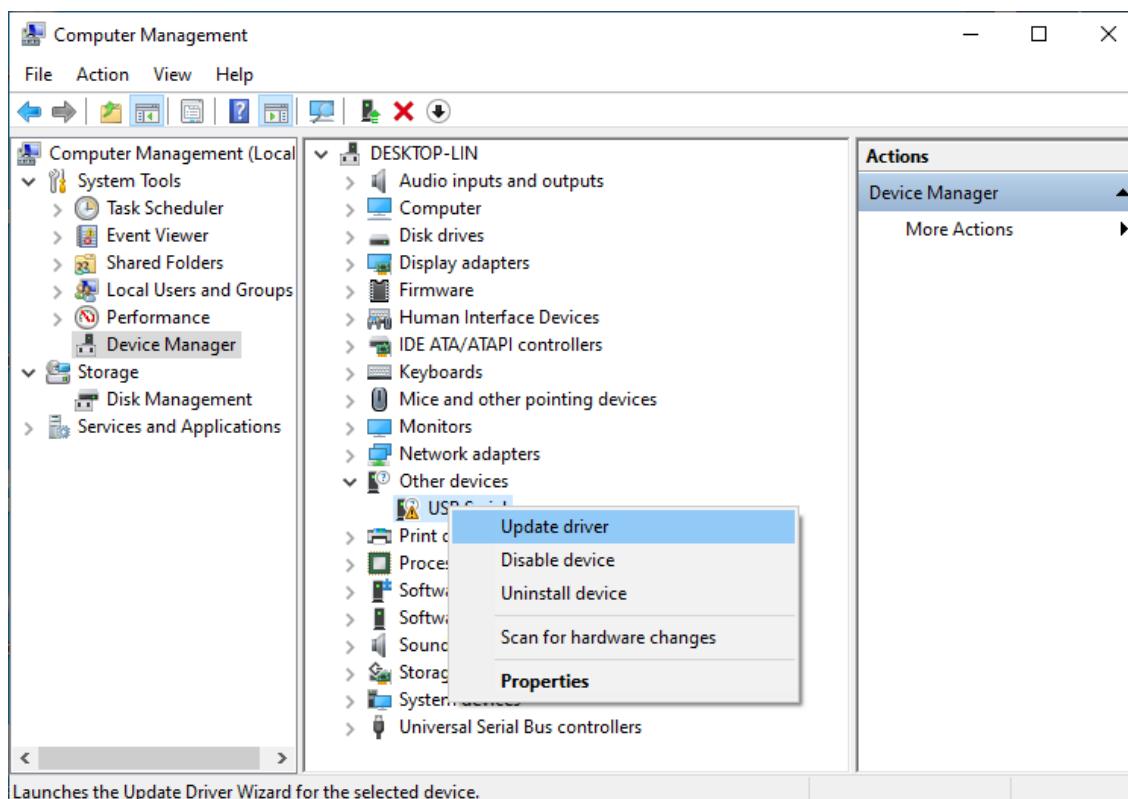
## Installing CH340

### Method1

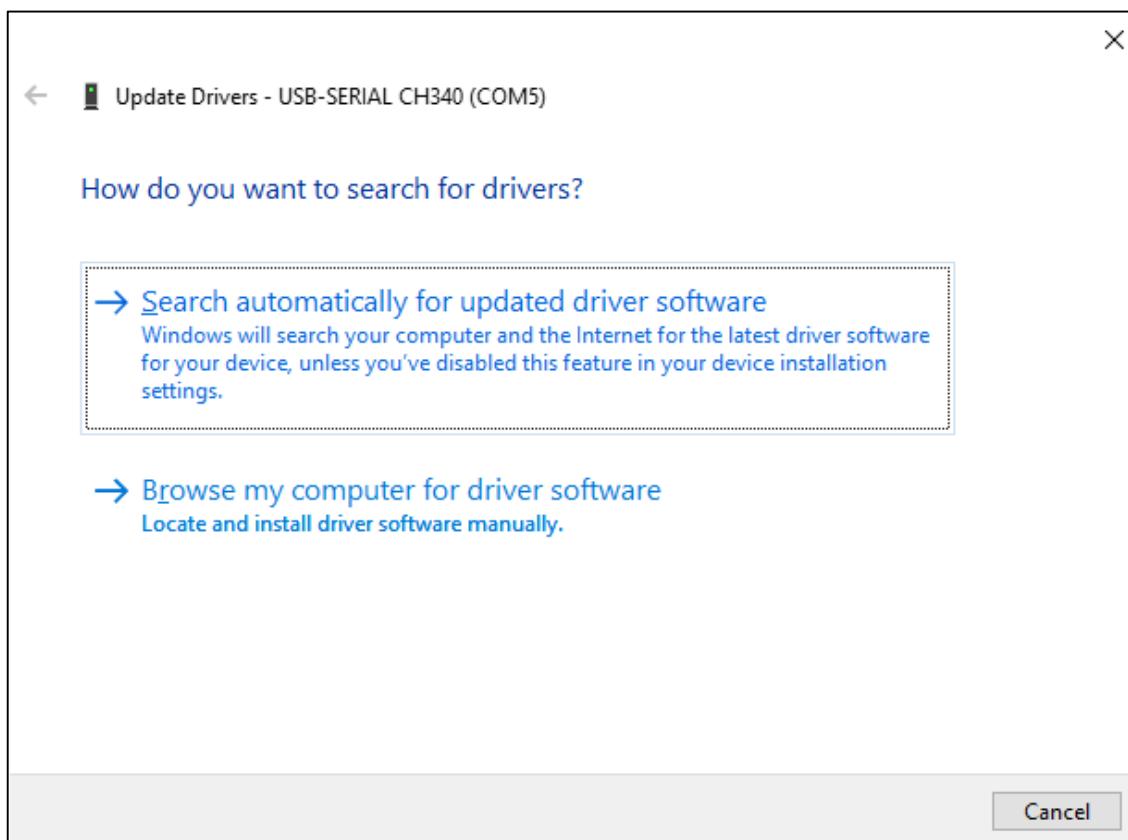
- If you have not yet installed CH340, you'll see the following interface.



2. Click “USB Serial” and right-click to select “Update driver”.

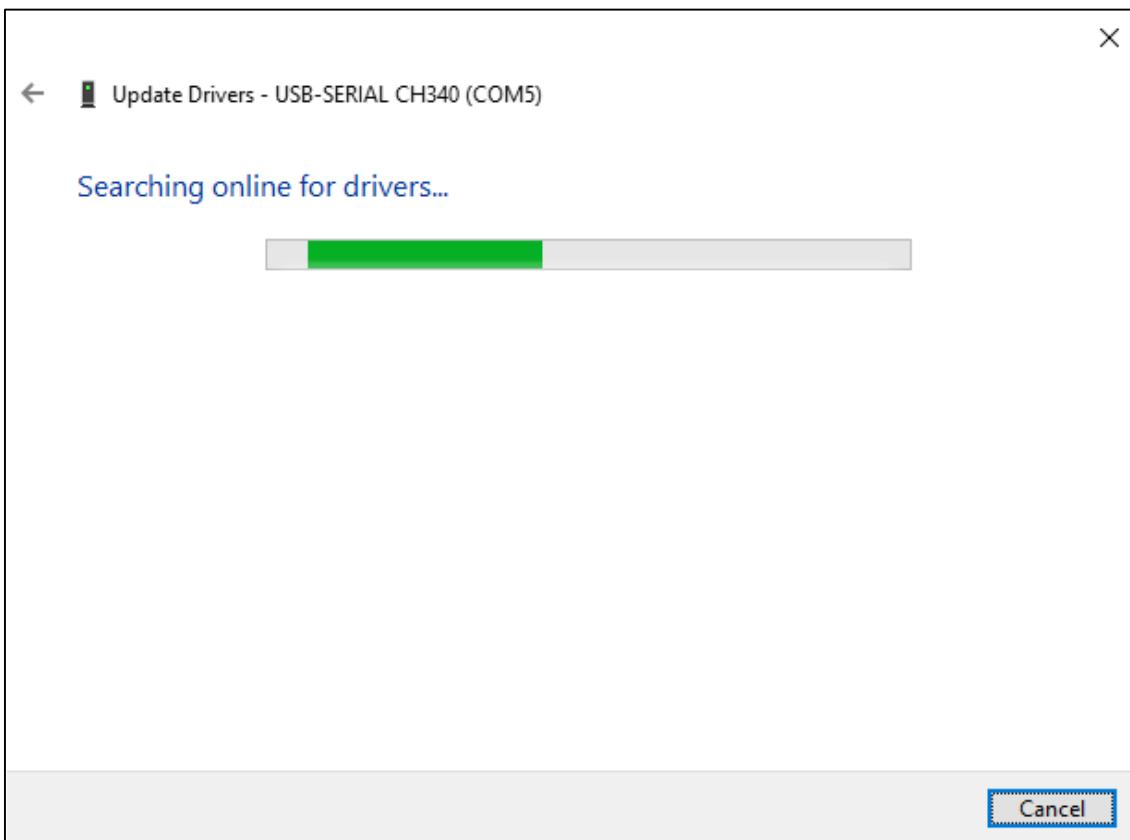


3. Click “Search automatically for updated driver software”.

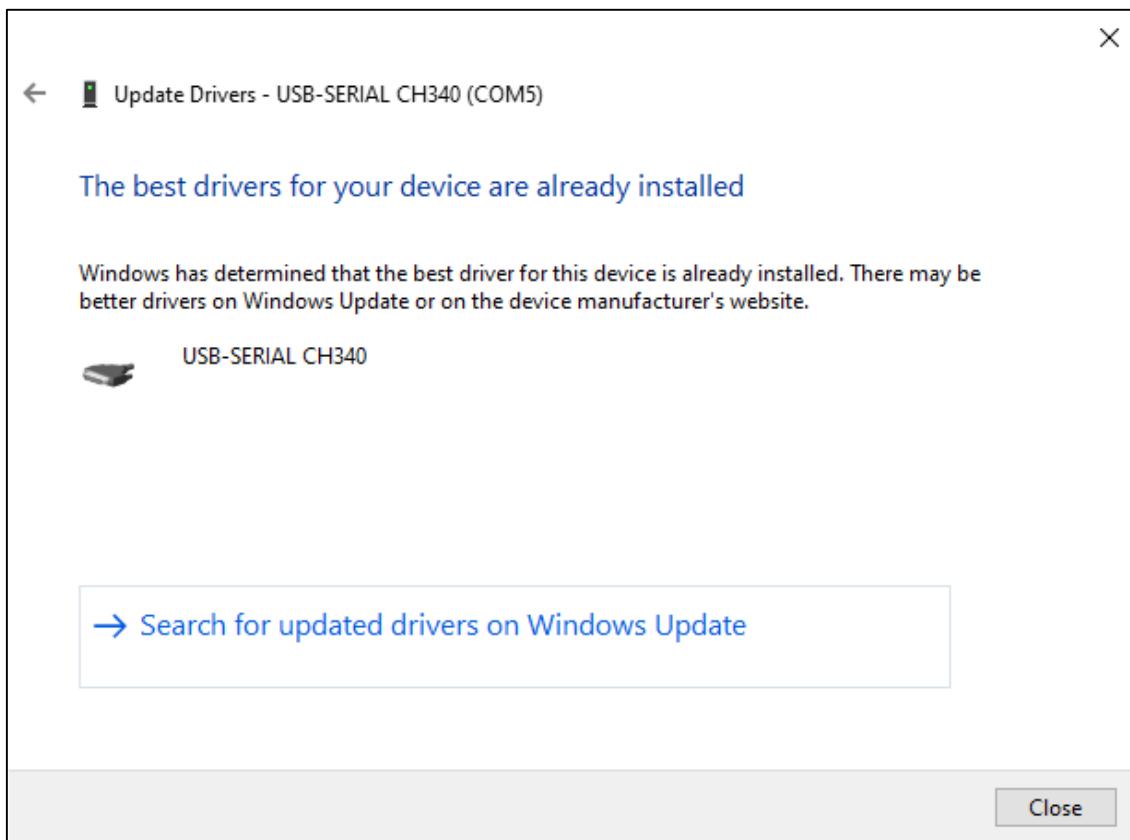




4. Wait for CH340 to finish installation.

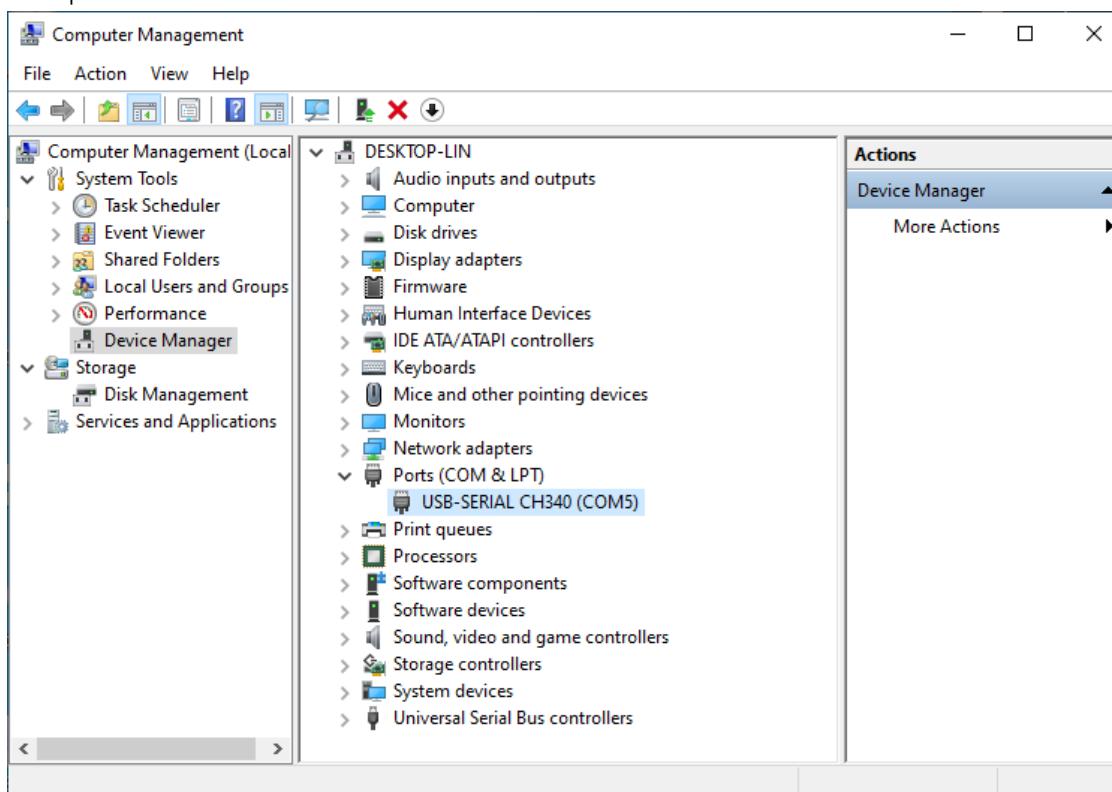


5. When you see the following interface, it indicates that CH340 has been installed to your computer. You can close the interface.



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6. When ESP32 is connected to computer, you can see the following interface. Click here to move to the next step.





## Method2

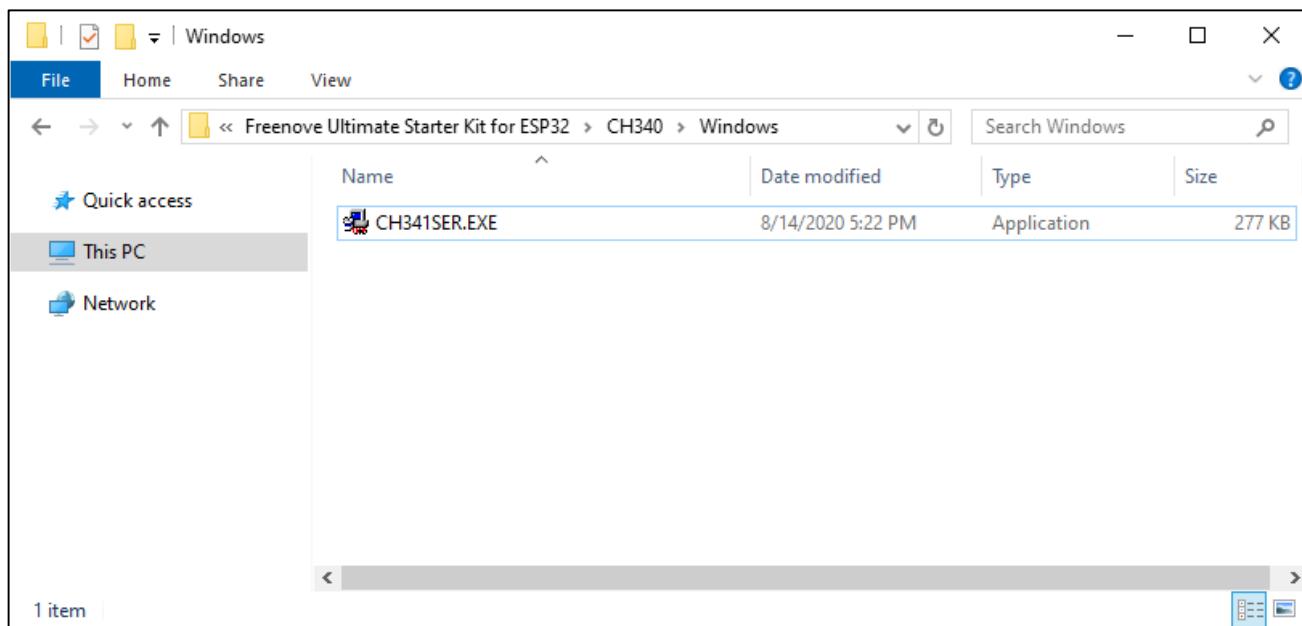
- First, download CH340 driver, click <http://www.wch-ic.com/search?q=CH340&t=downloads> to download the appropriate one based on your operating system.

file category	file content	version	upload time
Driver&Tools	CH341SER.EXE - CH340/CH341 USB to serial port Windows driver, supports 32/64-bit Windows 10/8.1/8/7/VISTA/XP, Server 2016/2012/2008/2003, 2000/ME/98	3.5	2019-03-18
Driver&Tools	CH341SER.ZIP - CH340/CH341 USB to serial port Windows driver, includes DLL dynamic library and non-standard baud rate settings and other instructions. Supports 32/64-bit Windows 10/8.1/8/7/VISTA/XP, Server 2016/2012/2008/2003, 2000/ME/98	3.5	2019-03-05
Driver&Tools	CH341SER_ANDROID... - CH340/CH341 USB to serial port Android free drive application library, for Android OS 3.1 and above version which supports USB Host mode already, no need to load Android kernel driver, no root privileges. Contains apk, lib library file (Linux Driver), App Demo Example (USB to UART Device Driver)	1.6	2019-04-19
Driver&Tools	CH341SER_LINUX.... - CH340/CH341 USB to serial port LINUX driver	1.5	2018-03-18
Driver&Tools	CH341SER_MAC.ZI... - CH340/CH341 USB to serial port MAC OS driver	1.5	2018-07-05
Others	PRODUCT_GUIDE.P... - Electronic selection of product selection manual, please refer to related product technical manual for more technical information.	1.4	2018-12-29
Others	InstallNoteOn64... - Instructions for the driver after 18 years of August cannot be installed under some 64-bit WIN7 (English)	1.0	2019-01-10

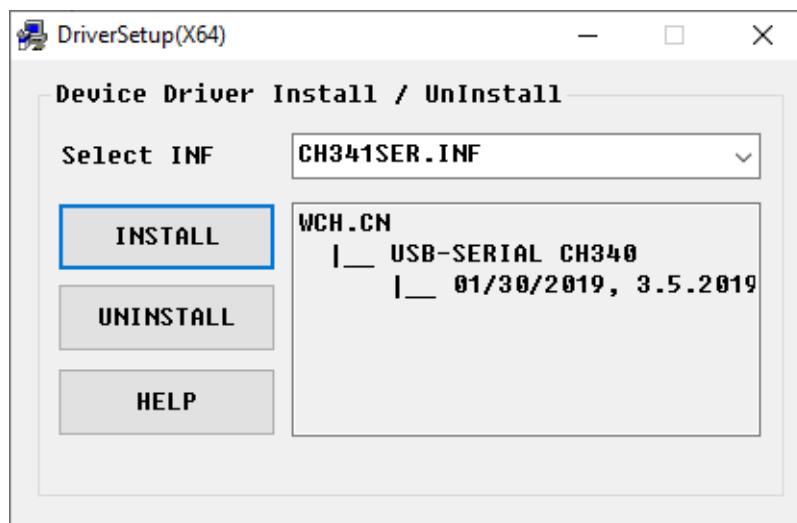
You can also open “Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32/CH340”, we have prepared the installation package.

Name	Date modified	Type	Size
Linux	8/14/2020 5:24 PM	File folder	
MAC	8/14/2020 5:23 PM	File folder	
Windows	8/14/2020 5:23 PM	File folder	

2. Open the folder “Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32/CH340/Windows/ch341ser”

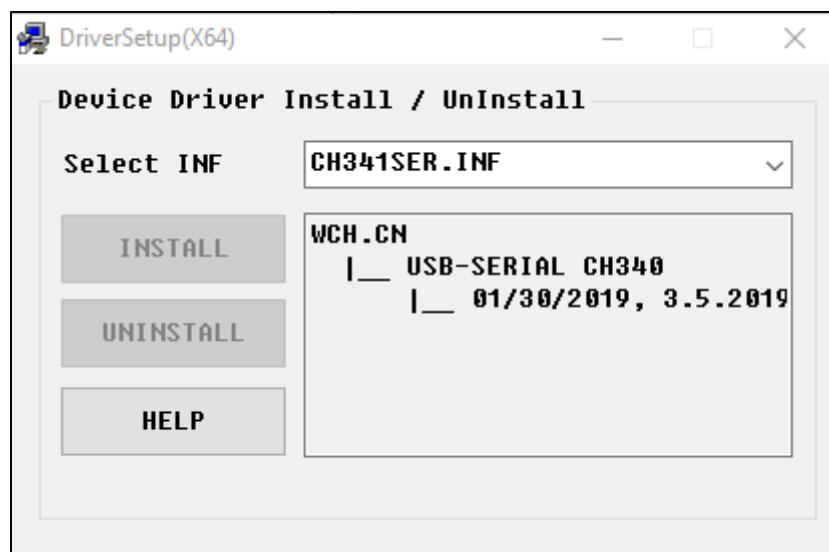


3. Double click “CH341SER.EXE”.

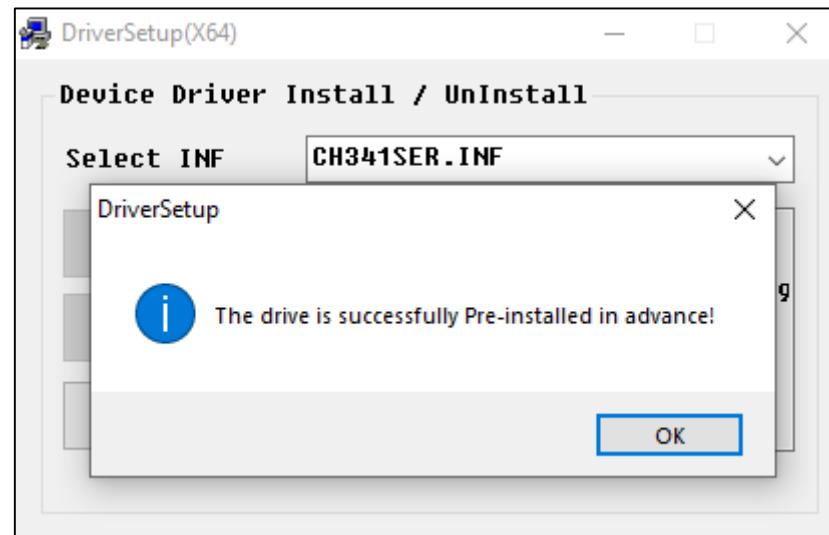




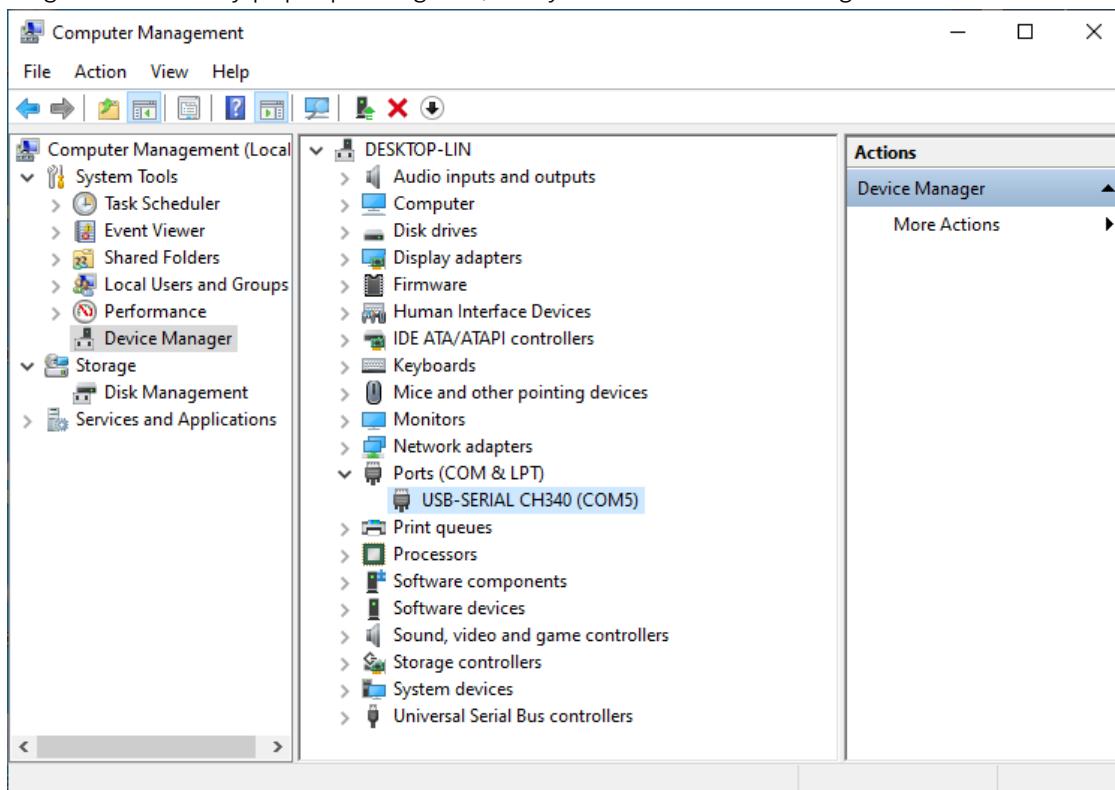
4. Click “INSTALL” and wait for the installation to complete.



5. Install successfully. Close all interfaces.



6. When ESP32 is connected to computer, select "This PC", right-click to select "Manage" and click "Device Manager" in the newly pop-up dialog box, and you can see the following interface.



7. So far, CH340 has been installed successfully. Close all dialog boxes.

## MAC

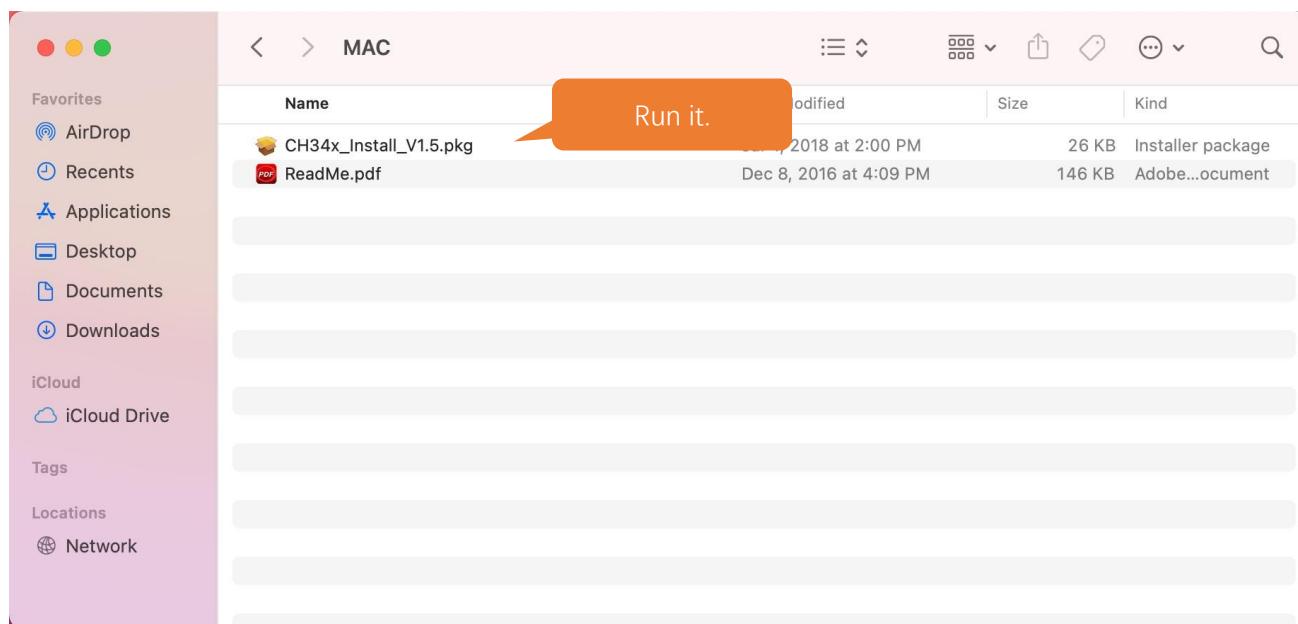
First, download CH340 driver, click <http://www.wch-ic.com/search?q=CH340&t=downloads> to download the appropriate one based on your operating system.

The screenshot shows a search results page for 'ch340' on the WCH website. The left sidebar has categories: All (14), Downloads (7), Products (4), Application (2), Video (1), and News (0). The main area shows search results for 'Downloads( 7 )'. There are three main sections highlighted with orange callouts: 'Windows' (CH341SER.EXE, CH341SER.ZIP, CH341SER\_ANDROID..., CH341SER\_LINUX..., CH341SER\_MAC.ZIP), 'Linux' (CH341SER\_LINUX...), and 'MAC' (CH341SER\_MAC.ZIP). Other files listed include CH340SER\_EXE and CH340SER\_MAC\_EXE.

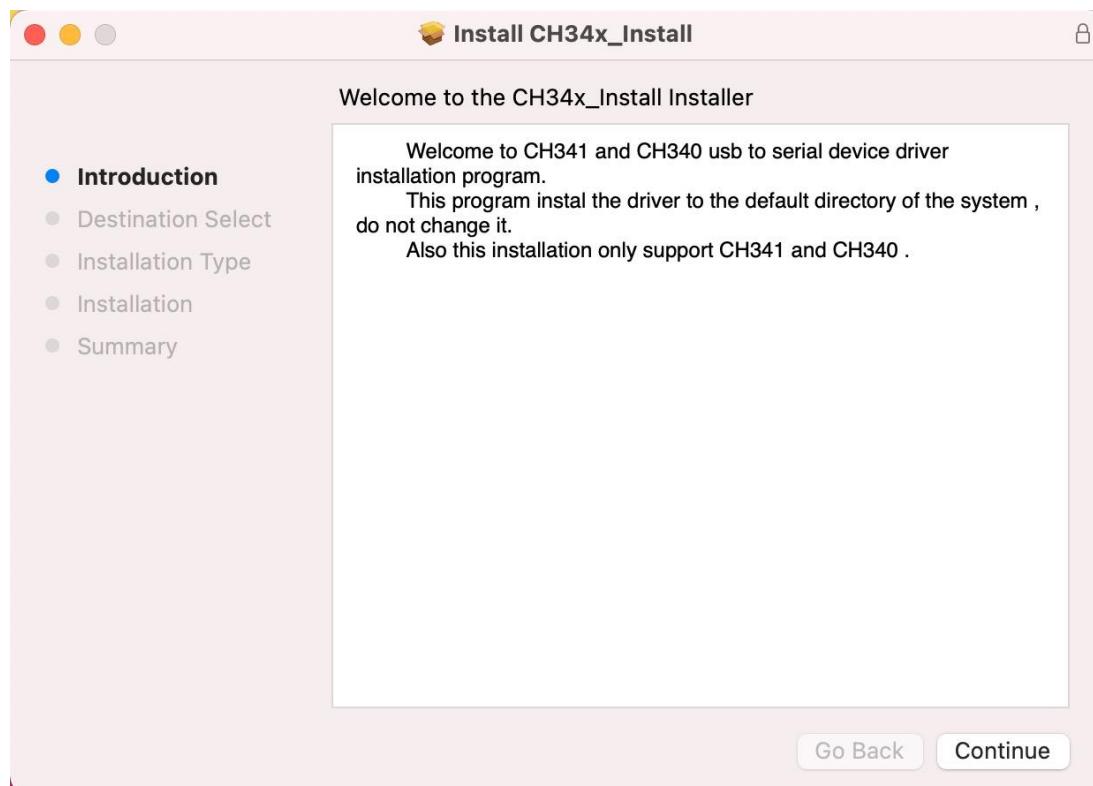
file category	file content	version	upload time
Driver&Tools	CH341SER.EXE	3.5	2019-03-18
	CH341SER.ZIP	3.5	2019-03-05
	CH341SER_ANDROID...	1.6	2019-04-19
	CH341SER_LINUX...	1.5	2018-03-18
	CH341SER_MAC.ZIP	1.5	2018-07-05
	Others		

If you would not like to download the installation package, you can open "Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32/CH340", we have prepared the installation package.

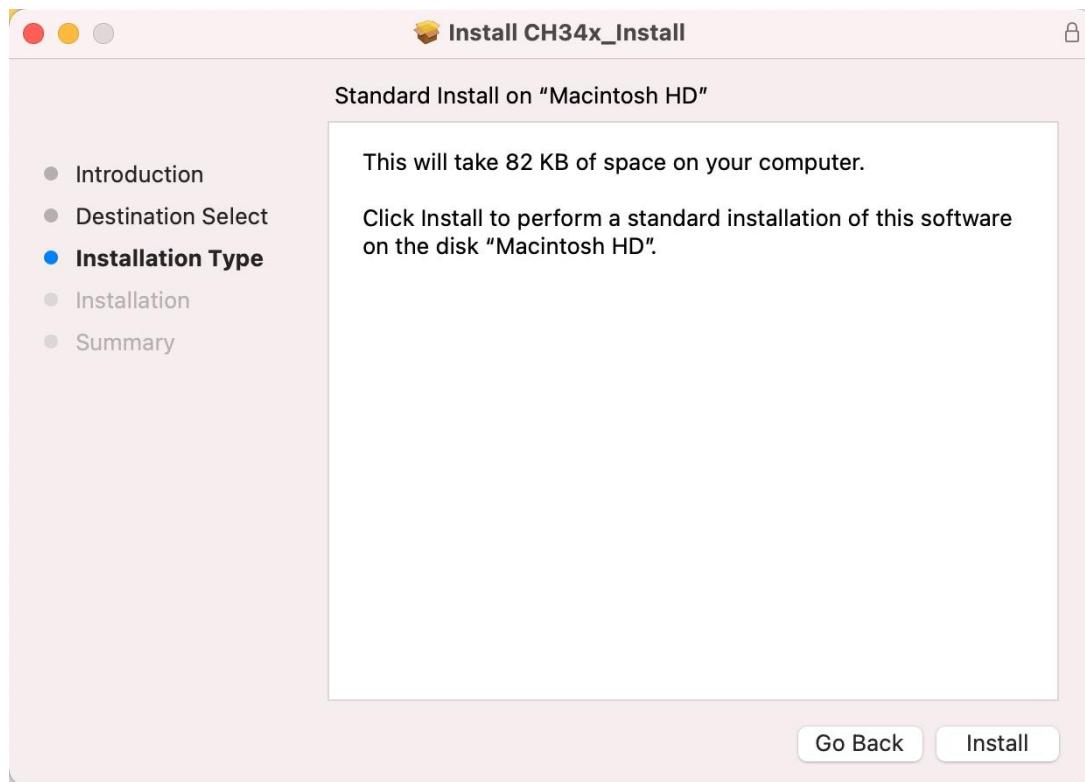
Second, open the folder "Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32/CH340/MAC/"



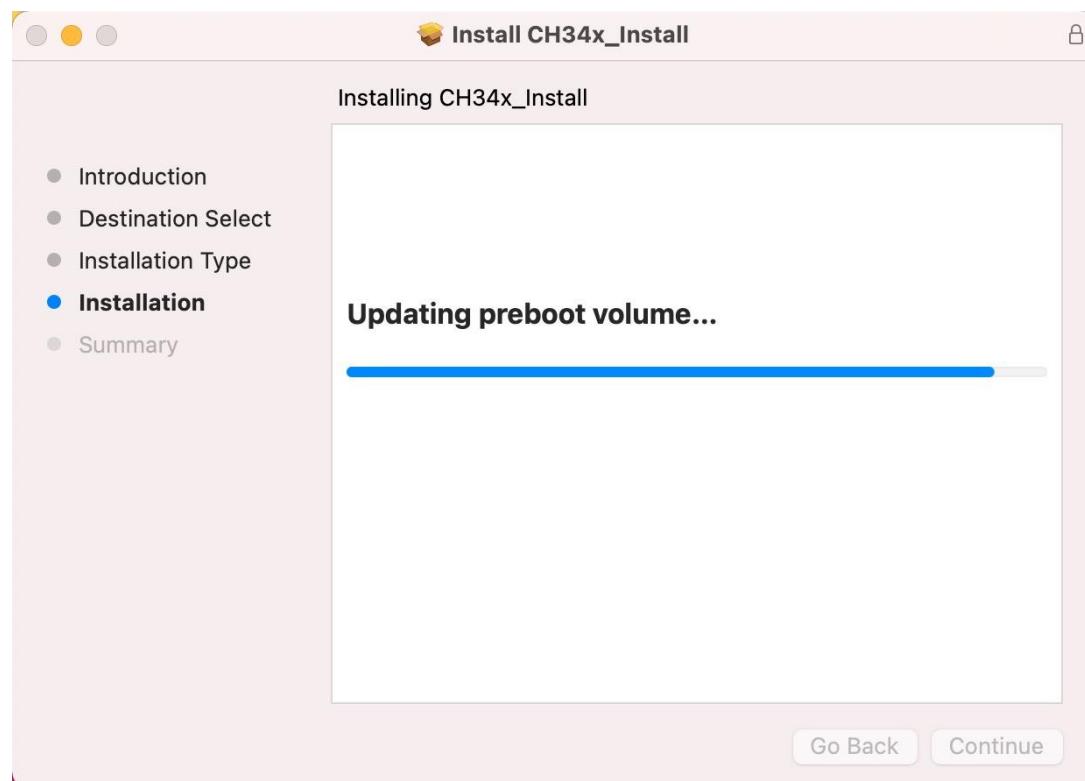
Third, click Continue.



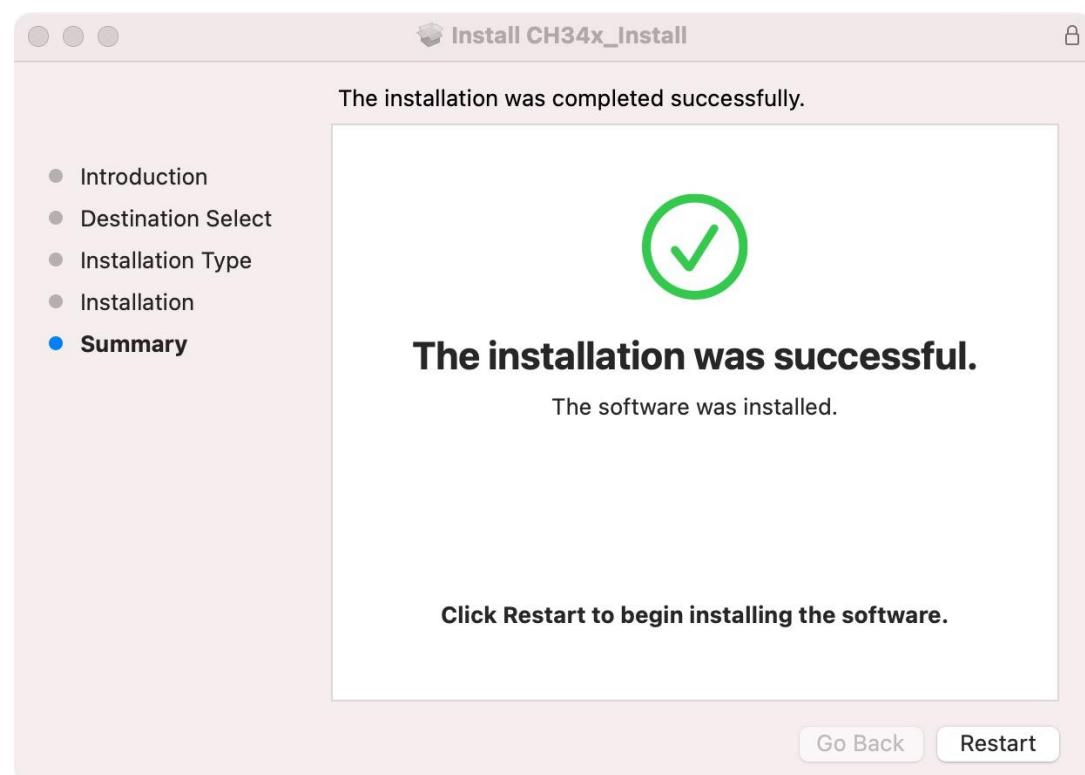
Fourth, click Install.



Then, waiting Finsh.

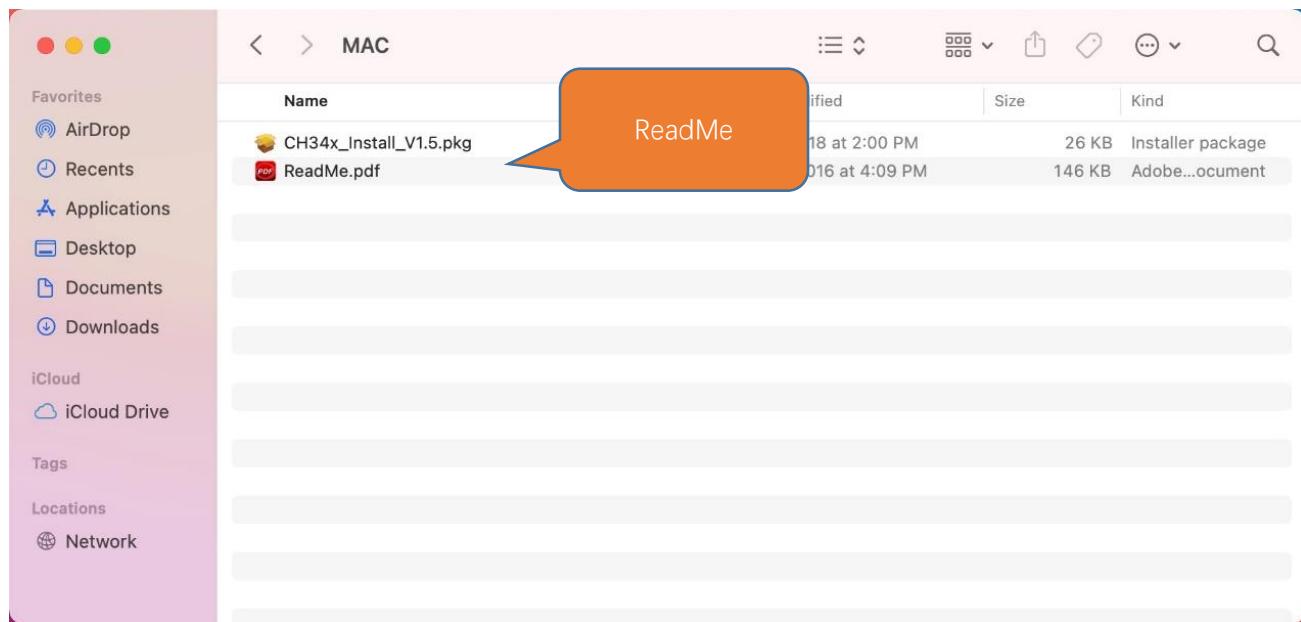


Finally, restart your PC.





If you still haven't installed the CH340 by following the steps above, you can view `readme.pdf` to install it.



Any concerns? ✉ [support@freenove.com](mailto:support@freenove.com)

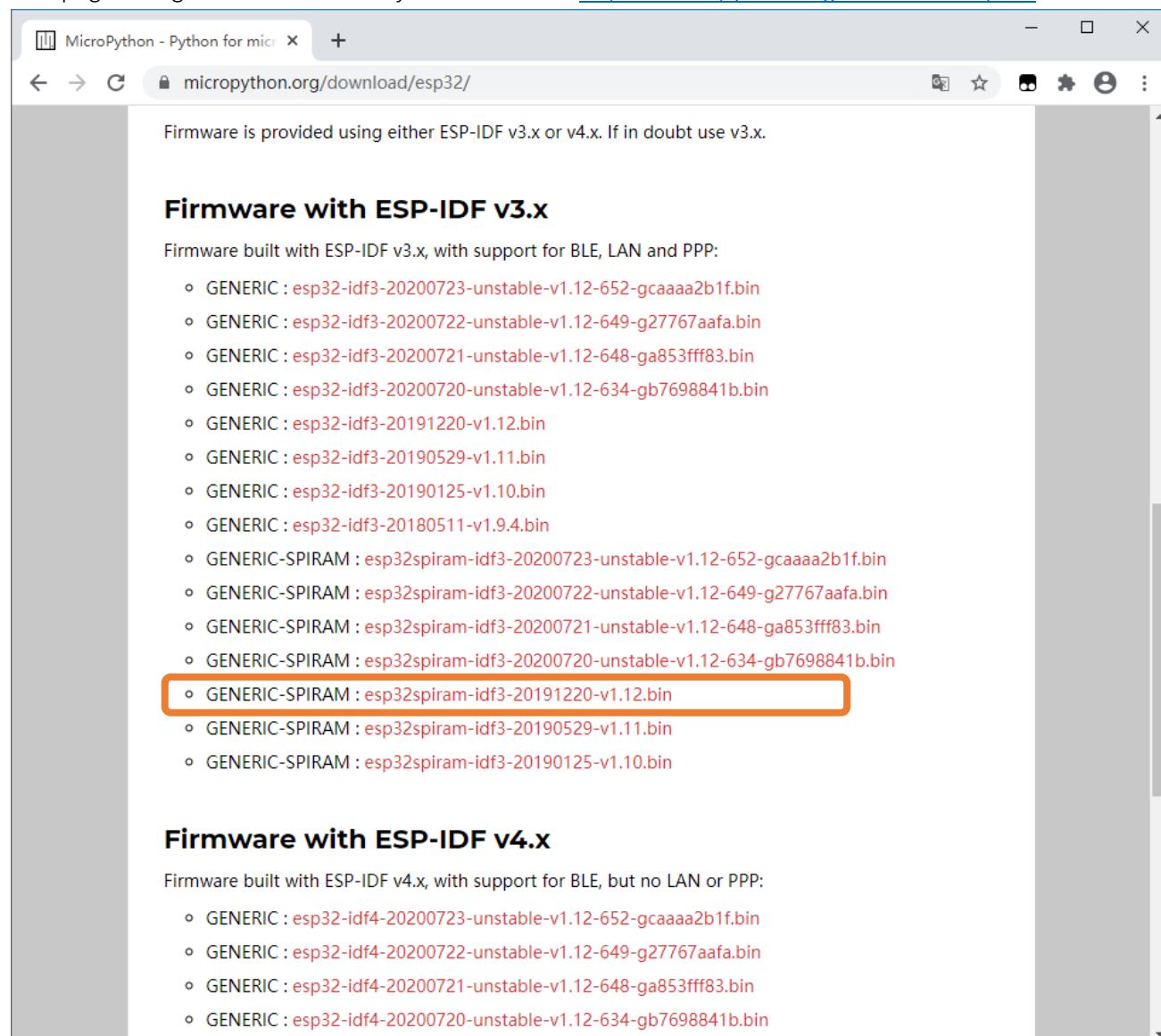
## 0.4 Burning Micropython Firmware (Important)

To run Python programs on ESP32, we need to burn a firmware to ESP32 first.

### Downloading Micropython Firmware

Official website of microPython: <http://micropython.org/>

Webpage listing firmware of microPython for ESP32: <https://micropython.org/download/esp32/>



Firmware is provided using either ESP-IDF v3.x or v4.x. If in doubt use v3.x.

### Firmware with ESP-IDF v3.x

Firmware built with ESP-IDF v3.x, with support for BLE, LAN and PPP:

- GENERIC : [esp32-idf3-20200723-unstable-v1.12-652-gaaaa2b1f.bin](#)
- GENERIC : [esp32-idf3-20200722-unstable-v1.12-649-g27767aafa.bin](#)
- GENERIC : [esp32-idf3-20200721-unstable-v1.12-648-ga853fff83.bin](#)
- GENERIC : [esp32-idf3-20200720-unstable-v1.12-634-gb7698841b.bin](#)
- GENERIC : [esp32-idf3-20191220-v1.12.bin](#)
- GENERIC : [esp32-idf3-20190529-v1.11.bin](#)
- GENERIC : [esp32-idf3-20190125-v1.10.bin](#)
- GENERIC : [esp32-idf3-20180511-v1.9.4.bin](#)
- GENERIC-SPIRAM : [esp32spiram-idf3-20200723-unstable-v1.12-652-gaaaa2b1f.bin](#)
- GENERIC-SPIRAM : [esp32spiram-idf3-20200722-unstable-v1.12-649-g27767aafa.bin](#)
- GENERIC-SPIRAM : [esp32spiram-idf3-20200721-unstable-v1.12-648-ga853fff83.bin](#)
- GENERIC-SPIRAM : [esp32spiram-idf3-20200720-unstable-v1.12-634-gb7698841b.bin](#)
- **GENERIC-SPIRAM : [esp32spiram-idf3-20191220-v1.12.bin](#)**
- GENERIC-SPIRAM : [esp32spiram-idf3-20190529-v1.11.bin](#)
- GENERIC-SPIRAM : [esp32spiram-idf3-20190125-v1.10.bin](#)

### Firmware with ESP-IDF v4.x

Firmware built with ESP-IDF v4.x, with support for BLE, but no LAN or PPP:

- GENERIC : [esp32-idf4-20200723-unstable-v1.12-652-gaaaa2b1f.bin](#)
- GENERIC : [esp32-idf4-20200722-unstable-v1.12-649-g27767aafa.bin](#)
- GENERIC : [esp32-idf4-20200721-unstable-v1.12-648-ga853fff83.bin](#)
- GENERIC : [esp32-idf4-20200720-unstable-v1.12-634-gb7698841b.bin](#)

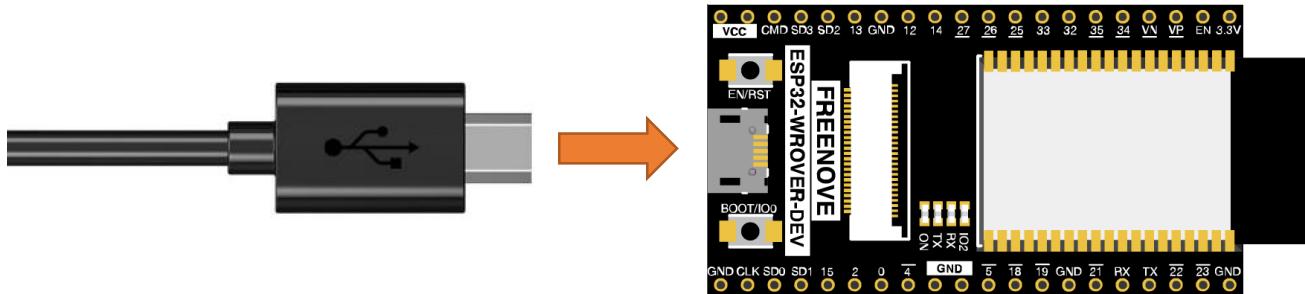
Firmware used in this tutorial is **esp32spiram-idf3-20191220-v1.12.bin**

Click the following link to download directly: <https://micropython.org/resources/firmware/esp32spiram-idf3-20191220-v1.12.bin>

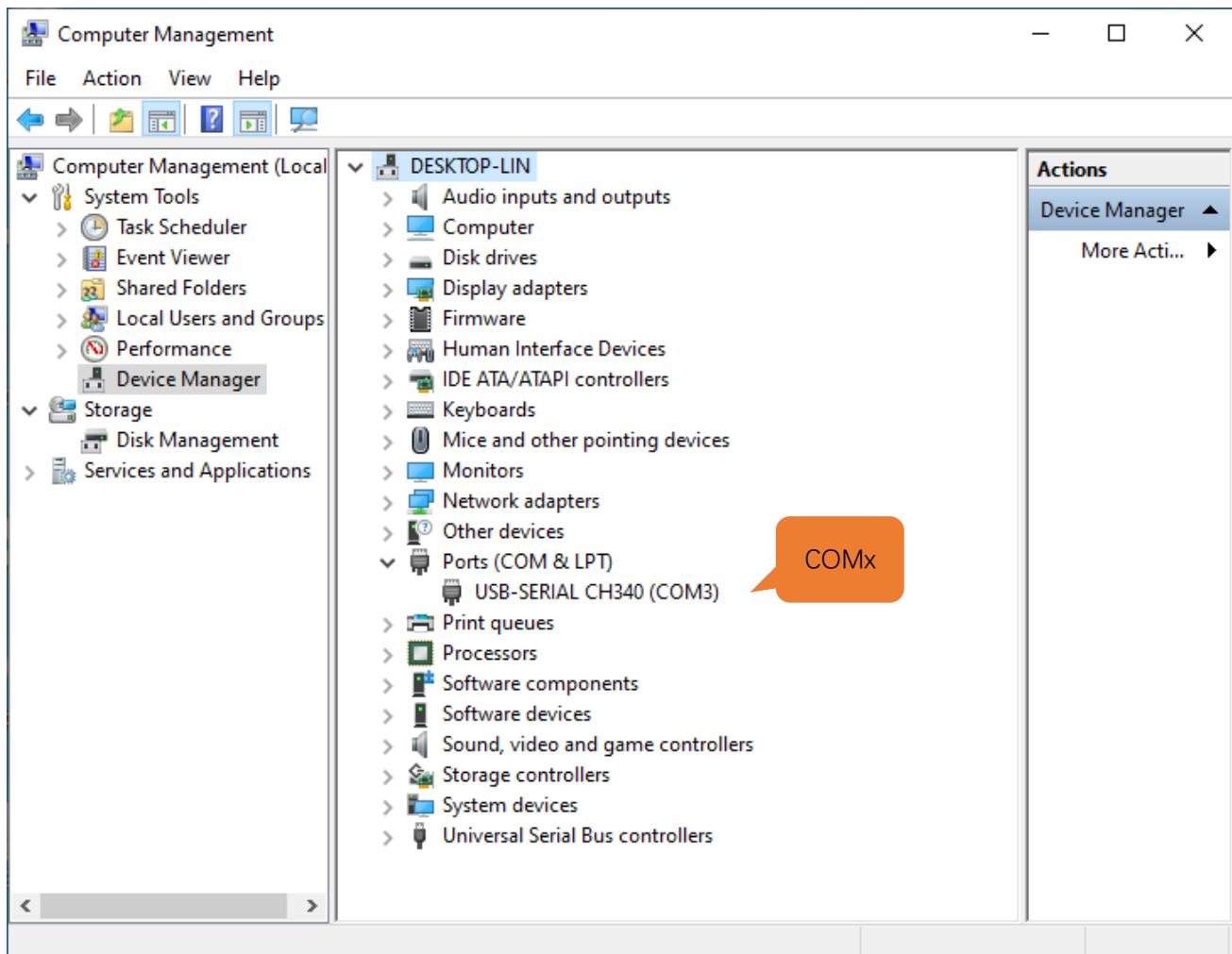
This file is also provided in our data folder "**Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32/Python/Python\_Firmware**".

## Burning a Micropython Firmware

Connect your computer and ESP32 with a USB cable.

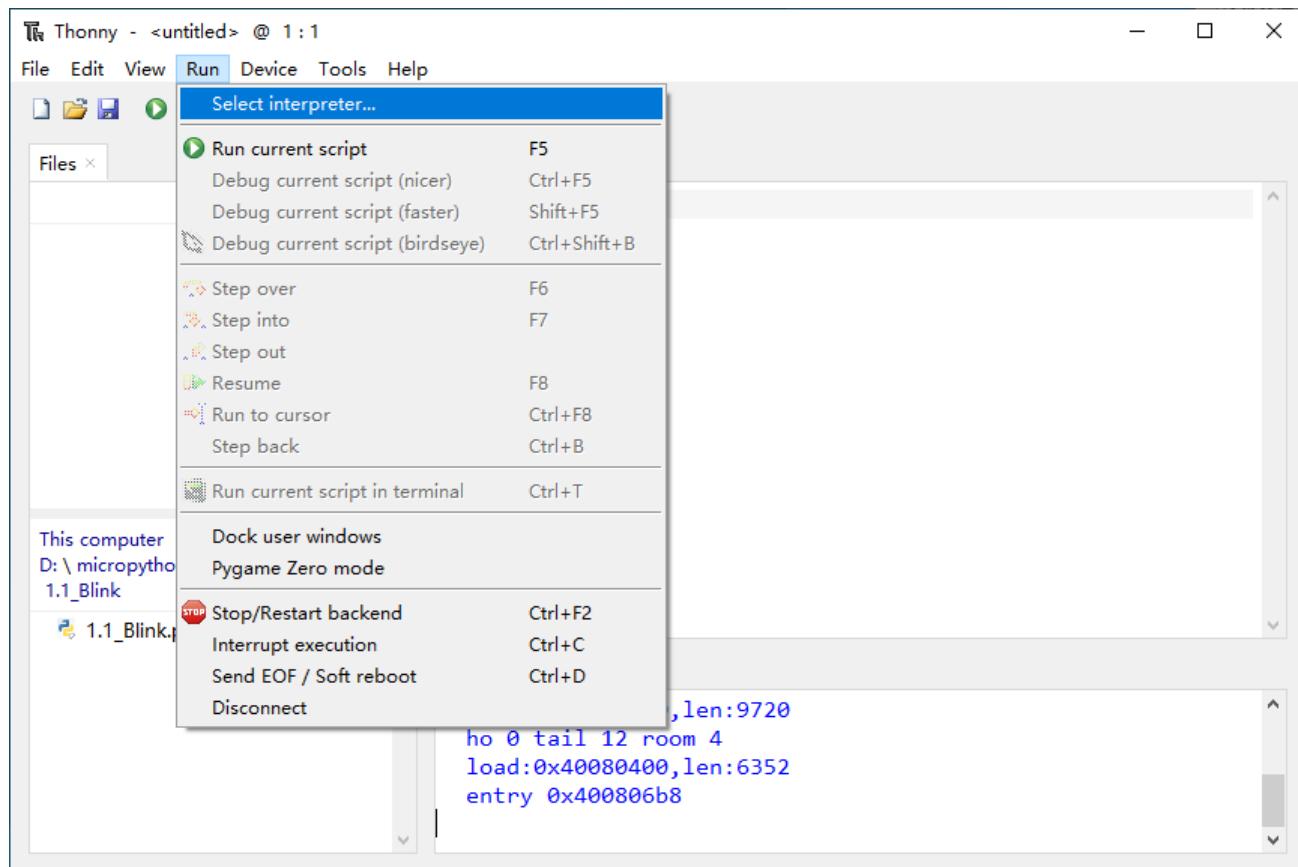


Make sure that the driver has been installed successfully and that it can recognize COM port correctly. Open device manager and expand “Ports”.



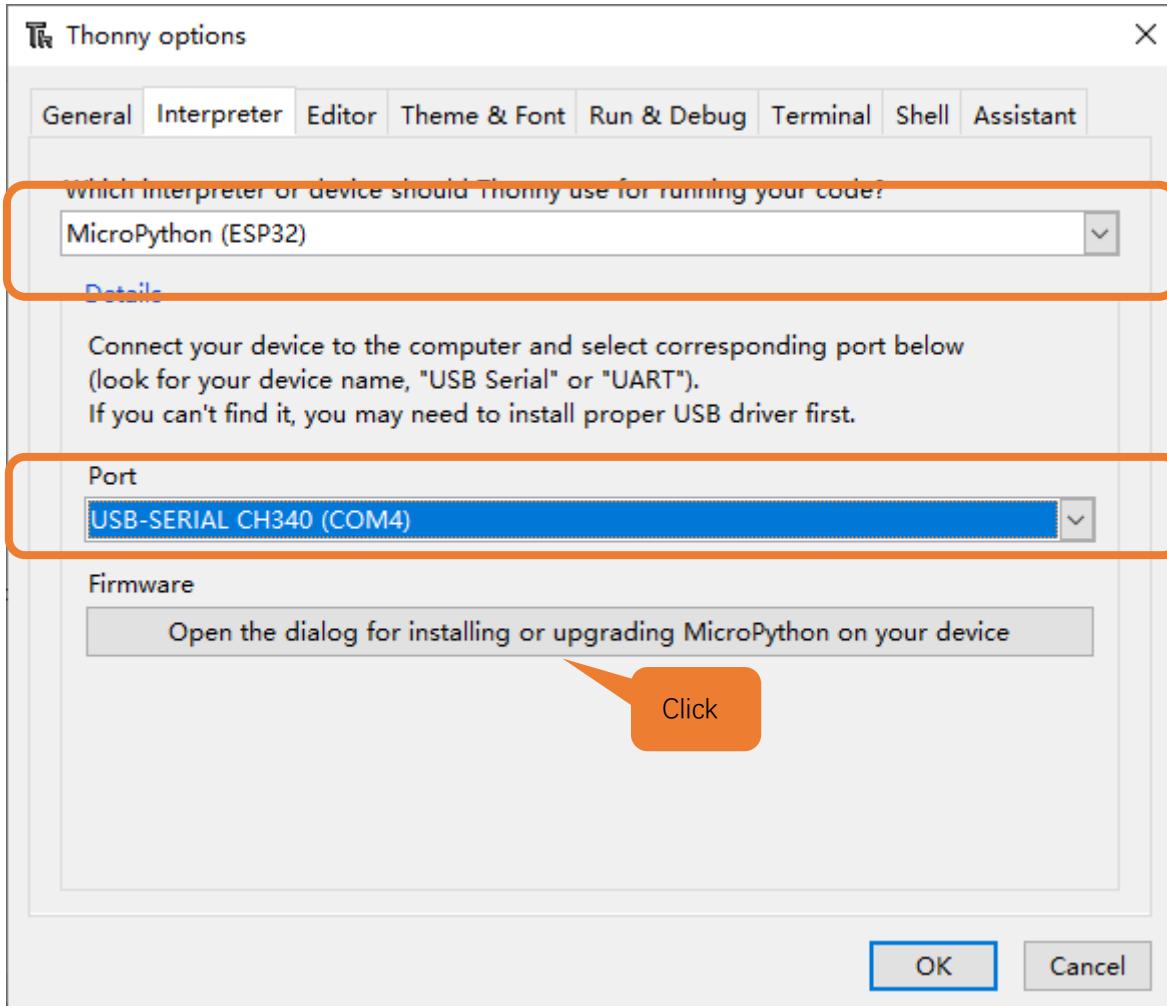
Note: the port of different people may be different, which is a normal situation.

1. Open Thonny, click "run" and select "Select interpreter..."

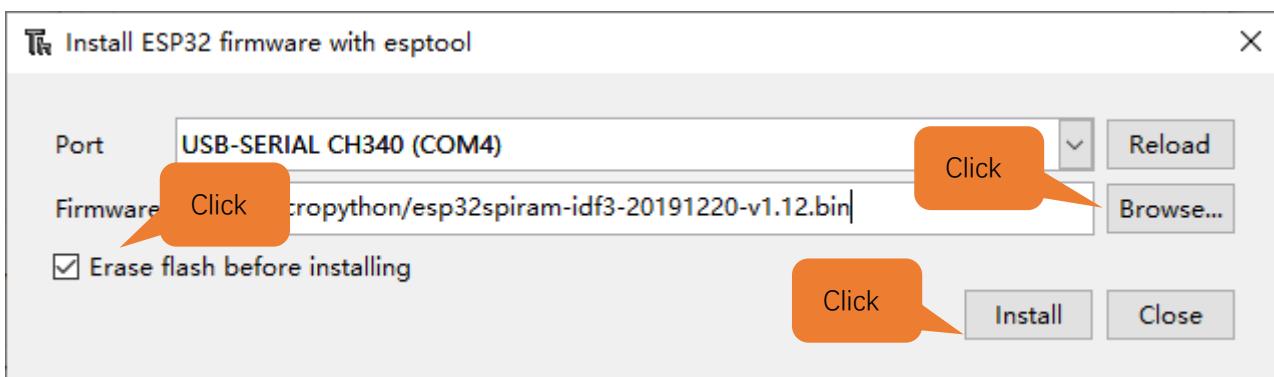




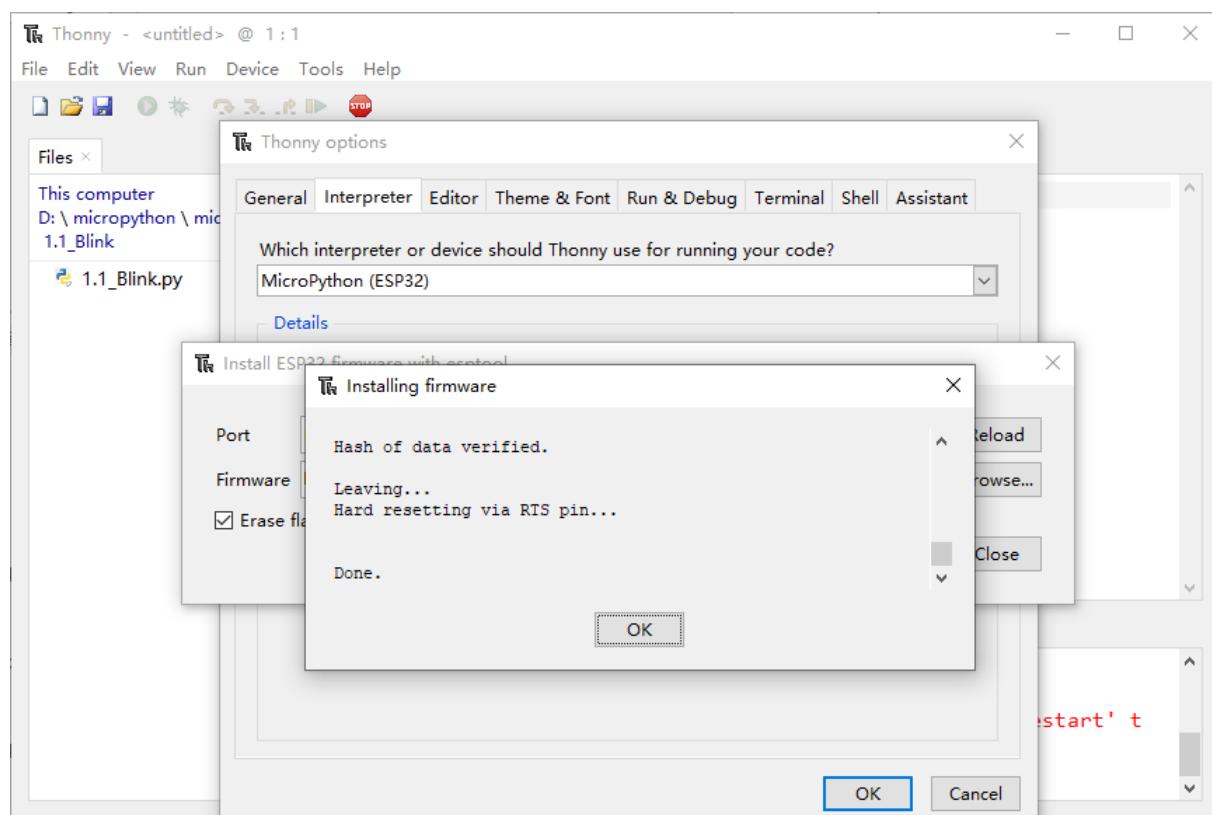
2. Select “Micropython (ESP32)”, select “USB-SERIAL CH340 (COM4)”, and then click the long button under “Firmware”.



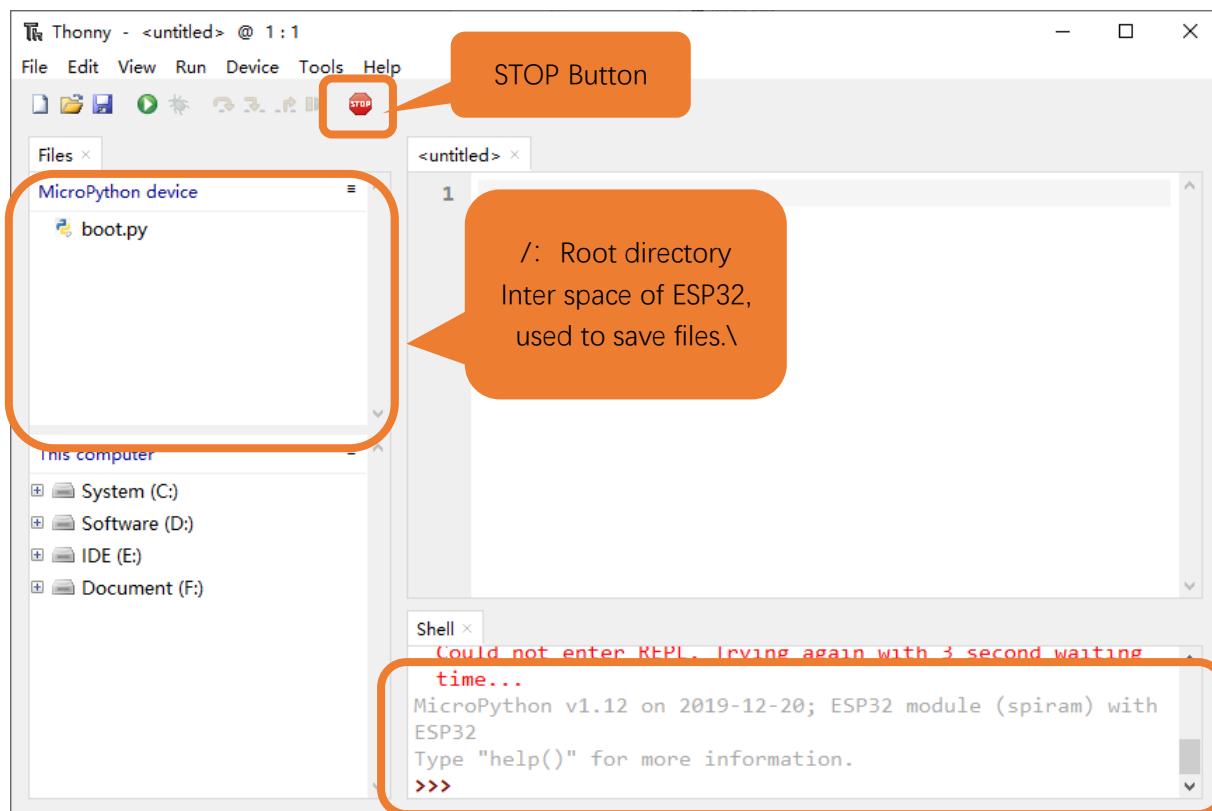
3. The following dialog box pops up. Select “USB-SERIAL CH340 (COM4)” for “Port” and then click “Browse...”. Select the previous prepared microPython firmware “**esp32spiram-idf3-20191220-v1.12.bin**”. Check “Erase flash before installing” and click “install” to wait for the prompt of finishing installation



4. Wait for the installation to be done.



5. Close all dialog boxes, turn to main interface and click "STOP". As shown in the illustration below



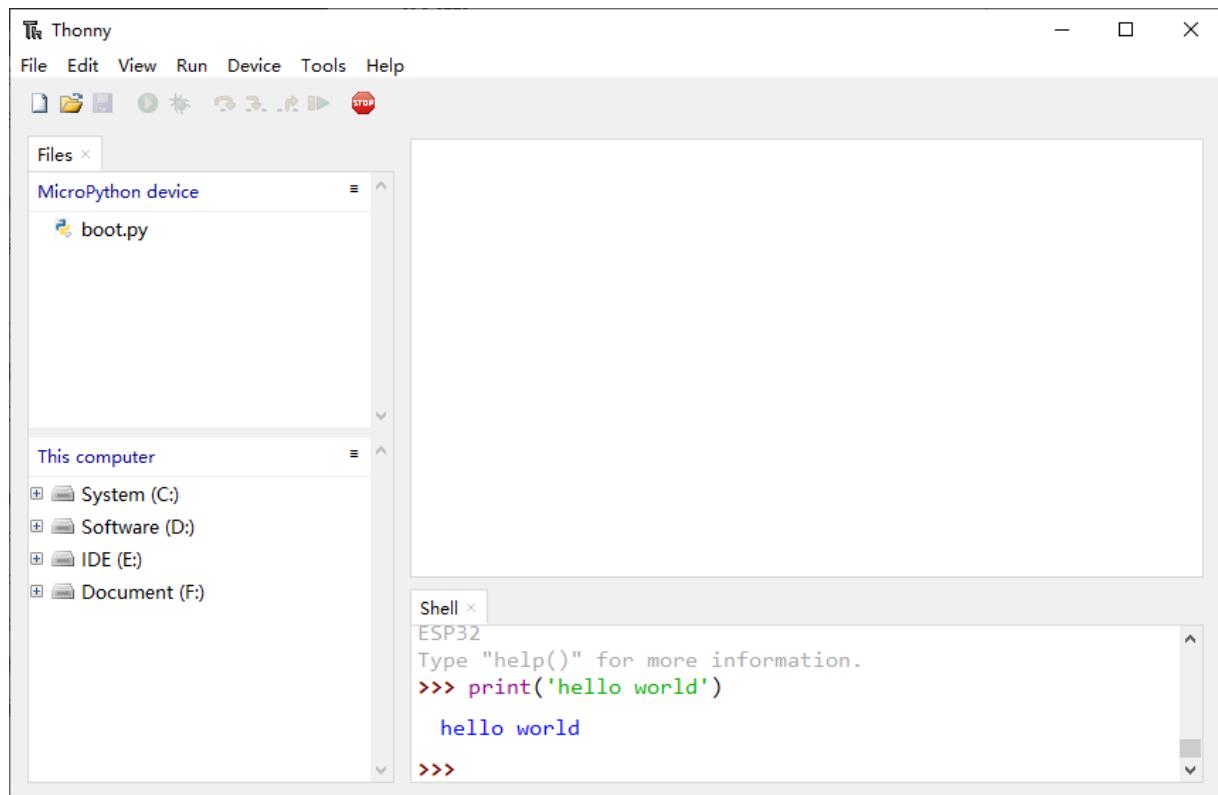
6. So far, all the preparations have been made.



## 0.5 Testing codes (Important)

### Testing Shell Command

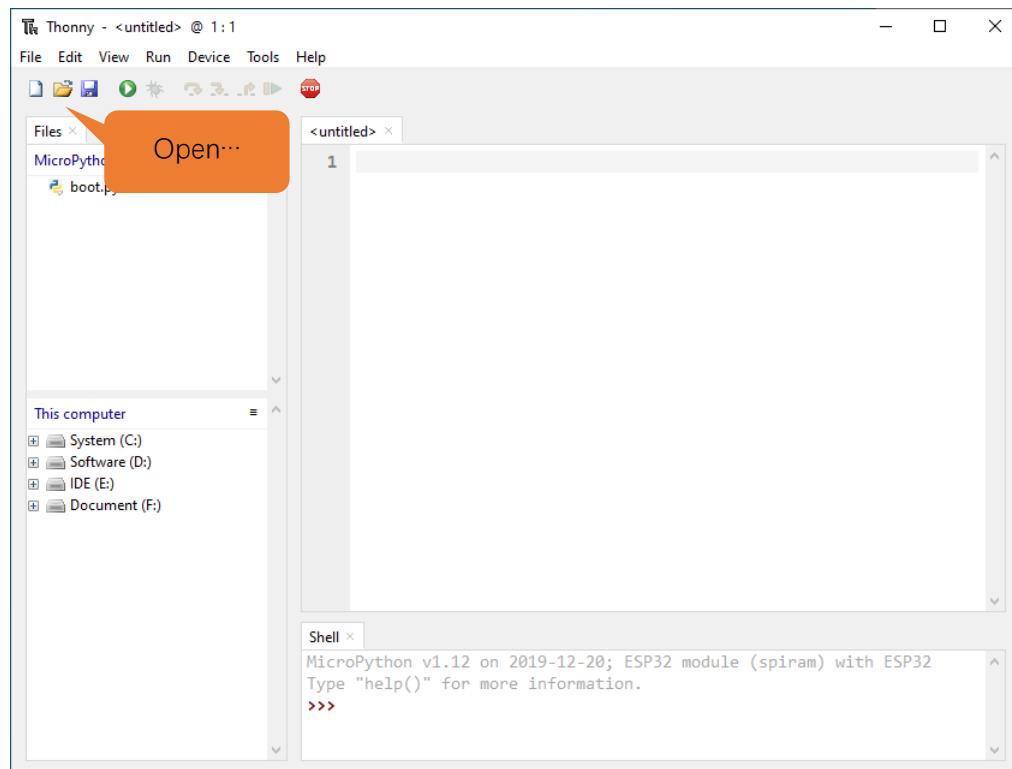
Enter “print('hello world')” in “Shell” and press Enter.



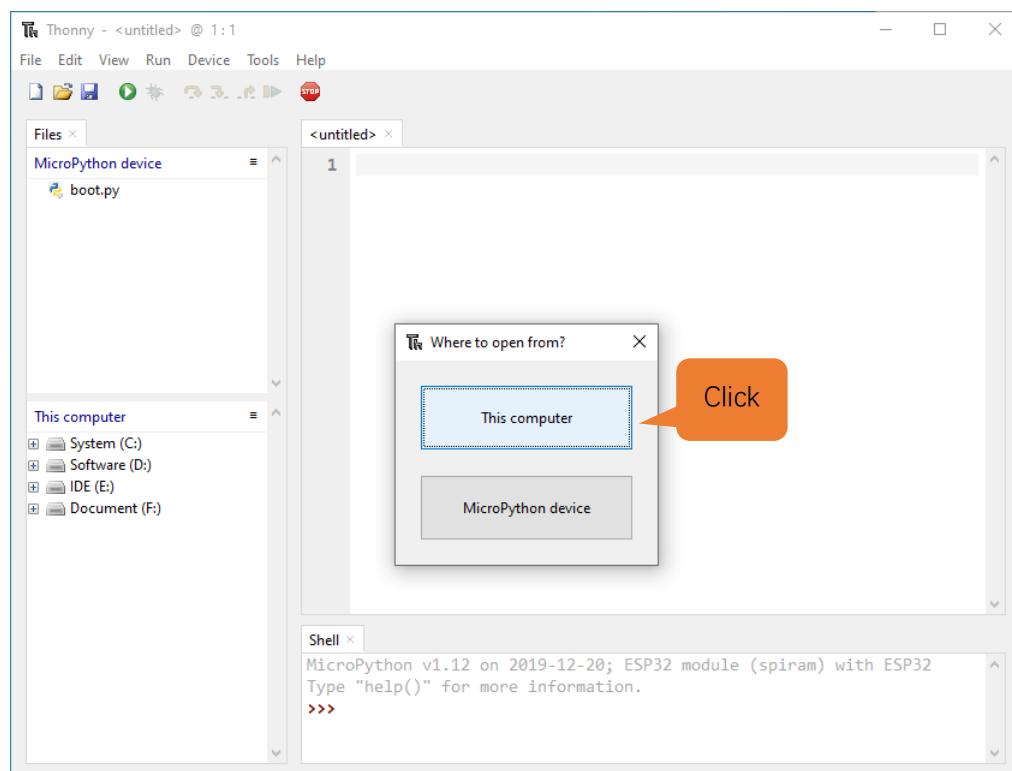
## Running Online

ESP32 needs to be connected to a computer when it is run online. Users can use Thonny to write and debug programs.

1. Open Thonny and click “Open…”.

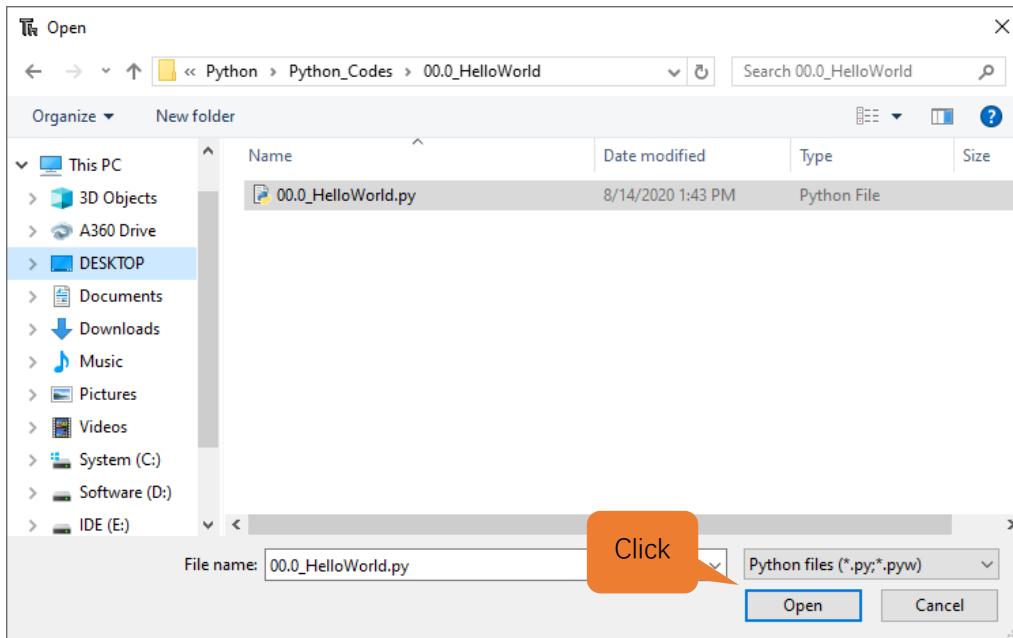


2. On the newly pop-up window, click “This computer”.

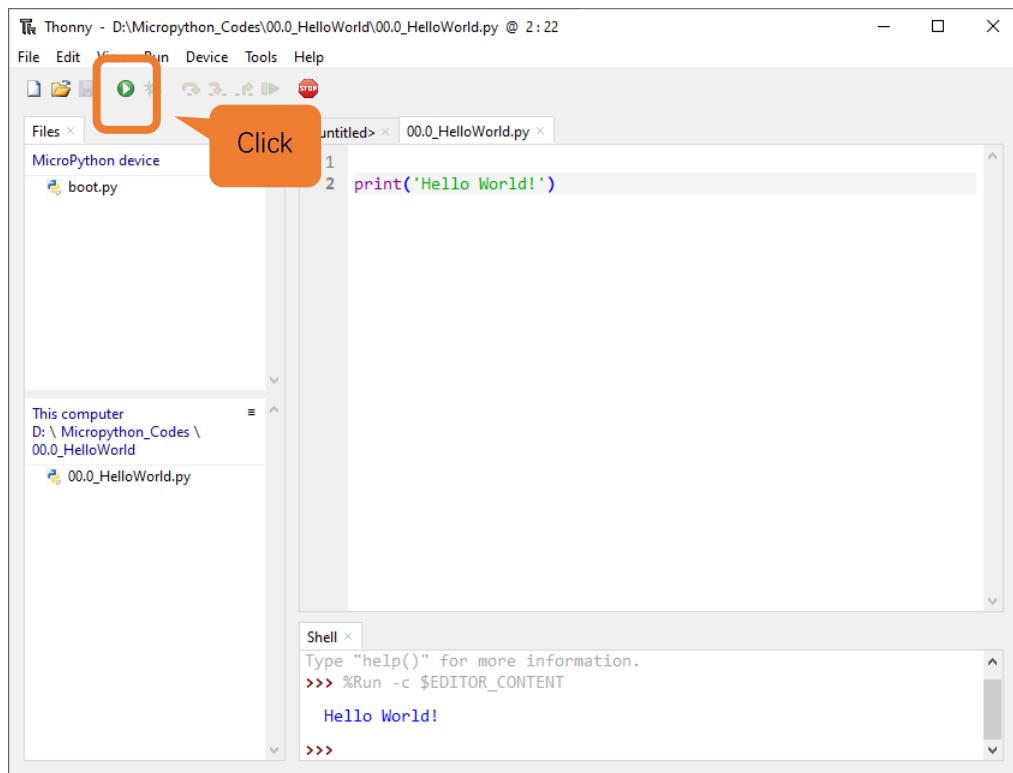




In the new dialog box, select “00.0\_HelloWorld.py” in “Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32/Python/Python\_Codes/00.0\_HelloWorld” folder.



Click “Run current script” to execute the program and “Hello World” will be printed in “Shell”.

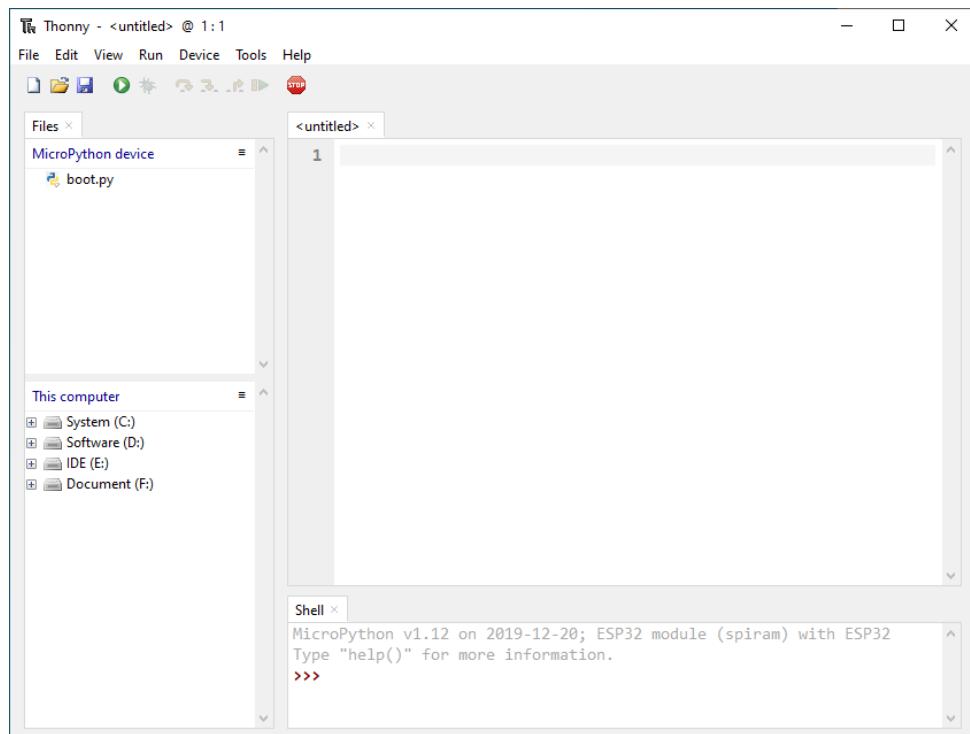


Note: When running online, if you press the reset key of ESP32, user's code will not be executed again. If you wish to run the code automatically after resetting the code, please refer to the following [Running Offline](#).

## Running Offline (Importance)

After ESP32 is reset, it runs the file boot.py in root directory first and then runs file main.py, and finally, it enters "Shell". Therefore, to make ESP32 execute user's programs after resetting, we need to add a guiding program in boot.py to execute user's code.

1. Move the program folder "**Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32/Python/Python\_Codes**" to disk(D) in advance with the path of "**D:/Micropython\_Codes**". Open "Thonny".



2. Expand "00.1\_Boot" in the "Micropython\_Codes" in the directory of disk(D), and double-click boot.py, which is provided by us to enable programs in "MicroPython device" to run offline.

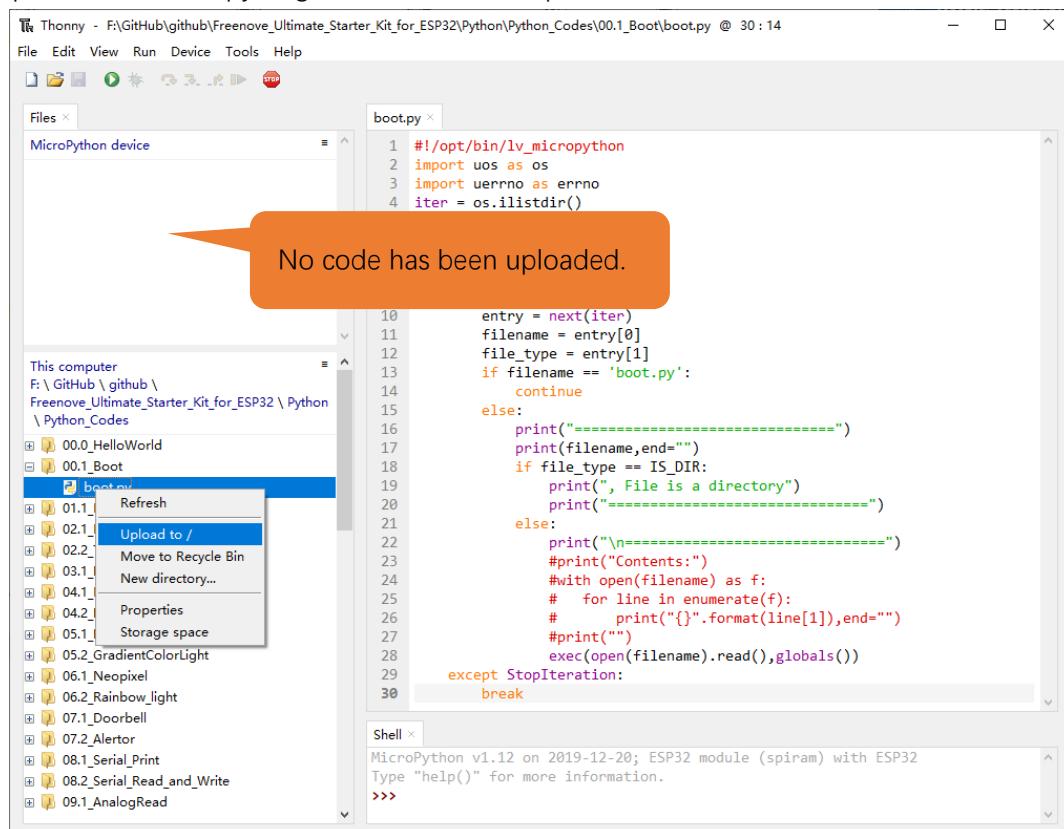
```

1 #!/opt/bin/lv_micropython
2 import uos as os
3 import uerrno as errno
4 iter = os.ilistdir()
5 IS_DIR = 0x4000
6 IS_REGULAR = 0x8000
7
8 while True:
9     try:
10         entry = next(iter)
11         filename = entry[0]
12         file_type = entry[1]
13         if filename == 'boot.py':
14             continue
15         else:
16             print("====")
17             print(filename,end="")
18             if file_type == IS_DIR:
19                 print(", File is a directory")
20                 print("====")
21             else:
22                 print("\n====")
23                 #print("Contents:")
24                 #with open(filename) as f:
25                 #    for line in enumerate(f):
26                 #        print("{}{}".format(line[1]),end="")
27                 #print("")
28                 exec(open(filename).read(),globals())
29
30     except StopIteration:
31         break

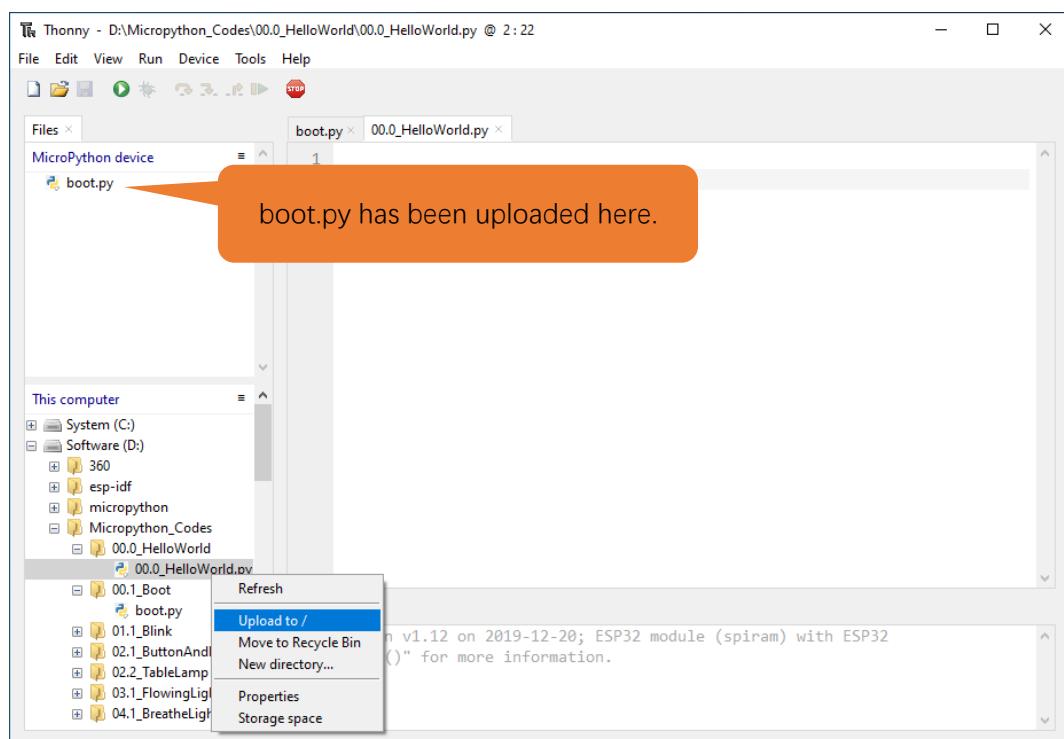
```

Shell x  
MicroPython v1.12 on 2019-12-20; ESP32 module (spiram) with ESP32  
Type "help()" for more information.  
>>>

If you want your written programs to run offline, you need to upload boot.py we provided and all your codes to “MicroPython device” and press ESP32’s reset key. Here we use programs 00.0 and 00.1 as examples. Select “boot.py”, right-click to select “Upload to /”.



Similarly, upload “00.0\_HelloWorld.py” to “MicroPython device”.





3. Press the reset key and in the box of the illustration below, you can see the code is executed.

The screenshot shows the Thonny IDE interface. In the top menu bar, it says "Thonny - F:\GitHub\github\Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32\Python\Python\_Codes\00.0\_HelloWorld\00.0\_HelloWorld.py @ 2 : 24". The left sidebar shows a file tree under "MicroPython device" with files "00.0\_HelloWorld.py" and "boot.py". The main area has a tab titled "00.0\_HelloWorld.py" containing the code:

```
1 print('Hello World!\n')
```

Below this is a "Shell" window showing the output of the program:

```
W (146) cpu_start: chip revision is higher than the one configured in menuconfig. Suggest to upgrade it.
I (149) cpu_start: Starting scheduler on PRO CPU.
T (150) cpu_start: Starting scheduler on APP CPU.
=====
00.0_HelloWorld.py
=====
Hello World!
```

The line "Hello World!" is highlighted with an orange rectangular box. At the bottom of the shell window, it says "MicroPython v1.12 on 2019-12-20; ESP32 module (spiram) with ESP32 Type "help()" for more information."

## 0.6 Thonny Common Operation

### Uploading Code to ESP32

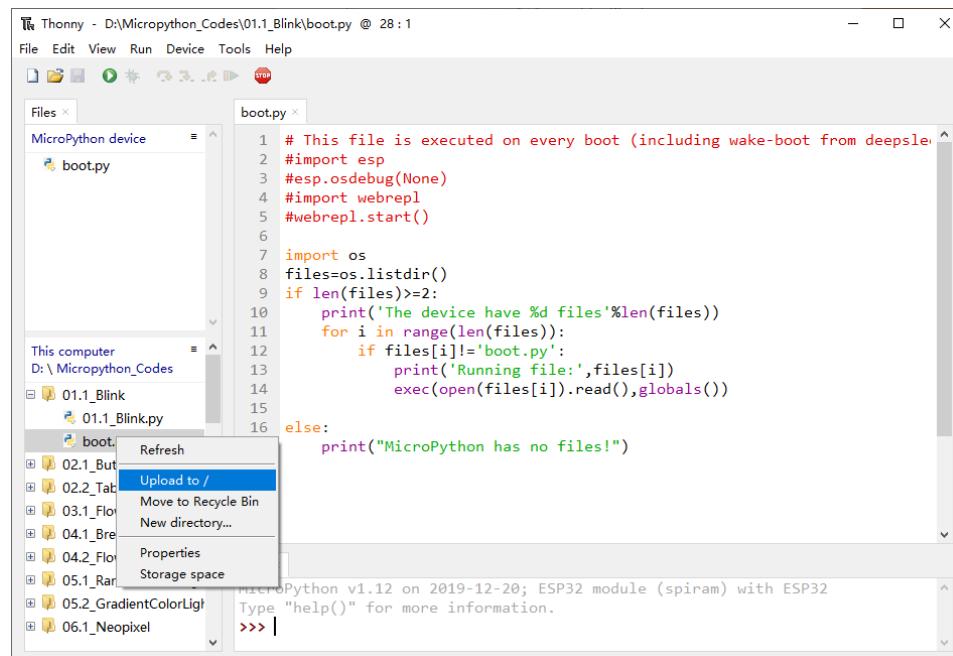
For convenience, we take the operation on “boot.py” as an example here. We have added “boot.py” to every code directory. Each time when ESP32 restarts, if there is a “boot.py” in the root directory, it will execute this code first.

```
# This file is executed on every boot (including wake-boot from deepsleep)
import esp
#esp.osdebug(None)
import webrepl
#webrepl.start()

import os
files=os.listdir()
if len(files)>=2:
    print('The device have %d files'%len(files))
    for i in range(len(files)):
        if files[i]!='boot.py':
            print('Running file:',files[i])
            exec(open(files[i]).read(),globals())
else:
    print("MicroPython has no files!")


```

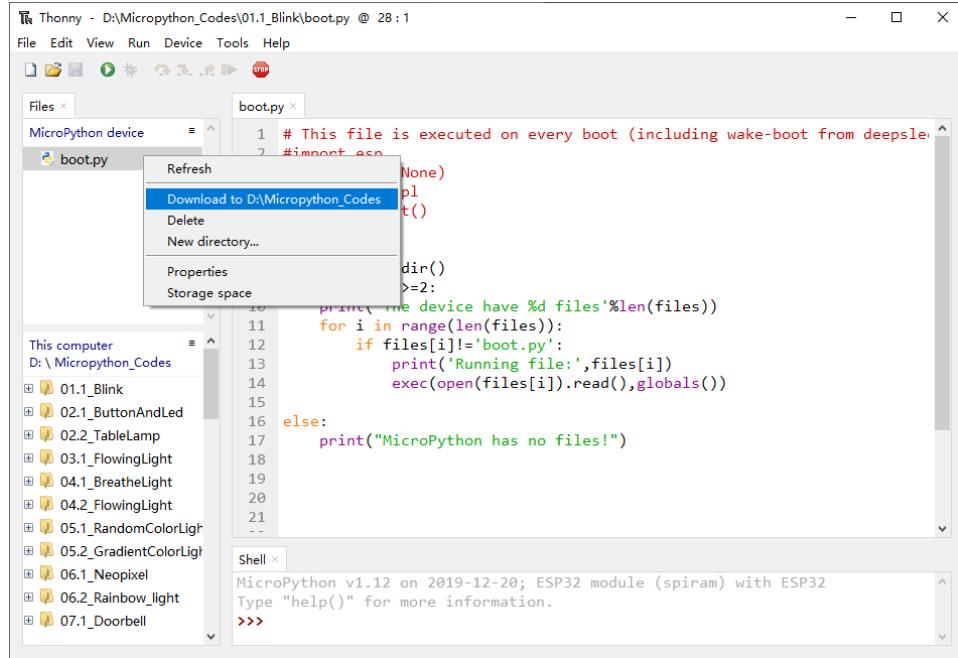
Select “boot.py” in “01.1\_Blink”, right-click your mouse and select “Upload to /” to upload code to ESP32’s root directory.





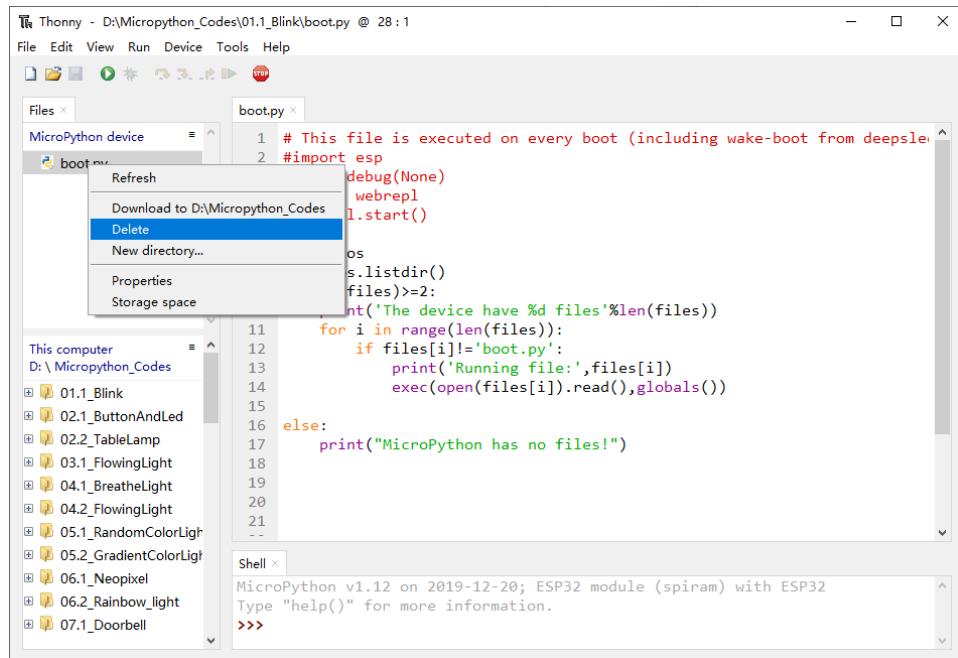
## Downloading Code to Computer

Select “boot.py” in “MicroPython device”, right-click to select “Download to ...” to download the code to your computer.



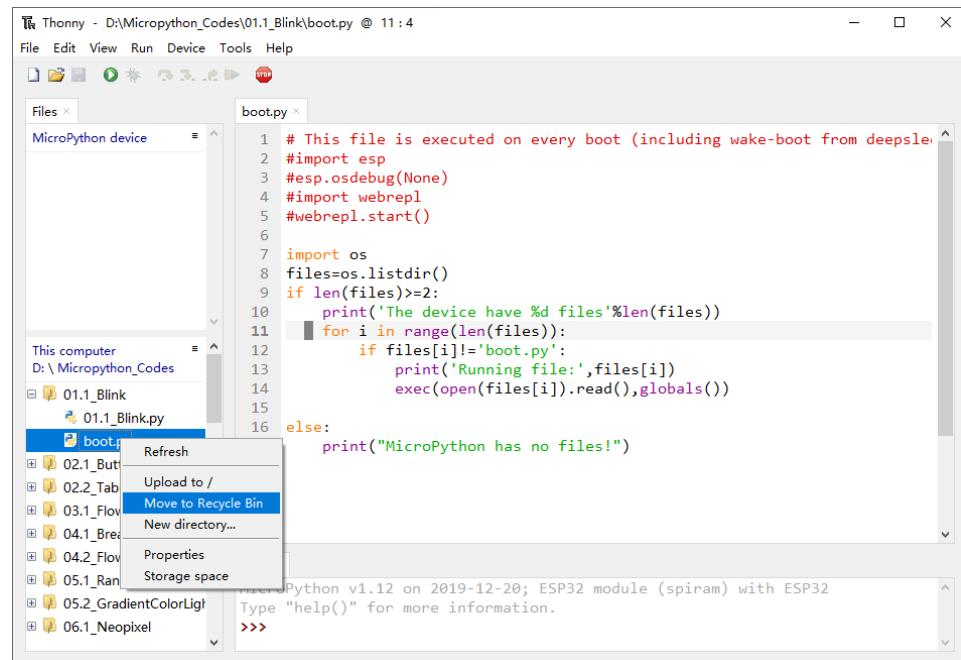
## Deleting Files from ESP32's Root Directory

Select “boot.py” in “MicroPython device”, right-click it and select “Delete” to delete “boot.py” from ESP32’s root directory.



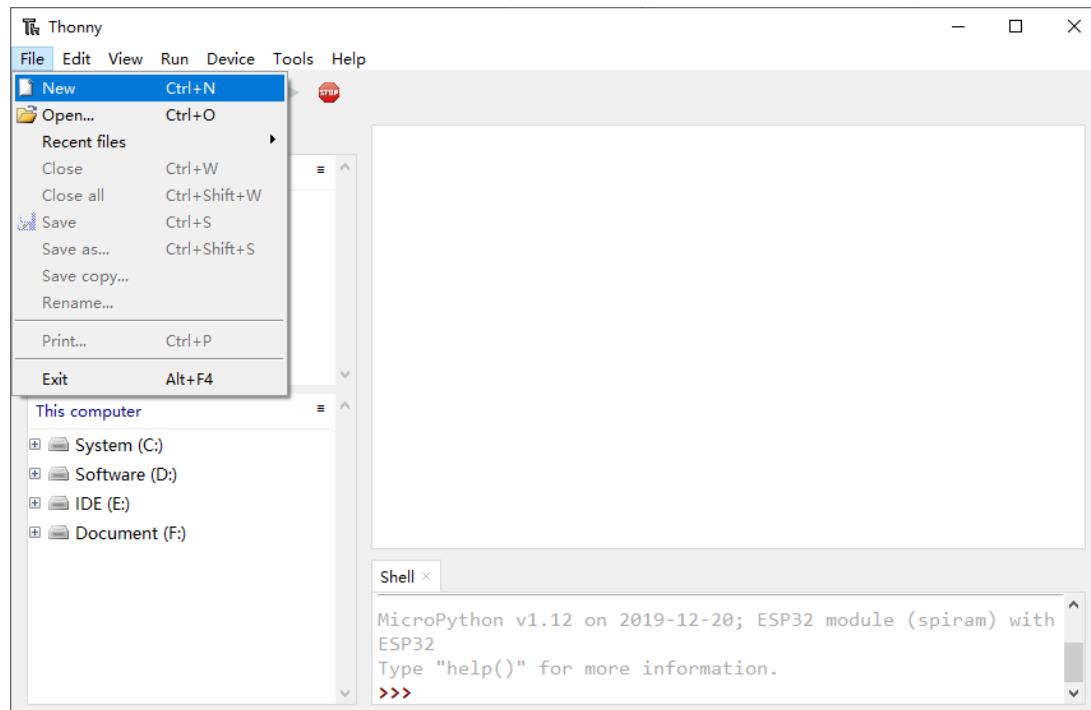
## Deleting Files from your Computer Directory

Select “boot.py” in “01.1\_Blink”, right-click it and select “Move to Recycle Bin” to delete it from “01.1\_Blink”.



## Creating and Saving the code

Click “File”→“New” to create and write codes.



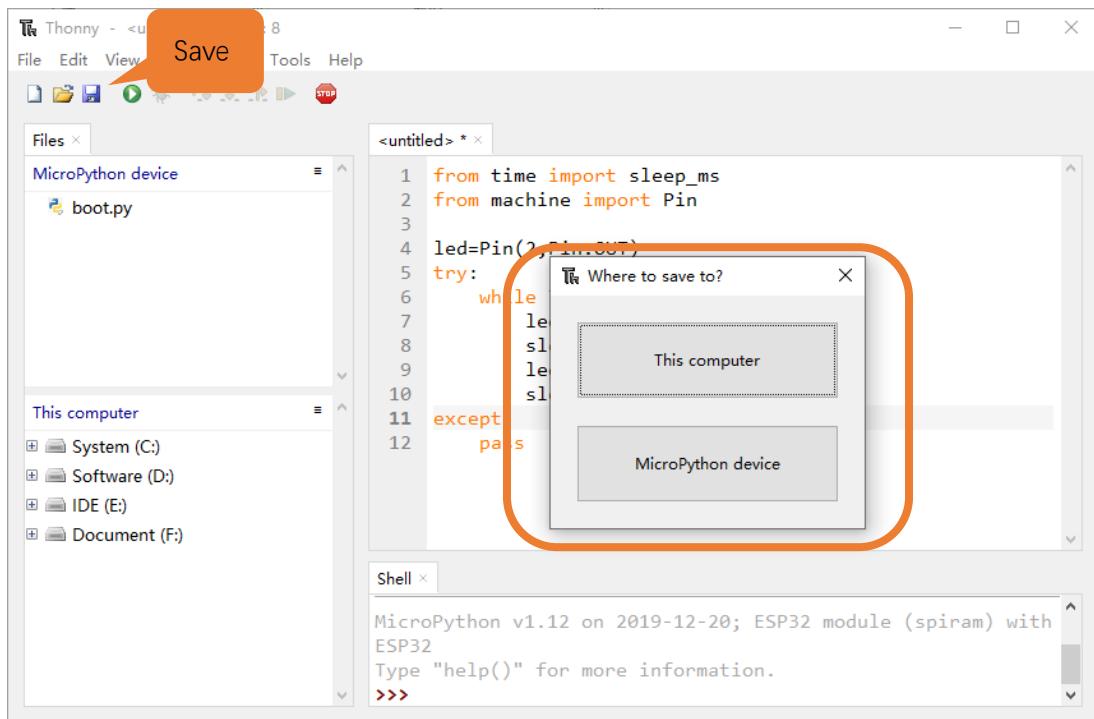


Enter codes in the newly opened file. Here we use codes of “01.1\_Blink.py” as an example.

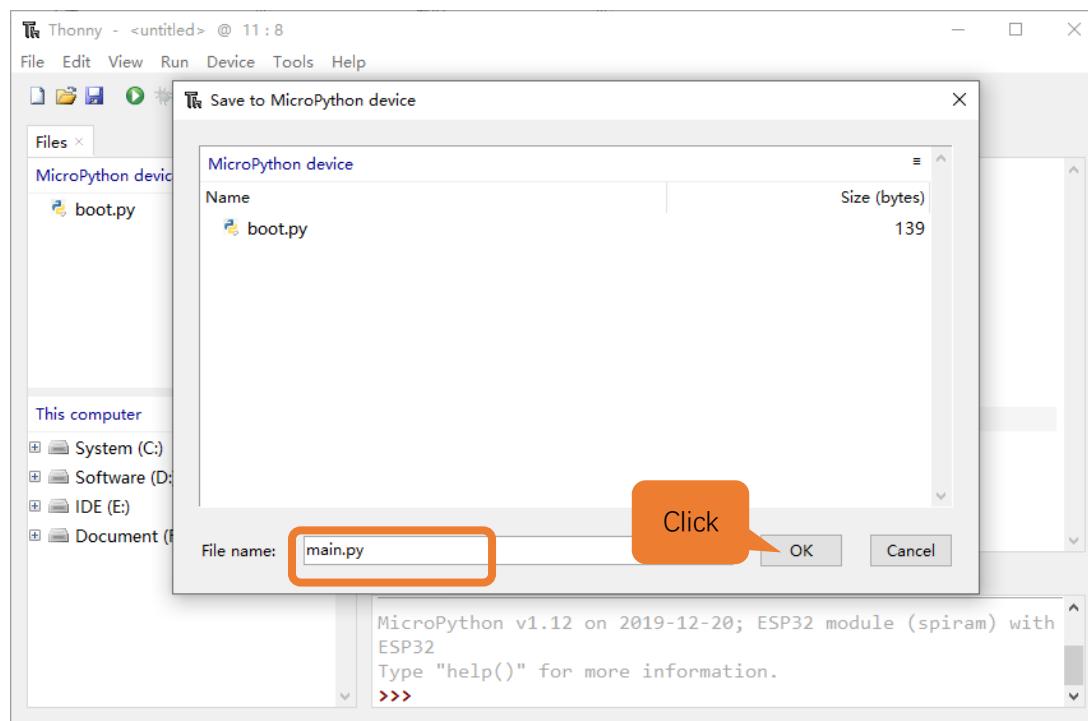
The screenshot shows the Thonny IDE interface. The menu bar includes File, Edit, View, Run, Device, Tools, and Help. The left sidebar shows a 'Files' tab with a tree view of 'MicroPython device' and 'boot.py'. The main code editor window contains the following Python code:

```
1 from time import sleep_ms
2 from machine import Pin
3
4 led=Pin(2,Pin.OUT)
5 try:
6     while True:
7         led.value(1)
8         sleep_ms(1000)
9         led.value(0)
10        sleep_ms(1000)
11 except:
12     pass
```

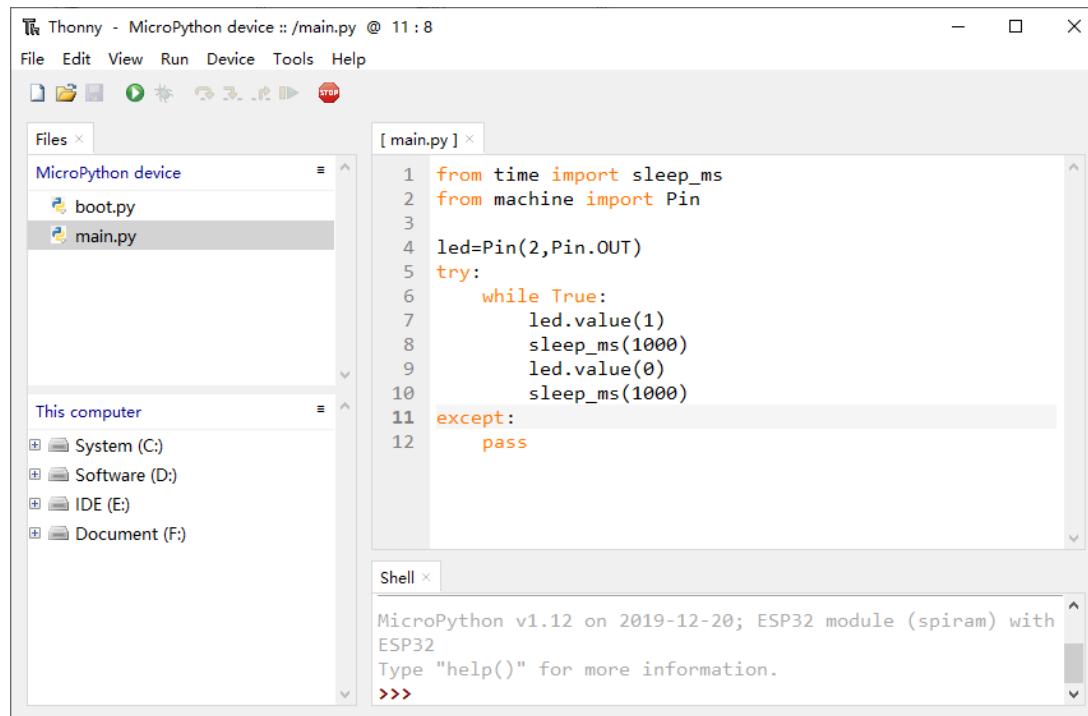
Click “Save” on the menu bar. You can save the codes either to your computer or to ESP32-WROVER.



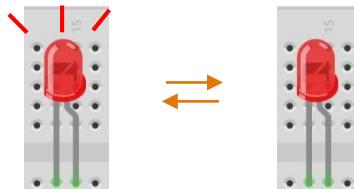
Select “MicroPython device”, enter “main.py” in the newly pop-up window and click “OK”.



You can see that codes have been uploaded to ESP32-WROVER.



Disconnect and reconnect USB cable, and you can see that LED is ON for one second and then OFF for one second, which repeats in an endless loop.



## 0.7 Note

Though there are many pins available on ESP32, some of them have been connected to peripheral equipment, so we should avoid using such pins to prevent pin conflicts. For example, when downloading programs, make sure that the pin state of Strapping Pin, when resetting, is consistent with the default level; do NOT use Flash Pin; Do NOT use Cam Pin when using Camera function.

## Strapping Pin

The state of Strapping Pin can affect the functions of ESP32 after it is reset, as shown in the table below.

Voltage of Internal LDO (VDD_SDIO)				
Pin	Default	3.3 V	1.8 V	
MTDI	Pull-down	0	1	
Booting Mode				
Pin	Default	SPI Boot	Download Boot	
GPIO0	Pull-up	1	0	
GPIO2	Pull-down	Don't-care	0	
Enabling/Disabling Debugging Log Print over U0TXD During Booting				
Pin	Default	U0TXD Active	U0TXD Silent	
MTDO	Pull-up	1	0	
Timing of SDIO Slave				
Pin	Default	Falling-edge Sampling Falling-edge Output	Rising-edge Sampling Falling-edge Output	Rising-edge Sampling Rising-edge Output
MTDO	Pull-up	0	0	1
GPIO5	Pull-up	0	1	0
				1

If you have any difficulties or questions with this tutorial or toolkit, feel free to ask for our quick and free technical support through support@freenove.com at any time.

or check: [https://www.espressif.com/sites/default/files/documentation/esp32-wrover\\_datasheet\\_en.pdf](https://www.espressif.com/sites/default/files/documentation/esp32-wrover_datasheet_en.pdf)

## Flash Pin

GPIO6-11 has been used to connect the integrated SPI flash on the module, and is used when GPIO 0 is power on and at high level. Flash is related to the operation of the whole chip, so the external pin GPIO6-11 cannot be used as an experimental pin for external circuits, otherwise it may cause errors in the operation of

**Any concerns? ✉ support@freenove.com**

the program.

GPIO16-17 has been used to connect the integrated PSRAM on the module.

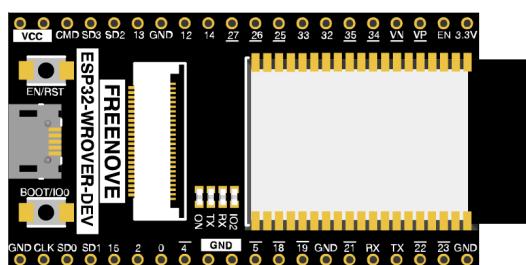
Because of external pull-up, MTDI pin is not suggested to be used as a touch sensor. For details, please refer to Peripheral Interface and Sensor chapter in "[ESP32 Data Sheet](#)".

For more relevant information, please click:

[https://www.espressif.com/sites/default/files/documentation/esp32-wrover\\_datasheet\\_en.pdf](https://www.espressif.com/sites/default/files/documentation/esp32-wrover_datasheet_en.pdf).

## Cam Pin

When using the cam camera of our ESP32-WROVER, please check the pins of it. Pins with underlined numbers are used by the cam camera function, if you want to use other functions besides it, please avoid using them.



CAM_Pin	GPIO_pin
I2C_SDA	GPIO26
I2C_SCL	GPIO27
CSI_VSYNC	GPIO25
CSI_HREF	GPIO23
CSI_Y9	GPIO35
XCLK	GPIO21
CSI_Y8	GPIO34
CSI_Y7	GPIO39
CSI_PCLK	GPIO22
CSI_Y6	GPIO36
CSI_Y2	GPIO4
CSI_Y5	GPIO19
CSI_Y3	GPIO5
CSI_Y4	GPIO18

If you have any questions about the information of GPIO, you can click [here](#) to go back to ESP32-WROVER to view specific information about GPIO.

Or check: [https://www.espressif.com/sites/default/files/documentation/esp32-wrover\\_datasheet\\_en.pdf](https://www.espressif.com/sites/default/files/documentation/esp32-wrover_datasheet_en.pdf).

# Chapter 1 LED (Important)

This chapter is the Start Point in the journey to build and explore ESP32 electronic projects. We will start with simple “Blink” project.

## Project 1.1 Blink

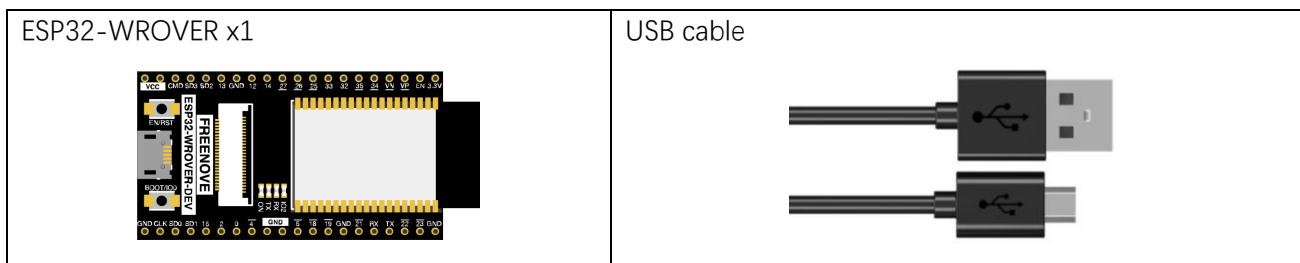
In this project, we will use ESP32 to control blinking a common LED.

If you have not yet installed Thonny, click [here](#).

If you have not yet downloaded Micropython Firmware, click [here](#).

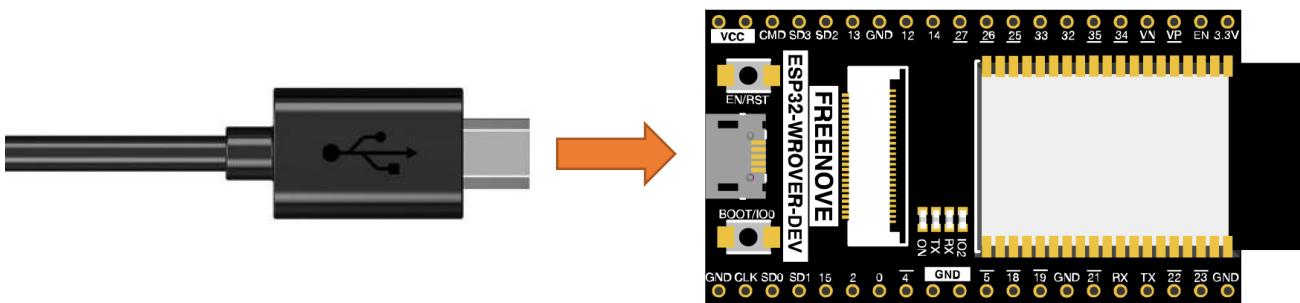
If you have not yet loaded Micropython Firmware, click [here](#).

## Component List



### Power

ESP32-WROVER needs 5v power supply. In this tutorial, we need connect ESP32-WROVER to computer via USB cable to power it and program it. We can also use other 5v power source to power it.



In the following projects, we only use USB cable to power ESP32-WROVER by default.

In the whole tutorial, we don't use T extension to power ESP32-WROVER. So 5V and 3.3V (including EXT 3.3V) on the extension board are provided by ESP32-WROVER.

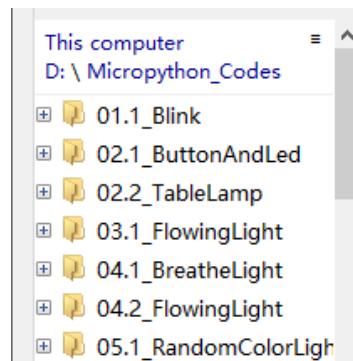
We can also use DC jack of extension board to power ESP32-WROVER. In this way, 5v and EXT 3.3v on extension board are provided by external power resource.

## Code

Codes used in this tutorial are saved in “**Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32/Python/Python\_Codes**”. You can move the codes to any location. For example, we save the codes in Disk(D) with the path of “**D:/Micropython\_Codes**”.

### 01.1\_Blink

Open “Thonny”, click “This computer” → “D:” → “Micropython\_Codes”.



Expand folder “01.1\_Blink” and double click “01.1\_Blink.py” to open it. As shown in the illustration below.

```

from time import sleep_ms
from machine import Pin

led=Pin(2,Pin.OUT) #create LED object from pin2,Set Pin2 to output
try:
    while True:
        led.value(1)      #Set led turn on
        sleep_ms(1000)
        led.value(0)      #Set led turn off
        sleep_ms(1000)
except:
    pass

```

Make sure ESP32 has been connected with the computer with ESP32 correctly. Click “Stop/Restart backend” or press the reset button, and then wait to see what interface will show up.

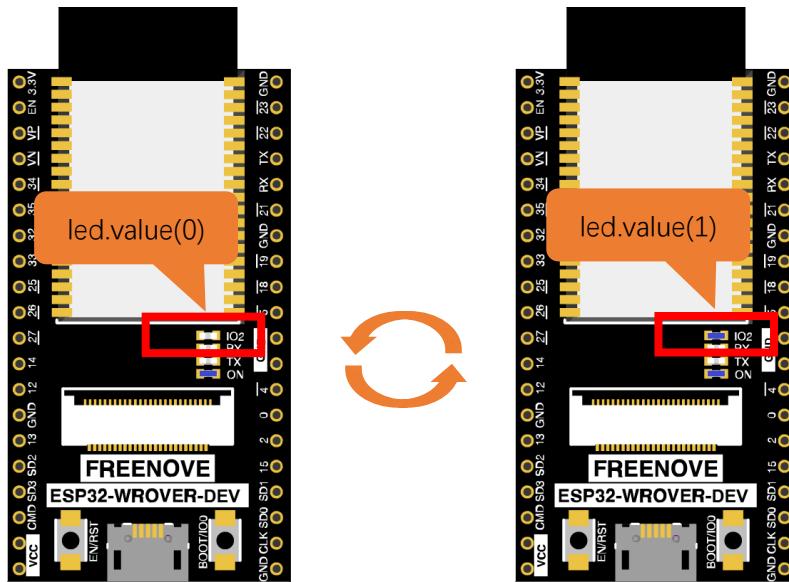
```

1.1_Blink.py x
1. from time import sleep_ms
2. from machine import Pin
3.
4. led = Pin(2,Pin.OUT) #create LED object from pin2,Set Pin
5. while True:
6.     led.value(1)           #Set led turn on
7.     sleep_ms(1000)
8.     led.value(0)           #Set led turn off
9.     sleep_ms(1000)
10. except:
11.     pass

```

This indicates that the connection is successful.

Click "Run current script" shown in the box above, the code starts to be executed and the LED in the circuit starts to blink.



#### Note:

This is the code [running online](#). If you disconnect USB cable and repower ESP32 or press its reset key, LED stops blinking and the following messages will be displayed in Thonny.

The screenshot shows the Thonny IDE interface. The left sidebar displays a file tree with several Python files under 'D:\Micropython\_Codes\01.1\_Blink'. The main editor window shows the code for '01.1\_Blink.py':

```

from time import sleep_ms
from machine import Pin

led=Pin(2,Pin.OUT) #create LED object from pin2,Set Pin2 to output
try:
    while True:
        led.value(1)      #Set led turn on
        sleep_ms(1000)
        led.value(0)      #Set led turn off
        sleep_ms(1000)
except:
    pass

```

The shell window at the bottom shows a connection error:

```

raise ConnectionClosedException(self._error)
thonny.plugins.micropython.connection.ConnectionClosedException: GetOverlappedResult failed (PermissionError(13, 'Access is denied.', None, 5))

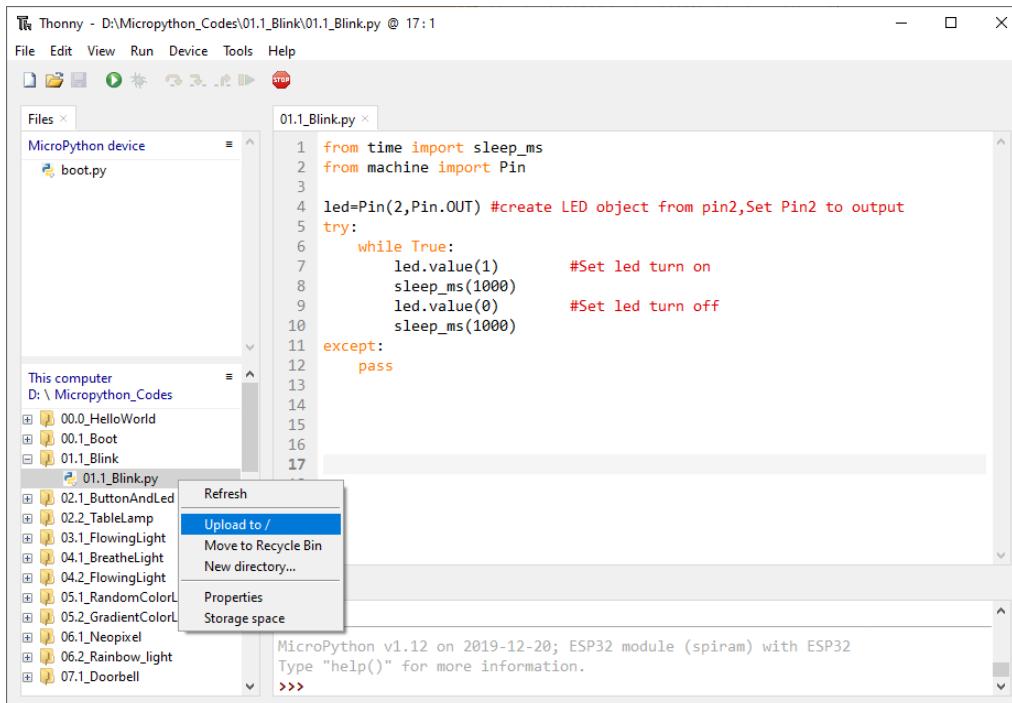
>>>
Connection lost (GetOverlappedResult failed (PermissionError(13, 'Access is denied.', None, 5)))

Use Stop/Restart to reconnect.

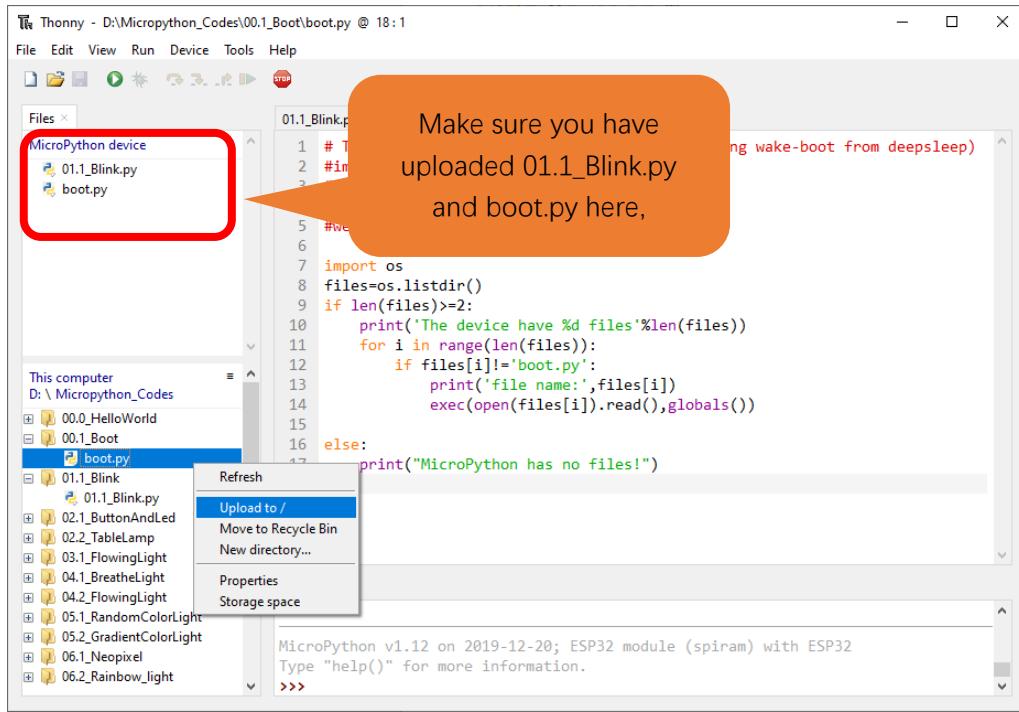
```

### Uploading code to ESP32

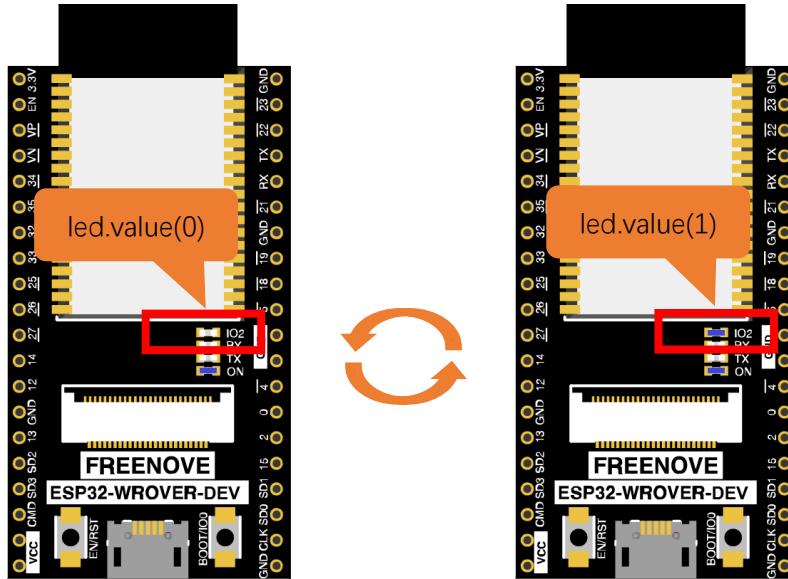
As shown in the following illustration, right-click the file 01.1\_Blink.py and select “Upload to /” to upload code to ESP32.



Upload boot.py in the same way.

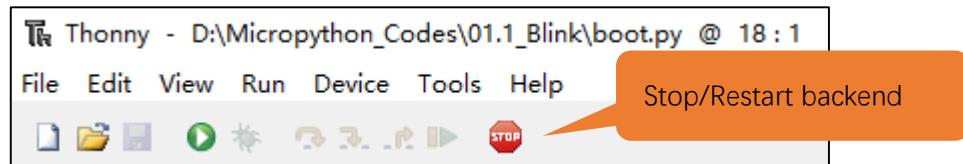


Press the reset key of ESP32 and you can see LED is ON for one second and then OFF for one second, which repeats in an endless loop.



Note:

Codes here is run offline. If you want to stop running offline and enter Shell, just click "Stop" in Thonny.



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

Any concerns? ✉ [support@freenove.com](mailto:support@freenove.com)

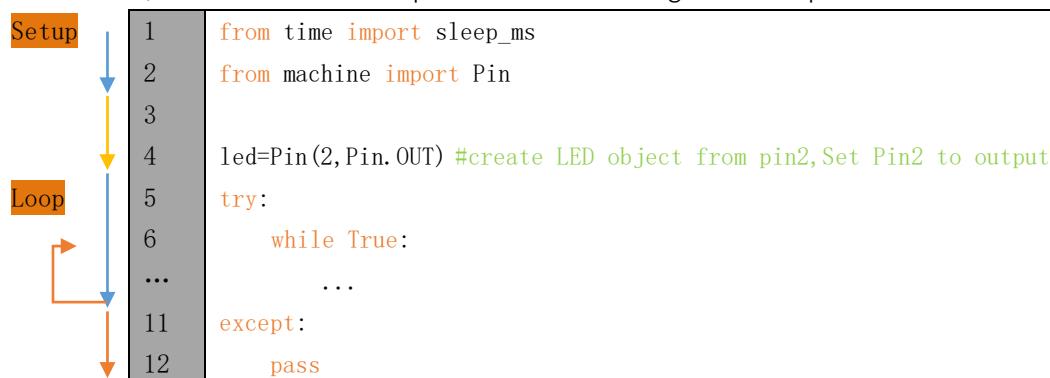
The following is the program code:

```

1  from time import sleep_ms
2  from machine import Pin
3
4  led=Pin(2,Pin.OUT) #create LED object from pin2, Set Pin2 to output
5  try:
6      while True:
7          led.value(1) #Set led turn on
8          sleep_ms(1000)
9          led.value(0) #Set led turn off
10         sleep_ms(1000)
11 except:
12     pass

```

Each time a new file is opened, the program will be executed from top to bottom. When encountering a loop construction, it will execute the loop statement according to the loop condition.



`Print()` function is used to print data to Terminal. It can be executed in Terminal directly or be written in a Python file and executed by running the file.

```
print("Hello world!")
```

Each time when using the functions of ESP32, you need to import modules corresponding to those functions:  
Import `sleep_ms` module of `time` module and `Pin` module of `machine` module.

```

1  from time import sleep_ms
2  from machine import Pin

```

Configure GPIO2 of ESP32-WROVER to output mode and assign it to an object named "led".

```
4  led=Pin(2,Pin.OUT) #create LED object from pin2, Set Pin2 to output
```

It means that from now on, LED represents GPIO2 that is in output mode.

Set the value of LED to 1 and GPIO2 will output high level.

```
7  led.value(1) #Set led turn on
```

Set the value of LED to 0 and GPIO2 will output low level.

```
9  led.value(0) #Set led turn on
```

Execute codes in a while loop.

```

6  while True:
...

```

Put statements that may cause an error in “try” block and the executing statements when an error occurs in “except” block. In general, when the program executes statements, it will execute those in “try” block.

However, when an error occurs to ESP32 due to some interference or other reasons, it will execute statements in “except” block.

“Pass” is an empty statement. When it is executed, nothing happens. It is useful as a placeholder to make the structure of a program look better.

```
5   try:  
...  
11  except:  
12    pass
```

The single-line comment of Micropython starts with a “#” and continues to the end of the line. Comments help us to understand code. When programs are running, Thonny will ignore comments.

```
9 #Set led turn on
```

MicroPython uses indentations to distinguish different blocks of code instead of braces. The number of indentations is changeable, but it must be consistent throughout one block. If the indentation of the same code block is inconsistent, it will cause errors when the program runs.

```
6   while True:  
7       led.value(1) #Set led turn on  
8       sleep_ms(1000)  
9       led.value(0) #Set led turn off  
10      sleep_ms(1000)
```

### How to import python files

Whether to import the built-in python module or to import that written by users, the command “import” is needed.

If you import the module directly you should indicate the module to which the function or attribute belongs when using the function or attribute (constant, variable) in the module. The format should be: <module name>.<function or attribute>, otherwise an error will occur.

```
import random  
  
num = random.randint(1, 100)  
print(num)
```

If you only want to import a certain function or attribute in the module, use the from...import statement. The format is as follows

```
from random import randint  
num = randint(1, 100)  
print(num)
```

When using “from...import” statement to import function, to avoid conflicts and for easy understanding, you can use “as” statement to rename the imported function, as follows

```
from random import randint as rand  
num = rand(1, 100)  
print(num)
```

## Reference

### Class machine

Before each use of the **machine** module, please add the statement “**import machine**” to the top of python file.

**machine.freq(freq\_val):** When freq\_val is not specified, it is to return to the current CPU frequency; Otherwise, it is to set the current CPU frequency.

**freq\_val:** 80000000(80MHz)、160000000(160MHz)、240000000(240MHz)

**machine.reset():** A reset function. When it is called, the program will be reset.

**machine.unique\_id():** Obtains MAC address of the device.

**machine.idle():** Turns off any temporarily unused functions on the chip and its clock, which is useful to reduce power consumption at any time during short or long periods.

**machine.disable\_irq():** Disables interrupt requests and return the previous IRQ state. The disable\_irq () function and enable\_irq () function need to be used together; Otherwise the machine will crash and restart.

**machine.enable\_irq(state):** To re-enable interrupt requests. The parameter **state** should be the value that was returned from the most recent call to the disable\_irq() function

**machine.time\_pulse\_us(pin, pulse\_level, timeout\_us=1000000):**

Tests the duration of the external pulse level on the given pin and returns the duration of the external pulse level in microseconds. When pulse level = 1, it tests the high level duration; When pulse level = 0, it tests the low level duration.

If the setting level is not consistent with the current pulse level, it will wait until they are consistent, and then start timing. If the set level is consistent with the current pulse level, it will start timing immediately.

When the pin level is opposite to the set level, it will wait for timeout and return “-2”. When the pin level and the set level is the same, it will also wait timeout but return “-1”. **timeout\_us** is the duration of timeout.

**Class Pin(id[, mode, pull, value])**

Before each use of the **Pin** module, please add the statement “**from machine import Pin**” to the top of python file.

**id:** Arbitrary pin number

**mode:** Mode of pins

**Pin.IN:** Input Mode

**Pin.OUT:** Output Mode

**Pin.OPEN\_DRAIN:** Open-drain Mode

**Pull:** Whether to enable the internal pull up and down mode

**None:** No pull up or pull down resistors

**Pin.PULL\_UP:** Pull-up Mode, outputting high level by default

**Pin.PULL\_DOWN:** Pull-down Mode, outputting low level by default

**Value:** State of the pin level, 0/1

**Pin.init(mode, pull):** Initialize pins

**Pin.value([value]):** Obtain or set state of the pin level, return 0 or 1 according to the logic level of pins.

Without parameter, it reads input level. With parameter given, it is to set output level.

**value:** It can be either True/False or 1/0.

**Pin.irq(trigger, handler):** Configures an interrupt handler to be called when the pin level meets a condition.

**trigger:**

**Pin.IRQ\_FALLING:** interrupt on falling edge

**Pin.IRQ\_RISING:** interrupt on rising edge

**3:** interrupt on both edges

**Handler:** callback function

**Class time**

Before each use of the **time** module, please add the statement “**import time**” to the top of python file

**time.sleep(sec):** Sleeps for the given number of seconds

**sec:** This argument should be either an int or a float.

**time.sleep\_ms(ms):** Sleeps for the given number of milliseconds, ms should be an int.

**time.sleep\_us(us):** Sleeps for the given number of microseconds, us should be an int.

**time.time():** Obtains the timestamp of CPU, with second as its unit.

**time.ticks\_ms():** Returns the incrementing millisecond counter value, which recounts after some values.

**time.ticks\_us():** Returns microsecond

**time.ticks\_cpu():** Similar to ticks\_ms() and ticks\_us(), but it is more accurate(return clock of CPU).

**time.ticks\_add(ticks, delta):** Gets the timestamp after the offset.

**ticks:** ticks\_ms()、 ticks\_us()、 ticks\_cpu()

**delta:** Delta can be an arbitrary integer number or numeric expression

**time.ticks\_diff(old\_t, new\_t):** Calculates the interval between two timestamps, such as ticks\_ms(), ticks\_us() or ticks\_cpu().

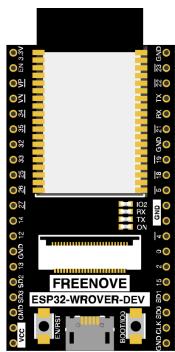
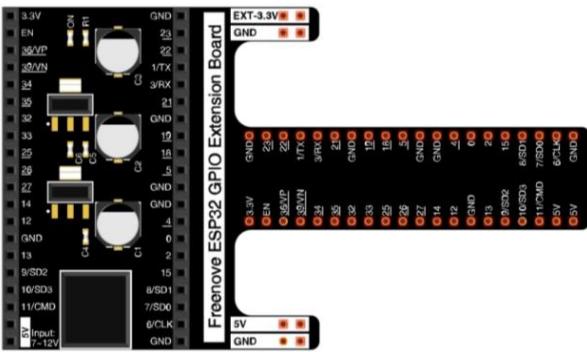
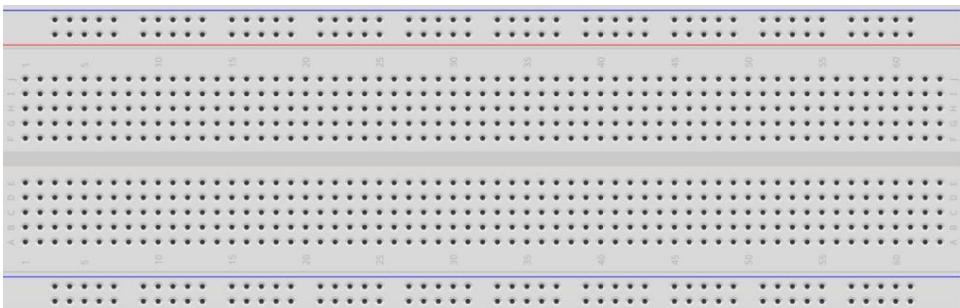
**old\_t:** Starting time

**new\_t:** Ending time

## Project 1.2 Blink

In this project, we will use ESP32 to control blinking a common LED.

### Component List

ESP32-WROVER x1	GPIO Extension Board x1
 	
Breadboard x1	
	
LED x1	Resistor 220Ω x1
	
	Jumper M/M x2
	

### Component knowledge

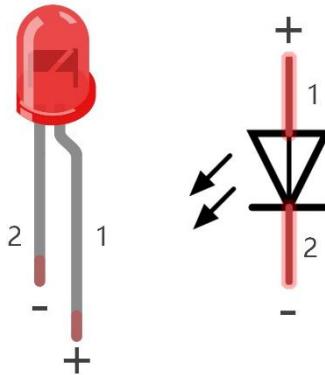
#### LED

An LED is a type of diode. All diodes only work if current is flowing in the correct direction and have two Poles. An LED will only work (light up) if the longer pin (+) of LED is connected to the positive output from a power source and the shorter pin is connected to the negative (-). Negative output is also referred to as Ground

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(GND). This type of component is known as “Polar” (think One-Way Street).

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



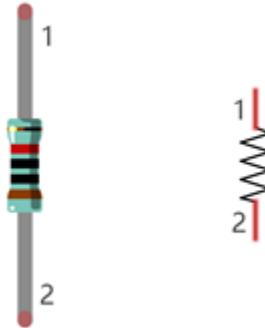
LED	Voltage	Maximum current	Recommended current
Red	1.9-2.2V	20mA	10mA
Green	2.9-3.4V	10mA	5mA
Blue	2.9-3.4V	10mA	5mA
Volt ampere characteristics conform to diode			

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

### Resistor

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

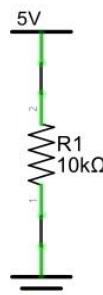
A resistor is a passive electrical component that limits or regulates the flow of current in an electronic circuit. On the left, we see a physical representation of a resistor, and the right is the symbol used to represent the presence of a resistor in a circuit diagram or schematic.



The bands of color on a resistor is a shorthand code used to identify its resistance value. For more details of resistor color codes, please refer to the appendix of this tutorial.

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

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



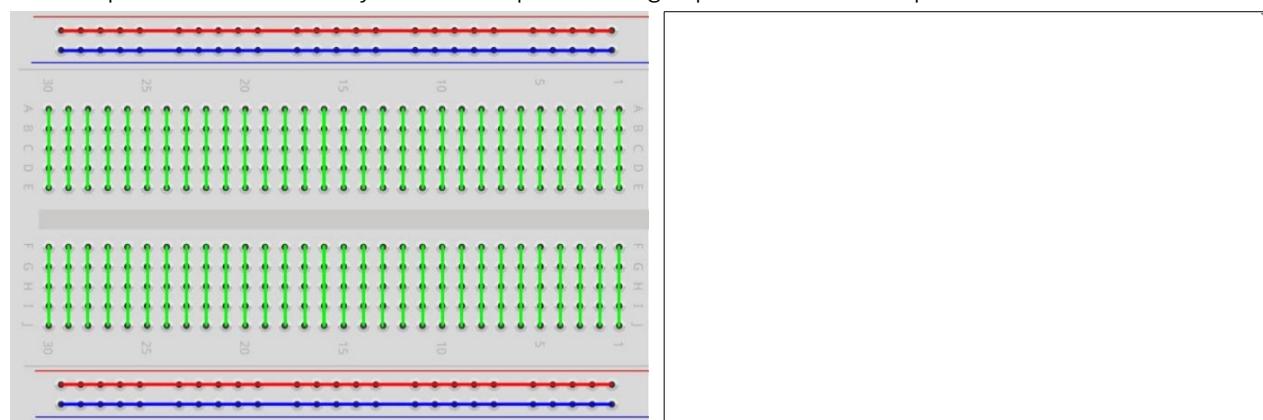
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**WARNING:** Never connect the two poles of a power supply with anything of low resistance value (i.e. a metal object or bare wire) this is a Short and results in high current that may damage the power supply and electronic components.

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

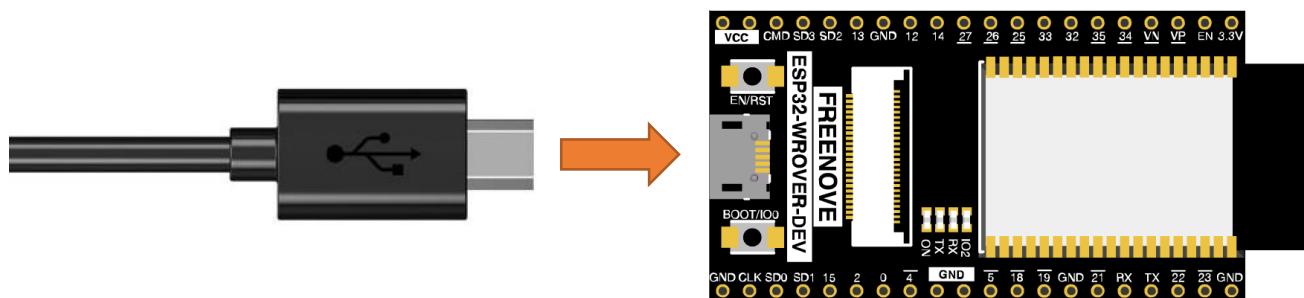
### Breadboard

Here we have a small breadboard as an example of how the rows of holes (sockets) are electrically attached. The left picture shows the way to connect pins. The right picture shows the practical internal structure.



### Power

ESP32-WROVER needs 5v power supply. In this tutorial, we need connect ESP32-WROVER to computer via USB cable to power it and program it. We can also use other 5v power source to power it.



Later, we only use USB cable to power ESP32-WROVER in default.

In the whole tutorial, we don't use T extension to power ESP32-WROVER. So 5V and 3.3V (include EXT 3.3V) on the extension board are from ESP32-WROVER.

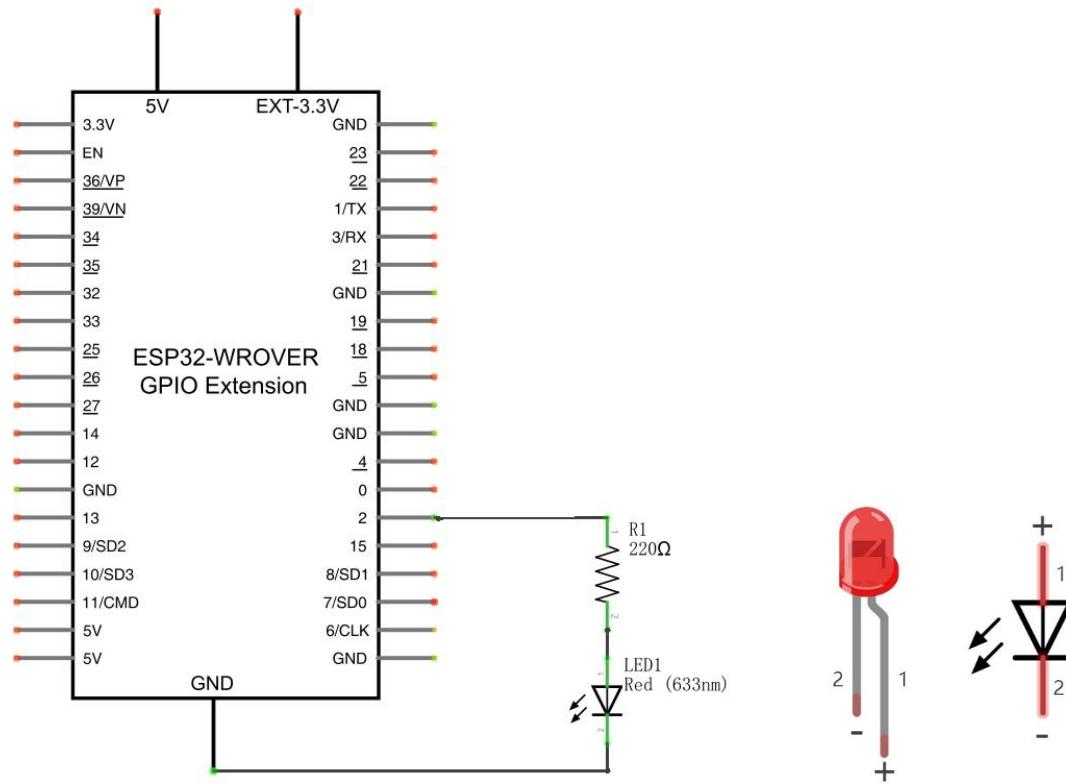
We can also use DC jack of extension board to power ESP32-WROVER. Then 5v and EXT 3.3v on extension board are from external power resource.

## Circuit

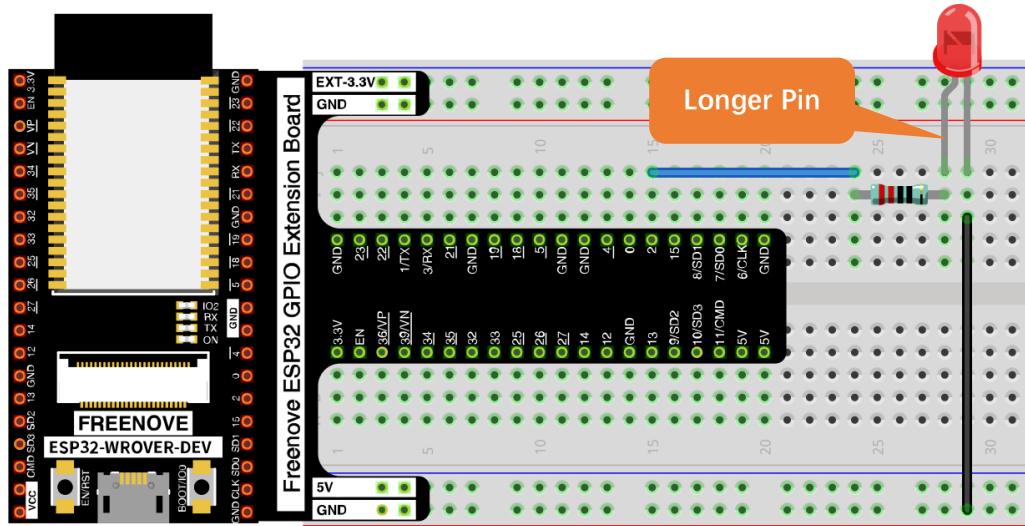
First, disconnect all power from the ESP32-WROVER. Then build the circuit according to the circuit and hardware diagrams. After the circuit is built and verified correct, connect the PC to ESP32-WROVER.

**CAUTION:** Avoid any possible short circuits (especially connecting 5V or GND, 3.3V and GND)! **WARNING:** A short circuit can cause high current in your circuit, create excessive component heat and cause permanent damage to your hardware!

Schematic diagram



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



**Don't rotate ESP32-WROVER 180° for connection.**

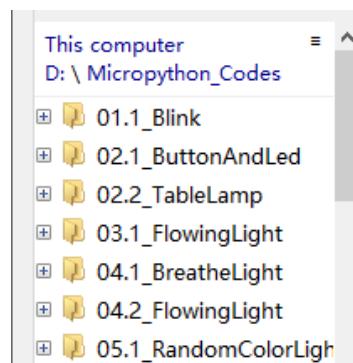
Any concerns? ✉ [support@freenove.com](mailto:support@freenove.com)

## Code

Codes used in this tutorial are saved in “**Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32/Python/Python\_Codes**”. You can move the codes to any location. For example, we save the codes in Disk(D) with the path of “**D:/Micropython\_Codes**”.

### 01.1\_Blink

Open “Thonny”, click “This computer”→“D:”→“Micropython\_Codes”.



Expand folder “01.1\_Blink” and double click “01.1\_Blink.py” to open it. As shown in the illustration below.

```

from time import sleep_ms
from machine import Pin

led=Pin(2,Pin.OUT) #create LED object from pin2,Set Pin2 to output
try:
    while True:
        led.value(1)      #Set led turn on
        sleep_ms(1000)
        led.value(0)      #Set led turn off
        sleep_ms(1000)
except:
    pass

```

Make sure ESP32 has been connected with the computer with ESP32 correctly. Click “Stop/Restart backend” or press the reset button, and then wait to see what interface will show up.

This indicates that the connection is successful.

1, Stop/Restart backend

2, Run current script

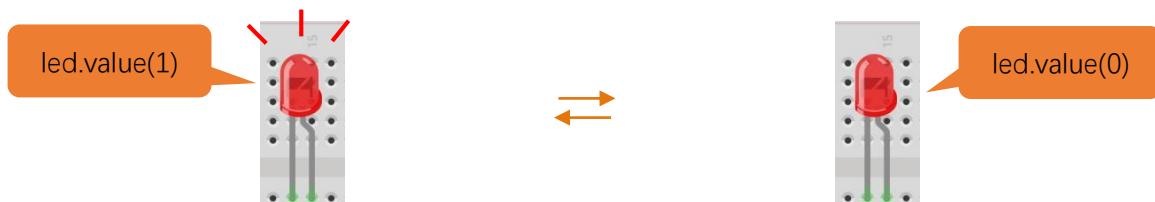
```

1 from time import sleep_ms
2 from machine import Pin
3
4 led = Pin(2,Pin.OUT) #create LED object from pin2,Set Pin 2 as output
5
6     while True:
7         led.value(1)           #Set led turn on
8         sleep_ms(1000)
9         led.value(0)          #Set led turn off
10        sleep_ms(1000)
11
12 except:
13     pass
    
```

Shell

Micropython v1.12 on 2019-12-20; ESP32 module (spiram) with ESP32  
Type "help()" for more information.  
=> %Run -c \$EDITOR\_CONTENT

Click “Run current script” shown in the box above, the code starts to be executed and the LED in the circuit starts to blink.



#### Note:

This is the code [running online](#). If you disconnect USB cable and repower ESP32 or press its reset key, LED stops blinking and the following messages will be displayed in Thonny.

The screenshot shows the Thonny IDE interface. The top menu bar includes File, Edit, View, Run, Device, Tools, and Help. The main window has two panes: 'Files' on the left and '01.1\_Blink.py' on the right. The 'Files' pane lists various Python files under 'D:\Micropython\_Codes\01.1\_Blink'. The '01.1\_Blink.py' pane contains the following code:

```

from time import sleep_ms
from machine import Pin

led=Pin(2,Pin.OUT) #create LED object from pin2,Set Pin2 to output
try:
    while True:
        led.value(1)      #Set led turn on
        sleep_ms(1000)
        led.value(0)      #Set led turn off
        sleep_ms(1000)
except:
    pass

```

Below the code is a 'Shell' pane with the following error message:

```

raise ConnectionClosedException(self._error)
thonny.plugins.micropython.connection.ConnectionClosedException: GetOverlappedResult failed (PermissionError(13, 'Access is denied.', None, 5))

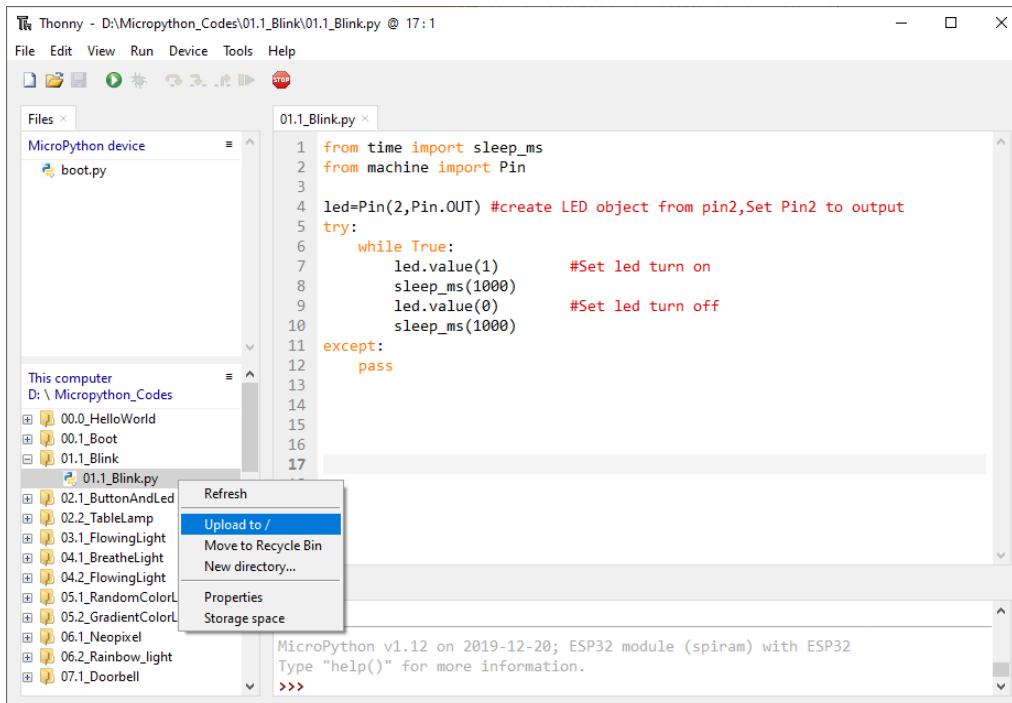
>>>
Connection lost (GetOverlappedResult failed (PermissionError(13, 'Access is denied.', None, 5)))

Use Stop/Restart to reconnect.

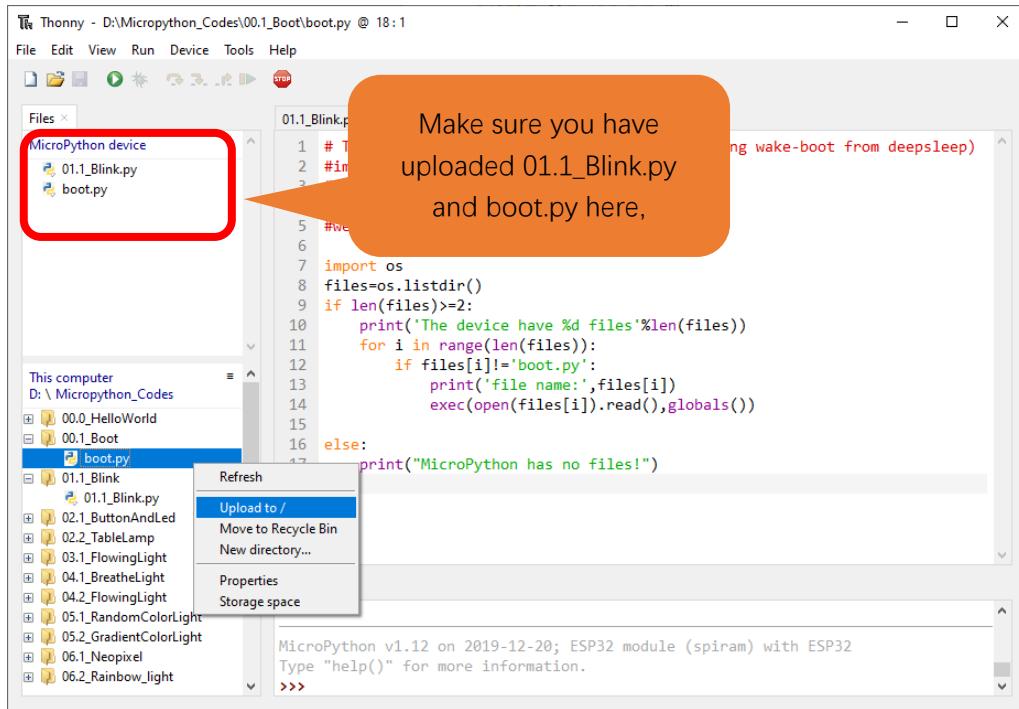
```

### Uploading code to ESP32

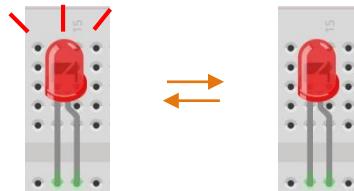
As shown in the following illustration, right-click the file 01.1\_Blink.py and select “Upload to /” to upload code to ESP32.



Upload boot.py in the same way.

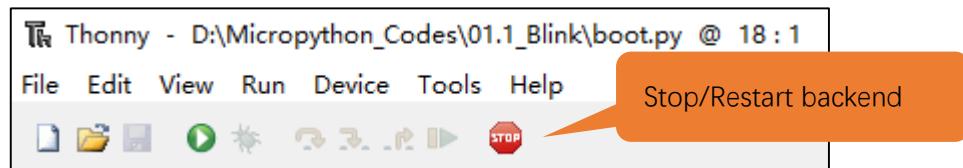


Press the reset key of ESP32 and you can see LED is ON for one second and then OFF for one second, which repeats in an endless loop.



Note:

Codes here is run offline. If you want to stop running offline and enter Shell, just click "Stop" in Thonny.

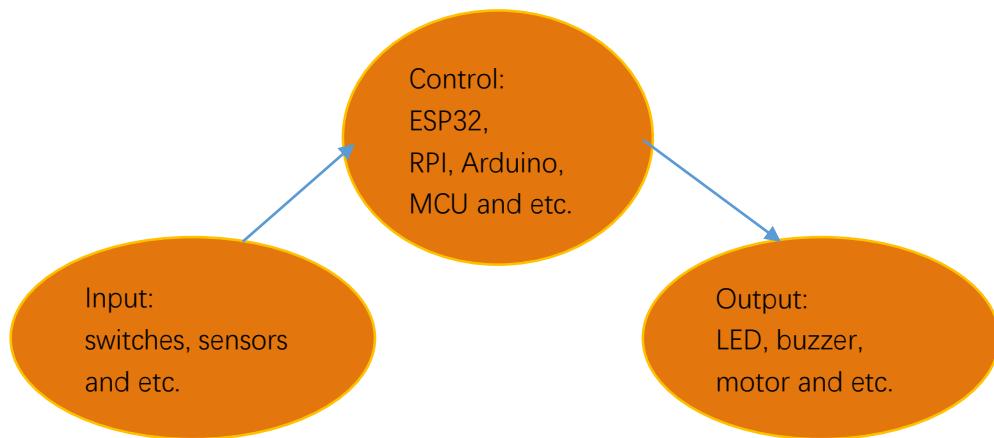


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# Chapter 2 Button & LED

Usually, there are three essential parts in a complete automatic control device: INPUT, OUTPUT, and CONTROL. In last section, the LED module was the output part and ESP32 was the control part. In practical applications, we not only make LEDs flash, but also make a device sense the surrounding environment, receive instructions and then take the appropriate action such as LEDs light up, make a buzzer turn ON and so on.

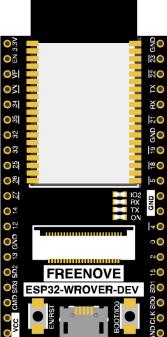
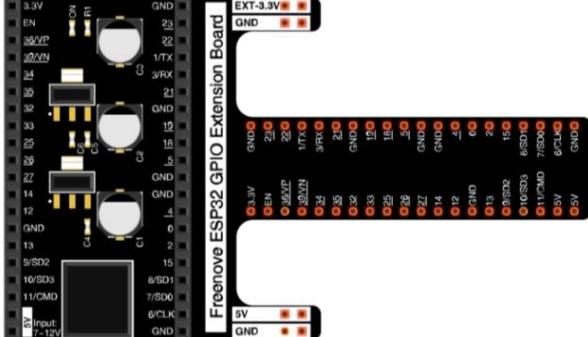


Next, we will build a simple control system to control an LED through a push button switch.

## Project 2.1 Button & LED

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

## Component List

ESP32-WROVER x1	GPIO Extension Board x1	Breadboard x1			
					
Jumper M/M x4	LED x1	Resistor 220Ω x1	Resistor 10kΩ x2	Push button x1	
					

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## Component knowledge

### Push button

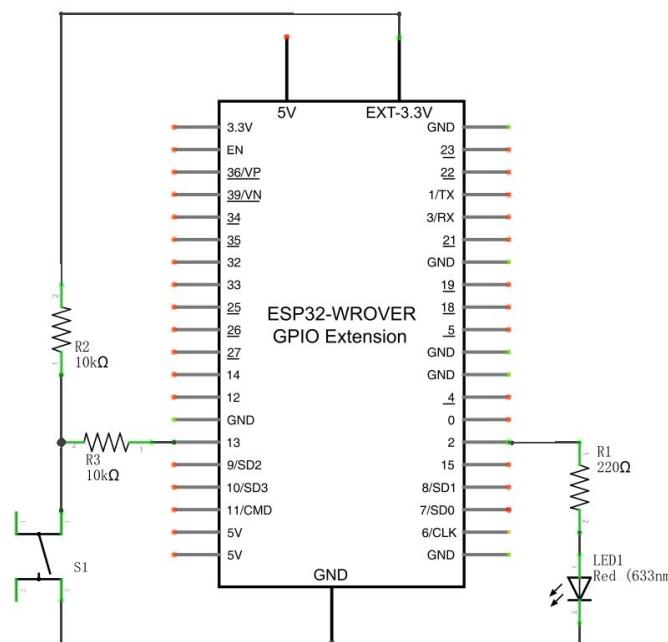
This type of Push Button Switch has 4 pins (2 Pole Switch). Two pins on the left are connected, and both left and right sides are the same per the illustration:



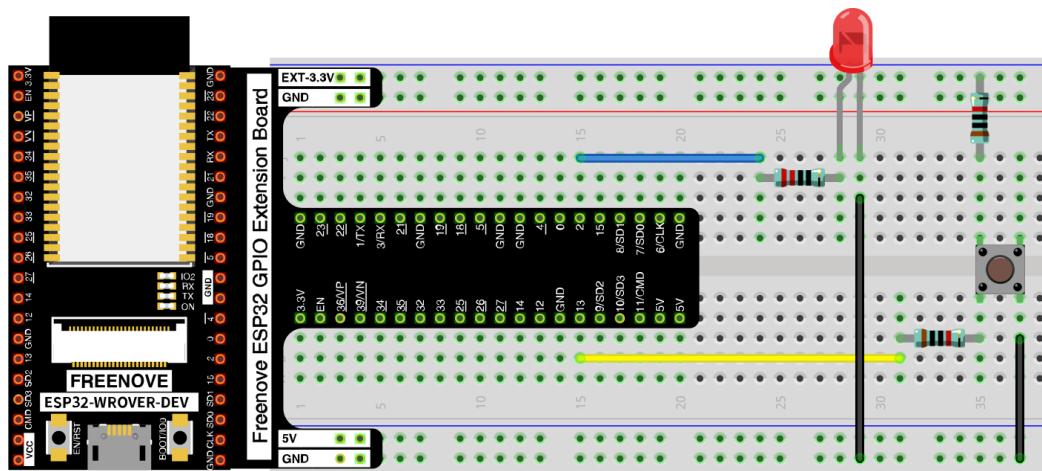
When the button on the switch is pressed, the circuit is completed (your project is Powered ON).

## Circuit

Schematic diagram



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



Any concerns? [✉ support@freenove.com](mailto:support@freenove.com)

## Code

This project is designed to learn to control an LED with a push button switch. First, we need to read the state of the switch and then decide whether the LED is turned on or not based on it.

Move the program folder “Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32/Python/Python\_Codes” to disk(D) in advance with the path of “**D:/Micropython\_Codes**”.

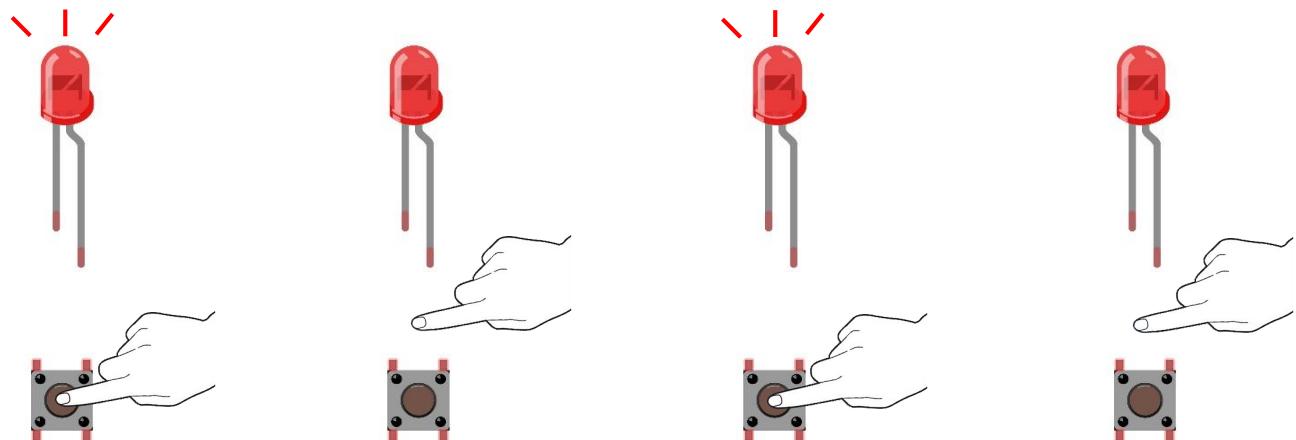
Open “Thonny”, click “This computer” → “D:” → “Micropython\_Codes” → “02.1\_ButtonAndLed” and double click “02.1\_ButtonAndLed.py”.

### 02.1\_ButtonAndLed

```

1 from machine import Pin
2
3 led = Pin(2, Pin.OUT)
4
5 #create button object from pin13,Set Pin13 to Input
6 button = Pin(13, Pin.IN,Pin.PULL_UP)
7
8 try:
9     while True:
10         if not button.value():
11             led.value(1) #Set led turn on
12         else:
13             led.value(0) #Set led turn off
14
15 except:
16     pass
    
```

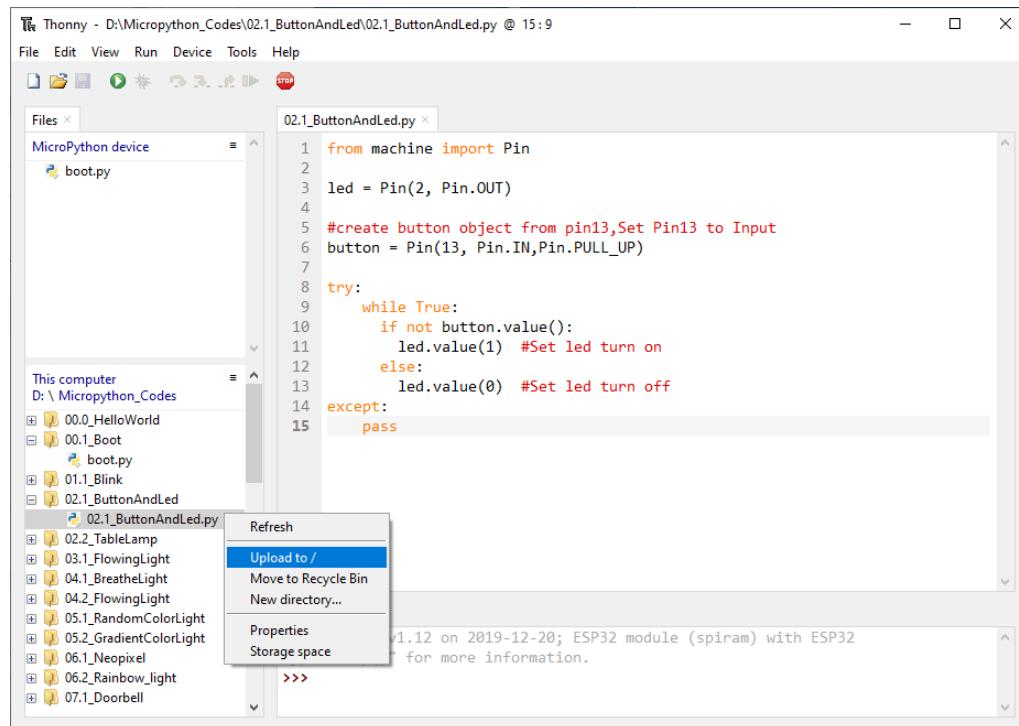
Click “Run current script” shown in the box of the above illustration, press the push button switch, LED turns ON; release the switch, LED turns OFF.



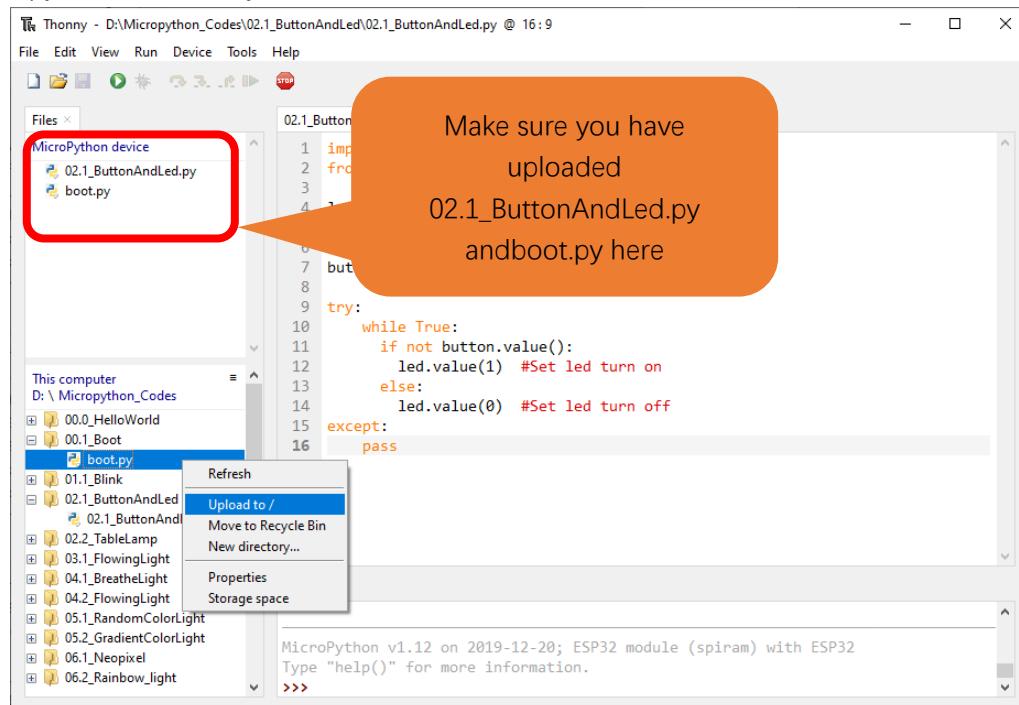
Any concerns? ✉ support@freenove.com

## Upload Code to ESP32

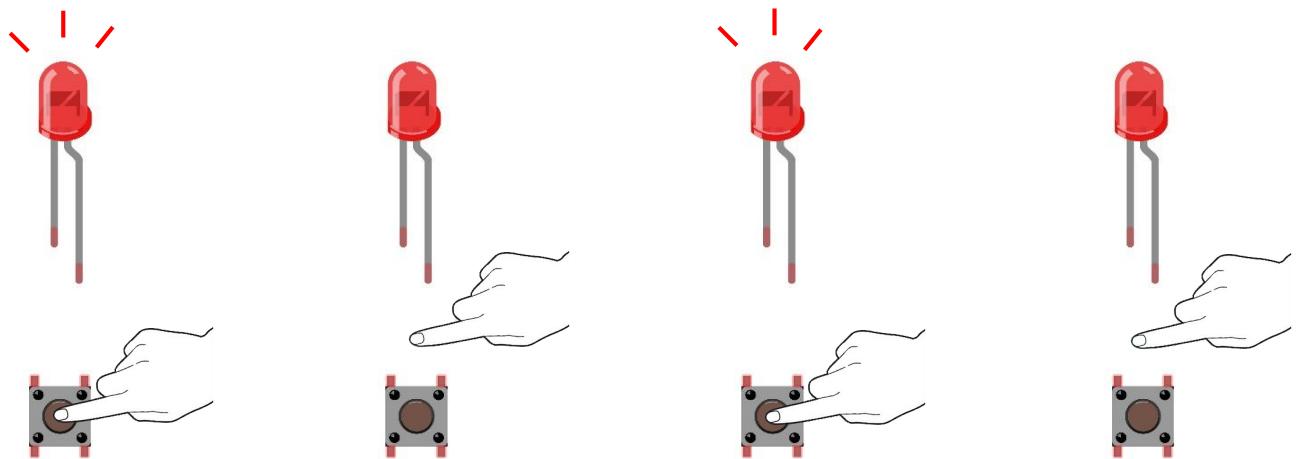
As shown in the following illustration, right-click file 02.1\_ButtonAndLed and select “Upload to /” to upload code to ESP32.



Upload boot.py in the same way.



Press ESP32's reset key, and then push the button switch, LED turns ON; Push the button again, LED turns OFF.



The following is the program code:

```

1 from machine import Pin
2
3 led = Pin(2, Pin.OUT)
4
5 #create button object from pin13, Set Pin13 to Input
6 button = Pin(13, Pin.IN, Pin.PULL_UP)
7
8 try:
9     while True:
10        if not button.value():
11            led.value(1) #Set led turn on
12        else:
13            led.value(0) #Set led turn off
14 except:
15     pass

```

In this project, we use the Pin module of the machine, so before initializing the Pin, we need to import this module first.

```
1 from machine import Pin
```

In the circuit connection, LED and Button are connected with GPIO2 and GPIO13 respectively, so define led and button as 2 and 13 respectively.

```

3 led = Pin(2, Pin.OUT)
4
5 #create button object from pin13, Set Pin13 to Input
6 button = Pin(13, Pin.IN, Pin.PULL_UP)

```

Read the pin state of button with value() function. Press the button switch, the function returns low level and the result of "if" is true, and then LED will be turned ON; Otherwise, LED is turned OFF.

```
9  while True:  
10     if not button.value():  
11         led.value(1) #Set led turn on  
12     else:  
13         led.value(0) #Set led turn off
```

If statement is used to execute the next statement when a certain condition is proved to be true (or non0). It is often used together with "else" statement, which judges other statements except the if statement. If you need to judge if the result of a condition is 0, you can use if not statement.

```
10    if not button.value():  
11        ...  
12    else:  
13        ...
```

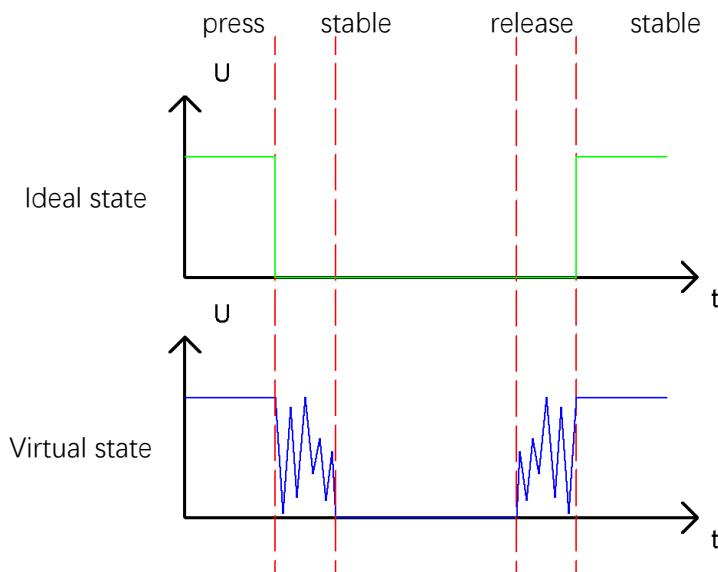
## Project 2.2 MINI table lamp

We will also use a Push Button Switch, LED and ESP32 to make a MINI Table Lamp but this will function differently: Press the button, the LED will turn ON, and pressing the button again, the LED turns OFF. The ON switch action is no longer momentary (like a door bell) but remains ON without needing to continually press on the Button Switch.

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

### Debounce for Push Button

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



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

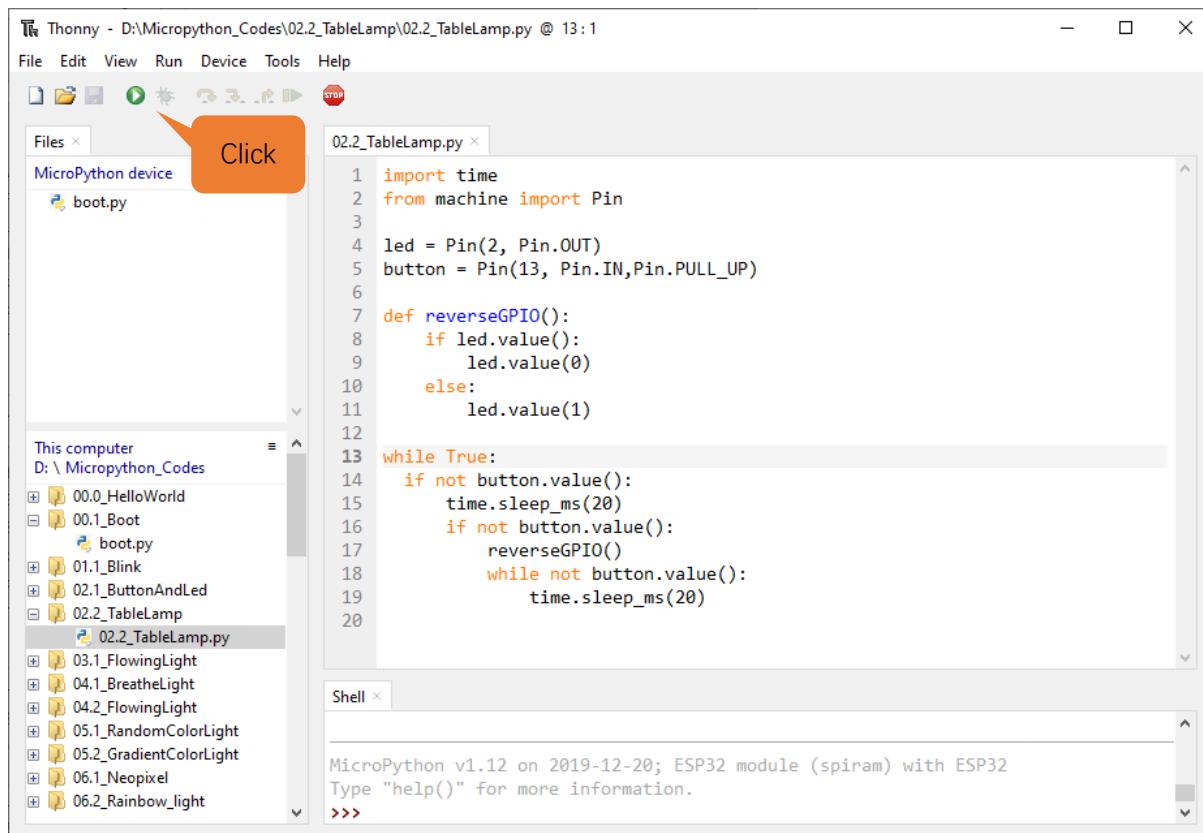
This project needs the same components and circuits as we used in the previous section.

## Code

### 02.2\_Tablelamp

Move the program folder “Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32/Python/Python\_Codes” to disk(D) in advance with the path of “D:/Micropython\_Codes”.

Open “Thonny”, click “This computer” → “D:” → “Micropython\_Codes” → “02.2\_TableLamp” and double click “02.2\_TableLamp.py”.



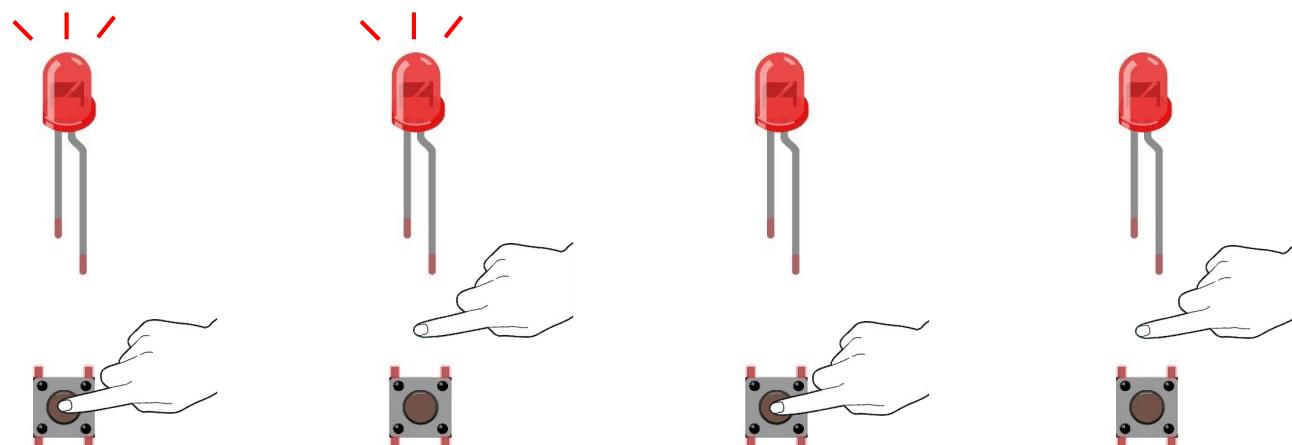
```

1 import time
2 from machine import Pin
3
4 led = Pin(2, Pin.OUT)
5 button = Pin(13, Pin.IN,Pin.PULL_UP)
6
7 def reverseGPIO():
8     if led.value():
9         led.value(0)
10    else:
11        led.value(1)
12
13 while True:
14     if not button.value():
15         time.sleep_ms(20)
16         if not button.value():
17             reverseGPIO()
18             while not button.value():
19                 time.sleep_ms(20)
20

```

MicroPython v1.12 on 2019-12-20; ESP32 module (spiram) with ESP32  
Type "help()" for more information.  
>>>

Click “Run current script” shown in the box of the above illustration, press the push button switch, LED turns ON; press it again, LED turns OFF.

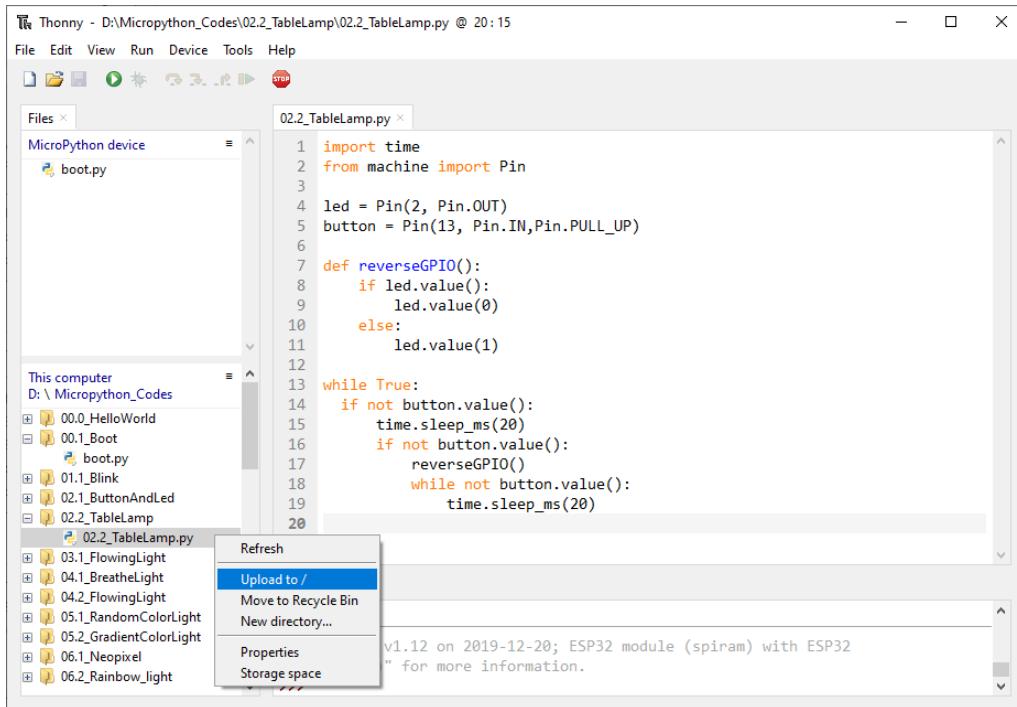


If you have any concerns, please contact us via: [support@freenove.com](mailto:support@freenove.com)

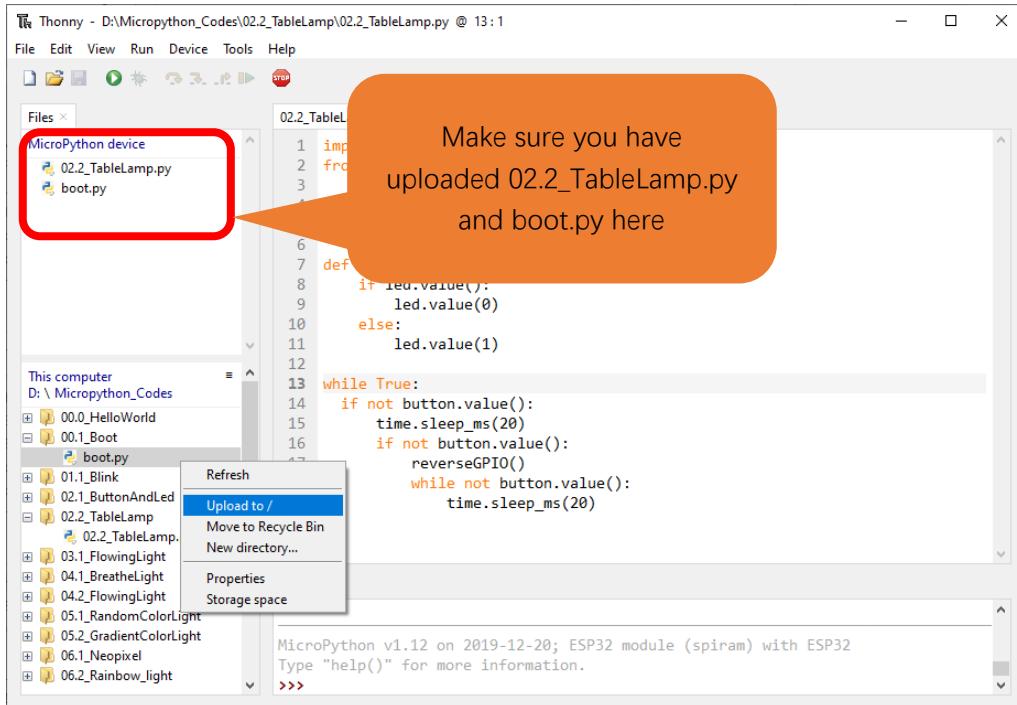
Any concerns? ✉ [support@freenove.com](mailto:support@freenove.com)

### Upload code to ESP32

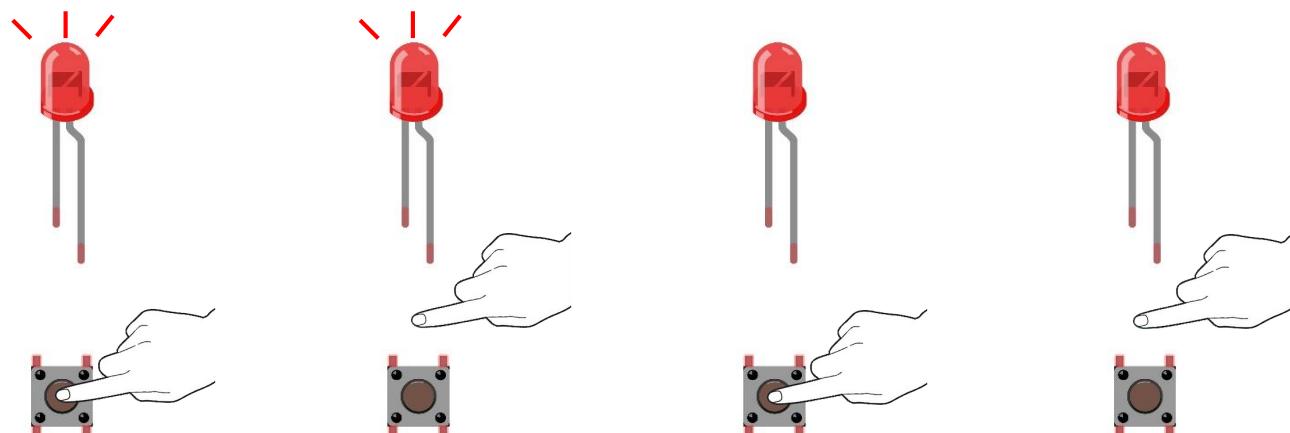
As shown in the following illustration, right-click file 02.2\_TableLamp and select “Upload to /” to upload code to ESP32.



Upload `boot.py` in the same way.



Press ESP32's reset key, and then push the button switch, LED turns ON; Push the button again, LED turns OFF.



The following is the program code:

```

1 import time
2 from machine import Pin
3
4 led = Pin(2, Pin.OUT)
5 button = Pin(13, Pin.IN, Pin.PULL_UP)
6
7 def reverseGPIO():
8     if led.value():
9         led.value(0)
10    else:
11        led.value(1)
12
13 while True:
14     if not button.value():
15         time.sleep_ms(20)
16         if not button.value():
17             reverseGPIO()
18             while not button.value():
19                 time.sleep_ms(20)
20

```

When the button is detected to be pressed, delay 20ms to avoid the effect of bounce, and then check whether the button has been pressed again. If so, the conditional statement will be executed, otherwise it will not be executed.

```

13 while True:
14     if not button.value():
15         time.sleep_ms(20)
16         if not button.value():
17             reverseGPIO()
18             while not button.value():
19                 time.sleep_ms(20)

```



Customize a function and name it reverseGPIO(), which reverses the output level of the LED.

```
7  def reverseGPIO():
8      if led.value():
9          led.value(0)
10     else:
11         led.value(1)
```

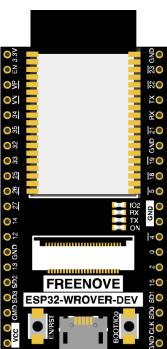
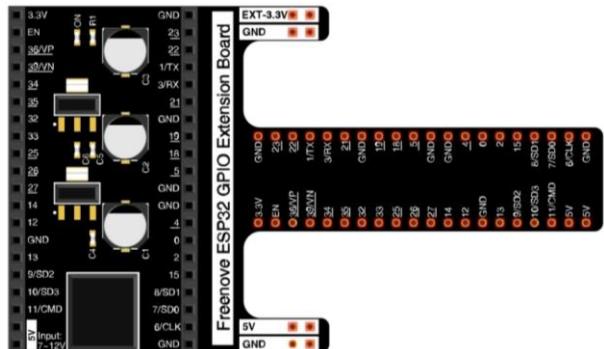
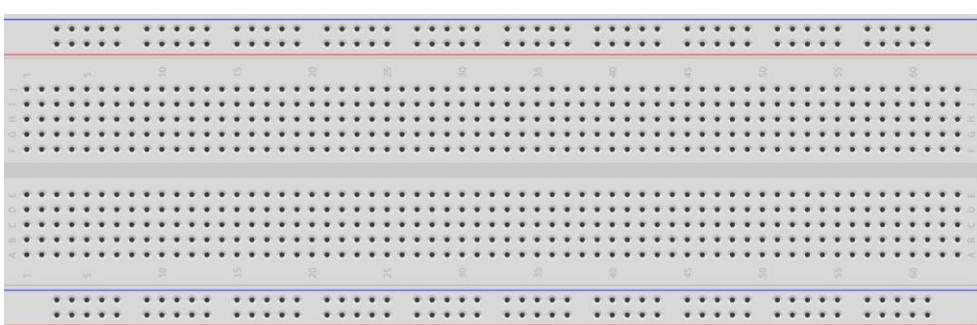
# Chapter 3 LED Bar

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

## Project 3.1 Flowing Light

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

### Component List

ESP32-WROVER x1	GPIO Extension Board x1
	
Breadboard x1	
	
Jumper M/M x10	LED bar graph x1
	
Resistor 220Ω x10	
	

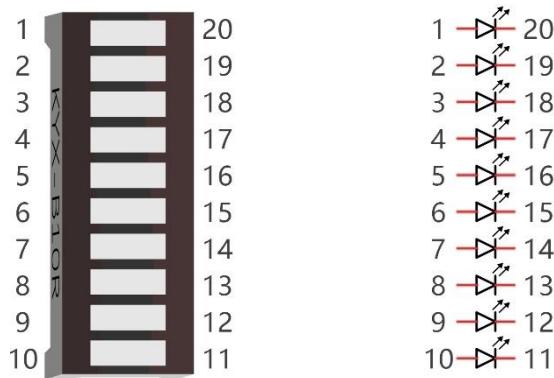


## Component knowledge

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

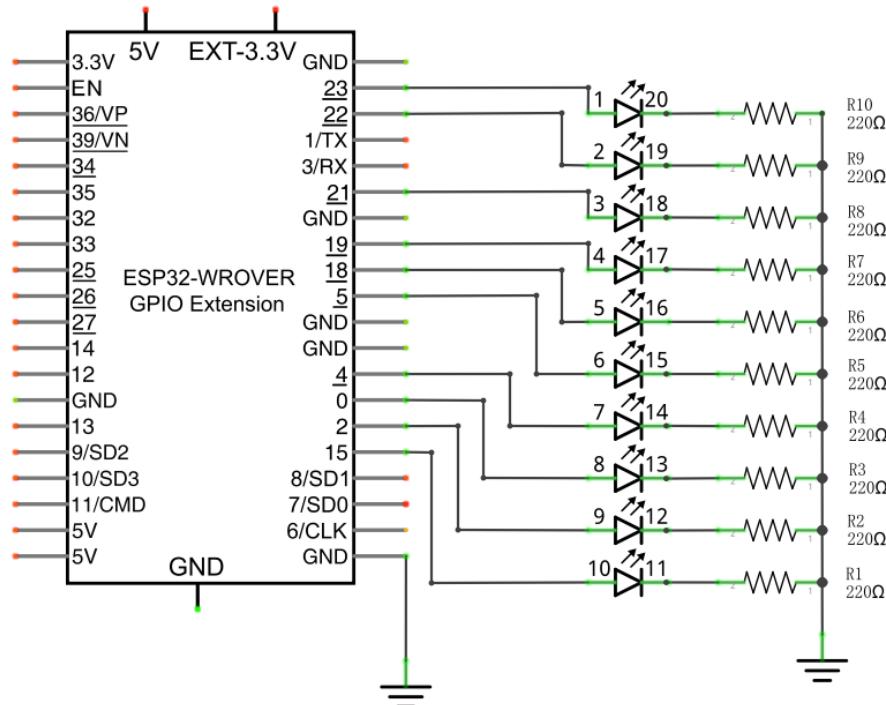
### LED bar

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

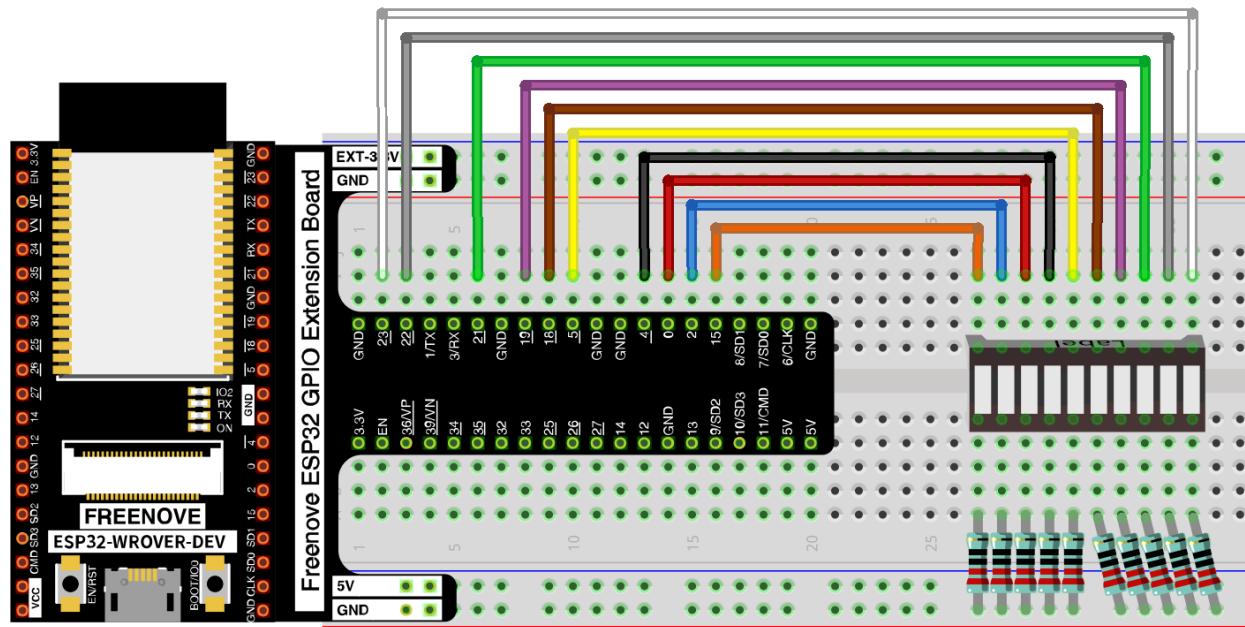


## Circuit

Schematic diagram



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



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



## Code

This project is designed to make a flowing water lamp. Which are these actions: First turn LED #1 ON, then turn it OFF. Then turn LED #2 ON, and then turn it OFF... and repeat the same to all 10 LEDs until the last LED is turns OFF. This process is repeated to achieve the “movements” of flowing water.

### 03.1\_FlowingLight

Move the program folder “**Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32/Python/Python\_Codes**” to disk(D) in advance with the path of “**D:/Micropython\_Codes**”.

Open “Thonny”, click “This computer” → “D:” → “Micropython\_Codes” → “03.1\_FlowingLight” and double click “03.1\_FlowingLight.py”.

```

Thonny - D:\Micropython_Codes\03.1_FlowingLight\03.1_FlowingLight.py @ 21:1
File Edit View Run Device Tools Help
File MicroPython device
  boot.py
This computer
D: \ Micropython_Codes
  00.0_HelloWorld
  00.1_Boot
    boot.py
  01.1_Blink
  02.1_ButtonAndLed
  02.2_TableLamp
  03.1_FlowingLight
    03.1_FlowingLight.py
  04.1_BreatheLight
  04.2_FlowingLight
  05.1_RandomColorLight
  05.2_GradientColorLight
  06.1_Neopixel
  06.2_Rainbow_light
  03.1_FlowingLight.py

03.1_FlowingLight.py
1 import time
2 from machine import Pin
3
4 pins=[15,2,0,4,5,18,19,21,22,23]
5
6 def showed():
7     length=len(pins)
8     for i in range(0,length):
9         Led=Pin(pins[i],Pin.OUT)
10        Led.value(1)
11        time.sleep_ms(100)
12        led.value(0)
13     for i in range(0,length):
14         Led=Pin(pins[(length-i-1)],Pin.OUT)
15         Led.value(1)
16         time.sleep_ms(100)
17         led.value(0)
18
19 while True:
20     showed()
21
Shell
MicroPython v1.12 on 2019-12-20; ESP32 module (spiram) with ESP32
Type "help()" for more information.
>>>

```

Click “Run current script” shown in the box above, LED Bar Graph will light up from left to right and then back from right to left.



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

Any concerns? ✉ [support@freenove.com](mailto:support@freenove.com)

The following is the program code:

```
1 import time
2 from machine import Pin
3
4 pins=[15, 2, 0, 4, 5, 18, 19, 21, 22, 23]
5
6 def showled():
7     length=len(pins)
8     for i in range(0, length):
9         led=Pin(pins[i], Pin.OUT)
10        led.value(1)
11        time.sleep_ms(100)
12        led.value(0)
13     for i in range(0, length):
14         led=Pin(pins[(length-i-1)], Pin.OUT)
15         led.value(1)
16         time.sleep_ms(100)
17         led.value(0)
18
19 while True:
20     showled()
```

Use an array to define 10 GPIO ports connected to LED Bar Graph for easier operation.

```
4 pins=[15, 2, 0, 4, 5, 18, 19, 21, 22, 23]
```

Use len() function to obtain the amount of elements in the list and use a for loop to configure pins as output mode.

```
7     length=len(pins)
8     for i in range(0, length):
9         led=Pin(pins[i], Pin.OUT)
```

Use two for loops to turn on LEDs separately from left to right and then back from right to left.

```
8     for i in range(0, length):
9         led=Pin(pins[i], Pin.OUT)
10        led.value(1)
11        time.sleep_ms(100)
12        led.value(0)
13     for i in range(0, length):
14         led=Pin(pins[(length-i-1)], Pin.OUT)
15         led.value(1)
16         time.sleep_ms(100)
17         led.value(0)
```



## Reference

**for i in range(start,end,num: int=1)**

For loop is used to execute a program endlessly and iterate in the order of items (a list or a string) in the sequence

start: The initial value, the for loop starts with it

end: The ending value, the for loop end with it

num: Num is automatically added each time to the data. The default value is 1

# Chapter 4 Analog & PWM

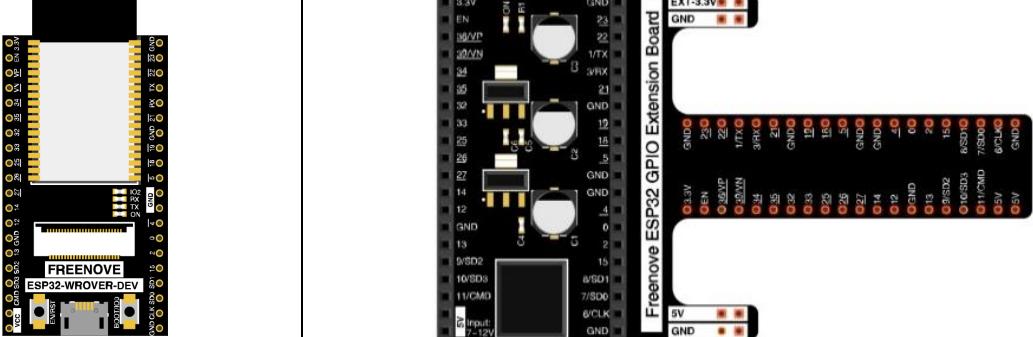
In previous study, we have known that one button has two states: pressed and released, and LED has light-on/off state, then how to enter a middle state? How to output an intermediate state to let LED "semi bright"? That's what we're going to learn.

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, and 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.

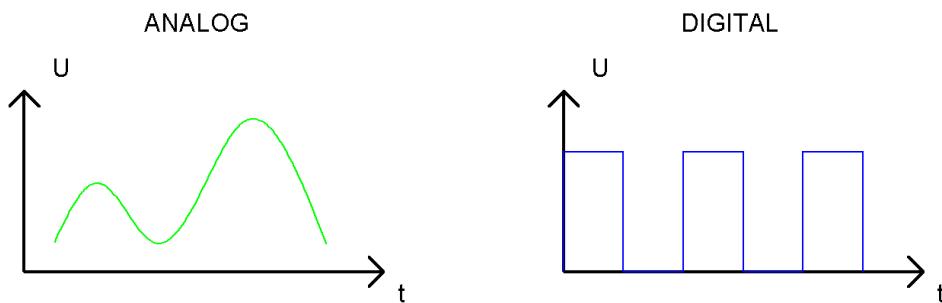
### Component List

ESP32-WROVER x1	GPIO Extension Board x1	
		
Breadboard x1		
LED x1	Resistor 220Ω x1	Jumper M/M x2

## Related knowledge

### Analog & Digital

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



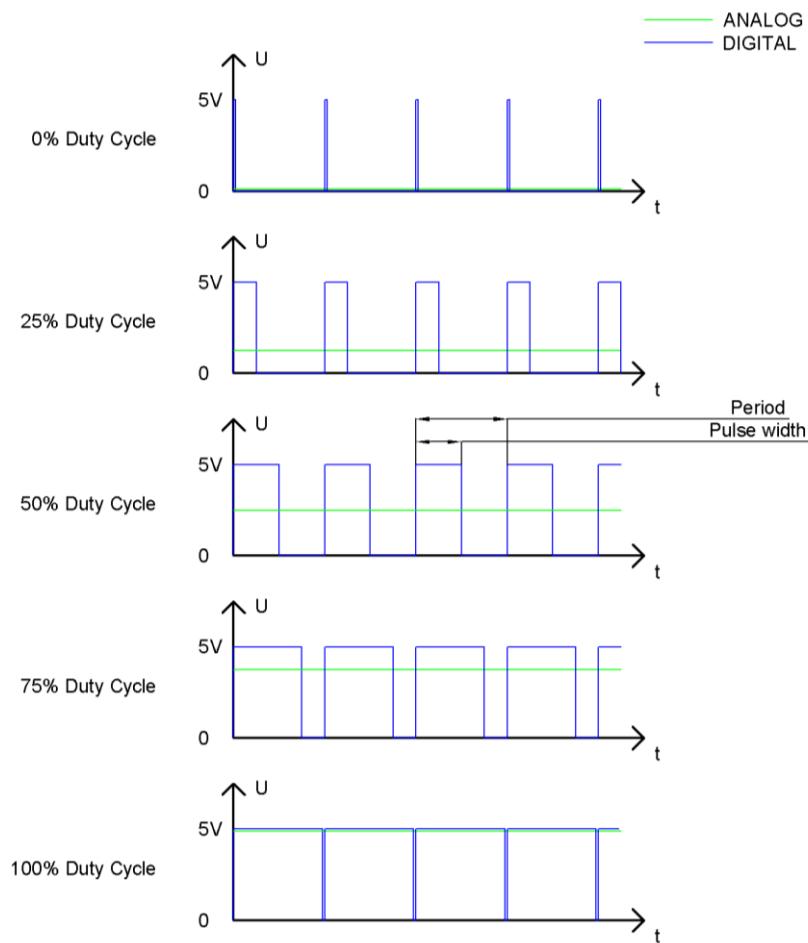
In practical application, we often use binary as the digital signal, that is a series of 0's and 1's. Since a binary signal only has two values (0 or 1), it has great stability and reliability. Lastly, both analog and digital signals can be converted into the other.

### PWM

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

PWM technology uses digital pins to send certain frequencies of square waves, that is, the output of high levels and low levels, which alternately last for a while. The total time for each set of high levels and low levels is generally fixed, which is called the period (Note: the reciprocal of the period is frequency). The time of high level outputs are generally called "pulse width", and the duty cycle is the percentage of the ratio of pulse duration, or pulse width (PW) to the total period (T) of the waveform.

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



The longer the PWM duty cycle is, the higher the output power will be. Now that we understand this relationship, we can use PWM to control the brightness of an LED or the speed of DC motor and so on. It is evident from the above that PWM is not 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.

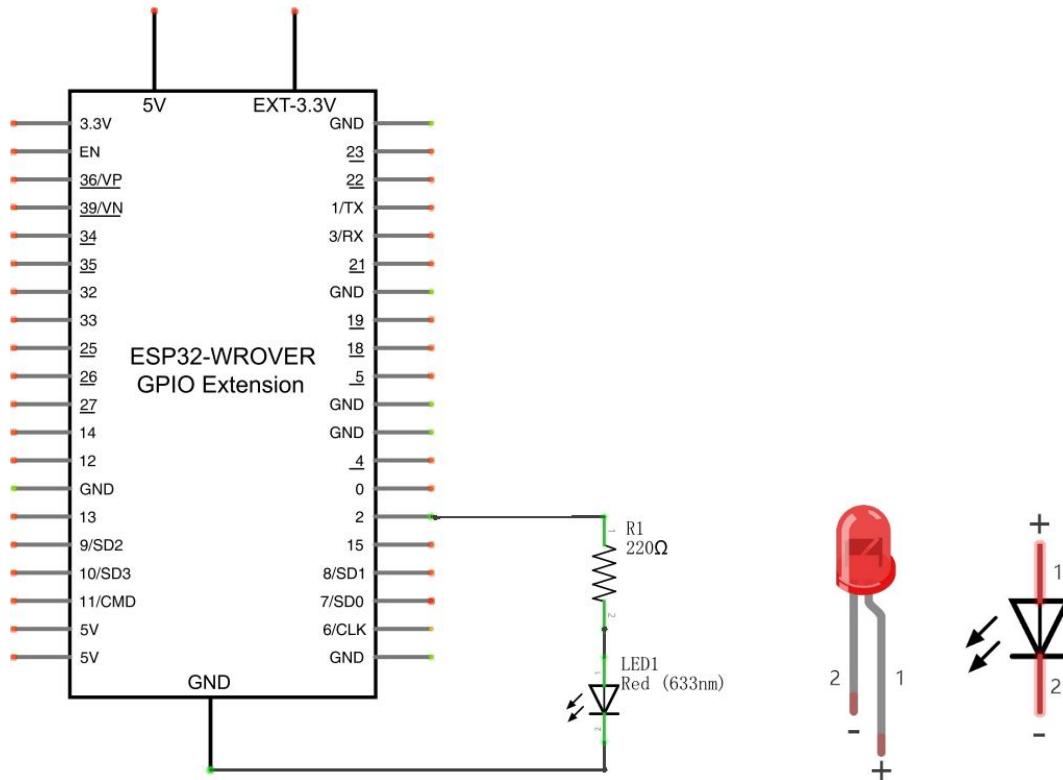
### ESP32 and PWM

The ESP32 PWM controller has 8 independent channels, each of which can independently control frequency, duty cycle, and even accuracy. Unlike traditional PWM pins, the PWM output pins of ESP32 are configurable and they can be configured to PWM.

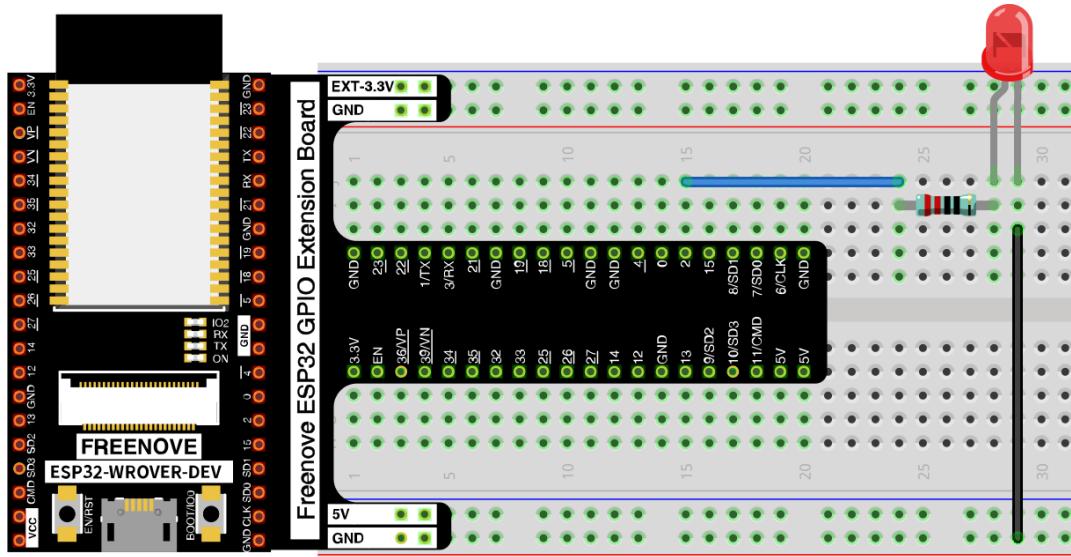
## Circuit

This circuit is the same as the one in project Blink.

Schematic diagram



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



Any concerns? ✉ support@freenove.com

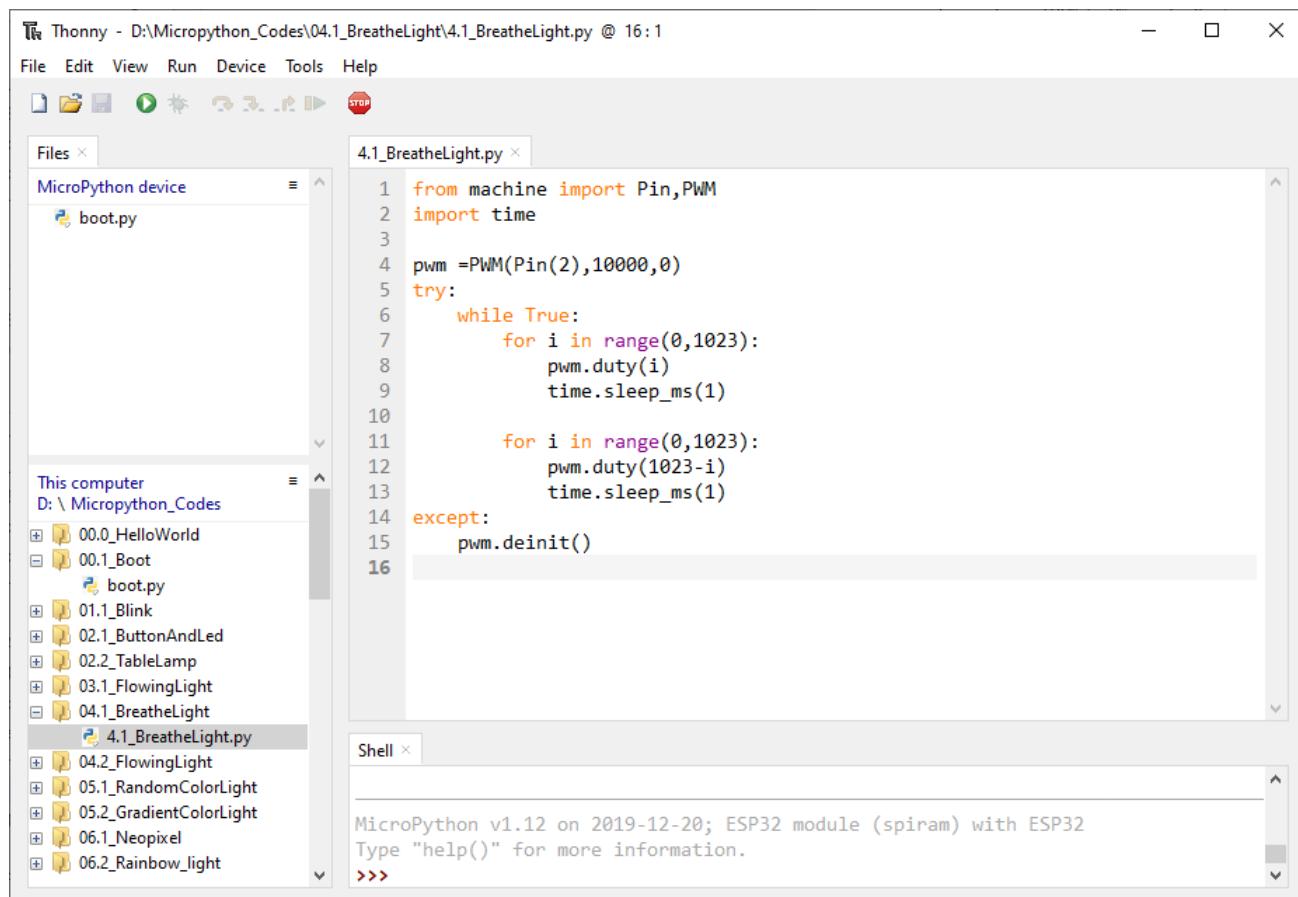
## Code

This project is designed to make PWM output GPIO2 with pulse width increasing from 0% to 100%, and then reducing from 100% to 0% gradually.

Move the program folder “**Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32/Python/Python\_Codes**” to disk(D) in advance with the path of “**D:/Micropython\_Codes**”.

Open “Thonny”, click“This computer” → “D:” → “Micropython\_Codes” → “04.1\_BreatheLight” and double click “04.1\_BreatheLight.py”.

### 04.1\_BreatheLight



```

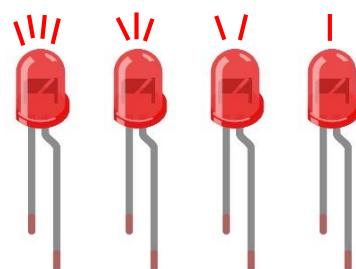
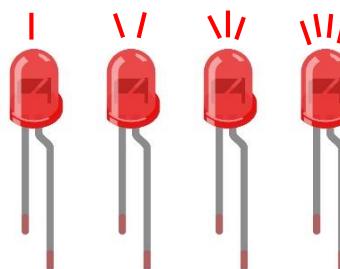
from machine import Pin,PWM
import time

pwm = PWM(Pin(2),10000,0)
try:
    while True:
        for i in range(0,1023):
            pwm.duty(i)
            time.sleep_ms(1)

        for i in range(0,1023):
            pwm.duty(1023-i)
            time.sleep_ms(1)
except:
    pwm.deinit()

```

Click “Run current script”, and you'll see that LED is turned from ON to OFF and then back from OFF to ON gradually like breathing.



The following is the program code:

```
1  from machine import Pin, PWM
2  import time
3
4  pwm = PWM(Pin(2, Pin.OUT), 10000, 0)
5  try:
6      while True:
7          for i in range(0, 1023):
8              pwm.duty(i)
9              time.sleep_ms(1)
10
11         for i in range(0, 1023):
12             pwm.duty(1023-i)
13             time.sleep_ms(1)
14 except:
15     pwm.deinit()
```

The way that the ESP32 PWM pins output is different from traditionally controllers. It can change frequency and duty cycle by configuring PWM's parameters at the initialization stage. Define GPIO2's output frequency as 10000Hz and its duty cycle as 0, and assign them to PWM.

```
4  pwm =PWM(Pin(2, Pin.OUT), 10000, 0)
```

The range of duty cycle is 0-1023, so we use the first for loop to control PWM to change the duty cycle value, making PWM output 0% -100%; Use the second for loop to make PWM output 100%-0%.

```
7  for i in range(0, 1023):
8      pwm.duty(i)
9      time.sleep_ms(1)
10
11     for i in range(0, 1023):
12         pwm.duty(1023-i)
13         time.sleep_ms(1)
```

Each time PWM is used, the hardware Timer will be turned ON to cooperate it. Therefore, after each use of PWM, deinit() needs to be called to turned OFF the timer. Otherwise, the PWM may fail to work next time.

```
15  pwm.deinit()
```

## Reference

### Class `PWM(pin, freq, duty)`

Before each use of PWM module, please add the statement “**from machine import PWM**” to the top of the python file.

**pin**: PWM pins are supported, such as Pin(0)、Pin(2)、Pin(4)、Pin(5)、Pin(10)、Pin(12~19)、Pin(21)、Pin(22)、Pin(23)、Pin(25~27).

**freq**: Output frequency, with the range of 0-78125 Hz

**duty**: Duty cycle, with the range of 0-1023.

**PWM.init(freq, duty)**: Initialize PWM, parameters are the same as above.

**PWM.freq([freq\_val])**: When there is no parameter, the function obtains and returns PWM frequency; When parameters are set, the function is used to set PWM frequency and returns nothing.

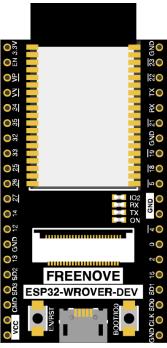
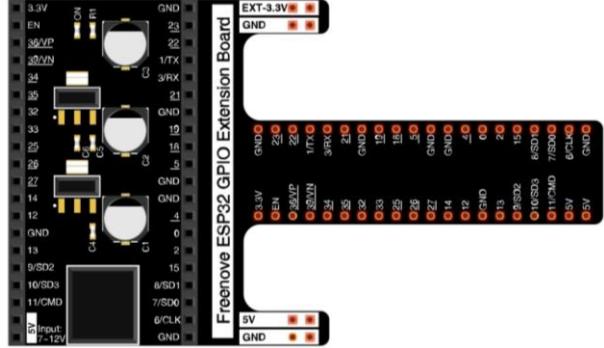
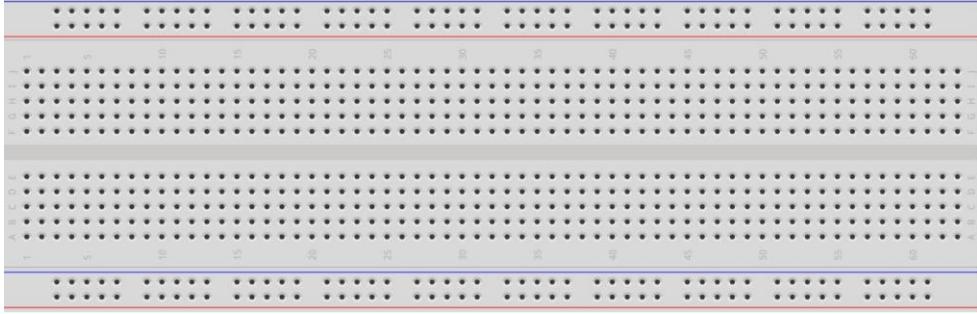
**PWM.duty([duty\_val])**: When there is no parameter, the function obtains and returns PWM duty cycle; When parameters are set, the function is used to set PWM duty cycle.

**PWM.deinit()**: Turn OFF PWM.

## Project 4.2 Meteor Flowing Light

After learning about PWM, we can use it to control LED Bar Graph and realize a cooler Flowing Light.

### Component List

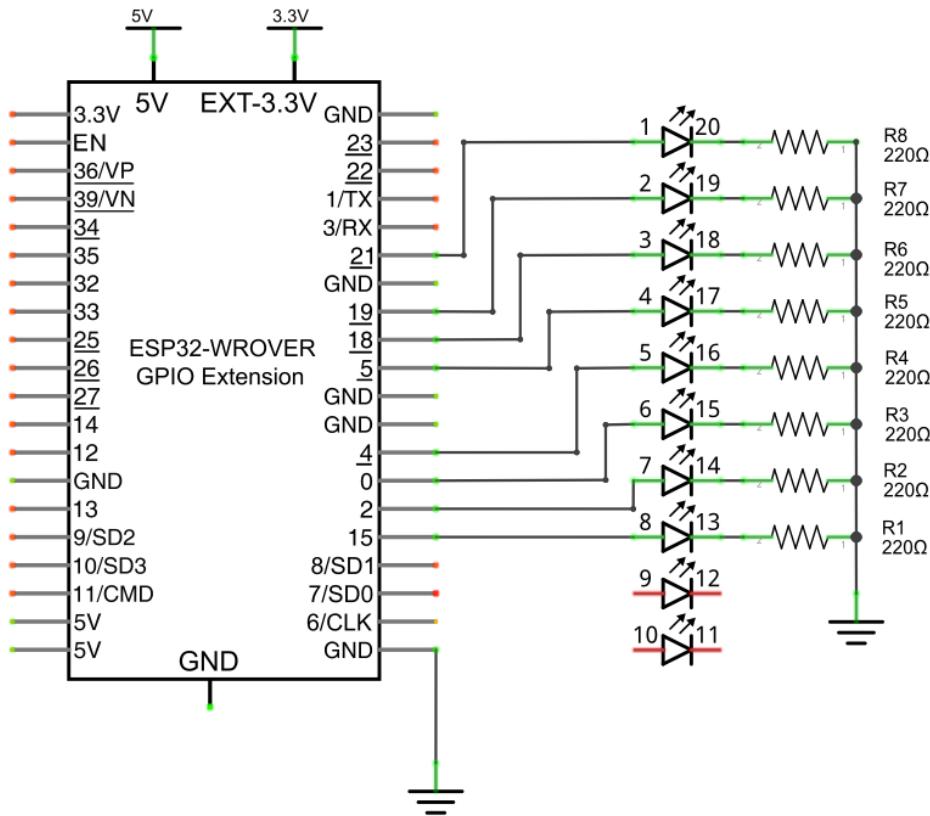
ESP32-WROVER x1	GPIO Extension Board x1	Breadboard x1
		

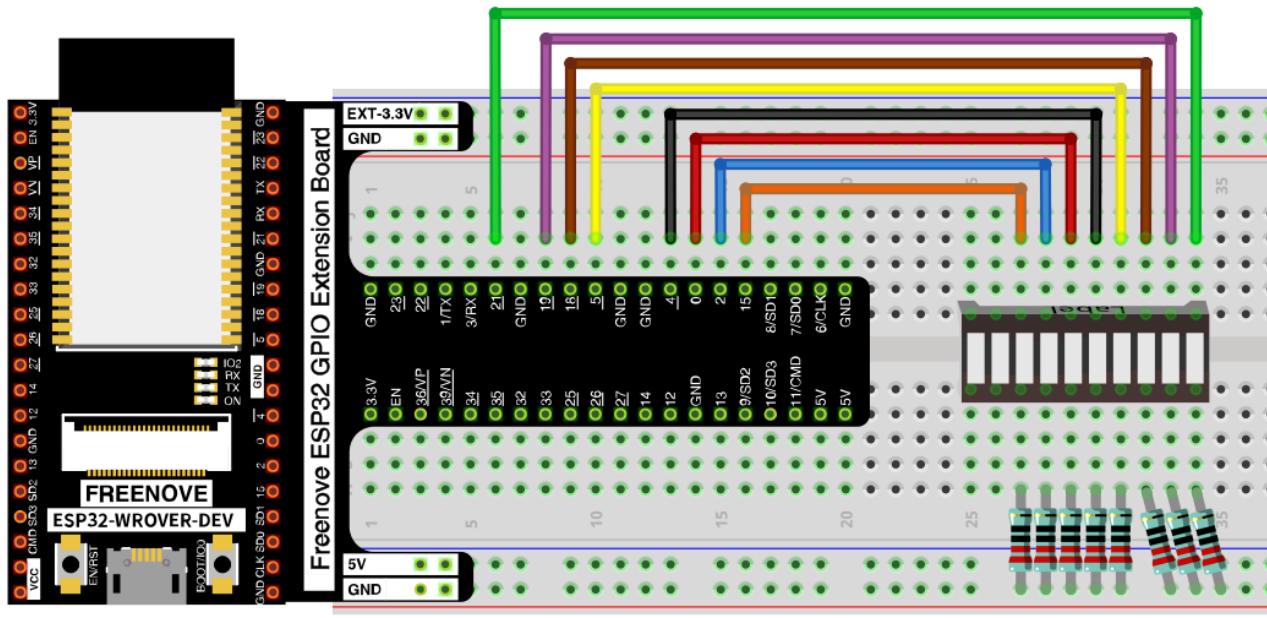
Jumper M/M x10	LED bar graph x1	Resistor 220Ω x10
		

## Circuit

Schematic diagram



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



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

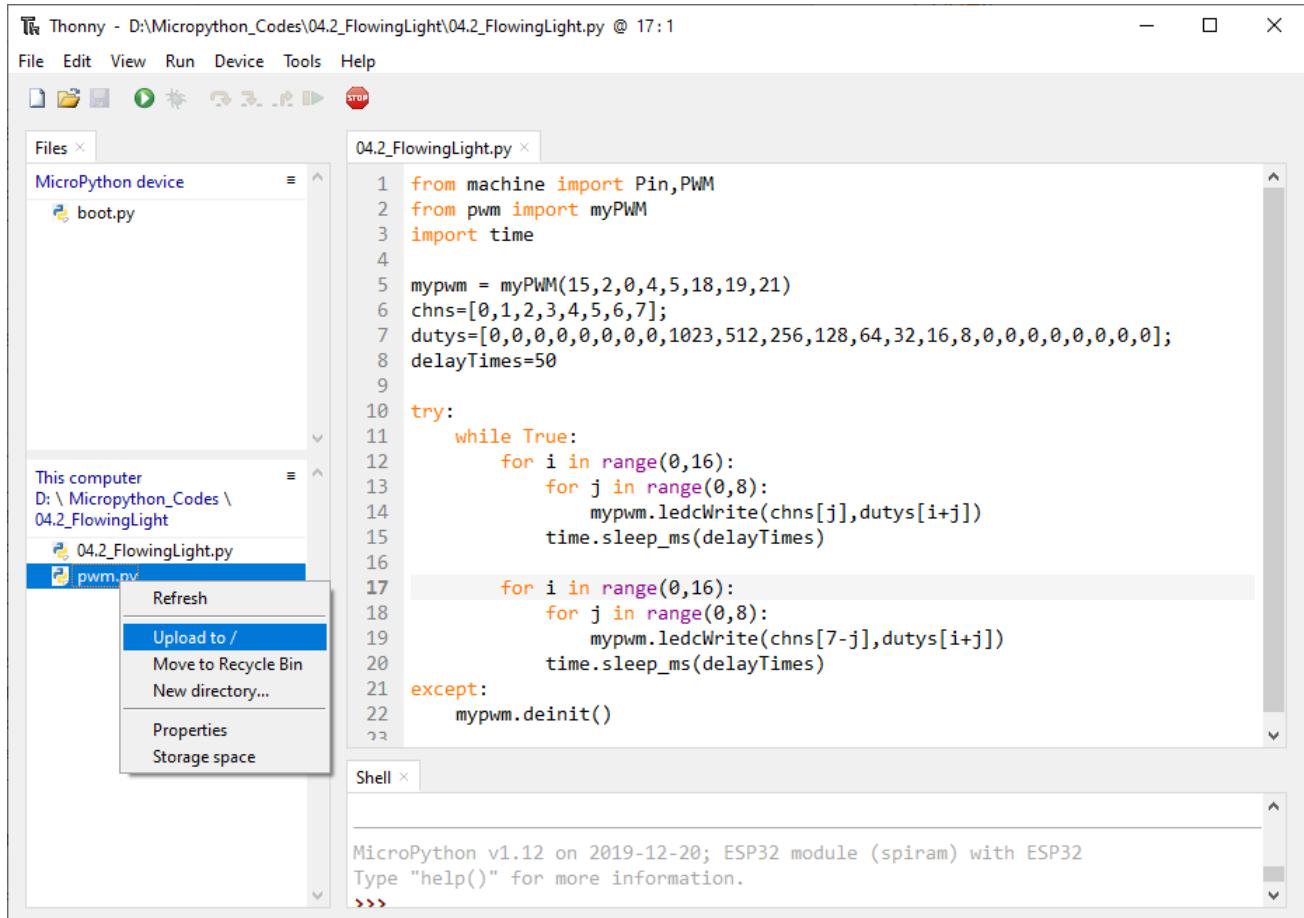
Any concerns? [✉ support@freenove.com](mailto:support@freenove.com)

## Code

Flowing Light with tail was implemented with PWM.

Open “Thonny”, click “This computer” → “D:” → “Micropython\_Codes” → “04.2\_FlowingLight”. Select “pwm.py”, right click to select “Upload to /”, wait for “pwm.py” to be uploaded to ESP32-WROVER and then double click “04.2\_FlowingLight.py”

### 04.2\_FlowingLight



```

from machine import Pin,PWM
from pwm import myPWM
import time

mypad = myPWM(15,2,0,4,5,18,19,21)
chns=[0,1,2,3,4,5,6,7];
dutys=[0,0,0,0,0,0,0,1023,512,256,128,64,32,16,8,0,0,0,0,0,0,0];
delayTimes=50

try:
    while True:
        for i in range(0,16):
            for j in range(0,8):
                mypad.ledcWrite(chns[j],dutys[i+j])
            time.sleep_ms(delayTimes)

        for i in range(0,16):
            for j in range(0,8):
                mypad.ledcWrite(chns[7-j],dutys[i+j])
            time.sleep_ms(delayTimes)
except:
    mypad.deinit()

```

The screenshot shows the Thonny IDE interface. The left sidebar displays a file tree with 'This computer' and 'D:\Micropython\_Codes\04.2\_FlowingLight'. Inside this folder, '04.2\_FlowingLight.py' and 'pwm.py' are listed. A context menu is open over 'pwm.py', with 'Upload to /' highlighted. The main window shows the code for '04.2\_FlowingLight.py'. Below the code is a 'Shell' window displaying the MicroPython prompt: 'MicroPython v1.12 on 2019-12-20; ESP32 module (spiram) with ESP32' and 'Type "help()" for more information.' At the bottom of the shell window, there is a red '>>>>' prompt.

Click “Run current script”, and LED Bar Graph will gradually light up and out from left to right, then light up and out from right to left.

The following is the program code:

```

1  from machine import Pin, PWM
2  from pwm import myPWM
3  import time
4
5  mypwm = myPWM(15, 2, 0, 4, 5, 18, 19, 21)
6  chns=[0, 1, 2, 3, 4, 5, 6, 7];
7  dutys=[0, 0, 0, 0, 0, 0, 0, 1023, 512, 256, 128, 64, 32, 16, 8, 0, 0, 0, 0, 0, 0, 0];
8  delayTimes=50
9
10 try:
11     while True:
12         for i in range(0, 16):
13             for j in range(0, 8):
14                 mypwm.ledcWrite(chns[j], dutys[i+j])
15                 time.sleep_ms(delayTimes)
16
17         for i in range(0, 16):
18             for j in range(0, 8):
19                 mypwm.ledcWrite(chns[7-j], dutys[i+j])
20                 time.sleep_ms(delayTimes)
21 except:
22     mypwm.deinit()

```

Import the object myPWM from pwm.py and set corresponding pins for PWM channel.

```

2  from pwm import myPWM
...
5  mypwm = myPWM(15, 2, 0, 4, 5, 18, 19, 21)

```

First we defined 8 GPIO, 8 PWM channels, and 24 pulse width values.

```

5  mypwm = myPWM(15, 2, 0, 4, 5, 18, 19, 21)
6  chns=[0, 1, 2, 3, 4, 5, 6, 7];
7  dutys=[0, 0, 0, 0, 0, 0, 0, 1023, 512, 256, 128, 64, 32, 16, 8, 0, 0, 0, 0, 0, 0, 0];

```

Call ledcWrite()to set duty cycle dutys[i+j] for the chns[j] channel of PWM.

```
14  mypwm.ledcWrite(chns[j], dutys[i+j])
```

Close the PWM of the object myPWM.

```
14  mypwm.deinit()
```



In the code, a nesting of two for loops are used to achieve this effect.

```

12     for i in range(0, 16):
13         for j in range(0, 8):
14             mypwm.ledcWrite(chns[j], dutys[i+j])
15             time.sleep_ms(delayTimes)
16
17     for i in range(0, 16):
18         for j in range(0, 8):
19             mypwm.ledcWrite(chns[7-j], dutys[i+j])
20             time.sleep_ms(delayTimes)

```

In the main function, a nested for loop is used to control the pulse width of the PWM. Every time *i* in the first for loop increases by 1, the LED Bar Graph will move one grid, and gradually change according to the value in the array *dutys*. As shown in the following table, the value in the second row is the value of the array *dutys*, and the 8 green grids in each row below represent the 8 LEDs on the LED Bar Graph. Each time *i* increases by 1, the value of the LED Bar Graph will move to the right by one grid, and when it reaches the end, it will move from the end to the starting point, achieving the desired effect.

0	1	2	3	4	5	6	7	8	9	1	1	1	1	1	1	1	1	2	2	2	2	2
d	0	0	0	0	0	0	0		1	5	2	1	6	3	1	8	0	0	0	0	0	0
i									0	1	5	2	4	2	6							
0																						
1																						
...																						
14																						
15																						
16																						

#### How to import a custom python module

Each Python file, as long as it's stored on the file system of ESP32, is a module. To import a custom module, the module file needs to be located in the MicroPython environment variable path or in the same path as the currently running program.

First, customize a python module "custom.py". Create a new py file and name it "custom.py". Write code to it and save it to ESP32.



Second, import custom module "custom" to main.py

The screenshot shows a code editor interface with two tabs: [main.py] and [custom.py]. The [main.py] tab contains the following code:

```
1 import custom
2 import time
3 while True:
4     custom.rand()
5     time.sleep(1)
```

Annotations with orange arrows point to specific parts of the code:

- An arrow points to the first line (`import custom`) with the text "Import custom module".
- An arrow points to the line (`custom.rand()`) with the text "Call function rand() of custom module".

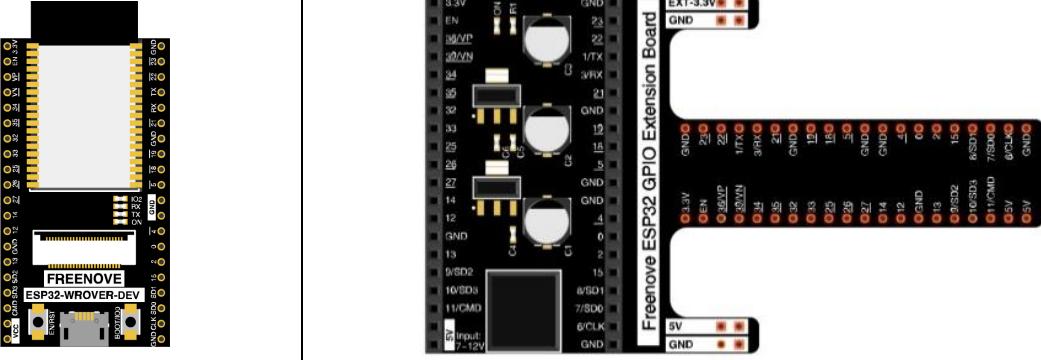
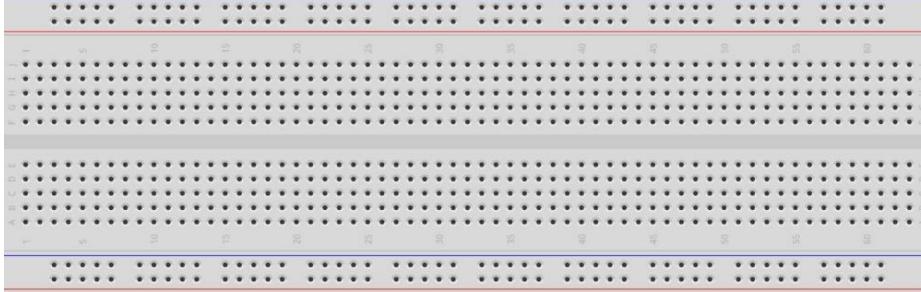
# Chapter 5 RGBLED

In this chapter, we will learn how to control a RGBLED. It can emit different colors of light. Next, we will use RGBLED to make a multicolored light.

## Project 5.1 Random Color Light

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

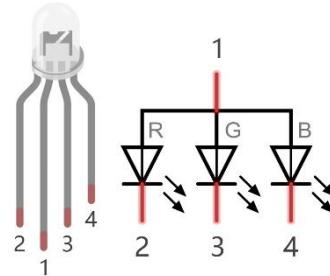
### Component List

ESP32-WROVER x1	GPIO Extension Board x1	
		
Breadboard x1		
		
RGBLED x1	Resistor 220Ω x3	Jumper M/M x4
		

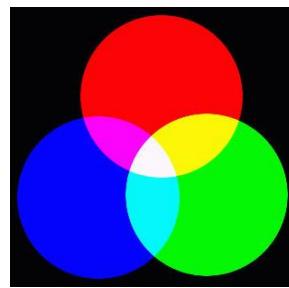
Any concerns? ✉ support@freenove.com

## Related knowledge

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 is shown below. We can make RGB LED emit various colors of light by controlling these 3 LEDs to emit light with different brightness,



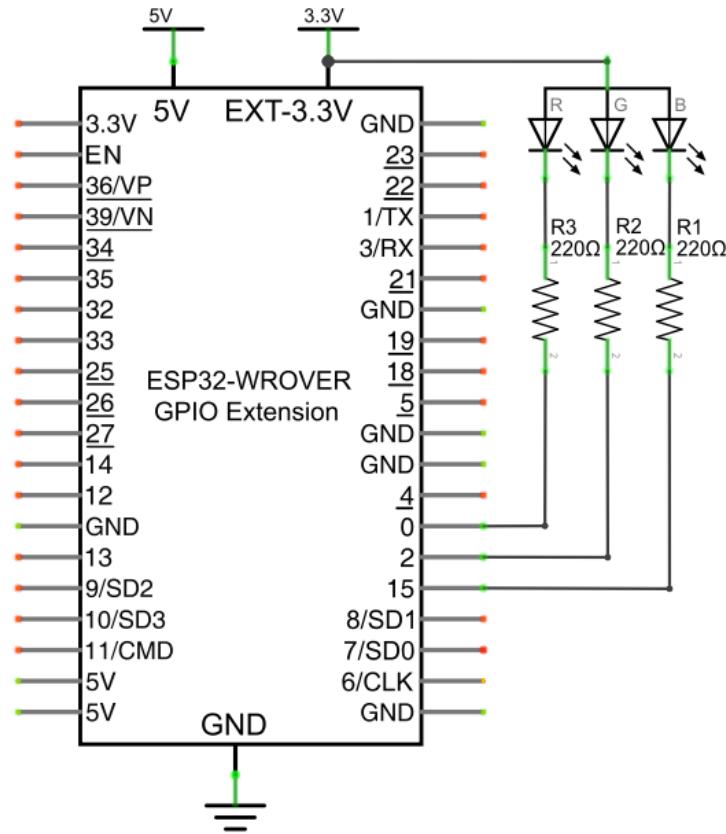
Red, green, and blue light are known as three primary colors. When you combine these three primary-color lights with different brightness, it can produce almost all kinds of visible lights. Computer screens, single pixel of cell phone screen, neon, and etc. are working under this principle.



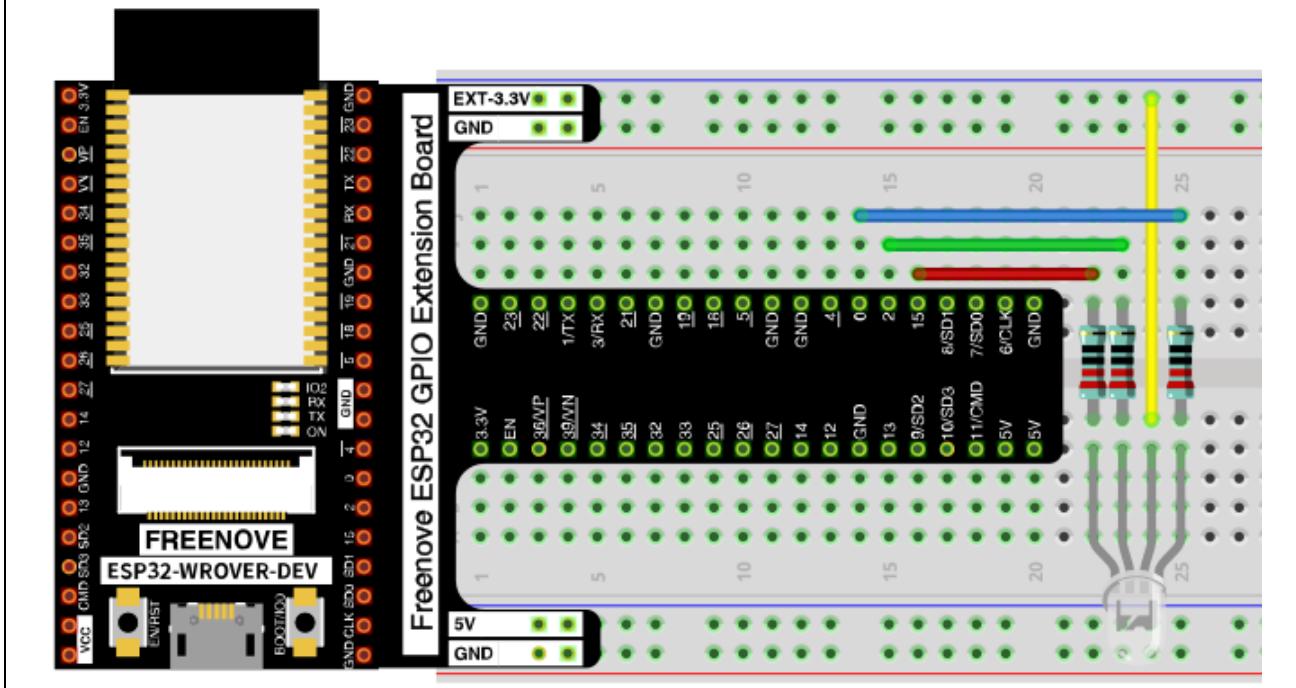
If we use three 10-bit PWM to control the RGBLED, in theory, we can create  $2^{10} * 2^{10} * 2^{10} = 1,073,741,824$ (1 billion) colors through different combinations.

## Circuit

Schematic diagram



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



Any concerns? ✉ [support@freenove.com](mailto:support@freenove.com)

## Code

We need to create three PWM channels and use random duty cycle to make random RGBLED color.

Move the program folder “**Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32/Python/Python\_Codes**” to disk(D) in advance with the path of “**D:/Micropython\_Codes**”.

Open “Thonny”, click “This computer” → “D:” → “Micropython\_Codes” → “05.1\_RandomColorLight” and double click “05.1\_RandomColorLight.py”.

### 05.1\_RandomColorLight

```

from machine import Pin,PWM
from random import randint
import time

pins=[15,2,0]

pwm0=PWM(Pin(pins[0]),10000)
pwm1=PWM(Pin(pins[1]),10000)
pwm2=PWM(Pin(pins[2]),10000)

def setColor(r,g,b):
    pwm0.duty(1023-r)
    pwm1.duty(1023-g)
    pwm2.duty(1023-b)

try:
    while True:
        red = randint(0,1023)
        green = randint(0,1023)
        blue = randint(0,1023)
        setColor(red,green,blue)
        time.sleep_ms(200)

```

MicroPython v1.12 on 2019-12-20; ESP32 module (spiram) with ESP32  
Type "help()" for more information.  
=>

Click “Run current script”, RGBLED begins to display random colors.

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

The following is the program code:

```

1  from machine import Pin, PWM
2  from random import randint
3  import time
4
5  pins=[15, 2, 0]
6
7  pwm0=PWM(Pin(pins[0]), 10000)
8  pwm1=PWM(Pin(pins[1]), 10000)
9  pwm2=PWM(Pin(pins[2]), 10000)
10
11 def setColor(r, g, b):
12     pwm0.duty(1023-r)
13     pwm1.duty(1023-g)
14     pwm2.duty(1023-b)
15
16 try:
17     while True:
18         red    = randint(0, 1023)
19         green  = randint(0, 1023)
20         blue   = randint(0, 1023)
21         setColor(red, green, blue)
22         time.sleep_ms(200)
23 except:
24     pwm0.deinit()
25     pwm1.deinit()
26     pwm2.deinit()
```

Import Pin, PWM and Random Function modules.

```

12  from machine import Pin, PWM
13  from random import randint
14  import time
```

Configure ouput mode of GPIO15, GPIO2 and GPIO0 as PWM output and PWM frequency as 10000Hz

```

5  pins=[15, 2, 0]
6
7  pwm0=PWM(Pin(pins[0]), 10000)
8  pwm1=PWM(Pin(pins[1]), 10000)
9  pwm2=PWM(Pin(pins[2]), 10000)
```

Define a function to set the color of RGBLED.

```

11 def setColor(r, g, b):
12     pwm0.duty(1023-r)
13     pwm1.duty(1023-g)
14     pwm2.duty(1023-b)
```

Call random function randint()to generate a random number in the range of 0-1023 and assign the value to red.

```
18    red = randint(0, 1023)
```

Obtain 3 random number every 200 milliseconds and call function setColor to make RGBLED display dazzling colors.

```
17    while True:
18        red = randint(0, 1023)
19        green = randint(0, 1023)
20        blue = randint(0, 1023)
21        setColor(red, green, blue)
22        time.sleep_ms(200)
```

## Reference

### Class random

Before each use of the module **random**, please add the statement “**import random**” to the top of Python file.

**randint(start, end)**: Randomly generates an integer between the value of start and end.

**start**: Starting value in the specified range, which would be included in the range.

**end**: Ending value in the specified range, which would be included in the range.

**random()**: Randomly generates a floating point number between 0 and 1.

**random.uniform(start, end)**: Randomly generates a floating point number between the value of start and end

**start**: Starting value in the specified range, which would be included in the range.

**end**: Ending value in the specified range, which would be included in the range.

**random.getrandbits(size)**: Generates an integer with **size** random bits

For example:

size = 4, it generates an integer in the range of 0 to 0b1111

size = 8, it generates an integer in the range of 0 to 0b11111111

**random.randrange(start, end, step)**: Randomly generates a positive integer in the range from start to end and increment to step.

**start**: Starting value in the specified range, which would be included in the range

**end**: Ending value in the specified range, which would be included in the range.

**step**: An integer specifying the incrementation.

**random.seed(sed)**: Specifies a random seed, usually being applied in conjunction with other random number generators

**sed**: Random seed, a starting point in generating random numbers.

**random.choice(obj)**: Randomly generates an element from the object obj.

**obj**: list of elements

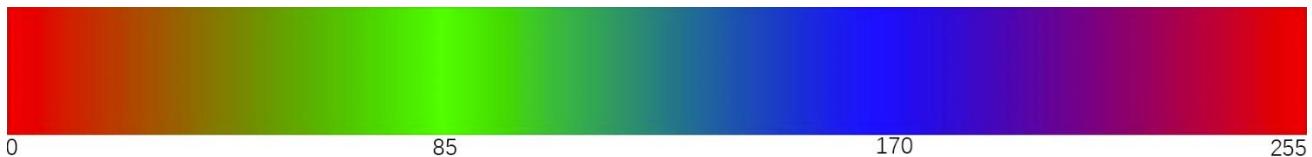


## Project 5.2 Gradient Color Light

In the previous project, we have mastered the usage of RGBLED, but the random color display is rather stiff. This project will realize a fashionable Light with soft color changes.

Component list, the circuit is exactly the same as the project random color light.

Using a color model, the color changes from 0 to 255 as shown below.



In this code, the color model will be implemented and RGBLED will change colors along the model.

Open “Thonny”, click “This computer” → “D:” → “Micropython\_Codes” → “05.2\_GradientColorLight” and double click “05.2\_GradientColorLight.py”.

### 05.2\_GradientColorLight

The following is the program code:

```

1  from machine import Pin, PWM
2  import time
3
4  pins=[15, 2, 0];
5
6  pwm0=PWM(Pin(pins[0]), 1000)
7  pwm1=PWM(Pin(pins[1]), 1000)
8  pwm2=PWM(Pin(pins[2]), 1000)
9
10 def setColor(rgb):
11     pwm0.duty(1023-(rgb>>20))
12     pwm1.duty(1023-(rgb>>10))
13     pwm2.duty(1023-(rgb>>0))
14
15 def wheel(pos):
16     WheelPos=pos%1023
17     if WheelPos<341:
18         return (((1023-WheelPos*3)<<20) | ((WheelPos*3)<<10))
19     elif WheelPos>=341 and WheelPos<682:
20         WheelPos -= 341;
21         return (((1023-WheelPos*3)<<10) | (WheelPos*3))
22     else :
23         WheelPos -= 682;
24         return (((WheelPos*3)<<20) | (1023-WheelPos*3))
25
26 try:

```

```
27     while True:  
28         for i in range(0, 1023):  
29             setColor(wheel( i ))  
30             time.sleep_ms(5)  
31     except:  
32         pwm0.deinit()  
33         pwm1.deinit()  
34         pwm2.deinit()
```

In the function **setColor()**, we use a variable to represent the value of RGB, making it more convenient for the passing of parameters. As the range of PWM's duty cycle is 0-1023, which is 2 to the tenth power, when split, the value of each color channel can be obtained with a simple bitwise operation.

```
10     def setColor(rgb):  
11         pwm0.duty(1023-(rgb>>20))  
12         pwm1.duty(1023-(rgb>>10))  
13         pwm2.duty(1023-(rgb>>0))
```

The function **wheel()** is a color selection method of the color model introduced earlier. The value range of the parameter pos is 0-1023. The function will return a data containing the duty cycle values of 3 pins.

```
15     def wheel(pos):  
16         WheelPos=pos%1023  
17         if WheelPos<341:  
18             return (((1023-WheelPos*3)<<20) | ((WheelPos*3)<<10))  
19         elif WheelPos>=341 and WheelPos<682:  
20             WheelPos -= 341;  
21             return (((1023-WheelPos*3)<<10) | (WheelPos*3))  
22         else :  
23             WheelPos -= 682;  
24             return (((WheelPos*3)<<20) | (1023-WheelPos*3))
```

# Chapter 6 NeoPixel

This chapter will help you learn to use a more convenient RGBLED lamp, which requires only one GPIO control and can be connected in infinite series in theory. Each LED can be controlled independently.

## Project 6.1 NeoPixel

Learn the basic usage of NeoPixel and use it to flash red, green, blue and white.

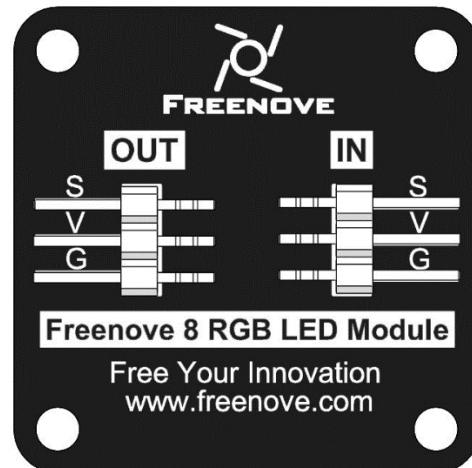
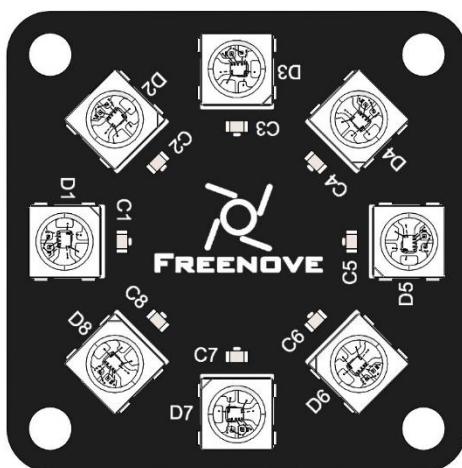
### Component List

ESP32-WROVER x1	GPIO Extension Board x1
Breadboard x1	
Freenove 8 RGB LED Module x1	Jumper F/M x3

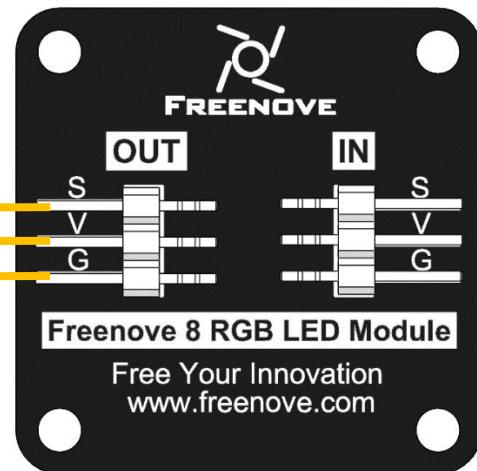
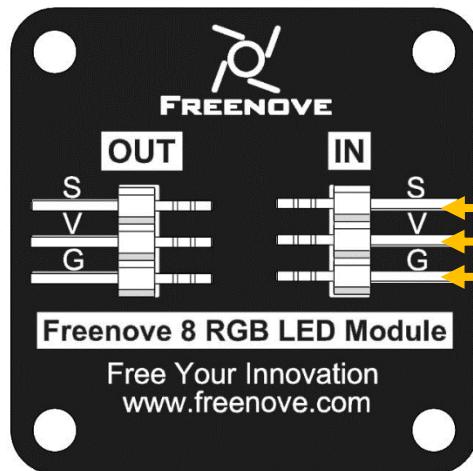
## Related knowledge

### Freenove 8 RGB LED Module

The Freenove 8 RGB LED Module is as below. You can use only one data pin to control eight LEDs on the module. As shown below:



And you can also control many modules at the same time. Just connect OUT pin of one module to IN pin of another module. In this way, you can use one data pin to control 8, 16, 32 ... LEDs.

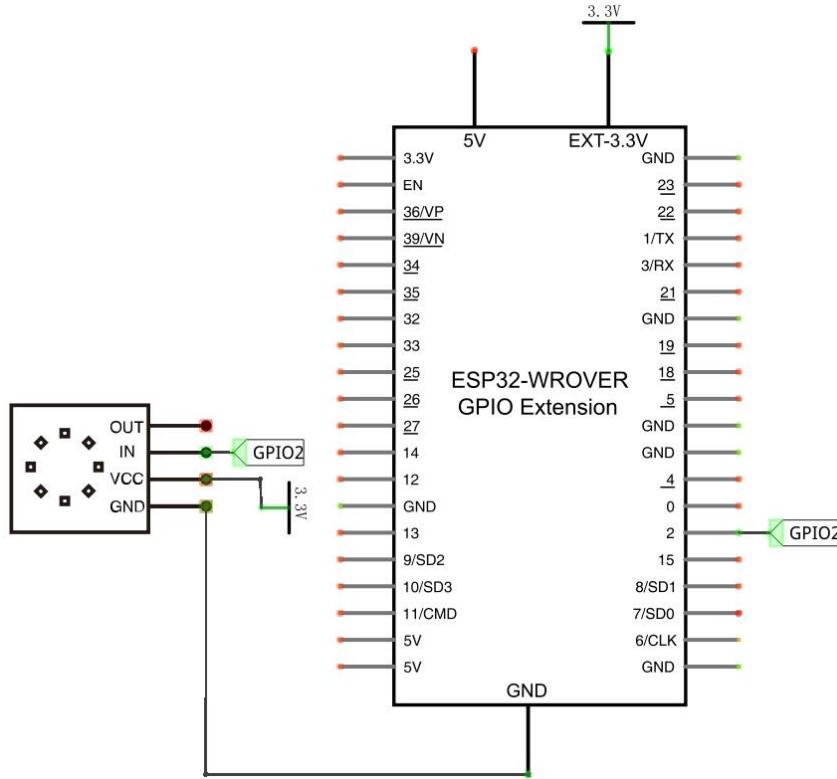


### Pin description:

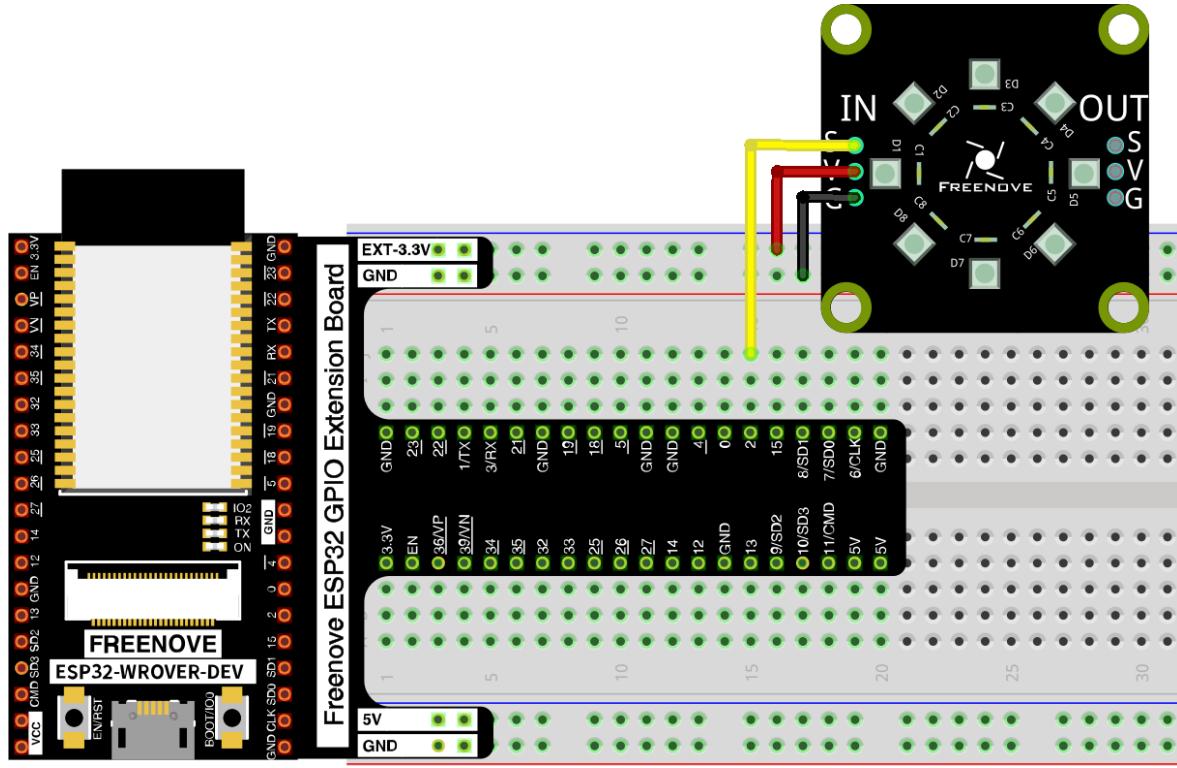
(IN)		(OUT)	
symbol	Function	symbol	Function
S	Input control signal	S	Output control signal
V	Power supply pin, +3.5V~5.5V	V	Power supply pin, +3.5V~5.5V
G	GND	G	GND

## Circuit

Schematic diagram



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



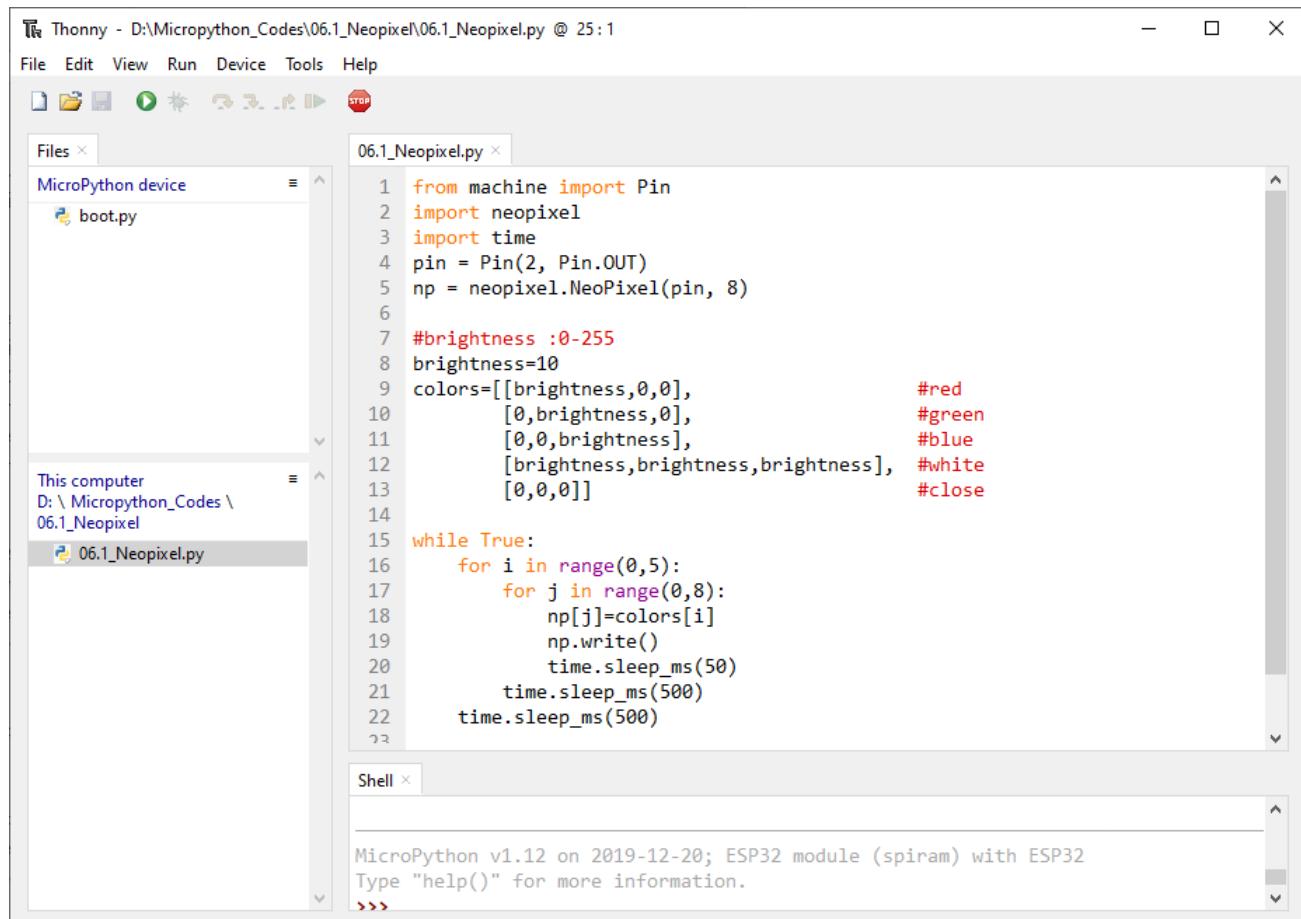
Any concerns? ✉ [support@freenove.com](mailto:support@freenove.com)

## Code

Move the program folder “**Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32/Python/Python\_Codes**” to disk(D) in advance with the path of “**D:/Micropython\_Codes**”.

Open “Thonny”, click “This computer” → “D:” → “Micropython\_Codes” → “06.1\_Neopixel” and double click “06.1\_Neopixel.py”.

### 06.1\_Neopixel



```

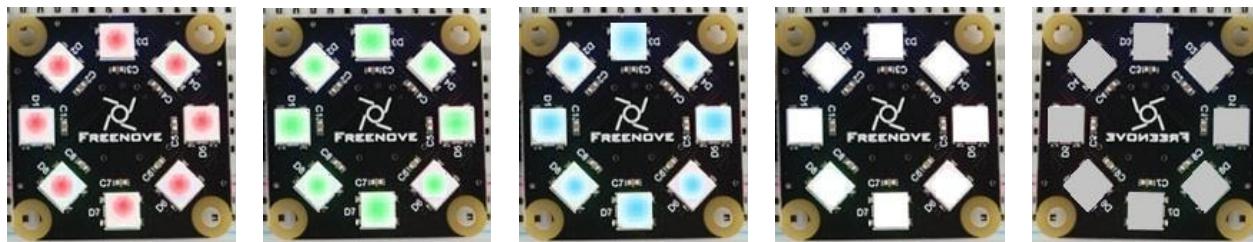
from machine import Pin
import neopixel
import time
pin = Pin(2, Pin.OUT)
np = neopixel.NeoPixel(pin, 8)

#brightness :0-255
brightness=10
colors=[[brightness,0,0], #red
        [0,brightness,0], #green
        [0,0,brightness], #blue
        [brightness,brightness,brightness], #white
        [0,0,0]] #close

while True:
    for i in range(0,5):
        for j in range(0,8):
            np[j]=colors[i]
            np.write()
            time.sleep_ms(50)
    time.sleep_ms(500)
    time.sleep_ms(500)

```

Click “Run current script”, and Neopixel begins to light up in red, green, blue, white and black.





The following is the program code:

```

1  from machine import Pin
2  import neopixel
3  import time
4  pin = Pin(2, Pin.OUT)
5  np = neopixel.NeoPixel(pin, 8)

6
7  #brightness :0~255
8  brightness=10
9  colors=[[brightness, 0, 0],           #red
10    [0, brightness, 0],                 #green
11    [0, 0, brightness],                #blue
12    [brightness, brightness, brightness], #white
13    [0, 0, 0]]                      #close

14
15 while True:
16     for i in range(0, 5):
17         for j in range(0, 8):
18             np[j]=colors[i]
19             np.write()
20             time.sleep_ms(50)
21             time.sleep_ms(500)
22             time.sleep_ms(500)

```

Import Pin, neopixel and time modules.

```

1  from machine import Pin
2  import neopixel
3  import time

```

Define the number of pin and LEDs connected to neopixel.

```

4  pin = Pin(2, Pin.OUT)
5  np = neopixel.NeoPixel(pin, 8)

```

Define the brightness of neopixel's LED and an array to store color.

```

7  #brightness :0~255
8  brightness=10
9  colors=[[brightness, 0, 0],           #red
10    [0, brightness, 0],                 #green
11    [0, 0, brightness],                #blue
12    [brightness, brightness, brightness], #white
13    [0, 0, 0]]                      #close

```

Assign the color data to the array np and call function write() to send np array data to neopixel module.

```

18      np[j]=colors[i]
19      np.write()

```

Nest two for loops to make the module repeatedly display five states of red, green, blue, white and OFF.

```
15 while True:  
16     for i in range(0, 5):  
17         for j in range(0, 8):  
18             np[j]=colors[i]  
19             np.write()  
20             time.sleep_ms(50)  
21             time.sleep_ms(500)  
22             time.sleep_ms(500)
```

#### Reference

##### Class neopixel

Before each usr of **neopixel** module, please add the statement “**import neopixel**” to the top of Python file.

**NeoPixel(pin, n)**: Define the number of output pins and LEDs of neopixel module

**pin**: Output pins

**n**: The number of LEDs.

**NeoPixel.write()**: Write data to LEDs.

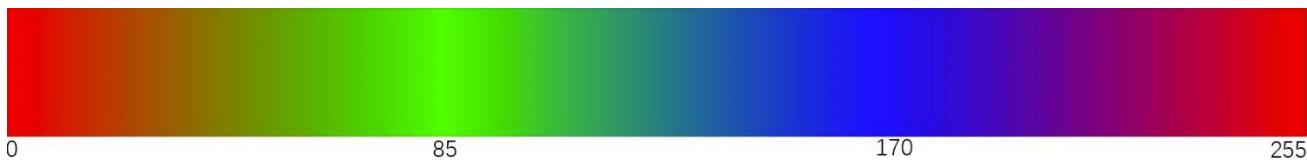


## Project 6.2 Rainbow Light

In the previous project, we have mastered the usage of NeoPixel. This project will realize a slightly complicated Rainbow Light. The component list and the circuit are exactly the same as the project fashionable Light.

### Code

Continue to use the following color model to equalize the color distribution of the 8 leds and gradually change.



Move the program folder “**Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32/Python/Python\_Codes**” to disk(D) in advance with the path of “**D:/Micropython\_Codes**”.

Open “Thonny”, click “This computer” → “D:” → “Micropython\_Codes” → “06.2\_Rainbow\_light” and then double click “06.2\_Rainbow\_light.py”.

#### 06.2\_Rainbow\_light

```

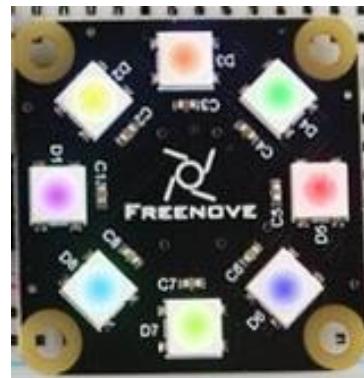
from machine import Pin
import neopixel
import time
pin = Pin(2, Pin.OUT)
np = neopixel.NeoPixel(pin, 8)

brightness=0.1      #brightness: 0-1.0
red=0                #red
green=0              #green
blue=0               #blue

def wheel(pos):
    global red,green,blue
    WheelPos=pos%255
    if WheelPos<85:
        red=(255-WheelPos*3)
        green=(WheelPos*3)
        blue=0
    elif WheelPos>=85 and WheelPos<170:
        WheelPos -= 85;
        red=0
        green=(255-WheelPos*3)
        blue=(WheelPos*3)
    else:
        red=255
        green=0
        blue=0
    return (red,green,blue)

```

Click “Run current script”, and the Freenove 8 RGB LED Strip displays different colors and the color changes gradually.



The following is the program code:

```
1  from machine import Pin
2  import neopixel
3  import time
4  pin = Pin(2, Pin.OUT)
5  np = neopixel.NeoPixel(pin, 8)
6
7  brightness=0.1      #brightness: 0 ~ 1.0
8  red=0               #red
9  green=0              #green
10 blue=0               #blue
11
12 def wheel(pos):
13     global red,green,blue
14     WheelPos=pos%255
15     if WheelPos<85:
16         red=(255-WheelPos*3)
17         green=(WheelPos*3)
18         blue=0
19     elif WheelPos>=85 and WheelPos<170:
20         WheelPos -= 85;
21         red=0
22         green=(255-WheelPos*3)
23         blue=(WheelPos*3)
24     else :
25         WheelPos -= 170;
26         red=(WheelPos*3)
27         green=0
28         blue=(255-WheelPos*3)
29
30 while True:
```

```

31     for i in range(0, 255) :
32         for j in range(0, 8) :
33             wheel(i+j*255//8)
34             np[j]=(int(red*brightness), int(green*brightness), int(blue*brightness))
35             np.write()
36             time.sleep_ms(5)

```

Define a wheel() function to process the color data of neopixel module.

```

12 def wheel(pos) :
13     global red, green, blue
14     WheelPos=pos%255
15     if WheelPos<85:
16         red=(255-WheelPos*3)
17         green=(WheelPos*3)
18         blue=0
19     elif WheelPos>=85 and WheelPos<170:
20         WheelPos -= 85;
21         red=0
22         green=(255-WheelPos*3)
23         blue=(WheelPos*3)
24     else :
25         WheelPos -= 170;
26         red=(WheelPos*3)
27         green=0
28         blue=(255-WheelPos*3)

```

Set the color brightness of the module.

7	brightness=0.1                   #brightness: 0 – 1.0
---	---

Use a nesting of two for loops. The first for loop makes the value of i increase from 0 to 255 automatically and the wheel() function processes the value of i into data of the module's three colors; the second for loop writes the color data to the module.

```

31     for i in range(0, 255) :
32         for j in range(0, 8) :
33             wheel(i+j*255//8)
34             np[j]=(int(red*brightness), int(green*brightness), int(blue*brightness))
35             np.write()
36             time.sleep_ms(5)

```

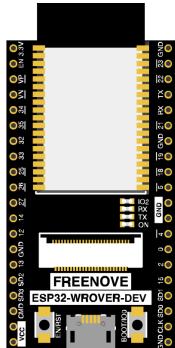
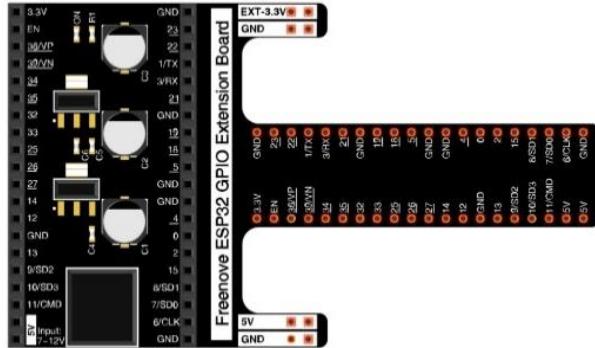
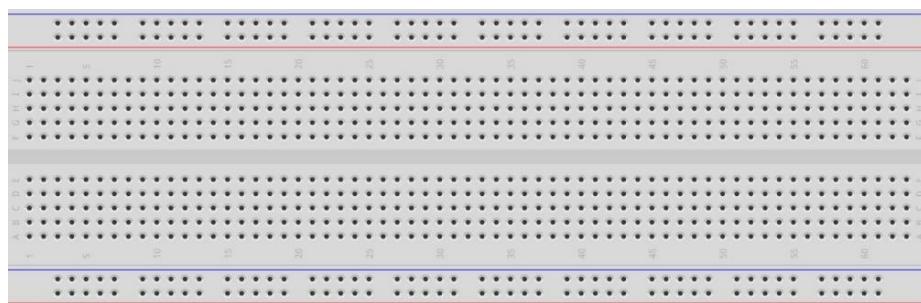
# Chapter 7 Buzzer

In this chapter, we will learn about buzzers and the sounds they make.

## Project 7.1 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

ESP32-WROVER x1	GPIO Extension Board x1
	
	
Breadboard x1	
	
Jumper M/M x6	
NPN transistor x1 (S8050)	
Active buzzer x1	
Push button x1	
Resistor 1kΩ x1	
Resistor 10kΩ x2	

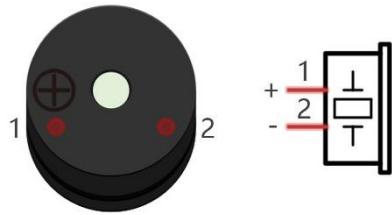


## Component knowledge

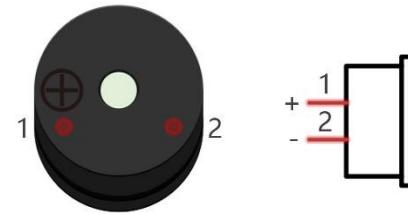
### Buzzer

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

Active buzzer



Passive buzzer



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

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

### How to identify active and passive buzzer?

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

Active buzzer



Passive buzzer

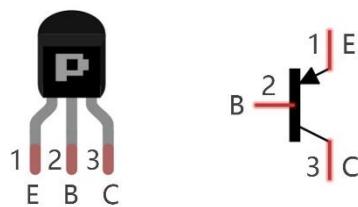


## Transistor

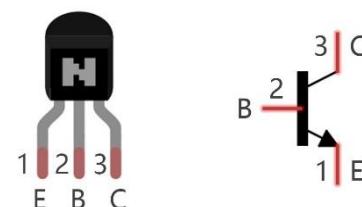
Because the buzzer requires such large current that GPIO of ESP32 output capability cannot meet the requirement, a transistor of NPN type is needed here to amplify the current.

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 as shown below: PNP and NPN,

PNP transistor



NPN transistor

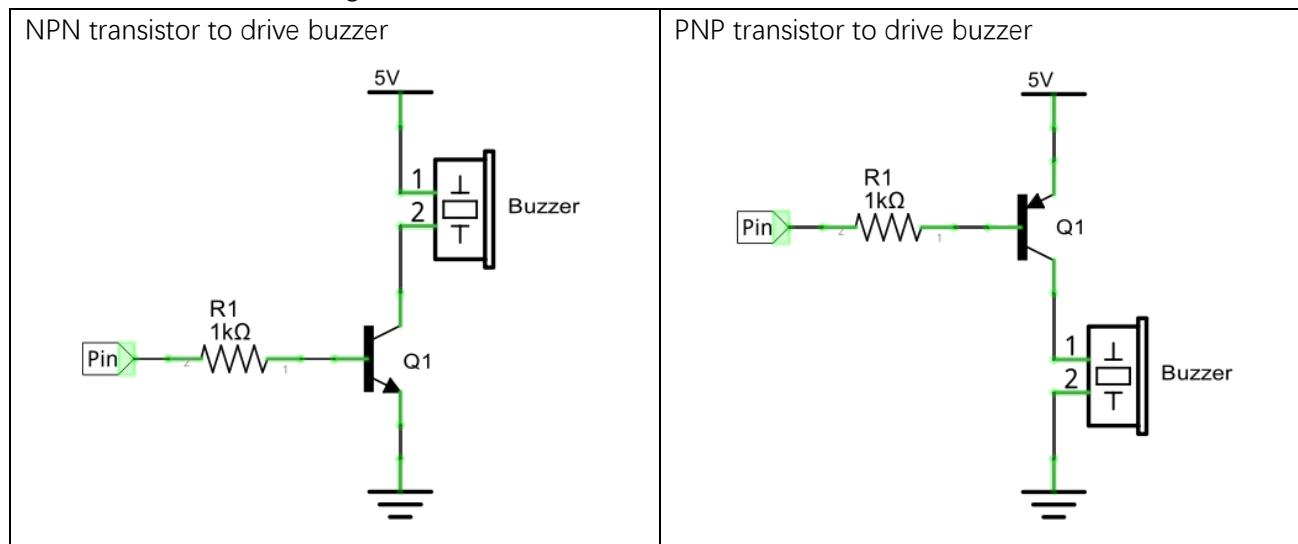


In our kit, the PNP transistor is marked with 8550, and the NPN transistor is marked with 8050.

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

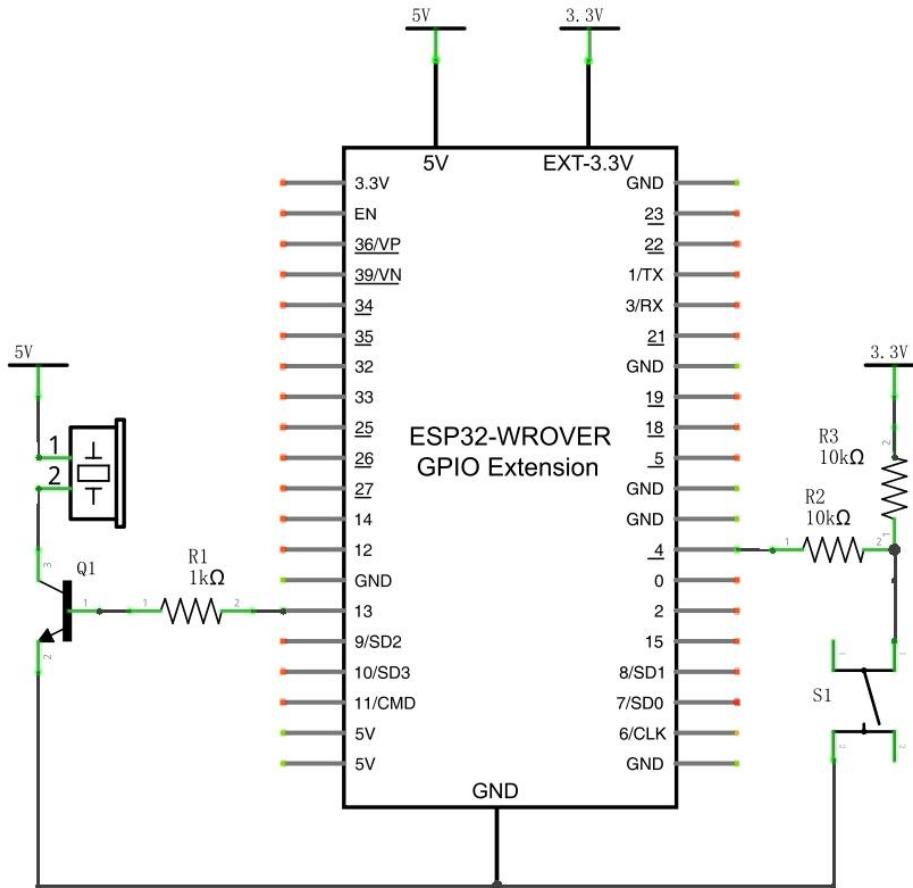
When using NPN transistor to drive buzzer, we often adopt the following method. If GPIO outputs high level, current will flow through R1, the transistor will get conducted, and the buzzer will sound. If GPIO outputs low level, no current flows through R1, the transistor will not be conducted, and buzzer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

When using PNP transistor to drive buzzer, we often adopt the following method. If GPIO outputs low level, current will flow through R1, the transistor will get conducted, and the buzzer will sound. If GPIO outputs high level, no current flows through R1, the transistor will not be conducted, and buzzer will not sound.

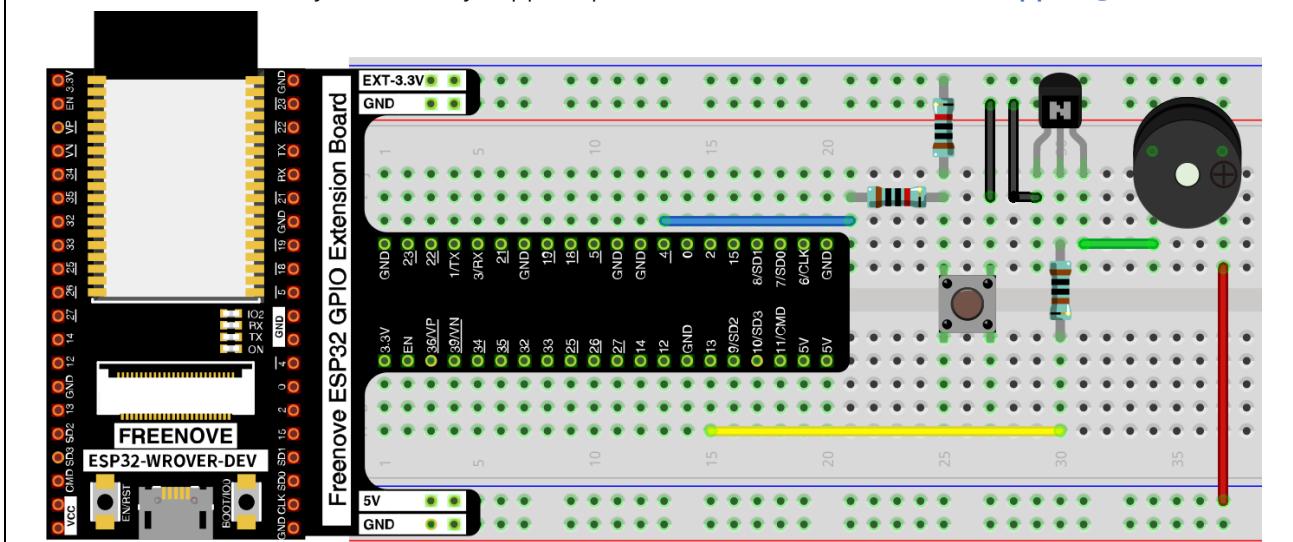


## Circuit

Schematic diagram



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

Any concerns? ✉ [support@freenove.com](mailto:support@freenove.com)

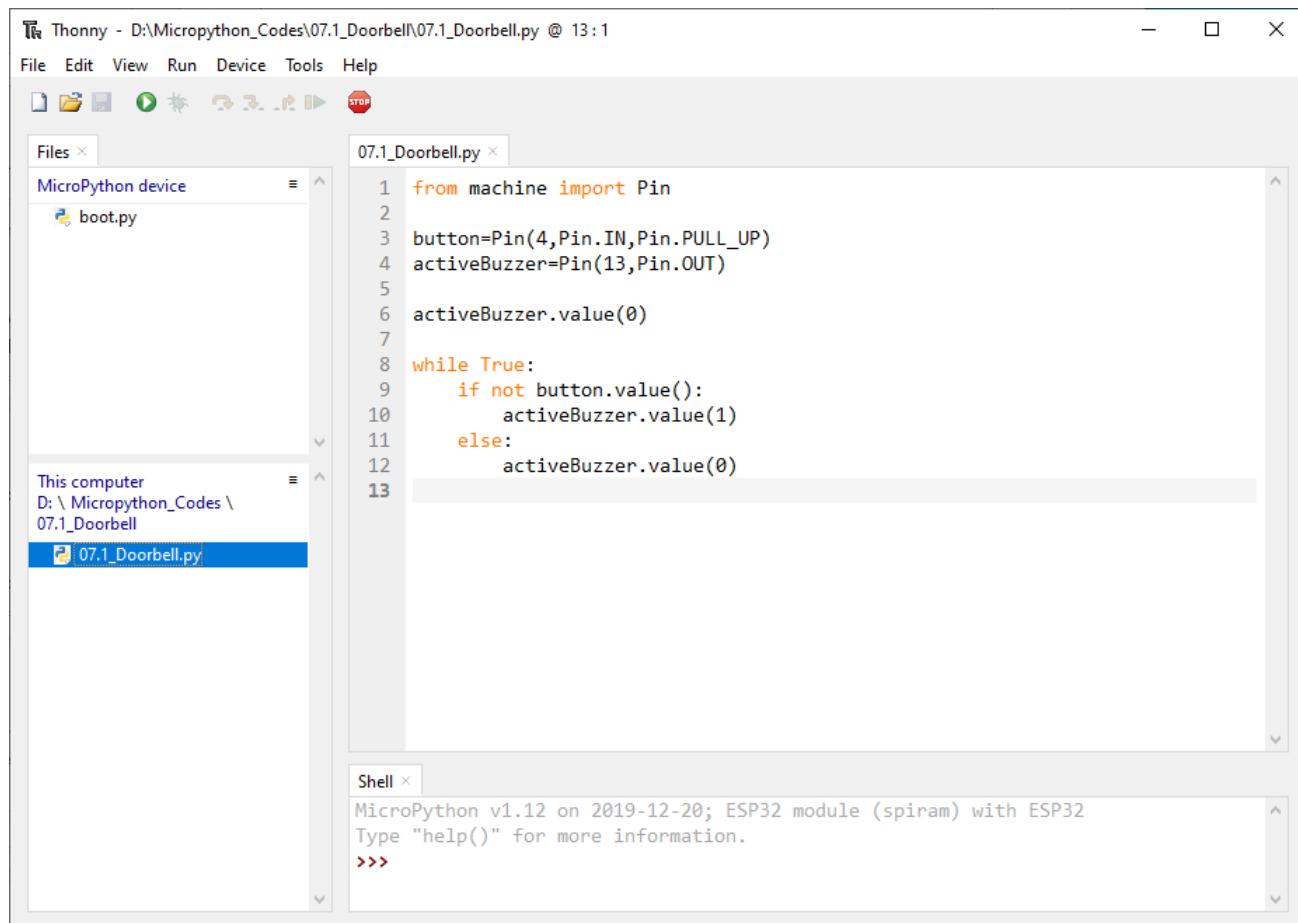
## Code

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

Move the program folder “**Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32/Python/Python\_Codes**” to disk(D) in advance with the path of “**D:/Micropython\_Codes**”.

Open “Thonny”, click “This computer” → “D:” → “Micropython\_Codes” → “07.1\_Doorbell” and double click “07.1\_Doorbell.py”.

### 07.1\_Doorbell



The screenshot shows the Thonny IDE interface. The title bar reads "Thonny - D:\Micropython\_Codes\07.1\_Doorbell\07.1\_Doorbell.py @ 13:1". The menu bar includes File, Edit, View, Run, Device, Tools, and Help. Below the menu is a toolbar with icons for file operations like Open, Save, and Run. The left sidebar has a "Files" tab showing a tree structure with "MicroPython device" expanded, showing "boot.py". Under "This computer", "D:\ Micropython\_Codes \ 07.1\_Doorbell" is expanded, and "07.1\_Doorbell.py" is selected and highlighted in blue. The main workspace shows the Python code for "07.1\_Doorbell.py":

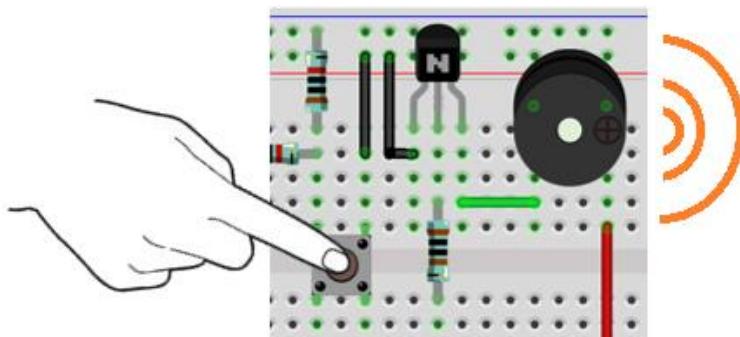
```
1 from machine import Pin
2
3 button=Pin(4,Pin.IN,Pin.PULL_UP)
4 activeBuzzer=Pin(13,Pin.OUT)
5
6 activeBuzzer.value(0)
7
8 while True:
9     if not button.value():
10         activeBuzzer.value(1)
11     else:
12         activeBuzzer.value(0)
```

Below the code editor is a "Shell" tab with the text:

```
MicroPython v1.12 on 2019-12-20; ESP32 module (spiram) with ESP32
Type "help()" for more information.
>>>
```



Click “Run current script”, press the push button switch and the buzzer will sound. Release the push button switch and the buzzer will stop.



The following is the program code:

```
1 from machine import Pin  
2  
3 button=Pin(4,Pin.IN,Pin.PULL_UP)  
4 activeBuzzer=Pin(13,Pin.OUT)  
5  
6 activeBuzzer.value(0)  
7  
8 while True:  
9     if not button.value():  
10         activeBuzzer.value(1)  
11     else:  
12         activeBuzzer.value(0)
```

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

## Project 7.2 Alertor

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

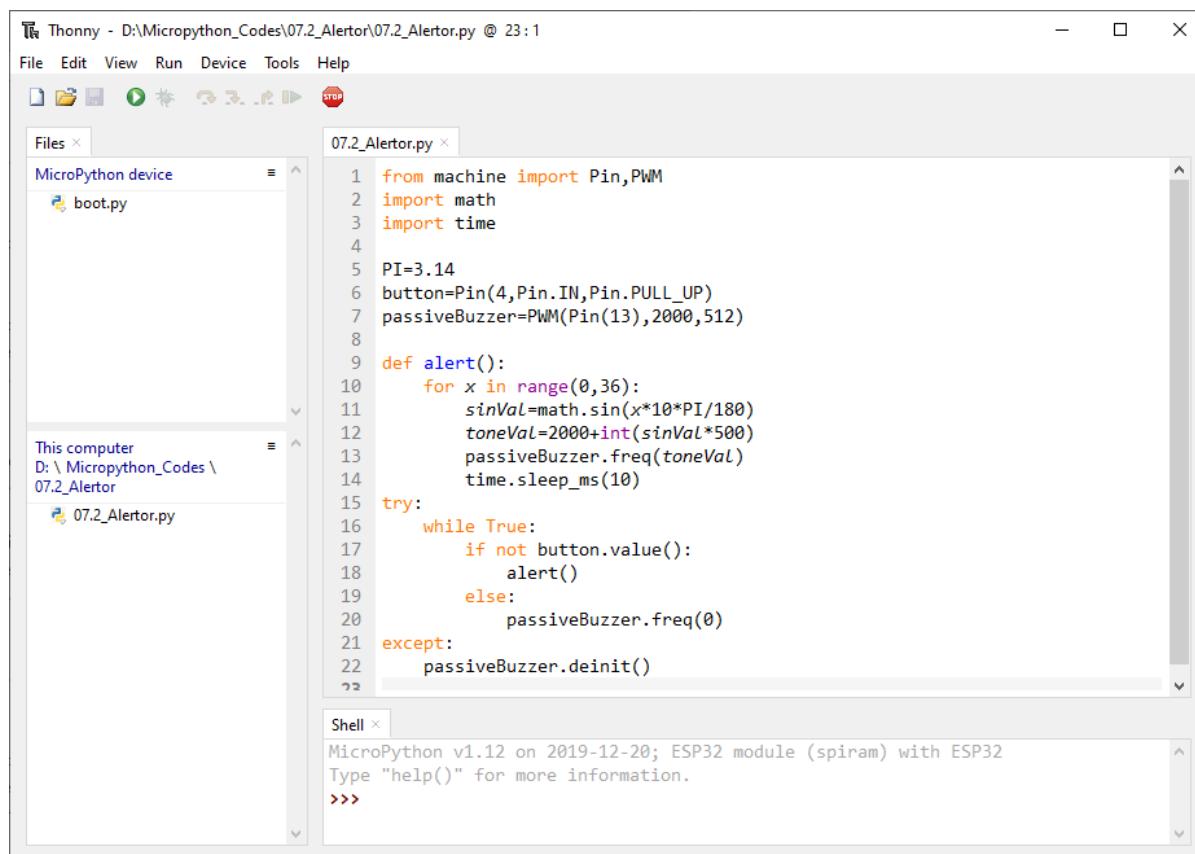
Component list and the circuit part is similar to last section. In the Doorbell circuit only the **active buzzer** needs to be **replaced** with a **passive buzzer**.

## 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 as using button to control LED. In the control method, passive buzzer requires PWM of certain frequency to sound.

Open “Thonny”, click “This computer” → “D:” → “Micropython\_Codes” → “07.2\_Alertor”, and double click “07.2\_Alertor.py”.

### 07.2\_Alertor



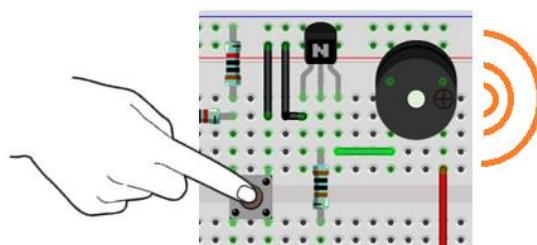
```

from machine import Pin,PWM
import math
import time
PI=3.14
button=Pin(4,Pin.IN,Pin.PULL_UP)
passiveBuzzer=PWM(Pin(13),2000,512)

def alert():
    for x in range(0,36):
        sinVal=math.sin(x*10*PI/180)
        toneVal=2000+int(sinVal*500)
        passiveBuzzer.freq(toneVal)
        time.sleep_ms(10)
try:
    while True:
        if not button.value():
            alert()
        else:
            passiveBuzzer.freq(0)
except:
    passiveBuzzer.deinit()

```

Click “Run current script”, press the button, then alarm sounds. And when the button is release, the alarm will stop sounding.



Any concerns? ✉ support@freenove.com

The following is the program code:

```

1  from machine import Pin, PWM
2  import math
3  import time
4
5  PI=3.14
6  button=Pin(4, Pin.IN, Pin.PULL_UP)
7  passiveBuzzer=PWM(Pin(13), 2000, 512)
8
9  def alert():
10     for x in range(0, 36):
11         sinVal=math.sin(x*10*PI/180)
12         toneVal=2000+int(sinVal*500)
13         passiveBuzzer.freq(toneVal)
14         time.sleep_ms(10)
15     try:
16         while True:
17             if not button.value():
18                 alert()
19             else:
20                 passiveBuzzer.freq(0)
21     except:
22         passiveBuzzer.deinit()
```

Import PWM, Pin, math and time modules.

```

1  from machine import Pin, PWM
2  import math
3  import time
```

Define the pins of the button and passive buzzer.

```

5  PI=3.14
6  button=Pin(4, Pin.IN, Pin.PULL_UP)
7  passiveBuzzer=PWM(Pin(13), 2000, 512)
```

Call sin function of math module to generate the frequency data of the passive buzzer.

```

9  def alert():
10     for x in range(0, 36):
11         sinVal=math.sin(x*10*PI/180)
12         toneVal=2000+int(sinVal*500)
13         passiveBuzzer.freq(toneVal)
14         time.sleep_ms(10)
```

When not using PWM, please turn it OFF in time.

```
22  passiveBuzzer.deinit()
```

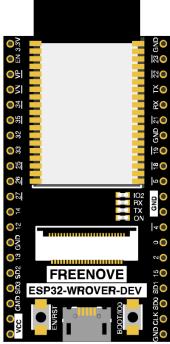
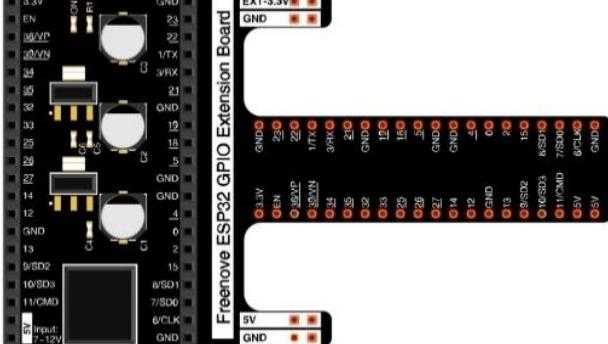
# Chapter 8 Serial Communication

Serial Communication is a means of Communication between different devices/devices. This section describes ESP32's Serial Communication.

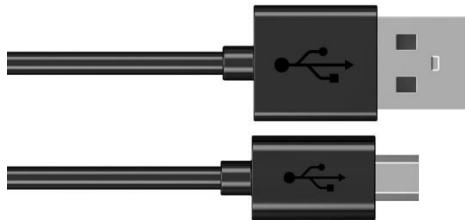
## Project 8.1 Serial Print

This project uses ESP32's serial communicator to send data to the computer and print it on the serial monitor.

### Component List

ESP32-WROVER x1	GPIO Extension Board x1
	

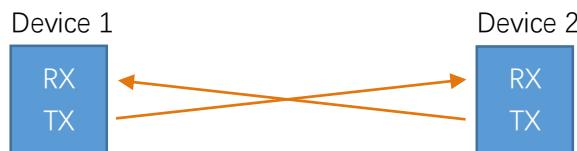
Micro USB Wire x1



## Related knowledge

### Serial communication

Serial communication generally refers to the Universal Asynchronous Receiver/Transmitter (UART), which is commonly used in electronic circuit communication. It has two communication lines, one is responsible for sending data (TX line) and the other for receiving data (RX line). The serial communication connections two devices use is as follows:



Before serial communication starts, the baud rate of both sides must be the same. Communication between devices can work only if the same baud rate is used. The baud rates commonly used is 9600 and 115200.

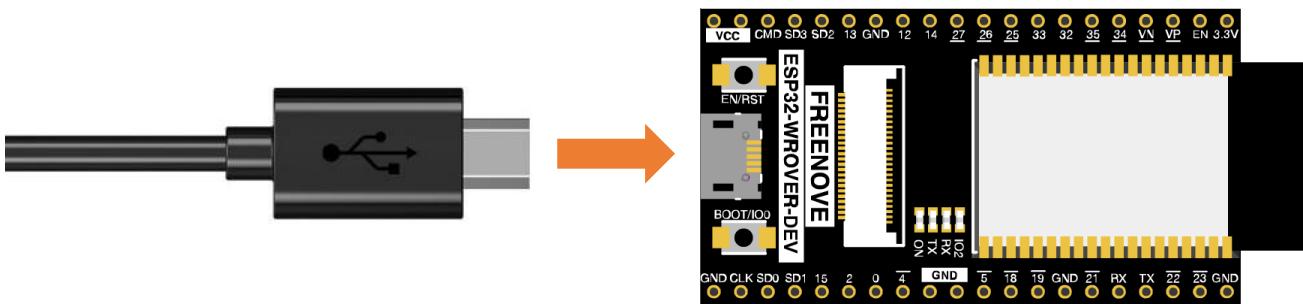
### Serial port on ESP32

Freenove ESP32 has integrated USB to serial transfer, so it could communicate with computer connecting to USB cable.



## Circuit

Connect Freenove ESP32 to the computer with USB cable

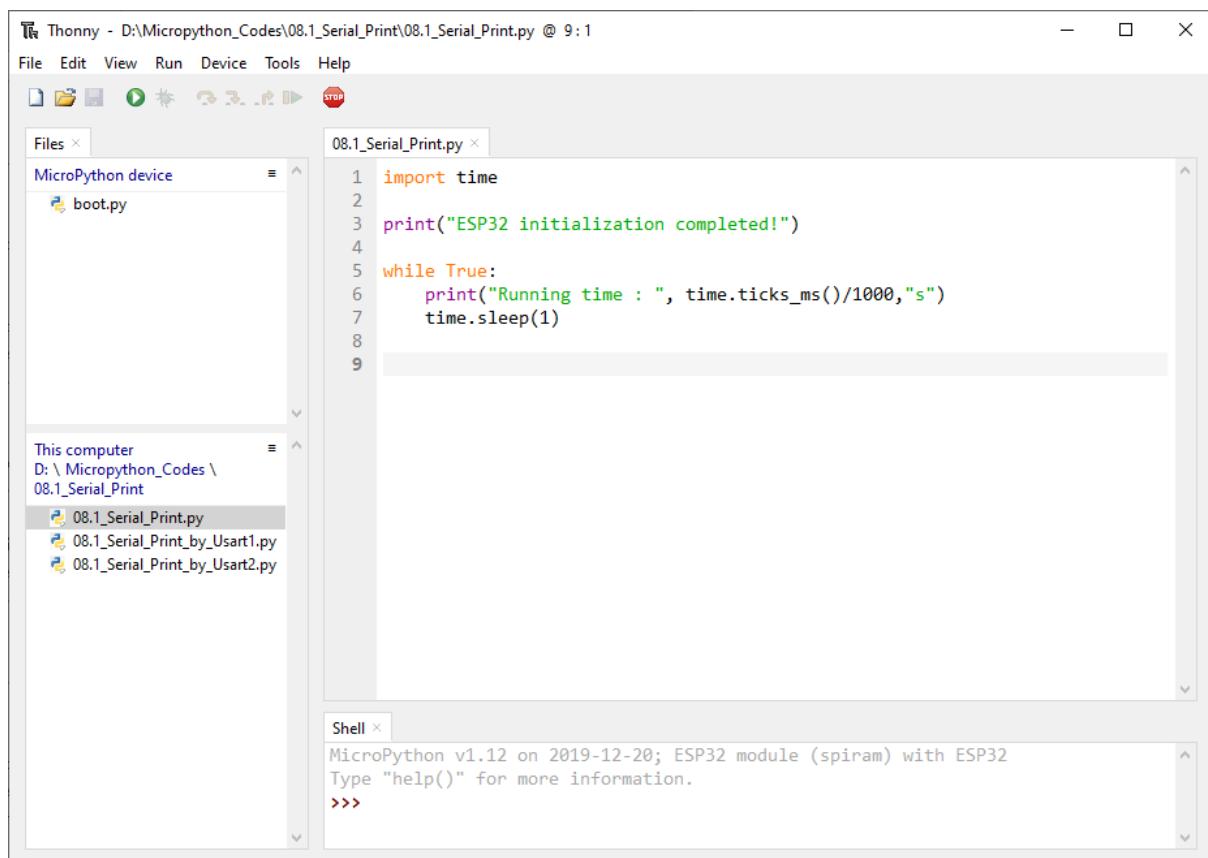


## Code

Move the program folder “**Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32/Python/Python\_Codes**” to disk(D) in advance with the path of “**D:/Micropython\_Codes**”.

Open “Thonny”, click “This computer” → “D.” → “Micropython\_Codes” → “08.1\_Serial\_Print” and double “08.1\_Serial\_Print.py”.

### 08.1\_Serial\_Print



Click “Run current script” and observe the changes of “Shell”, which will display the time when ESP32 is powered on once per second.



The following is the program code:

```

1 import time
2
3 print("ESP32 initialization completed!")
4
5 while True:
6     print("Running time : ", time.ticks_ms()/1000, "s")
7     time.sleep(1)

```



ESP32-WROVER has 3 serial ports, one of which is used as REPL, that is, Pin(1) and Pin(3) are occupied, and generally it is not recommended to be used as tx, rx. The other two serial ports can be configured simply by calling the UART module.

```

Thonny - D:\Micropython_Codes\8.1_Serial_Print\8.1_Serial_Print_by_Usart1.py @ 12 : 18
File Edit View Run Device Tools Help
Files x 8.1_Serial_Print.py x 8.1_Serial_Print_by_Usart1.py x 8.1_Serial_Print_by_Usart2.py x
MicroPython device
boot.py
This computer
D:\Micropython_Codes\8.1_Serial_Print
8.1_Serial_Print.py
8.1_Serial_Print_by_Usart1.py
8.1_Serial_Print_by_Usart2.py
1 from machine import UART
2 import time
3
4 myUsart = UART(1, baudrate=115200, bits=8, parity=0, rx=5, tx=2, timeout=10)
5 myUsart.write("ESP32 initialization completed!\r\n")
6
7 while True:
8     myUsart.write("Running time : ")
9     a=str(time.ticks_ms()/1000)
10    myUsart.write(a)
11    myUsart.write(" s\r\n")
12    time.sleep(1)

```

Shell x  
Use Stop/Restart to reconnect.  
MicroPython v1.12 on 2019-12-20; ESP32 module (spiram) with ESP32  
Type "help()" for more information.  
>>>

## Reference

### Class UART

Before each use of **UART** module, please add the statement “**from machine import UART**” to the top of python file.

**UART(id, baudrate, bits, parity, rx, tx, stop, timeout)**: Define serial ports and configure parameters for them.

**id**: Serial Number. The available serial port number is 1 or 2

**baudrate**: Baud rate

**bits**: The number of each character.

**parity**: Check even or odd, with 0 for even checking and 1 for odd checking.

**rx, tx**: UAPT's reading and writing pins

Pin(0)、Pin(2)、Pin(4)、Pin(5)、Pin(9)、Pin(10)、Pin(12~19)、Pin(21~23)、Pin(25)、Pin(26)、  
Pin(34~36)、Pin(39)

Note: Pin(1) and Pin(3) are occupied and not recommend to be used as tx,rx.

**stop**: The number of stop bits, and the stop bit is 1 or 2.

**timeout**: timeout period (Unit: millisecond)

0 < timeout ≤ 0xFFFF FFFF (decimal: 0 < timeout ≤ 2147483647)

**UART.init(baudrate, bits, parity, stop, tx, rx, rts, cts)**: Initialize serial ports

**tx**: writing pins of uart

**rx**: reading pins of uart

**rts**: rts pins of uart

**cts**: cts pins of uart

**UART.read(nbytes)**: Read nbytes bytes

**UART.read()**: Read data

**UART.write(buf)**: Write byte buffer to UART bus

**UART.readline()**: Read a line of data, ending with a newline character.

**UART.readinto(buf)**: Read and write data into buffer.

**UART.readinto(buf, nbytes)**: Read and write data into buffer.

**UART.any()**: Determine whether there is data in serial ports. If yes, return the number of bytes; Otherwise, return 0.



## Project 8.2 Serial Read and Write

From last section, we use Serial port on Freenove ESP32 to send data to a computer, now we will use that to receive data from computer.

Component and Circuit are the same as in the previous project.

### Code

Open “Thonny”, click “This computer” → “D:” → “Micropython\_Codes” → “08.2\_Serial\_Read\_and\_Write” and double click “08.2\_Serial\_Read\_and\_Write.py”.

#### 08.2\_Serial\_Read\_and\_Write

```

Thonny - D:\Micropython_Codes\08.2_Serial_Read_and_Write\08.2_Serial_Read_and_Write.py @ 5:35
File Edit View Run Device Tools Help
Stop

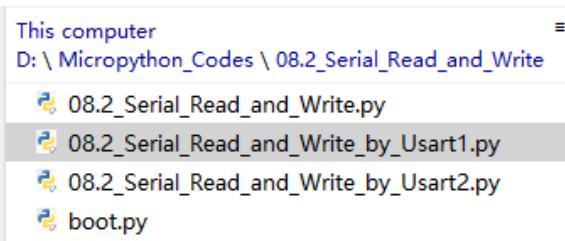
Files ×
MicroPython device
boot.py

08.2_Serial_Read_and_Write.py ×
1 print(str("\nESP32 initialization completed!\n"))
2     + str("Please input some characters,\n")
3     + str("select \"Newline\" below and click send button. \n"))
4 while True:
5     print("inputString: ",input())
This computer
D: \ Micropython_Codes \
08.2_Serial_Read_and_Write
08.2_Serial_Read_and_Write.py
08.2_Serial_Read_and_Write_by.
08.2_Serial_Read_and_Write_by.

Shell ×
MicroPython v1.12 on 2019-12-20; ESP32 module (spiram) with ESP32
Type "help()" for more information.
>>>

```

Click “Run current script” and ESP32 will print out data at “Shell” and wait for users to enter any messages. Press Enter to end the input, and “Shell” will print out data that the user entered. If you want to use other serial ports, you can use other python files in the same directory.



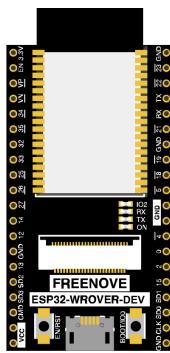
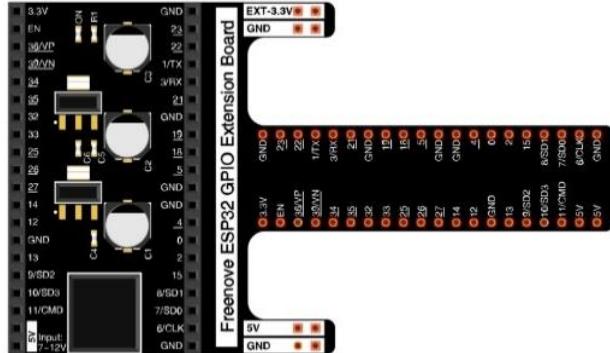
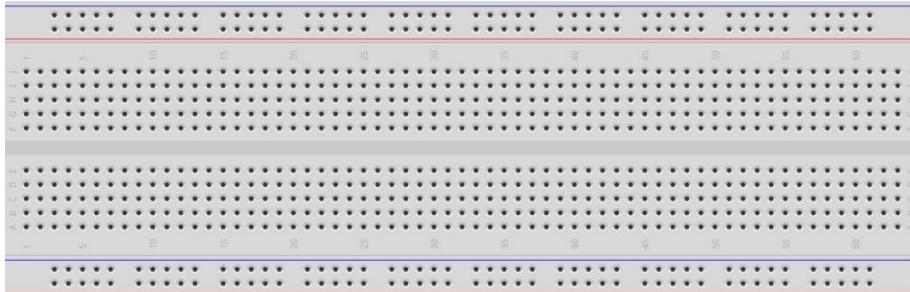
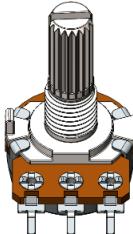
# Chapter 9 AD/DA Converter

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, convert it into digital and convert the digital into analog output. That is, ADC and DAC.

## Project 9.1 Read the Voltage of Potentiometer

In this project, we will use the ADC function of ESP32 to read the voltage value of potentiometer. And then output the voltage value through the DAC to control the brightness of LED.

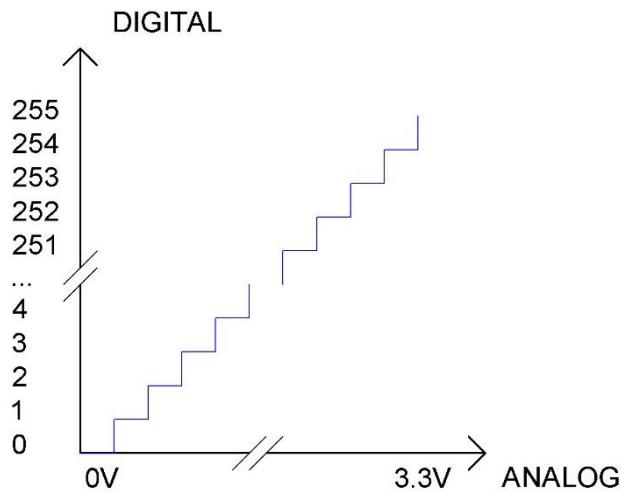
### Component List

ESP32-WROVER x1	GPIO Extension Board x1		
			
Breadboard x1			
			
Rotary potentiometer x1	Resistor 220Ω x1	LED x1	Jumper M/M x5
			

## Related knowledge

### ADC

An ADC is an electronic integrated circuit used to convert analog signals such as voltages to digital or binary form consisting of 1s and 0s. The range of our ADC on ESP32 is 12 bits, that means the resolution is  $2^{12}=4096$ , and it represents a range (at 3.3V) will be divided equally to 4096 parts. The range of analog values corresponds to ADC values. So the more bits the ADC has, the denser the partition of analog will be and the greater the precision of the resulting conversion.



Subsection 1: the analog in range of 0V---3.3/4095 V corresponds to digital 0;

Subsection 2: the analog in range of 3.3/4095 V---2\*3.3 / 4095V corresponds to digital 1;

...

The following analog will be divided accordingly.

The conversion formula is as follows:

$$ADCValue = \frac{\text{Analog Voltage}}{3.3} * 4095$$

### DAC

The reversing of this process requires a DAC, Digital-to-Analog Converter. The digital I/O port can output high level and low level (0 or 1), but cannot output an intermediate voltage value. This is where a DAC is useful. ESP32 has two DAC output pins with 8-bit accuracy, GPIO25 and GPIO26, 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 the accuracy of DAC, the higher the accuracy of output voltage value will be.

The conversion formula is as follows:

$$Analog\ Voltage = \frac{DAC\ Value}{255} * 3.3\ (V)$$

### ADC on ESP32

ESP32 has 6 pins can be used to measure analog signals. GPIO pin sequence number and analog pin definition are shown in the following table.

ADC number in ESP32	ESP32 GPIO number
ADC1	GPIO 36
ADC2	GPIO 39
ADC3	GPIO 34
ADC4	GPIO 35
ADC5	GPIO 32
ADC6	GPIO 33

### DAC on ESP32

ESP32 has two 8-bit digital analog converters to be connected to GPIO25 and GPIO26 pins, respectively, and it is immutable. As shown in the following table,

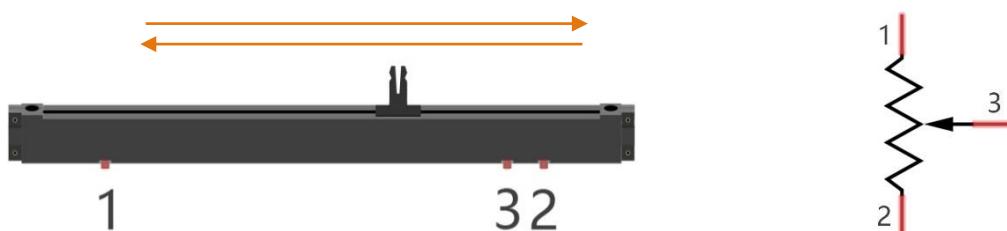
Simulate pin number	GPIO number
DAC1	25
DAC2	26

Note: In this ESP32, GPIO26 is connected to 3.3V through a resistor. Therefore, DAC2 cannot be used.

## Component knowledge

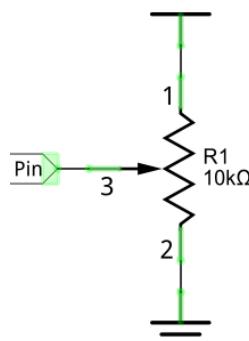
### Potentiometer

Potentiometer is a resistive element with three Terminal parts. Unlike the resistors that we have used thus far in our project which have a fixed resistance value, the resistance value of a potentiometer can be adjusted. A potentiometer is often made up by a resistive substance (a wire or carbon element) and movable contact brush. When the brush moves along the resistor element, there will be a change in the resistance of the potentiometer's output side (3) (or change in the voltage of the circuit that is a part). The illustration below represents a linear sliding potentiometer and its electronic symbol on the right.



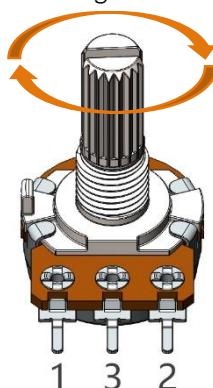
What between potentiometer pin 1 and pin 2 is the resistor body, and pins 3 is connected to brush. When brush moves from pin 1 to pin 2, the resistance between pin 1 and pin 3 will increase up to body resistance linearly, and the resistance between pin 2 and pin 3 will decrease down to 0 linearly.

In the circuit. The 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.



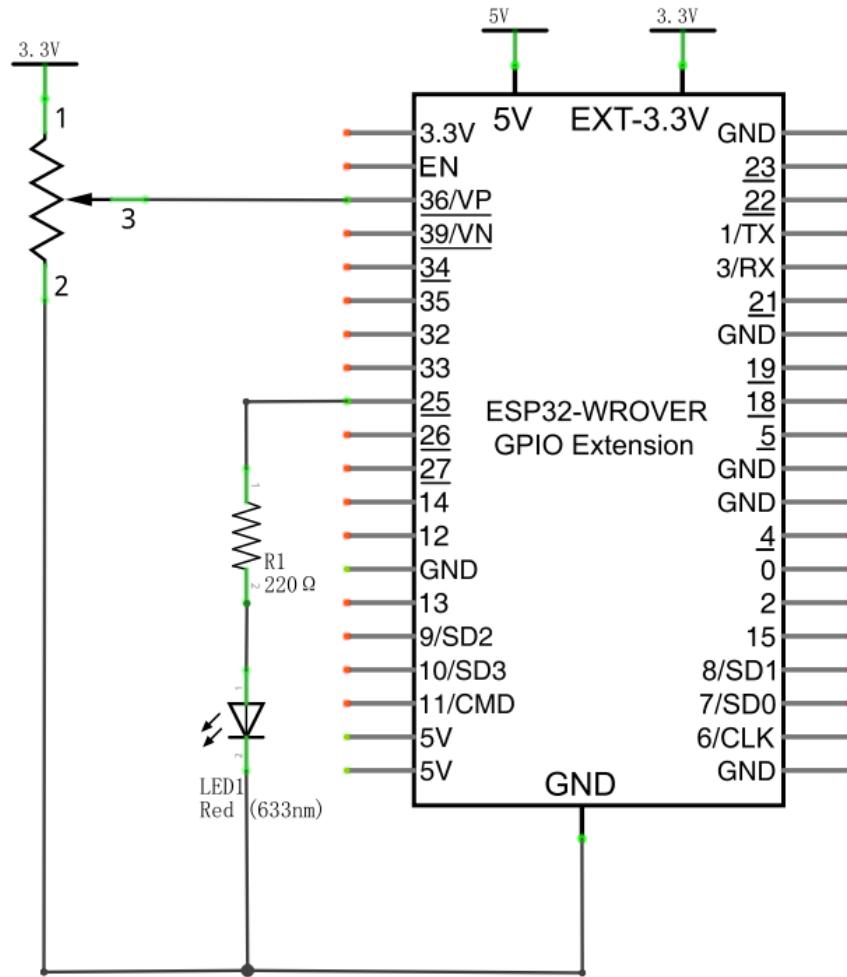
### Rotary potentiometer

Rotary potentiometers and linear potentiometers have the same function; the only difference being the physical action being a rotational rather than a sliding movement.

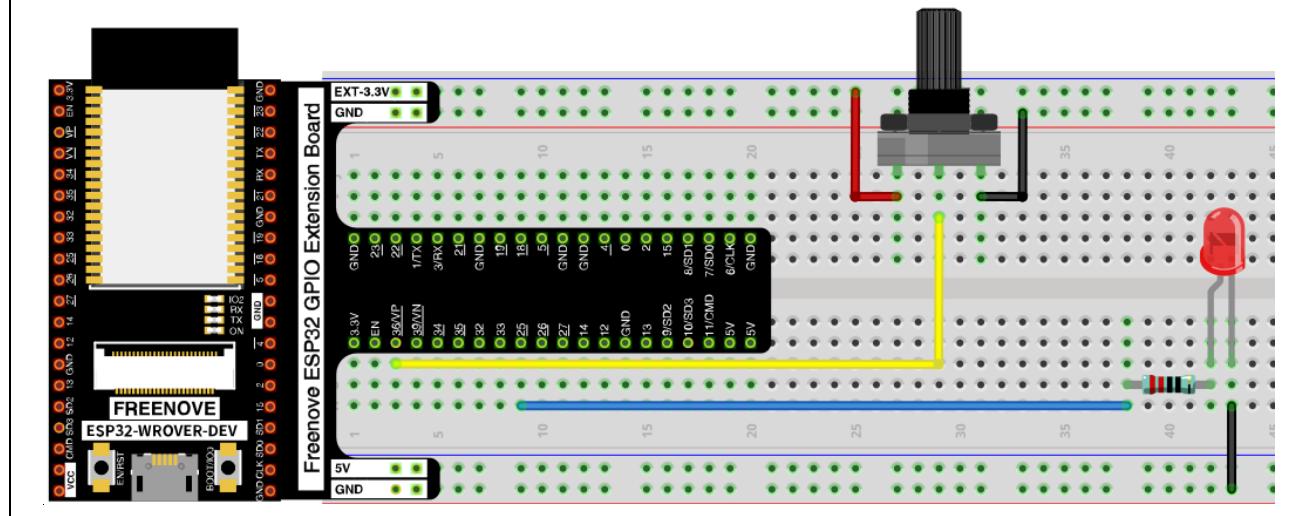


## Circuit

Schematic diagram



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



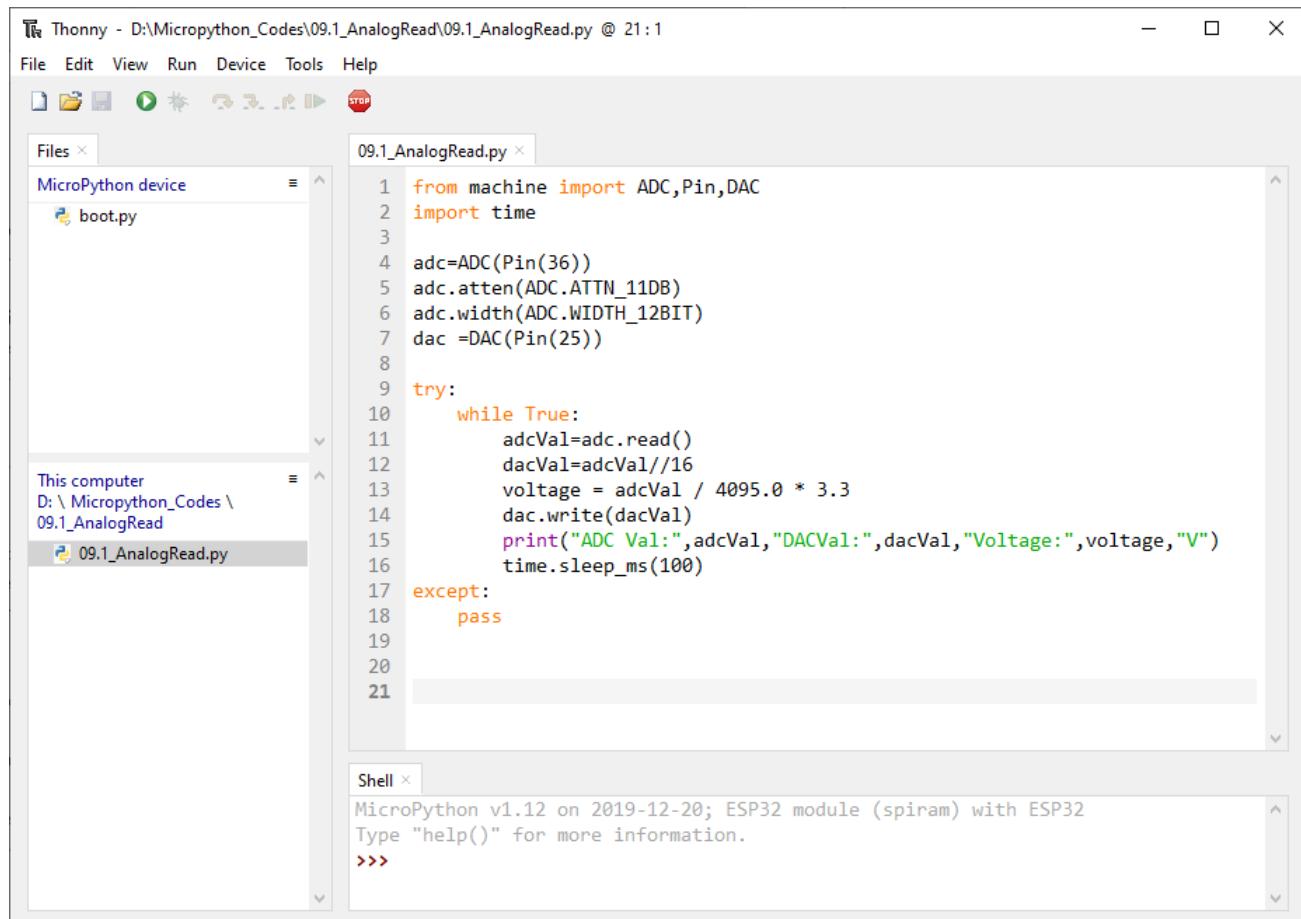
Any concerns? ✉ [support@freenove.com](mailto:support@freenove.com)

## Code

Move the program folder “**Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32/Python/Python\_Codes**” to disk(D) in advance with the path of “**D:/Micropython\_Codes**”.

Open “Thonny”, click “This computer” → “D:” → “Micropython\_Codes” → “09.1\_AnalogRead” and then click “09.1\_AnalogRead.py”.

### 09.1\_AnalogRead



```

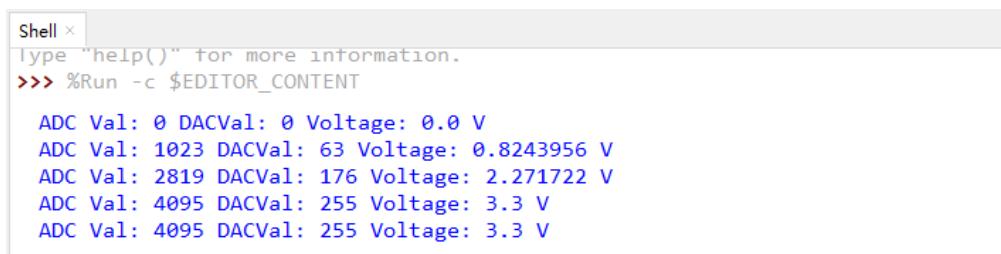
from machine import ADC,Pin,DAC
import time

adc=ADC(Pin(36))
adc.atten(ADC.ATTN_11DB)
adc.width(ADC.WIDTH_12BIT)
dac =DAC(Pin(25))

try:
    while True:
        adcVal=adc.read()
        dacVal=adcVal//16
        voltage = adcVal / 4095.0 * 3.3
        dac.write(dacVal)
        print("ADC Val:",adcVal,"DACVal:",dacVal,"Voltage:",voltage,"V")
        time.sleep_ms(100)
except:
    pass

```

Click “Run current script” and observe the message printed in “Shell”.

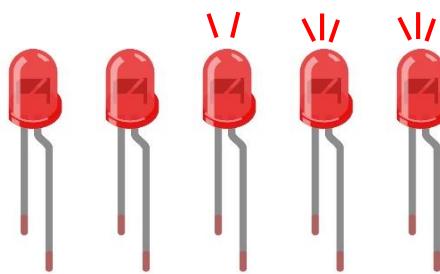


```

Type "help()" for more information.
>>> %Run -c $EDITOR_CONTENT
ADC Val: 0 DACVal: 0 Voltage: 0.0 V
ADC Val: 1023 DACVal: 63 Voltage: 0.8243956 V
ADC Val: 2819 DACVal: 176 Voltage: 2.271722 V
ADC Val: 4095 DACVal: 255 Voltage: 3.3 V
ADC Val: 4095 DACVal: 255 Voltage: 3.3 V

```

LEDs display as below:



"Shell" prints ADC value, DAC value, the output voltage of potentiometer and other information. In the code, we make the output voltage of the DAC pin equal to the input voltage of the ADC pin. Rotate the handle of the potentiometer, the printed information will change. When the voltage is greater than 1.6V (turn-on voltage of red LED), the LED starts to emit light. If you continue to increase the output voltage, the LED will gradually become brighter. And when the voltage is less than 1.6V, the LED will not light up, because this does not reach the turn-on voltage of the LED, which indirectly proves the difference between DAC and PWM. (If you have an oscilloscope, you can view the waveform output by the DAC through the oscilloscope)

The following is the code:

```

1  from machine import ADC, Pin, DAC
2  import time
3
4  adc=ADC(Pin(36))
5  adc.atten(ADC.ATTN_11DB)
6  adc.width(ADC.WIDTH_12BIT)
7  dac =DAC(Pin(25))
8
9  try:
10     while True:
11         adcVal=adc.read()
12         dacVal=adcVal//16
13         voltage = adcVal / 4095.0 * 3.3
14         dac.write(dacVal)
15         print("ADC Val:",adcVal,"DACVal:",dacVal,"Voltage:",voltage,"V")
16         time.sleep_ms(100)
17     except:
18         pass

```

Import Pin, ADC and DAC modules.

```

1  from machine import ADC, Pin, DAC
2  import time

```

Turn on and configure the ADC with the range of 0-3.3V and the data width of 12-bit data width, and turn on the DAC pin.

```

4  adc=ADC(Pin(36))
5  adc.atten(ADC.ATTN_11DB)
6  adc.width(ADC.WIDTH_12BIT)
7  dac =DAC(Pin(25))

```

Read ADC value once every 100 millisecods, convert ADC value to DAC value and output it, control the brightness of LED and print these data to “Shell”.

```

10     while True:
11         adcVal=adc.read()
12         dacVal=adcVal//16
13         voltage = adcVal / 4095.0 * 3.3
14         dac.write(dacVal)
15         print("ADC Val:",adcVal,"DACVal:",dacVal,"Voltage:",voltage,"V")
16         time.sleep_ms(100)

```

## Reference

### Class ADC

Before each use of ACD module, please add the statement “**from machine import ADC**” to the top of the python file.

**machine.ADC(pin)**: Create an ADC object associated with the given pin.

**pin**: Available pins are: Pin(36)、Pin(39)、Pin(34)、Pin(35)、Pin(32)、Pin(33)。

**ADC.read()**: Read ADC and return the value.

**ADC.attenu(db)**: Set attenuation ration (that is, the full range voltage, such as the voltage of 11db full range is 3.3V)

**db**: attenuation ratio

**ADC.ATTIN\_0DB** —full range of 1.2V

**ADC.ATTN\_2\_5\_DB** —full range of 1.5V

**ADC.ATTN\_6DB** —full range of 2.0 V

**ADC.ATTN\_11DB** —full range of 3.3V

**ADC.width(bit)**: Set data width.

**bit**: data bit

**ADC.WIDTH\_9BIT** —9 data width

**ADC.WIDTH\_10BIT** — 10 data width

**ADC.WIDTH\_11BIT** — 11 data width

**ADC.WIDTH\_12BIT** — 12 data width

### Class DAC

Before each use of **DAC** module, please add the statement “**from machine import DAC**” to the top of the python file.

**machine.DAC(pin)**: Create a DAC object associated with the given pin.

**pin**: Available pins are: Pin(25)、Pin(26)

**DAC.write(value)**: Output voltage

**value**: The range of data value: 0-255, corresponding output voltage of 0-3.3V

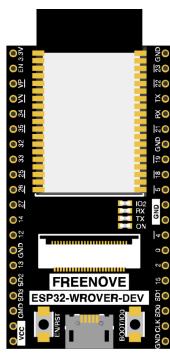
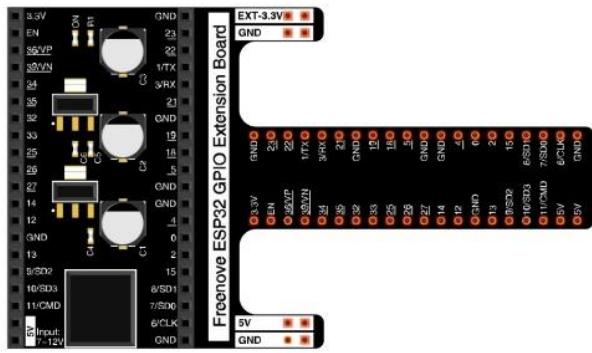
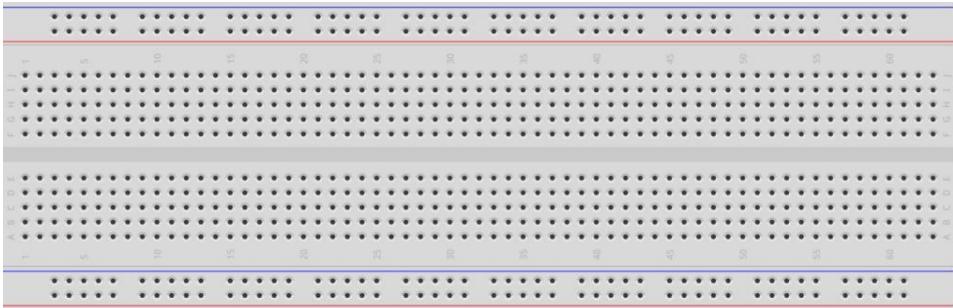
# Chapter 10 TouchSensor

ESP32 offers up to 10 capacitive touch GPIO, and as you can see from the previous section, mechanical switches are prone to jitter that must be eliminated when used, which is not the case with ESP32's built-in touch sensor. In addition, on the service life, the touch switch also has advantages that mechanical switch is completely incomparable.

## Project 10.1 Read Touch Sensor

This project reads the value of the touch sensor and prints it out.

### Component List

ESP32-WROVER x1	GPIO Extension Board x1
	
Breadboard x1	
Jumper M/M x1	



## Related knowledge

### Touch sensor

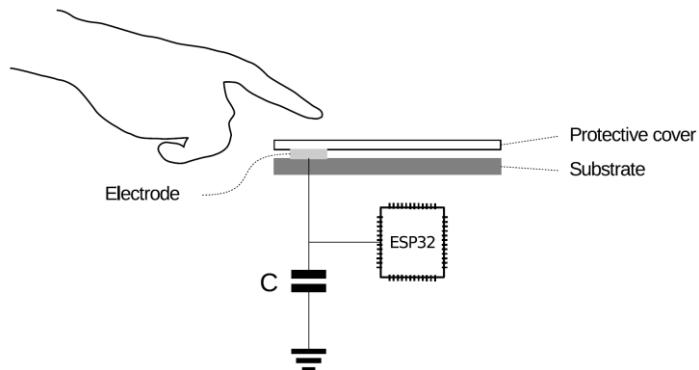
ESP32's touch sensor supports up to 7 GPIO channels as capacitive touch pins. Each pin can be used separately as an independent touch switch or be combined to produce multiple touch points. The following table is a list of available touch pins on ESP32.

Functions of pins	ESP32 GPIO number
<b>GPIO4</b>	GPIO4
<b>MTDO</b>	GPIO15
<b>MTCK</b>	GPIO13
<b>MTDI</b>	GPIO12
<b>MTMS</b>	GPIO14
<b>32K_XN</b>	GPIO33
<b>32K_XP</b>	GPIO32

The pin numbers are shown in the figure above. When you need to use the TouchPad, you only need to call the TouchPad function to initialize the corresponding pins.

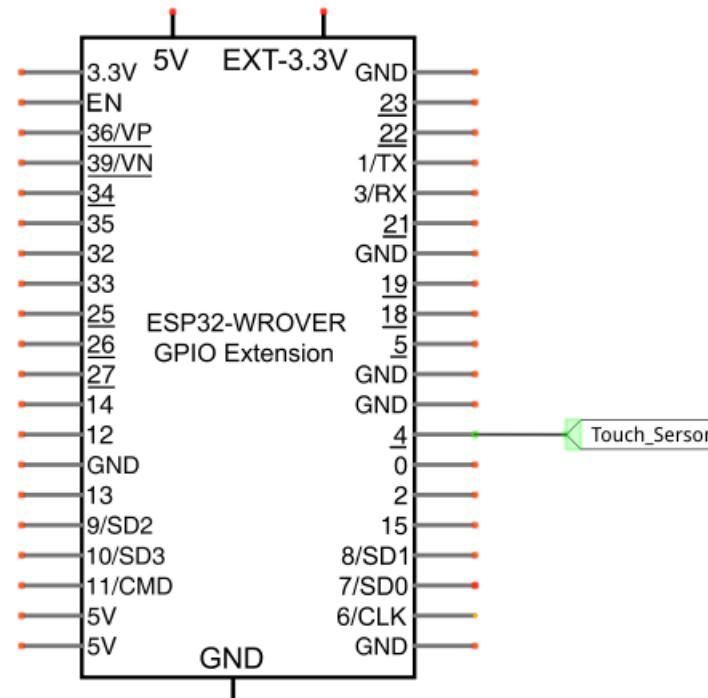
The electronic signals generated with the touch are analog, which are converted by the internal ADC. You may have found that all touch pins have featured with ADC.

The way to connect the hardware is as follows:

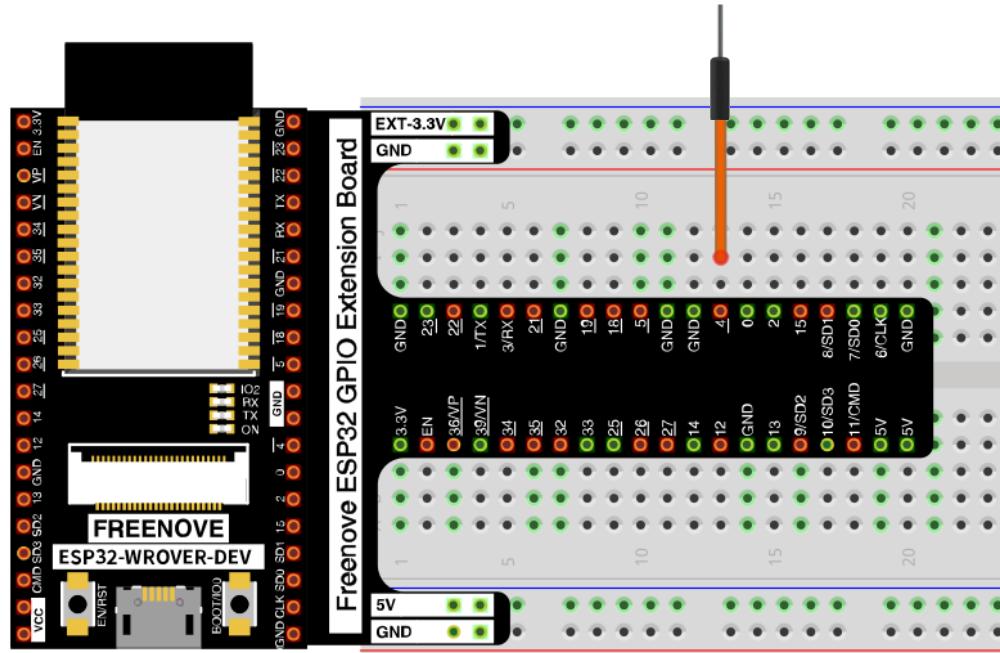


## Circuit

Schematic diagram



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





## Code

Move the program folder “**Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32/Python/Python\_Codes**” to disk(D) in advance with the path of “**D:/Micropython\_Codes**”.

Open “Thonny”, click “This computer” → “D:” → “Micropython\_Codes” → “10.1\_Read\_Touch\_Sensor” and double click “10.1\_Read\_Touch\_Sensor.py”.

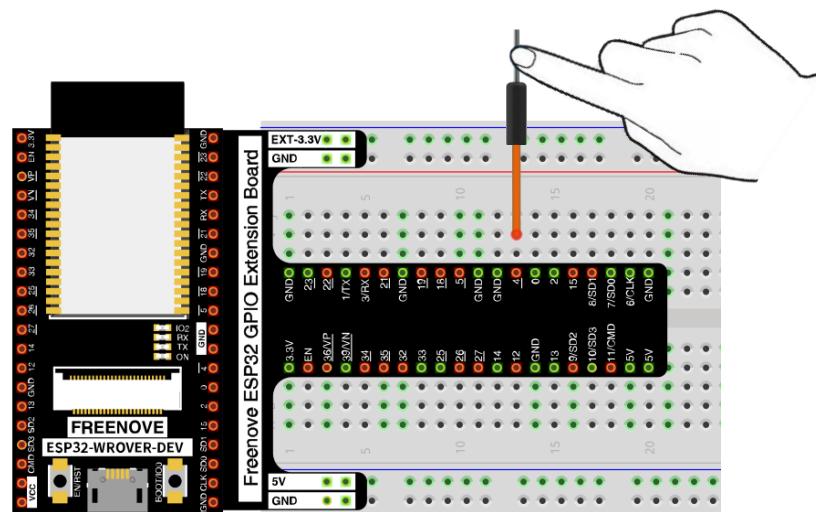
### 10.1\_Read\_Touch\_Sensor

```

Thonny - D:\Micropython_Codes\10.1_Read_Touch_Sensor\10.1_Read_Touch_Sensor.py @ 8 : 1
File Edit View Run Device Tools Help
File boot.py
10.1_Read_Touch_Sensor.py
1 from machine import TouchPad, Pin
2 import time
3
4 tp = TouchPad(Pin(4,Pin.IN,Pin.PULL_UP))
5 while True:
6     print("Touch value:",tp.read())
7     time.sleep_ms(1000)
8
This computer
D:\Micropython_Codes\
10.1_Read_Touch_Sensor
10.1_Read_Touch_Sensor.py
Shell
MicroPython v1.12 on 2019-12-20; ESP32 module (spiram) with ESP32
Type "help()" for more information.
>>>

```

Click “Run current script”, touch the jumper wire with your finger and observe the messages printed in “Shell”.



Messages printed at "Shell":

The screenshot shows the Thonny IDE interface. In the top menu bar, it says "Thonny - D:\Micropython\_Codes\10.1\_Read\_Touch\_Sensor\10.1\_Read\_Touch\_Sensor.py @ 8:1". The menu includes File, Edit, View, Run, Device, Tools, Help. Below the menu is a toolbar with icons for file operations like Open, Save, Run, Stop, and others. On the left, there's a "Files" sidebar showing "MicroPython device" with "boot.py" and "This computer" with "D:\Micropython\_Codes\10.1\_Read\_Touch\_Sensor\10.1\_Read\_Touch\_Sensor.py". The main area has tabs for "10.1\_Read\_Touch\_Sensor.py" and "Shell". The code in "10.1\_Read\_Touch\_Sensor.py" is:

```

1 from machine import TouchPad, Pin
2 import time
3
4 tp = TouchPad(Pin(4,Pin.IN,Pin.PULL_UP))
5 while True:
6     print("Touch value:",tp.read())
7     time.sleep_ms(1000)
8

```

The "Shell" tab shows the output of the code execution:

```

MicroPython v1.12 on 2019-12-20; ESP32 module (spiram) with ESP32
Type "help()" for more information.
>>> %Run -c $EDITOR_CONTENT
Touch value: 329
Touch value: 47
Touch value: 330
Touch value: 329
Touch value: 330
Touch value: 47
Touch value: 330
Touch value: 52
Touch value: 49
Touch value: 330
Touch value: 48

```

## Reference

### Class TouchPad

Before each use of **TouchPad** module, please add the statement "**from machine import TouchPad**" to the top of the python file.

**TouchPad(pin)**: Initialize the TouchPad object and associate it with ESP32 pins.

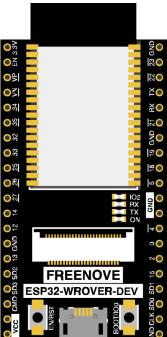
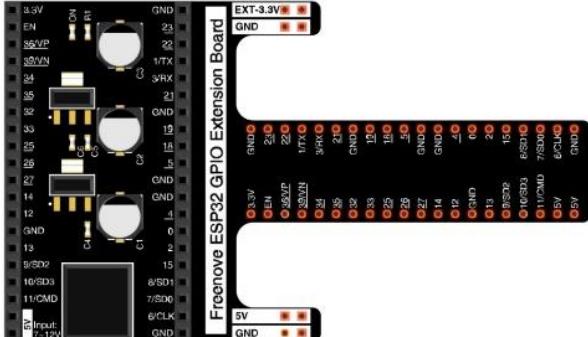
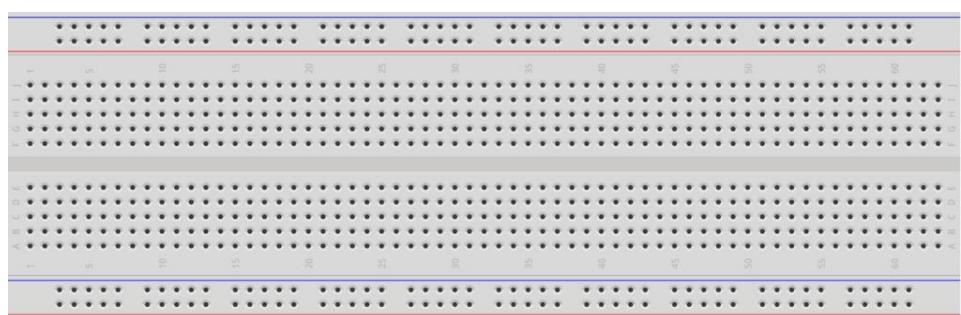
**pin**: Pin(4)、Pin(15)、Pin(13)、Pin(12)、Pin(14)、Pin(32)、Pin(33)

**TouchPad.read()**: Read the capacitance of touchpad. If your fingers touch TouchPad pins, the capacitance decreases; Otherwise, it will not change.

## Project 10.2 TouchLamp

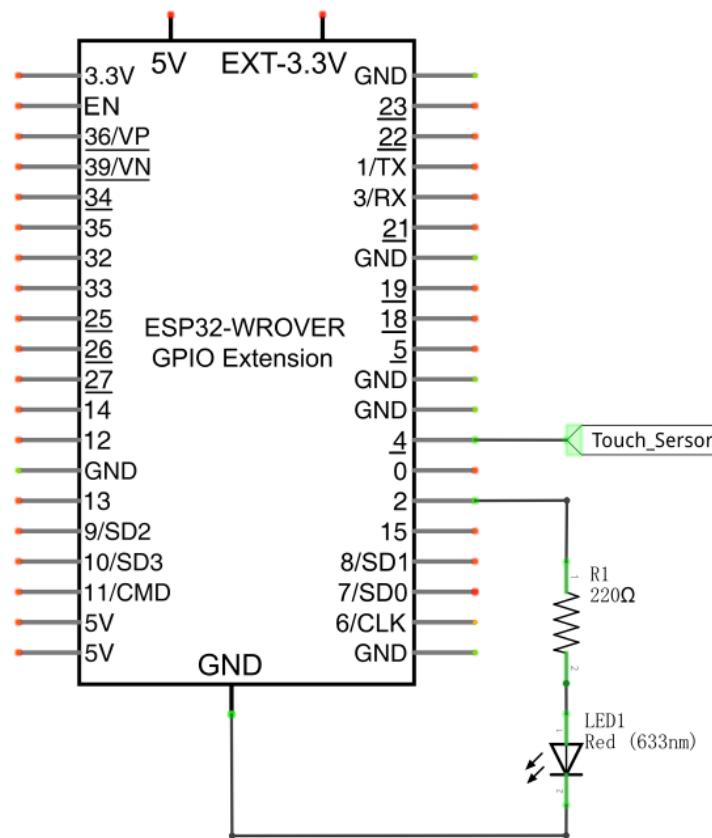
In this project, we will use ESP32's touch sensor to create a touch switch lamp.

### Component List

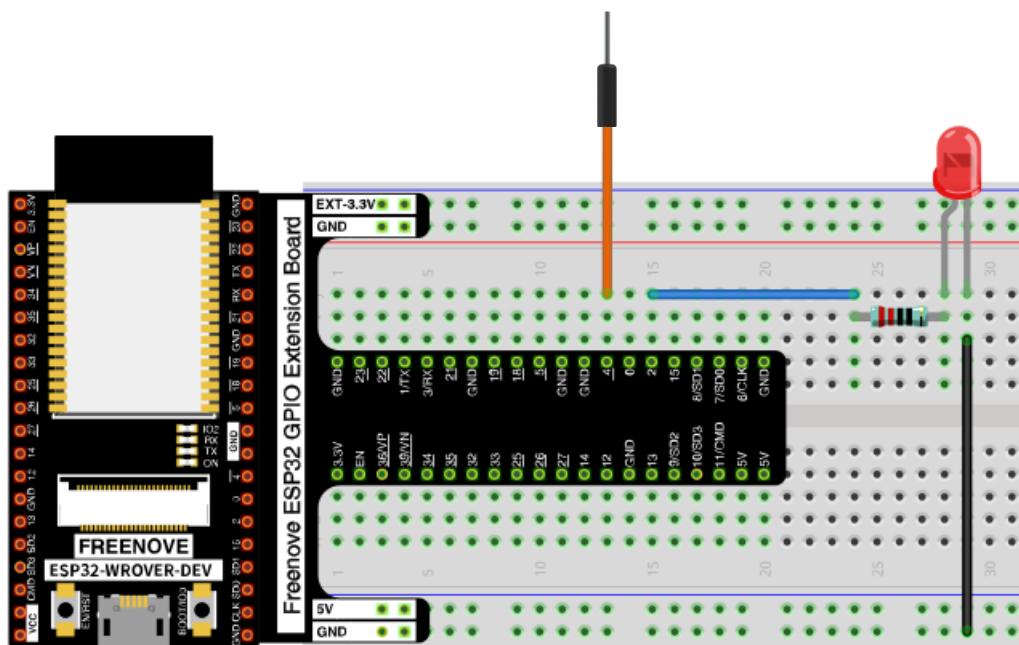
ESP32-WROVER x1	GPIO Extension Board x1	
		
Breadboard x1		
		
Jumper M/M x3	LED x1	Resistor 220Ω x1
		

## Circuit

Schematic diagram



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

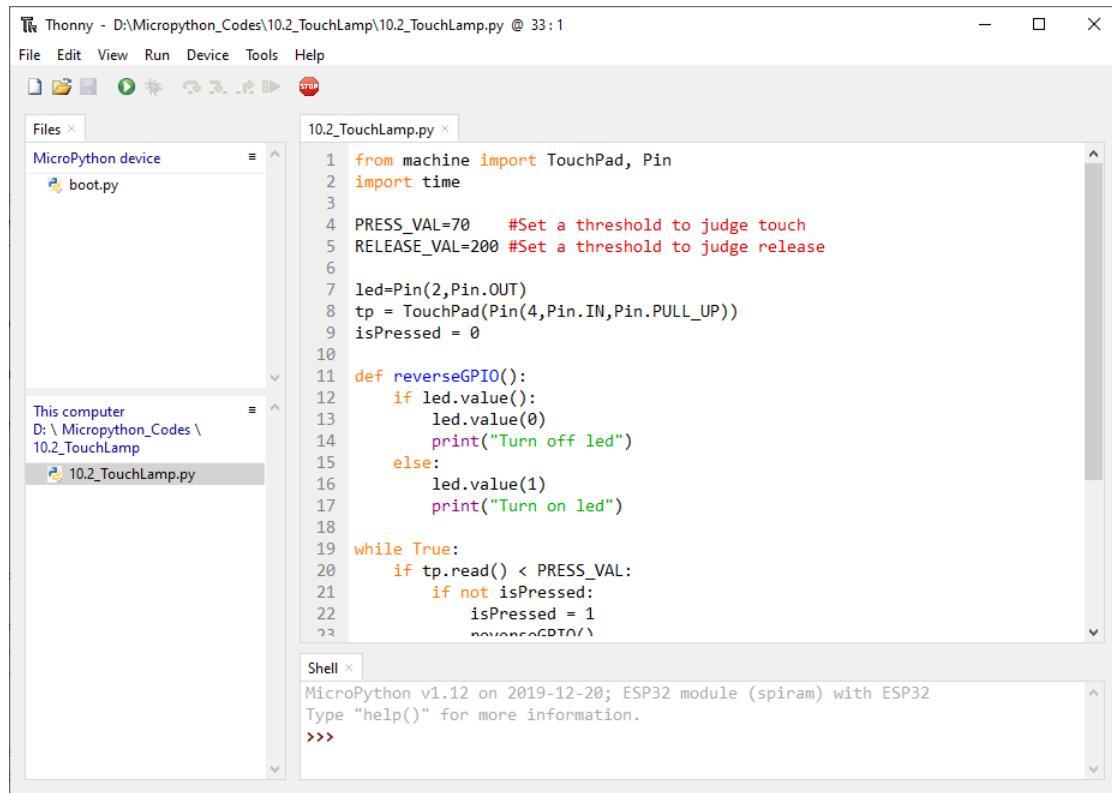


## Code

Move the program folder “**Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32/Python/Python\_Codes**” to disk(D) in advance with the path of “**D:/Micropython\_Codes**”.

Open “Thonny, click “This computer” → “D:” → “Micropython\_Codes” → “10.2\_TouchLamp” and double click “10.2\_TouchLamp.py”.

### 10.2\_TouchLamp



```

from machine import TouchPad, Pin
import time

PRESS_VAL=70    #Set a threshold to judge touch
RELEASE_VAL=200 #Set a threshold to judge release

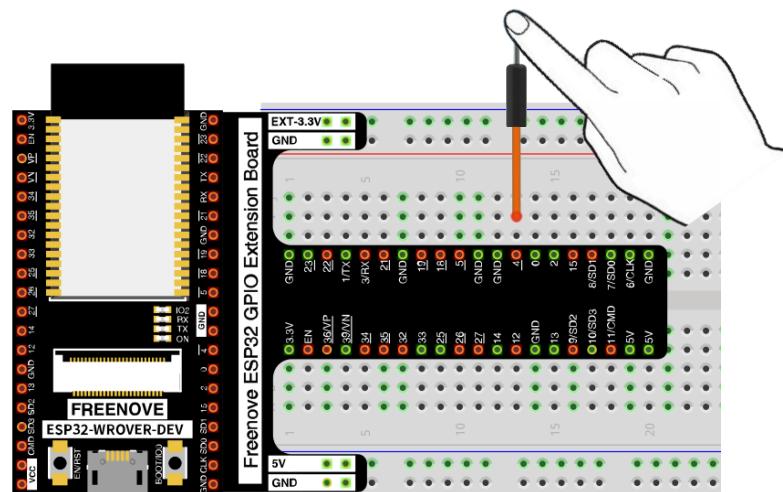
led=Pin(2,Pin.OUT)
tp = TouchPad(Pin(4,Pin.IN,Pin.PULL_UP))
isPressed = 0

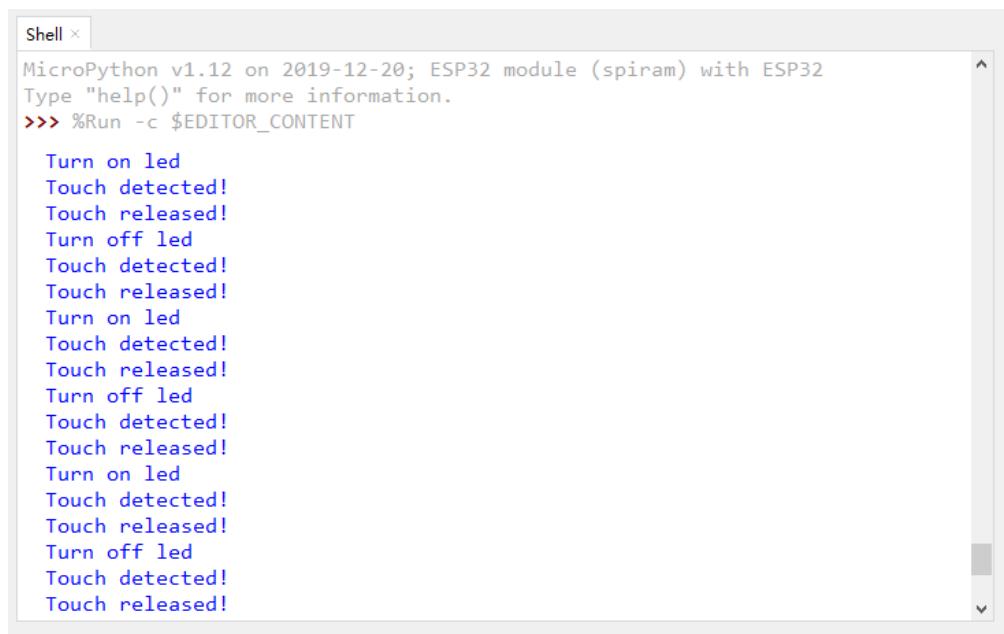
def reverseGPIO():
    if led.value():
        led.value(0)
        print("Turn off led")
    else:
        led.value(1)
        print("Turn on led")

while True:
    if tp.read() < PRESS_VAL:
        if not isPressed:
            isPressed = 1
            reverseGPIO()
    if tp.read() > RELEASE_VAL:
        if isPressed:
            isPressed = 0
            reverseGPIO()

```

Click “Run current script” and then touch the jumper wire with your finger. The state of LED will change with each touch and the detection state of the touch sensor will be printed in the “Shell”





```

Shell >
MicroPython v1.12 on 2019-12-20; ESP32 module (spiram) with ESP32
Type "help()" for more information.
>>> %Run -c $EDITOR_CONTENT

Turn on led
Touch detected!
Touch released!
Turn off led
Touch detected!
Touch released!
Turn on led
Touch detected!
Touch released!
Turn off led
Touch detected!
Touch released!
Turn on led
Touch detected!
Touch released!
Turn off led
Touch detected!
Touch released!

```

LED displays as follows:



The following is the program code:

```

1 from machine import TouchPad, Pin
2 import time
3
4 PRESS_VAL=70      #Set a threshold to judge touch
5 RELEASE_VAL=200 #Set a threshold to judge release
6
7 led=Pin(2,Pin.OUT)
8 tp = TouchPad(Pin(4,Pin.IN,Pin.PULL_UP))
9 isPressed = 0
10
11 def reverseGPIO():
12     if led.value():
13         led.value(0)
14         print("Turn off led")
15     else:
16         led.value(1)
17         print("Turn on led")
18 while True:
19     if tp.read() < PRESS_VAL:

```

```

20     if not isPressed:
21         isPressed = 1
22         reverseGPIO()
23         print("Touch detected!")
24         time.sleep_ms(100)
25     if tp.read() > RELEASE_VAL:
26         if isPressed:
27             isPressed = 0
28             print("Touch released!")
29             time.sleep_ms(100)

```

Import Pin and TouchPad modules.

```

1  from machine import TouchPad, Pin
2  import time

```

The closer the return value of the function read() is to 0, the more obviously the touch action is detected. As this is not a fixed value, a threshold value needs to be defined. When the value of the sensor is less than the threshold, it is considered a valid touch action. Similarly, define a threshold value for the released state, and the value between the sensor value and the threshold is regarded as an invalid interference value.

```

4  PRESS_VAL=70      #Set a threshold to judge touch
5  RELEASE_VAL=200 #Set a threshold to judge release

```

First, decide whether the touch is detected. If yes, print some messages, reverse the state of LED and set the flag bit isProcessed to 1 to avoid repeatedly executing the program after a touch is detected.

```

19    if tp.read() < PRESS_VAL:
20        if not isPressed:
21            isPressed = 1
22            reverseGPIO()
23            print("Touch detected!")
24            time.sleep_ms(100)

```

And then decide whether the touch key is released. If yes, print some messages, and set isProcessed to 0 to avoid repeatedly executing the program after a touch is released and to prepare for the next touch detector.

```

25    if tp.read() > RELEASE_VAL:
26        if isPressed:
27            isPressed = 0
28            print("Touch released!")
29            time.sleep_ms(100)

```

Customize a function that reverses the output level of the LED each time it is called.

```

11  def reverseGPIO():
12      if led.value():
13          led.value(0)
14          print("Turn off led")
15      else:
16          led.value(1)
17          print("Turn on led")

```

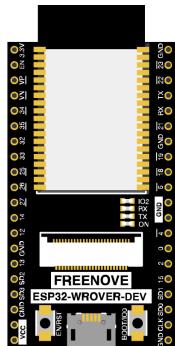
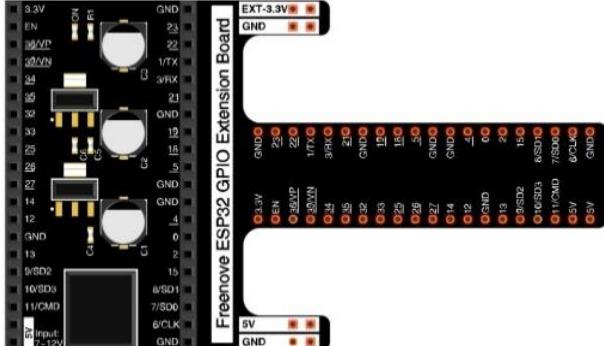
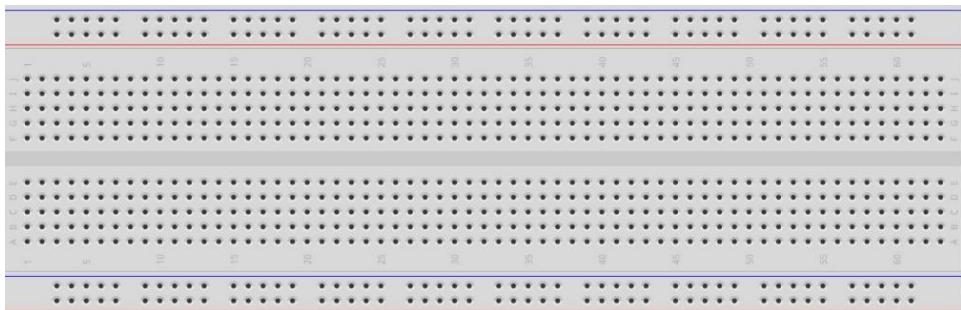
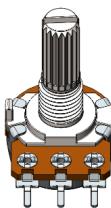
# Chapter 11 Potentiometer & LED

We have learned how to use ADC and DAC before. When using DAC output analog to drive LED, we found that, when the output voltage is less than led turn-on voltage, the LED does not light; when the output analog voltage is greater than the LED voltage, the LED lights. This leads to a certain degree of waste of resources. Therefore, in the control of LED brightness, we should choose a more reasonable way of PWM control. In this chapter, we learn to control the brightness of LED through a potentiometer.

## Project 11.1 Soft Light

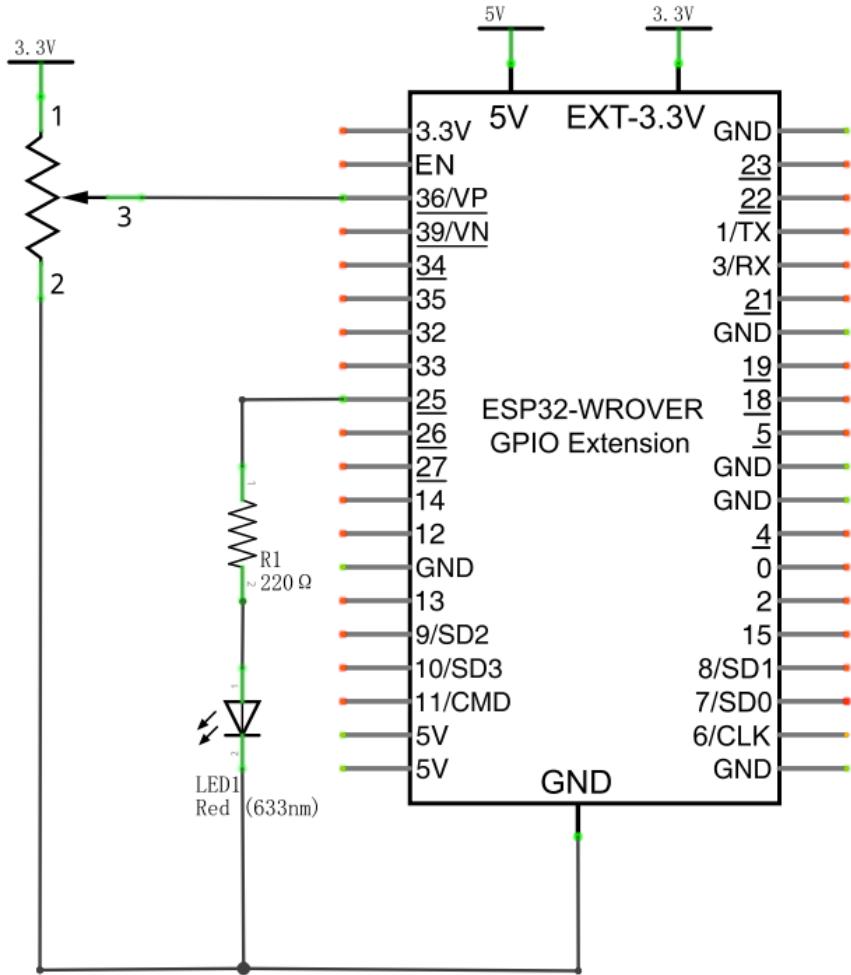
In this project, we will make a soft light. We will use an ADC Module to read ADC values of a potentiometer and map it to duty cycle of the PWM used to control the brightness of an LED. Then you can change the brightness of an LED by adjusting the potentiometer.

### Component List

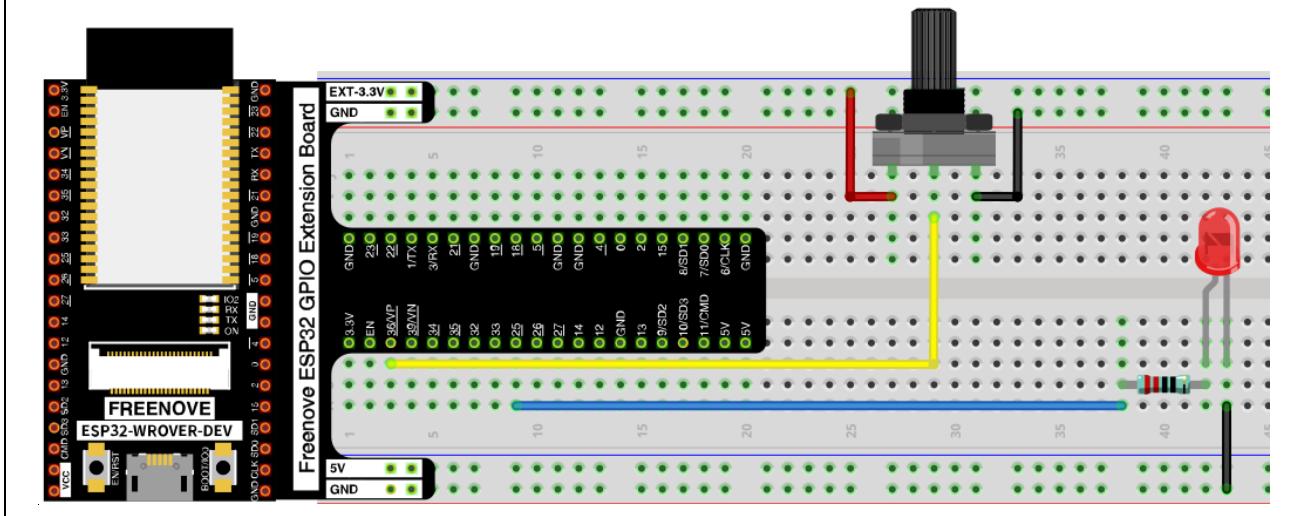
ESP32-WROVER x1	GPIO Extension Board x1			
				
Breadboard x1				
	Rotary potentiometer x1	Resistor 220Ω x1	LED x1	Jumper M/M x5
				

## Circuit

Schematic diagram



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



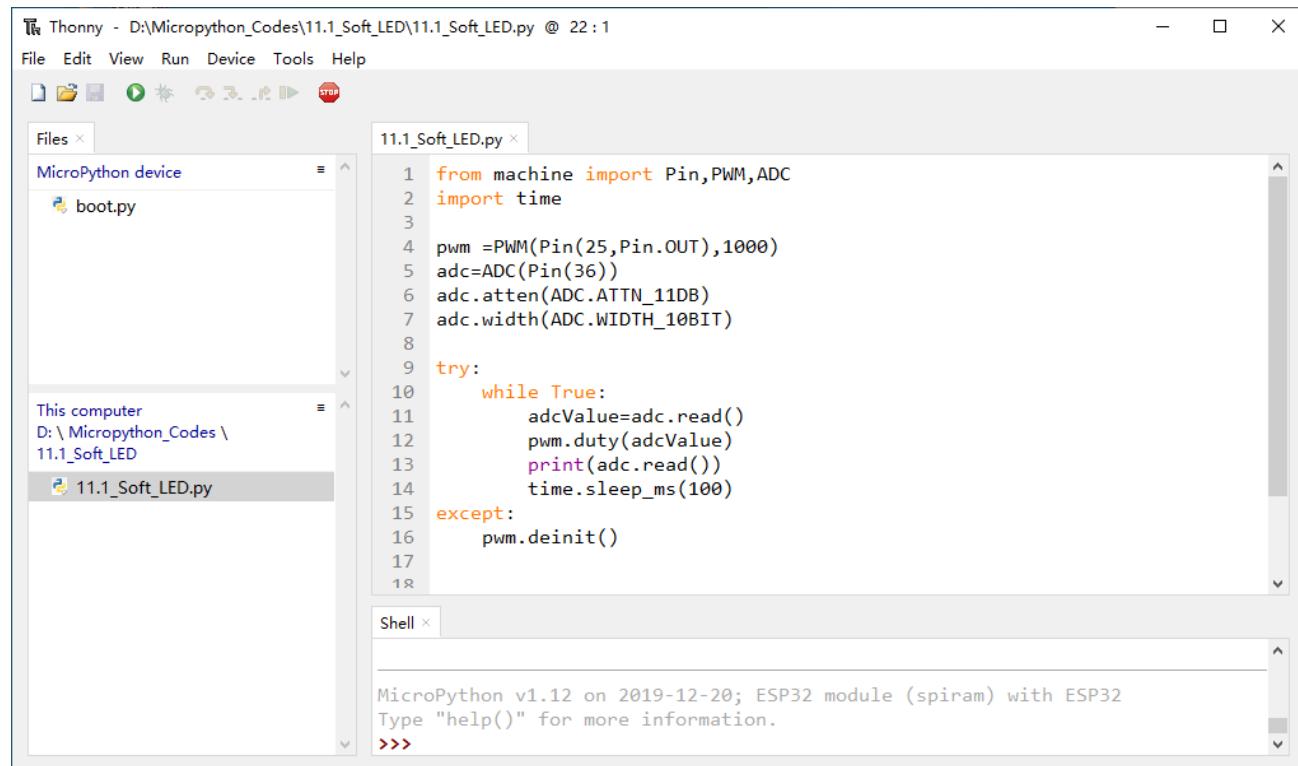
Any concerns? ✉ [support@freenove.com](mailto:support@freenove.com)

## Code

Move the program folder “**Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32/Python/Python\_Codes**” to disk(D) in advance with the path of “**D:/Micropython\_Codes**”.

Open “Thonny”, click “This computer” → “D:” → “Micropython\_Codes” → “11.1\_Soft\_LED” and double click “11.1\_Soft\_LED.py”.

### 11.1\_Soft\_LED



Click “Run current script”. Rotate the handle of potentiometer and the brightness of LED will change correspondingly.

The following is the code:

```

1  from machine import Pin,PWM,ADC
2  import time
3
4  pwm = PWM(Pin(25,Pin.OUT),1000)
5  adc=ADC(Pin(36))
6  adc.atten(ADC.ATTN_11DB)
7  adc.width(ADC.WIDTH_10BIT)
8
9  try:
10     while True:
11         adcValue=adc.read()
12         pwm.duty(adcValue)
13         print(adc.read())

```

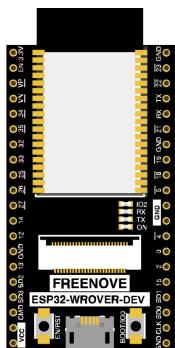
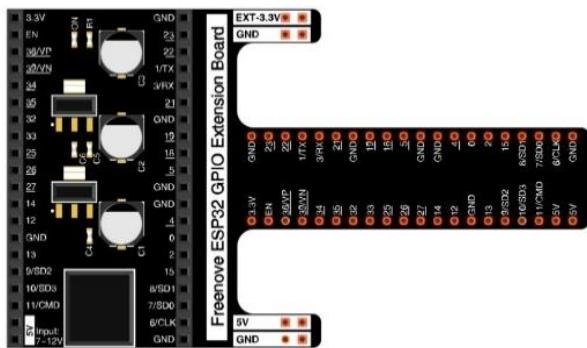
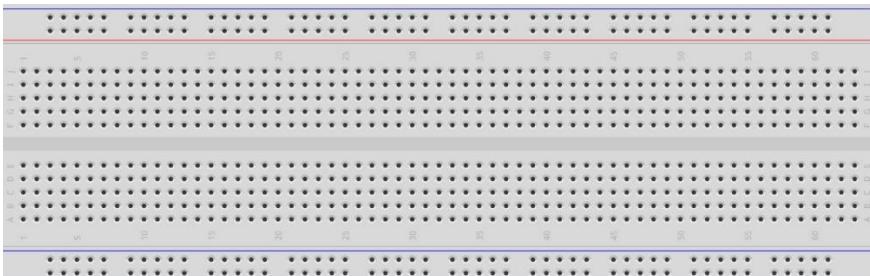
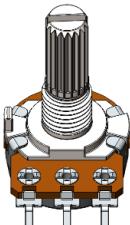
```
14     time.sleep_ms(100)
except:
    pwm.deinit()
```

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

## Project 11.2 Soft Colorful Light

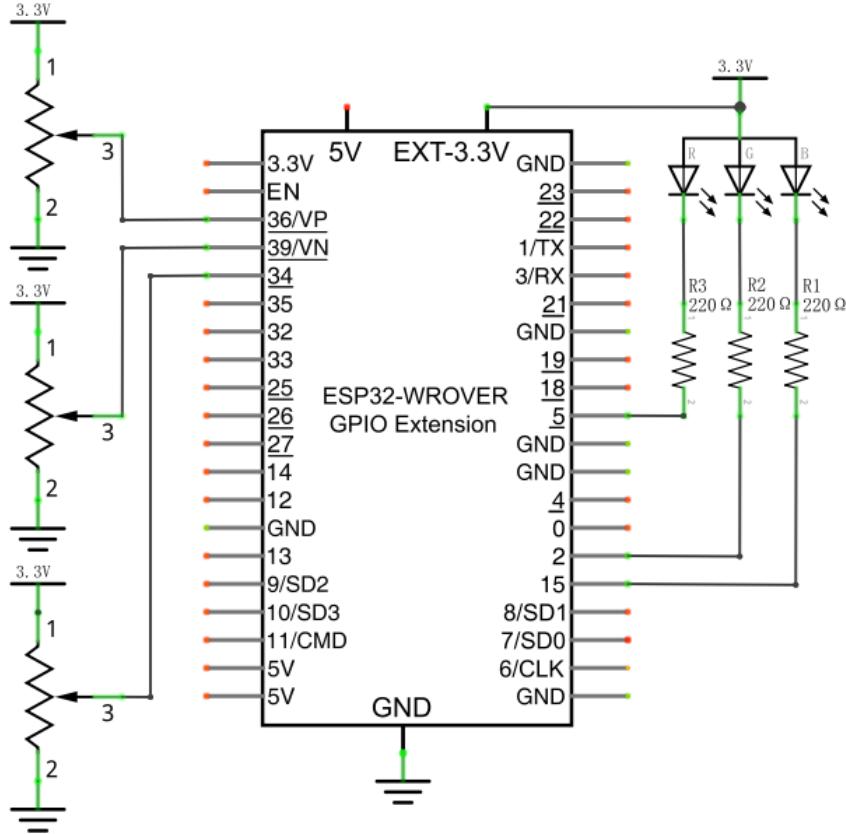
In this project, 3 potentiometers are used to control the RGB LED and in principle it is the same as the Soft Light project. Namely, read the voltage value of the potentiometer and then convert it to PWM used to control LED brightness. Difference is that the original project only controlled one LED, but this project required (3) RGB LEDs.

### Component List

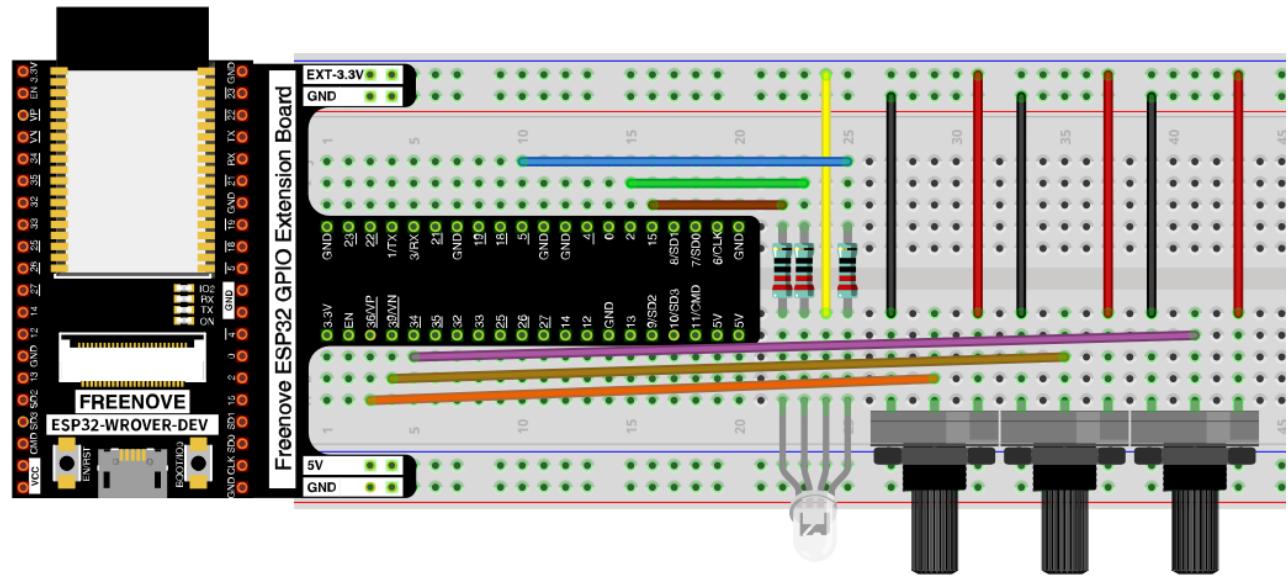
ESP32-WROVER x1	GPIO Extension Board x1		
			
Breadboard x1			
			
Rotary potentiometer x3	Resistor 220Ω x3	RGBLED x1	Jumper M/M x13
			

## Circuit

Schematic diagram



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

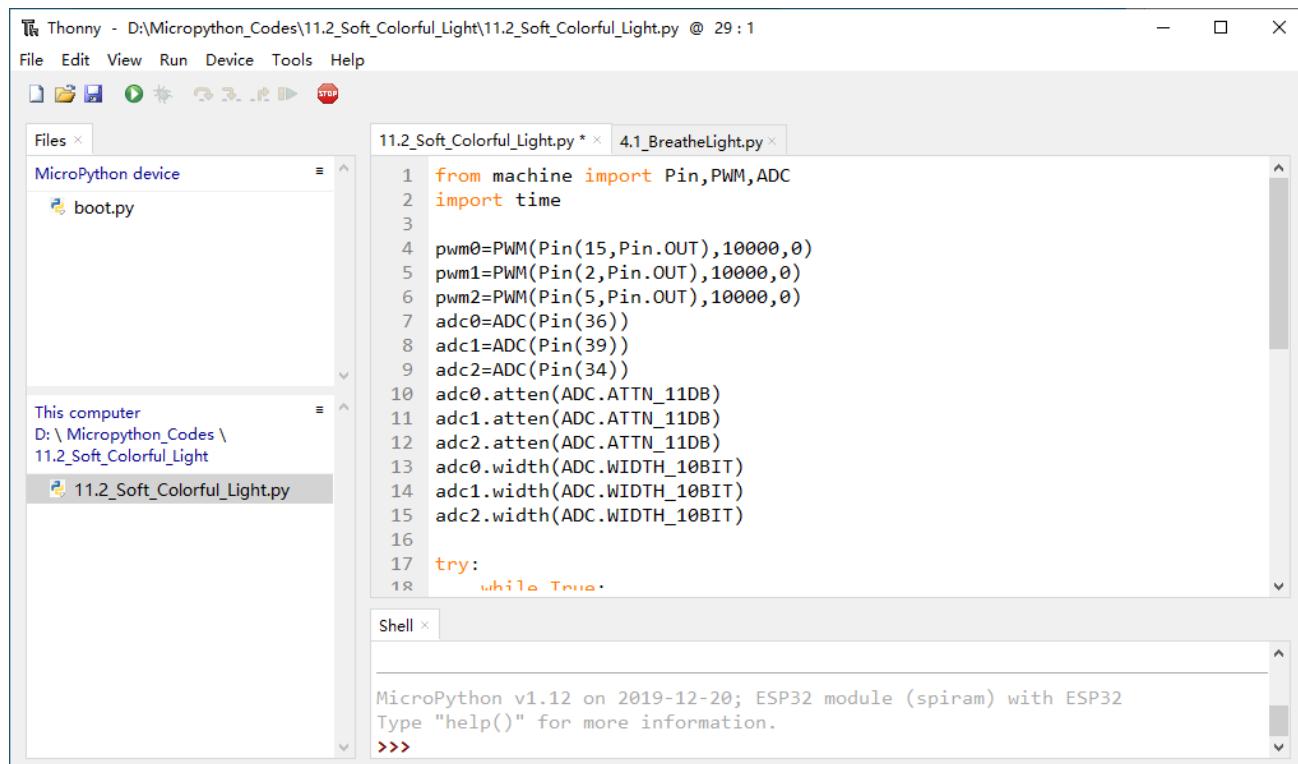


Any concerns? ✉ [support@freenove.com](mailto:support@freenove.com)

## Code

Open “Thonny”, click “This computer” → “D:” → “Micropython\_Codes” → “11.2\_Soft\_Colorful\_Light” and double click “11.2\_Soft\_Colorful\_Light.py”.

### 11.2\_Soft\_Colorful\_Light



Click “Run current script” and control the change of RGBLED color by rotating the handles of three rotary potentiometers.

The following is the program code:

```

from machine import Pin,PWM,ADC
import time

pwm0=PWM(Pin(15,Pin.OUT),10000,0)
pwm1=PWM(Pin(2,Pin.OUT),10000,0)
pwm2=PWM(Pin(5,Pin.OUT),10000,0)
adc0=ADC(Pin(36))
adc1=ADC(Pin(39))
adc2=ADC(Pin(34))
adc0.atten(ADC.ATTN_11DB)
adc1.atten(ADC.ATTN_11DB)
adc2.atten(ADC.ATTN_11DB)
adc0.width(ADC.WIDTH_10BIT)
adc1.width(ADC.WIDTH_10BIT)
adc2.width(ADC.WIDTH_10BIT)

```

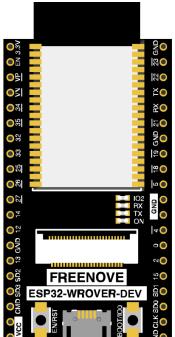
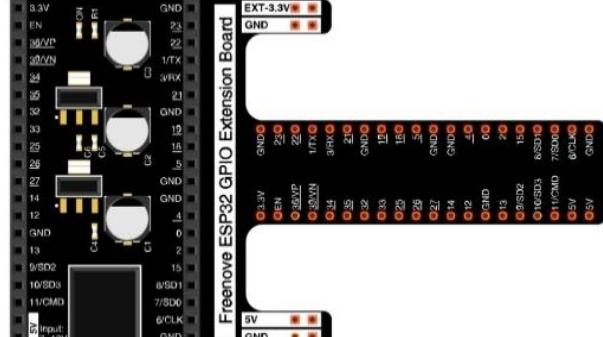
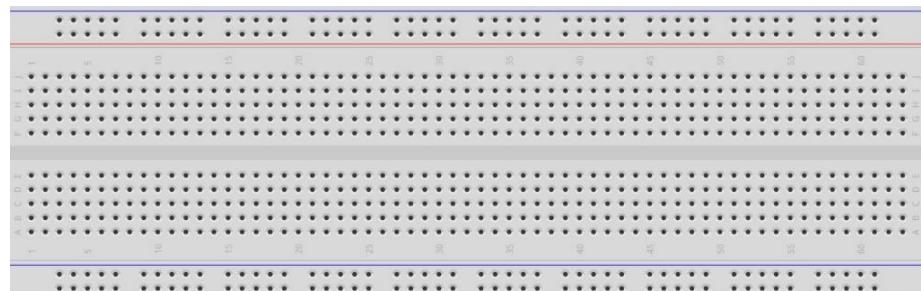
```
17 try:  
18     while True:  
19         pwm0.duty(1023-adc0.read())  
20         pwm1.duty(1023-adc1.read())  
21         pwm2.duty(1023-adc2.read())  
22         time.sleep_ms(100)  
23     except:  
24         pwm0.deinit()  
25         pwm1.deinit()  
26         pwm2.deinit()
```

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.

## Project 11.3 Soft Rainbow Light

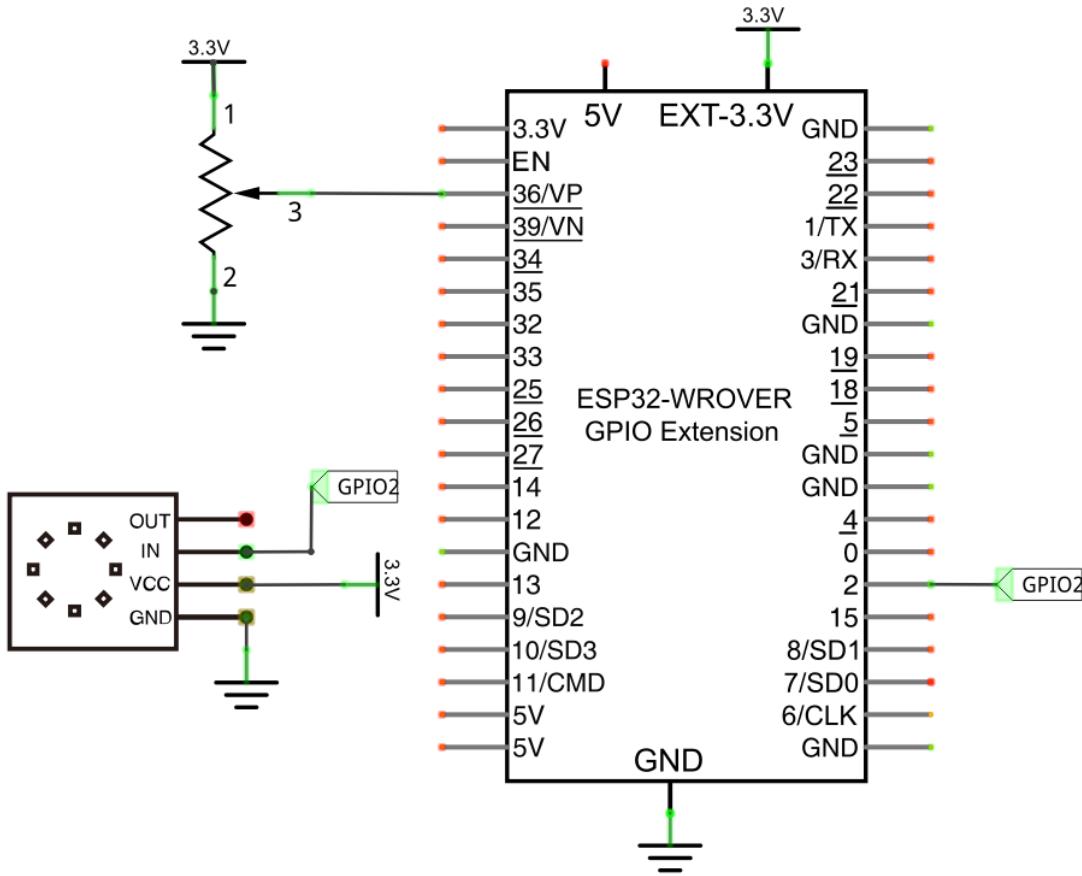
In this project, we use a potentiometer to control Freenove 8 RGBLED Module.

### Component List

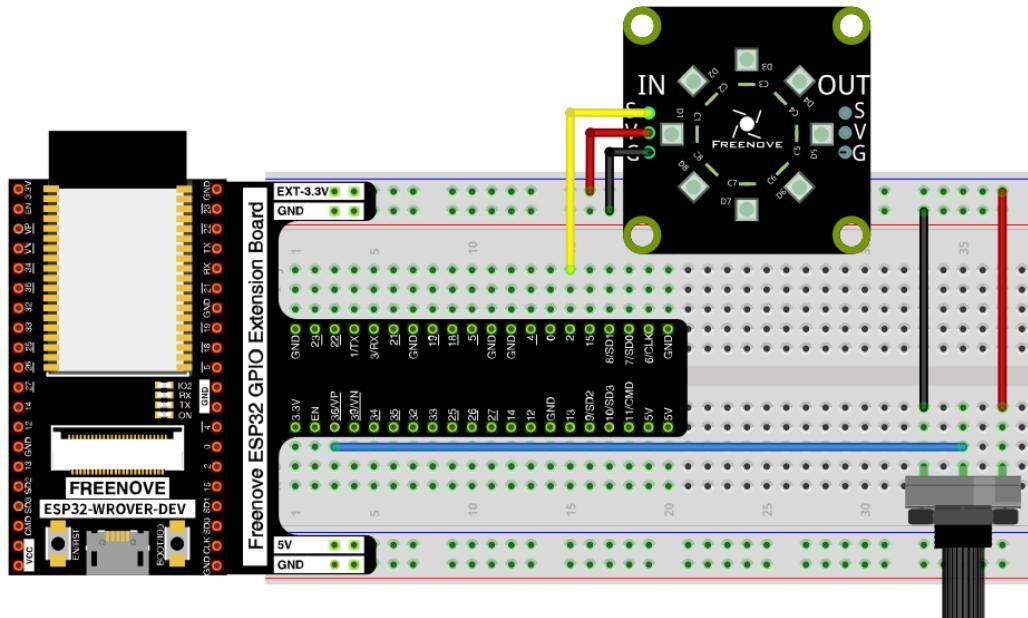
ESP32-WROVER x1	GPIO Extension Board x1
	
Breadboard x1	
Freenove 8 RGB LED Module x1	Jumper F/M x3 Jumper M/M x3
	

## Circuit

Schematic diagram



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

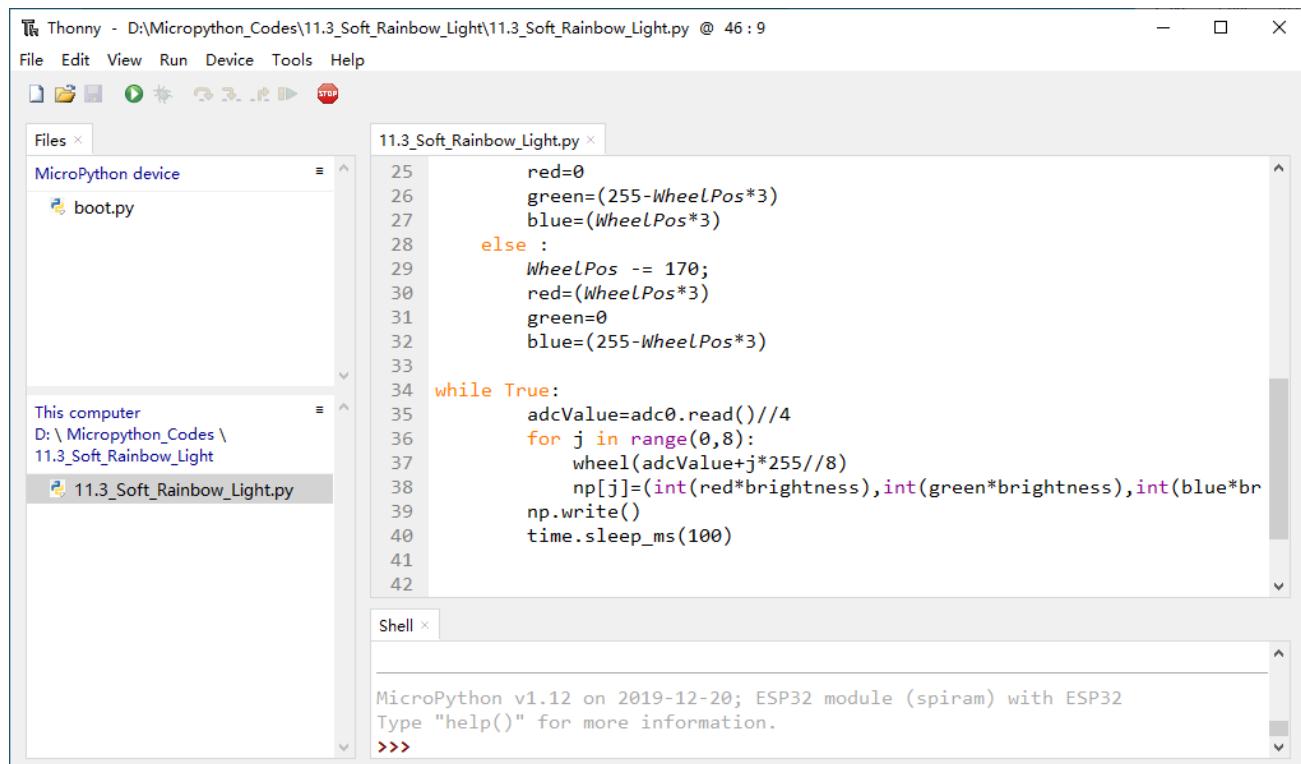


Any concerns? ✉ [support@freenove.com](mailto:support@freenove.com)

## Code

Open “Thonny”, click “This computer” → “D:” → “Micropython\_Codes” → “11.3\_Soft\_Rainbow\_Light” and double click “11.3\_Soft\_Rainbow\_Light.py”.

### 11.3\_Soft\_Rainbow\_Light

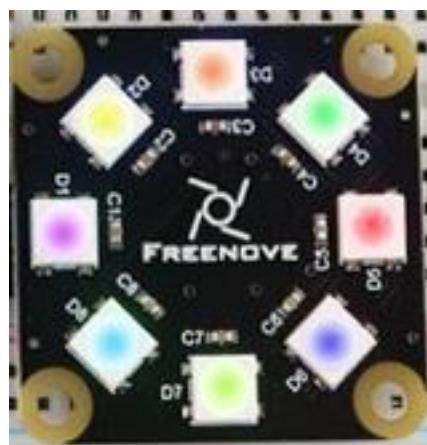


The screenshot shows the Thonny IDE interface. The title bar says "Thonny - D:\Micropython\_Codes\11.3\_Soft\_Rainbow\_Light\11.3\_Soft\_Rainbow\_Light.py @ 46 : 9". The menu bar includes File, Edit, View, Run, Device, Tools, and Help. Below the menu is a toolbar with icons for file operations like Open, Save, and Run. The left sidebar has a "Files" tab and a tree view showing "MicroPython device" with "boot.py" selected, and "This computer" with "D:\Micropython\_Codes\11.3\_Soft\_Rainbow\_Light\11.3\_Soft\_Rainbow\_Light.py" selected. The main code editor window contains the following Python code:

```
25     red=0
26     green=(255-WheelPos*3)
27     blue=(WheelPos*3)
28     else :
29         WheelPos -= 170;
30         red=(WheelPos*3)
31         green=0
32         blue=(255-WheelPos*3)
33
34 while True:
35     adcValue=adc0.read()//4
36     for j in range(0,8):
37         wheel(adcValue+j*255//8)
38         np[j]=(int(red*brightness),int(green*brightness),int(blue*brightness))
39         np.write()
40         time.sleep_ms(100)
41
42
```

The bottom right pane is a "Shell" window displaying the MicroPython prompt: "MicroPython v1.12 on 2019-12-20; ESP32 module (spiram) with ESP32". It also shows the command "Type "help()" for more information." and the prompt "=>>>".

Click “Run current script”. Rotate the handle of potentiometer and the color of the lights will change.



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



The following is the program code:

```
1  from machine import Pin,ADC
2  import neopixel
3  import time
4
5  np = neopixel.NeoPixel(Pin(2, Pin.OUT), 8)
6
7  brightness=0.1      #brightbess
8  red=0              #red
9  green=0             #green
10 blue=0              #blue
11
12 adc0=ADC(Pin(36))
13 adc0.atten(ADC.ATTN_11DB)
14 adc0.width(ADC.WIDTH_10BIT)
15
16 def wheel(pos):
17     global red,green,blue
18     WheelPos=pos%255
19     if WheelPos<85:
20         red=(255-WheelPos*3)
21         green=(WheelPos*3)
22         blue=0
23     elif WheelPos>=85 and WheelPos<170:
24         WheelPos -= 85;
25         red=0
26         green=(255-WheelPos*3)
27         blue=(WheelPos*3)
28     else :
29         WheelPos -= 170;
30         red=(WheelPos*3)
31         green=0
32         blue=(255-WheelPos*3)
33
34 while True:
35     adcValue=adc0.read()//4
36     for j in range(0,8):
37         wheel((adcValue+j*255)//8)
38         np[j]=(int(red*brightness), int(green*brightness), int(blue*brightness))
39         np.write()
40         time.sleep_ms(100)
```

The logic of the code is basically the same as the previous project [Rainbow Light](#). The difference is that in this code, the starting point of the color is controlled by the potentiometer.

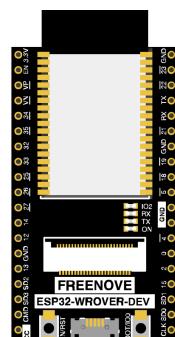
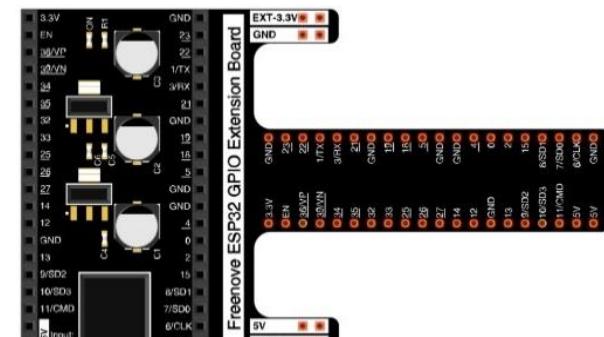
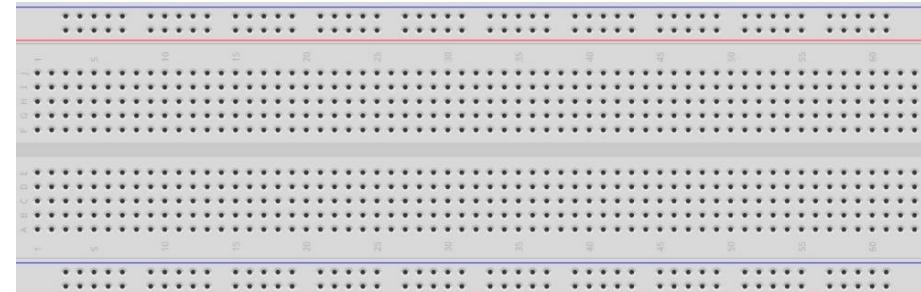
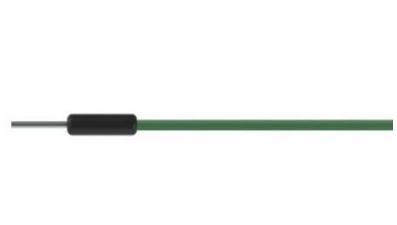
# Chapter 12 Photoresistor & LED

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

## Project 12.1 NightLamp

A Photoresistor is very sensitive to the amount of light present. We can take advantage of the characteristic to make a nightlight with the following function: when the ambient light is less (darker environment) the LED will automatically become brighter to compensate and when the ambient light is greater (brighter environment) the LED will automatically dim to compensate.

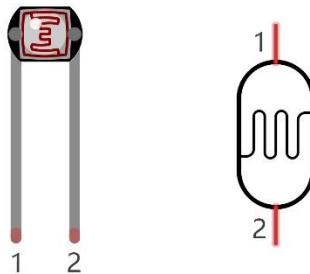
### Component List

ESP32-WROVER x1	GPIO Extension Board x1
	
	
Breadboard x1	
	
Photoresistor x1	Resistor
	
220Ω x1      10KΩ x1	
	
LED x1	
	
Jumper M/M x4	

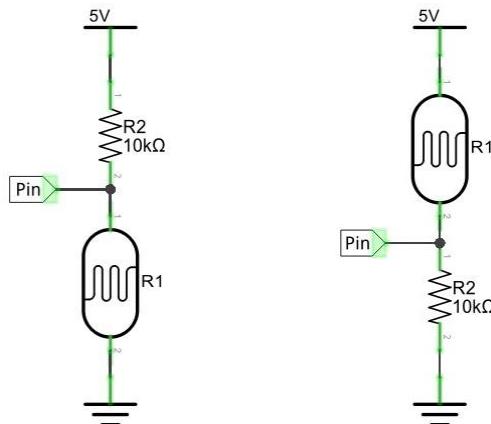
## Component knowledge

### Photoresistor

Photoresistor is simply a light sensitive resistor. It is an active component that decreases resistance with respect to receiving luminosity (light) on the component's light sensitive surface. Photoresistor's resistance value will change in proportion to the ambient light detected. With this characteristic, we can use a Photoresistor to detect light intensity. The Photoresistor and its electronic symbol are as follows.



The circuit below is used to detect the change of a Photoresistor's resistance value:

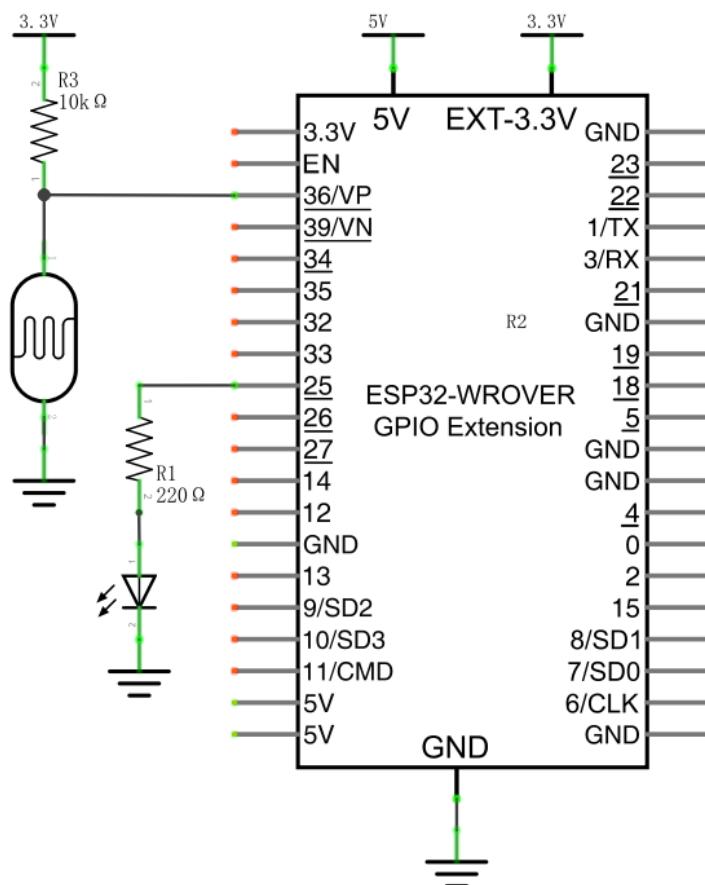


In the above circuit, when a Photoresistor's resistance value changes due to a change in light intensity, the voltage between the Photoresistor and Resistor R1 will also change. Therefore, the intensity of the light can be obtained by measuring this voltage.

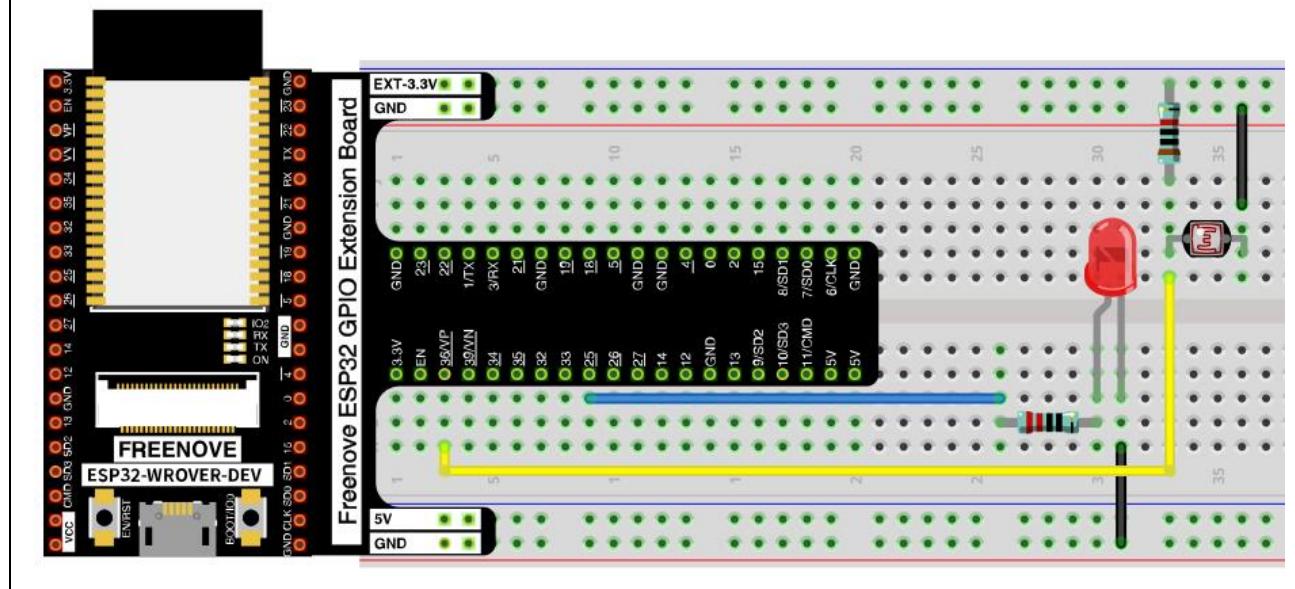
## Circuit

The circuit of this project is similar to SoftLight. The only difference is that the input signal is changed from a potentiometer to a 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](mailto:support@freenove.com)



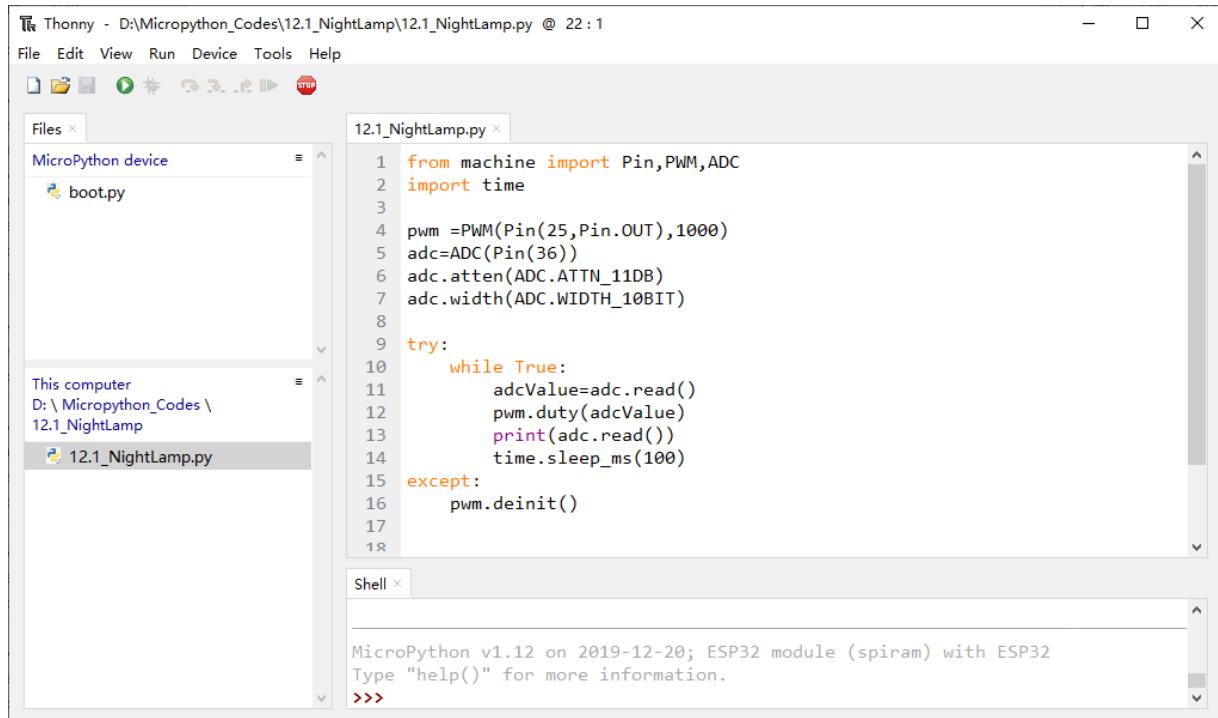
Any concerns? [✉ support@freenove.com](mailto:support@freenove.com)

## Code

Move the program folder “**Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32/Python/Python\_Codes**” to disk(D) in advance with the path of “**D:/Micropython\_Codes**”.

Codes of this project is logically the same as the project [Soft Light](#).

### 12.1\_Nightlamp



Click “Run current script”. Cover the photoresistor with your hands or illuminate it with lights, the brightness of LEDs will change.

The following is the program code:

```

1  from machine import Pin,PWM,ADC
2  import time
3
4  pwm =PWM(Pin(25,Pin.OUT),1000)
5  adc=ADC(Pin(36))
6  adc.atten(ADC.ATTN_11DB)
7  adc.width(ADC.WIDTH_10BIT)
8
9  try:
10     while True:
11         adcValue=adc.read()
12         pwm.duty(adcValue)
13         print(adc.read())
14         time.sleep_ms(100)
15     except:
16         pwm.deinit()

```

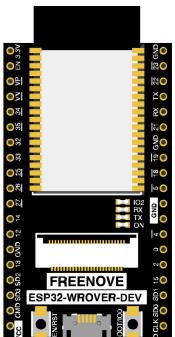
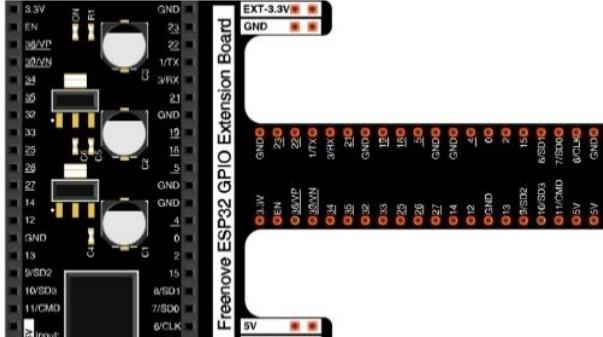
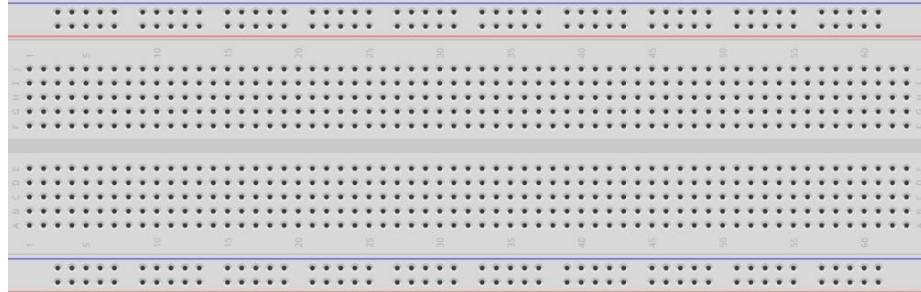
# Chapter 13 Thermistor

In this chapter, we will learn about Thermistors which are another kind of Resistor

## Project 13.1 Thermometer

A Thermistor is a type of Resistor whose resistance value is dependent on temperature and changes in temperature. Therefore, we can take advantage of this characteristic to make a Thermometer.

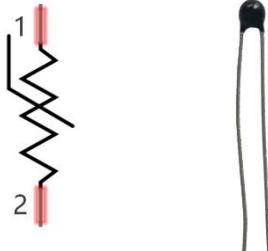
### Component List

ESP32-WROVER x1	GPIO Extension Board x1	Breadboard x1	Thermistor x1	Resistor 1kΩ x1	Jumper M/M x3
					

## Component knowledge

### Thermistor

A Thermistor is a temperature sensitive resistor. When it senses a change in temperature, the resistance of the Thermistor will change. We can take advantage of this characteristic by using a Thermistor to detect temperature intensity. A Thermistor and its electronic symbol are shown below.



The relationship between resistance value and temperature of a thermistor is:

$$R_t = R * \text{EXP} \left[ B * \left( \frac{1}{T_2} - \frac{1}{T_1} \right) \right]$$

**Where:**

Rt is the thermistor resistance under T2 temperature;

R is the nominal resistance of thermistor under T1 temperature;

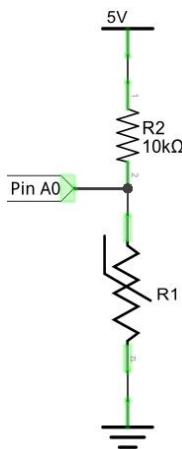
**EXP[n]** is nth power of e;

B is for thermal index;

T1, T2 is Kelvin temperature (absolute temperature). Kelvin temperature=273.15 + Celsius temperature.

For the parameters of the Thermistor, we use: B=3950, R=10k, T1=25.

The circuit connection method of the Thermistor is similar to photoresistor, as the following:



We can use the value measured by the ADC converter to obtain the resistance value of Thermistor, and then we can use the formula to obtain the temperature value.

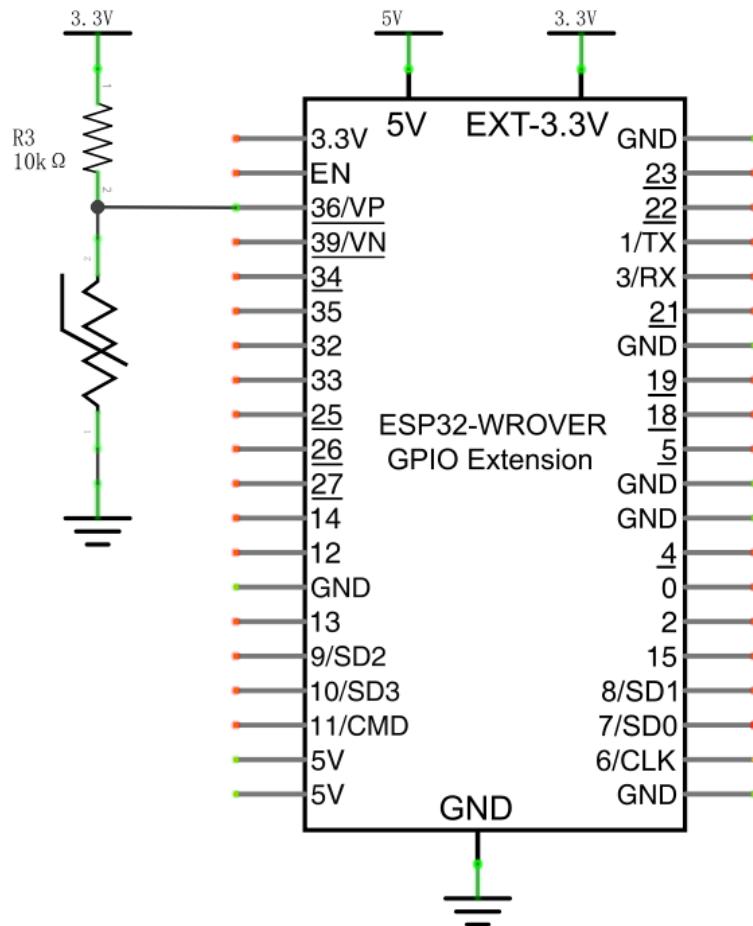
Therefore, the temperature formula can be derived as:

$$T_2 = 1 / \left( \frac{1}{T_1} + \ln \left( \frac{R_t}{R} \right) / B \right)$$

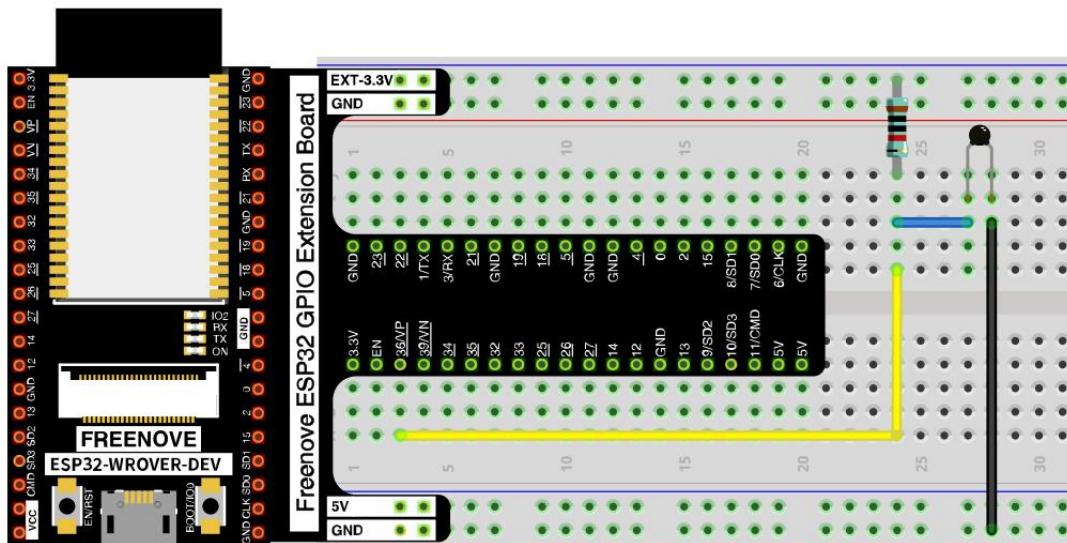
## Circuit

The circuit of this project is similar to the one in the previous chapter. The only difference is that the Photoresistor is replaced by a Thermistor.

Schematic diagram



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



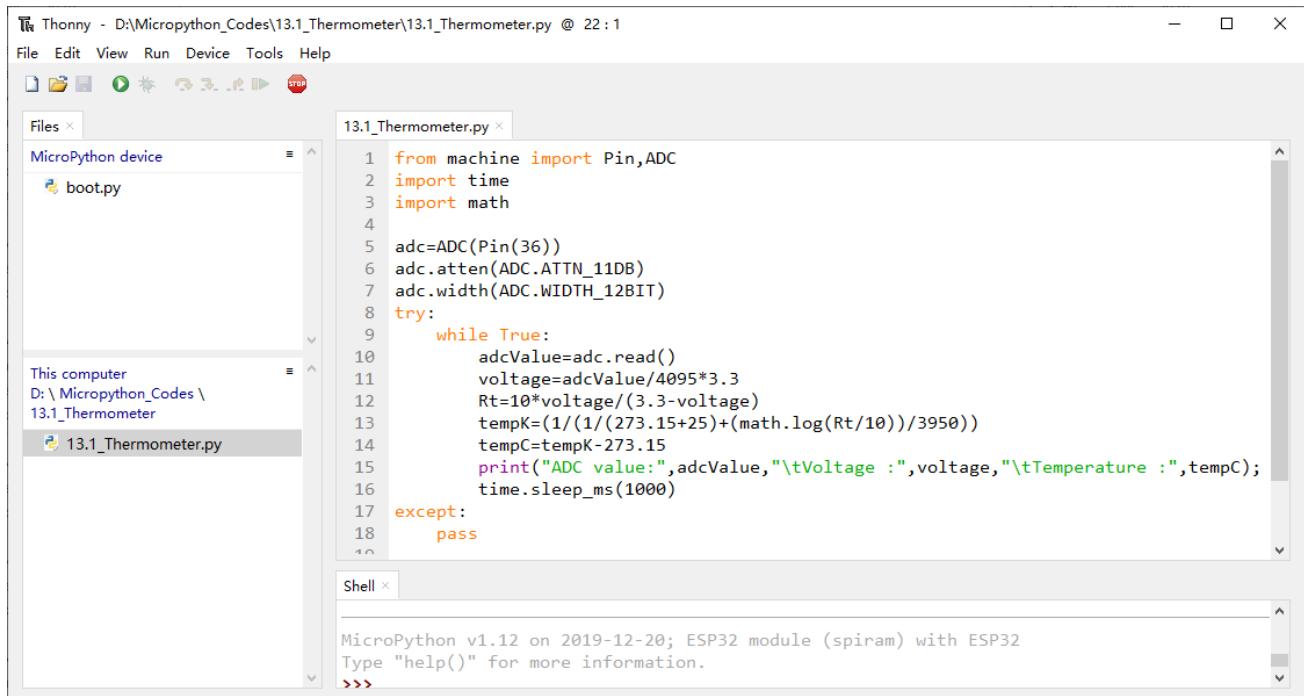
Any concerns? [✉ support@freenove.com](mailto:support@freenove.com)

## Code

Move the program folder “**Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32/Python/Python\_Codes**” to disk(D) in advance with the path of “**D:/Micropython\_Codes**”.

Open “Thonny”, click “This computer” → “D:” → “Micropython\_Codes” → “13.1\_Thermometer” and double click “13.1\_Thermometer.py”.

### 13.1\_Thermometer



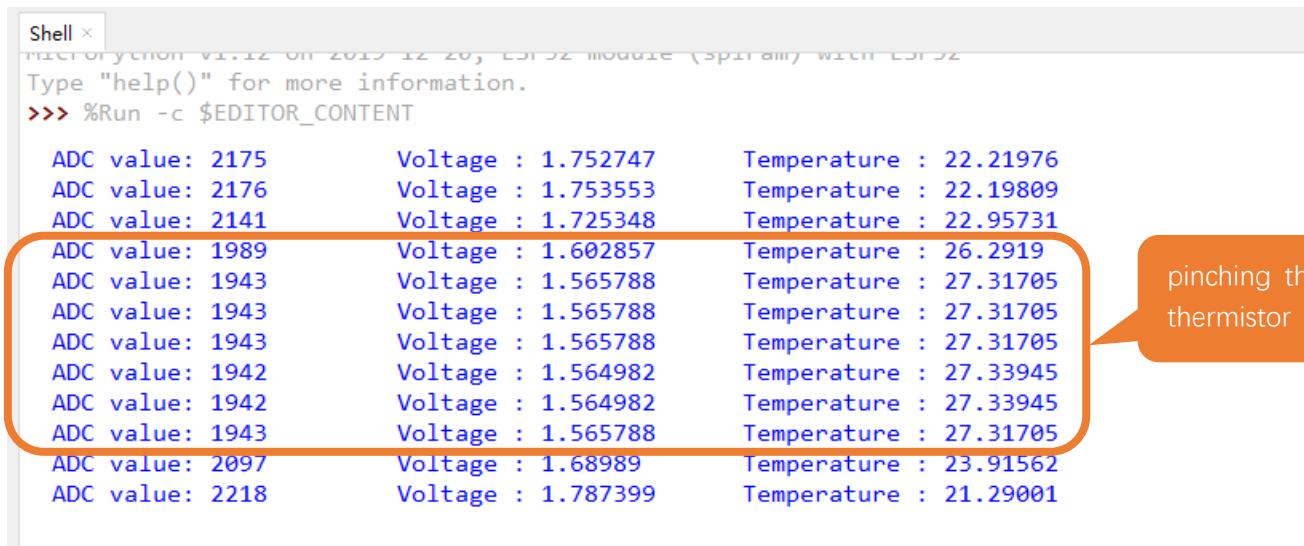
```

from machine import Pin,ADC
import time
import math
adc=ADC(Pin(36))
adc.atten(ADC.ATTN_11DB)
adc.width(ADC.WIDTH_12BIT)
try:
    while True:
        adcValue=adc.read()
        voltage=adcValue/4095*3.3
        Rt=10*voltage/(3.3-voltage)
        tempK=(1/(1/(273.15+25)+(math.log(Rt/10))/3950))
        tempC=tempK-273.15
        print("ADC value:",adcValue,"Voltage :",voltage,"Temperature :",tempC);
        time.sleep_ms(1000)
except:
    pass

```

Click “Run current script” and “Shell” will constantly display the current ADC value, voltage value and temperature value. Try to “pinch” the thermistor (without touching the leads) with your index finger and thumb for a brief time, you should see that the temperature value increases.

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



```

Type "help()" for more information.
>>> %Run -c $EDITOR_CONTENT
ADC value: 2175      Voltage : 1.752747      Temperature : 22.21976
ADC value: 2176      Voltage : 1.753553      Temperature : 22.19809
ADC value: 2141      Voltage : 1.725348      Temperature : 22.95731
ADC value: 1989      Voltage : 1.602857      Temperature : 26.2919
ADC value: 1943      Voltage : 1.565788      Temperature : 27.31705
ADC value: 1943      Voltage : 1.565788      Temperature : 27.31705
ADC value: 1943      Voltage : 1.565788      Temperature : 27.31705
ADC value: 1942      Voltage : 1.564982      Temperature : 27.33945
ADC value: 1942      Voltage : 1.564982      Temperature : 27.33945
ADC value: 1943      Voltage : 1.565788      Temperature : 27.31705
ADC value: 2097      Voltage : 1.68989       Temperature : 23.91562
ADC value: 2218      Voltage : 1.787399      Temperature : 21.29001

```

Any concerns? ✉ [support@freenove.com](mailto:support@freenove.com)

The following is the code:

```
1  from machine import Pin,ADC
2  import time
3  import math
4
5  adc=ADC(Pin(36))
6  adc.atten(ADC.ATTN_11DB)
7  adc.width(ADC.WIDTH_12BIT)
8
9  try:
10     while True:
11         adcValue=adc.read()
12         voltage=adcValue/4095*3.3
13         Rt=10*voltage/(3.3-voltage)
14         tempK=(1/(1/(273.15+25)+(math.log(Rt/10))/3950))
15         tempC=tempK-273.15
16         print("ADC value:",adcValue,"Voltage : ",voltage,"Temperature : ",tempC);
17         time.sleep_ms(1000)
18     except:
19         pass
```

In the code, the ADC value of ADC module A0 port is read, and then it calculates the voltage and the resistance of Thermistor according to Ohms Law. Finally, it calculates the temperature sensed by the Thermistor, according to the formula.



# Chapter 14 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 14.1 Joystick

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

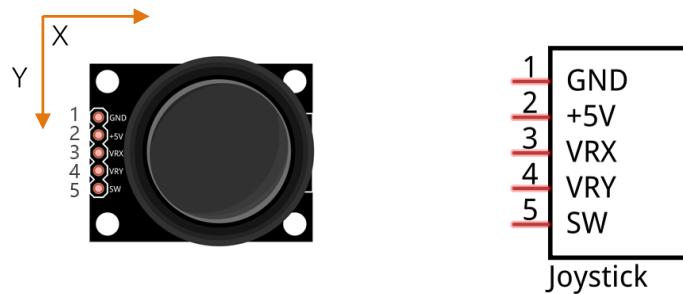
### Component List

ESP32-WROVER x1	GPIO Extension Board x1
Breadboard x1	
Joystick x1	Jumper F/M x5

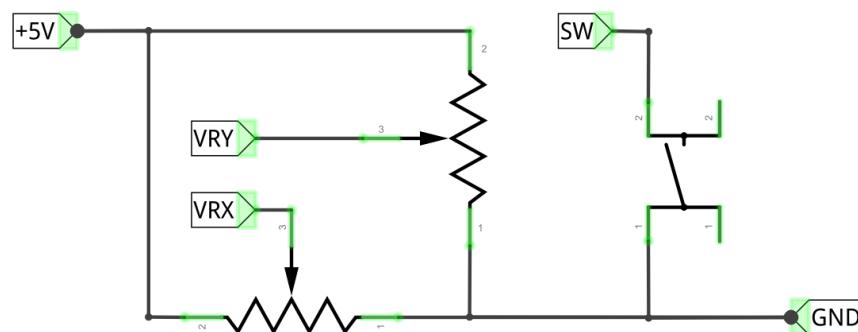
## Component knowledge

### Joystick

A Joystick is a kind of input sensor used with your fingers. You should be familiar with this concept already as they are widely used in gamepads and remote controls. It can receive input on two axes (Y and or X) at the same time (usually used to control direction on a two dimensional plane). And it also has a third direction capability by pressing down (Z axis/direction).



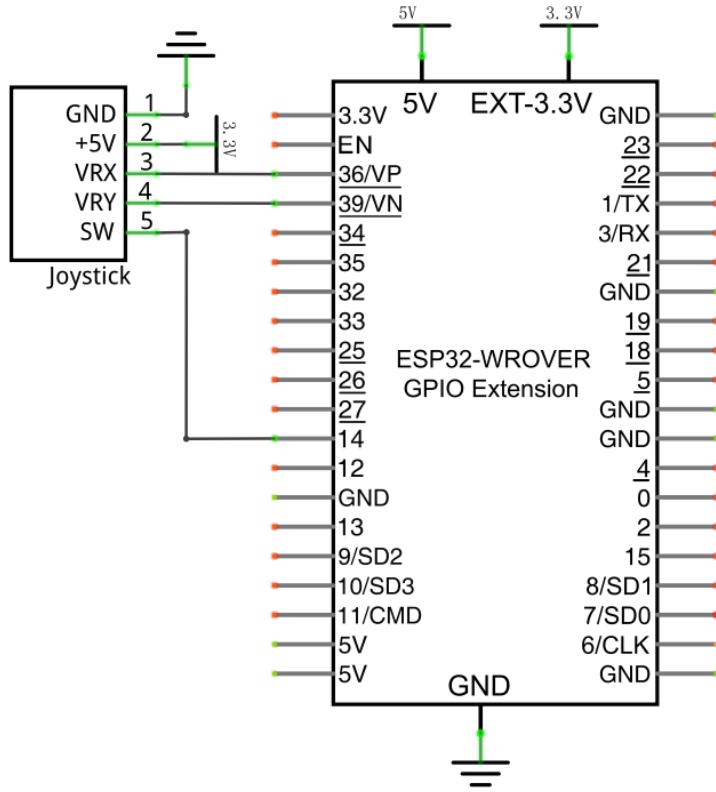
This is accomplished by incorporating two rotary potentiometers inside the Joystick Module at 90 degrees of each other, placed in such a manner as to detect shifts in direction in two directions simultaneously and with a Push Button Switch in the “vertical” axis, which can detect when a User presses on the Joystick.



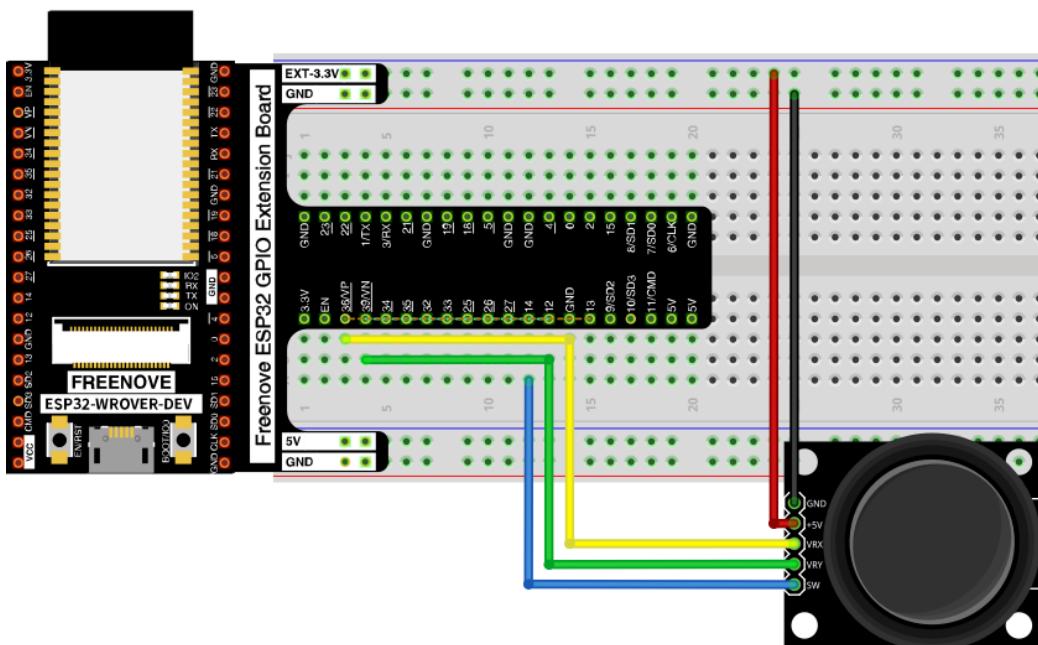
When the Joystick data is read, there are some differences between the axes: data of X and Y axes is analog, which needs to use the ADC. The data of the Z axis is digital, so you can directly use the GPIO to read this data or you have the option to use the ADC to read this.

## Circuit

Schematic diagram



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



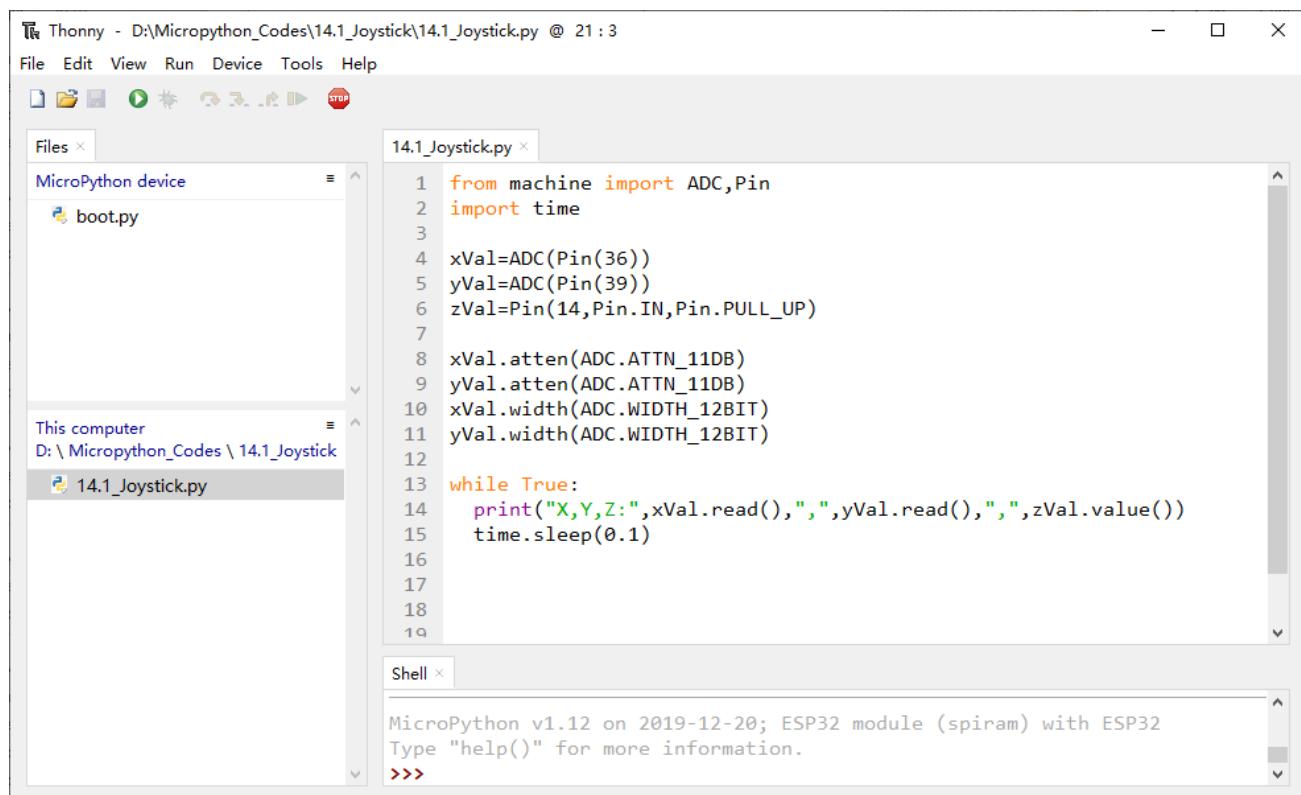
## Code

In this project's code, we will read the ADC values of X and Y axes of the Joystick, and read digital quality of the Z axis, then display these out in Terminal.

Move the program folder “**Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32/Python/Python\_Codes**” to disk(D) in advance with the path of “**D:/Micropython\_Codes**”.

Open “Thonny”, click “This computer” → “D:” → “Micropython\_Codes” → “14.1\_Joystick” and double click “14.1\_Joystick.py”.

### 14.1\_Joystick



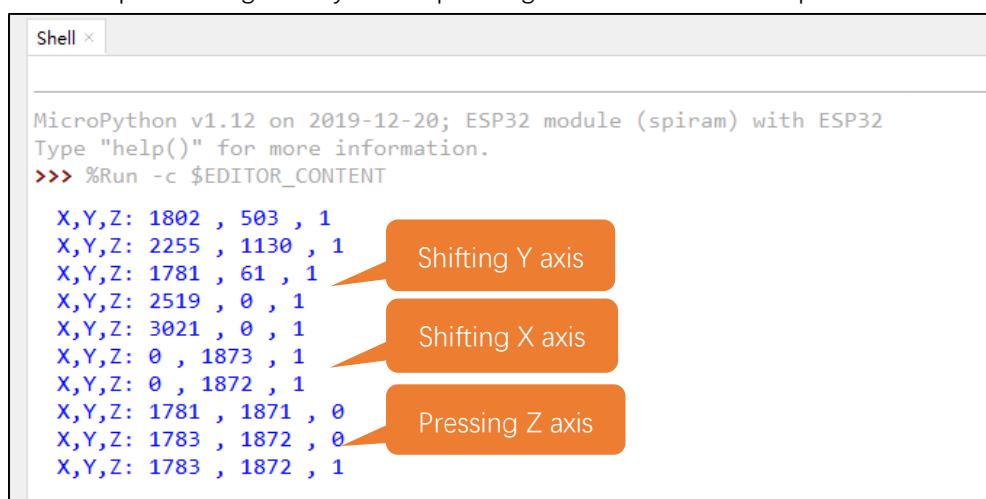
```
from machine import ADC,Pin
import time

xVal=ADC(Pin(36))
yVal=ADC(Pin(39))
zVal=Pin(14,Pin.IN,Pin.PULL_UP)

xVal.atten(ADC.ATTN_11DB)
yVal.atten(ADC.ATTN_11DB)
xVal.width(ADC.WIDTH_12BIT)
yVal.width(ADC.WIDTH_12BIT)

while True:
    print("X,Y,Z:",xVal.read()," ",yVal.read()," ",zVal.value())
    time.sleep(0.1)
```

Click “Run current script”. Shifting the Joystick or pressing it down will make the printed data in “Shell” change.



```
MicroPython v1.12 on 2019-12-20; ESP32 module (spiram) with ESP32
Type "help()" for more information.
>>> %Run -c $EDITOR_CONTENT

X,Y,Z: 1802 , 503 , 1
X,Y,Z: 2255 , 1130 , 1
X,Y,Z: 1781 , 61 , 1
X,Y,Z: 2519 , 0 , 1
X,Y,Z: 3021 , 0 , 1
X,Y,Z: 0 , 1873 , 1
X,Y,Z: 0 , 1872 , 1
X,Y,Z: 1781 , 1871 , 0
X,Y,Z: 1783 , 1872 , 0
X,Y,Z: 1783 , 1872 , 1
```

The flowing is the code:

```
1 from machine import ADC, Pin
2 import time
3
4 xVal=ADC(Pin(36))
5 yVal=ADC(Pin(39))
6 zVal=Pin(14, Pin.IN, Pin.PULL_UP)
7
8 xVal.atten(ADC.ATTN_11DB)
9 yVal.atten(ADC.ATTN_11DB)
10 xVal.width(ADC.WIDTH_12BIT)
11 yVal.width(ADC.WIDTH_12BIT)
12
13 while True:
14     print("X, Y, Z:", xVal.read(), ", ", yVal.read(), ", ", zVal.value())
15     time.sleep(1)
```

Set the acquisition range of voltage of the two ADC channels to 0-3.3V, and the acquisition width of data to 0-4095.

```
8 xVal.atten(ADC.ATTN_11DB)
9 yVal.atten(ADC.ATTN_11DB)
10 xVal.width(ADC.WIDTH_12BIT)
11 yVal.width(ADC.WIDTH_12BIT)
```

In the code, configure Z\_Pin to pull-up input mode. In loop(), use Read () to read the value of axes X and Y and use value() to read the value of axis Z, and then display them.

```
14 print("X, Y, Z:", xVal.read(), ", ", yVal.read(), ", ", zVal.value())
```

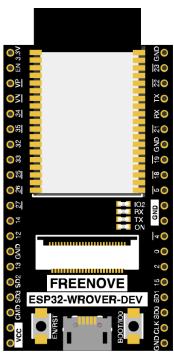
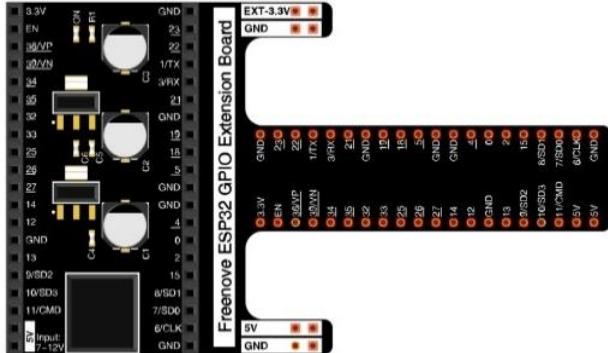
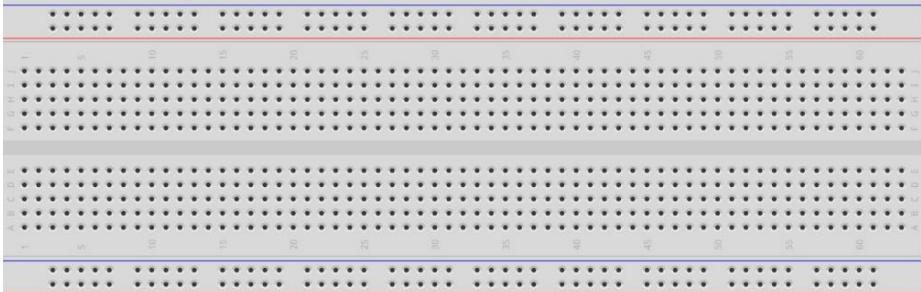
# Chapter 15 74HC595 & LED Bar Graph

We have used LED Bar Graph to make a flowing water light, in which 10 GPIO ports of ESP32 is occupied. More GPIO ports mean that more peripherals can be connected to ESP32, 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 15.1 Flowing Water Light

Now let's learn how to use the 74HC595 IC Chip to make a flowing water light using less GPIO.

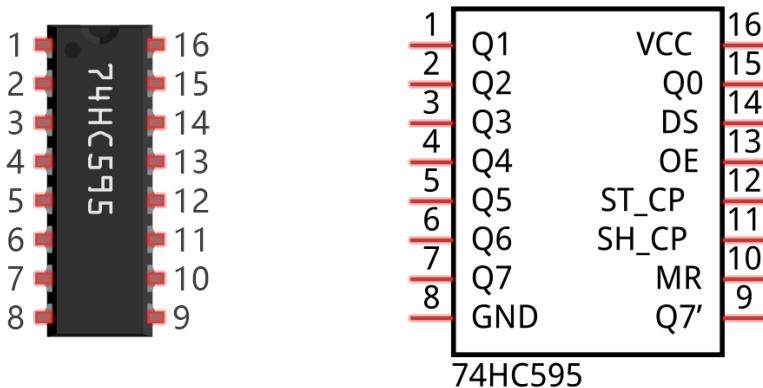
### Component List

ESP32-WROVER x1	GPIO Extension Board x1
	
	
Breadboard x1	
74HC595 x1	LED Bar Graph x1
	
Resistor 220Ω x8	Jumper M/M x15
	

## Related knowledge

### 74HC595

A 74HC595 chip is used to convert serial data into parallel data. A 74HC595 chip can convert the serial data of one byte into 8 bits, and send its corresponding level to each of the 8 ports correspondingly. With this characteristic, the 74HC595 chip can be used to expand the IO ports of an ESP32. At least 3 ports are required to control the 8 ports of the 74HC595 chip.



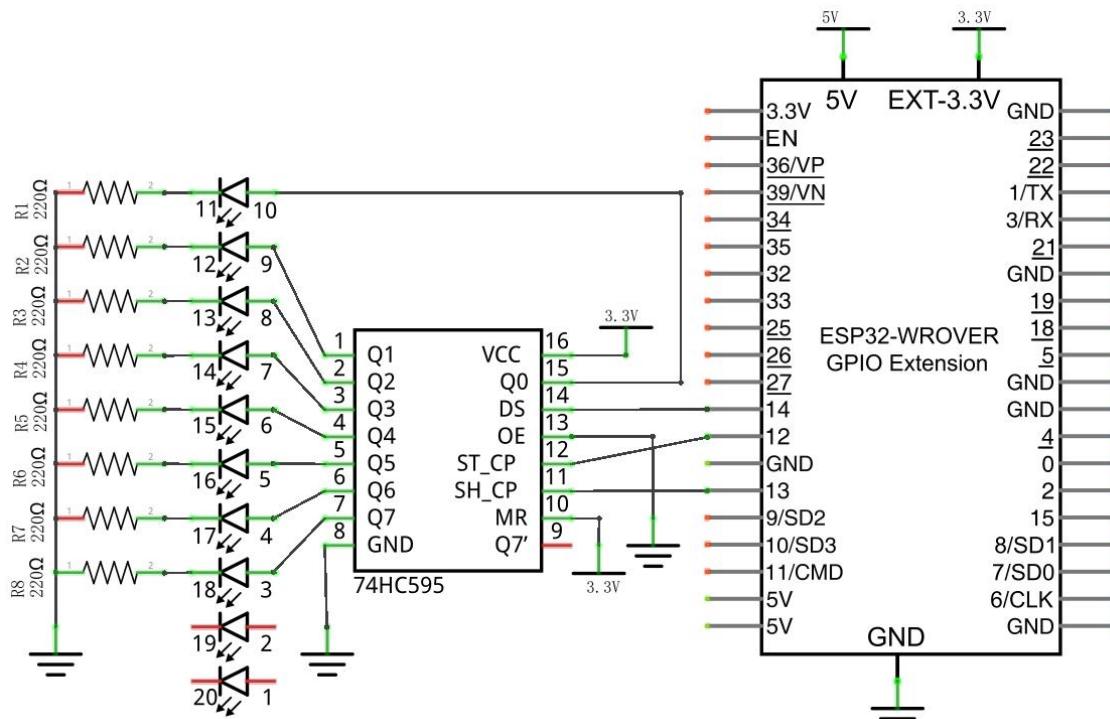
The ports of the 74HC595 chip are described as follows:

Pin name	GPIO 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.

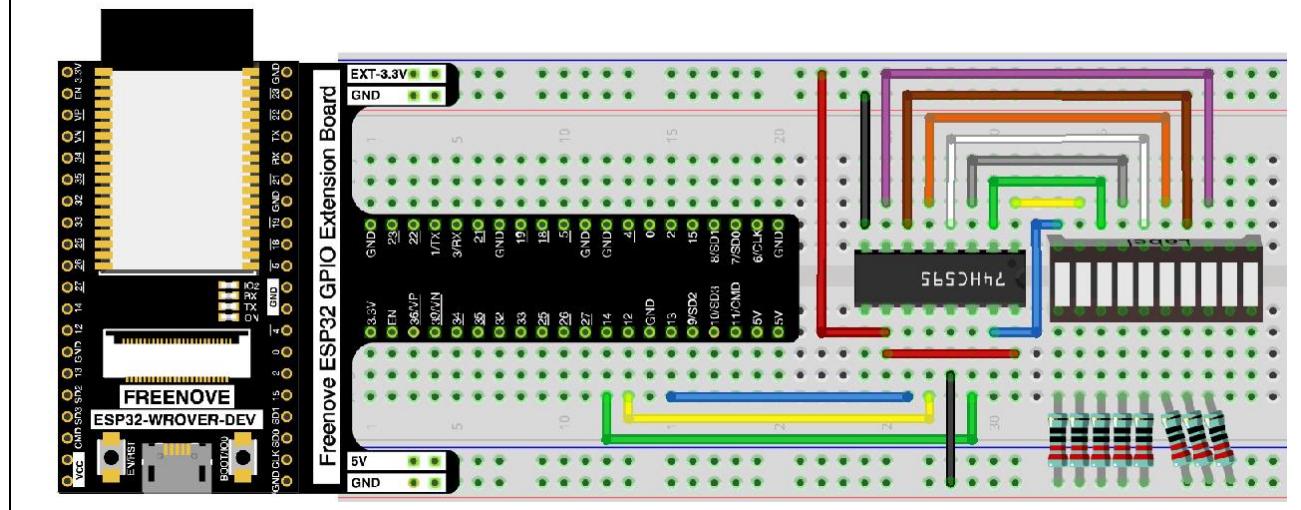
For more detail, please refer to the datasheet on the 74HC595 chip.

## Circuit

Schematic diagram



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



## Code

In this project, we will make a flowing water light with a 74HC595 chip to learn about its functions.

Move the program folder “**Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32/Python/Python\_Codes**” to disk(D) in advance with the path of “**D:/Micropython\_Codes**”.

Open “Thonny”, click “This computer” → “D:” → “Micropython\_Codes” → “15.1\_Flowing\_Water\_Light”.

Select “my74HC595.py”, right click your mouse to select “Upload to /”, wait for “my74HC595.py” to be uploaded to ESP32-WROVER and then double click “15.1\_Flowing\_Water\_Light.py”.

### 15.1\_Flowing\_Water\_Light

```

1 import time
2 from my74HC595 import Chip74HC595
3
4 chip = Chip74HC595(14,12,13)
5 # ESP32-14: 74HC595-DS(14)
6 # ESP32-12: 74HC595-STCP(12)
7 # ESP32-13: 74HC595-SHCP(11)
8
9 while True:
10     x=0x01
11     for count in range(8):
12         chip.shiftOut(1,x) #High bit is sent first
13         x=x<<1
14         time.sleep_ms(300)
15     x=0x01
16     for count in range(8):
17         chip.shiftOut(0,x) #Low bit is sent first
18         x=x<<1
19         time.sleep_ms(300)

```

The screenshot shows the Thonny IDE interface. The title bar says "Thonny - D:\Micropython\_Codes\15.1\_Flowing\_Water\_Light\15.1\_Flowing\_Water\_Light.py @ 23 : 4". The menu bar includes File, Edit, View, Run, Device, Tools, and Help. The toolbar has icons for file operations like Open, Save, and Run. The left sidebar shows a file tree with "MicroPython device" and "This computer" sections. In the "This computer" section, there is a folder "15.1\_Flowing\_Water\_Light" containing "boot.py" and "my74HC595.py". A context menu is open over "my74HC595.py", with the "Upload to /" option highlighted in blue. Other options in the menu include Refresh, Move to Recycle Bin, New directory..., Properties, and Storage space. The main code editor window displays the Python script "15.1\_Flowing\_Water\_Light.py" with the code provided above. The status bar at the bottom indicates "v1.12 on 2019-12-20; ESP32 module (spiram) with ESP32 ()" for more information.

Click “Run current script” and you will see that Bar Graph LED starts with the flowing water pattern flashing from left to right and then back from right to left. If it displays nothing, maybe the LED Bar is connected upside down, please unplug it and then re-plug it reversely.

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

The following is the program code:

```

1 import time
2 from my74HC595 import Chip74HC595
3
4 chip = Chip74HC595(14, 12, 13)
# ESP32-14: 74HC595-DS(14)
# ESP32-12: 74HC595-STCP(12)
# ESP32-13: 74HC595-SHCP(11)
5
6
7
8
9 while True:
10     x=0x01
11     for count in range(8):
12         chip.shiftOut(1, x) #High bit is sent first
13         x=x<<1
14         time.sleep_ms(300)
15     x=0x01
16     for count in range(8):
17         chip.shiftOut(0, x) #Low bit is sent first
18         x=x<<1
19         time.sleep_ms(300)

```

Import time and my74HC595 modules.

```

1 import time
2 from my74HC595 import Chip74HC595

```

Assign pins for ESP32-WROVER to connect to 74HC595.

```

4 chip = Chip74HC595(14, 12, 13)

```

The first for loop makes LED Bar display separately from left to right while the second for loop make it display separately from right to left.

```

10     x=0x01
11     for count in range(8):
12         chip.shiftOut(1, x) #High bit is sent first
13         x=x<<1
14         time.sleep_ms(300)
15     x=0x01
16     for count in range(8):
17         chip.shiftOut(0, x) #Low bit is sent first
18         x=x<<1
19         time.sleep_ms(300)

```



## Reference

### Class Chip74HC595

Before each use of the object **Chip74HC595**, make sure my74HC595.py has been uploaded to "/" of ESP32, and then add the statement "**from my74HC595 import Chip74HC595**" to the top of the python file.

**Chip74HC595()**:An object. By default, 74HC595's DS pin is connected to Pin(14) of ESP32, ST\_CP pin is connected to ESP32's Pin(12) and OE pin is connected to ESP's Pin(5). If you need to modify the pins, just do the following operations.

**chip=Chip74HC595()** or **chip=Chip74HC595(14,12,13,5)**

**shiftOut(direction, data)**: Write data to 74HC595.

**direction**: 1/0. "1" presents that high-order byte will be sent first while "0" presents that low-order byte will be sent first.

**data**: The content that is sent, which is one-byte data.

**clear()**: Clear the latch data of 74HC595..

# Chapter 16 74HC595 & 7-Segment Display.

In this chapter, we will introduce the 7-Segment Display.

## Project 16.1 7-Segment Display.

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

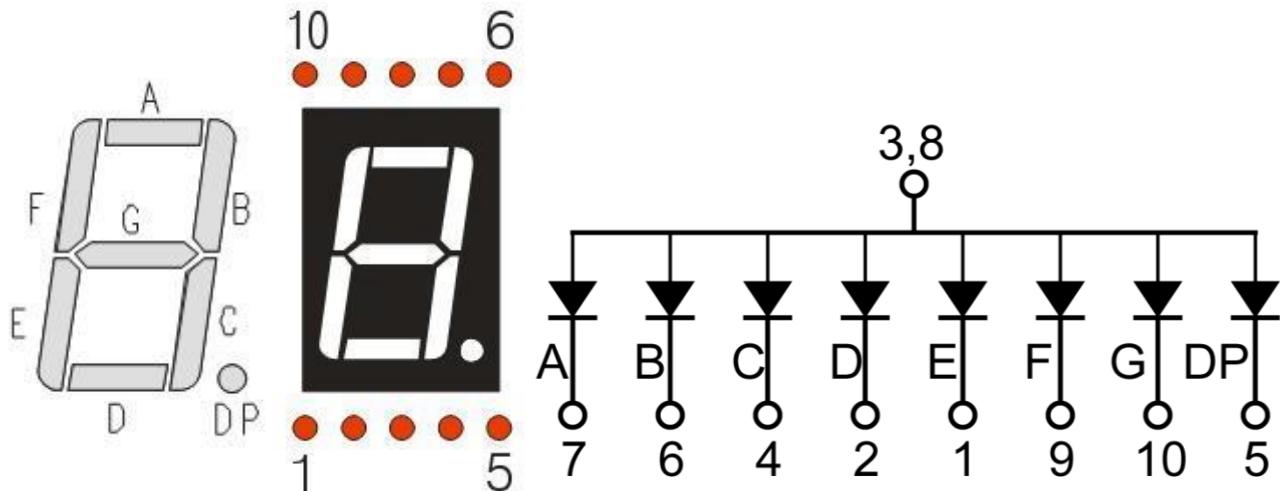
### Component List

ESP32-WROVER x1	GPIO Extension Board x1		
Breadboard x1			
74HC595 x1	7-segment display x1	Resistor 220Ω x8	Jumper M/M

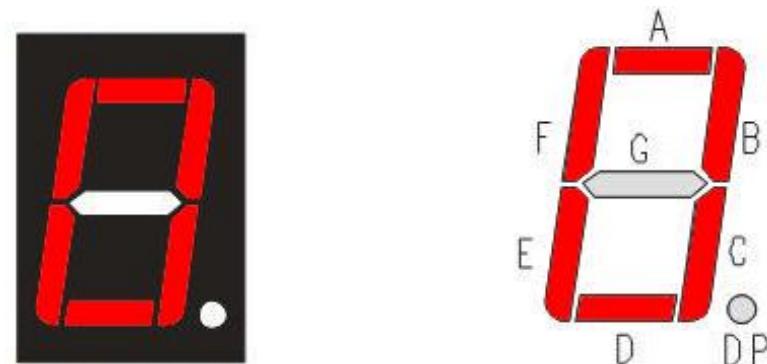
## Component knowledge

### 7-segment display

A 7-Segment Display is a digital electronic display device. There is a figure "8" and a decimal point represented, which consists of 8 LEDs. The LEDs have a Common Anode and individual Cathodes. Its internal structure and pin designation diagram is shown below:



As we can see in the above circuit diagram, we can control the state of each LED separately. Also, by combining LEDs with different states of ON and OFF, we can display different characters (Numbers and Letters). For example, to display a "0": we need to turn ON LED segments A, B, C, D, E and F, and turn OFF LED segments G and DP.

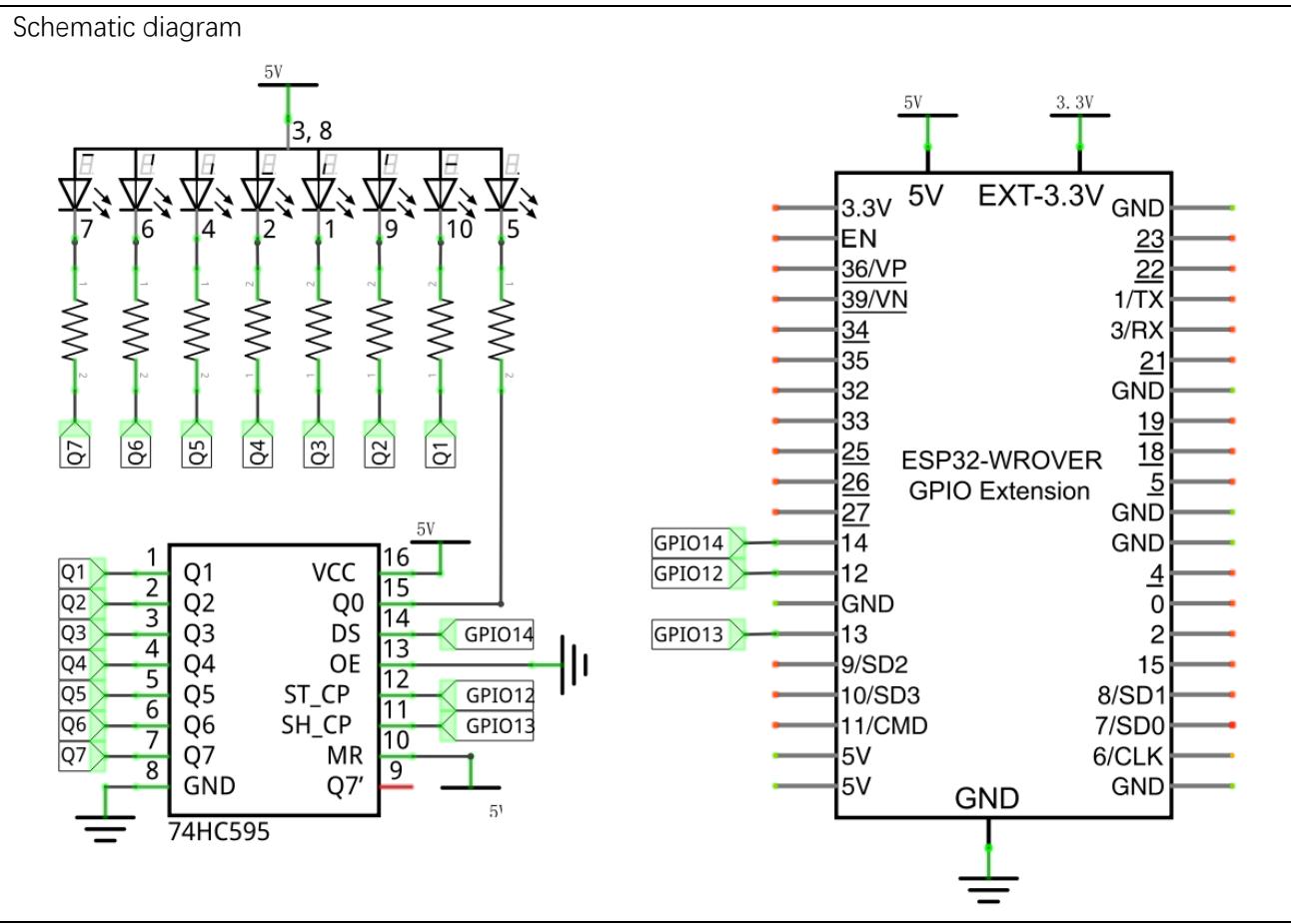


In this project, we will use a 7-Segment Display with a Common Anode. Therefore, when there is an input low level to an LED segment the LED will turn ON. Defining segment "A" as the lowest level and segment "DP" as the highest level, from high to low would look like this: "DP", "G", "F", "E", "D", "C", "B", "A". Character "0" corresponds to the code:  $1100\ 0000_2 = 0xc0$ .

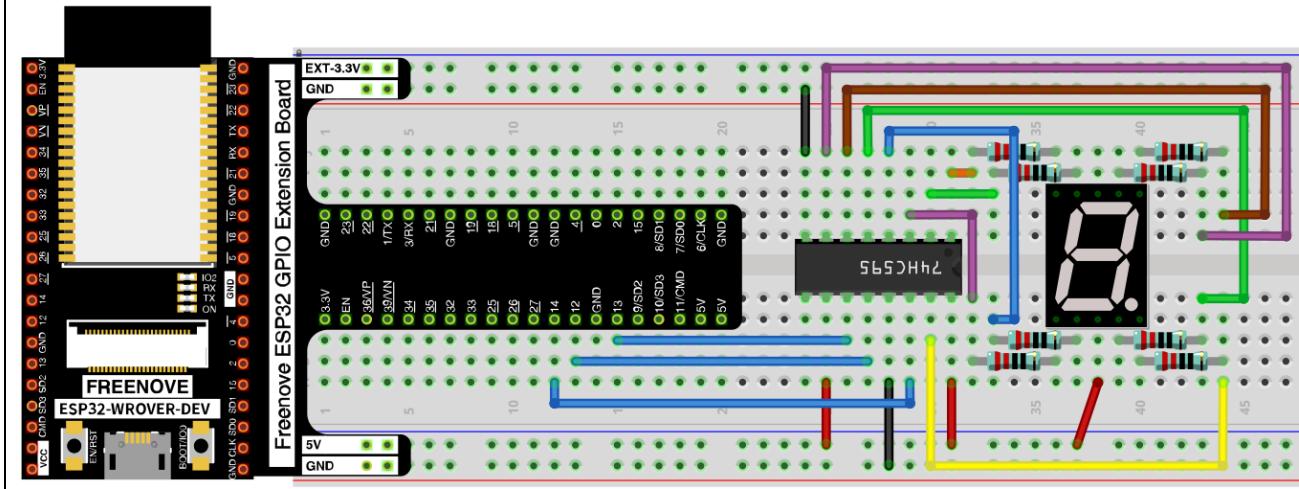
For detailed code values, please refer to the following table (common anode).

CHAR	DP	G	F	E	D	C	B	A	Hex	ASCII
0	1	1	0	0	0	0	0	0	0xc0	1100 0000
1	1	1	1	1	1	0	0	1	0xf9	1111 1001
2	1	0	1	0	0	1	0	0	0xa4	1010 0100
3	1	0	1	1	0	0	0	0	0xb0	1011 0000
4	1	0	0	1	1	0	0	1	0x99	1001 1001
5	1	0	0	1	0	0	1	0	0x92	1001 0010
6	1	0	0	0	0	0	1	0	0x82	1000 0010
7	1	1	1	1	1	0	0	0	0xf8	1111 1000
8	1	0	0	0	0	0	0	0	0x80	1000 0000
9	1	0	0	1	0	0	0	0	0x90	1001 0000
A	1	0	0	0	1	0	0	0	0x88	1000 1000
B	1	0	0	0	0	0	1	1	0x83	1000 0011
C	1	1	0	0	0	1	1	0	0xc6	1100 0110
D	1	0	1	0	0	0	0	1	0xa1	1010 0001
E	1	0	0	0	0	1	1	0	0x86	1000 0110
F	1	0	0	0	1	1	1	0	0x8e	1000 1110

## Circuit



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



## Code

In this section, the 74HC595 is used in the same way as in the previous section, but with different values transferred. We can learn how to master the digital display by sending the code value of "0" - "F".

Move the program folder “**Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32/Python/Python\_Codes**” to disk(D) in advance with the path of “**D:/Micropython\_Codes**”.

Open “Thonny”, click “This computer” → “D:” → “Micropython\_Codes” → “16.1\_74HC595\_and\_7\_segment\_display”.

Select “my74HC595.py”, right click your mouse to select “Upload to /”, wait for “my74HC595.py” to be uploaded to ESP32-WROVER and then double click“16.1\_74HC595\_and\_7\_segment\_display.py”.

### 16.1\_74HC595\_and\_7\_segment\_display

```

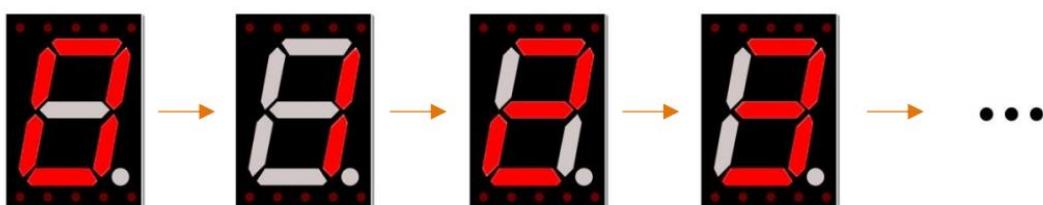
import time
from my74HC595 import Chip74HC595

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

chip = Chip74HC595(14,12,13)
try:
    while True:
        for count in range(16):
            chip.shiftOut(0,lists[count])
        time.sleep_ms(500)
except:
    pass

```

Click “Run current script”, and you'll see a 1-bit, 7-segment display displaying 0-f in a loop.





The following is the program code:

```
1 import time
2 from my74HC595 import Chip74HC595
3
4 lists =[0xc0, 0xf9, 0xa4, 0xb0, 0x99, 0x92, 0x82, 0xf8,
5         0x80, 0x90, 0x88, 0x83, 0xc6, 0xa1, 0x86, 0x8e]
6
7 chip = Chip74HC595(14, 12, 13)
8 try:
9     while True:
10        for count in range(16):
11            chip.shiftOut(0, lists[count])
12            time.sleep_ms(500)
13    except:
14        pass
```

Import time and my74HC595 modules.

```
1 import time
2 from my74HC595 import Chip74HC595
```

Put the encoding "0" - "F" into the list.

```
4 lists =[0xc0, 0xf9, 0xa4, 0xb0, 0x99, 0x92, 0x82, 0xf8,
5         0x80, 0x90, 0x88, 0x83, 0xc6, 0xa1, 0x86, 0x8e]
```

Define an object, whose pins applies default configuration, to drive 74HC595.

```
7 chip = Chip74HC595(14, 12, 13)
```

Send data of digital tube to 74HC595 chip.

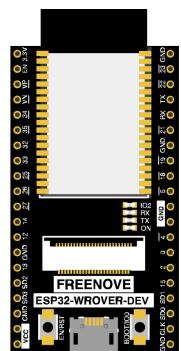
```
11 chip.shiftOut(0, lists[count])
```

## Project 16.2 4-Digit 7-Segment Display

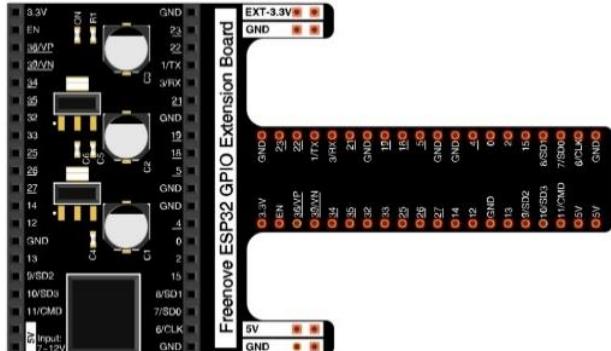
Now, let's try to control a more-digit 7-segment display

### Component List

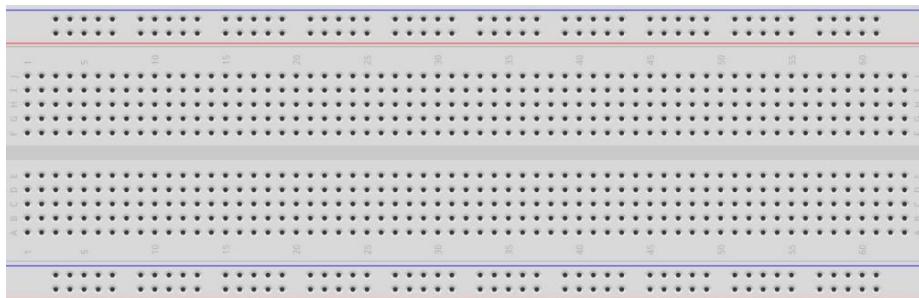
ESP32-WROVER x1



GPIO Extension Board x1



Breadboard x1



74HC595 x1



7-segment display x1



Resistor 220Ω x8



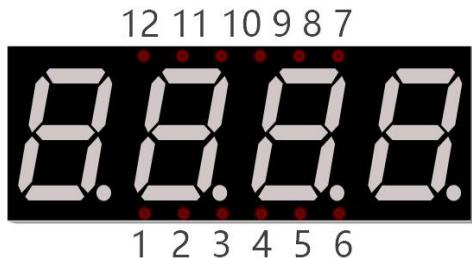
Jumper M/M



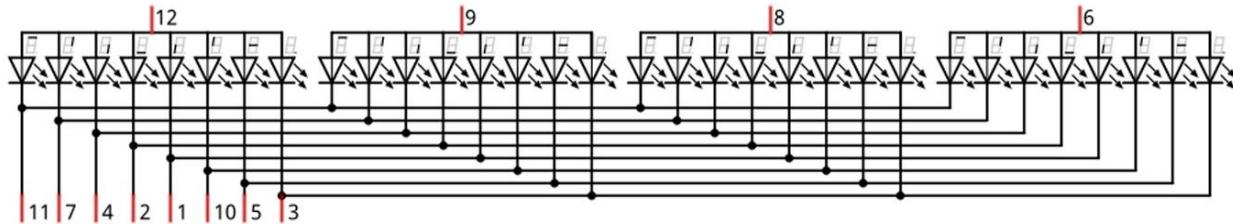
## Component knowledge

### 4 Digit 7-Segment Display

A 4 Digit 7-segment display integrates four 7-Segment Displays into one module, therefore it can display more characters. All of the LEDs contained have a Common Anode and individual Cathodes. Its internal structure and pin designation diagram is shown below:



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

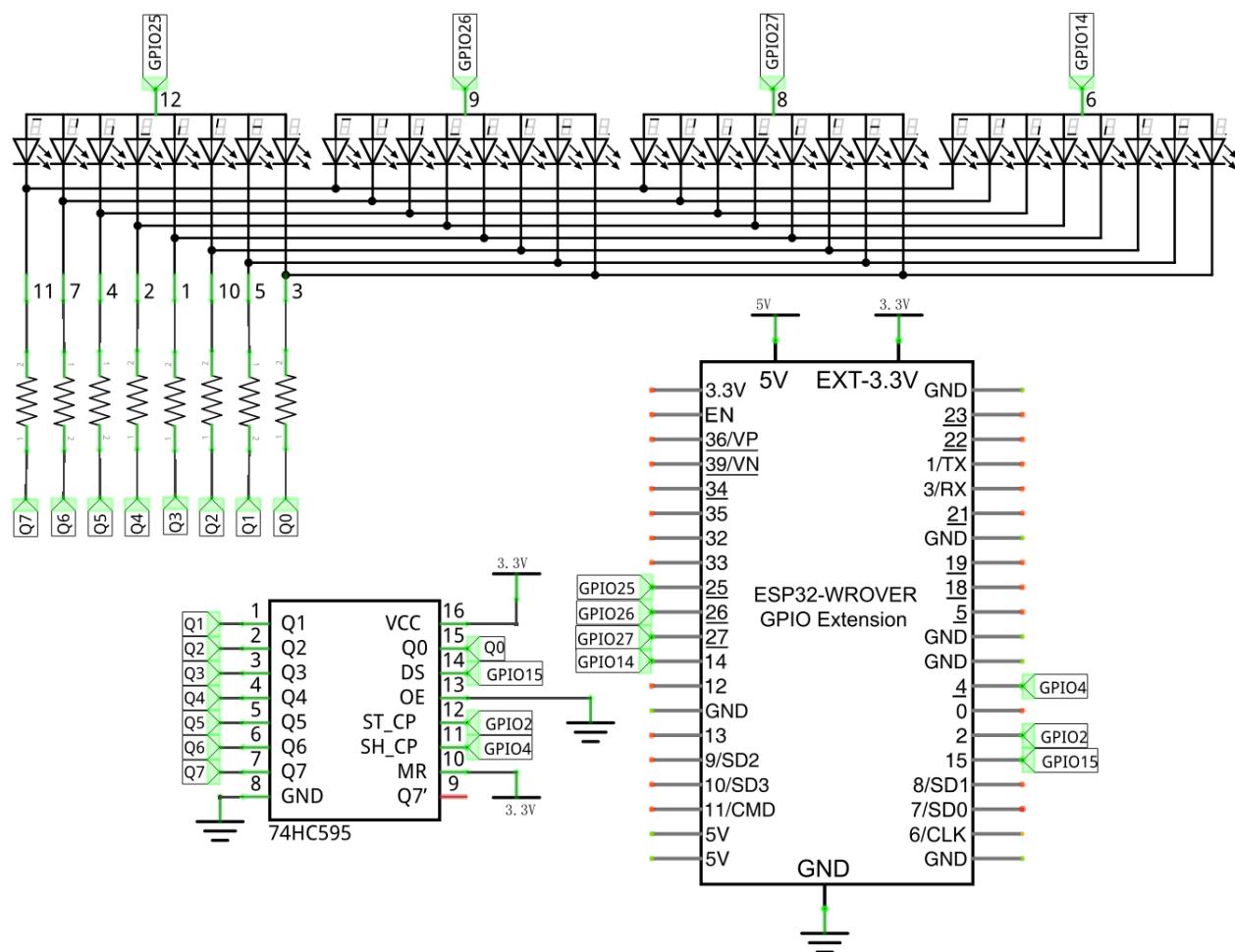


Display method of 4 Digit 7-segment display is similar to 1 Digit 7-segment display. The difference between them is that the 4-Digit displays each Digit visibly in turn, one by one and not together. We need to first send high level to the common end of the first Digit Display, and send low level to the remaining three common ends, and then send content to 8 LED cathode pins of the first Digit Display. At this time, the first 7-Segment Display will show visible content and the remaining three will be OFF.

Similarly, the second, third and fourth 7-Segment Displays will show visible content in turn by scanning the display. Although the four number characters are displayed in turn separately, this process is so fast that it is imperceptible to the naked eye. This is due to the principle of optical afterglow effect and the vision persistence effect in human sight. This is how we can see all 4 number characters at the same time. However, if each number character is displayed for a longer period, you will be able to see that the number characters are displayed separately.

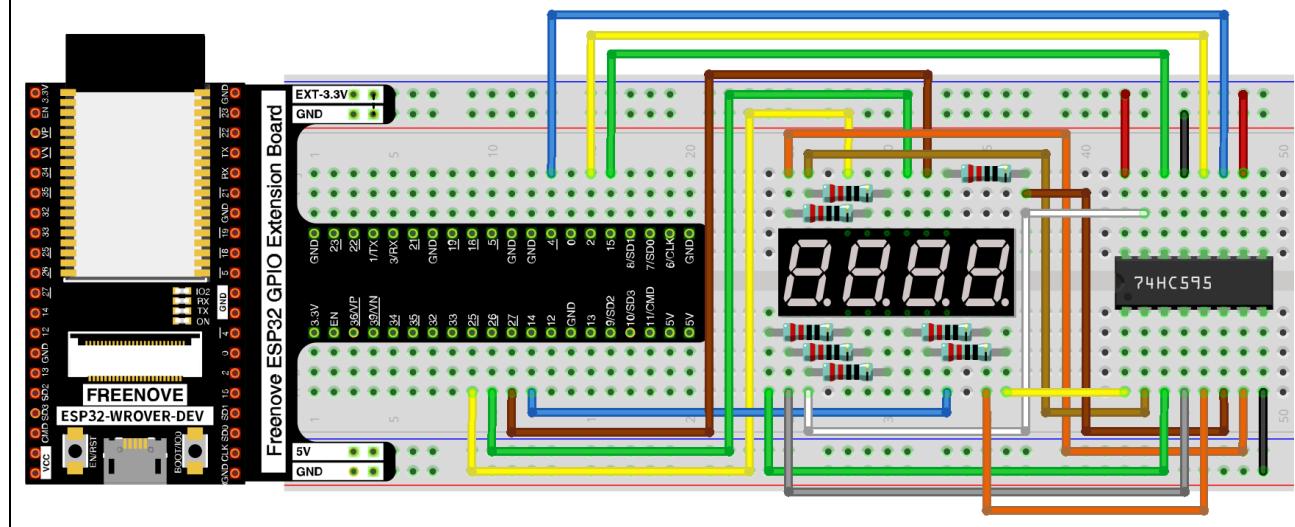
## Circuit

Schematic diagram



Q0-Q7 connecting in inverted sequence

Hardware connection:

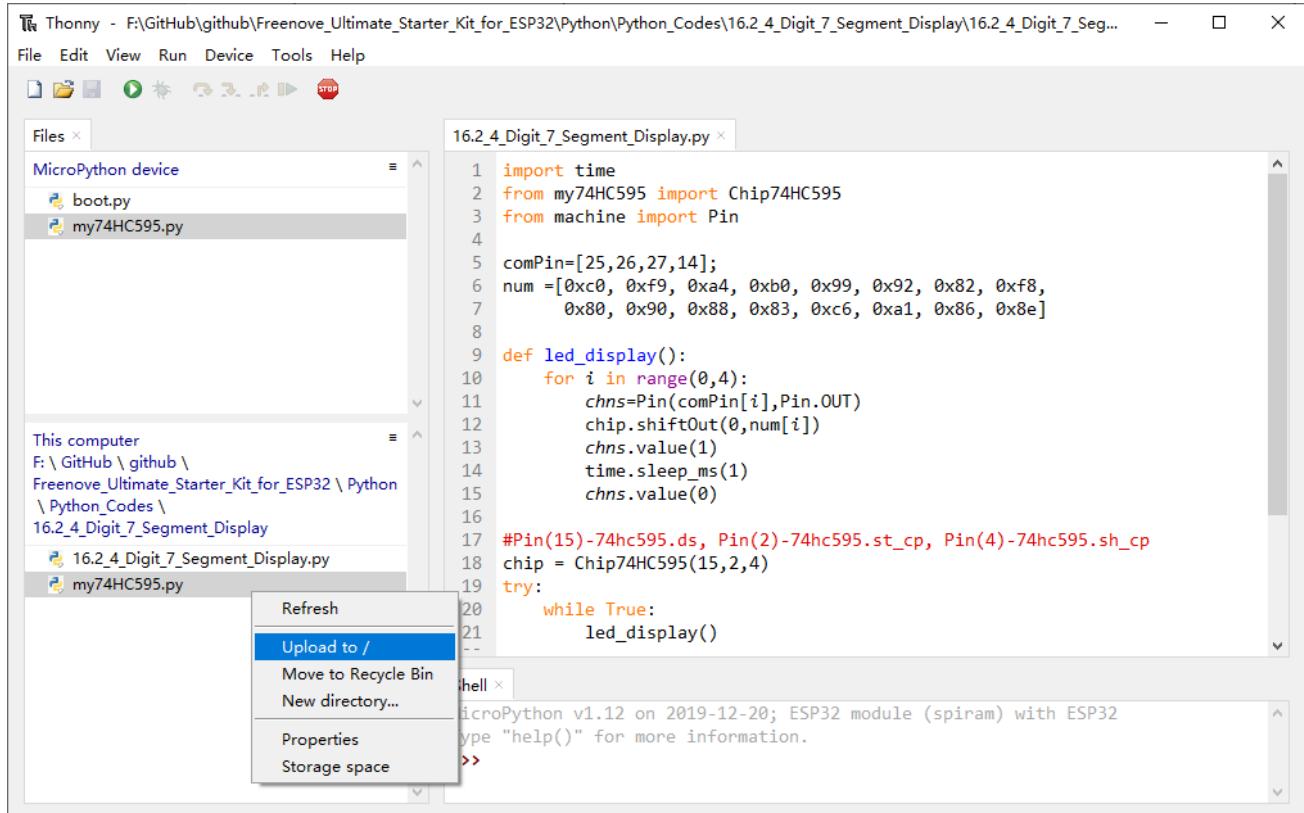


## Code

In this code, we use the 74HC595 IC Chip to control the 4-Digit 7-Segment Display, and use the dynamic scanning method to show the changing number characters.

Open “Thonny”, click “This computer” → “D:” → “Micropython\_Codes” → “16.2\_4\_Digit\_7\_Segment\_Display”. Select “my74HC595.py”, right click your mouse to select “Upload to /”, wait for “my74HC595.py” to be uploaded to ESP32-WROVER and double click “16.2\_4\_Digit\_7\_Segment\_Display.py”.

### 16.2\_4\_Digit\_7\_Segment\_Display



```

1 import time
2 from my74HC595 import Chip74HC595
3 from machine import Pin
4
5 comPin=[25,26,27,14];
6 num =[0xc0, 0xf9, 0xa4, 0xb0, 0x99, 0x92, 0x82, 0xf8,
7       0x80, 0x90, 0x88, 0x83, 0xc6, 0xa1, 0x86, 0xe]
8
9 def led_display():
10     for i in range(0,4):
11         chns=Pin(comPin[i],Pin.OUT)
12         chip.shiftOut(0,num[i])
13         chns.value(1)
14         time.sleep_ms(1)
15         chns.value(0)
16
17 #Pin(15)-74hc595.ds, Pin(2)-74hc595.st_cp, Pin(4)-74hc595.sh_cp
18 chip = Chip74HC595(15,2,4)
19 try:
20     while True:
21         led_display()

```

Click “Run current script”, and the Nixie tube display as shown in the image below.



The following is the program code:

```

1 import time
2 from my74HC595 import Chip74HC595
3 from machine import Pin
4
5 comPin = [25, 26, 27, 14];
6 num = [0xc0, 0xf9, 0xa4, 0xb0, 0x99, 0x92, 0x82, 0xf8,
7         0x80, 0x90, 0x88, 0x83, 0xc6, 0xa1, 0x86, 0x8e]
8
9 def led_display():
10     for i in range(0, 4):
11         chns=Pin(comPin[i],Pin.OUT)
12         chip.shiftOut(0, num[i])
13         chns.value(1)
14         time.sleep_ms(1)
15         chns.value(0)
16
17 #Pin(15)-74hc595.ds, Pin(2)-74hc595.st_cp, Pin(4)-74hc595.sh_cp
18 chip = Chip74HC595(15, 2, 4)
19 try:
20     while True:
21         led_display()
22 except:
23     pass

```

Import time, my74HC595 and Pin modules.

```

1 import time
2 from my74HC595 import Chip74HC595
3 from machine import Pin

```

Define common anode pins for digital tubes and request a list to put character encodings in it.

```

5 comPin = [25, 26, 27, 14];
6 num = [0xc0, 0xf9, 0xa4, 0xb0, 0x99, 0x92, 0x82, 0xf8,
7         0x80, 0x90, 0x88, 0x83, 0xc6, 0xa1, 0x86, 0x8e]

```

Request an object to drive 74HC595 and associate pins with it.

```
18 chip = Chip74HC595(15, 2, 4)
```

Make the digital tube display "0123".

```

9 def led_display():
10     for i in range(0, 4):
11         chns=Pin(comPin[i],Pin.OUT)
12         chip.shiftOut(0, num[i])
13         chns.value(1)
14         time.sleep_ms(1)
15         chns.value(0)

```

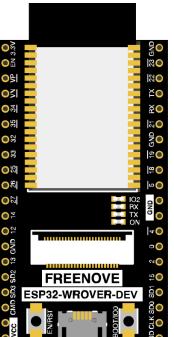
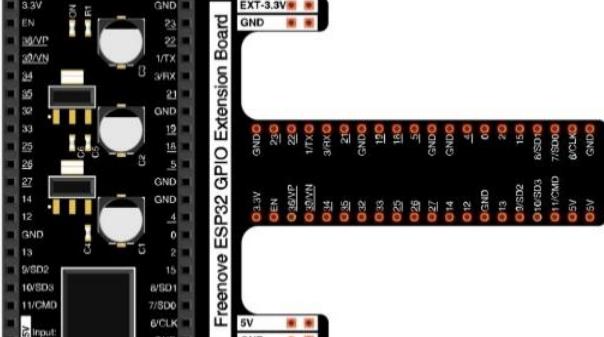
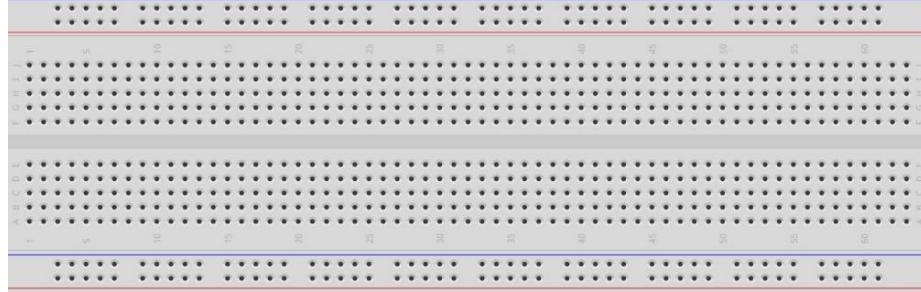
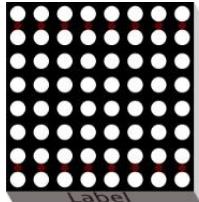
# Chapter 16 74HC595 & LED Matrix

Thus far we have learned how to use the 74HC595 IC Chip to control the Bar Graph LED and the 7-Segment Display. We will now use 74HC595 IC Chips to control an LED Matrix.

## Project 16.3 LED Matrix

In this project, we will use two 74HC595 IC chips to control a monochrome (one color) (8X8) LED Matrix to make it display both simple graphics and characters.

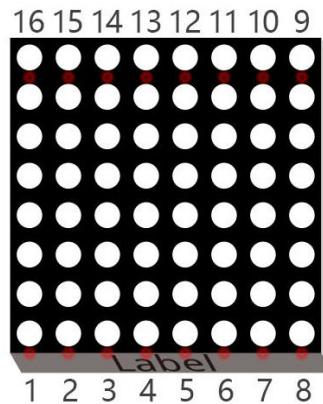
### Component List

ESP32-WROVER x1	GPIO Extension Board x1		
			
Breadboard x1			
			
74HC595 x2	8*8 LEDMatrix x1	Resistor 220Ω x8	Jumper M/M
			

## Component knowledge

### LED matrix

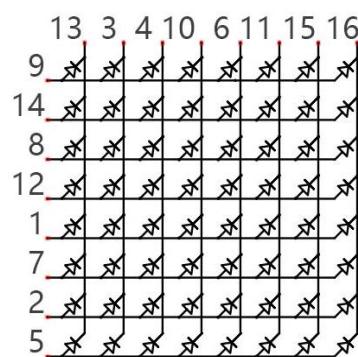
A LED Matrix is a rectangular display module that consists of a uniform grid of LEDs. The following is an 8X8 monochrome (one color) LED Matrix containing 64 LEDs (8 rows by 8 columns).



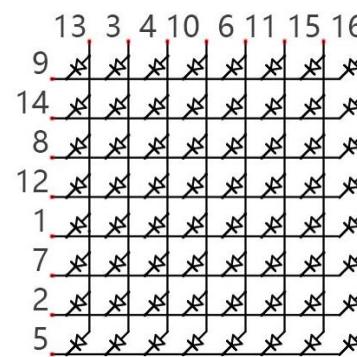
In order to facilitate the operation and reduce the number of ports required to drive this component, the Positive Poles of the LEDs in each row and Negative Poles of the LEDs in each column are respectively connected together inside the LED Matrix module, which is called a Common Anode. There is another arrangement type. Negative Poles of the LEDs in each row and the Positive Poles of the LEDs in each column are respectively connected together, which is called a Common Cathode.

The LED Matrix that we use in this project is a Common Anode LED Matrix.

Connection mode of common anode

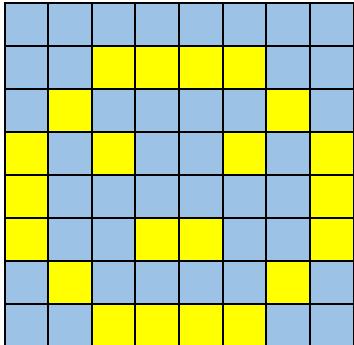


Connection mode of common cathode





Here is how a Common Anode LED Matrix works. First, choose 16 ports on ESP32 board to connect to the 16 ports of LED Matrix. Configure one port in columns for low level, which makes that column the selected port. Then configure the eight port in the row to display content in the selected column. Add a delay value and then select the next column that outputs the corresponding content. This kind of operation by 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

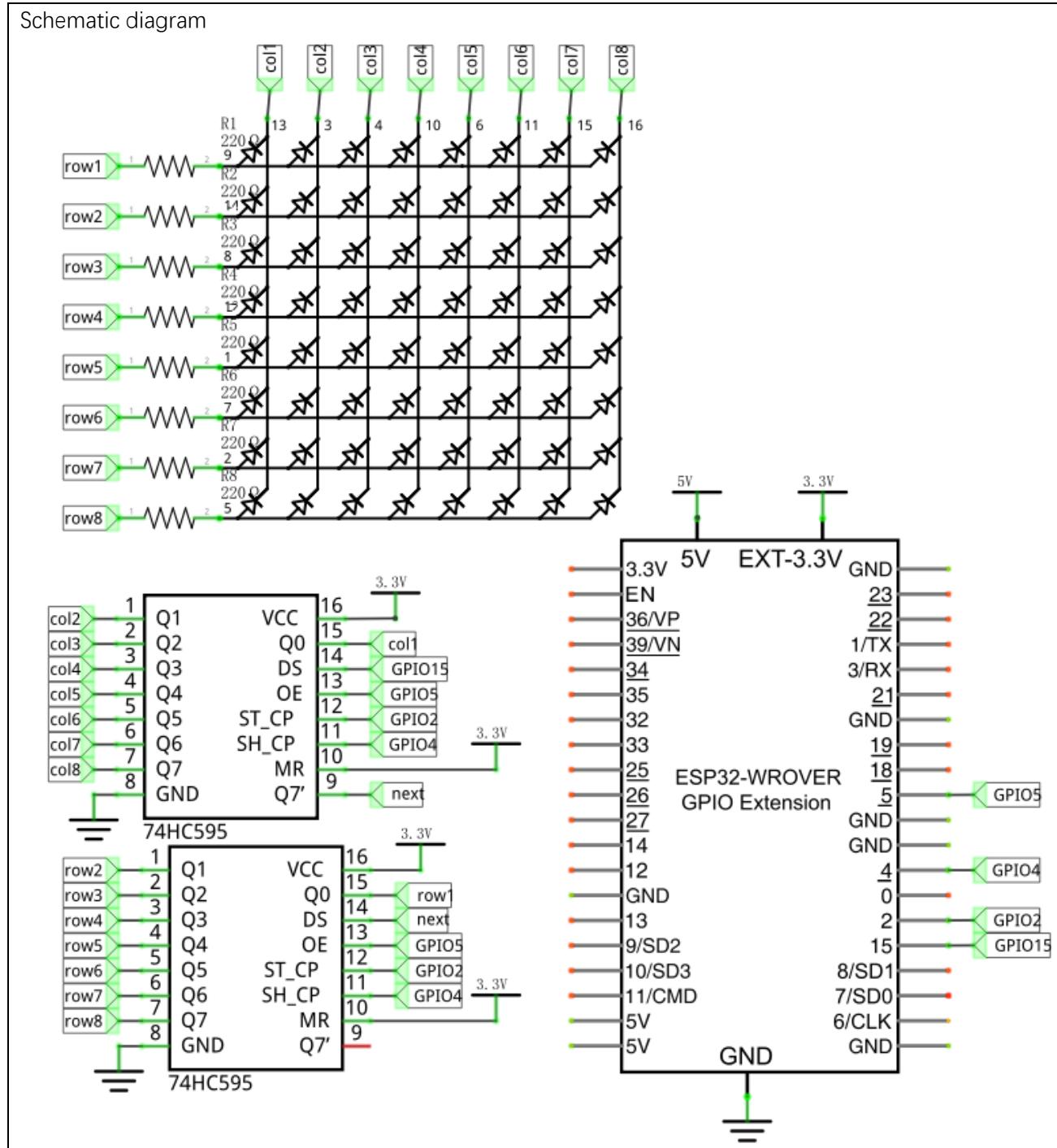
To begin, display the first column, then turn off the first column and display the second column. (and so on) .... turn off the seventh column and display the 8th column, and then start the process over from the first column again like the control of LED Bar Graph project. The whole process will be repeated rapidly in a loop. Due to the principle of optical afterglow effect and the vision persistence effect in human sight, we will see a picture of a smiling face directly rather than individual columns of LEDs turned ON one column at a time (although in fact this is the reality we cannot perceive).

Then, to save the number of GPIO, we use a 74HC595. When the first column is turned ON, set the lights that need to be displayed in the first column to "1", otherwise to "0", as shown in the above example, where the value of the first column is 0x1c. This value is sent to 74HC595 to control the display of the first column of the LEDMatrix. Following the above idea, turn OFF the display of the first column, then turn ON the second column, and then send the value of the second column to 74HC595 ..... Until each column is displayed, the LEDMatrix is displayed again from the first column.

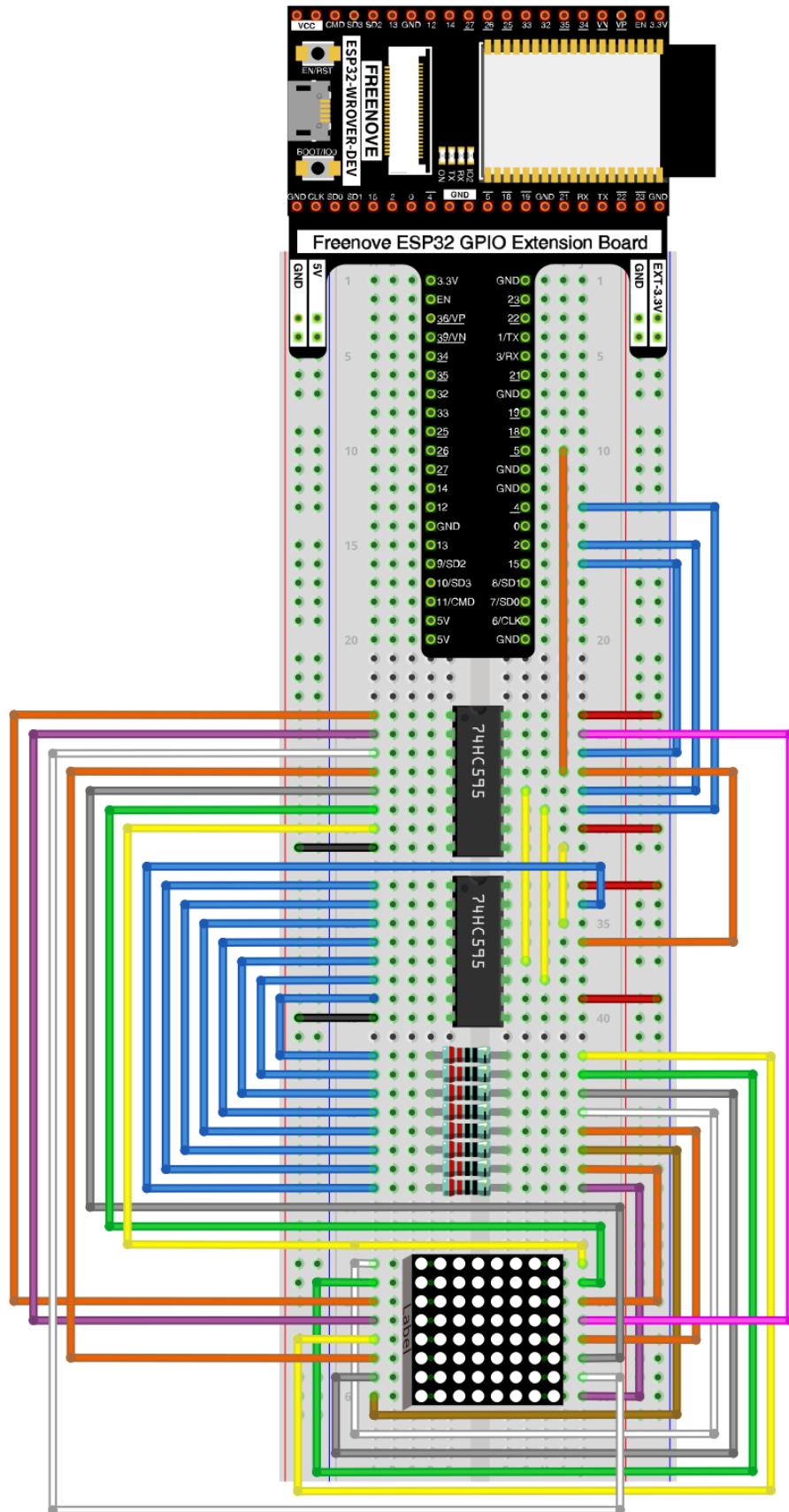
## Circuit

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

Schematic diagram



Hardware connection:



## Code

The following code will make LEDMatrix display a smiling face, and then display scrolling character "0-F". Open "Thonny", click "This computer" → "D:" → "Micropython\_Codes" → "Micropython\_Codes". Select "HC595.py", right click your mouse to select "Upload to /", wait for "HC595.py" to be uploaded to ESP32-WROVER and double click "16.3\_LED\_Matrix.py".

### 16.3\_LED\_Matrix

The screenshot shows the Thonny IDE interface. The title bar says "Thonny - D:\Micropython\_Codes\16.3\_LED\_Matrix\16.3\_LED\_Matrix.py @ 7 : 12". The menu bar includes File, Edit, View, Run, Device, Tools, and Help. Below the menu is a toolbar with icons for file operations. The left sidebar has two sections: "MicroPython device" and "This computer". In the "MicroPython device" section, there are files "boot.py" and "my74HC595.py". In the "This computer" section, there are files "16.3\_LED\_Matrix.py", "boot.py", and "my74HC595.py". A context menu is open over "my74HC595.py", with the "Upload to /" option highlighted in blue. The main editor window displays the code for "16.3\_LED\_Matrix.py". The bottom right corner shows a "Shell" window with the text: "MicroPython v1.12 on 2019-12-20; ESP32 module (spiram) with ESP32" and "Type "help()" for more information."

```
37 chip = Chip74HC595(15,2,4,5)
38 try:
39     while True:
40         for j in range(100):
41             cols=0x01
42             for i in range(8):
43                 chip.disable()
44                 chip.shiftOut(1,smilingFace[i])
45                 chip.shiftOut(1,~cols)
46                 time.sleep_us(500)
47                 cols<<=1
48                 chip.enable()
49             for i in range(136):
50                 for k in range(5):
51                     cols=0x01
52                     for j in range(i,8+i):
53                         chip.disable()
54                         chip.shiftOut(1,numdata[j])
55                         chip.shiftOut(0,~cols)
56                         cols<<=1
57                         chip.enable()
58                         time.sleep_us(500)
```

Click "Run current script", and the LED Matrix display a smiling face, and then display characters "0 to F" scrolling in a loop on the LED Matrix.

The following is the program code:

```

1 import time
2 from my74HC595 import Chip74HC595
3
4 smilingFace=[0x1C, 0x22, 0x51, 0x45, 0x45, 0x51, 0x22, 0x14]#^_^#
5 numdata = [
6     0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, # " "
7     0x00, 0x00, 0x3E, 0x41, 0x41, 0x3E, 0x00, 0x00, # "0"
8     0x00, 0x00, 0x21, 0x7F, 0x01, 0x00, 0x00, 0x00, # "1"
9     0x00, 0x00, 0x23, 0x45, 0x49, 0x31, 0x00, 0x00, # "2"
10    0x00, 0x00, 0x22, 0x49, 0x49, 0x36, 0x00, 0x00, # "3"
11    0x00, 0x00, 0x0E, 0x32, 0x7F, 0x02, 0x00, 0x00, # "4"
12    0x00, 0x00, 0x79, 0x49, 0x49, 0x46, 0x00, 0x00, # "5"
13    0x00, 0x00, 0x3E, 0x49, 0x49, 0x26, 0x00, 0x00, # "6"
14    0x00, 0x00, 0x60, 0x47, 0x48, 0x70, 0x00, 0x00, # "7"
15    0x00, 0x00, 0x36, 0x49, 0x49, 0x36, 0x00, 0x00, # "8"
16    0x00, 0x00, 0x32, 0x49, 0x49, 0x3E, 0x00, 0x00, # "9"
17    0x00, 0x00, 0x3F, 0x44, 0x44, 0x3F, 0x00, 0x00, # "A"
18    0x00, 0x00, 0x7F, 0x49, 0x49, 0x36, 0x00, 0x00, # "B"
19    0x00, 0x00, 0x3E, 0x41, 0x41, 0x22, 0x00, 0x00, # "C"
20    0x00, 0x00, 0x7F, 0x41, 0x41, 0x3E, 0x00, 0x00, # "D"
21    0x00, 0x00, 0x7F, 0x49, 0x49, 0x41, 0x00, 0x00, # "E"
22    0x00, 0x00, 0x7F, 0x48, 0x48, 0x40, 0x00, 0x00, # "F"
23    0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, # " "
24 ]
25
26 ,,
27 Pin(15)      -  74HC595(1).ds,
28 Pin(2)        -  74HC595(1).st_cp,
29 Pin(4)        -  74HC595(1).sh_cp,
30 Pin(5)        -  74HC595(1).oe
31
32 74HC595(1).q7' -  74HC595(2).ds,
33 Pin(2)        -  74HC595(2).st_cp,
34 Pin(4)        -  74HC595(2).sh_cp,
35 Pin(5)        -  74HC595(2).oe
36 ,,
37 chip = Chip74HC595(15, 2, 4, 5)
38 try:
39     while True:
40         for j in range(100):
41             cols=0x01
42             for i in range(8):
43                 chip.disable()

```

```

44     chip.shiftOut(1, smilingFace[i])
45     chip.shiftOut(1, ~cols)
46     time.sleep_us(500)
47     cols<<=1
48     chip.enable()
49     for i in range(136):
50         for k in range(5):
51             cols=0x01
52             for j in range(i, 8+i):
53                 chip.disable()
54                 chip.shiftOut(1, numdata[j])
55                 chip.shiftOut(0, ~cols)
56                 cols<<=1
57                 chip.enable()
58                 time.sleep_us(500)
59     except:
60         pass

```

Import time and my 74HC595 modules.

```

1 import time
2 from my74HC595 import Chip74HC595

```

Use a nesting of two for loops to display a smiling face.

```

20    for j in range(100):
21        cols=0x01
22        for i in range(8):
23            chip.disable()
24            chip.shiftOut(1, smilingFace[i])
25            chip.shiftOut(1, ~cols)
26            time.sleep_us(500)
27            cols<<=1
28            chip.enable()

```

Use a nesting of two for loops to display "0"-“F”.

```

32     for i in range(136):
33         for k in range(5):
34             cols=0x01
35             for j in range(i, 8+i):
36                 chip.disable()
37                 chip.shiftOut(1, numdata[j])
38                 chip.shiftOut(0, ~cols)
39                 cols<<=1
40                 chip.enable()
41                 time.sleep_us(500)

```

The amount of pins of ESP32 is limited, so we need to find ways to save pins. If we use ESP32's GPIO to control the LEDMatrix instead of 74HC595, we need 16 pins to drive LED matrix. In this example, we use two 74HC595 chips to drive the LED matrix, requiring only three pins, so that we could save the rest of 13 pins.

## Reference

### Class HC595

Before each use of HC595, please make sure HC595.py has been uploaded to “/” of ESP32, and then add the statement “**import HC595**” to the top of the python file.

**Chip74HC595()**: The object to control LEDMatrix.

**chip=Chip74HC595()** or **chip=Chip74HC595(15,2,4,5)**

**set\_bit\_data(data)**: Write data to 74HC595.

**clear()**: Clear the latch data of 74HC595.

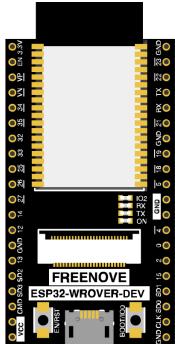
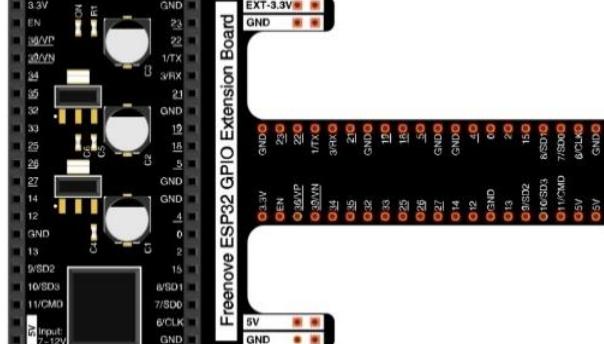
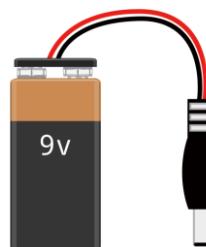
# Chapter 17 Relay & Motor

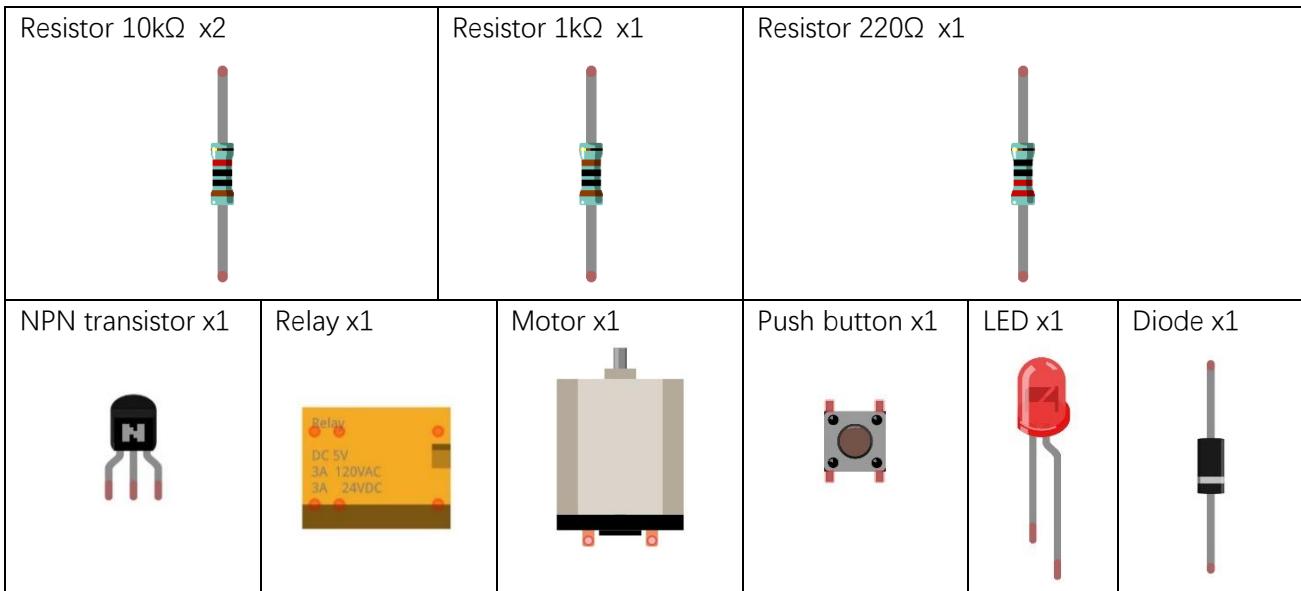
In this chapter, we will learn a kind of special switch module, Relay Module.

## Project 17.1 Relay & Motor

In this project, we will use a Push Button Switch indirectly to control the motor via a Relay.

### Component List

ESP32-WROVER x1		GPIO Extension Board x1	
Breadboard x1			
Jumper M/M			
9V battery (prepared by yourself) & battery line			

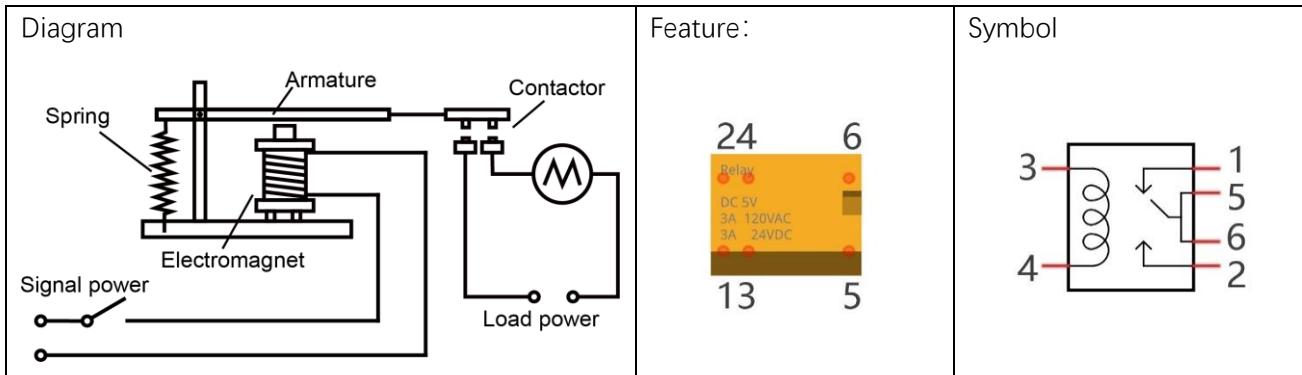


## Component knowledge

### Relay

A 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 are used in high power circuit. When the electromagnet is energized, it will attract contacts.

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



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.

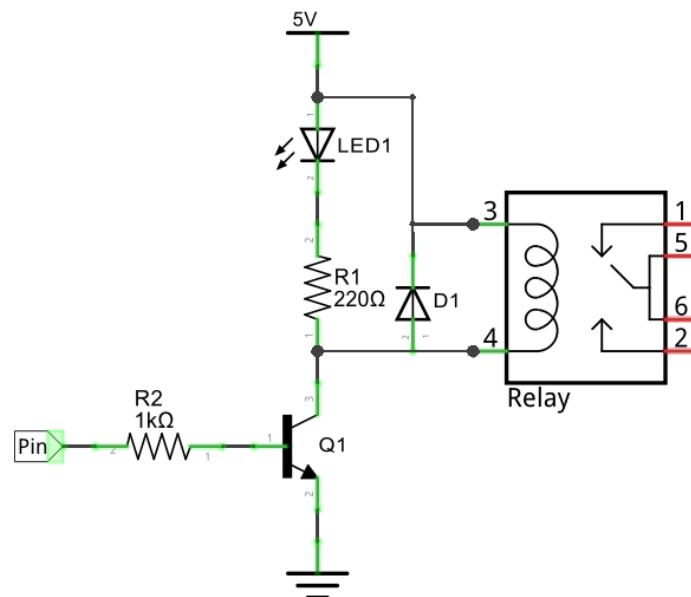
### Inductor

The symbol of Inductance is “L” and the unit of inductance is the “Henry” (H). Here is an example of how this can be encountered:  $1\text{H}=1000\text{mH}$ ,  $1\text{mH}=1000\mu\text{H}$ .

An 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. Inductors hinder the change of current passing through it. When the current passing through it increases, it will attempt to hinder the increasing trend of current; and when the current passing through it decreases, it will attempt to hinder the decreasing trend of current. So the current passing through inductor is not transient.

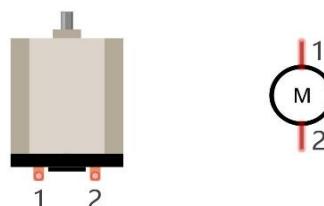


The reference circuit for relay is as follows. The coil of relays can be equivalent to that of inductors, when the transistor disconnects power supply of the relay, the current in the coil of the relay can't stop immediately, causing an impact on power supply. So a parallel diode will get connected to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

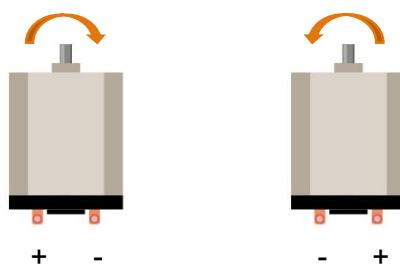


### Motor

A 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.

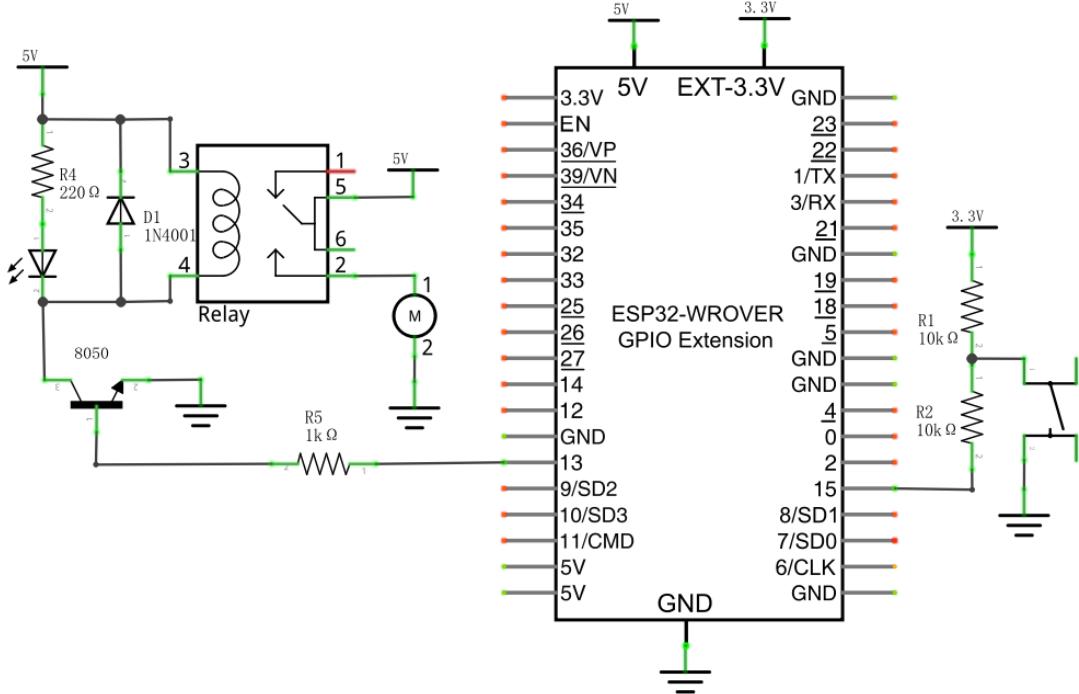


When a motor gets connected to the power supply, it will rotate in one direction. Reverse the polarity of power supply, then the motor rotates in opposite direction.

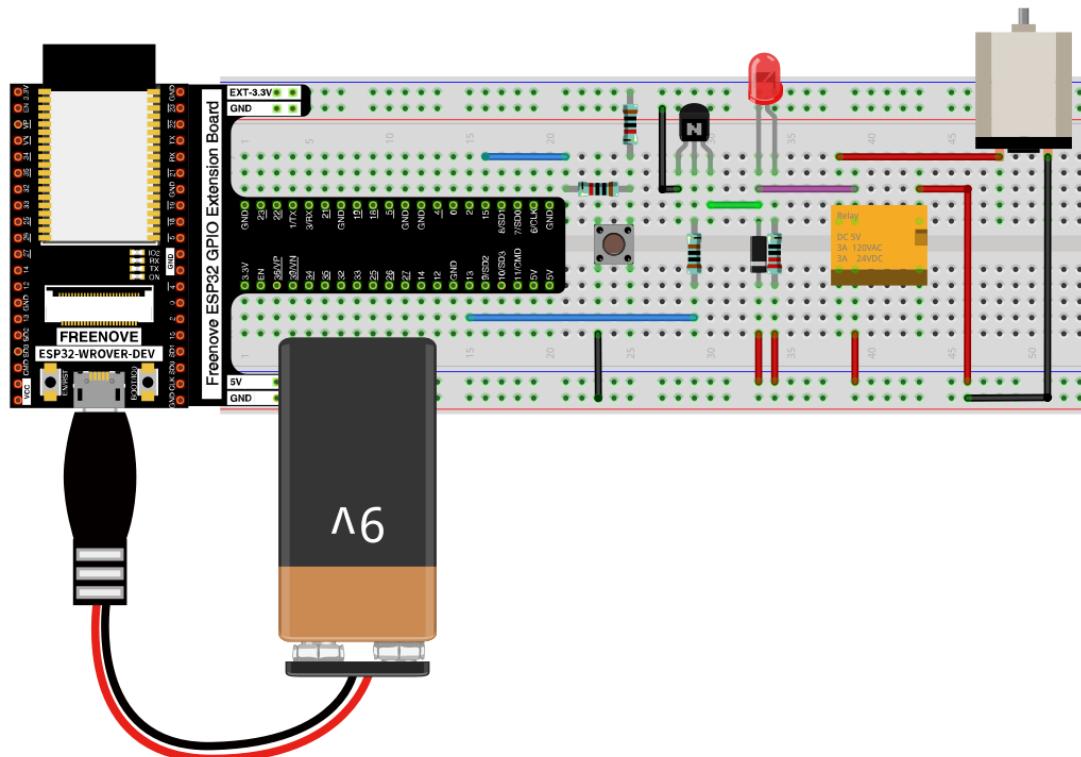


## Circuit

Schematic diagram



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



Note: the motor circuit uses a large current, about 0.2-0.3A without load. We recommend that you use a 9V battery to power the extension board.

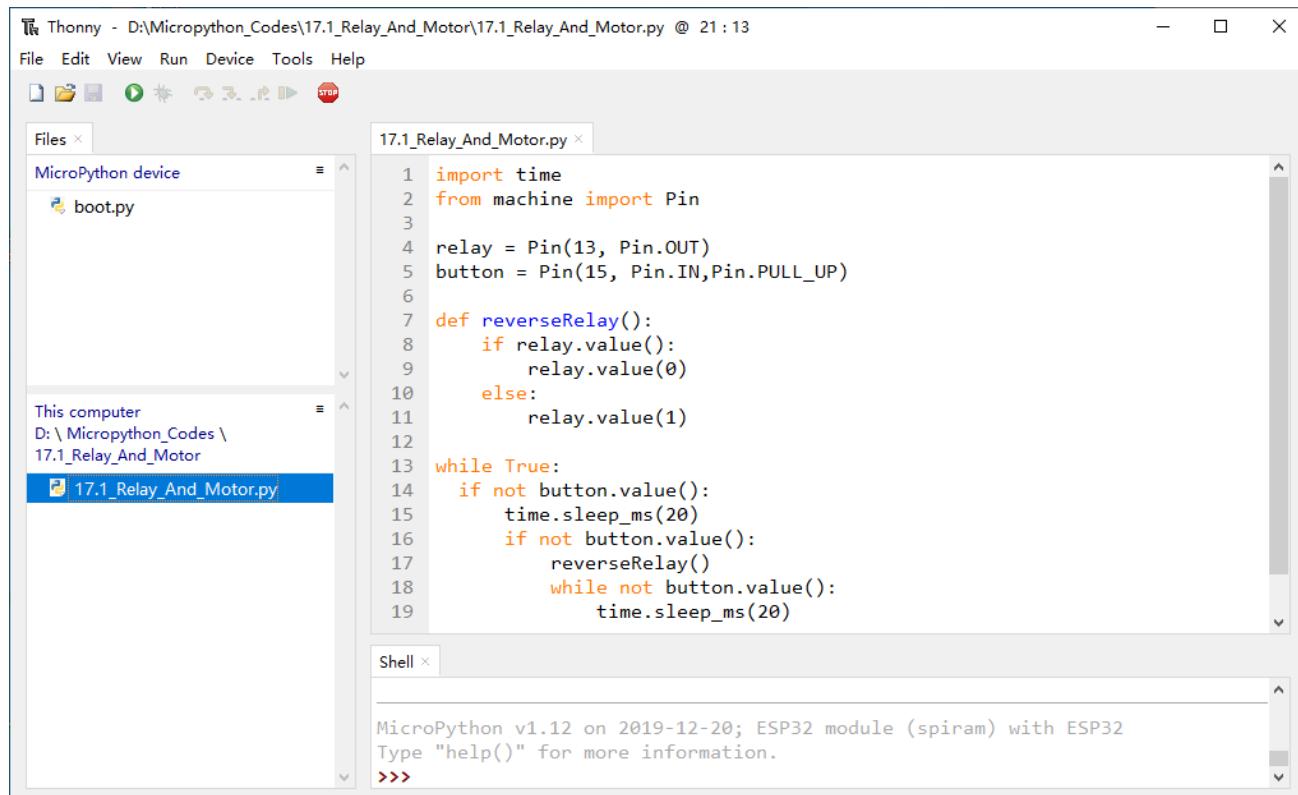
## Code

Use buttons to control the relays and motors.

Move the program folder “Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32/Python/Python\_Codes” to disk(D) in advance with the path of “D:/Micropython\_Codes”.

Open “Thonny”, click “This computer” → “D:” → “Micropython\_Codes” → “17.1\_Relay\_And\_Motor” and double click “17.1\_Relay\_And\_Motor.py”.

### 17.1\_Relay\_And\_Motor



```

import time
from machine import Pin

relay = Pin(13, Pin.OUT)
button = Pin(15, Pin.IN,Pin.PULL_UP)

def reverseRelay():
    if relay.value():
        relay.value(0)
    else:
        relay.value(1)

while True:
    if not button.value():
        time.sleep_ms(20)
        if not button.value():
            reverseRelay()
            while not button.value():
                time.sleep_ms(20)

```

Click “Run current script”. When the DC Motor is connected to a power supply, it will rotate in one direction. If you reverse the polarity of the power supply, the DC Motor will rotate in opposite direction.





The following is the program code:

```
1 import time
2 from machine import Pin
3
4 relay = Pin(13, Pin.OUT)
5 button = Pin(15, Pin.IN, Pin.PULL_UP)
6
7 def reverseRelay():
8     if relay.value():
9         relay.value(0)
10    else:
11        relay.value(1)
12
13 while True:
14     if not button.value():
15         time.sleep_ms(20)
16         if not button.value():
17             reverseRelay()
18             while not button.value():
19                 time.sleep_ms(20)
```

This section of code is basically the same as that of project Tablelamp. If you don't understand the program, you can click [here](#) to go back to the Tablelamp and study again.

## Project 17.2 Control Motor with Potentiometer

Control the direction and speed of the motor with a potentiometer.

### Component List

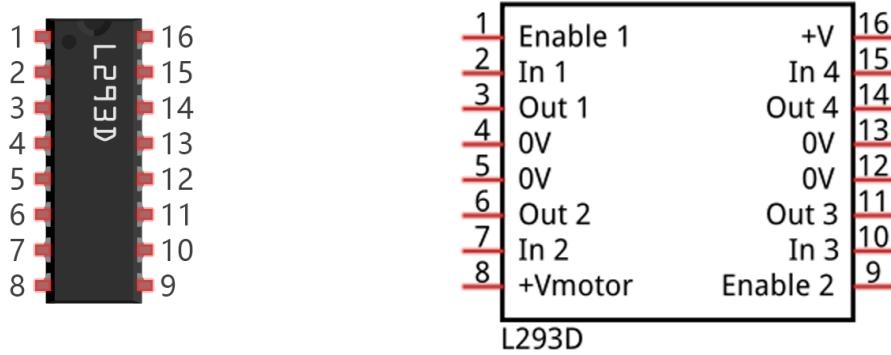
ESP32-WROVER x1	GPIO Extension Board x1
Breadboard x1	
Jumper M/M	9V battery (prepared by yourself) & battery line
Rotary potentiometer x1	Motor x1
L293D	



## Component knowledge

### L293D

L293D is an IC Chip (Integrated Circuit Chip) with a 4-channel motor drive. You can drive a Unidirectional DC Motor with 4 ports or a Bi-Directional DC Motor with 2 ports or a Stepper Motor (Stepper Motors are covered later in this Tutorial).



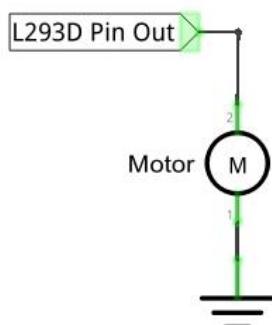
Port description of L293D module is as follows:

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 3.0~36V
+Vmotor	8	Positive electrode of load power supply, provide power supply for the Out pin x, the supply voltage is +V~36V

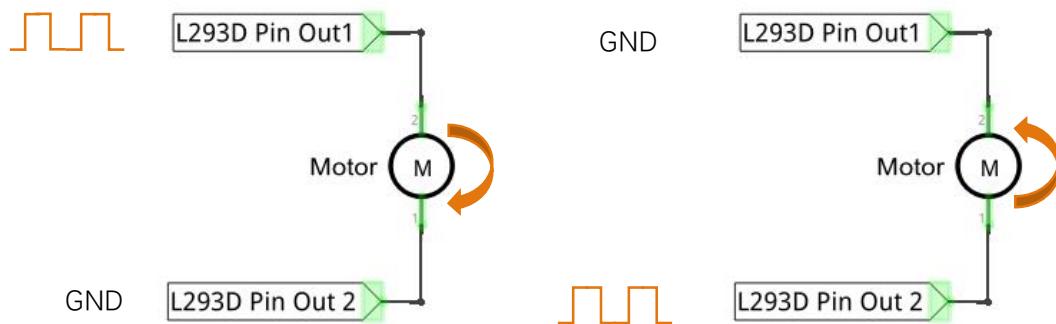
For more detail, please refer to the datasheet for this IC Chip.

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

The following connection option uses one channel of the L293D, which can control motor speed through the PWM, However the motor then can only rotate in one direction.



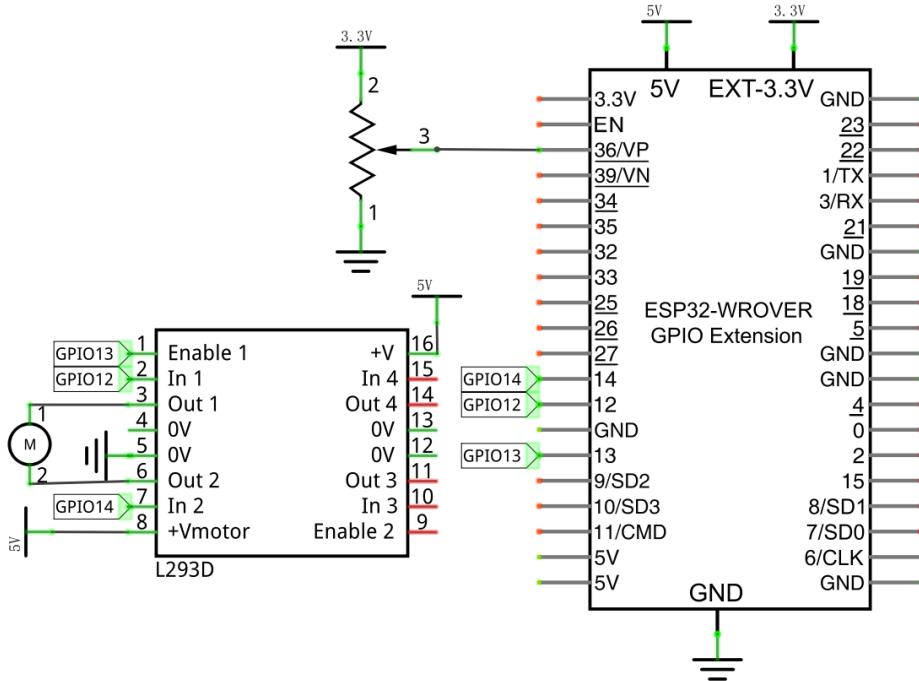
The following connection uses two channels of the L293D: one channel outputs the PWM wave, and the other channel connects to GND, therefore you can control the speed of the motor. When these two channel signals are exchanged, not only can they control the speed of motor, but also control the direction of the motor.



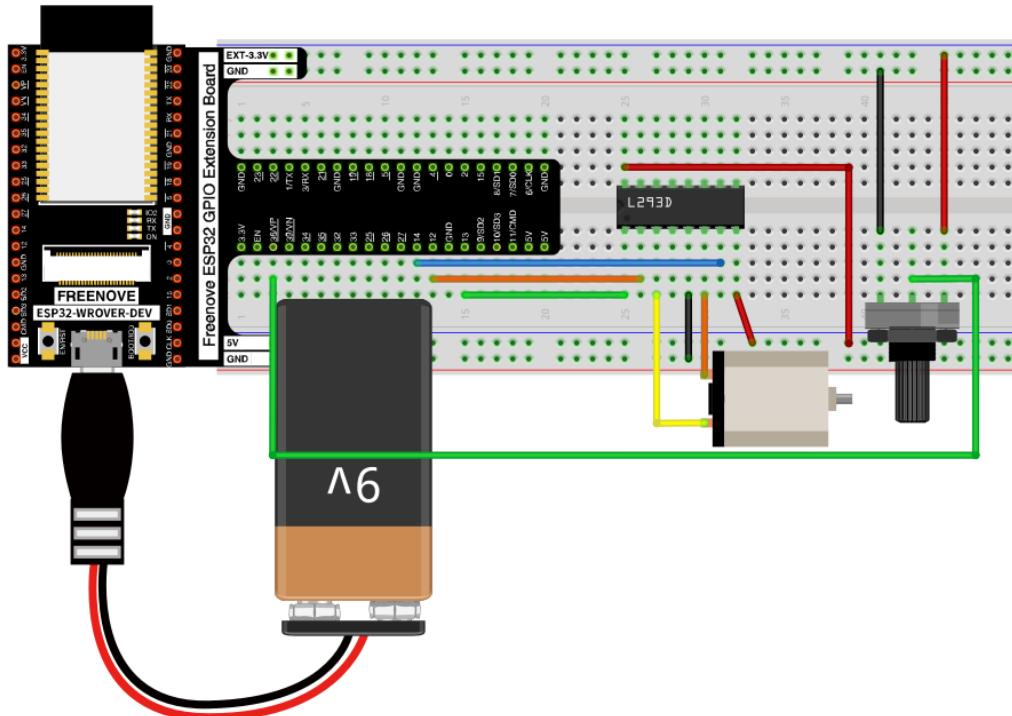
In practical use the motor is usually connected to channels 1 and 2 by outputting different levels to in1 and in2 to control the rotational direction of the motor, and output to the PWM wave to Enable1 port to control the motor's rotational speed. If the motor is connected to channel 3 and 4 by outputting different levels to in3 and in4 to control the motor's rotation direction, and output to the PWM wave to Enable2 pin to control the motor's rotational speed.

## Circuit

Schematic diagram



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



Note: the motor circuit uses A large current, about 0.2-0.3A without load. We recommend that you use a 9V battery to power the extension board.

## Code

Move the program folder “**Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32/Python/Python\_Codes**” to disk(D) in advance with the path of “**D:/Micropython\_Codes**”.

Open “Thonny”, click “This computer” → “D:” → “Micropython\_Codes” → “17.2\_Motor\_And\_Driver” and double click “17.2\_Motor\_And\_Driver.py”.

### 17.2\_Motor\_And\_Driver

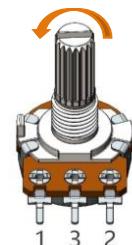
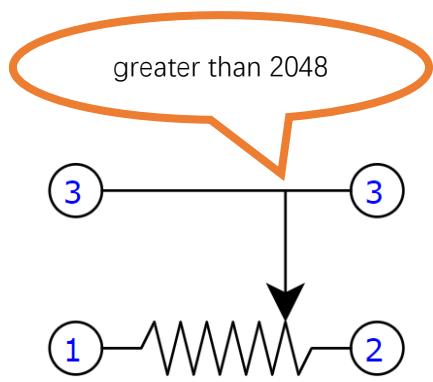
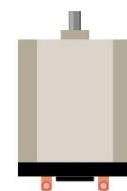
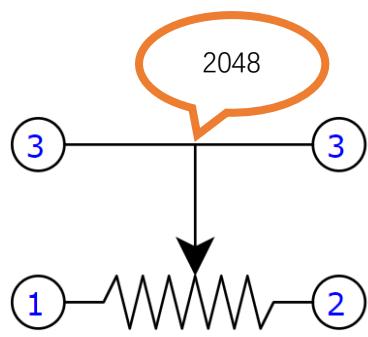
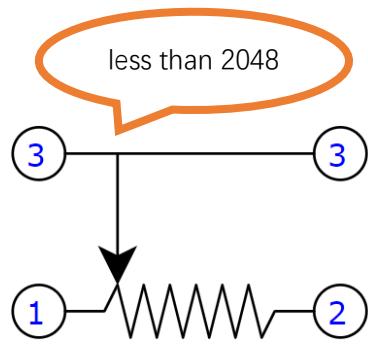
The screenshot shows the Thonny IDE interface. The title bar reads "Thonny - D:\Micropython\_Codes\17.2\_Motor\_And\_Driver\17.2\_Motor\_And\_Driver.py @ 36 : 17". The menu bar includes File, Edit, View, Run, Device, Tools, and Help. Below the menu is a toolbar with icons for file operations. The left sidebar has two sections: "MicroPython device" containing "boot.py" and "This computer" which lists "D:\ Micropython\_Codes\17.2\_Motor\_And\_Driver\17.2\_Motor\_And\_Driver.py". The main area displays the code for "17.2\_Motor\_And\_Driver.py". The code defines a function "driveMotor" that takes direction and speed parameters. It uses digital pins to control a motor and a PWM pin to set the speed. A "try" block contains a loop that reads a potentiometer value, calculates rotation speed based on the value, and calls the "driveMotor" function. The rotation direction is determined by the potentiometer value relative to 2048. The shell window at the bottom shows the MicroPython version and a prompt for help.

```
14 def driveMotor(dir,spd):
15     if dir:
16         in1Pin.value(1)
17         in2Pin.value(0)
18     else :
19         in1Pin.value(0)
20         in2Pin.value(1)
21     pwm.duty(spd)
22
23 try:
24     while True:
25         potenVal = adc.read()
26         rotationSpeed = potenVal - 2048
27         if (potenVal > 2048):
28             rotationDir = 1;
29         else:
30             rotationDir = 0;
31         rotationSpeed=int(math.fabs((potenVal-2047)//2)-1)
32         driveMotor(rotationDir,rotationSpeed)
33         time.sleep_ms(10)
34
```

Shell <

```
MicroPython v1.12 on 2019-12-20; ESP32 module (spiram) with ESP32
Type "help()" for more information.
>>>
```

Click “Run current script”, rotate the potentiometer in one direction and the motor speeds up slowly in one direction. Rotate the potentiometer in the other direction and the motor will slow down to stop. And then rotate it in the original direction to accelerate the motor.



The following is the Code:

```
1  from machine import ADC, Pin, PWM
2  import time
3  import math
4
5  in1Pin=Pin(12, Pin.OUT)
6  in2Pin=Pin(14, Pin.OUT)
7
8  enablePin=Pin(13, Pin.OUT)
9  pwm=PWM(enablePin, 10000, 512)
10
11 adc=ADC(Pin(36))
12 adc.atten(ADC.ATTN_11DB)
13 adc.width(ADC.WIDTH_12BIT)
14
15 def driveMotor(dir, spd):
16     if dir :
17         in1Pin.value(1)
18         in2Pin.value(0)
19     else :
20         in1Pin.value(0)
21         in2Pin.value(1)
22     pwm.duty(spd)
23
24 try:
25     while True:
26         potenVal = adc.read()
27         rotationSpeed = potenVal - 2048
28         if (potenVal > 2048):
29             rotationDir = 1;
30         else:
31             rotationDir = 0;
32         rotationSpeed=int(math.fabs((potenVal-2047)//2)-1)
33         driveMotor(rotationDir, rotationSpeed)
34         time.sleep_ms(10)
35 except:
36     pass
```



The ADC of ESP32 has a 12-bit accuracy, corresponding to a range from 0 to 4095. In this program, set the number 2048 as the midpoint. If the value of ADC is less than 2048, make the motor rotate in one direction. If the value of ADC is greater than 2048, make the motor rotate in the other direction. Subtract 2048 from the ADC value and take the absolute value, and then divide this result by 2 to be the speed of the motor.

```

26     potenVal = adc.read()
27     rotationSpeed = potenVal - 2048
28     if (potenVal > 2048):
29         rotationDir = 1;
30     else:
31         rotationDir = 0;
32     rotationSpeed=int(math.fabs((potenVal-2047)//2)-1)
33     driveMotor(rotationDir, rotationSpeed)
34     time.sleep_ms(10)

```

Initialize pins of L293D chip.

```

5     in1Pin=Pin(12, Pin.OUT)
6     in2Pin=Pin(14, Pin.OUT)
7
8     enablePin=Pin(13, Pin.OUT)
9     pwm=PWM(enablePin, 10000, 512)

```

Initialize ADC pins, set the range of voltage to 0-3.3V and the acquisition width of data to 0-4095.

```

11    adc=ADC(Pin(36))
12    adc.atten(ADC.ATTN_11DB)
13    adc.width(ADC.WIDTH_12BIT)

```

Function `driveMotor` is used to control the rotation direction and speed of the motor. The `dir` represents direction while `spd` refers to speed.

```

15    def driveMotor(dir, spd):
16        if dir :
17            in1Pin.value(1)
18            in2Pin.value(0)
19        else :
20            in1Pin.value(0)
21            in2Pin.value(1)
22        pwm.duty(spd)

```

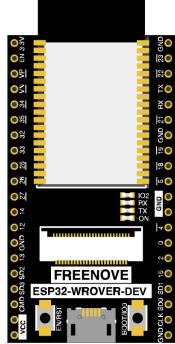
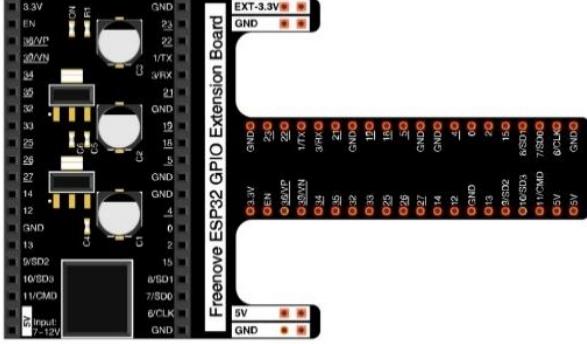
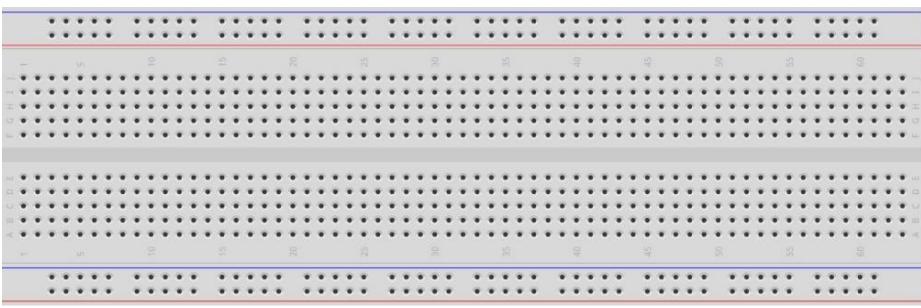
# Chapter 18 Servo

Previously, we learned how to control the speed and rotational direction of a Motor. In this chapter, we will learn about Servos which are a rotary actuator type motor that can be controlled to rotate to specific angles.

## Project 18.1 Servo Sweep

First, we need to learn how to make a Servo rotate.

### Component List

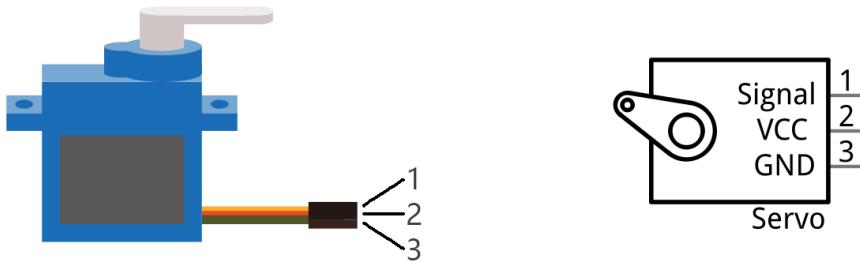
ESP32-WROVER x1	GPIO Extension Board x1
	
Breadboard x1	
Servo x1	Jumper M/M x3
	



## Component knowledge

### Servo

Servo is a compact package which consists of a DC Motor, a set of reduction gears to provide torque, a sensor and control circuit board. Most Servos only have a 180-degree range of motion via their "horn". Servos can output higher torque than a simple DC Motor alone and they are widely used to control motion in model cars, model airplanes, robots, etc. Servos have three wire leads which usually terminate to a male or female 3-pin plug. Two leads are for electric power: Positive (2-VCC, Red wire), Negative (3-GND, Brown wire), and the signal line (1-Signal, Orange wire) as represented in the Servo provided in your Kit.



We will use a 50Hz PWM signal with a duty cycle in a certain range to drive the Servo. The time interval of 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:

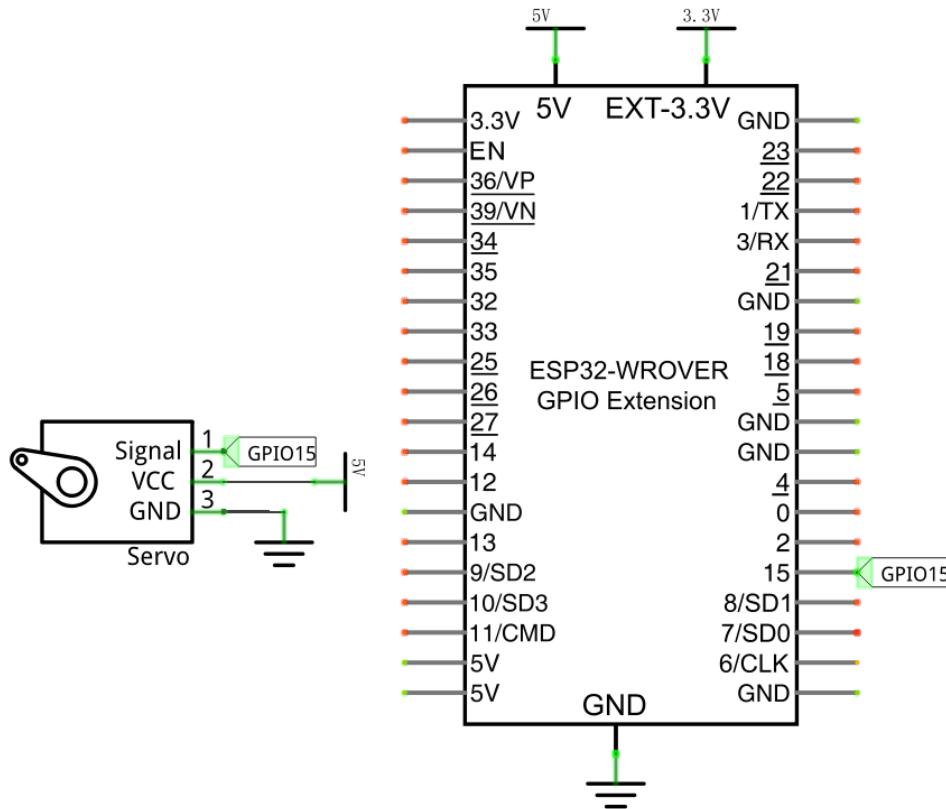
High level time	Servo angle
0.5ms	0 degree
1ms	45 degree
1.5ms	0 degree
2ms	45 degree
2.5ms	180 degree

When you change the Servo signal value, the Servo will rotate to the designated angle.

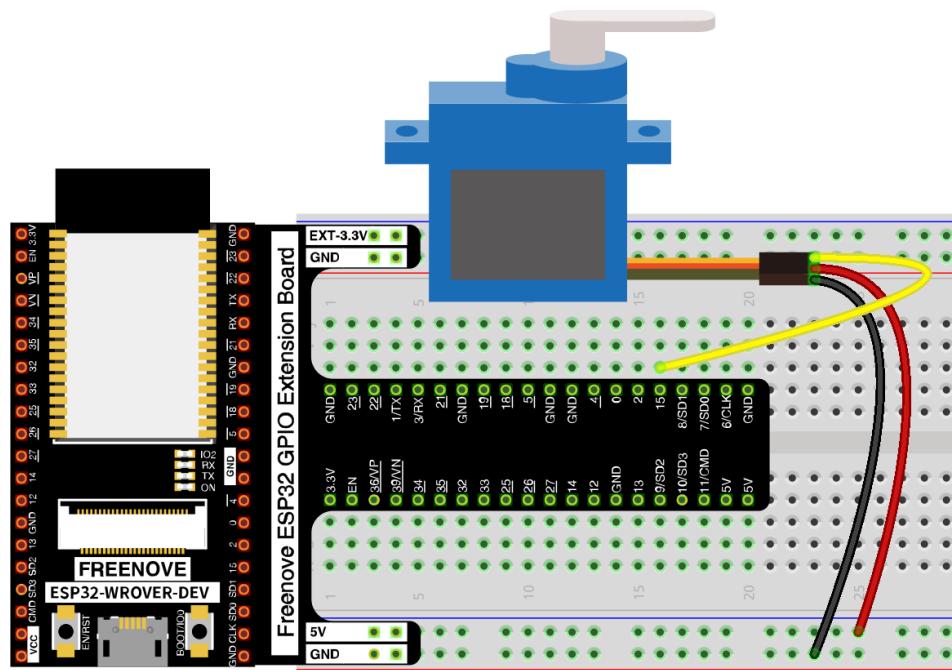
## Circuit

Use caution when supplying power to the Servo, it should be 5V. Make sure you do not make any errors when connecting the Servo to the power supply.

Schematic diagram



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



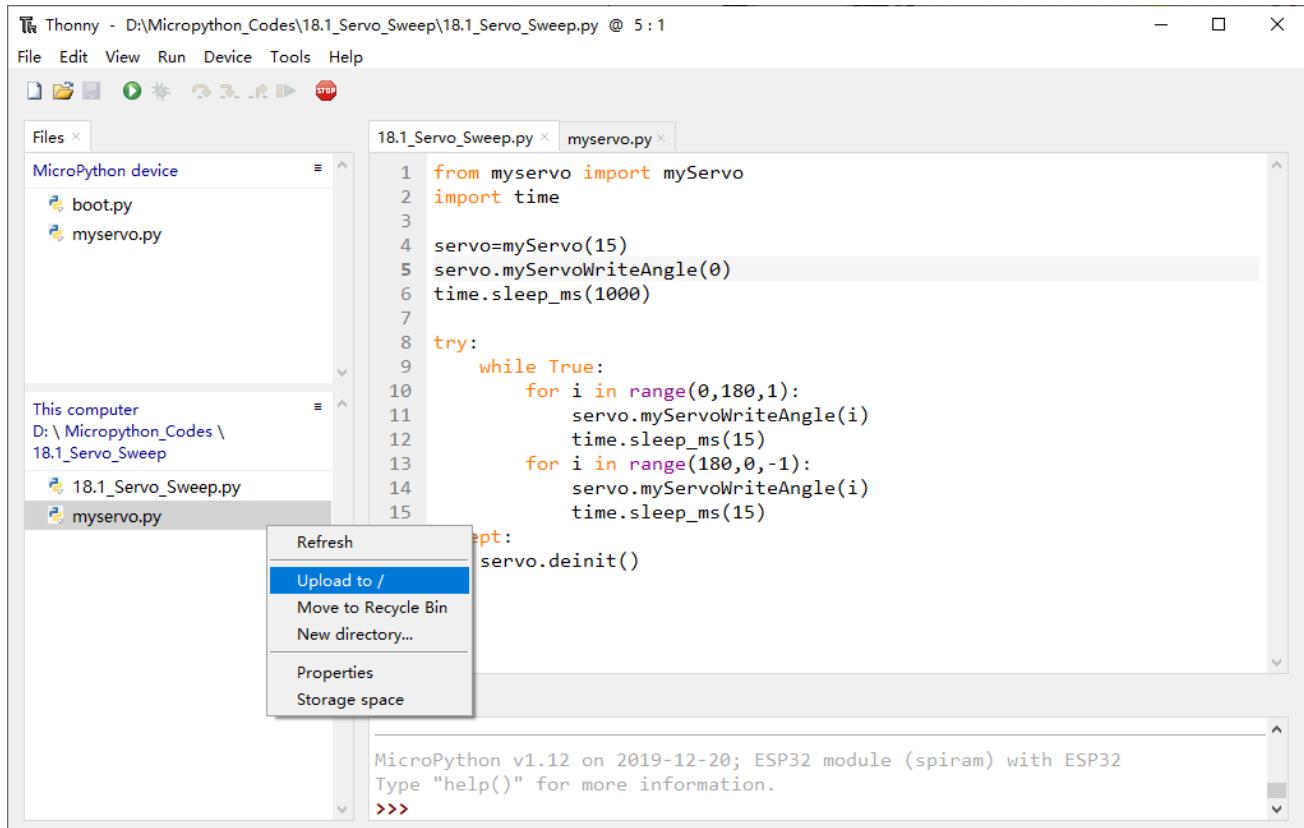
Any concerns? [✉ support@freenove.com](mailto:support@freenove.com)

## Code

Move the program folder “**Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32/Python/Python\_Codes**” to disk(D) in advance with the path of “**D:/Micropython\_Codes**”.

Open “Thonny”, click “This computer” → “D:” → “Micropython\_Codes” → “18.1\_Servo\_Sweep”. Select “myservo.py”, right click your mouse to select “Upload to /”, wait for “myservo.py” to be uploaded to ESP32-WROVER and then double click “18.1\_Servo\_Sweep.py”.

### 18.1\_Servo\_Sweep



```

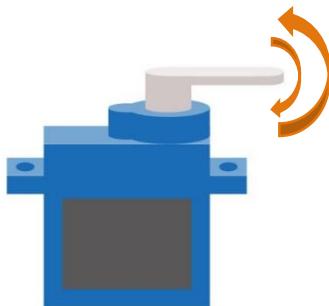
from myservo import myServo
import time

servo=myServo(15)
servo.myServoWriteAngle(0)
time.sleep_ms(1000)

try:
    while True:
        for i in range(0,180,1):
            servo.myServoWriteAngle(i)
            time.sleep_ms(15)
        for i in range(180,0,-1):
            servo.myServoWriteAngle(i)
            time.sleep_ms(15)
except:
    servo.deinit()

```

Click “Run current script”, the Servo will rotate from 0 degrees to 180 degrees and then reverse the direction to make it rotate from 180 degrees to 0 degrees and repeat these actions in an endless loop.



The following is the program code:

```
1 from myservo import myServo  
2 import time  
3  
4 servo=myServo(15)  
5 servo.myServoWriteAngle(0)  
6 time.sleep_ms(1000)  
7  
8 try:  
9     while True:  
10         for i in range(0, 180, 1):  
11             servo.myServoWriteAngle(i)  
12             time.sleep_ms(15)  
13         for i in range(180, 0, -1):  
14             servo.myServoWriteAngle(i)  
15             time.sleep_ms(15)  
16     except:  
17         servo.deinit()
```

Import myservo module.

```
1 from myservo import myServo
```

Initialize pins of the servo and set the starting point of the servo to 0 degree.

```
4 servo=myServo(15)  
5 servo.myServoWriteAngle(0)  
6 time.sleep_ms(1000)
```

Control the servo to rotate to a specified angle within the range of 0-180 degrees.

```
8 servo.myServoWriteAngle(i)
```

Use two for loops. The first one controls the servo to rotate from 0 degree to 180 degrees while the other controls it to rotate back from 180 degrees to 0 degree.

```
10     for i in range(0, 180, 1):  
11         servo.myServoWriteAngle(i)  
12         time.sleep_ms(15)  
13     for i in range(180, 0, -1):  
14         servo.myServoWriteAngle(i)  
15         time.sleep_ms(15)
```

## Reference

```
class myServo
```

Before each use of **myServo**, please make sure myservo.py has been uploaded to “/” of ESP32, and then add the statement “**from myservo import myServo**” to the top of the python file.

**myServo ()**: The object that controls the servo, with the default pin Pin(15), default frequency 50Hz and default duty cycle 512.

**myServoWriteDuty(duty)**: The function that writes duty cycle to control the servo.

**duty**: Range from 26 to 128, with 26 corresponding to the servo's 0 degree and 128 corresponding to 180 degrees.

**myServoWriteAngle(pos)**: Function that writes angle value to control the servo.

**pos**: Ranging from 0-180, corresponding the 0-180 degrees of the servo.

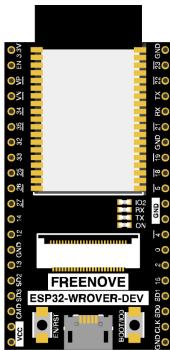
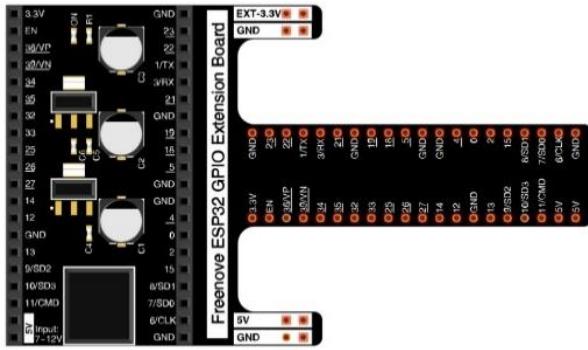
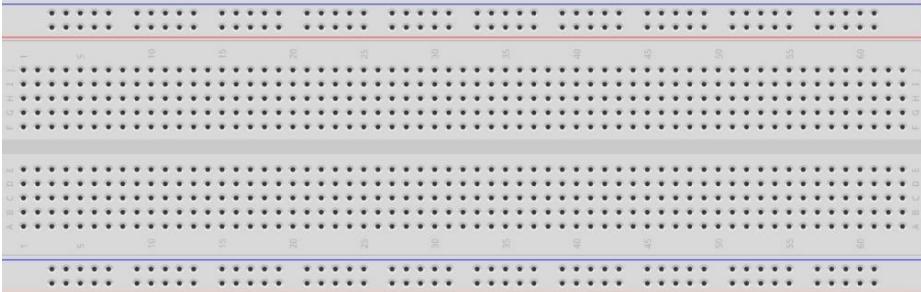
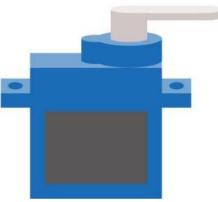
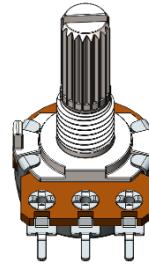
**myServoWriteTime(us)**: Writes time to control the servo.

**us**: Range from 500-2500, with 500 corresponding to the servo's 0 degree and 2500 corresponding to 180 degrees.

## Project 18.2 Servo Knop

Use a potentiometer to control the servo motor to rotate at any angle.

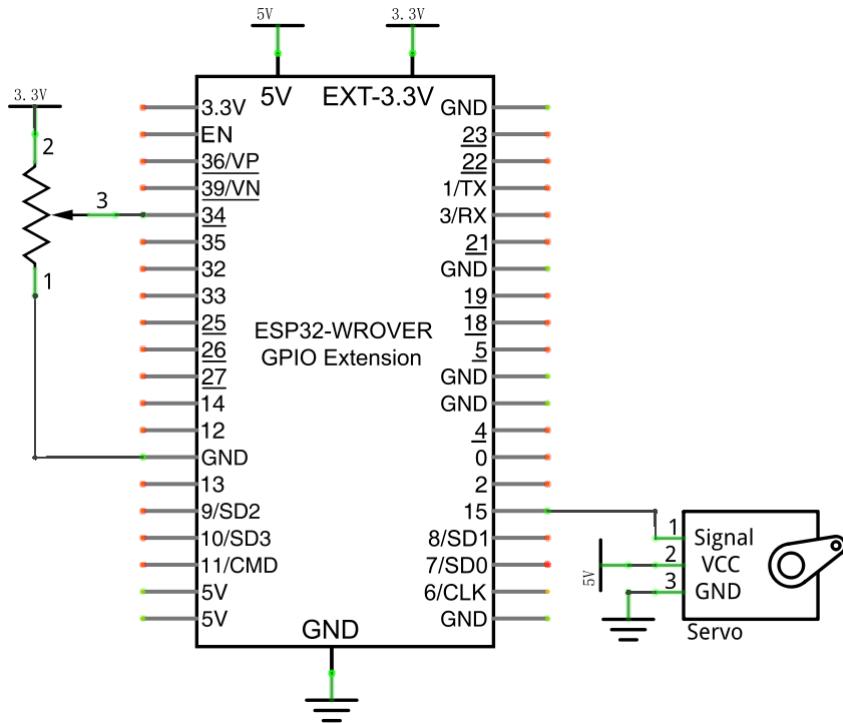
### Component List

ESP32-WROVER x1	GPIO Extension Board x1	
		
Breadboard x1		
Servo x1	Jumper M/M x6	Rotary potentiometer x1
		

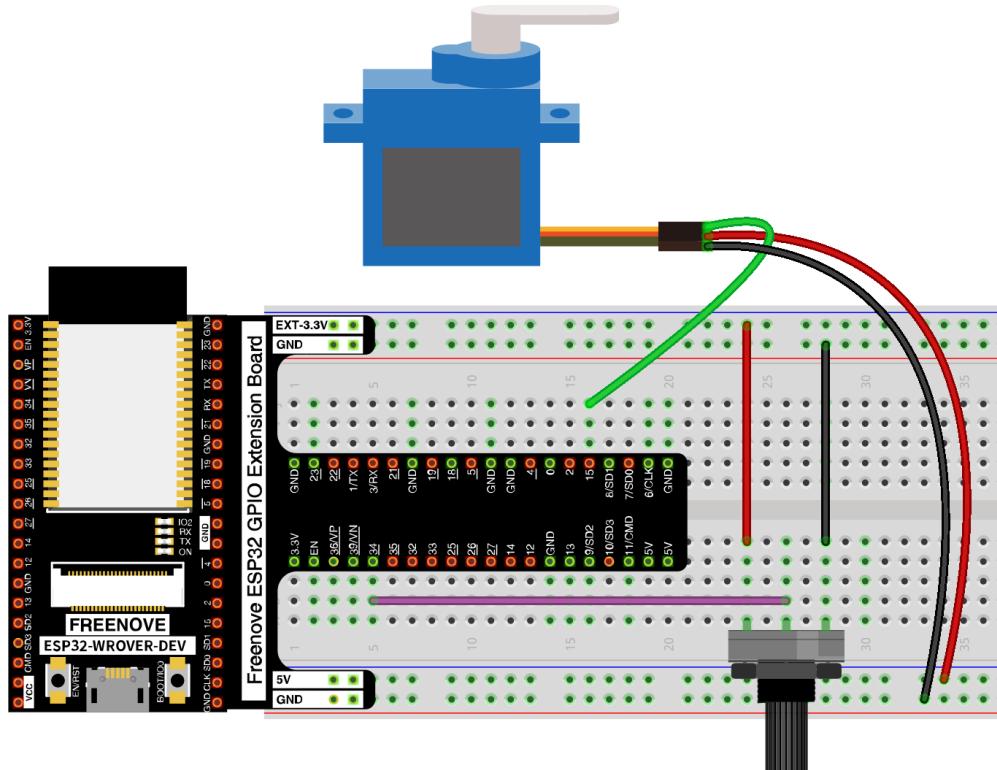
## Circuit

Use caution when supplying power to the Servo, it should be 5V. Make sure you do not make any errors when connecting the Servo to the power supply.

Schematic diagram



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



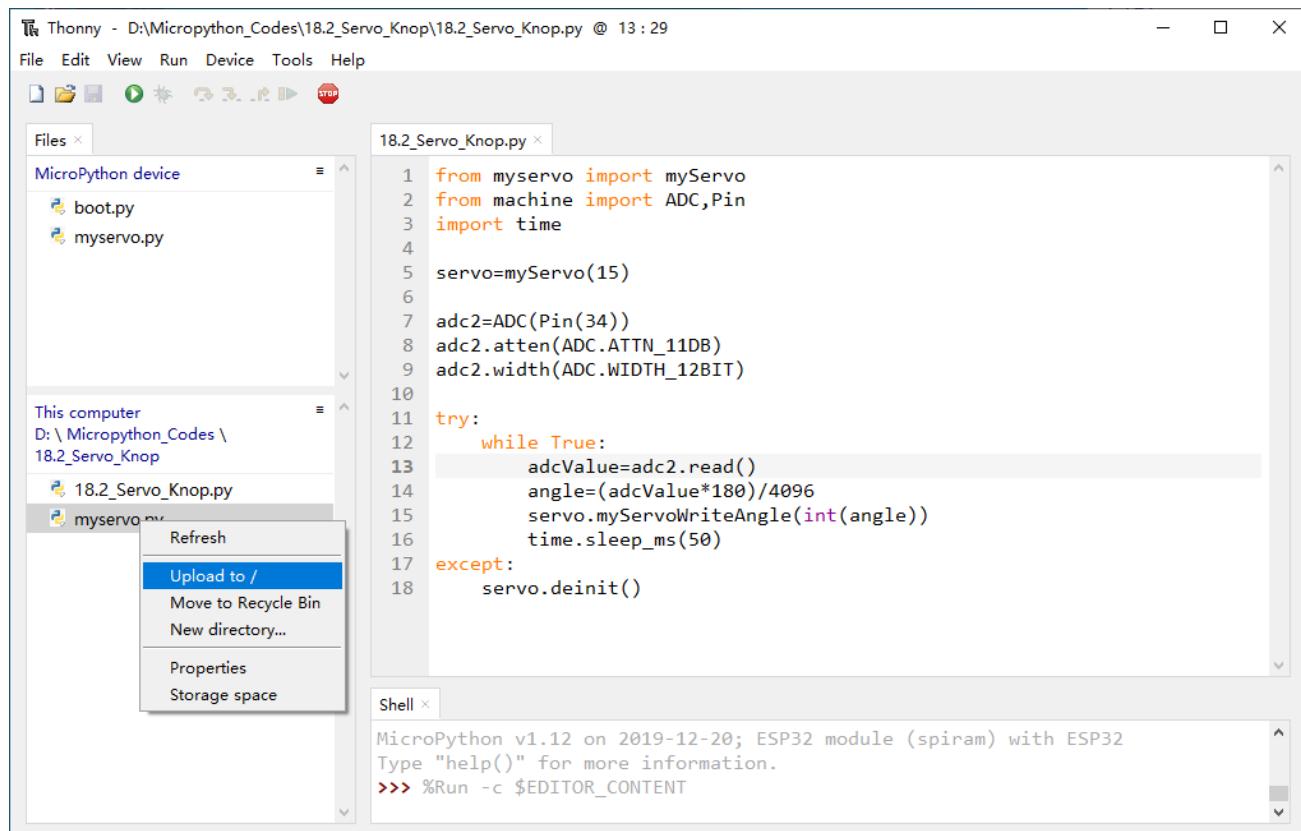
Any concerns? ✉ [support@freenove.com](mailto:support@freenove.com)

## Code

Move the program folder “**Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32/Python/Python\_Codes**” to disk(D) in advance with the path of “**D:/Micropython\_Codes**”.

Open “Thonny”, click “This computer” → “D:” → “Micropython\_Codes” → “18.2\_Servo\_Knop”. Select “myservo.py”, right click your mouse to select “Upload to /”, wait for “myservo.py” to be uploaded to ESP32-WROVER and then double click “18.2\_Servo\_Knop.py”.

### 18.2\_Servo\_Knop



The screenshot shows the Thonny IDE interface. The title bar says "Thonny - D:\Micropython\_Codes\18.2\_Servo\_Knop\18.2\_Servo\_Knop.py @ 13:29". The menu bar includes File, Edit, View, Run, Device, Tools, and Help. The left sidebar has a "Files" tab and a "MicroPython device" section containing "boot.py" and "myservo.py". Below that is a "This computer" section showing "D:\Micropython\_Codes\18.2\_Servo\_Knop" with files "18.2\_Servo\_Knop.py" and "myservo.py". A context menu is open over "18.2\_Servo\_Knop.py" with options: Refresh, Upload to / (which is highlighted in blue), Move to Recycle Bin, New directory..., Properties, and Storage space. The main editor window displays the code for "18.2\_Servo\_Knop.py":

```

1 from myservo import myServo
2 from machine import ADC,Pin
3 import time
4
5 servo=myServo(15)
6
7 adc2=ADC(Pin(34))
8 adc2.atten(ADC.ATTN_11DB)
9 adc2.width(ADC.WIDTH_12BIT)
10
11 try:
12     while True:
13         adcValue=adc2.read()
14         angle=(adcValue*180)/4096
15         servo.myServoWriteAngle(int(angle))
16         time.sleep_ms(50)
17 except:
18     servo.deinit()

```

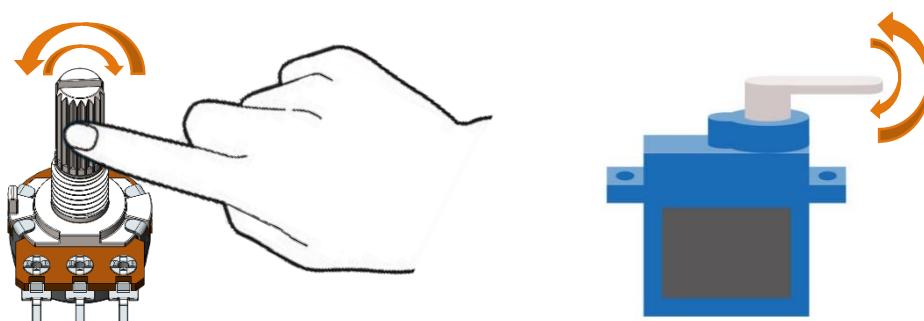
The bottom shell window shows the MicroPython environment:

```

MicroPython v1.12 on 2019-12-20; ESP32 module (spiram) with ESP32
Type "help()" for more information.
>>> %Run -c $EDITOR_CONTENT

```

Click “Run current script”, twist the potentiometer back and forth, and the servo motor rotates accordingly.



The following is the program code:

```
1  from myservo import myServo
2  from machine import ADC, Pin
3  import time
4
5  servo=myServo(15)
6
7  adc2=ADC(Pin(34))
8  adc2.atten(ADC.ATTN_11DB)
9  adc2.width(ADC.WIDTH_12BIT)
10
11 try:
12     while True:
13         adcValue=adc2.read()
14         angle=(adcValue*180)/4096
15         servo.myServoWriteAngle(int(angle))
16         time.sleep_ms(50)
17     except:
18         servo.deinit()
```

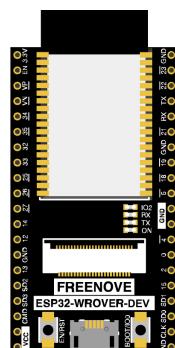
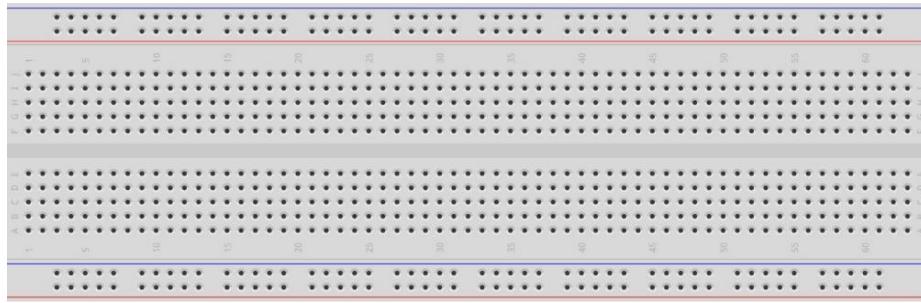
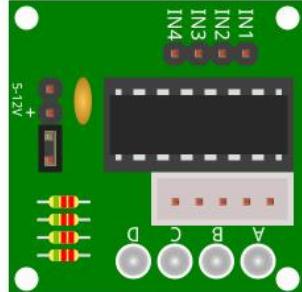
In this project, we will use Pin(34) of ESP32 to read the ADC value of the rotary potentiometer and then convert it to the angle value required by the servo and control the servo to rotate to the corresponding angle.

# Chapter 19 Stepper Motor

In this project, we will learn how to drive a Stepper Motor, and understand its working principle.

## Project 19.1 Stepping Motor

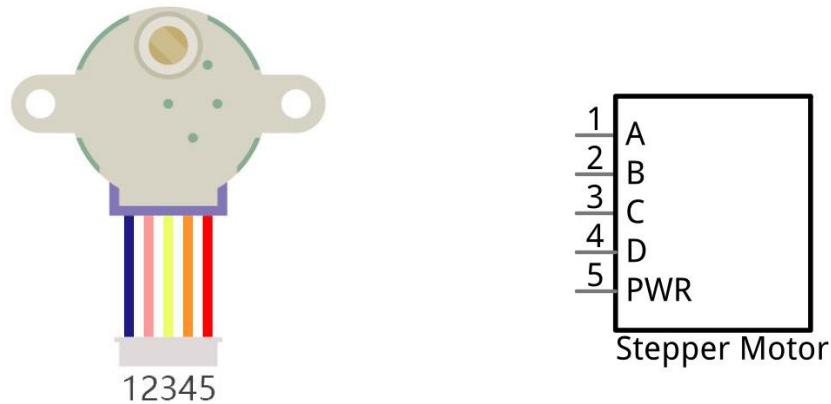
### Component List

ESP32-WROVER x1	GPIO Extension Board x1
	
Breadboard x1	
Stepping Motor x1	ULN2003 Stepper motorDriver x1
	
	Jumper F/M x6

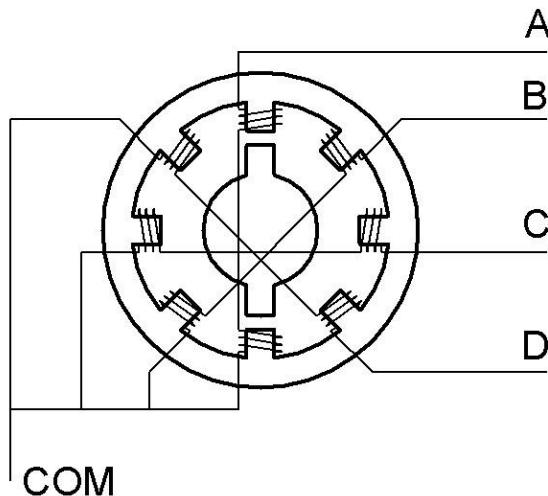
## Component knowledge

### Stepper Motor x1

Stepper Motors are an open-loop control device, which converts an electronic pulse signal into angular displacement or linear displacement. In a non-overload condition, the speed of the motor and the location of the stops depend only on the pulse signal frequency as well as the number of pulses and are not affected by changes in load as with a DC Motor. A small Four-Phase Deceleration Stepper Motor is shown here:

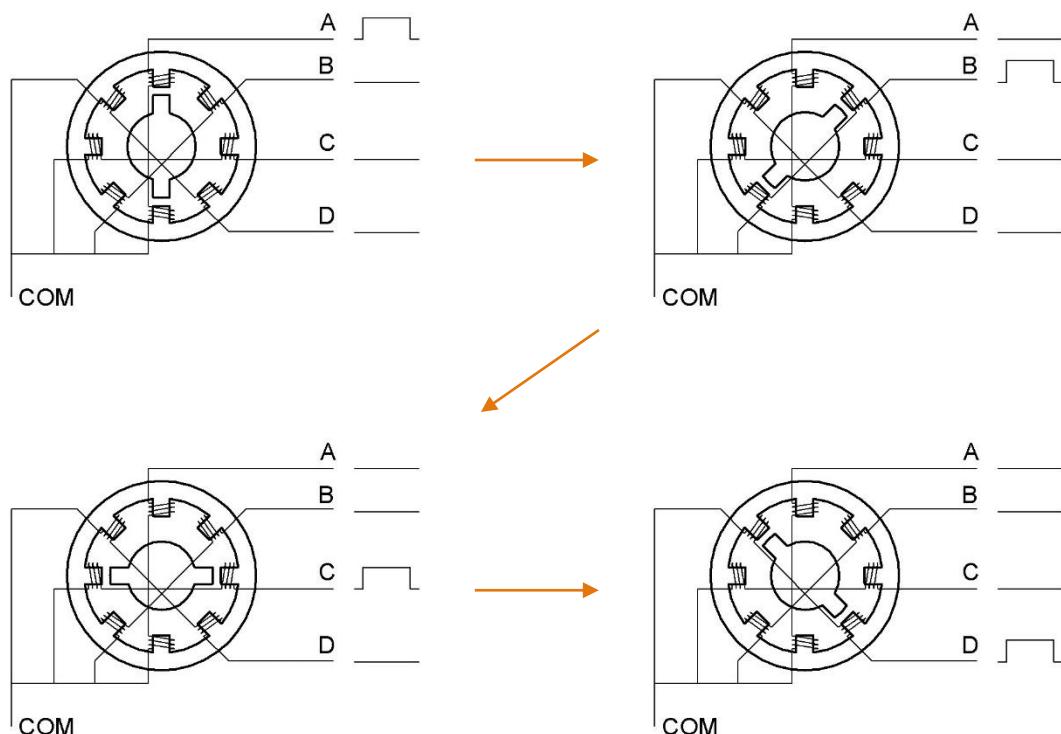


The electronic schematic diagram of a Four-Phase Stepper Motor is shown below:



The outside case or housing of the Stepper Motor is the Stator and inside the Stator is the Rotor. There are a specific number of individual coils, usually an integer multiple of the number of phases the motor has, when the Stator is powered ON, an electromagnetic field will be formed to attract a corresponding convex diagonal groove or indentation in the Rotor's surface. The Rotor is usually made of iron or a permanent magnet. Therefore, the Stepper Motor can be driven by powering the coils on the Stator in an ordered sequence (producing a series of "steps" or stepped movements).

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:  $A \rightarrow B \rightarrow C \rightarrow D \rightarrow A \rightarrow \dots$ . 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,  $D \rightarrow C \rightarrow B \rightarrow A \rightarrow D \rightarrow \dots$ , the rotor will rotate in anti-clockwise direction.

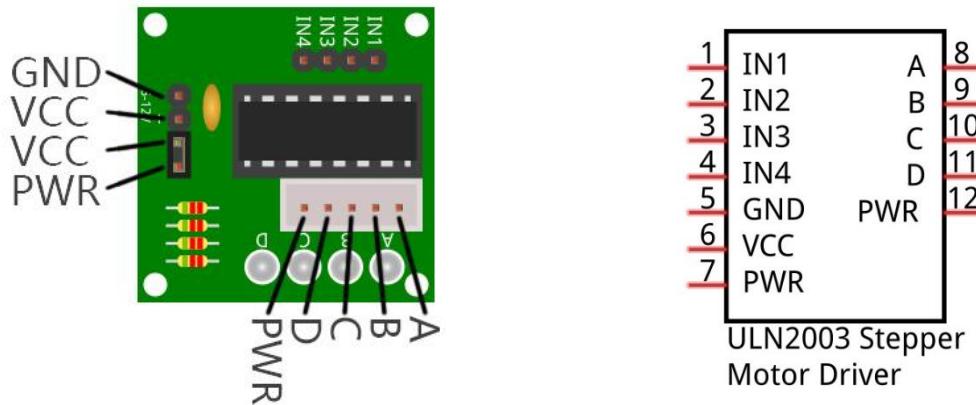
There are other methods to control Stepper Motors, such as: connect A phase, then connect A B phase, the stator will be located in the center of A B, which is called a half-step. This method can improve the stability of the Stepper Motor and reduces noise. The sequence of powering the coils looks like this:  $A \rightarrow AB \rightarrow B \rightarrow BC \rightarrow C \rightarrow CD \rightarrow D \rightarrow DA \rightarrow A \rightarrow \dots$ , the rotor will rotate in accordance to this sequence at a half-step at a time, called four-steps, eight-part. Conversely, if the coils are powered ON in the reverse order the Stepper Motor will rotate in the opposite direction.

The stator in the Stepper Motor we have supplied has 32 magnetic poles. Therefore, to complete one full revolution requires 32 full steps. The rotor (or output shaft) of the Stepper Motor is connected to a speed reduction set of gears and the reduction ratio is 1:64. Therefore, the final output shaft (exiting the Stepper Motor's housing) requires  $32 \times 64 = 2048$  steps to make one full revolution.



### ULN2003 Stepping motor driver

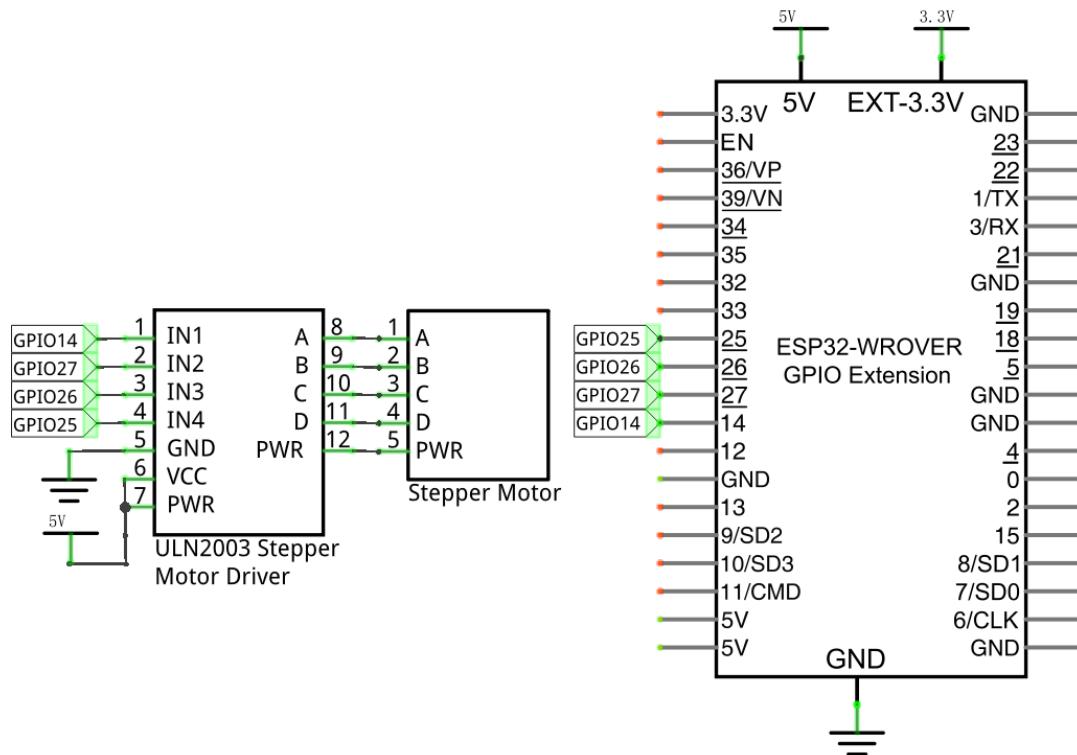
A ULN2003 Stepper Motor Driver is used to convert weak signals into more powerful control signals in order to drive the Stepper Motor. In the illustration below, the input signal IN1-IN4 corresponds to the output signal A-D, and 4 LEDs are integrated into the board to indicate the state of these signals. The PWR interface can be used as a power supply for the Stepper Motor. By default, PWR and VCC are connected.



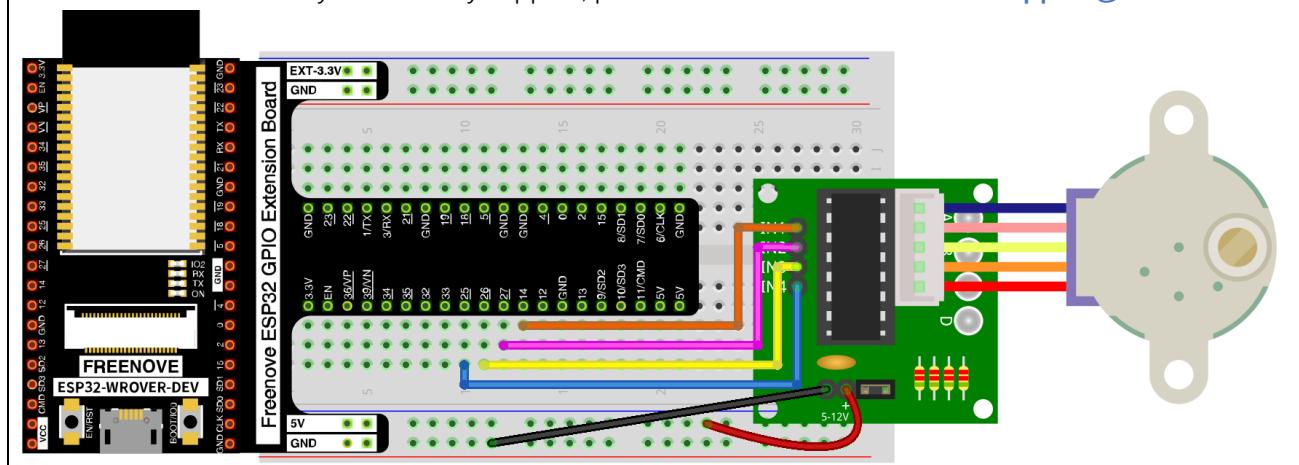
## Circuit

When building the circuit, note that rated voltage of the Stepper Motor is 5V, and we need to use the Breadboard power supply independently. Additionally, the Breadboard power supply needs to share Ground with ESP32.

Schematic diagram



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





## Code

This code uses the four-step, four-part mode to drive the Stepper Motor in the clockwise and anticlockwise directions.

Move the program folder “**Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32/Python/Python\_Codes**” to disk(D) in advance with the path of “**D:/Micropython\_Codes**”.

Open “Thonny”, click “This computer” → “D:” → “Micropython\_Codes” → “19.1\_Stepping\_Motor”. Select “stepmotor.py”, right click your mouse to select “Upload to /”, wait for “myservo.py” to be uploaded to ESP32-WROVER and then double click “19.1\_Stepping\_Motor.py”.

### 19.1\_Stepping\_Motor

```

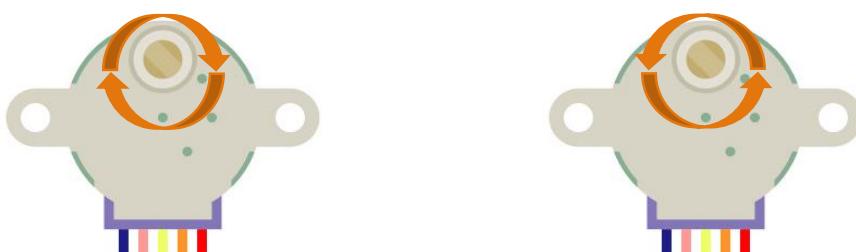
from stepmotor import mystepmotor
import time

myStepMotor=mysstepmotor(14,27,26,25)

try:
    while True:
        myStepMotor.moveSteps(1,32*64,2000)
        myStepMotor.stop()
        time.sleep_ms(1000)
        myStepMotor.moveSteps(0,32*64,2000)
        myStepMotor.stop()
        time.sleep_ms(1000)
except:
    pass

```

Click “Run current script”, the stepper motor will rotate 360° clockwise and stop for 1s, and then rotate 360° anticlockwise and stop for 1s. And it will repeat this action in an endless loop.



The following is the program code:

```
1 from stepmotor import mystepmotor  
2 import time  
3  
4 myStepMotor=mystepmotor(14, 27, 26, 25)  
5  
6 try:  
7     while True:  
8         myStepMotor.moveSteps(1, 32*64, 2000)  
9         myStepMotor.stop()  
10        time.sleep_ms(1000)  
11        myStepMotor.moveSteps(0, 32*64, 2000)  
12        myStepMotor.stop()  
13        time.sleep_ms(1000)  
14 except:  
15     pass
```

Import time and stepmotor modules.

```
1 from stepmotor import mystepmotor  
2 import time
```

In this project, we define four pins to drive the stepper motor.

```
4 myStepMotor=mystepmotor(14, 27, 26, 25)
```

Call the function moveSteps to control the stepper motor to rotate for 360° and then call function stop() to stop it.

```
8     myStepMotor.moveSteps(1, 32*64, 2000)  
9     myStepMotor.stop()
```

Repeatedly control the stepmotor to rotate 360° clockwise and then rotate 360° anti-clockwise.

```
7     while True:  
8         myStepMotor.moveSteps(1, 32*64, 2000)  
9         myStepMotor.stop()  
10        time.sleep_ms(1000)  
11        myStepMotor.moveSteps(0, 32*64, 2000)  
12        myStepMotor.stop()  
13        time.sleep_ms(1000)
```

## Reference

**class myServo**

Before each use of the object **mystepper**, please make sure that stepmotor.py has been uploaded to "/" of ESP32, and then add the statement "**from stepmotor import mystepper**" to the top of the python file.

**mystepper()**: The object to control the stepper motor. The default control pins are Pin(14), Pin(27), Pin(26) and Pin(25).

**moveSteps(direction,steps,us)**: Control the stepper motor to rotate a specified number of steps.

**direction**: The rotation direction of stepper motor.

**Steps**: Rotation steps of the stepper motor.

**us**: Time required by the stepper motor to rotate for one step.

**moveAround(direction,turns,us)**: Control the stepper motor to rotate a specific number of turns.

**Turns**: Number of turns that the stepper motor rotates.

**moveAngle(direction,angles,us)**: Control the stepper motor to rotate a specific angle.

**Angles**: Rotation angles that the stepper motor rotates.

**stop()**: Stop the stepper motor.

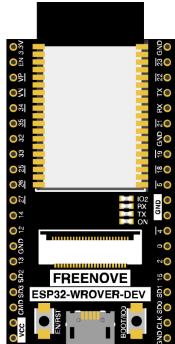
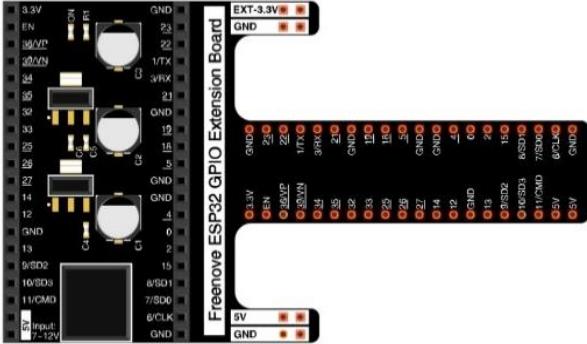
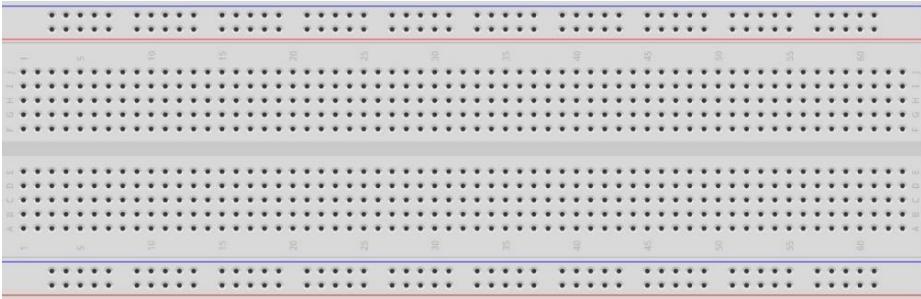
# Chapter 20 LCD1602

In this chapter, we will learn about the LCD1602 Display Screen

## Project 20.1 LCD1602

In this section we learn how to use lcd1602 to display something.

### Component List

ESP32-WROVER x1	GPIO Extension Board x1
 	
Breadboard x1	
LCD1602 Module x1	Jumper F/M x4



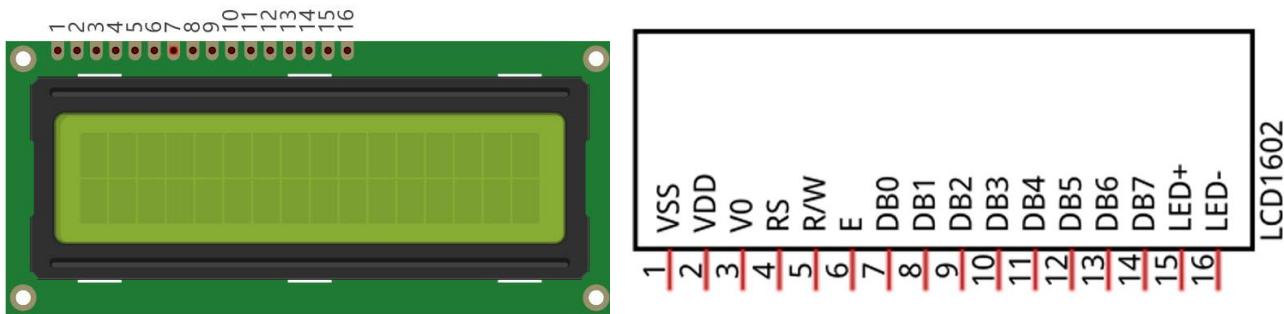
## Component knowledge

### I2C communication

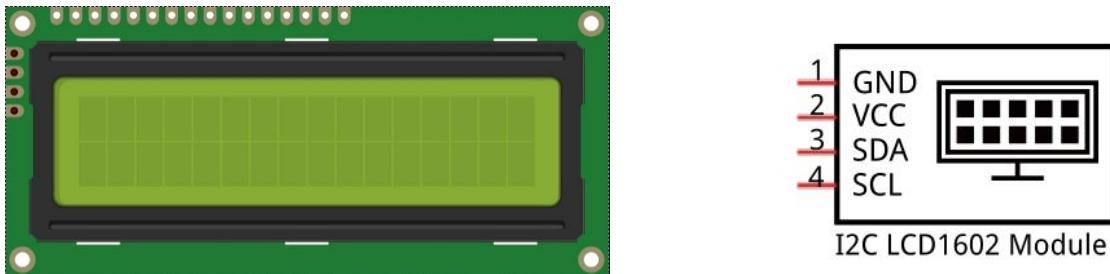
I2C (Inter-Integrated Circuit) is a two-wire serial communication mode, which can be used for the connection of micro controllers and their peripheral equipment. Devices using I2C communication must be connected to the serial data (SDA) line, and serial clock (SCL) line (called I2C bus). Each device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

### LCD1602 communication

The LCD1602 Display Screen can display 2 lines of characters in 16 columns. It is capable of displaying numbers, letters, symbols, ASCII code and so on. As shown below is a monochrome LCD1602 Display Screen along with its circuit pin diagram

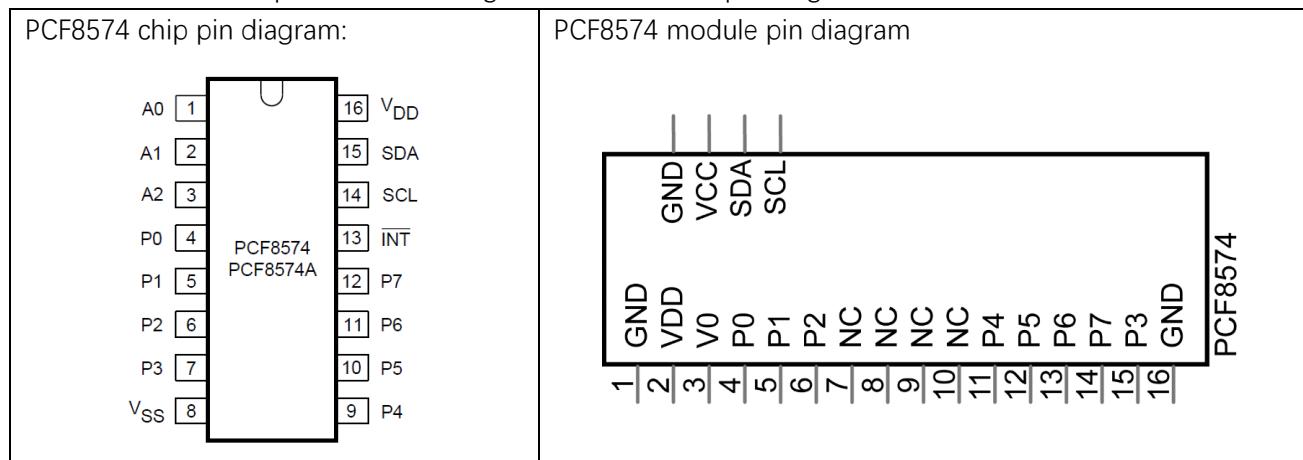


I2C LCD1602 Display Screen integrates an I2C interface, which connects the serial-input & parallel-output module to the LCD1602 Display Screen. This allows us to use only 4 lines to operate the LCD1602.

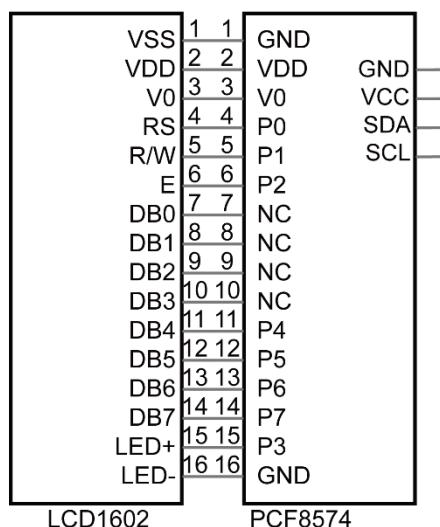


The serial-to-parallel IC chip used in this module is PCF8574T (PCF8574AT), and its default I2C address is 0x27(0x3F). You can also view the ESP32 bus on your I2C device address through command "i2cdetect -y 1".

Below is the PCF8574 pin schematic diagram and the block pin diagram:



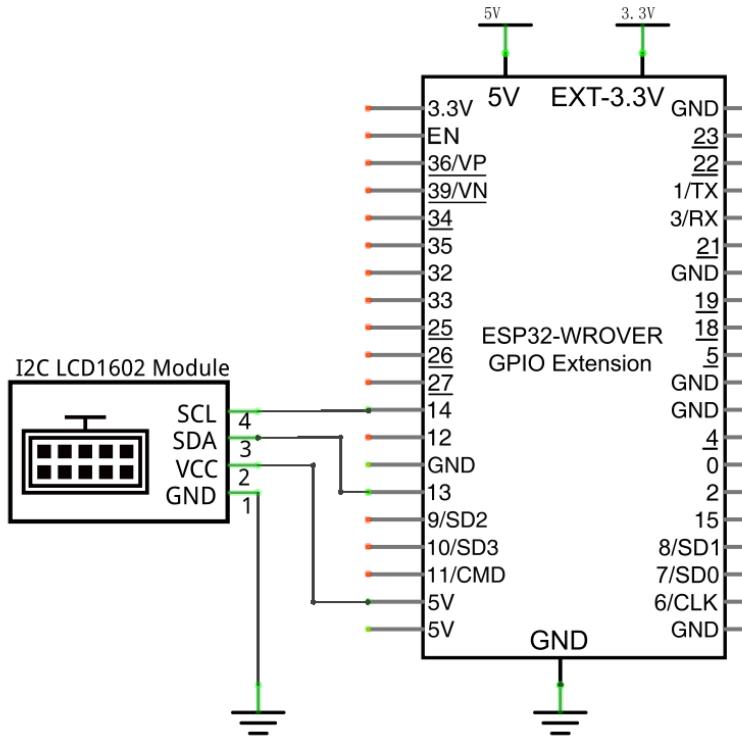
PCF8574 module pin and LCD1602 pin are corresponding to each other and connected with each other:



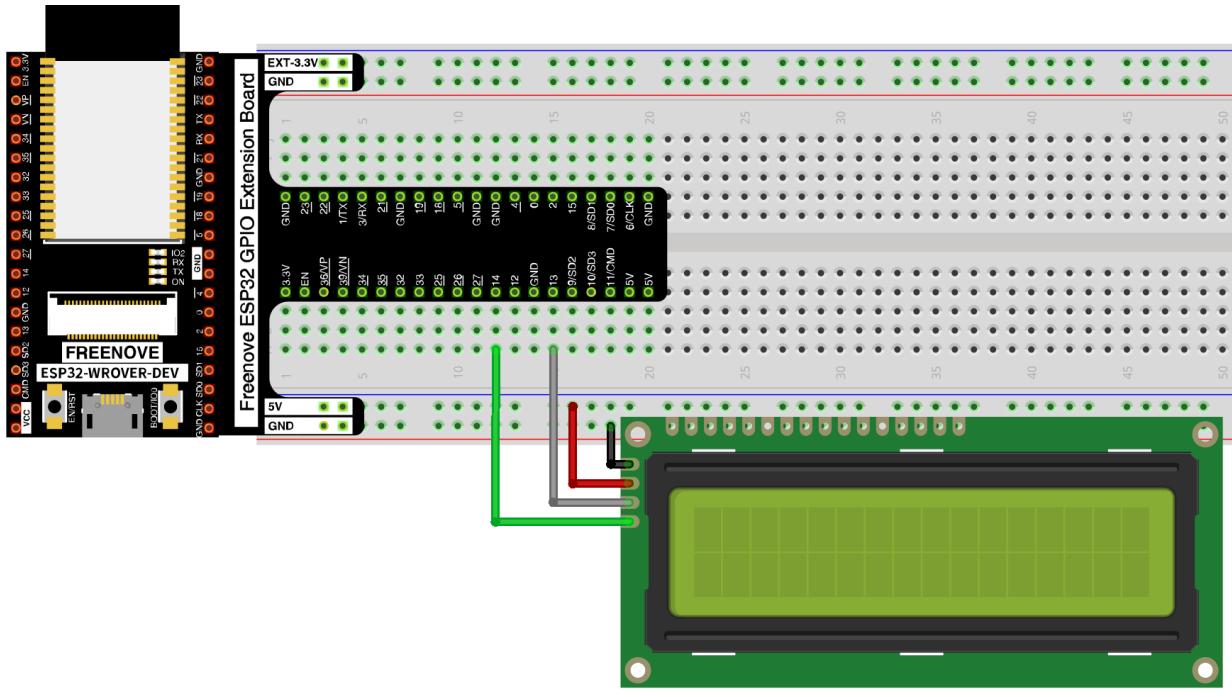
So we only need 4 pins to control the 16 pins of the LCD1602 Display Screen through the I<sub>2</sub>C interface. In this project, we will use the I<sub>2</sub>C LCD1602 to display some static characters and dynamic variables.

## Circuit

Schematic diagram



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

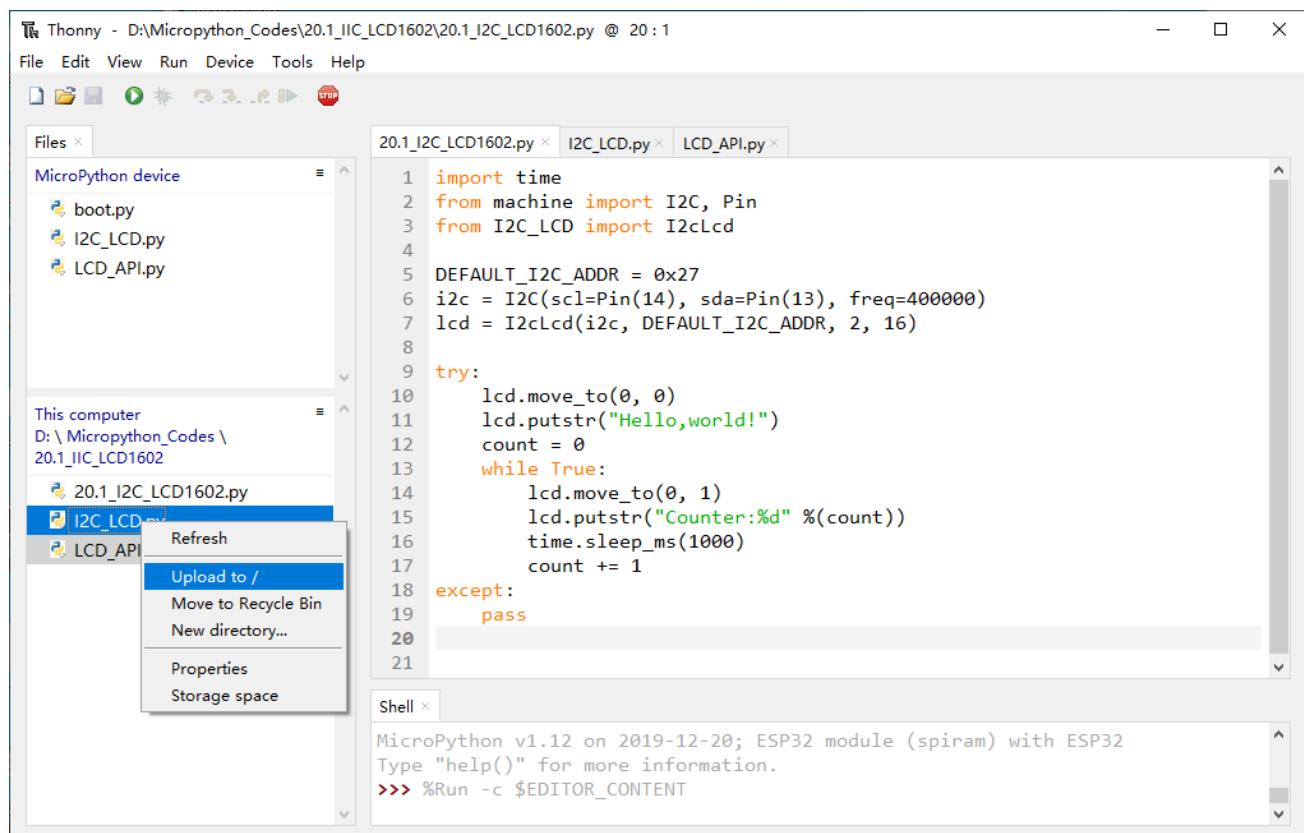


## Code

Move the program folder “**Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32/Python/Python\_Codes**” to disk(D) in advance with the path of “**D:/Micropython\_Codes**”.

Open “Thonny”, click “This computer” → “D:” → “Micropython\_Codes” → “20.1\_I2C\_LCD1602”. Select “I2C\_LCD.py” and “LCD\_API.py”, right click your mouse to select “Upload to /”, wait for “I2C\_LCD.py” and “LCD\_API.py” to be uploaded to ESP32-WROVER and then double click “20.1\_I2C\_LCD1602.py”.

### 20.1\_I2C\_LCD1602



Click “Run current script” and LCD1602 displays some characters.





If you cannot see anything on the display or the display is not clear, try rotating the white knob on back of LCD1602 slowly, which adjusts the contrast, until the screen can display clearly.



The following is the program code:

```

1 import time
2 from machine import I2C, Pin
3 from I2C_LCD import I2cLcd
4
5 DEFAULT_I2C_ADDR = 0x27
6 i2c = I2C(scl=Pin(14), sda=Pin(13), freq=400000)
7 lcd = I2cLcd(i2c, DEFAULT_I2C_ADDR, 2, 16)
8
9 try:
10     lcd.move_to(0, 0)
11     lcd.putstr("Hello, world!")
12     count = 0
13     while True:
14         lcd.move_to(0, 1)
15         lcd.putstr("Counter:%d" %(count))
16         time.sleep_ms(1000)
17         count += 1
18     except:
19         pass

```

Import time, I2C and I2C\_LCD modules.

```

1 import time
2 from machine import I2C, Pin
3 from I2C_LCD import I2cLcd

```

Instantiate the I2C LCD1602 screen. It should be noted here that if your LCD driver chip uses PCF8574T, set the I2C address to 0x27, and if uses PCF8574AT, set the I2C address to 0x3F.

```
5 DEFAULT_I2C_ADDR = 0x27
```

Initialize I2C pins and associate them with I2CLCD module, and then set the number of rows and columns for LCD1602.

```

6 i2c = I2C(scl=Pin(14), sda=Pin(13), freq=400000)
7 lcd = I2cLcd(i2c, DEFAULT_I2C_ADDR, 2, 16)

```

Move the cursor of LCD1602 to the first row, first column, and print out "Hello, world!"

```

10 lcd.move_to(0, 0)
11 lcd.putstr("Hello, world!")

```

**Any concerns? ✉ support@freenove.com**

The second line of LCD1602 continuously prints the number of seconds after the ESP32 program runs.

```
13     while True:  
14         lcd.move_to(0, 1)  
15         lcd.putstr("Counter:%d" %(count))  
16         time.sleep_ms(1000)  
17         count += 1
```

## Reference

### Class I2cLcd

Before each use of the object **I2cLcd**, please make sure that **I2C\_LCD.py** and **LCD\_API.py** have been uploaded to “/” of ESP32, and then add the statement “**from I2C\_LCD import I2cLcd**” to the top of the python file.

**clear()**: Clear the LCD1602 screen display.

**show\_cursor()**: Show the cursor of LCD1602.

**hide\_cursor()**: Hide the cursor of LCD1602.

**blink\_cursor\_on()**: Turn on cursor blinking.

**blink\_cursor\_off()**: Turn off cursor blinking.

**display\_on()**: Turn on the display function of LCD1602.

**display\_off()**: Turn on the display function of LCD1602.

**backlight\_on()**: Turn on the backlight of LCD1602.

**backlight\_off()**: Turn on the backlight of LCD1602.

**move\_to(cursor\_x, cursor\_y)**: Move the cursor to a specified position.

**cursor\_x**: Column cursor\_x

**cursor\_y** : Row cursor\_y

**putchar(char)** : Print the character in the bracket on LCD1602

**putstr(string)** : Print the string in the bracket on LCD1602.

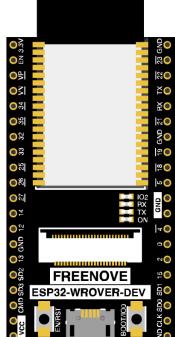
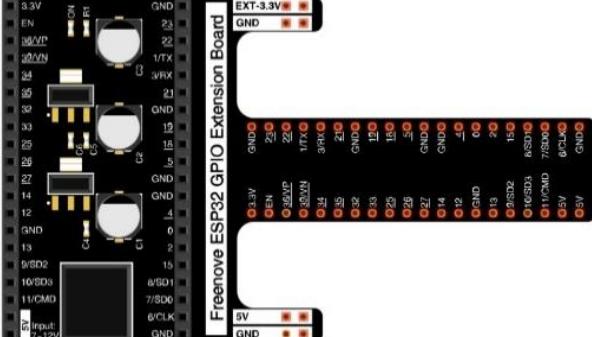
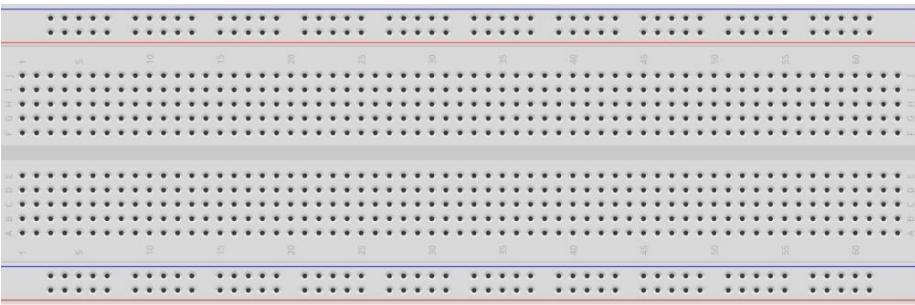
# Chapter 21 Ultrasonic Ranging

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

## Project 21.1 Ultrasonic Ranging

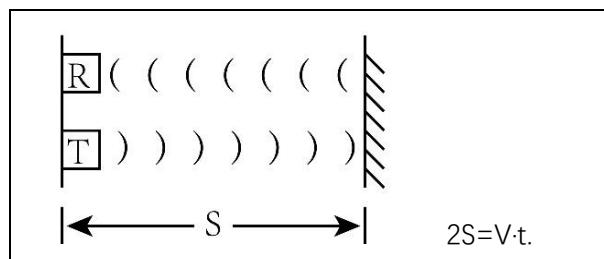
In this project, we use ultrasonic ranging module to measure distance, and print out the data in the terminal.

### Component List

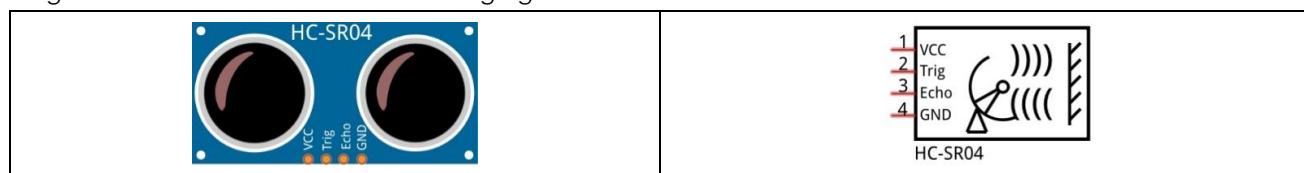
ESP32-WROVER x1	GPIO Extension Board x1
	
Breadboard x1	
Jumper F/M x4	HC SR04 x1
	

## Component Knowledge

The Ultrasonic Ranging Module uses the principle that ultrasonic waves will reflect when they encounter any obstacles. This is possible by counting the time interval between when the ultrasonic wave is transmitted to when the ultrasonic wave reflects back after encountering an obstacle. Time interval counting will end after an ultrasonic wave is received, and the time difference (delta) is the total time of the ultrasonic wave's journey from being transmitted to being received. Because the speed of sound in air is a constant, and is about  $v=340\text{m/s}$ , we can calculate the distance between the Ultrasonic Ranging Module and the obstacle:  $s=vt/2$ .



The HC-SR04 Ultrasonic Ranging Module integrates both an ultrasonic transmitter and a receiver. The transmitter is used to convert electrical signals (electrical energy) into high frequency (beyond human hearing) sound waves (mechanical energy) and the function of the receiver is opposite of this. The picture and the diagram of the HC SR04 Ultrasonic Ranging Module are shown below:



Pin description:

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

### Technical specs:

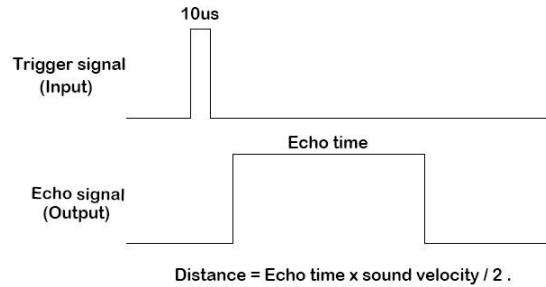
Working voltage: 5V

Working current: 12mA

Minimum measured distance: 2cm

Maximum measured distance: 200cm

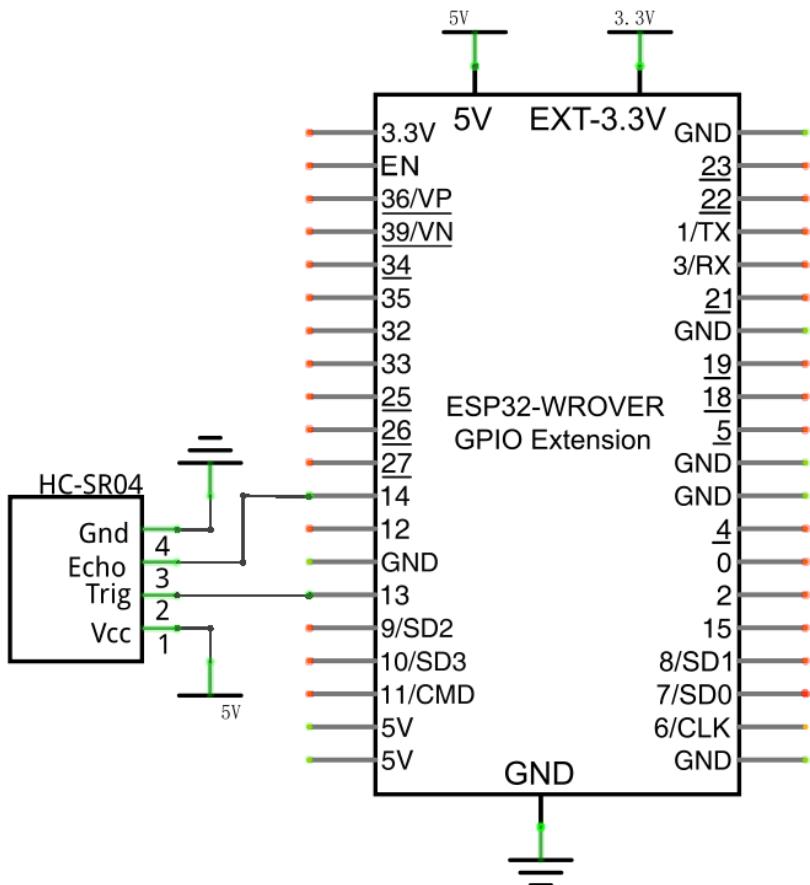
Instructions for Use: output a high-level pulse in Trig pin lasting for least 10us, the module begins to transmit ultrasonic waves. At the same time, the Echo pin is pulled up. When the module receives the returned ultrasonic waves from encountering an obstacle, the Echo pin will be pulled down. The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



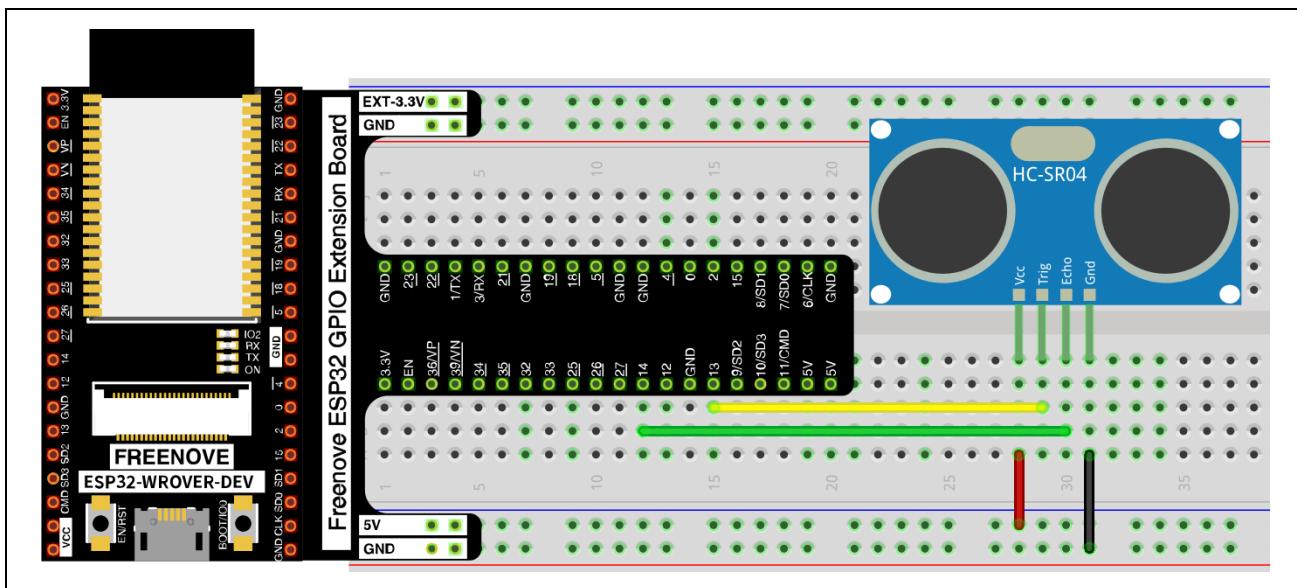
## Circuit

Note that the voltage of ultrasonic module is 5V in the circuit.

Schematic diagram



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

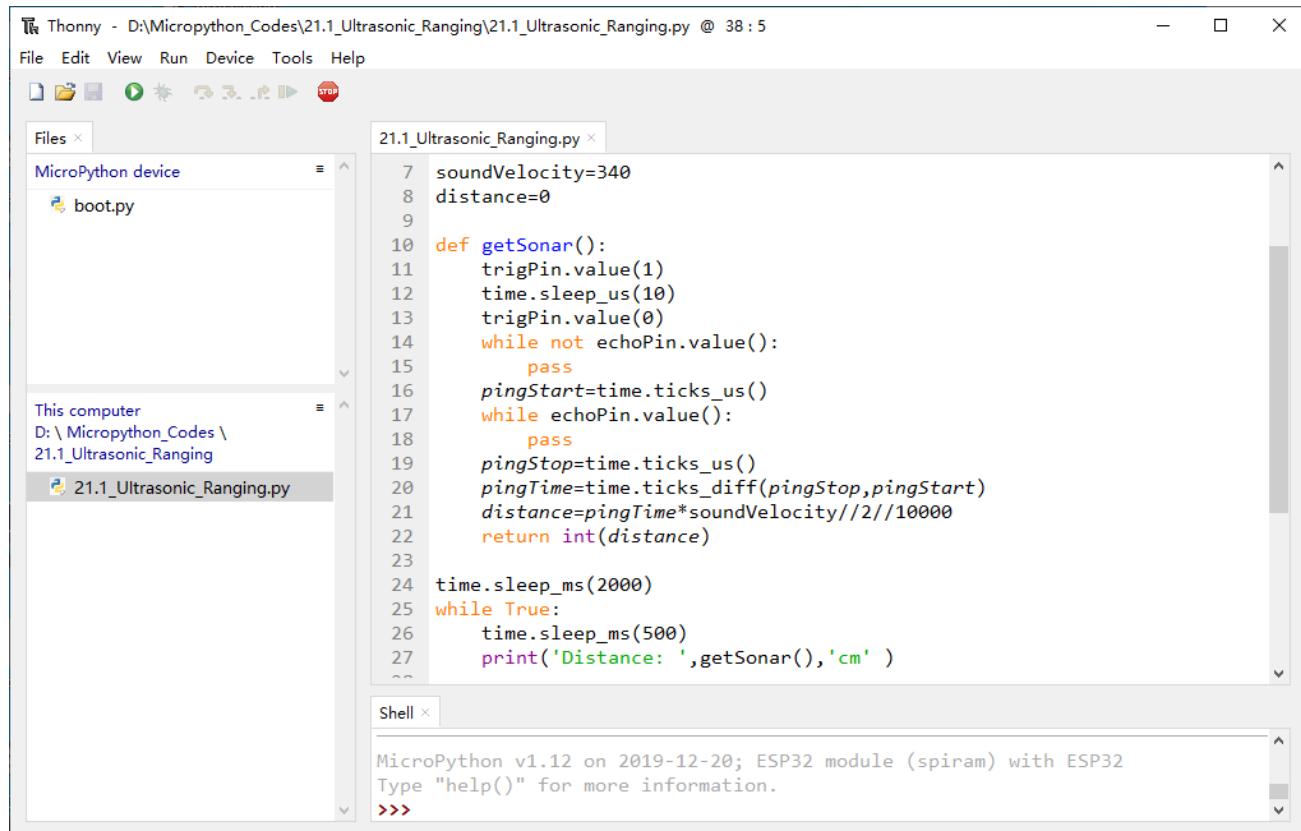


## Code

Move the program folder “**Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32/Python/Python\_Codes**” to disk(D) in advance with the path of “**D:/Micropython\_Codes**”.

Open “Thonny”, click “This computer” → “D:” → “Micropython\_Codes” → “21.1\_Ultrasonic\_Ranging” and double click “21.1\_Ultrasonic\_Ranging.py”.

### 21.1\_Ultrasonic\_Ranging

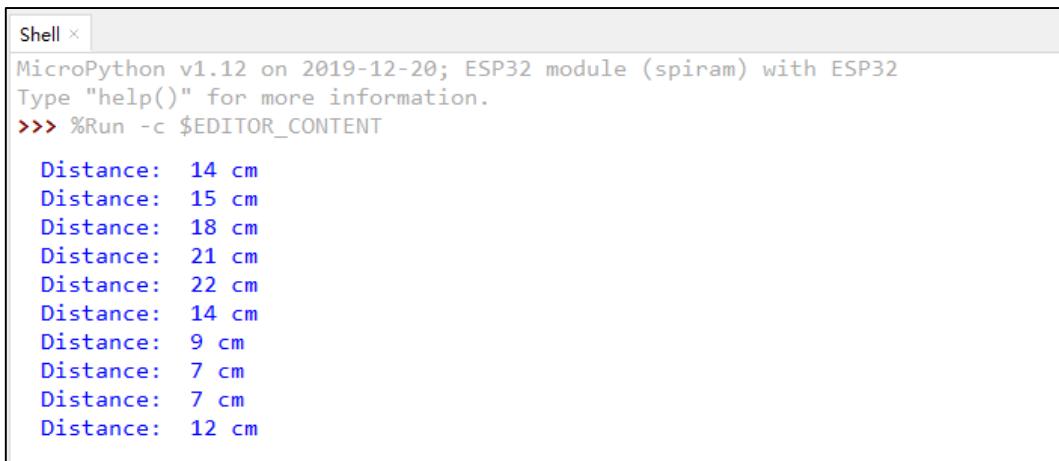


```

7 soundVelocity=340
8 distance=0
9
10 def getSonar():
11     trigPin.value(1)
12     time.sleep_us(10)
13     trigPin.value(0)
14     while not echoPin.value():
15         pass
16     pingStart=time.ticks_us()
17     while echoPin.value():
18         pass
19     pingStop=time.ticks_us()
20     pingTime=time.ticks_diff(pingStop,pingStart)
21     distance=pingTime*soundVelocity//10000
22     return int(distance)
23
24 time.sleep_ms(2000)
25 while True:
26     time.sleep_ms(500)
27     print('Distance: ',getSonar(),'cm' )

```

Click “Run current script”, you can use it to measure the distance between the ultrasonic module and the object. As shown in the following figure:



```

MicroPython v1.12 on 2019-12-20; ESP32 module (spiram) with ESP32
Type "help()" for more information.
>>> %Run -c $EDITOR_CONTENT
Distance: 14 cm
Distance: 15 cm
Distance: 18 cm
Distance: 21 cm
Distance: 22 cm
Distance: 14 cm
Distance: 9 cm
Distance: 7 cm
Distance: 7 cm
Distance: 12 cm

```

The following is the program code:

```

1  from machine import Pin
2  import time
3
4  trigPin=Pin(13,Pin.OUT,0)
5  echoPin=Pin(14,Pin.IN,0)
6
7  soundVelocity=340
8  distance=0
9
10 def getSonar():
11     trigPin.value(1)
12     time.sleep_us(10)
13     trigPin.value(0)
14     while not echoPin.value():
15         pass
16     pingStart=time.ticks_us()
17     while echoPin.value():
18         pass
19     pingStop=time.ticks_us()
20     pingTime=time.ticks_diff(pingStop,pingStart)
21     distance=pingTime*sounVelocity//2//10000
22     return int(distance)
23
24 time.sleep_ms(2000)
25 while True:
26     time.sleep_ms(500)
27     print('Distance: ',getSonar(),'cm')

```

Define the control pins of the ultrasonic ranging module.

```

4  trigPin=Pin(13,Pin.OUT,0)
5  echoPin=Pin(14,Pin.IN,0)

```

Set the speed of sound.

```

7  soundVelocity=340
8  distance=0

```

Subfunction `getSonar()` is used to start the Ultrasonic Module to begin measurements, and return the measured distance in centimeters. In this function, first let `trigPin` send 10us high level to start the Ultrasonic Module. Then use `pulseIn()` to read the Ultrasonic Module and return the duration time of high level. Finally, the measured distance according to the time is calculated.

```

10 def getSonar():
11     trigPin.value(1)
12     time.sleep_us(10)
13     trigPin.value(0)
14     while not echoPin.value():
15         pass

```

```
16 pingStart=time.ticks_us()
17 while echoPin.value():
18     pass
19 pingStop=time.ticks_us()
20 pingTime=time.ticks_diff(pingStop,pingStart)
21 distance=pingTime*soundVelocity//2//10000
22 return int(distance)
```

Delay for 2 seconds and wait for the ultrasonic module to stabilize. Print data obtained from ultrasonic module every 500 milliseconds

```
24 time.sleep_ms(2000)
25 while True:
26     time.sleep_ms(500)
27     print('Distance: ',getSonar(),'cm')
```

## Project 21.2 Ultrasonic Ranging

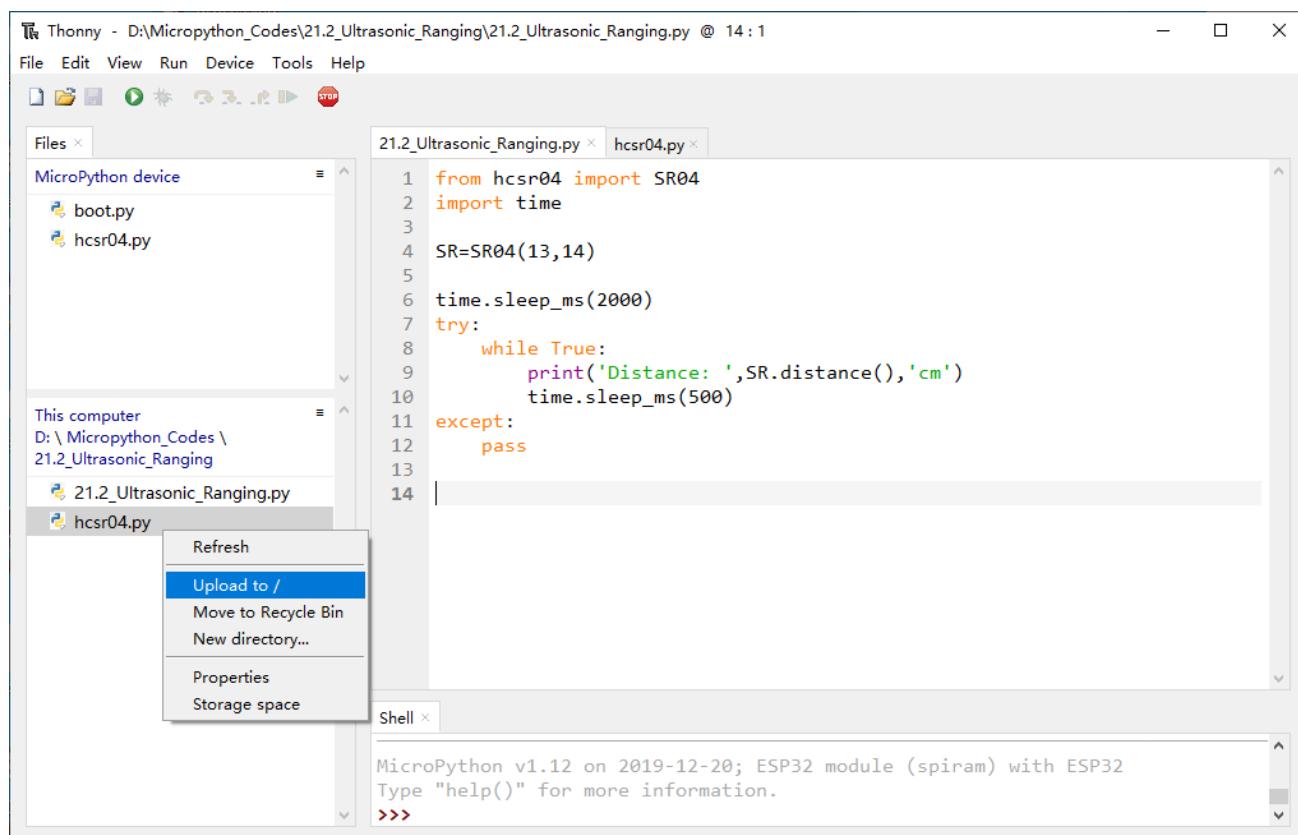
### Component List and Circuit

Component List and Circuit are the same as the previous section.

### Code

Open “Thonny”, click “This computer” → “D:” → “Micropython\_Codes” → “21.2\_Ultrasonic\_Ranging”. Select “hcsr04.py”, right click your mouse to select “Upload to /”, wait for “hcsr04.py” to be uploaded to ESP32-WROVER and then double click “21.2\_Ultrasonic\_Ranging.py”.

#### 21.2\_Ultrasonic\_Ranging



The screenshot shows the Thonny IDE interface. The title bar says "Thonny - D:\Micropython\_Codes\21.2\_Ultrasonic\_Ranging\21.2\_Ultrasonic\_Ranging.py @ 14 : 1". The menu bar includes File, Edit, View, Run, Device, Tools, Help. The toolbar has icons for file operations like Open, Save, Run, Stop, and Device. The left sidebar shows a "Files" tree with "MicroPython device" expanded, showing "boot.py" and "hcsr04.py". Below it, "This computer" shows "D:\ Micropython\_Codes \ 21.2\_Ultrasonic\_Ranging" with "21.2\_Ultrasonic\_Ranging.py" and "hcsr04.py". A context menu is open over "hcsr04.py", with "Upload to /" highlighted in blue. The main code editor window contains the following Python code:

```
1 from hcsr04 import SR04
2 import time
3
4 SR=SR04(13,14)
5
6 time.sleep_ms(2000)
7 try:
8     while True:
9         print('Distance: ',SR.distance(),'cm')
10        time.sleep_ms(500)
11 except:
12     pass
13
14
```

The bottom shell window displays the MicroPython prompt: "MicroPython v1.12 on 2019-12-20; ESP32 module (spiram) with ESP32 Type "help()" for more information. >>>"



Click “Run current script”. Use the ultrasonic module to measure distance. As shown in the following figure:

```
Shell ×
Distance: 6.647 cm
Distance: 5.151 cm
Distance: 5.151 cm
Distance: 6.052 cm
Distance: 7.225 cm
Distance: 7.531 cm
Distance: 8.721 cm
Distance: 12.121 cm
Distance: 11.798 cm
Distance: 13.6 cm
Distance: 14.467 cm
Distance: 16.116 cm
Distance: 17.442 cm
Distance: 19.652 cm
Distance: 22.015 cm
```

The following is the program code:

```
1 from hcsr04 import SR04
2 import time
3
4 SR=SR04(13, 14)
5
6 time.sleep_ms(2000)
7 try:
8     while True:
9         print('Distance: ',SR.distance(), 'cm')
10        time.sleep_ms(500)
11    except:
12        pass
```

Import hcsr04 module.

```
1 from hcsr04 import SR04
```

Define an ultrasonic object and associate with the pins.

```
3 SR=SR04(13, 14)
```

Obtain the distance data returned from the ultrasonic ranging module.

```
9 SR.distance()
```

Obtain the ultrasonic data every 500 milliseconds and print them out in “Shell”.

```
8 while True:
9     print('Distance: ',SR.distance(), 'cm')
10    time.sleep_ms(500)
```

## Reference

### Class hcsr04

Before each use of object **SR04**, please add the statement “**from hcsr04 import SR04**” to the top of python file.

**SR04()**: Object of ultrasonic module. By default, trig pin is Pin(13) and echo pinis Pin(14).

**distanceCM()**: Obtain the distance from the ultrasonic to the measured object with the data type being int type, and the unit being cm.

**distanceMM()**: Obtain the distance from the ultrasonic to the measured object with the data type being int type, and the unit being mm.

**distance()**: Obtain the distance from the ultrasonic to the measured object with the data type being float type, and the unit being cm.

# Chapter 22 Matrix Keypad

Earlier we learned about a single Push Button Switch. In this chapter, we will learn about Matrix Keyboards, which integrates a number of Push Button Switches as Keys for the purposes of Input.

## Project 22.1 Matrix Keypad

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

### Component List

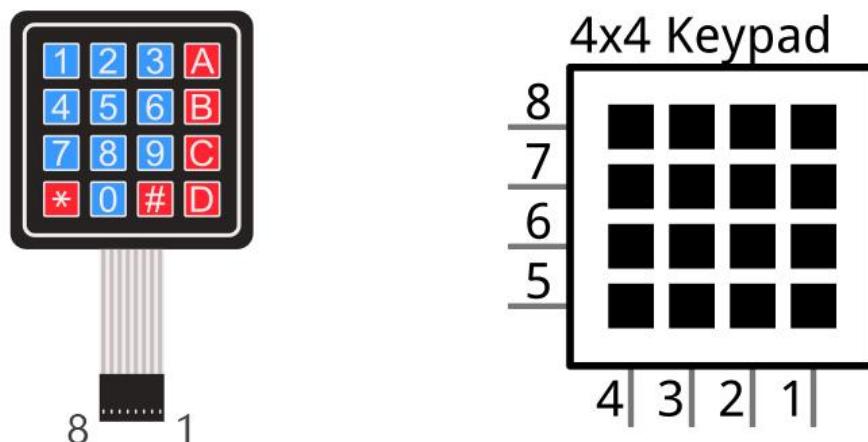
ESP32-WROVER x1	GPIO Extension Board x1
Breadboard x1	
Jumper M/M x8	4x4 Matrix Keypad x1

Any concerns? [✉ support@freenove.com](mailto:support@freenove.com)

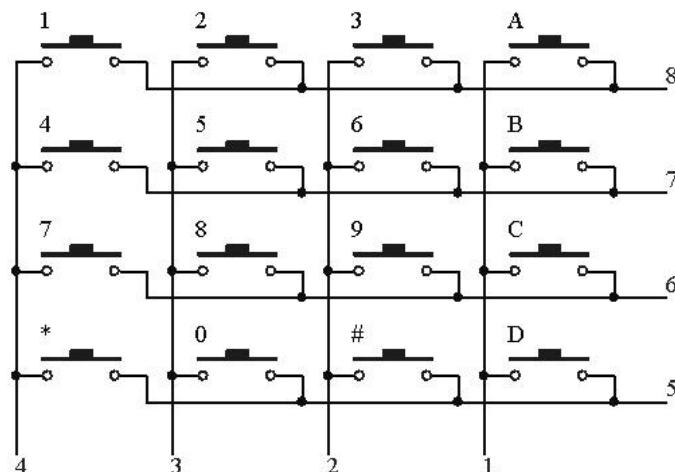
## Component knowledge

### 4x4 Matrix Keypad

A Keypad Matrix is a device that integrates a number of keys in one package. As is shown below, a 4x4 Keypad Matrix integrates 16 keys:



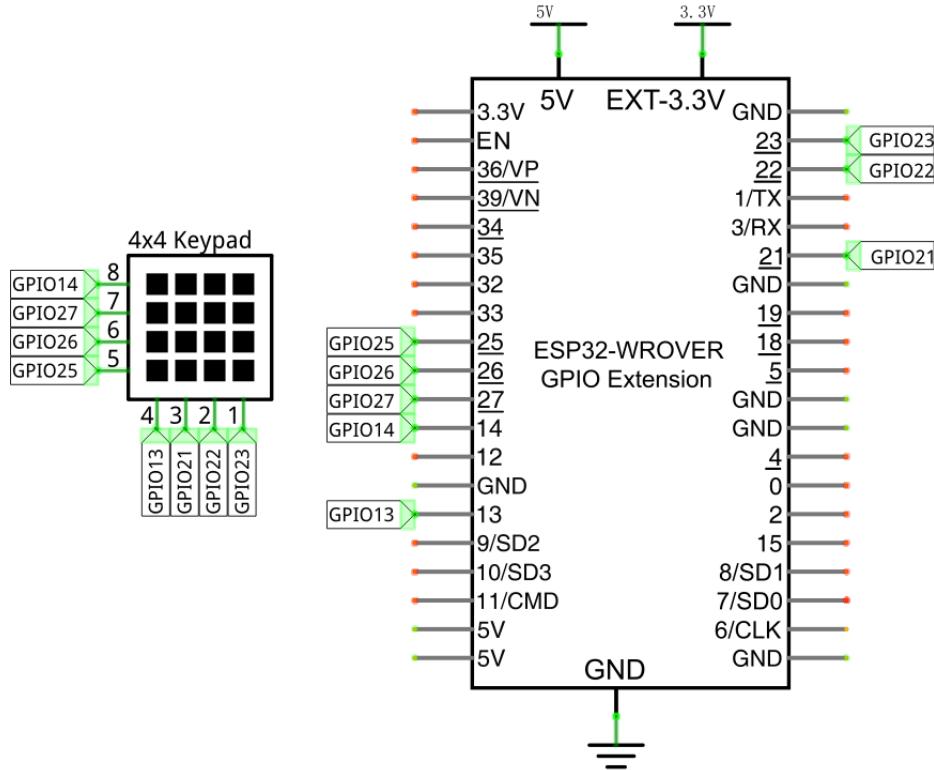
Similar to the integration of an LED Matrix, the 4x4 Keypad Matrix has each row of keys connected with one pin and this is the same for the columns. Such efficient connections reduce the number of processor ports required. The internal circuit of the Keypad Matrix is shown below.



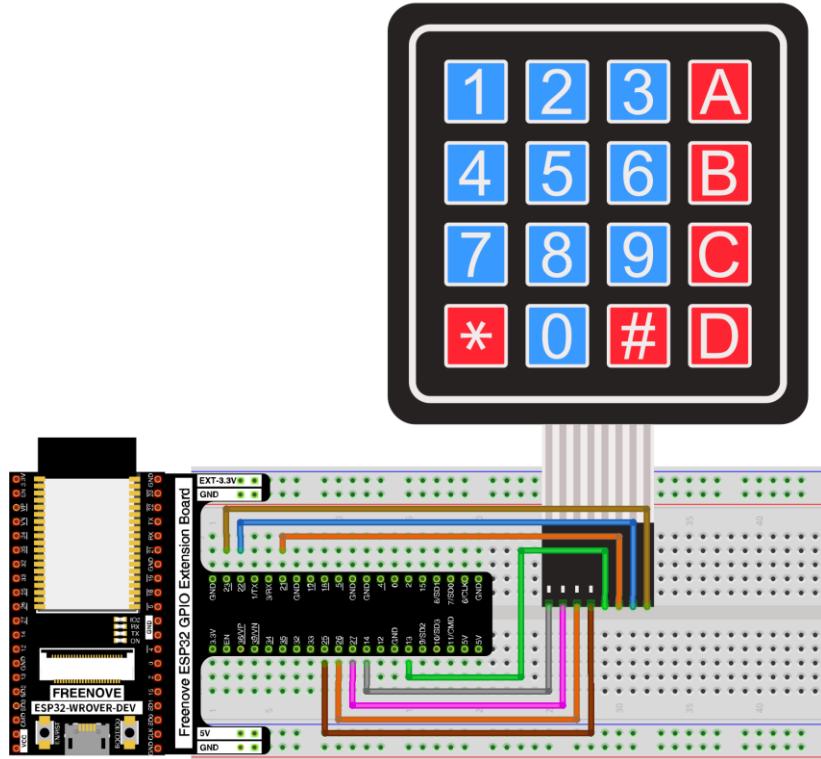
The method of usage is similar to the Matrix LED, by using a row or column scanning method to detect the state of each key's position by column and row. Take column scanning method as an example, send low level to the first 1 column (Pin1), detect level state of row 5, 6, 7, 8 to judge whether the key A, B, C, D are pressed. Then send low level to column 2, 3, 4 in turn to detect whether other keys are pressed. By this means, you can get the state of all of the keys.

## Circuit

Schematic diagram



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



Any concerns? ✉ [support@freenove.com](mailto:support@freenove.com)

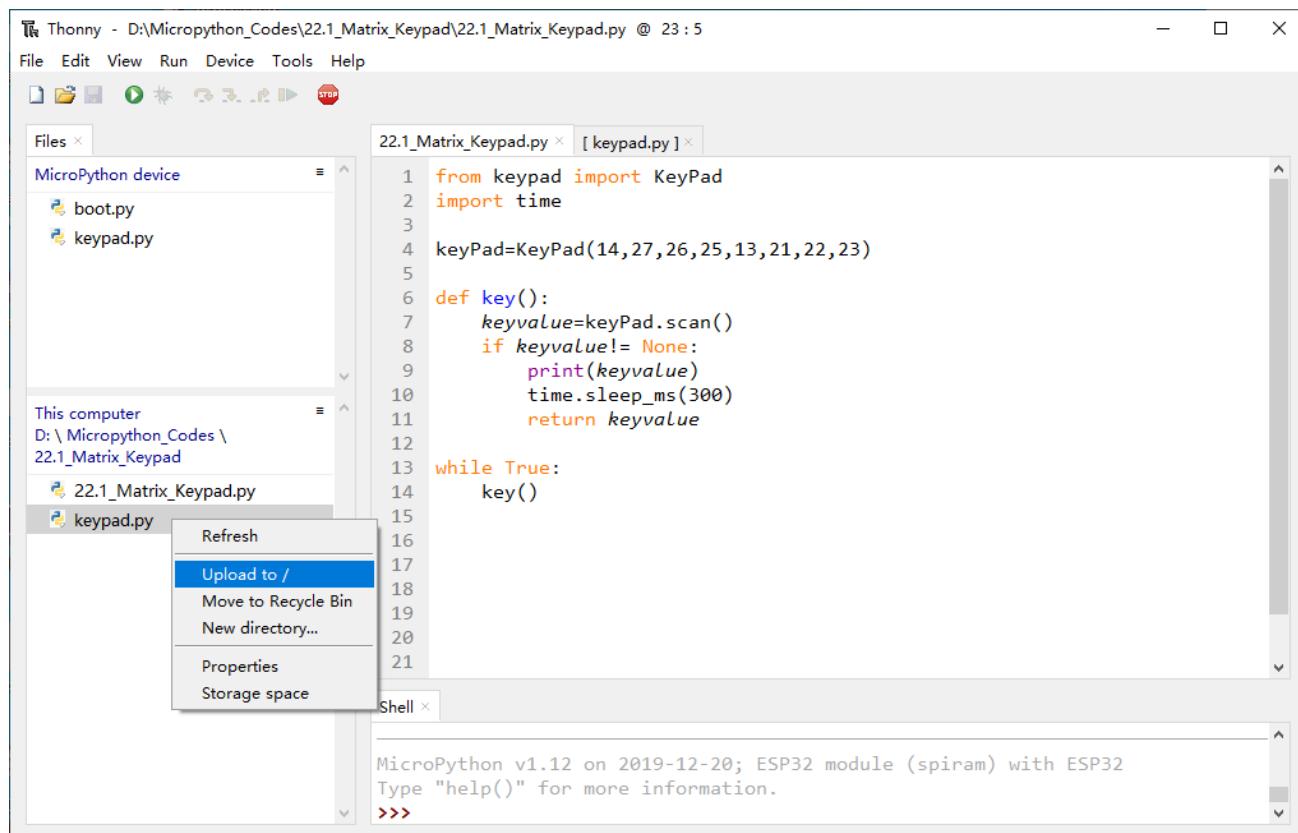
## Code

This code is used to obtain all key codes of the 4x4 Matrix Keypad, when one of the keys is pressed, the key code will be printed out via serial port.

Move the program folder “**Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32/Python/Python\_Codes**” to disk(D) in advance with the path of “**D:/Micropython\_Codes**”.

Open “Thonny”, click “This computer” → “D:” → “Micropython\_Codes” → “22.1\_Matrix\_Keypad”. Select “keypad.py”, right click your mouse to select “Upload to /”, wait for “keypad.py” to be uploaded to ESP32-WROVER and then double click “22.1\_Matrix\_Keypad.py”.

### 22.1\_Matrix\_Keypad





Click “Run current script”, push the key board and the key value will be printed in “Shell”. As shown in the illustration below:

```
Shell < 
MicroPython v1.12 on 2019-12-20; ESP32 module (spiram) with ESP32
Type "help()" for more information.
>>> %Run -c $EDITOR_CONTENT

1
2
3
A
4
5
6
B
7
8
9
C
*
0
#
D
```

The following is the program code:

```
1 from keypad import KeyPad
2 import time
3
4 keyPad=KeyPad(14, 27, 26, 25, 13, 21, 22, 23)
5
6 def key():
7     keyvalue=keyPad.scan()
8     if keyvalue!= None:
9         print(keyvalue)
10    time.sleep_ms(300)
11    return keyvalue
12
13 while True:
14     key()
```

Import keypad module.

```
1 from keypad import KeyPad
```

Associate the keypad module to ESP32 pins.

```
4 keyPad=KeyPad(14, 27, 26, 25, 13, 21, 22, 23)
```

Call function keypad.scan() of the keypad module. When the keypad module detects that the key is pressed, it returns the value of the pressed key; when no key is pressed, the return value is None.

```
7 keyPad.scan()
```

Call function keyPan.scan() to obtain the value of the pressed key. Once it is obtained, print it out.

```
6 def key():
7     keyvalue=keyPad.scan()
8     if keyvalue!= None:
9         print(keyvalue)
10    time.sleep_ms(300)
11    return keyvalue
```

**Any concerns? ✉ support@freenove.com**

## Reference

### Class keypad

Before each use of the object **KeyPad**, please make sure **keypad.py** has been uploaded to "/" of ESP32 and then add the statement "**from keypad import KeyPad**" to the top of python file.

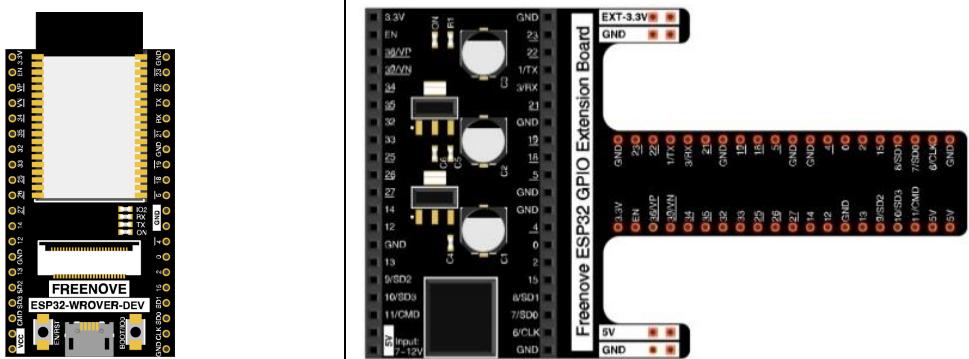
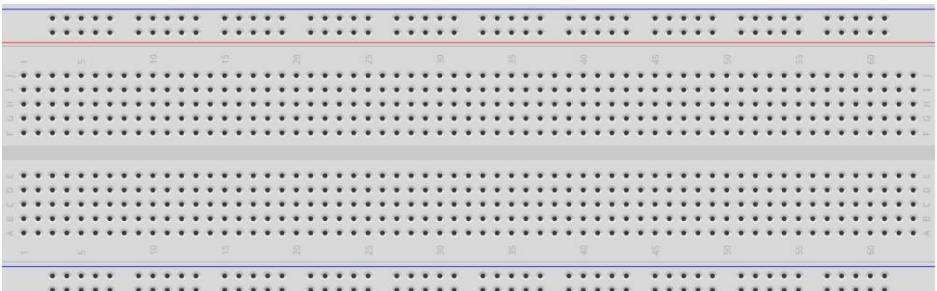
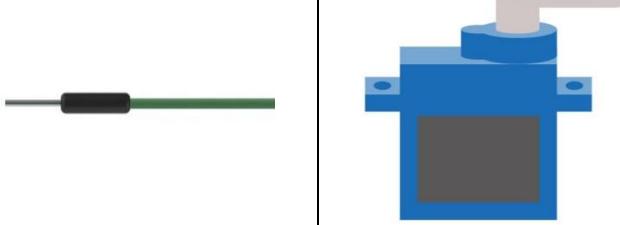
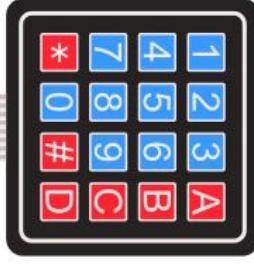
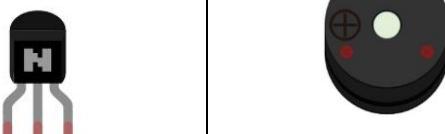
**KeyPad(row1, row2, row3, row4, col1, col2, col3, col4)**: Initialize keypad module and associate its pins with ESP32.

**scan()**: Non-blocking keypad scan function. If no key is pressed, it returns None; Otherwise, it returns the value of the pressed key.

## Project 22.2 Keypad Door

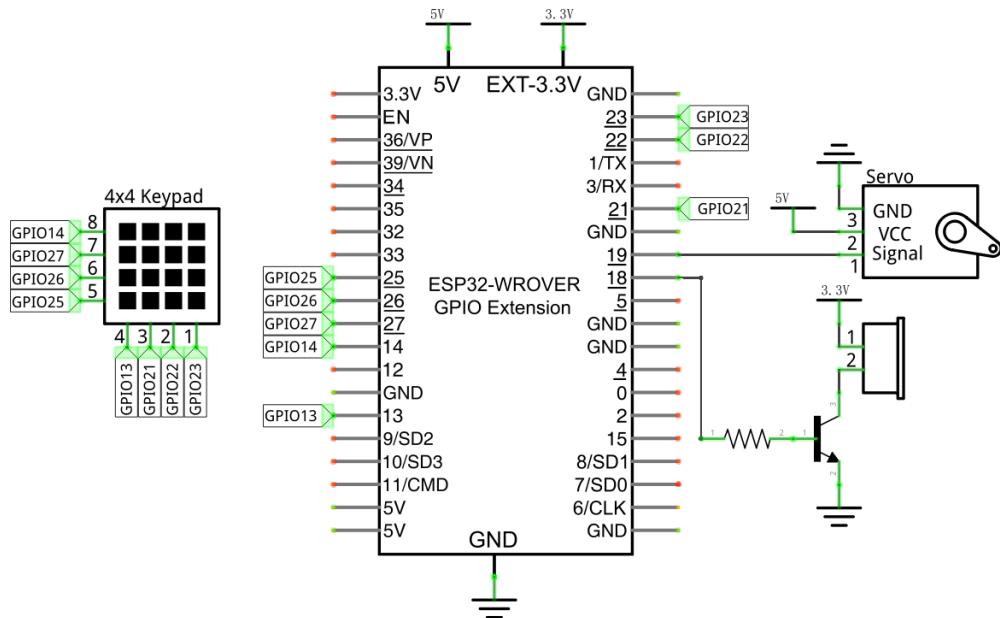
In this project, we use keypad as a keyboard to control the action of the servo motor.

### Component List

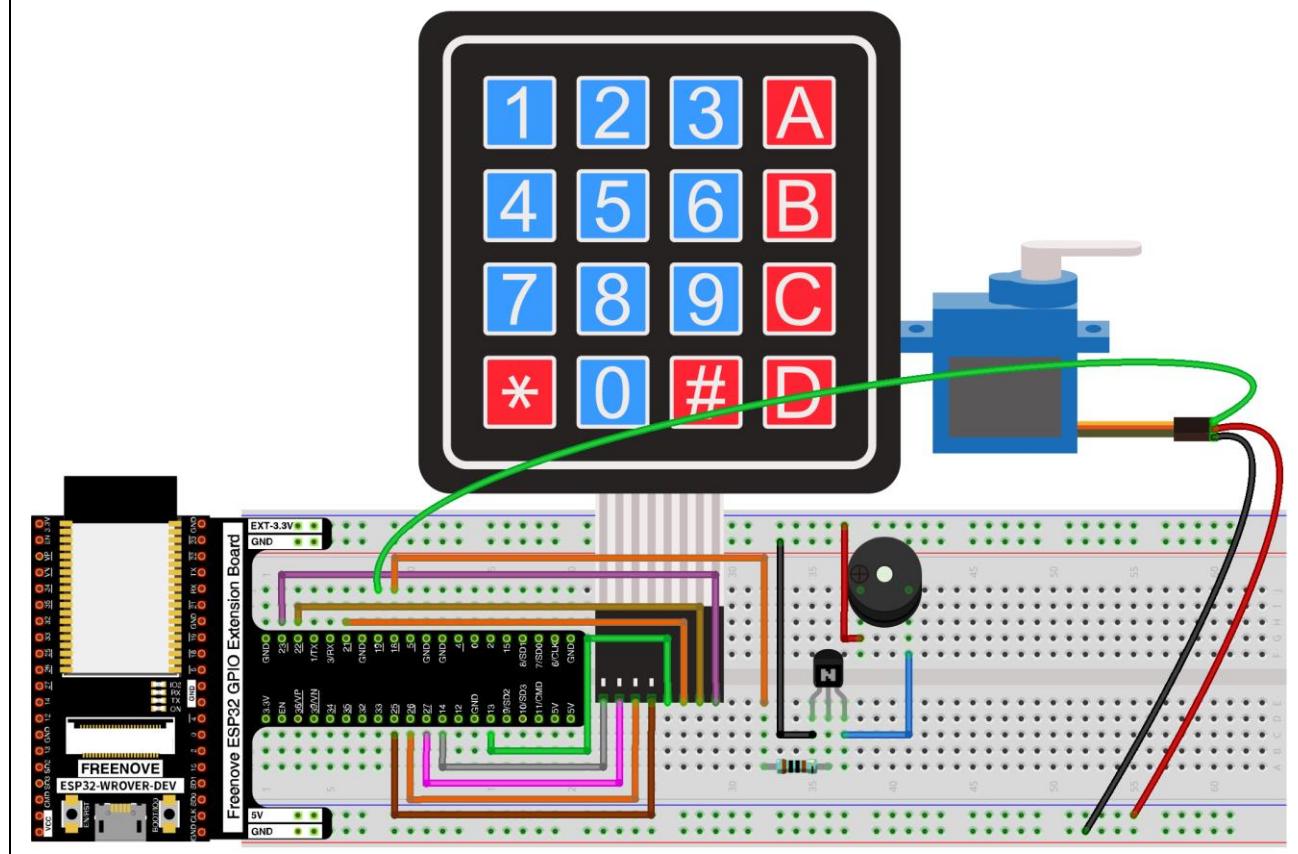
ESP32-WROVER x1	GPIO Extension Board x1	
		
Breadboard x1		
		
Jumper M/M	Servo x1	4x4 Matrix Keypad x1
		
NPN transistor x1 (S8050)	Active buzzer x1	Resistor 1kΩ x1
		

## Circuit

Schematic diagram



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

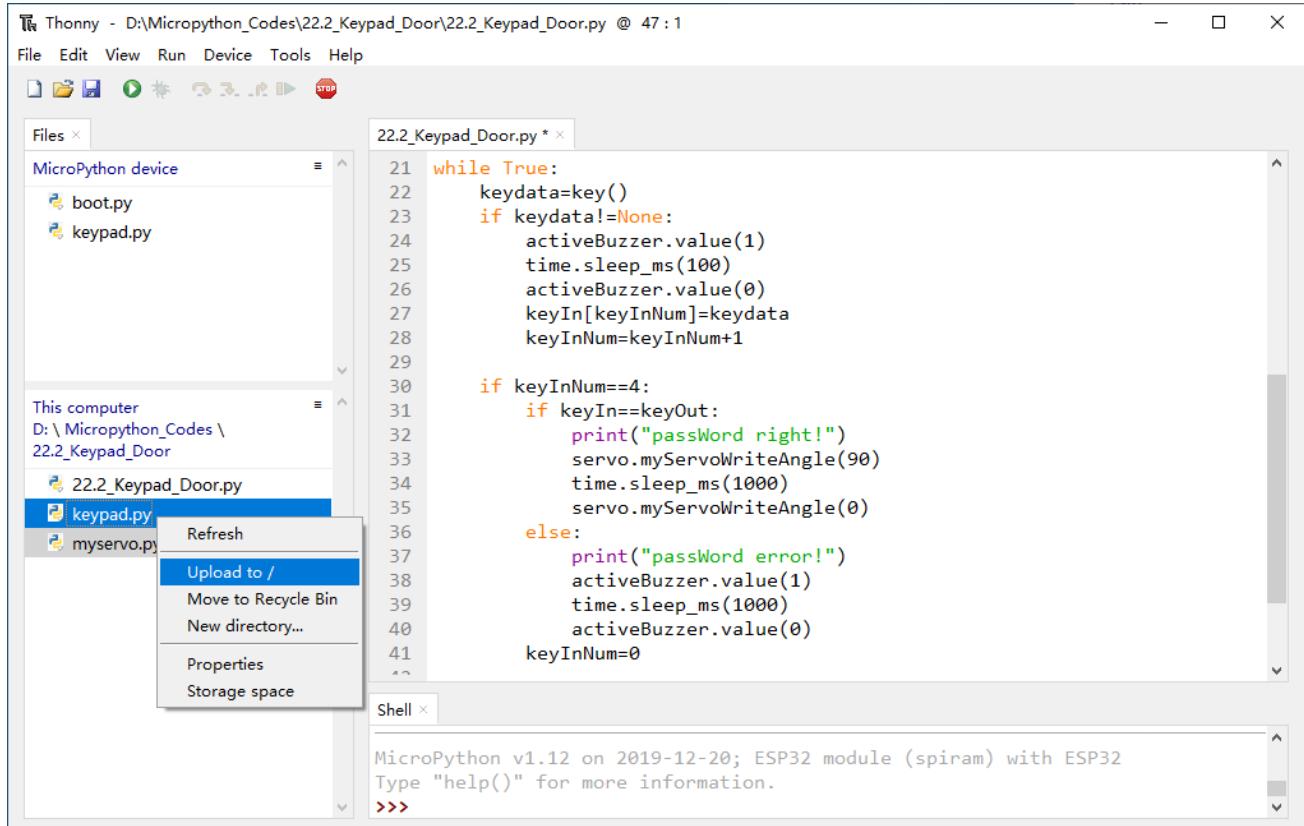


## Code

Move the program folder “**Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32/Python/Python\_Codes**” to disk(D) in advance with the path of “**D:/Micropython\_Codes**”.

Open “Thonny”, click “This computer” → “D:” → “Micropython\_Codes” → “22.2\_Keypad\_Door”. Select “keypad.py” and “myservo.py”, right click your mouse to select “Upload to /”, wait for “keypad.py” and “myservo.py” to be uploaded to ESP32-WROVER and then double click “22.2\_Keypad\_Door.py”.

### 22.2\_Keypad\_Door



Click “Run current script”, press the keypad to input password with 4 characters. If the input is correct, the servo will move to a certain degree, and then return to the original position. If the input is wrong, an input error alarm will be generated.

The following is the program code:

```
1  from myservo import myServo
2  from keypad import KeyPad
3  from machine import Pin
4  import time
5
6  keyPad=KeyPad(14, 27, 26, 25, 13, 21, 22, 23)
7  servo=myServo(19)
8  servo.myServoWriteAngle(0)
9  activeBuzzer=Pin(18, Pin.OUT)
10
11 keyOut = ['1', '2', '3', '4']
12 keyIn  = ['', '', '', '']
13 def key():
14     keyvalue=keyPad.scan()
15     if keyvalue!= None:
16         print('Your input:',keyvalue)
17         time.sleep_ms(200)
18         return keyvalue
19
20 keyInNum=0
21 while True:
22     keydata=key()
23     if keydata!=None:
24         activeBuzzer.value(1)
25         time.sleep_ms(100)
26         activeBuzzer.value(0)
27         keyIn[keyInNum]=keydata
28         keyInNum=keyInNum+1
29
30     if keyInNum==4:
31         if keyIn==keyOut:
32             print("passWord right!")
33             servo.myServoWriteAngle(90)
34             time.sleep_ms(1000)
35             servo.myServoWriteAngle(0)
36         else:
37             print("passWord error!")
38             activeBuzzer.value(1)
39             time.sleep_ms(1000)
40             activeBuzzer.value(0)
41         keyInNum=0
```



Define an array and set the password.

```
11 keyOut = ['1', '2', '3', '4']
```

Each time a key is pressed, the buzzer will short beep once, and the key value of the key will be stored in the keyIn array.

```
22 keydata=key()
23 if keydata!=None:
24     activeBuzzer.value(1)
25     time.sleep_ms(100)
26     activeBuzzer.value(0)
27     keyIn[keyInNum]=keydata
28     keyInNum=keyInNum+1
```

When 4 keys are pressed, it will judge whether the password is correct. If it is correct, the servo will rotate 90 degrees, and then turn back after 1 second. If the password is wrong, the buzzer will long beep once and the keyInNum value will be cleared.

```
30 if keyInNum==4:
31     if keyIn==keyOut:
32         print("passWord right!")
33         servo.myServoWriteAngle(90)
34         time.sleep_ms(1000)
35         servo.myServoWriteAngle(0)
36     else:
37         print("passWord error!")
38         activeBuzzer.value(1)
39         time.sleep_ms(1000)
40         activeBuzzer.value(0)
41     keyInNum=0
```

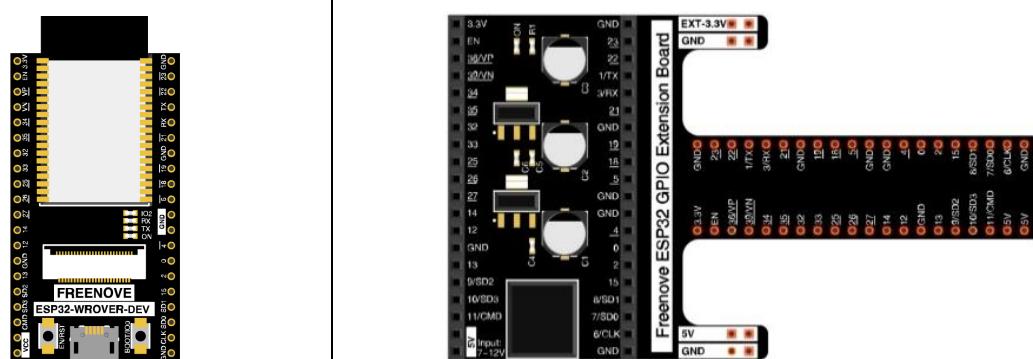
# Chapter 23 Infrared Remote

In this chapter, we'll learn how to use an infrared remote control, and control a LED.

## Project 23.1 Infrared Remote Control

First, we need to understand how infrared remote control works, then get the command sent from infrared remote control.

### Component List

ESP32-WROVER x1	GPIO Extension Board x1
	
Breadboard x1	
Jumper M/M x4	Infrared Remote x1 (May need CR2025 battery x1, please check the holder)
Infrared Remote x1	Resistor 10kΩ x1



## Component knowledge

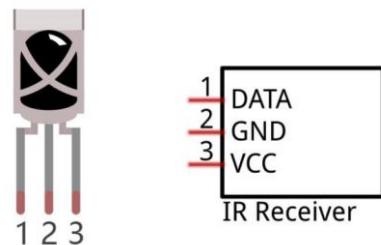
### Infrared Remote

An infrared(IR) remote control is a device with a certain number of buttons. Pressing down different buttons will make the infrared emission tube, which is located in the front of the remote control, send infrared ray with different command. Infrared remote control technology is widely used in electronic products such as TV, air conditioning, etc. Thus making it possible for you to switch TV programs and adjust the temperature of the air conditioning when away from them. The remote control we use is shown below:



### Infrared receiver

An infrared(IR) receiver is a component which can receive the infrared light, so we can use it to detect the signal emitted by the infrared remote control. DATA pin here outputs the received infrared signal.



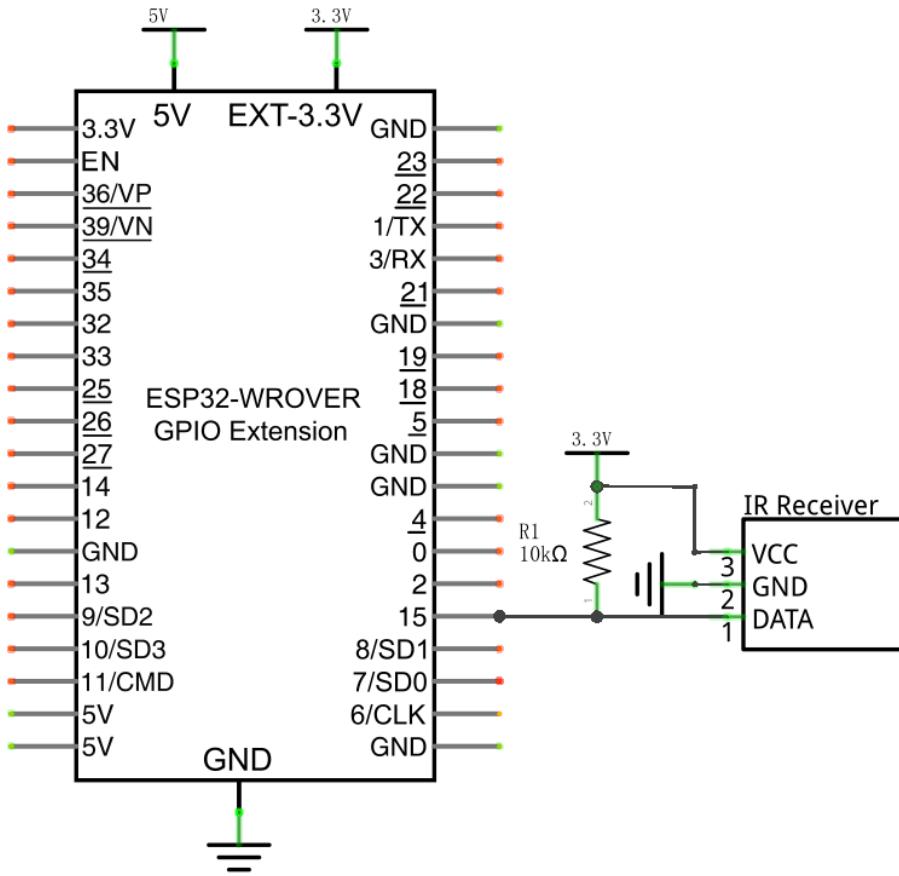
When you use the infrared remote control, the infrared remote control sends a key value to the receiving circuit according to the pressed keys. We can program the ESP32-WROVER to do things like lighting, when a key value is received.

The following is the key value that the receiving circuit will receive when each key of the infrared remote control is pressed.

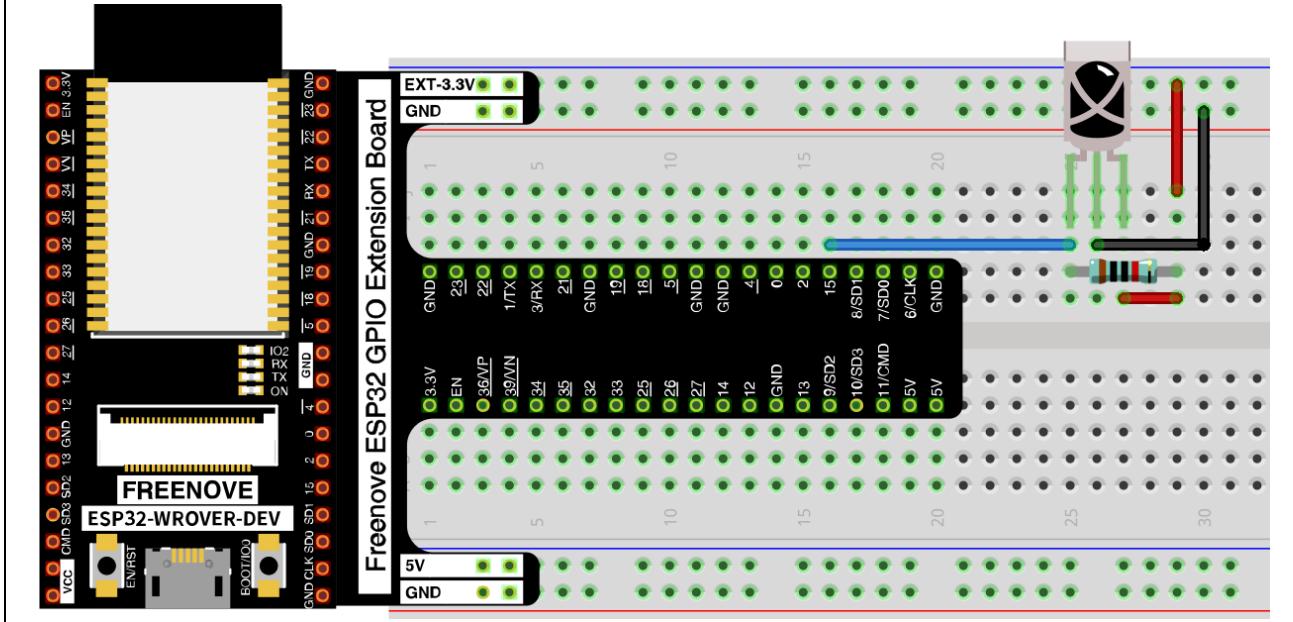
ICON	KEY Value	ICON	KEY Value
	FFA25D		FFB04F
	FFE21D		FF30CF
	FF22DD		FF18E7
	FF02FD		FF7A85
	FFC23D		FF10EF
	FFE01F		FF38C7
	FFA857		FF5AA5
	FF906F		FF42BD
	FF6897		FF4AB5
	FF9867		FF52AD

## Circuit

Schematic diagram



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



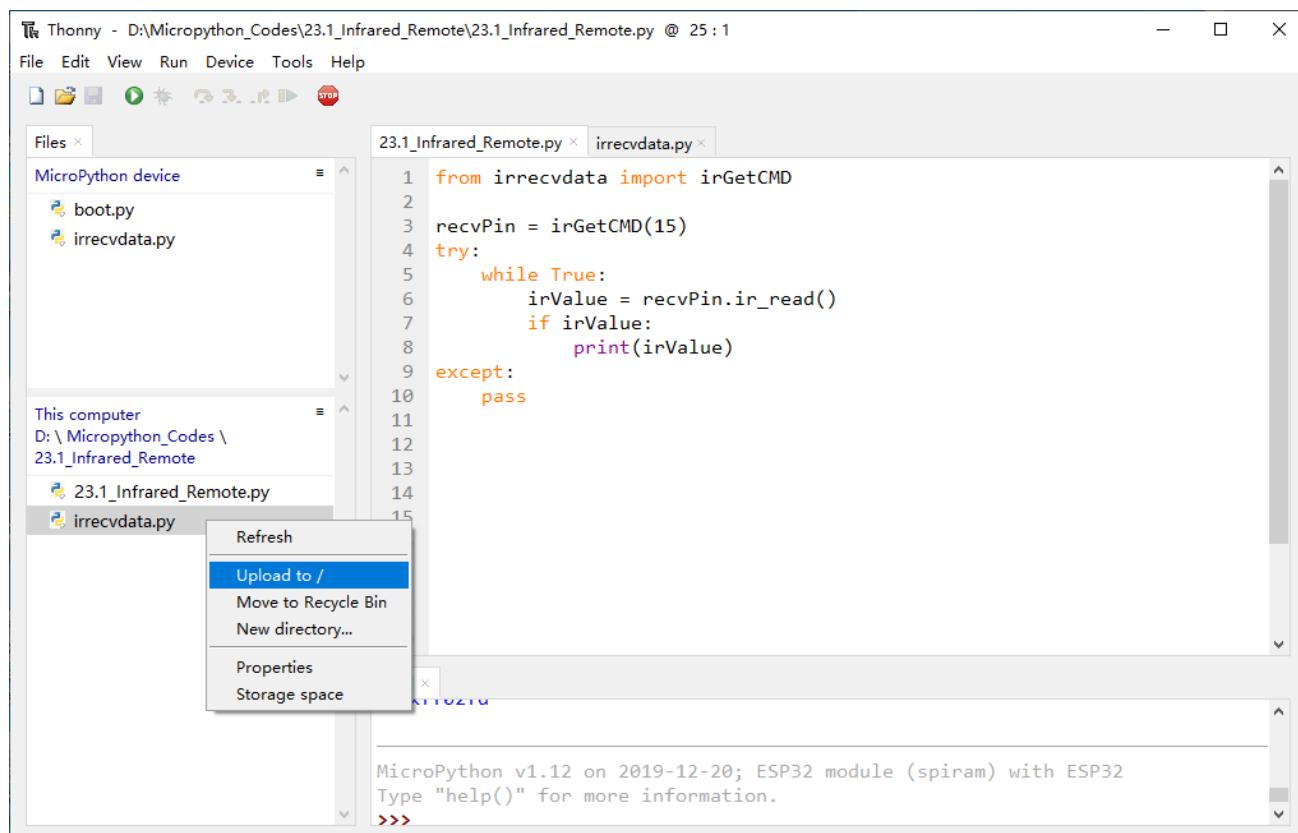
Any concerns? ✉ [support@freenove.com](mailto:support@freenove.com)

## Code

Move the program folder “**Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32/Python/Python\_Codes**” to disk(D) in advance with the path of “**D:/Micropython\_Codes**”.

Open “Thonny”, click “This computer” → “D:” → “Micropython\_Codes” → “23.1\_Infrared\_Remote”. Select “irrecvdata.py”, right click your mouse to select “Upload to /”, wait for “irrecvdata.py” to be uploaded to ESP32-WROVER and then double click “23.1\_Infrared\_Remote.py”.

### 23.1\_Infrared\_Remote



Click “Run current script”, press the key of the infrared remote and the key value will be printed in “Shell”. As shown in the illustration below:

The screenshot shows the Thonny Shell window. It displays the following text:

```

Shell x
>>>
Type "help()" for more information.
>>> %Run -c $EDITOR_CONTENT
0xff30cf
0xff18e7
0xff7a85
0xff10ef
0xff38c7
0xff5aa5
0xff42bd
0xff4ab5
0xff52ad
0xff6897
0xff9867

```

The following is the program code:

```
1  from irrecvdata import irGetCMD  
2  
3  recvPin = irGetCMD(15)  
4  try:  
5      while True:  
6          irValue = recvPin.ir_read()  
7          if irValue:  
8              print(irValue)  
9  except:  
10     pass
```

Import the infrared decoder.

```
1  from irrecvdata import irGetCMD
```

Associate the infrared decoder with Pin(15).

```
6  recvPin = irGetCMD(15)
```

Call `ir_read()` to read the value of the pressed key and assign it to `IRValue`.

```
12  irValue = recvPin.ir_read()
```

When infrared key value is obtained, print it out in "Shell".

```
5      while True:  
6          irValue = recvPin.ir_read()  
7          if irValue:  
8              print(irValue)
```

#### Reference

##### Class `irrecvdata`

Before each use of the object `irrecvdata`, please add the statement "`from irrecvdata import irGetCMD`" to the top of the python file.

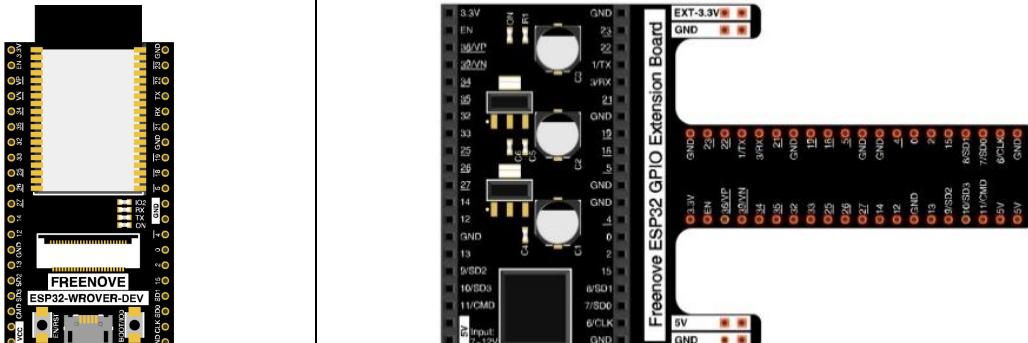
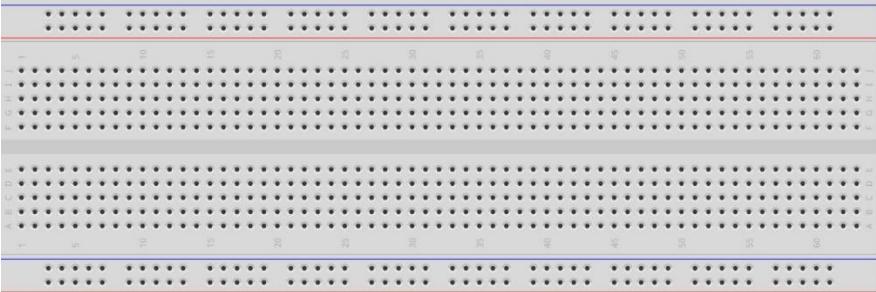
**irGetCMD()**: Object of infrared encoder, which is associated with Pin(15) by default.

**ir\_read()**: The function that reads the key value of infrared remote. When the value is read, it will be returned; when no value is obtained, character **None** will be returned.

## Project 23.2 Control LED through Infrared Remote

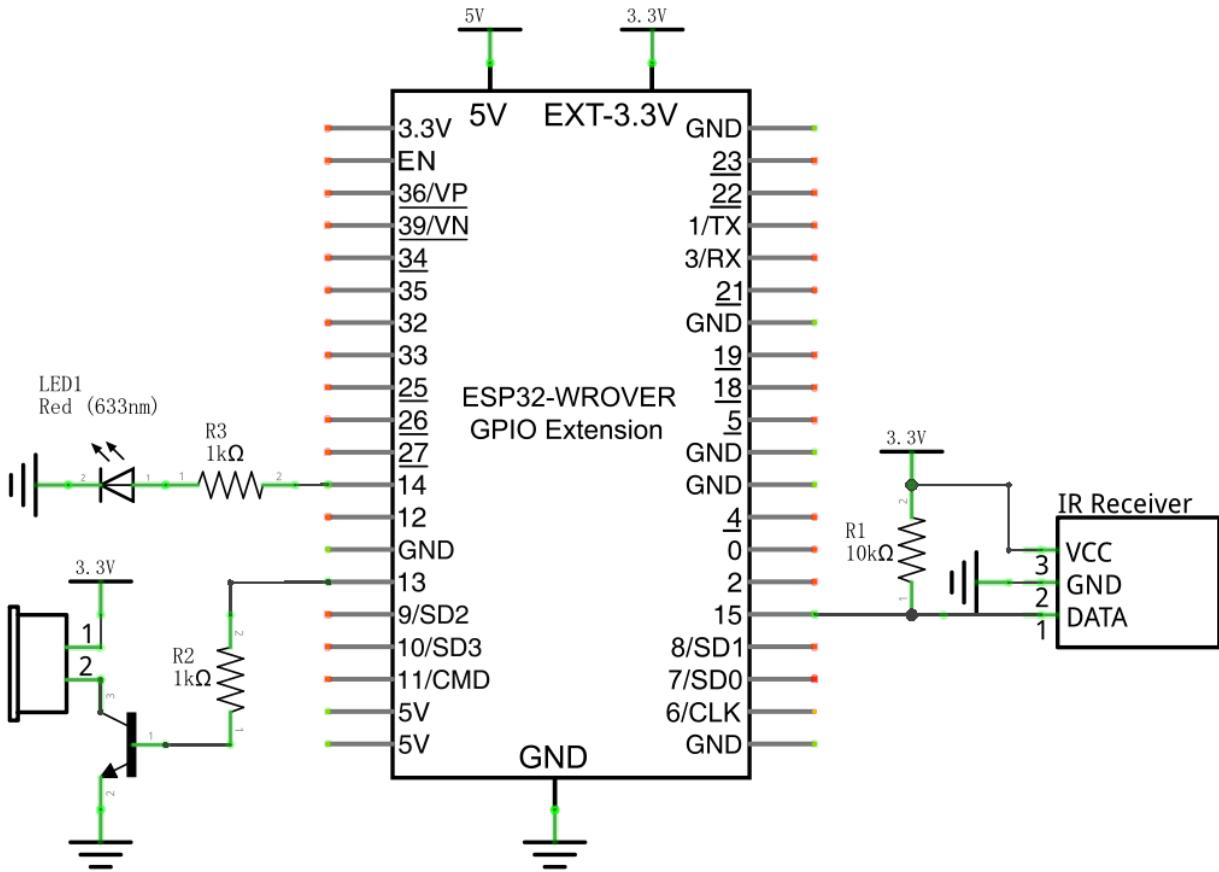
In this project, we will control the brightness of LED lights through an infrared remote control.

### Component List

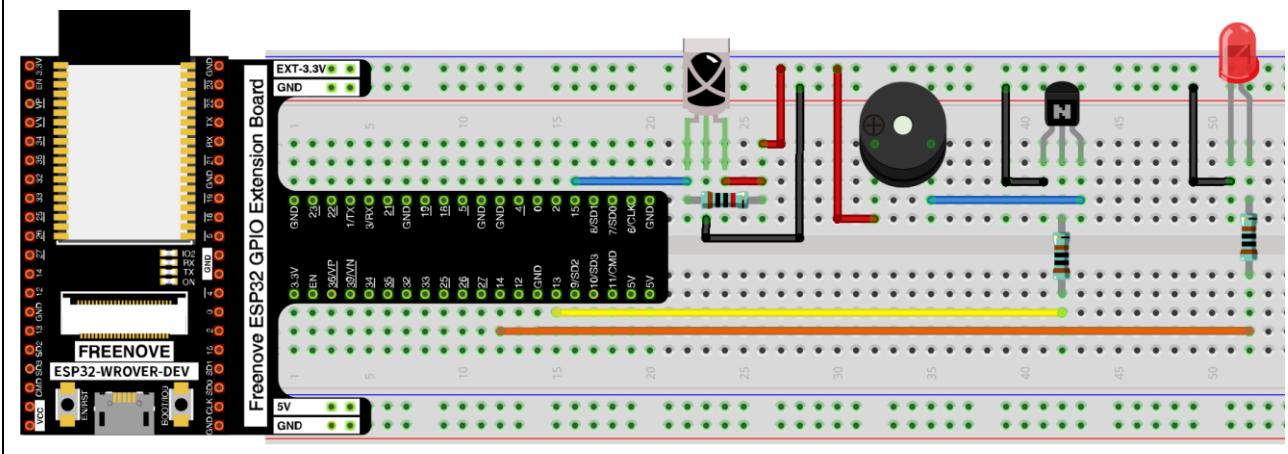
ESP32-WROVER x1	GPIO Extension Board x1
	
Breadboard x1	
Jumper M/M x10	Infrared Remote x1 (May need CR2025 battery x1, please check the holder)
LED x1	Resistor 1kΩ x2
	
Infrared receiver x1	Resistor 10kΩ x1
	

## Circuit

Schematic diagram



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



## Code

The Code controls the brightness of the LED by determining the key value of the infrared received.

Move the program folder “**Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32/Python/Python\_Codes**” to disk(D) in advance with the path of “**D:/Micropython\_Codes**”.

Open “Thonny”, click “This computer” → “D:” → “Micropython\_Codes” → “23.2\_Control\_LED\_through\_Infrared\_Remote”. Select “irrecvdata.py”, right click your mouse to select “Upload to /”, wait for “irrecvdata.py” to be uploaded to ESP32-WROVER and then double click “23.2\_Control\_LED\_through\_Infrared\_Remote.py”.

### 23.2\_Control\_LED\_through\_Infrared\_Remote

The screenshot shows the Thonny IDE interface. The title bar says "Thonny - D:\Micropython\_Codes\23.2\_Control\_LED\_through\_Infrared\_Remote\23.2\_Control\_LED\_through\_Infrared\_Remote.py". The menu bar includes File, Edit, View, Run, Device, Tools, and Help. Below the menu is a toolbar with icons for file operations. The left sidebar has a "Files" tab and a "MicroPython device" tab. Under "MicroPython device", there are files "boot.py" and "irrecvdata.py". Under "This computer", there is a folder "23.2\_Control\_LED\_through\_Infrared\_Remote" containing "irrecvdata.py". A context menu is open over "irrecvdata.py" with options: Refresh, Upload to / (which is highlighted in blue), Move to Recycle Bin, New directory..., Properties, and Storage space. The main editor window displays the Python code for "23.2\_Control\_LED\_through\_Infrared\_Remote.py". The code defines a function "handleControl" that prints a value and sets the duty of a ledPin based on the value. The code uses time.sleep\_ms(100). The bottom right corner shows a shell window with the text: "MicroPython v1.12 on 2019-12-20; ESP32 module (spiram) with ESP32". The shell prompt is ">>>".

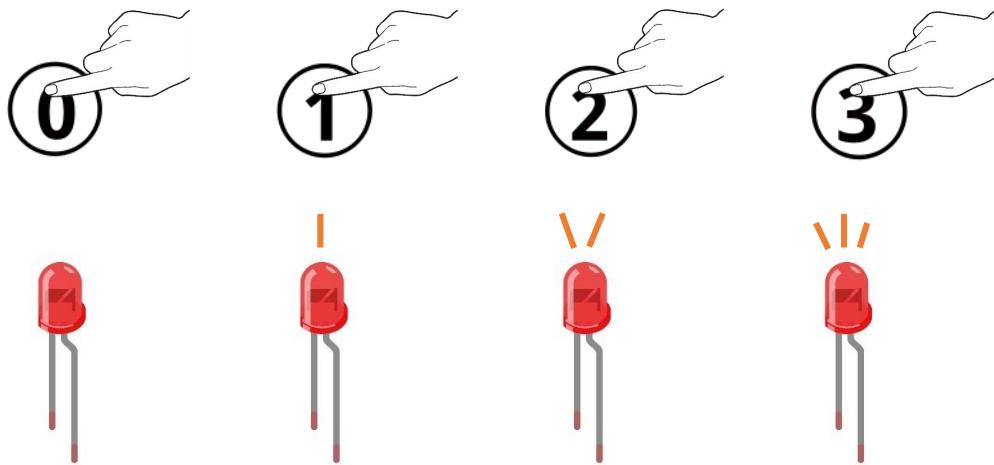
```
def handleControl(value):
    buzzerPin.value(1)
    time.sleep_ms(100)
    buzzerPin.value(0)

    if value == '0xff6897': #0
        print('0')
        ledPin.duty(1)
    elif value == '0xff30cf': #1
        print('1')
        ledPin.duty(100)
    elif value == '0xff18e7': #2
        print('2')
        ledPin.duty(300)
    elif value == '0xff7a85': #3
        print('3')
        ledPin.duty(1000)
    else:
        return
```



Click “Run current script”. When pressing “0”, “1”, “2”, “3” of the infrared remote control, the buzzer will sound once, and the brightness of the LED light will change correspondingly.

Rendering



The following is the program code:

```

1  from machine import Pin, PWM
2  import time
3  from irrecvdata import irGetCMD
4
5  ledPin=PWM(Pin(14,Pin.OUT), 10000, 512)
6  buzzerPin=Pin(13,Pin.OUT)
7  recvPin = irGetCMD(15)
8
9  def handleControl(value):
10     buzzerPin.value(1)
11     time.sleep_ms(100)
12     buzzerPin.value(0)
13
14     if value == '0xff6897': #0
15         print('0')
16         ledPin.duty(1)
17     elif value == '0xff30cf': #1
18         print('1')
19         ledPin.duty(100)
20     elif value == '0xff18e7': #2
21         print('2')
22         ledPin.duty(300)
23     elif value == '0xff7a85': #3
24         print('3')
25         ledPin.duty(1000)
26     else:
27         return

```

```

28 try:
29     while True:
30         irValue = recvPin.ir_read()
31         if irValue:
32             print(irValue)
33             handleControl(irValue)
34     except:
35         ledPin.deinit()

```

The handleControl() function is used to execute events corresponding to infrared code values. Every time when the function is called, the buzzer sounds once and determines the brightness of the LED based on the infrared key value. If the key value is not "0", "1", "2", "3", the buzzer sounds once, but the brightness of LED will not change.

```

9 def handleControl(value):
10     buzzerPin.value(1)
11     time.sleep_ms(100)
12     buzzerPin.value(0)
13
14     if value == '0xff6897': #0
15         print('0')
16         ledPin.duty(1)
17     elif value == '0xff30cf': #1
18         print('1')
19         ledPin.duty(100)
20     elif value == '0xff18e7': #2
21         print('2')
22         ledPin.duty(300)
23     elif value == '0xff7a85': #3
24         print('3')
25         ledPin.duty(1000)
26     else:
27         return

```

Each time the key value of IR remote is received, function handleControl() will be called to process it.

```

28 try:
29     while True:
30         irValue = recvPin.ir_read()
31         if irValue:
32             print(irValue)
33             handleControl(irValue)
34     except:
35         ledPin.deinit()

```

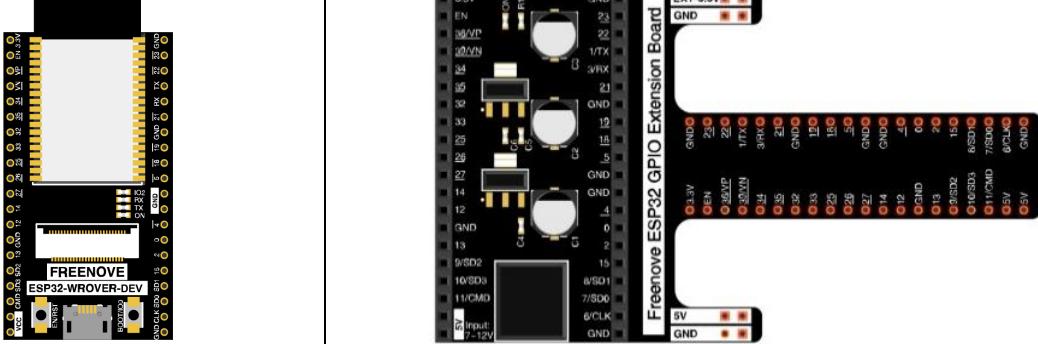
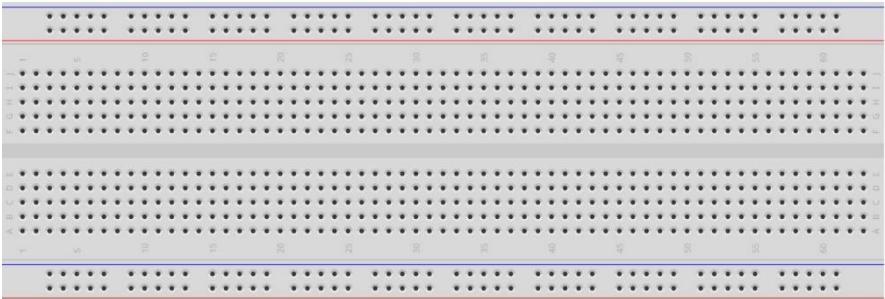
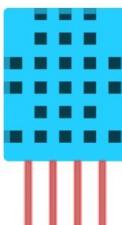
# Chapter 24 Hygrothermograph DHT11

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

## Project 24.1 Hygrothermograph

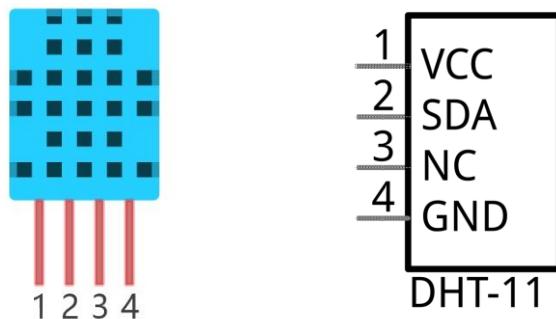
Hygrothermograph is an important tool in our lives to give us data on the temperature and humidity in our environment. In this project, we will use the ESP32 to read Temperature and Humidity data of the DHT11 Module.

### Component List

ESP32-WROVER x1	GPIO Extension Board x1
	
Breadboard x1	
	
Jumper M/M x4	DHT11 x1
	
	

## Component knowledge

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



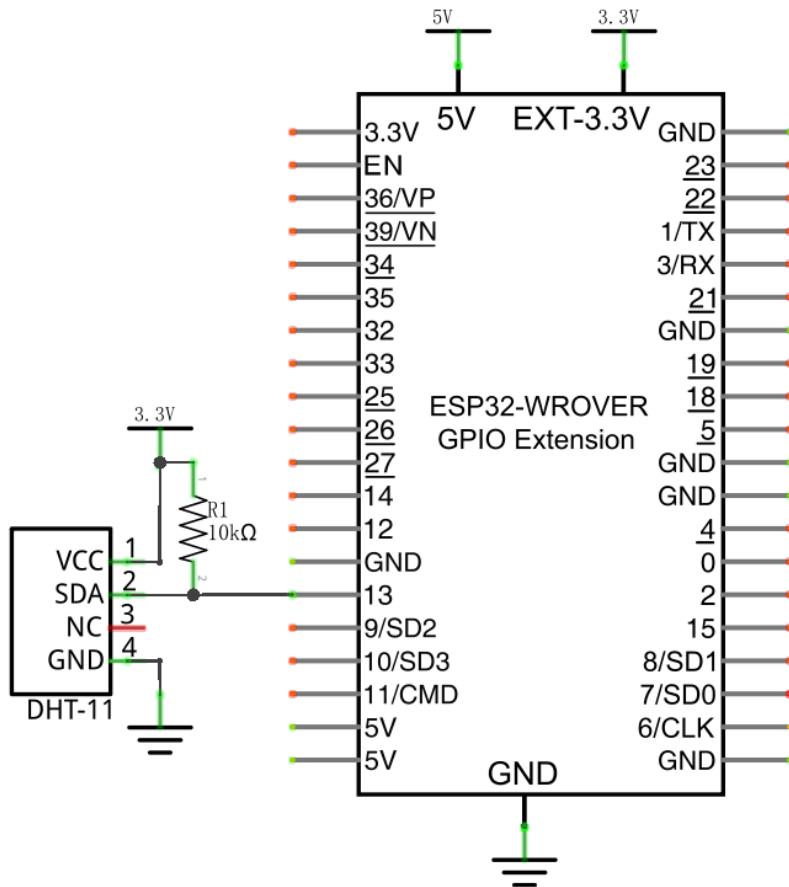
DHT11 uses customized single-line communication protocol, so we can use the library to read data more conveniently.

After being powered up, it will initialize in 1S's time. Its operating voltage is within the range of 3.3V-5.5V. The SDA pin is a data pin, which is used to communicate with other devices.

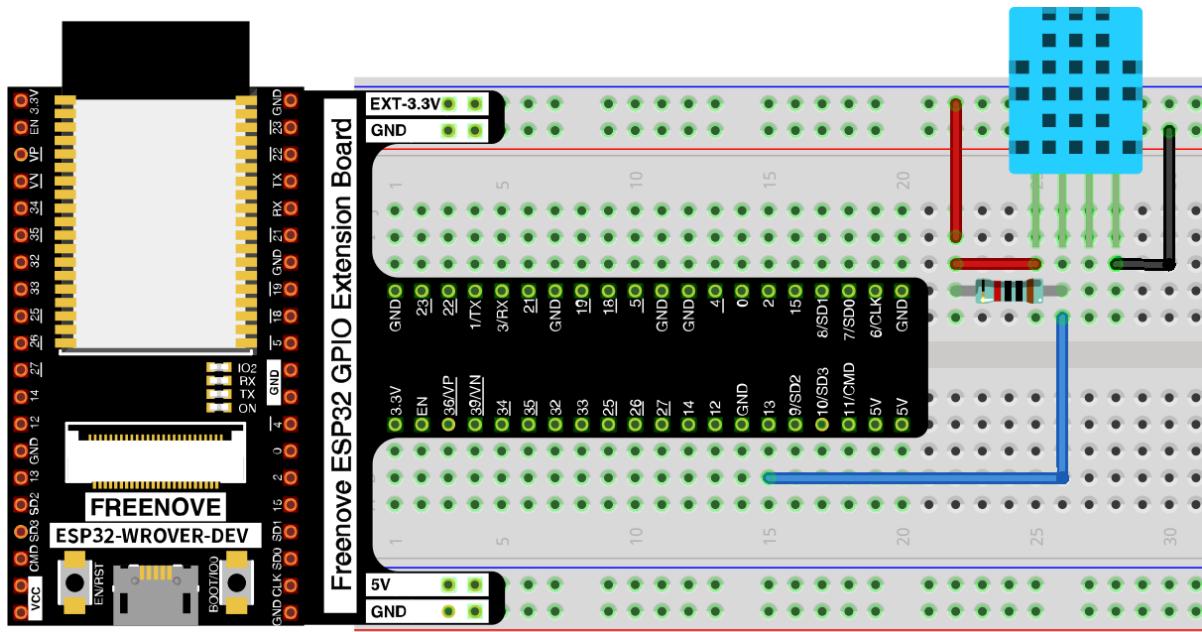
The NC pin (Not Connected Pin) is a type of pin found on various integrated circuit packages. Those pins have no functional purpose to the outside circuit (but may have an unknown functionality during manufacture and test). Those pins should not be connected to any of the circuit connections.

## Circuit

Schematic diagram



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



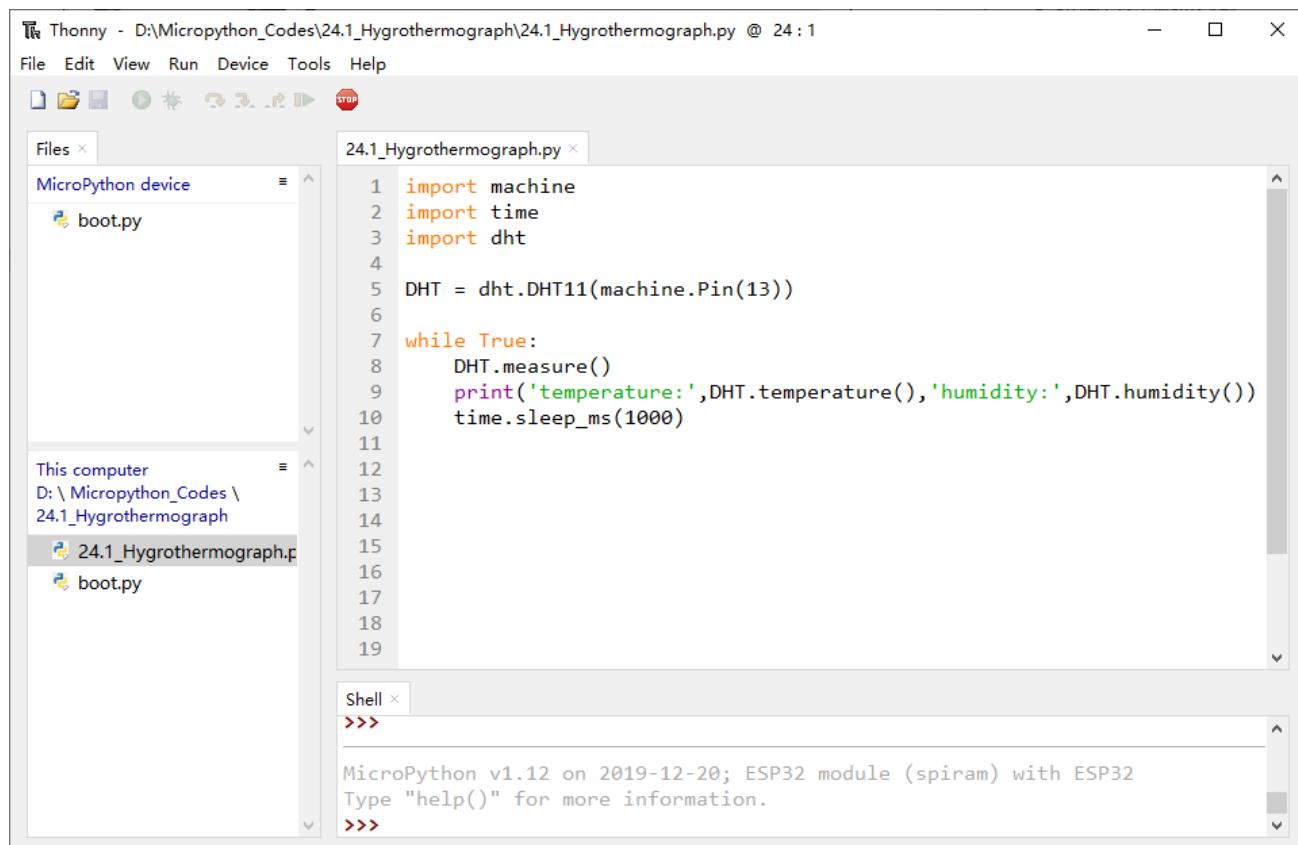
Any concerns? ✉ [support@freenove.com](mailto:support@freenove.com)

## Code

Move the program folder “**Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32/Python/Python\_Codes**” to disk(D) in advance with the path of “**D:/Micropython\_Codes**”.

Open “Thonny”, click “This computer” → “D:” → “Micropython\_Codes” → “24.1\_Hygrothermograph” and double click “24.1\_Hygrothermograph.py”.

### 24.1\_Hygrothermograph



Click “Run current script”. If your DHT11 is connected incorrectly, the following information will be printed in “Shell”.

```

MicroPython v1.12 on 2019-12-20; ESP32 module (spiram) with ESP32
Type "help()" for more information.
>>> %Run -c $EDITOR_CONTENT
Traceback (most recent call last):
  File "<stdin>", line 8, in <module>
    File "dht.py", line 16, in measure
      OSError: [Errno 110] ETIMEDOUT

```



Make sure your circuit is correctly connected and you will see the following messages printed in "Shell".

```
Shell x
Type "help()" for more information.
>>> %Run -c $EDITOR_CONTENT

temperature: 28 humidity: 60
temperature: 28 humidity: 46
temperature: 28 humidity: 49
temperature: 28 humidity: 50
temperature: 28 humidity: 53
temperature: 28 humidity: 55
temperature: 28 humidity: 57
temperature: 28 humidity: 59
temperature: 28 humidity: 61
temperature: 28 humidity: 63
temperature: 28 humidity: 61
temperature: 28 humidity: 59
temperature: 28 humidity: 57
temperature: 28 humidity: 56
temperature: 28 humidity: 54
temperature: 28 humidity: 54
```

The following is the program code:

```
1 import machine
2 import time
3 import dht
4
5 DHT = dht.DHT11(machine.Pin(13))
6
7 while True:
8     DHT.measure()
9     print(' temperature:', DHT.temperature(), 'humidity:', DHT.humidity())
10    time.sleep_ms(1000)
```

Import machine, time and dht modules.

```
1 import machine
2 import time
3 import dht
```

Associate DHT11 with Pin(13).

```
5 DHT = dht.DHT11(machine.Pin(13))
```

Start DHT11 to measure data once.

```
8 DHT.measure()
```

Call the built-in function of DHT to obtain temperature and humidity data and print them in "Shell".

```
9 print(' temperature:', DHT.temperature(), 'humidity:', DHT.humidity())
```

Obtain temperature and humidity data once per second and print them out.

```
7 while True:
8     DHT.measure()
9     print(' temperature:', DHT.temperature(), 'humidity:', DHT.humidity())
10    time.sleep_ms(1000)
```

## Reference

### Class dht

Before each use of object **dht**, please add the statement “**import dht**” to the top of python file.

**DHT11()**: Object of DHT11

**DHT12()**: Object of DHT12

**DHT11.measure()**: Start DHT11 to measure temperature and humidity data once.

**DHT11.temperature()**: Return temperature data obtained by DHT11.

**DHT11.humidity()**: Return humidity data obtained by DHT11.

**DHT12.measure()**: Start DHT12 to measure temperature and humidity data once

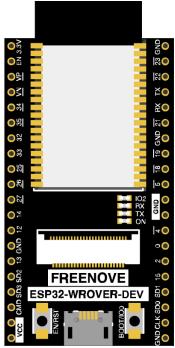
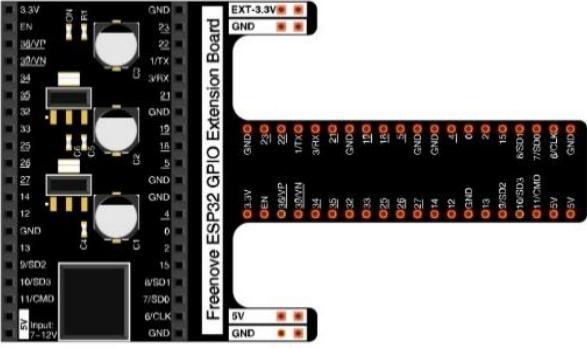
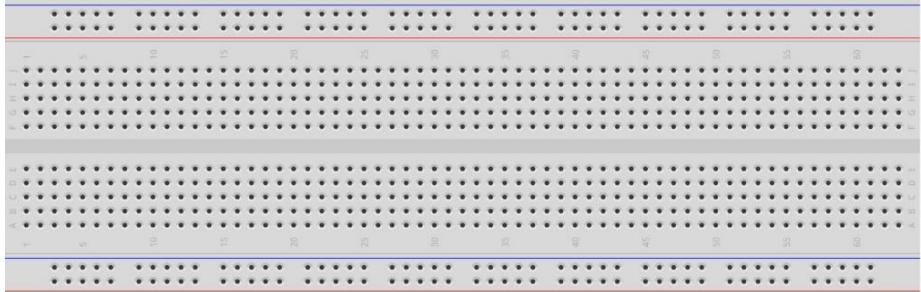
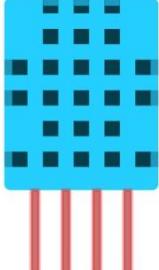
**DHT12.temperature()**: Return temperature data obtained by DHT12.

**DHT12.humidity()**: Return humidity data obtained by DHT12.

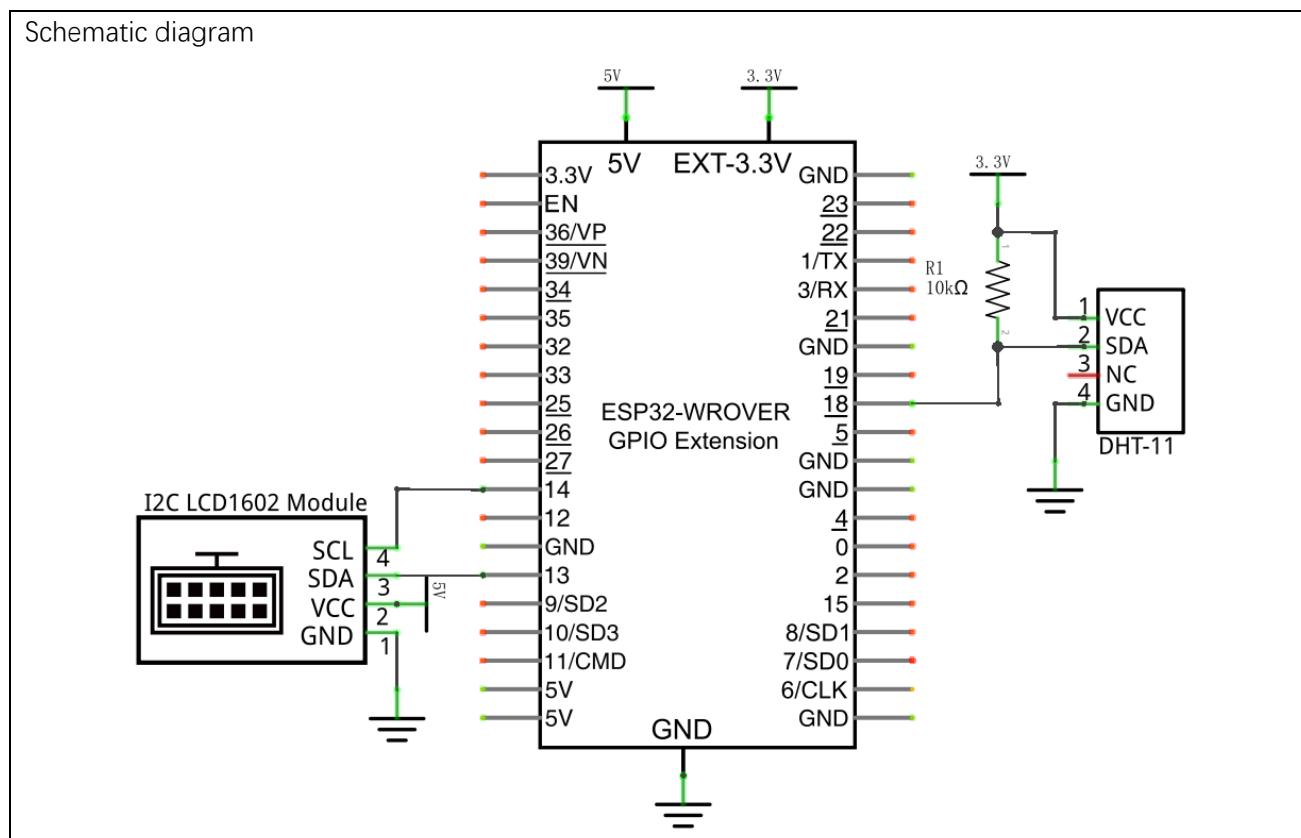
## Project 24.2 Hygrothermograph

In this project, we use L2C-LCD1602 to display data collected by DHT11.

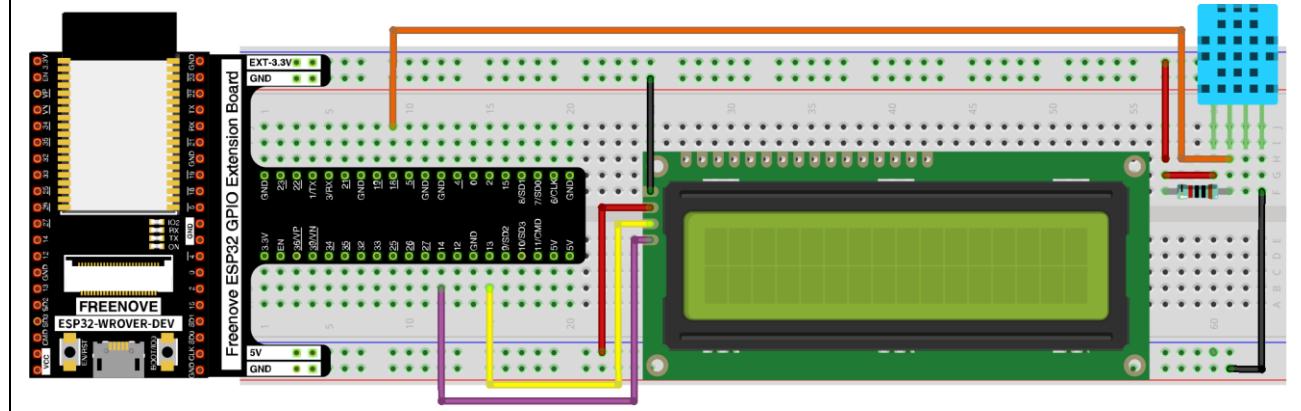
### Component List

ESP32-WROVER x1	GPIO Extension Board x1
 	
Breadboard x1	
	
LCD1602 Module x1	Resistor 10kΩ x1
Jumper F/M x4 Jumper M/M x4	DHT11 x1
 	

## Circuit



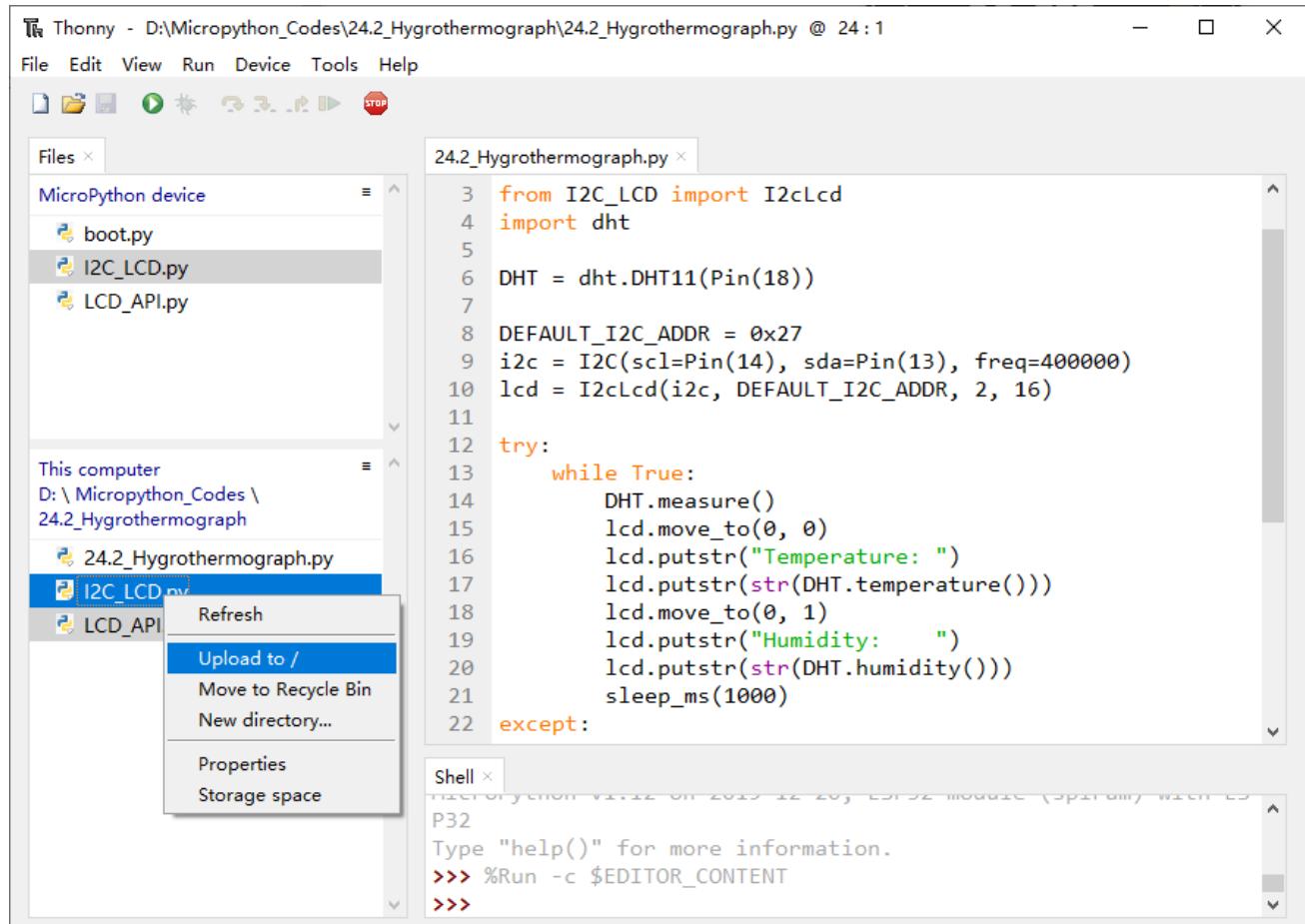
Hardware connection. If you need any support, please feel free to contact us via: [support@freenove.com](mailto:support@freenove.com)



## Code

Open “Thonny”, click “This computer” → “D:” → “Micropython\_Codes” → 24.2\_Hygrothermograph”. Select “I2C\_LCD.py” and “LCD\_API.py”, right click your mouse to select “Upload to /”, wait for “I2C\_LCD.py” and “LCD\_API.py” to be uploaded to ESP32-WROVER and then double click “24.2\_Hygrothermograph.py”.

### 24.2\_Hygrothermograph

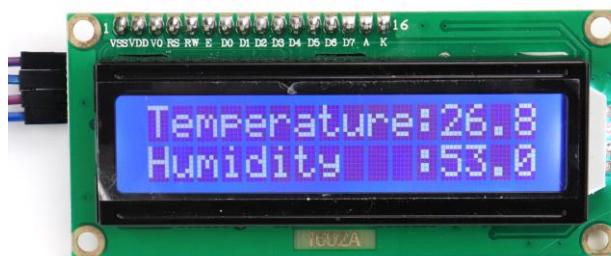


```

from I2C_LCD import I2cLcd
import dht
DHT = dht.DHT11(Pin(18))
DEFAULT_I2C_ADDR = 0x27
i2c = I2C(scl=Pin(14), sda=Pin(13), freq=400000)
lcd = I2cLcd(i2c, DEFAULT_I2C_ADDR, 2, 16)
try:
    while True:
        DHT.measure()
        lcd.move_to(0, 0)
        lcd.putstr("Temperature: ")
        lcd.putstr(str(DHT.temperature()))
        lcd.move_to(0, 1)
        lcd.putstr("Humidity:   ")
        lcd.putstr(str(DHT.humidity()))
        sleep_ms(1000)
except:

```

Click “Run current script”. The first row of LCD1602 is temperature value and the second row is humidity. Try to “pinch” the DHT11 (without touching the leads) with your index finger and thumb for a brief time, you should see that the displayed value on LCD1602 changes.



The following is the program code:

```

1  from time import sleep_ms
2  from machine import I2C, Pin
3  from I2C_LCD import I2cLcd
4  import dht
5
6  DHT = dht.DHT11(Pin(18))
7  DEFAULT_I2C_ADDR = 0x27
8  i2c = I2C(scl=Pin(14), sda=Pin(13), freq=400000)
9  lcd = I2cLcd(i2c, DEFAULT_I2C_ADDR, 2, 16)
10
11 try:
12     while True:
13         DHT.measure()
14         lcd.move_to(0, 0)
15         lcd.putstr("Temperature: ")
16         lcd.putstr(str(DHT.temperature()))
17         lcd.move_to(0, 1)
18         lcd.putstr("Humidity: ")
19         lcd.putstr(str(DHT.humidity()))
20         sleep_ms(1000)
21 except:
22     pass

```

Import DHT11 and I2C LCD1602 modules.

```

1  from time import sleep_ms
2  from machine import I2C, Pin
3  from I2C_LCD import I2cLcd
4  import dht

```

Assign Pin(18) to DHT11, Pin(13) and Pin(14) to LCD1602.

```

6  DHT = dht.DHT11(Pin(18))
7  DEFAULT_I2C_ADDR = 0x27
8  i2c = I2C(scl=Pin(14), sda=Pin(13), freq=400000)
9  lcd = I2cLcd(i2c, DEFAULT_I2C_ADDR, 2, 16)

```

Obtain data of Hygrothermograph every second and display them on LCD1602. The first line displays temperature and the second line displays humidity.

```

12 while True:
13     DHT.measure()
14     lcd.move_to(0, 0)
15     lcd.putstr("Temperature: ")
16     lcd.putstr(str(DHT.temperature()))
17     lcd.move_to(0, 1)
18     lcd.putstr("Humidity: ")
19     lcd.putstr(str(DHT.humidity()))
20     sleep_ms(1000)

```



# Chapter 25 Infrared Motion Sensor

In this chapter, we will learn a widely used sensor, Infrared Motion Sensor.

## Project 25.1 Infrared Motion Detector with LED Indicator

In this project, we will make a Motion Detector, with the human body infrared pyroelectric sensors.

When someone is in close proximity to the Motion Detector, it will automatically light up and when there is no one close by, it will be out.

This Infrared Motion Sensor can detect the infrared spectrum (heat signatures) emitted by living humans and animals.

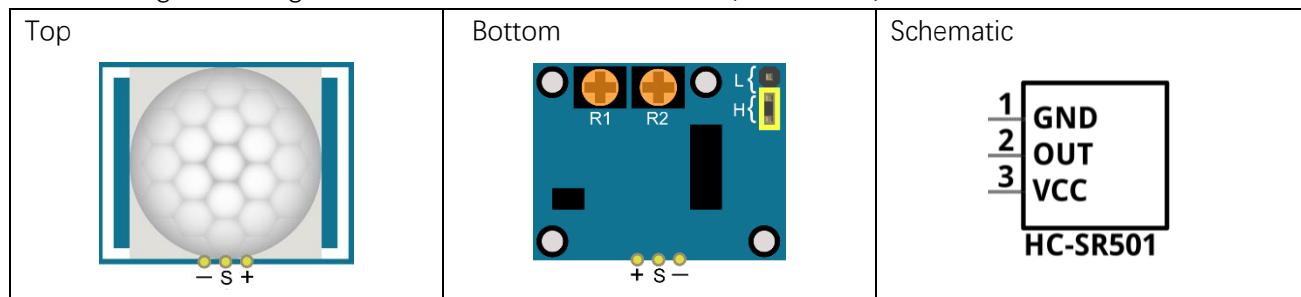
### Component List

ESP32-WROVER x1	GPIO Extension Board x1				
Breadboard x1					
HC SR501 x1	LED x1	Resistor 220Ω x1	Jumper F/M x3	Jumper M/M x2	

Any concerns? [✉ support@freenove.com](mailto:support@freenove.com)

## Component knowledge

The following is the diagram of the infrared Motion sensor (HC SR-501) :



Description:

Working voltage: 5v-20v(DC) Static current: 65uA.

Automatic Trigger. When a living body enters into the active area of sensor, the module will output high level (3.3V). When the body leaves the sensor's active detection area, it will output high level lasting for time period T, then output low level(0V). Delay time T can be adjusted by the potentiometer R1.

According to the position of jumper cap, you can choose non-repeatable trigger mode or repeatable mode.

L: non-repeatable trigger mode. The module output high level after sensing a body, then when the delay time is over, the module will output low level. During high level time, the sensor no longer actively senses bodies.

H: repeatable trigger mode. The distinction from the L mode is that it can sense a body until that body leaves during the period of high level output. After this, it starts to time and output low level after delaying T time.

Induction block time: the induction will stay in block condition and does not induce external signal at lesser time intervals (less than delay time) after outputting high level or low level.

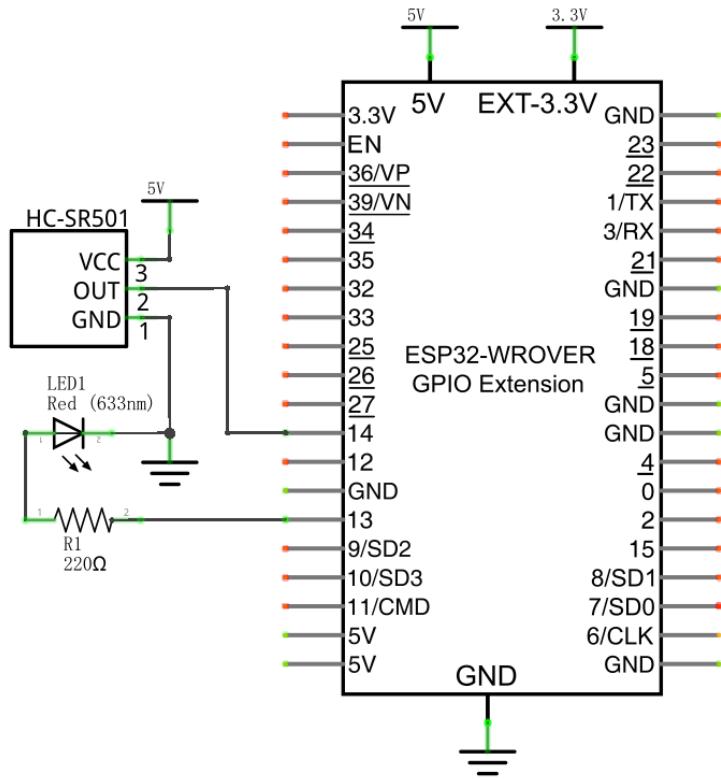
Initialization time: the module needs about 1 minute to initialize after being powered ON. During this period, it will alternately output high or low level.

One characteristic of this sensor is when a body moves close to or moves away from the sensor's dome edge, the sensor will work at high sensitivity. When a body moves close to or moves away from the sensor's dome in a vertical direction, the sensor cannot detect well (please take note of this deficiency). Note: The Sensing Range (distance before a body is detected) is adjusted by the potentiometer.

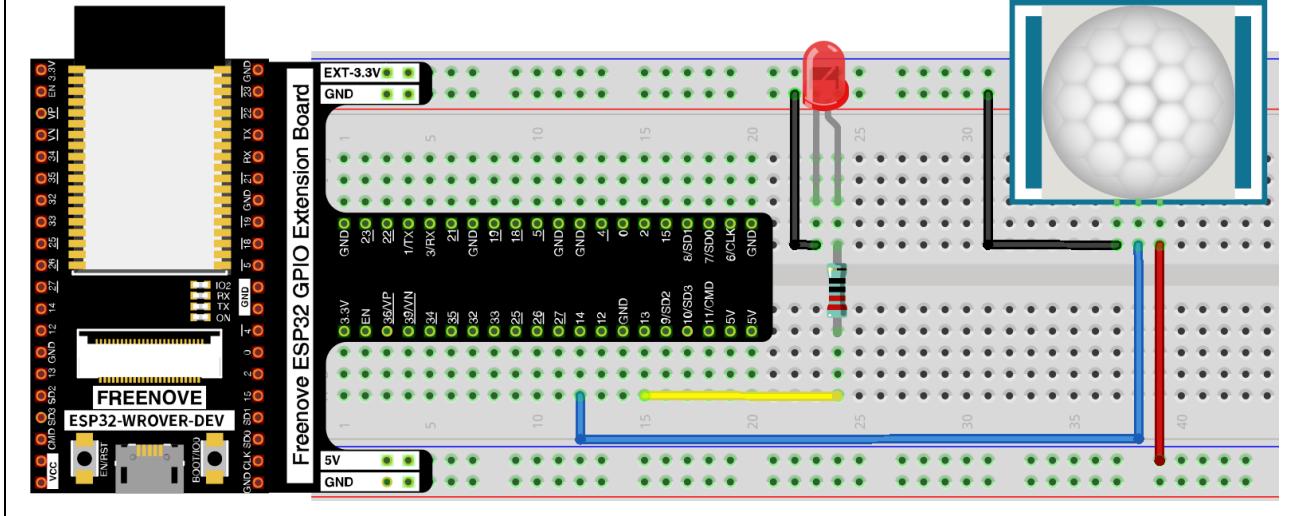
We can regard this sensor as a simple inductive switch when in use.

## Circuit

Schematic diagram



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



## Code

In this project, we will use an infrared motion sensor to trigger an LED, essentially using the infrared motion sensor as a motion switch. So the code of this project is similar to that of project "[Button & Led](#)". The difference is when infrared motion sensor detects changes, it will output high level; when it detects nothing, it will output low level. When the sensor outputs high level, LED turns ON; Otherwise, LED turns OFF.

Move the program folder "**Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32/Python/Python\_Codes**" to disk(D) in advance with the path of "**D:/Micropython\_Codes**".

Open "Thonny", click "This computer" → "D:" → "Micropython\_Codes" → "25.1\_Infrared\_Motion\_Detector" and then double click "25.1\_Infrared\_Motion\_Detector.py".

### 25.1\_Infrared\_Motion\_Detector

The screenshot shows the Thonny IDE interface. The title bar reads "Thonny - D:\Micropython\_Codes\25.1\_Infrared\_Motion\_Detector\25.1\_Infrared\_Motion\_Detector.py @ 27 : 5". The menu bar includes File, Edit, View, Run, Device, Tools, and Help. Below the menu is a toolbar with icons for file operations. The left sidebar has two tabs: "Files" and "This computer". Under "Files", there is a list of files: "MicroPython device", "boot.py", and "25.1\_Infrared\_Motion\_Detector.py". Under "This computer", there is a list of paths: "This computer", "D:\ Micropython\_Codes \ 25.1\_Infrared\_Motion\_Detector", and "25.1\_Infrared\_Motion\_Detector.py". The main central area displays the Python code for "25.1\_Infrared\_Motion\_Detector.py". The code uses the machine.Pin class from the machine module to control pins 14 and 13. It sets up a try-except loop where it checks the value of pin 14. If it's high (True), it sets pin 13 to 1 (ledPin.value(1)) to turn the LED on. If it's low (False), it sets pin 13 to 0 (ledPin.value(0)) to turn the LED off. The code ends with a pass statement. The bottom right corner of the code editor has a vertical scroll bar. At the bottom of the screen is a "Shell" window titled "P32". It contains the text: "Type "help()" for more information.", "=>>> %Run -c \$EDITOR\_CONTENT", and "=>>>".

```
from machine import Pin
import time

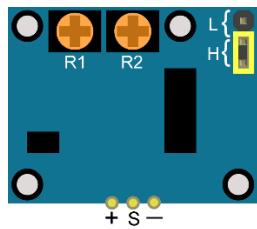
sensorPin=Pin(14,Pin.IN)
ledPin=Pin(13,Pin.OUT)

try:
    while True:
        if not sensorPin.value():
            ledPin.value(1) #Set led turn on
        else:
            ledPin.value(0) #Set led turn off
except:
    pass
```

Click "Run current script". Put the sensor on a stationary table and wait for about a minute. Then try to move away from or move closer to the Infrared Motion Sensor and observe whether the LED turns ON or OFF automatically.

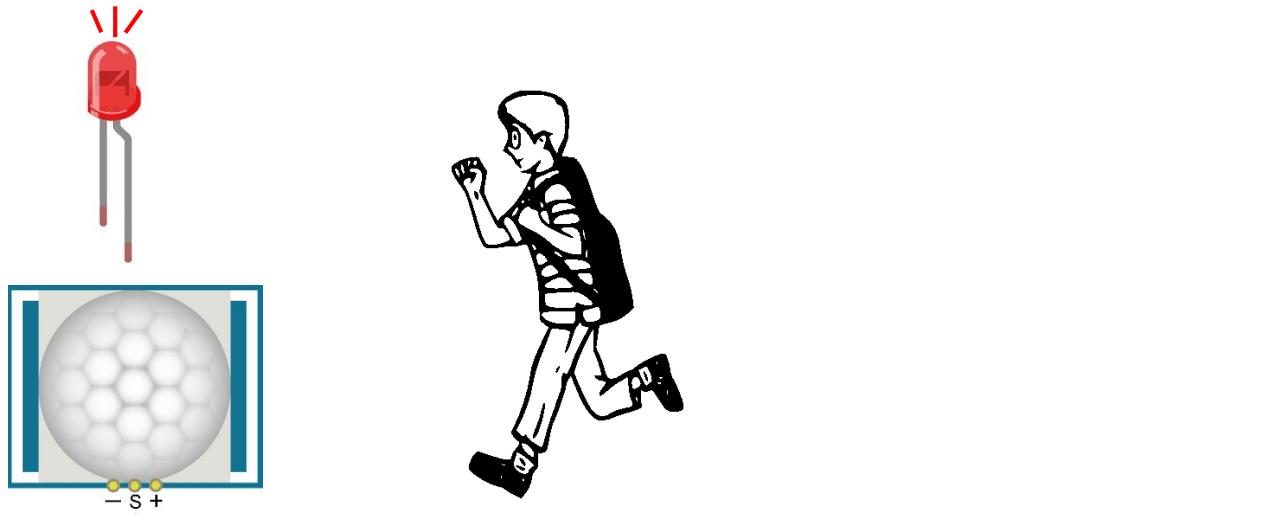


You can rotate the potentiometer on the sensor to adjust the detection effect, or use different modes by changing the jumper.



Apart from that, you can also use this sensor to control some other modules to implement different functions by reediting the code, such as the induction lamp, induction door.

#### Move to the Infrared Motion Sensor



#### Move away from the Infrared Motion Sensor



# Chapter 26 Attitude Sensor MPU6050

In this chapter, we will learn about a MPU6050 Attitude Sensor which integrates an Accelerometer and Gyroscope.

## Project 26.1 Read a MPU6050 Sensor Module

In this project, we will read Acceleration and Gyroscope Data of the MPU6050 Sensor

### Component List

ESP32-WROVER x1	GPIO Extension Board x1
Breadboard x1	
Jumper F/M x4	MPU6050 x1

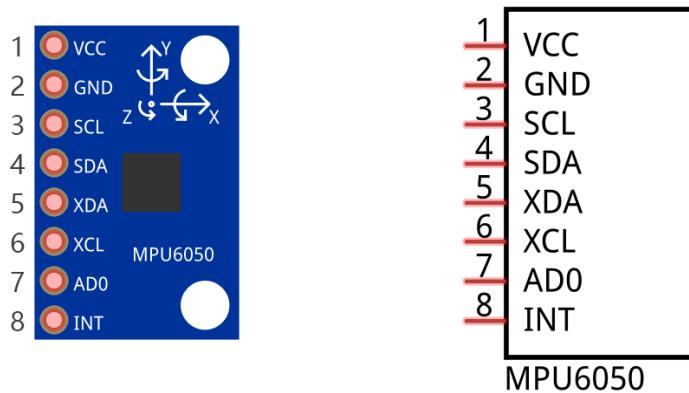


## Component knowledge

### MPU6050

MPU6050 Sensor Module is a complete 6-axis Motion Tracking Device. It combines a 3-axis Gyroscope, a 3-axis Accelerometer and a DMP (Digital Motion Processor) all in a small package. The settings of the Accelerometer and Gyroscope of MPU6050 can be changed. A precision wide range digital temperature sensor is also integrated to compensate data readings for changes in temperature, and temperature values can also be read. The MPU6050 Module follows the I2C communication protocol and the default address is 0x68.

MPU6050 is widely used to assist with balancing vehicles, robots and aircraft, mobile phones and other products which require stability to control stability and attitude or which need to sense same.



The port description of the MPU6050 module is as follows:

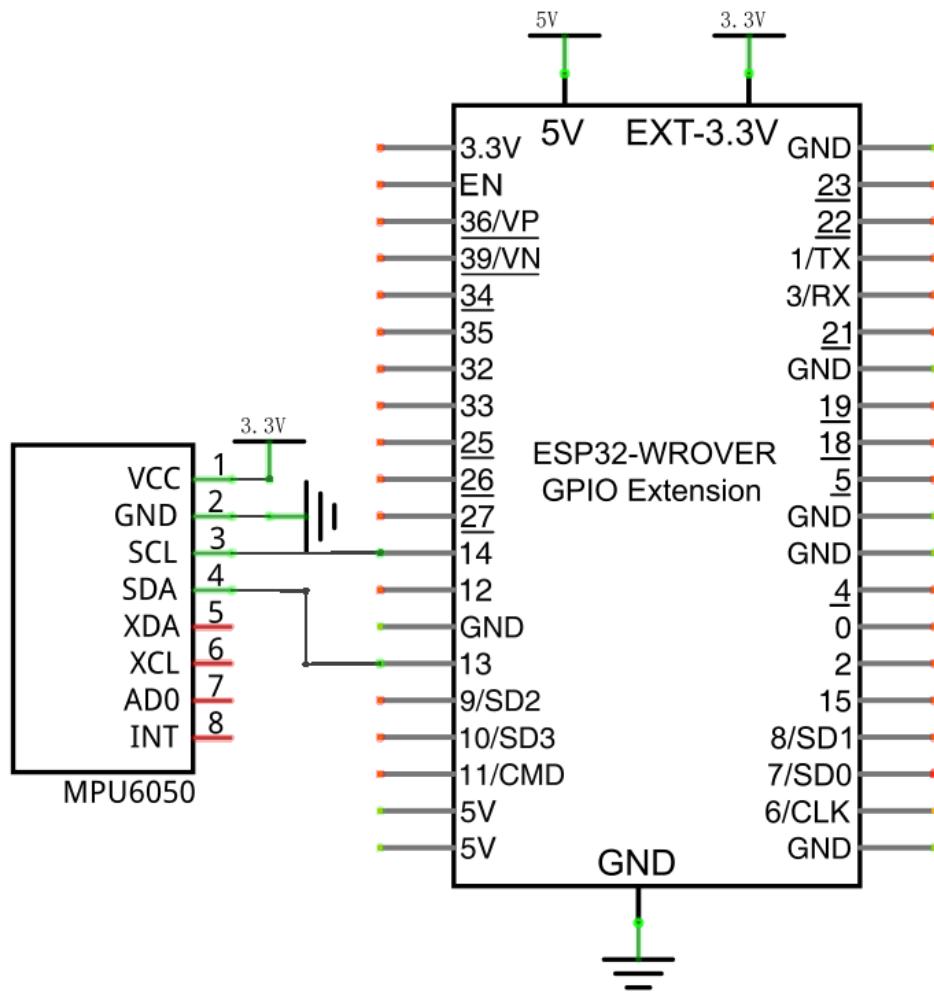
Pin name	Pin number	Description
VCC	1	Positive pole of power supply with voltage 5V
GND	2	Negative pole of power supply
SCL	3	I2C communication clock pin
SDA	4	I2C communication clock pin
XDA	5	I2C host data pin which can be connected to other devices.
XCL	6	I2C host clock pin which can be connected to other devices.
AD0	7	I2C address bit control pin. Low level: the device address is 0x68 High level: the device address is 0x69
INT	8	Output interrupt pin

For more detail, please refer to datasheet.

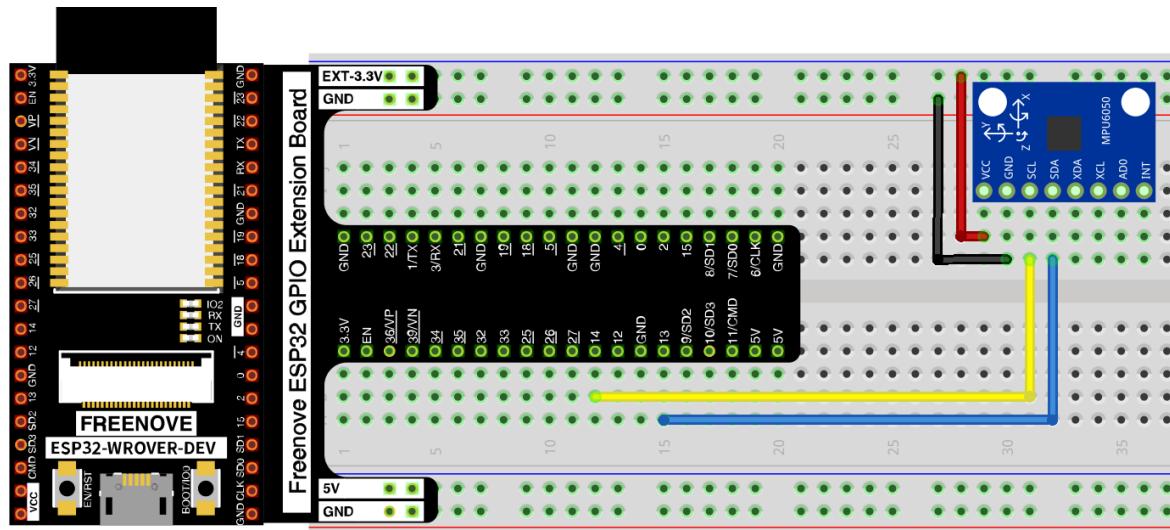
## Circuit

Note that the power supply voltage for MPU6050 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](mailto:support@freenove.com)

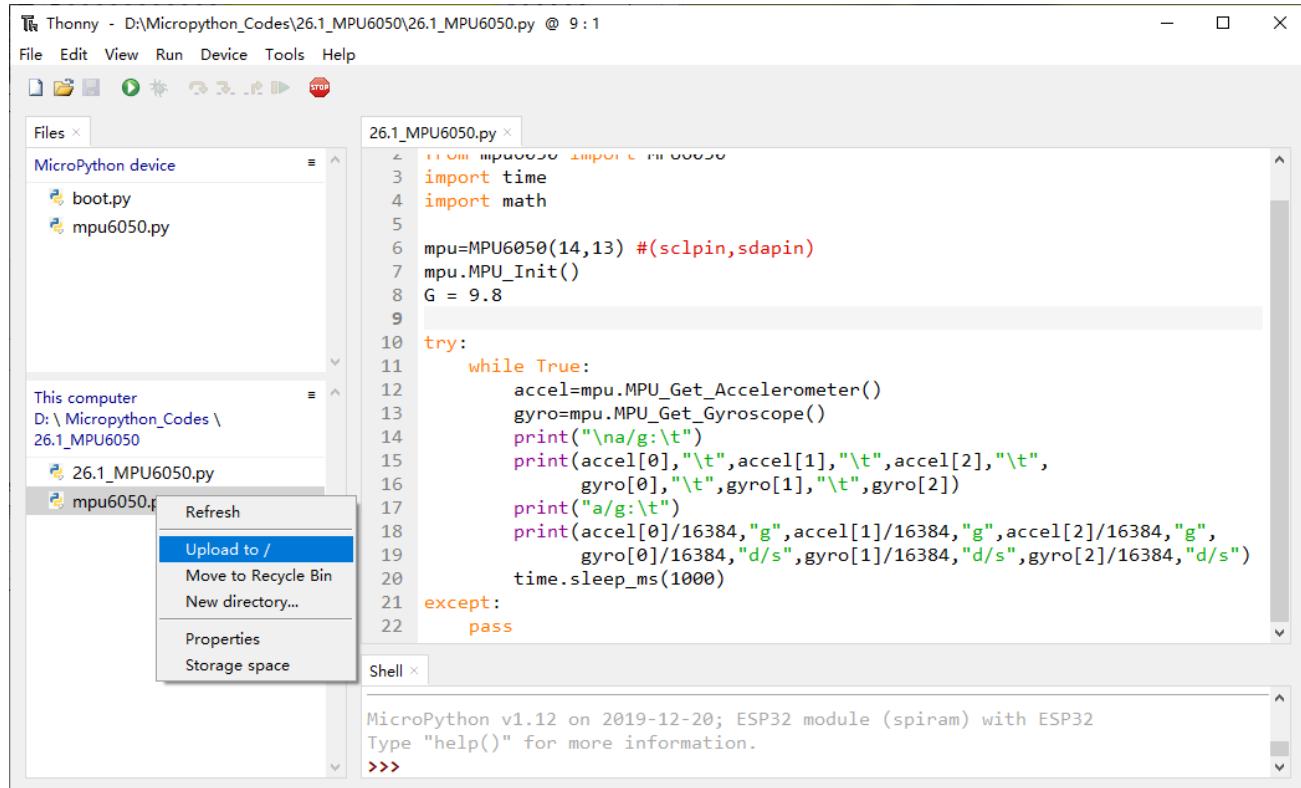


## Code

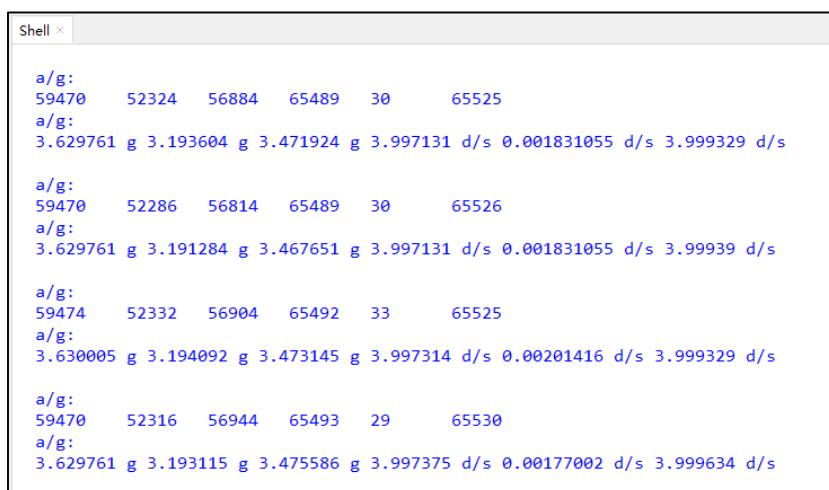
Move the program folder “**Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32/Python/Python\_Codes**” to disk(D) in advance with the path of “**D:/Micropython\_Codes**”.

Open “Thonny”, click “This computer” → “D:” → “Micropython\_Codes” → “26.1\_MPU6050”. Select “mpu6050.py”, right click your mouse to select “Upload to /”, wait for “mpu6050.py” to be uploaded to ESP32-WROVER and then double click “26.1\_MPU6050.py”.

### 26.1\_MPU6050



Click “Run current script”. When ESP32 obtains acceleration data and gyroscope data of MPU605, it will print them in “Shell”.



Note: The data transmission of MPU6050 is very sensitive. Therefore, when using it, please make sure the jumper wire is in good contact, otherwise the data may fail to be obtained.

The following is the program code:

```

1  from mpu6050 import MPU6050
2  import time
3
4  mpu=MPU6050(14, 13) #attach the IIC pin(sclpin, sdapin)
5  mpu.MPU_Init()      #initialize the MPU6050
6  G = 9.8
7  time.sleep_ms(1000)#waiting for MPU6050 to work steadily
8  try:
9      while True:
10         accel=mpu.MPU_Get_Accelerometer()#gain the values of Acceleration
11         gyro=mpu.MPU_Get_Gyroscope()      #gain the values of Gyroscope
12         print("\n\n/g:\t")
13         print(accel[0], "\t", accel[1], "\t", accel[2], "\t",
14               gyro[0], "\t", gyro[1], "\t", gyro[2])
15         print("a/g:\t")
16         print(accel[0]/16384, "g", accel[1]/16384, "g", accel[2]/16384, "g",
17               gyro[0]/16384, "d/s", gyro[1]/16384, "d/s", gyro[2]/16384, "d/s")
18         time.sleep_ms(1000)
19     except:
20         pass

```

Import MPU6050 and time modules.

```

1  from mpu6050 import MPU6050
2  import time

```

Set I2C pins and associate them with MPU6050 module, and then initialize MPU6050 and wait for the initialization to complete.

```

4  mpu=MPU6050(14, 13) #attach the IIC pin(sclpin, sdapin)
5  mpu.MPU_Init()      #initialize the MPU6050
6  G = 9.8
7  time.sleep_ms(1000)#waiting for MPU6050 to work steadily

```

Obtain the acceleration data of MPU6050 and store it in accel. Obtain the gyroscope data and store it in gyro.

```

10    accel=mpu.MPU_Get_Accelerometer()#gain the values of Acceleration
11    gyro=mpu.MPU_Get_Gyroscope()      #gain the values of Gyroscope

```

Update and collect the original data of the gyroscope every second and print the original data and processed acceleration and angular velocity data in "Shell".

```

10    accel=mpu.MPU_Get_Accelerometer()#gain the values of Acceleration
11    gyro=mpu.MPU_Get_Gyroscope()      #gain the values of Gyroscope
12    print("\n\n/g:\t")
13    print(accel[0], "\t", accel[1], "\t", accel[2], "\t",
14          gyro[0], "\t", gyro[1], "\t", gyro[2])
15    print("a/g:\t")
16    print(accel[0]/16384, "g", accel[1]/16384, "g", accel[2]/16384, "g",

```

```
17     gyro[0]/16384, "d/s", gyro[1]/16384, "d/s", gyro[2]/16384, "d/s")  
18     time.sleep_ms(1000)
```

#### Reference

##### Class mpu6050

Before each use of **mpu6050**, please add the statement “**from mpu6050 import MPU6050**” to the top of the python file.

**MPU6050(sclpin,sdapin)**: Create an object MPU6050 and associate I2C pin with it.

**MPU\_Init()**: Initialize MPU6050 module.

**MPU\_Get\_Accelerometer()**: Obtain original data of MPU6050's acceleration

**MPU\_Get\_Gyroscope()**: Obtain original data of MPU6050's Gyroscope

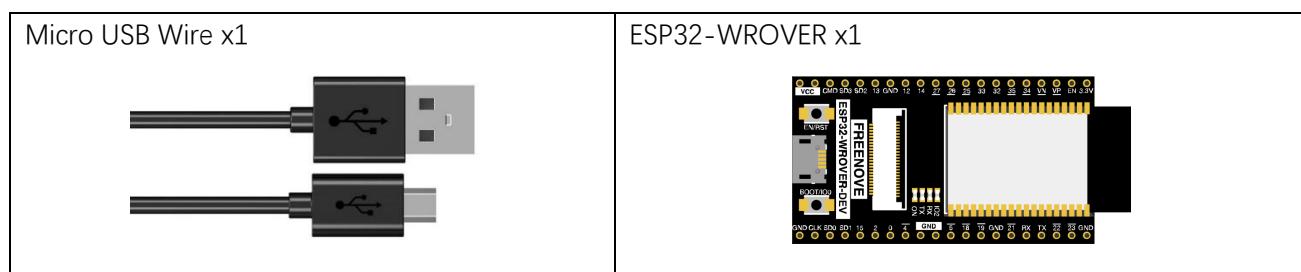
# Chapter 27 WiFi Working Modes

In this chapter, we'll focus on the WiFi infrastructure for ESP32-WROVER.

ESP32-WROVER has 3 different WiFi operating modes: Station mode, AP mode and AP+Station mode. All WiFi programming projects must be configured with WiFi operating mode before using WiFi, otherwise WiFi cannot be used.

## Project 27.1 Station mode

### Component List



### Component knowledge

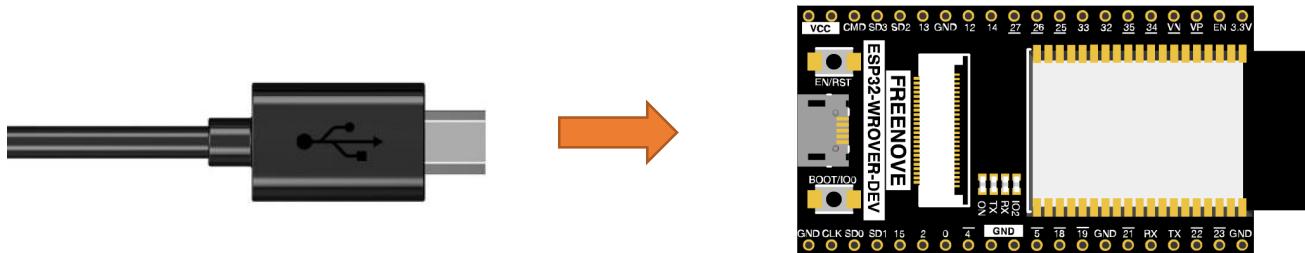
#### Station mode

When ESP32 selects Station mode, it acts as a WiFi client. It can connect to the router network and communicate with other devices on the router via WiFi connection. As shown below, the PC is connected to the router, and if ESP32 wants to communicate with the PC, it needs to be connected to the router.



## Circuit

Connect Freenove ESP32 to the computer using the USB cable.



## Code

Move the program folder “**Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32/Python/Python\_Codes**” to disk(D) in advance with the path of “**D:/Micropython\_Codes**”.

Open “Thonny”, click “This computer” → “D:” → “Micropython\_Codes” → “27.1\_Station\_mode” and double click “27.1\_Station\_mode.py”.

### 27.1\_Station\_mode

Enter the correct Router name and password.

```

import time
import network

ssidRouter      = '*****' #Enter the router name
passwordRouter = '*****' #Enter the router password

def STA_Setup(ssidRouter,passwordRouter):
    print("Setup start")
    sta_if = network.WLAN(network.STA_IF)
    if not sta_if.isconnected():
        print('connecting to',ssidRouter)
        sta_if.active(True)
        sta_if.connect(ssidRouter,passwordRouter)
        while not sta_if.isconnected():
            pass
        print('Connected, IP address:', sta_if.ifconfig())
    print("Setup End")

try:
    STA_Setup(ssidRouter,passwordRouter)
except:
    sta_if.disconnect()

```

MicroPython v1.12 on 2019-12-20; ESP32 module (spiram) with ESP32  
Type "help()" for more information.  
>>>

Because the names and passwords of routers in various places are different, before the Code runs, users need to enter the correct router's name and password in the box as shown in the illustration above.

After making sure the router name and password are entered correctly, compile and upload codes to ESP32-WROVER, wait for ESP32 to connect to your router and print the IP address assigned by the router to ESP32 in "Shell".

```
MicroPython v1.12 on 2019-12-20; ESP32 module (spiram) with ESP32
Type "help()" for more information.
>>> %Run -c $EDITOR_CONTENT

  Setup start
  connecting to FYI_2.4G
I (4155528) phy: phy_version: 4102, 2fa7a43, Jul 15 2019, 13:06:06,
0, 2
Connected, IP address: ('192.168.1.102', '255.255.255.0', '192.168.
1.1', '192.168.1.1')
  Setup End

>>>
```

The following is the program code:

```
1 import time
2 import network
3
4 ssidRouter      = '*****' #Enter the router name
5 passwordRouter = '*****' #Enter the router password
6
7 def STA_Setup(ssidRouter,passwordRouter):
8     print("Setup start")
9     sta_if = network.WLAN(network.STA_IF)
10    if not sta_if.isconnected():
11        print(' connecting to',ssidRouter)
12        sta_if.active(True)
13        sta_if.connect(ssidRouter,passwordRouter)
14        while not sta_if.isconnected():
15            pass
16        print(' Connected, IP address:', sta_if.ifconfig())
17        print("Setup End")
18
19 try:
20     STA_Setup(ssidRouter,passwordRouter)
21 except:
22     sta_if.disconnect()
```

Import network module.

```
2 import network
```

Enter correct router name and password.

```
3 const char *ssid_Router      = "*****"; //Enter the router name
4 const char *password_Router = "*****"; //Enter the router password
```

Set ESP32 in Station mode.

```
9 sta_if = network.WLAN(network.STA_IF)
```

Activate ESP32's Station mode, initiate a connection request to the router and enter the password to connect.

```
12     sta_if.active(True)
13     sta_if.connect(ssidRouter, passwordRouter)
```

Wait for ESP32 to connect to router until they connect to each other successfully.

```
14     while not sta_if.isconnected():
15         pass
```

Print the IP address assigned to ESP32-WROVER in "Shell".

```
16     print('Connected, IP address:', sta_if.ifconfig())
```

## Reference

### Class network

Before each use of **network**, please add the statement "**import network**" to the top of the python file.

**WLAN(interface\_id)**: Set to WiFi mode.

**network.STA\_IF**: Client, connecting to other WiFi access points.

**network.AP\_IF**: Access points, allowing other WiFi clients to connect.

**active(is\_active)**: With parameters, it is to check whether to activate the network interface; Without parameters, it is to query the current state of the network interface.

**scan(ssid, bssid, channel, RSSI, authmode, hidden)**: Scan for wireless networks available nearby (only scan on STA interface), return a tuple list of information about the WiFi access point.

**bssid**: The hardware address of the access point, returned in binary form as a byte object. You can use `ubinascii.hexlify()` to convert it to ASCII format.

**authmode**: Access type

```
AUTH_OPEN = 0
AUTH_WEP = 1
AUTH_WPA_PSK = 2
AUTH_WPA2_PSK = 3
AUTH_WPA_WPA2_PSK = 4
AUTH_MAX = 6
```

**Hidden**: Whether to scan for hidden access points

**False**: Only scanning for visible access points

**True**: Scanning for all access points including the hidden ones.

**isconnected()**: Check whether ESP32 is connected to AP in Station mode. In STA mode, it returns True if it is connected to a WiFi access point and has a valid IP address; Otherwise it returns False.

**connect(ssid, password)**: Connecting to wireless network.

**ssid**: WiFi name

**password**: WiFi password

**disconnect()**: Disconnect from the currently connected wireless network.

## Project 27.2 AP mode

### Component List & Circuit

Component List & Circuit are the same as in Section 27.1.

### Component knowledge

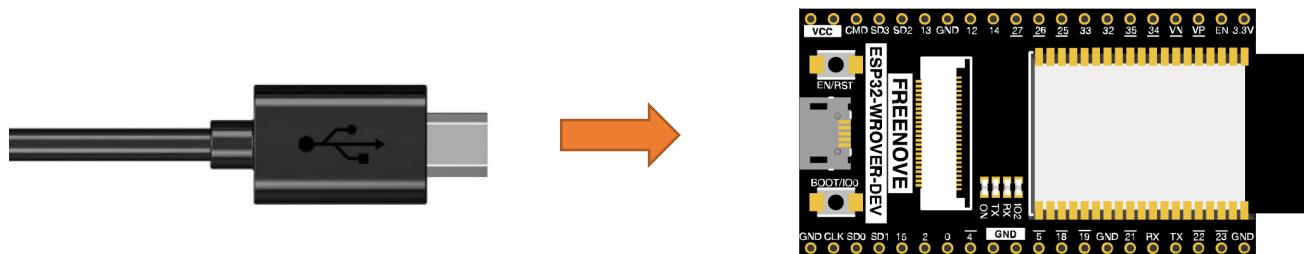
#### AP mode

When ESP32 selects AP mode, it creates a hotspot network that is separated from the Internet and waits for other WiFi devices to connect. As shown in the figure below, ESP32 is used as a hotspot. If a mobile phone or PC wants to communicate with ESP32, it must be connected to the hotspot of ESP32. Only after a connection is established with ESP32 can they communicate.



### Circuit

Connect Freenove ESP32 to the computer using the USB cable.



## Code

Move the program folder “**Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32/Python/Python\_Codes**” to disk(D) in advance with the path of “**D:/Micropython\_Codes**”.

Open “Thonny”, click “This computer” → “D:” → “Micropython\_Codes” → “27.2\_AP\_mode”. and double click “27.2\_AP\_mode.py”.

### 27.2\_AP\_mode

```

Thonny - D:\Micropython_Codes\27.2_AP_mode\27.2_AP_mode.py @ 33 : 5
File Edit View Run Device Tools Help
Files x
MicroPython device
boot.py
27.2_AP_mode.py x
1 import network
2
3 ssidAP      = 'WiFi_Name' #Enter the router name
4 passwordAP   = '12345678' #Enter the router password
5
6 local_IP     = '192.168.1.10'
7 gateway      = '192.168.1.1'
8 subnet       = '255.255.255.0'
9 dns          = '8.8.8.8'
10
11 ap_if = network.WLAN(network.AP_IF)
12
13 def AP_Setup(ssidAP,passwordAP):
14     ap_if.ifconfig([local_IP,gateway,subnet,dns])
15     print("Setting soft-AP ... ")
16     ap_if.config(essid=ssidAP,authmode=network.AUTH_WPA_WPA2_PSK, password=passwordAP)
17     ap_if.active(True)
18     print('Success, IP address:', ap_if.ifconfig())
19     print("Setup End\n")
20
21 try:
22     AP_Setup(ssidAP,passwordAP)

```

Shell x

```

MicroPython v1.12 on 2019-12-20; ESP32 module (spiram) with ESP32
Type "help()" for more information.
>>>

```

Before the Code runs, you can make any changes to the AP name and password for ESP32 in the box as shown in the illustration above. Of course, you can leave it alone by default.

Click “Run current script”, open the AP function of ESP32 and print the access point information.

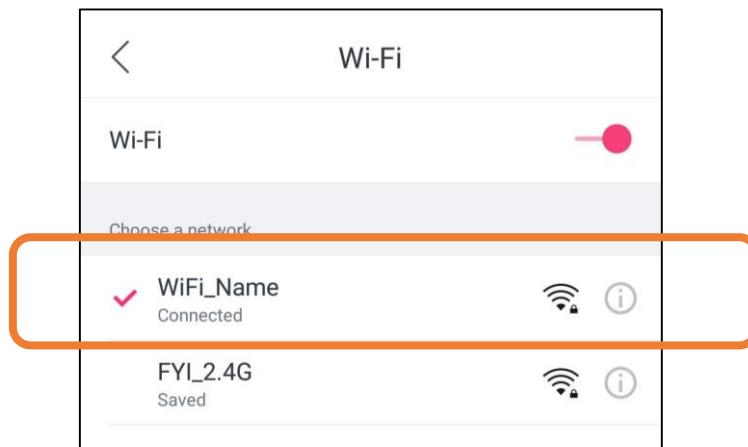
```

Shell x
MicroPython v1.12 on 2019-12-20; ESP32 module (spiram) with ESP32
Type "help()" for more information.
>>> %Run -c $EDITOR_CONTENT
Setting soft-AP ...
Success, IP address: ('192.168.1.10', '192.168.1.1', '255.255.255.0', '8.8.8.8')
Setup End

>>>

```

Turn on the WiFi scanning function of your phone, and you can see the ssid\_AP on ESP32, which is called "WiFi\_Name" in this Code. You can enter the password "12345678" to connect it or change its AP name and password by modifying Code.



The following is the program code:

```

1 import network
2
3 ssidAP      = 'WiFi_Name' #Enter the router name
4 passwordAP   = '12345678' #Enter the router password
5
6 local_IP     = '192.168.1.10'
7 gateway      = '192.168.1.1'
8 subnet       = '255.255.255.0'
9 dns          = '8.8.8.8'
10
11 ap_if = network.WLAN(network.AP_IF)
12
13 def AP_Setup(ssidAP, passwordAP):
14     ap_if.ifconfig([local_IP, gateway, subnet, dns])
15     print("Setting soft-AP ... ")
16     ap_if.config(essid=ssidAP, authmode=network.AUTH_WPA_WPA2_PSK, password=passwordAP)
17     ap_if.active(True)
18     print(' Success, IP address:', ap_if.ifconfig())
19     print("Setup End\n")
20
21 try:
22     AP_Setup(ssidAP, passwordAP)
23 except:
24     ap_if.disconnect()

```

Import network module.

1	import network
---	----------------

Enter correct AP name and password.

```
3   ssidAP      = 'WiFi_Name' #Enter the router name
4   passwordAP  = '12345678' #Enter the router password
```

Set ESP32 in AP mode.

```
11  ap_if = network.WLAN(network.AP_IF)
```

Configure IP address, gateway and subnet mask for ESP32.

```
14  ap_if.ifconfig([local_IP, gateway, subnet, dns])
```

Turn on an AP in ESP32, whose name is set by ssid\_AP and password is set by password\_AP.

```
16  ap_if.config(essid=ssidAP, authmode=network.AUTH_WPA_WPA2_PSK, password=passwordAP)
17  ap_if.active(True)
```

If the program is running abnormally, the AP disconnection function will be called.

```
14  ap_if.disconnect()
```

Reference

### Class network

Before each use of **network**, please add the statement “**import network**” to the top of the python file.

**WLAN(interface\_id)**: Set to WiFi mode.

**network.STA\_IF**: Client, connecting to other WiFi access points

**network.AP\_IF**: Access points, allowing other WiFi clients to connect

**active(is\_active)**: With parameters, it is to check whether to activate the network interface; Without parameters, it is to query the current state of the network interface

**isconnected()**: In AP mode, it returns True if it is connected to the station; otherwise it returns False.

**connect(ssid, password)**: Connecting to wireless network

**ssid**: WiFi name

**password**: WiFi password

**config(essid, channel)**: To obtain the MAC address of the access point or to set the WiFi channel and the name of the WiFi access point.

**ssid**: WiFi account name

**channel**: WiFi channel

**ifconfig([(ip, subnet, gateway, dns)])**: Without parameters, it returns a 4-tuple (ip, subnet\_mask, gateway, DNS\_server); With parameters, it configures static IP.

**ip**: IP address

**subnet\_mask**: subnet mask

**gateway**: gateway

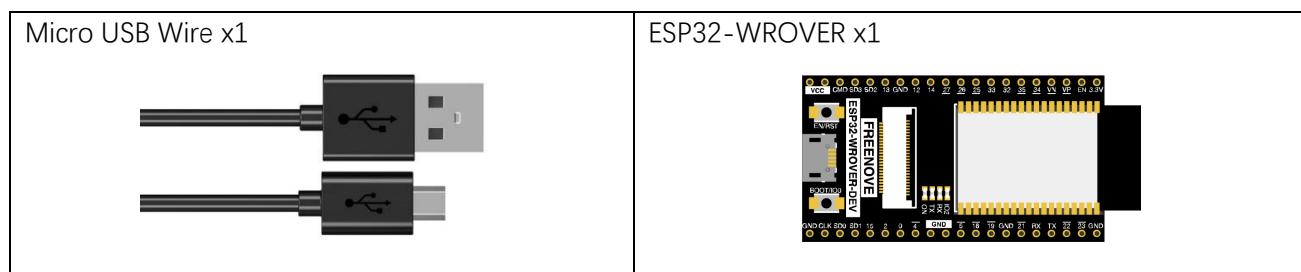
**DNS\_server**: DNS server

**disconnect()**: Disconnect from the currently connected wireless network

**status()**: Return the current status of the wireless connection

## Project 27.3 AP+Station mode

### Component List



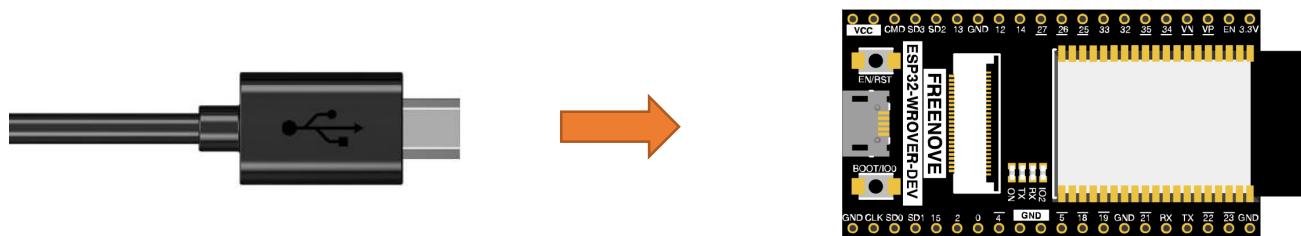
### Component knowledge

#### AP+Station mode

In addition to AP mode and Station mode, ESP32 can also use AP mode and Station mode at the same time. This mode contains the functions of the previous two modes. Turn on ESP32's Station mode, connect it to the router network, and it can communicate with the Internet via the router. At the same time, turn on its AP mode to create a hotspot network. Other WiFi devices can choose to connect to the router network or the hotspot network to communicate with ESP32.

### Circuit

Connect Freenove ESP32 to the computer using the USB cable.

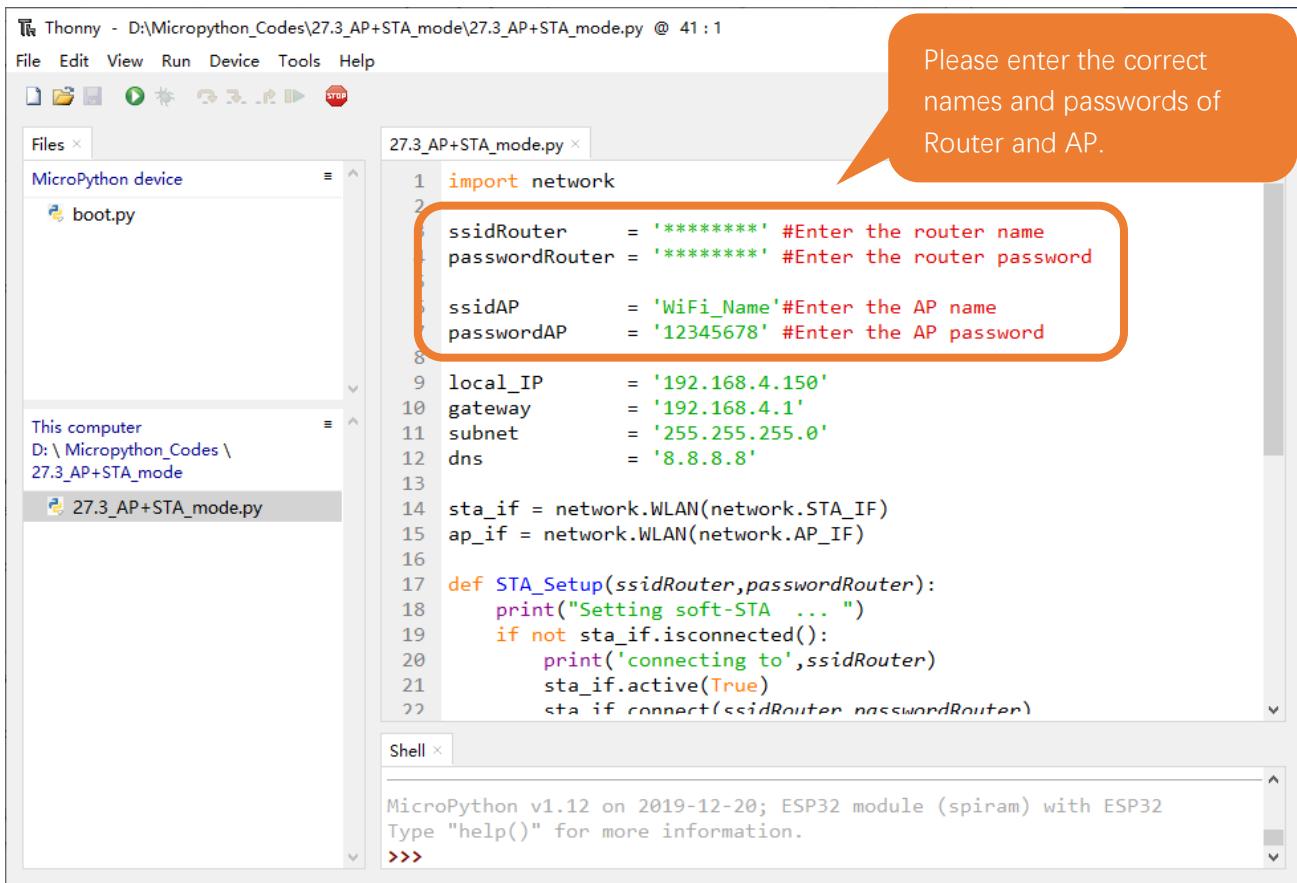


### Code

Move the program folder “**Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32/Python/Python\_Codes**” to disk(D) in advance with the path of “**D:/Micropython\_Codes**”.

Open “Thonny”, click “This computer” → “D:” → “Micropython\_Codes” → “27.3\_AP+STA\_mode” and double click “27.3\_AP+STA\_mode.py”.

### 27.3\_AP+STA\_mode



Please enter the correct names and passwords of Router and AP.

```

1 import network
2
3 ssidRouter = '*****' #Enter the router name
4 passwordRouter = '*****' #Enter the router password
5
6 ssidAP = 'WiFi_Name'#Enter the AP name
7 passwordAP = '12345678' #Enter the AP password
8
9 local_IP = '192.168.4.150'
10 gateway = '192.168.4.1'
11 subnet = '255.255.255.0'
12 dns = '8.8.8.8'
13
14 sta_if = network.WLAN(network.STA_IF)
15 ap_if = network.WLAN(network.AP_IF)
16
17 def STA_Setup(ssidRouter,passwordRouter):
18     print("Setting soft-STA ... ")
19     if not sta_if.isconnected():
20         print('connecting to',ssidRouter)
21         sta_if.active(True)
22         sta_if.connect(ssidRouter, passwordRouter)

```

Shell >>>

```

MicroPython v1.12 on 2019-12-20; ESP32 module (spiram) with ESP32
Type "help()" for more information.
>>>

```

It is analogous to project 27.1 and project 27.2. Before running the Code, you need to modify ssidRouter, passwordRouter, ssidAP and passwordAP shown in the box of the illustration above.

After making sure that the code is modified correctly, click “Run current script” and the “Shell” will display as follows:

```

Shell >>>
MicroPython v1.12 on 2019-12-20; ESP32 module (spiram) with ESP32
Type "help()" for more information.
>>> %Run -c $EDITOR_CONTENT

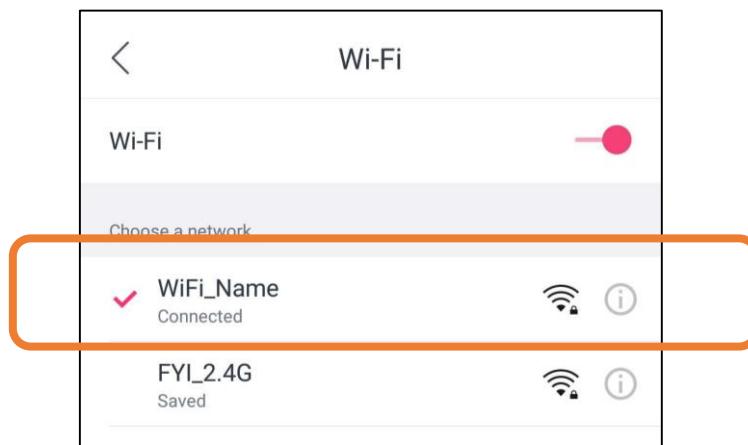
Setting soft-AP ...
Success, IP address: ('192.168.4.150', '192.168.4.1', '255.255.255.0', '8.8.8.8')
Setup End

Setting soft-STA ...
Connected, IP address: ('192.168.1.102', '255.255.255.0', '192.168.1.1', '192.168.1.1')
Setup End

>>>

```

Turn on the WiFi scanning function of your phone, and you can see the ssidAP on ESP32.



The following is the program code:

```
1 import network
2
3 ssidRouter      = '*****' #Enter the router name
4 passwordRouter = '*****' #Enter the router password
5
6 ssidAP          = 'WiFi_Name'#Enter the AP name
7 passwordAP      = '12345678' #Enter the AP password
8
9 local_IP        = '192.168.4.150'
10 gateway         = '192.168.4.1'
11 subnet          = '255.255.255.0'
12 dns             = '8.8.8.8'
13
14 sta_if = network.WLAN(network.STA_IF)
15 ap_if = network.WLAN(network.AP_IF)
16
17 def STA_Setup(ssidRouter, passwordRouter):
18     print("Setting soft-STA ... ")
19     if not sta_if.isconnected():
20         print(' connecting to',ssidRouter)
21         sta_if.active(True)
22         sta_if.connect(ssidRouter, passwordRouter)
23         while not sta_if.isconnected():
24             pass
25     print('Connected, IP address:', sta_if.ifconfig())
26     print("Setup End")
27
28 def AP_Setup(ssidAP, passwordAP):
29     ap_if.ifconfig([local_IP, gateway, subnet, dns])
30     print("Setting soft-AP ... ")
```

```
31     ap_if.config(essid=ssidAP, authmode=network.AUTH_WPA_WPA2_PSK, password=passwordAP)
32     ap_if.active(True)
33     print(' Success, IP address:', ap_if.ifconfig())
34     print("Setup End\n")
35
36 try:
37     AP_Setup(ssidAP, passwordAP)
38     STA_Setup(ssidRouter, passwordRouter)
39 except:
40     sta_if.disconnect()
41     ap_if.disconnect()
```

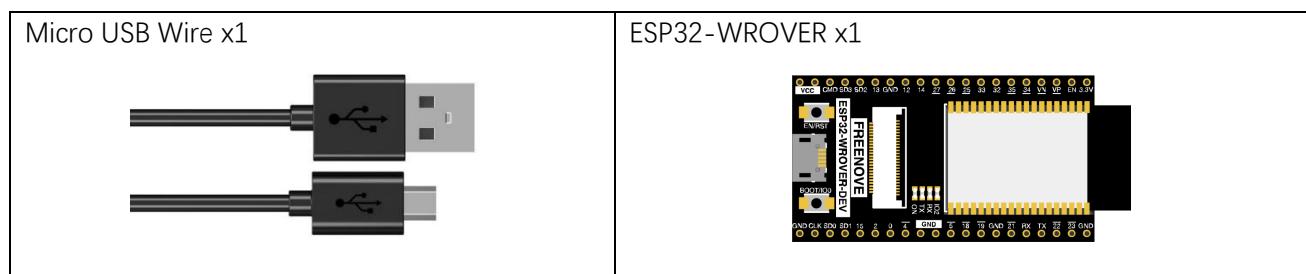
# Chapter 28 TCP/IP

In this chapter, we will introduce how ESP32 implements network communications based on TCP/IP protocol. There are two roles in TCP/IP communication, namely Server and Client, which will be implemented respectively with two projects in this chapter.

## Project 28.1 As Client

In this section, ESP32 is used as Client to connect Server on the same LAN and communicate with it.

### Component List



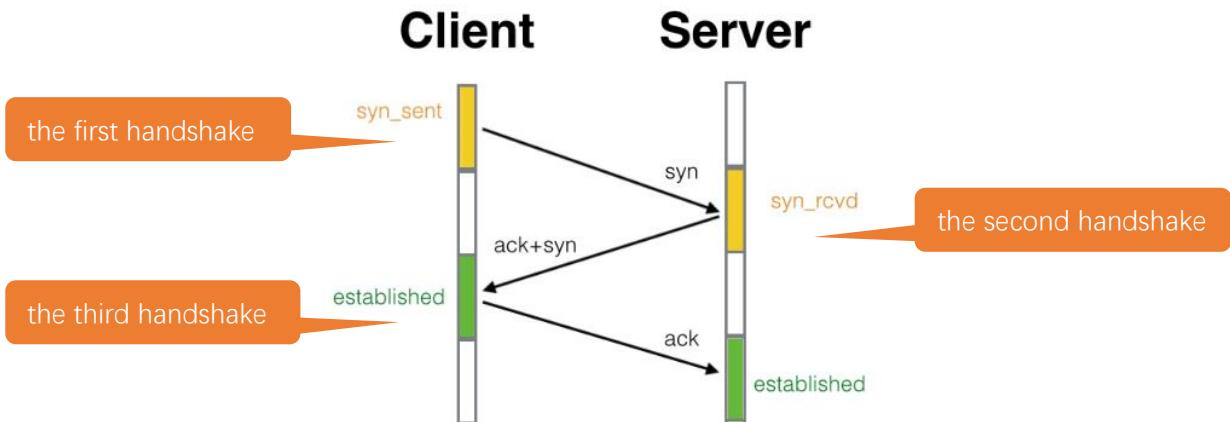
### Component knowledge

#### TCP connection

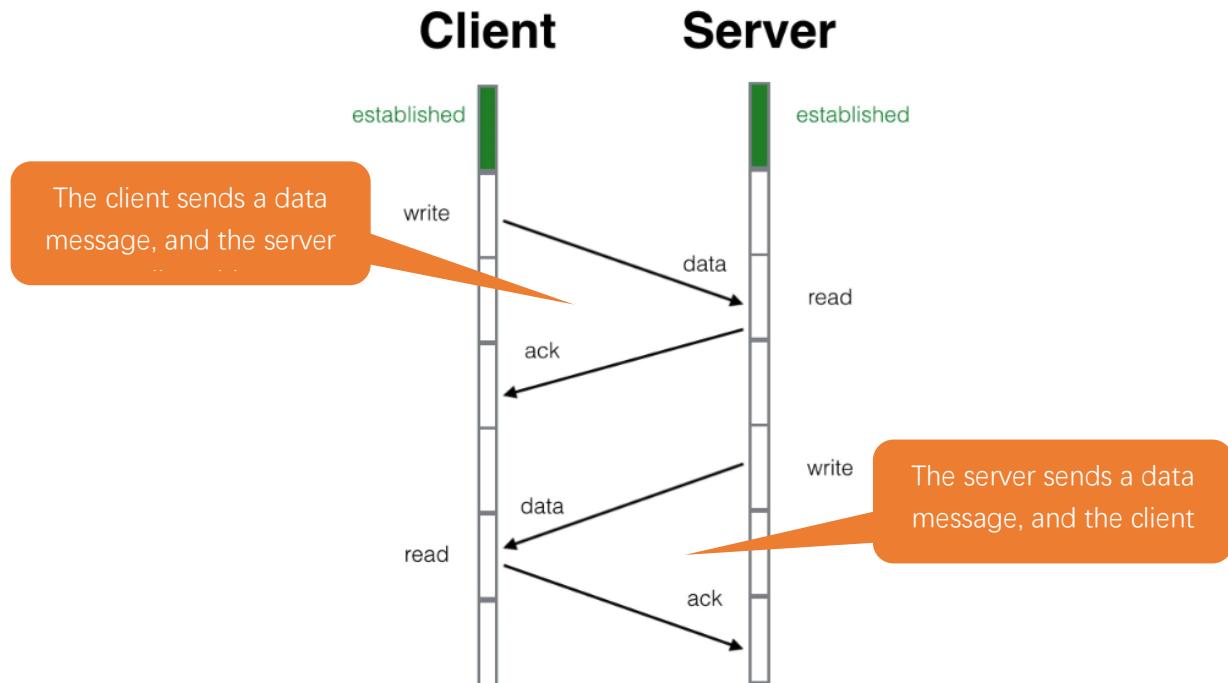
Before transmitting data, TCP needs to establish a logical connection between the sending end and the receiving end. It provides reliable and error-free data transmission between the two computers. In the TCP connection, the client and the server must be clarified. The client sends a connection request to the server, and each time such a request is proposed, a "three-times handshake" is required.

Three-times handshake: In the TCP protocol, during the preparation phase of sending data, the client and the server interact three times to ensure the reliability of the connection, which is called "three-times handshake". The first handshake, the client sends a connection request to the server and waits for the server to confirm. The second handshake, the server sends a response back to the client informing that it has received the connection request.

The third handshake, the client sends a confirmation message to the server again to confirm the connection.



TCP is a connection-oriented, low-level transmission control protocol. After TCP establishes a connection, the client and server can send and receive messages to each other, and the connection will always exist as long as the client or server does not initiate disconnection. Each time one party sends a message, the other party will reply with an ack signal.



## Install Processing

In this tutorial, we use Processing to build a simple TCP/IP communication platform.

If you've not installed Processing, you can download it by clicking <https://processing.org/download/>. You can choose an appropriate version to download according to your PC system.



The screenshot shows the official Processing website's download section. At the top, there are tabs for "Processing", "p5.js", "Processing.py", "Processing for Android", "Processing for Pi", and "Processing Foundation". Below the tabs, the main navigation menu includes "Cover", "Download", "Donate", "Exhibition", "Reference", "Libraries", "Tools", "Environment", "Tutorials", "Examples", "Books", "Overview", and "People". A large "Processing" logo is centered on the page. To the right, a search bar is available. The main content area displays the "Download Processing" section, which states: "Download Processing. Processing is available for Linux, Mac OS X, and Windows. Select your choice to download the software below." It shows the version "3.5.4 (17 January 2020)" and links for "Windows 64-bit", "Windows 32-bit", "Linux 64-bit", and "Mac OS X". Below this, there are links for "» Github", "» Report Bugs", "» Wiki", "» Supported Platforms", and a note about "changes in 3.0" with a link to "The list of revisions".

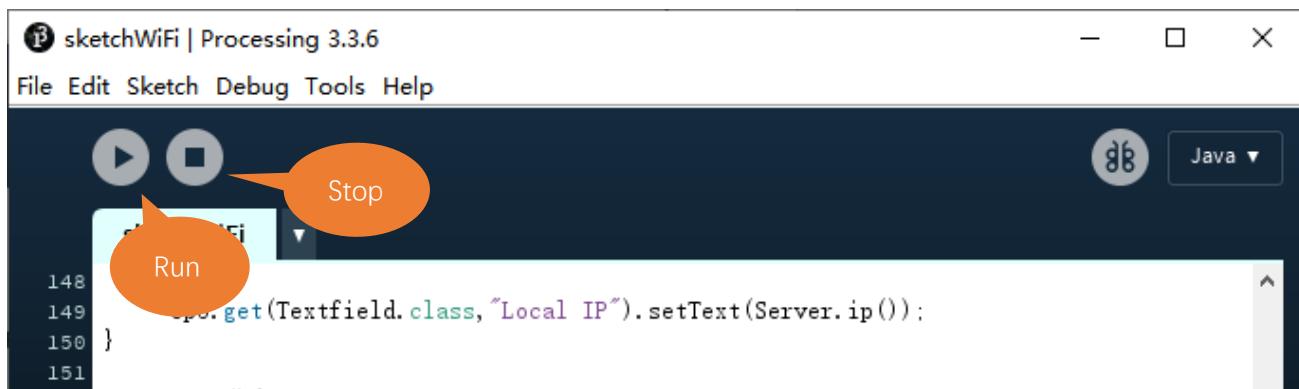
Unzip the downloaded file to your computer. Click "processing.exe" as the figure below to run this software.

 core	2020/1/17 12:16
 java	2020/1/17 12:17
 lib	2020/1/17 12:16
 modes	2020/1/17 12:16
 tools	2020/1/17 12:16
 processing.exe	2020/1/17 12:16
 processing-java.exe	2020/1/17 12:16
 revisions.txt	2020/1/17 12:16



Use Server mode for communication

Open the “**Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32/Codes/Micropython\_Codes/28.1\_TCP\_as\_Client/sketchWiFi/sketchWiFi.pde**”. Click “Run”.

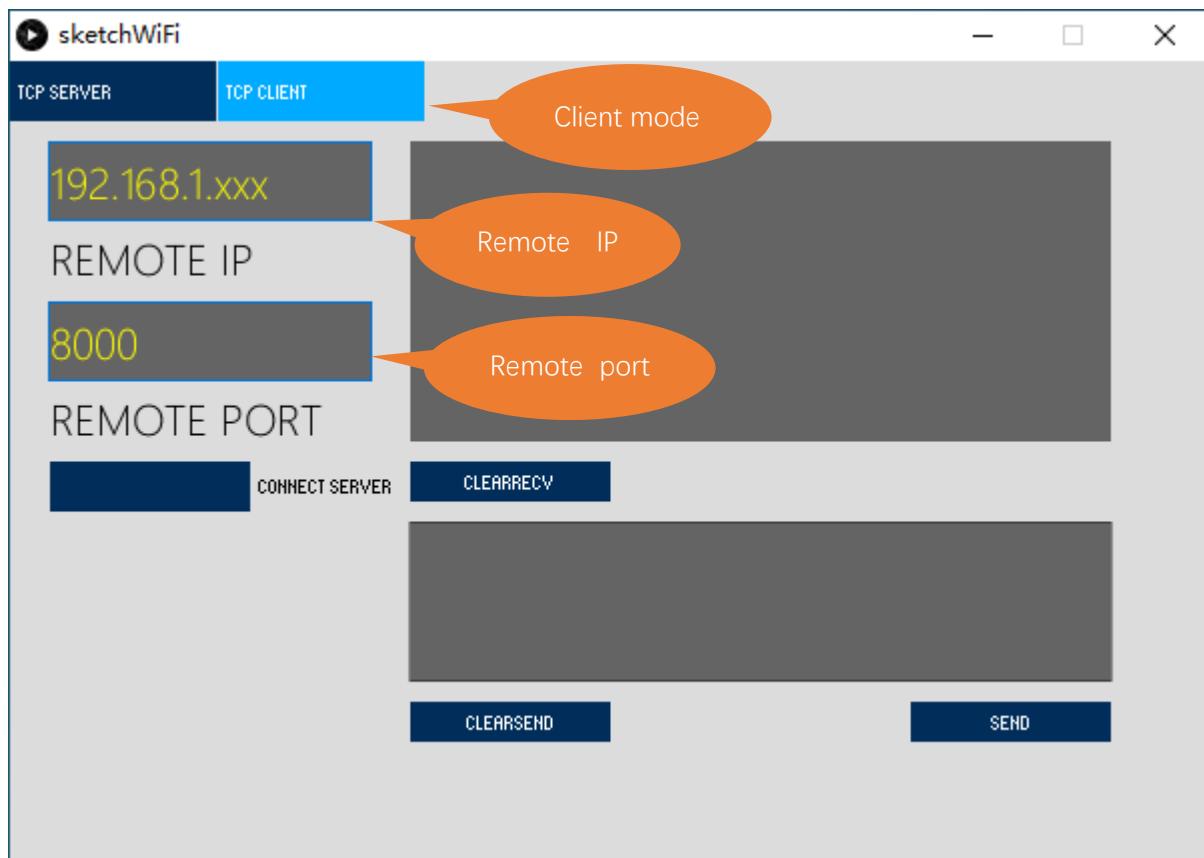


The new pop-up interface is as follows. If ESP32 is used as Client, select TCP SERVER mode for sketchWiFi.



When sketchWiFi selects TCP SERVER mode, ESP32 Code needs to be changed according to sketchWiFi's displaying of LOCAL IP or LOCAL PORT.

If ESP32 serves as Server, select TCP CLIENT mode for sketchWiFi.



When sketchWiFi selects TCP CLIENT mode, the LOCAL IP and LOCAL PORT of sketchWiFi need to be changed according to the IP address and port number printed by the serial monitor.

**Mode selection:** select **Server mode/Client mode**.

**IP address:** In Server mode, this option does not need to be filled in, and the computer will automatically obtain the IP address.

In Client mode, fill in the remote IP address to be connected.

**Port number:** In Server mode, fill in a port number for client devices to make an access connection.

In client mode, fill in port number given by the Server devices to make an access connection.

**Start button:** In server mode, push the button, and then the computer will serve as Server and open a port number for Client to make access connection. During this period, the computer will keep monitoring.

In client mode, before pushing the button, please make sure the server is on, remote IP address and remote port number is correct; push the button, and the computer will make access connection to the remote port number of the remote IP as a Client.

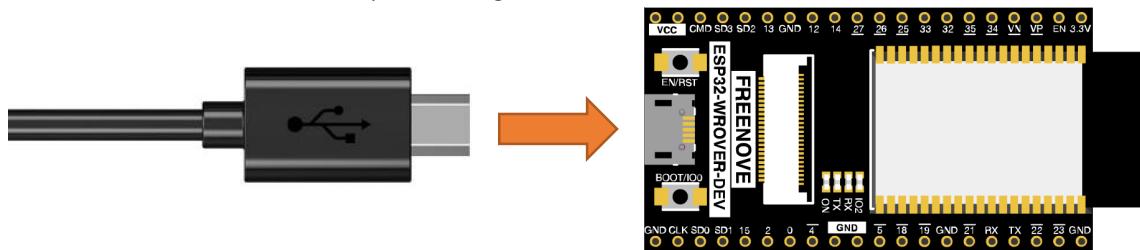
**clear receive:** clear out the content in the receiving text box

**clear send:** clear out the content in the sending text box

**Sending button:** push the sending button, the computer will send the content in the text box to others.

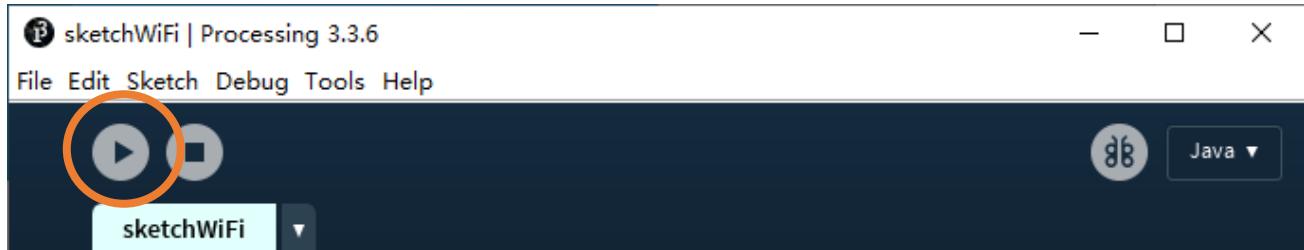
## Circuit

Connect Freenove ESP32 to the computer using USB cable.

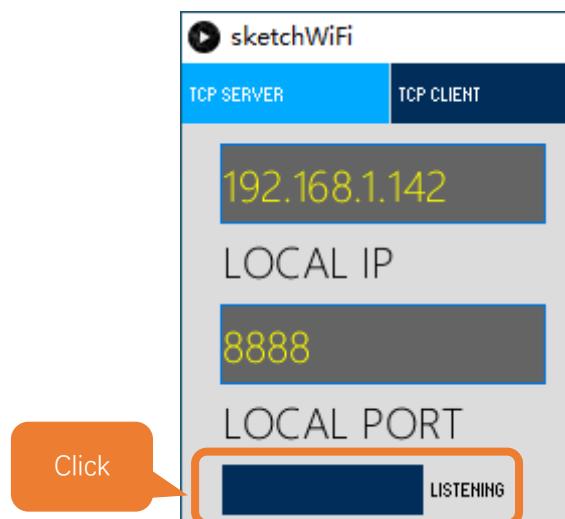


## Code

Before running the Code, please open “sketchWiFi.pde.” first, and click “Run”.



The newly pop up window will use the computer's IP address by default and open a data monitor port. Click “Listening”.

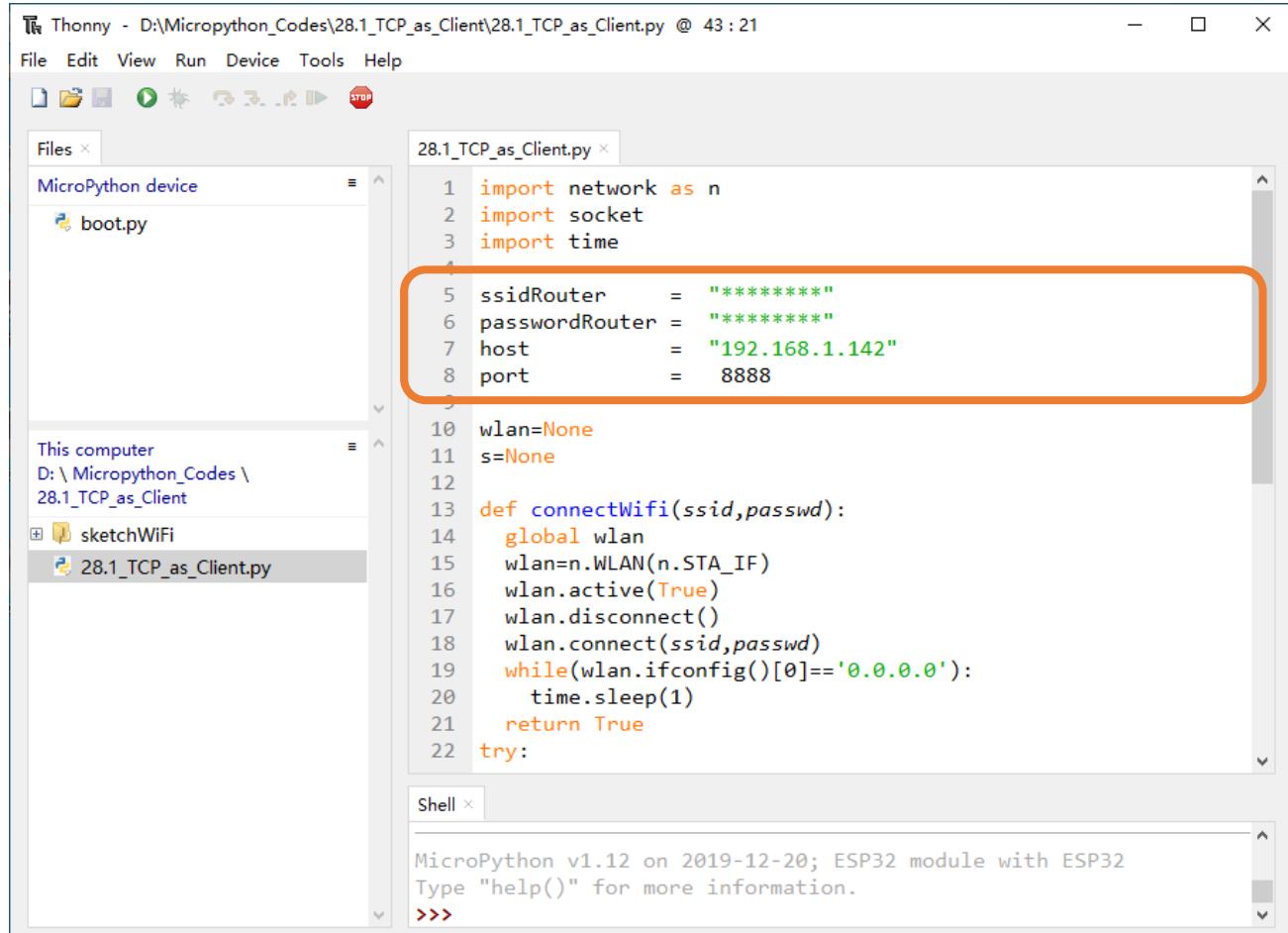


Move the program folder “**Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32/Python/Python\_Codes**” to disk(D) in advance with the path of “**D:/Micropython\_Codes**”.

Open “Thonny”, click “This computer” → “D:” → “Micropython\_Codes” → “28.1\_TCP\_as\_Client” and double click “28.1\_TCP\_as\_Client.py”.

Before clicking “Run current script”, please modify the name and password of your router and fill in the “host” and “port” according to the IP information shown in the box below:

### 28.1\_TCP\_as\_Client



```

import network as n
import socket
import time

ssidRouter      = "*****"
passwordRouter = "*****"
host            = "192.168.1.142"
port            = 8888

wlan=None
s=None

def connectWifi(ssid,passwd):
    global wlan
    wlan=n.WLAN(n.STA_IF)
    wlan.active(True)
    wlan.disconnect()
    wlan.connect(ssid,passwd)
    while(wlan.ifconfig()[0]=='0.0.0.0'):
        time.sleep(1)
    return True
try:

```

Click “Run current script” and in “Shell”, you can see ESP32-WROVER automatically connects to sketchWiFi.



```

MicroPython v1.12 on 2019-12-20; ESP32 module with ESP32
Type "help()" for more information.
>>> %Run -c $EDITOR_CONTENT

TCP Connected to: 192.168.1.142 : 8888

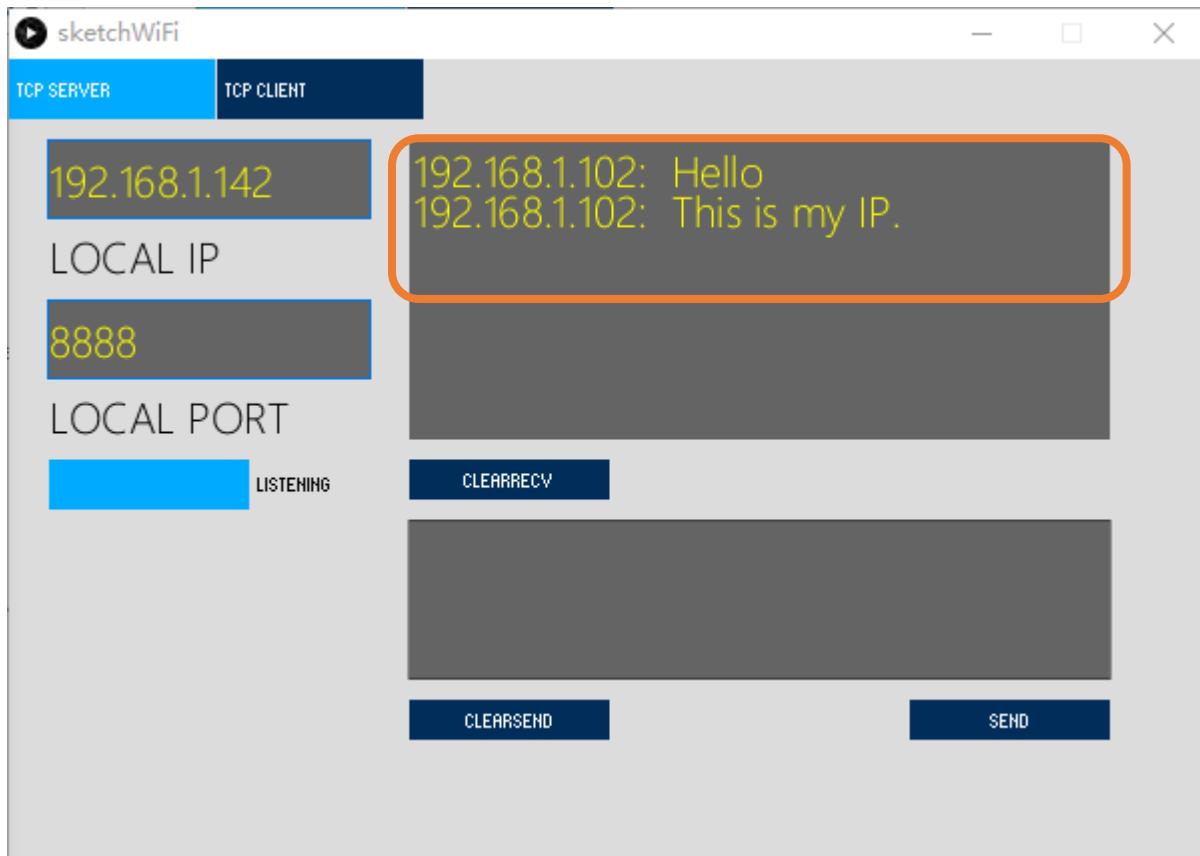
```

If you don't click "Listening" for sketchWiFi, ESP32-WROVER will fail to connect and will print information as follows:

```
Shell x
for connected to: 192.168.1.142 : 8888
  Close socket

>>> %Run -c $EDITOR_CONTENT
  TCP close, please reset!
>>>
```

ESP32 connects with TCP SERVER, and TCP SERVER receives messages from ESP32, as shown in the figure below.



The following is the program code:

```
1 import network
2 import socket
3 import time
4
5 ssidRouter      = "*****"          #Enter the router name
6 passwordRouter = "*****"          #Enter the router password
7 host           = "*****"          #input the remote server
8 port           = 8888             #input the remote port
9
10 wlan=None
11 s=None
```

```

12
13 def connectWifi(ssid,passwd):
14     global wlan
15     wlan= network.WLAN(network.STA_IF)
16     wlan.active(True)
17     wlan.disconnect()
18     wlan.connect(ssid,passwd)
19     while(wlan.ifconfig()[0]=='0.0.0.0'):
20         time.sleep(1)
21     return True
22 try:
23     connectWifi(ssidRouter,passwordRouter)
24     s = socket.socket()
25     s.setsockopt(socket.SOL_SOCKET, socket.SO_REUSEADDR, 1)
26     s.connect((host,port))
27     print("TCP Connected to:", host, ":", port)
28     s.send('Hello')
29     s.send('This is my IP.')
30     while True:
31         data = s.recv(1024)
32         if(len(data) == 0):
33             print("Close socket")
34             s.close()
35             break
36         print(data)
37         ret=s.send(data)
38 except:
39     print("TCP close, please reset!")
40     if (s):
41         s.close()
42     wlan.disconnect()
43     wlan.active(False)

```

Import network、socket、time modules.

```

1 import network
2 import socket
3 import time

```

Enter the actual router name, password, remote server IP address, and port number.

```

5 ssidRouter      = "*****"      #Enter the router name
6 passwordRouter = "*****"      #Enter the router password
7 host           = "*****"      #input the remote server
8 port           = 8888          #input the remote port

```

Connect specified Router until it is successful.

```

13 def connectWifi(ssid,passwd):
14     global wlan
15     wlan= network.WLAN(network.STA_IF)
16     wlan.active(True)
17     wlan.disconnect()
18     wlan.connect(ssid,passwd)
19     while(wlan.ifconfig()[0]=='0.0.0.0'):
20         time.sleep(1)
21     return True

```

Connect router and then connect it to remote server.

```

23 connectWifi(ssidRouter,passwordRouter)
24 s = socket.socket()
25 s.setsockopt(socket.SOL_SOCKET, socket.SO_REUSEADDR, 1)
26 s.connect((host,port))
27 print("TCP Connected to:", host, ":", port)

```

Send messages to the remote server, receive the messages from it and print them out, and then send the messages back to the server.

```

28 s.send('Hello')
29 s.send('This is my IP.')
30 while True:
31     data = s.recv(1024)
32     if(len(data) == 0):
33         print("Close socket")
34         s.close()
35         break
36     print(data)
37     ret=s.send(data)

```

If an exception occurs in the program, for example, the remote server is shut down, execute the following program, turn off the socket function, and disconnect the WiFi.

```

39 print("TCP close, please reset!")
40 if (s):
41     s.close()
42     wlan.disconnect()
43     wlan.active(False)

```

## Reference

### Class socket

Before each use of **socket**, please add the statement “**import socket**” to the top of the python file.

**socket([af, type, proto]):** Create a socket.

**af:** address

**socket.AF\_INET:** IPv4

**socket.AF\_INET6:** IPv6

**type:** type

**socket.SOCK\_STREAM** : TCP stream

**socket.SOCK\_DGRAM** : UDP datagram

**socket.SOCK\_RAW** : Original socket

**socket.SO\_REUSEADDR** : socket reusable

**proto:** protocol number

**socket.IPPROTO\_TCP**: TCPmode

**socket.IPPROTO\_UDP**: UDPmode

**socket.setsockopt(level, optname, value):** Set the socket according to the options.

**Level:** Level of socket option

**socket.SOL\_SOCKET**: Level of socket option. By default, it is 4095.

**optname:** Options of socket

**socket.SO\_REUSEADDR**: Allowing a socket interface to be tied to an address that is already in use.

**value:** The value can be an integer or a bytes-like object representing a buffer.

**socket.connect(address):** To connect to server.

**Address:** Tuple or list of the server's address and port number

**send(bytes):** Send data and return the bytes sent.

**recv(bufsize):** Receive data and return a bytes object representing the data received.

**close():** Close socket.

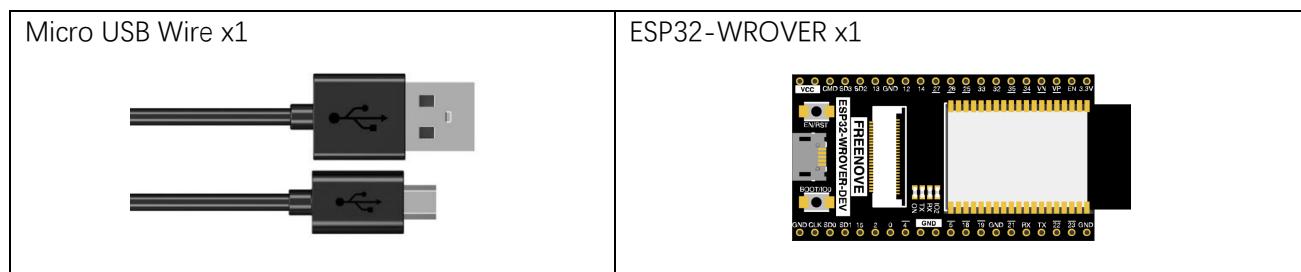
To learn more please visit: <http://docs.micropython.org/en/latest/>



## Project 28.2 As Server

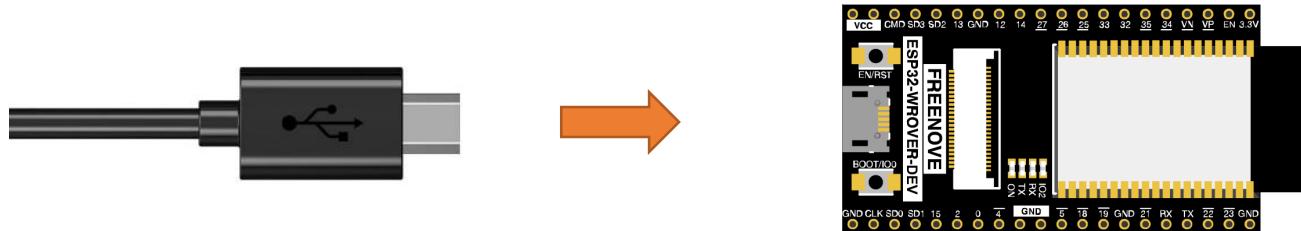
In this section, ESP32 is used as a Server to wait for the connection and communication with Client on the same LAN.

### Component List



### Circuit

Connect Freenove ESP32 to the computer using the USB cable.



## Code

Move the program folder “**Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32/Python/Python\_Codes**” to disk(D) in advance with the path of “**D:/Micropython\_Codes**”.

Open “Thonny”, click “This computer” → “D:” → “Micropython\_Codes” → “28.2\_TCP\_as\_Server” and double click “28.2\_TCP\_as\_Server.py”.

Before clicking “Run current script”, please modify the name and password of your router shown in the box below.

### 28.2\_TCP\_as\_Server

```

import network
import socket
import time

ssidRouter = "*****" #Enter the router name
passwordRouter = "*****" #Enter the router password
port = 8000 #Input the remote port

wlan=None
listenSocket=None

def connectWifi(ssid,passwd):
    global wlan
    wlan=network.WLAN(network.STA_IF)
    wlan.active(True)
    wlan.disconnect()
    wlan.connect(ssid,passwd)
    while(wlan.ifconfig()[0]!='0.0.0.0'):

MicroPython v1.12 on 2019-12-20; ESP32 module (spiram) with ESP32
Type "help()" for more information.
>>>

```

After making sure that the router's name and password are correct, click “Run current script” and in “Shell”, you can see a server opened by the ESP32- WROVER waiting to connecting to other network devices.

```

MicroPython v1.12 on 2019-12-20; ESP32 module (spiram) with ESP32
Type "help()" for more information.
>>> %Run -c $EDITOR_CONTENT
tcp waiting...
accepting...
Server IP: 192.168.1.102 Port: 8000

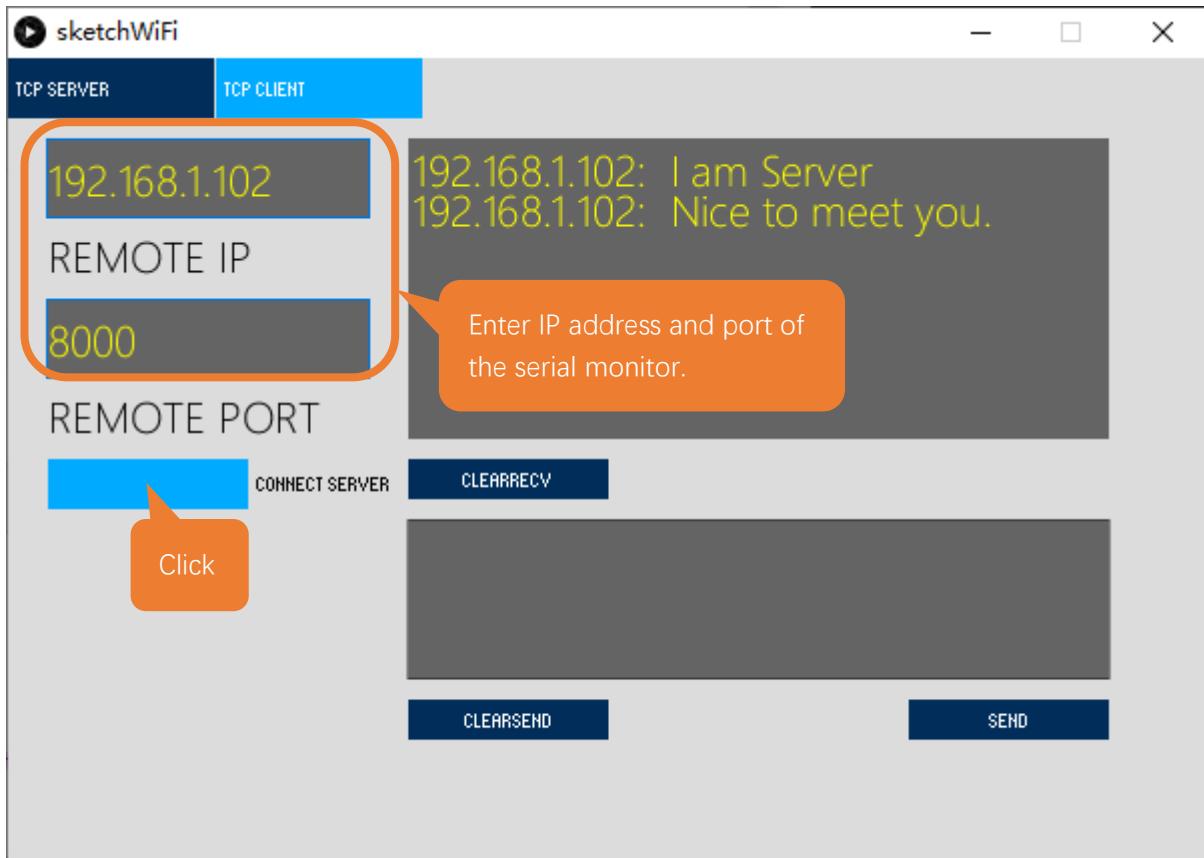
```



Processing:

Open the “[Freenove\\_Ultimate\\_Starter\\_Kit\\_for\\_ESP32/Codes/MicroPython\\_Codes/28.2\\_TCP\\_as\\_Server/sketchWiFi/sketchWiFi.pde](#)”.

Based on the message printed in "Shell", enter the correct IP address and port when processing, and click to establish a connection with ESP32 to communicate.



You can enter any information in the “Send Box” of sketchWiFi. Click “Send” and ESP32 will print the received messages to “Shell” and send them back to sketchWiFi.

```
Shell >
MicroPython v1.12 on 2019-12-20; ESP32 module (spiram) with ESP32
Type "help()" for more information.
>>> %Run -c $EDITOR_CONTENT
tcp waiting...
accepting.....
Server IP: 192.168.1.102      Port: 8000
('192.168.1.142', 51326) connected
b'Nice to meet you.'
```

The following is the program code:

```
1 import network
2 import socket
3 import time
4
5 ssidRouter      = "*****"          #Enter the router name
6 passwordRouter = "*****"          #Enter the router password
7 port           = 8000             #input the remote port
8 wlan            = None
9 listenSocket    = None
10
11 def connectWifi(ssid,passwd):
12     global wlan
13     wlan=network.WLAN(network.STA_IF)
14     wlan.active(True)
15     wlan.disconnect()
16     wlan.connect(ssid,passwd)
17     while(wlan.ifconfig()[0]=='0.0.0.0'):
18         time.sleep(1)
19     return True
20
21 try:
22     connectWifi(ssidRouter,passwordRouter)
23     ip=wlan.ifconfig()[0]
24     listenSocket = socket.socket()
25     listenSocket.bind((ip,port))
26     listenSocket.listen(1)
27     listenSocket.setsockopt(socket.SOL_SOCKET, socket.SO_REUSEADDR, 1)
28     print('tcp waiting...')
29     while True:
30         print("Server IP:",ip,"\tPort:",port)
31         print("accepting.....")
32         conn,addr = listenSocket.accept()
33         print(addr, "connected")
34         break
35     conn.send('I am Server')
36     while True:
37         data = conn.recv(1024)
38         if(len(data) == 0):
39             print("close socket")
40             listenSocket.close()
41             wlan.disconnect()
42             wlan.active(False)
43             break
```

```

44     else:
45         print(data)
46         ret = conn.send(data)
47     except:
48         print("Close TCP-Server, please reset.")
49         if(listenSocket):
50             listenSocket.close()
51             wlan.disconnect()
52             wlan.active(False)

```

Call function `connectWifi()` to connect to router and obtain the dynamic IP that it assigns to ESP32.

```

22     connectWifi(ssidRouter, passwordRouter)
23     ip=wlan.ifconfig()[0]

```

Open the socket server, bind the server to the dynamic IP, and open a data monitoring port.

```

24     listenSocket = socket.socket()
25     listenSocket.bind((ip, port))
26     listenSocket.listen(1)
27     listenSocket.setsockopt(socket.SOL_SOCKET, socket.SO_REUSEADDR, 1)

```

Print the server's IP address and port, monitor the port and wait for the connection of other network devices.

```

29     while True:
30         print("Server IP:", ip, "\tPort:", port)
31         print("accepting.....")
32         conn, addr = listenSocket.accept()
33         print(addr, "connected")
34         break

```

Each time receiving data, print them in “Shell” and send them back to the client.

```

36     while True:
37         data = conn.recv(1024)
38         if(len(data) == 0):
39             print("close socket")
40             listenSocket.close()
41             wlan.disconnect()
42             wlan.active(False)
43             break
44         else:
45             print(data)
46             ret = conn.send(data)

```

If the client is disconnected, close the server and disconnect WiFi.

```

47     except:
48         print("Close TCP-Server, please reset.")
49         if(listenSocket):
50             listenSocket.close()
51             wlan.disconnect()
52             wlan.active(False)

```

# Chapter 29 Soldering Circuit Board

## Project 29.1 Soldering a Buzzer

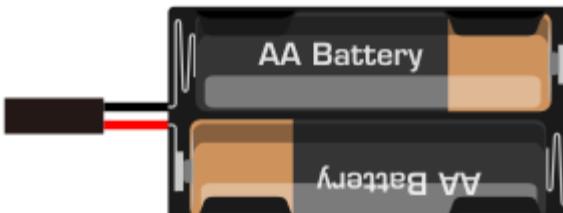
We have tried to use a buzzer in a previous chapter, and now we will solder a circuit that when the button is pressed, the buzzer sounds.

This circuit doesn't need programming and can work when it is powered on. And when the button is not pressed, there is no power consumption.

You can install it on your bike, bedroom door or any other places where it is needed.

### Component List

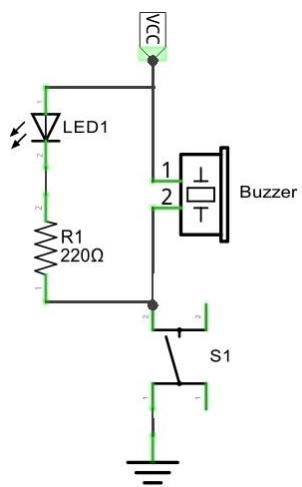
Pin header x2	LED x1	Resistor 220Ω x1	Active buzzer x1	Push button x1
AA Battery Holder x1				



## Circuit

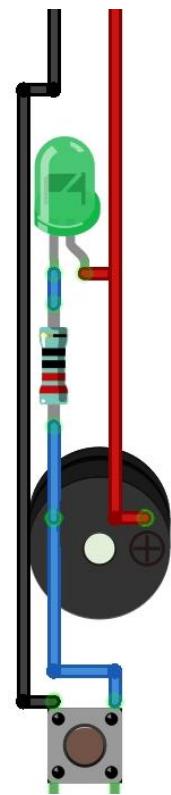
We will solder the following circuit on the main board.

Schematic diagram



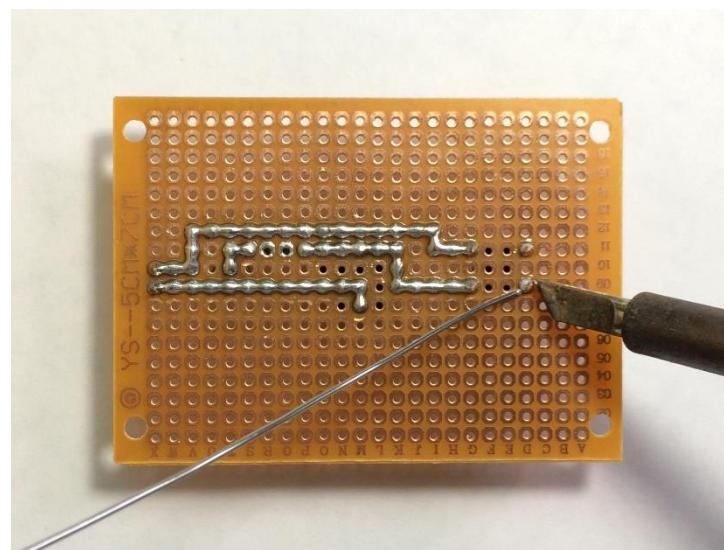
Hardware connection.

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

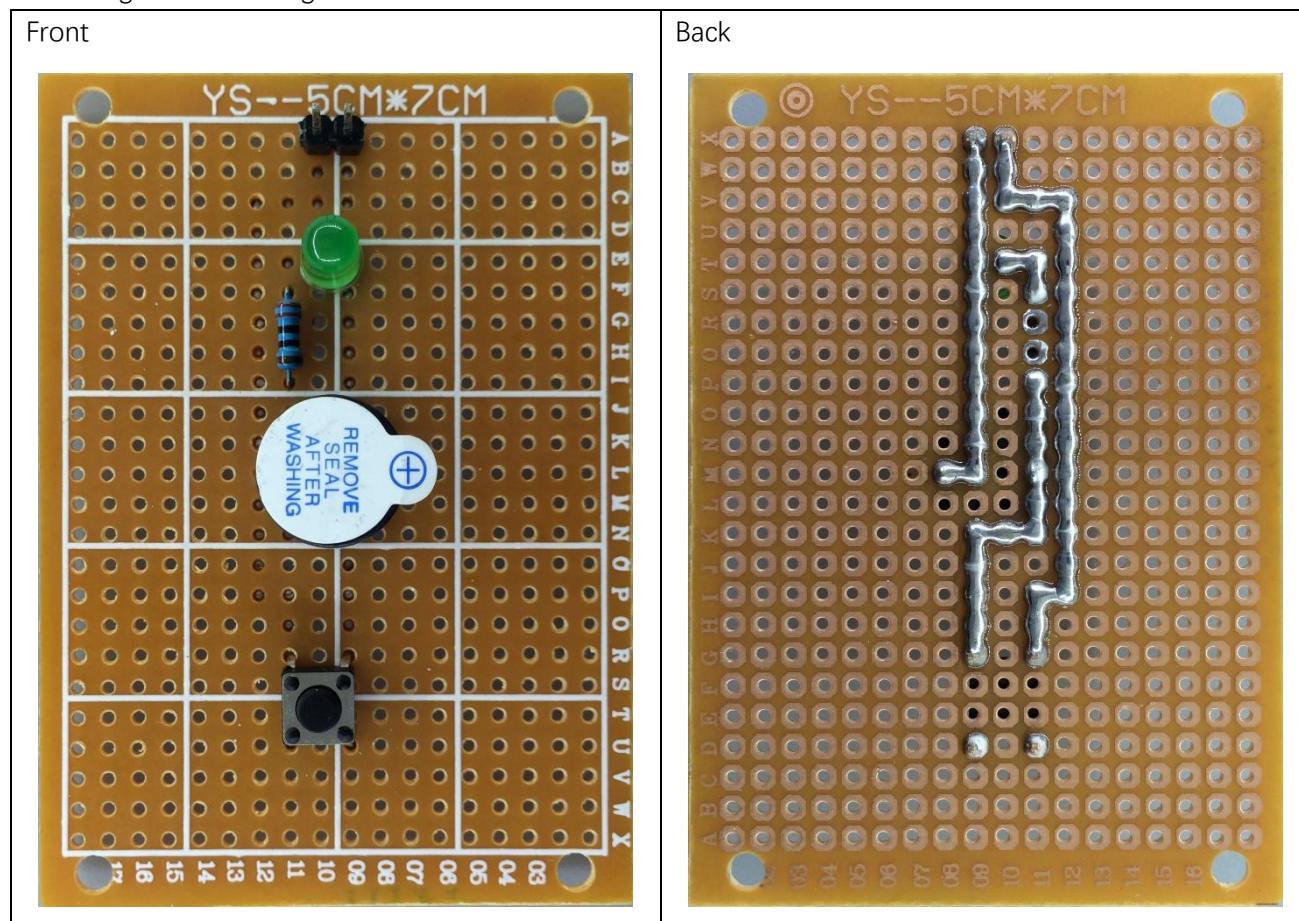


## Solder the Circuit

Insert the components on the main board and solder the circuit on its back.

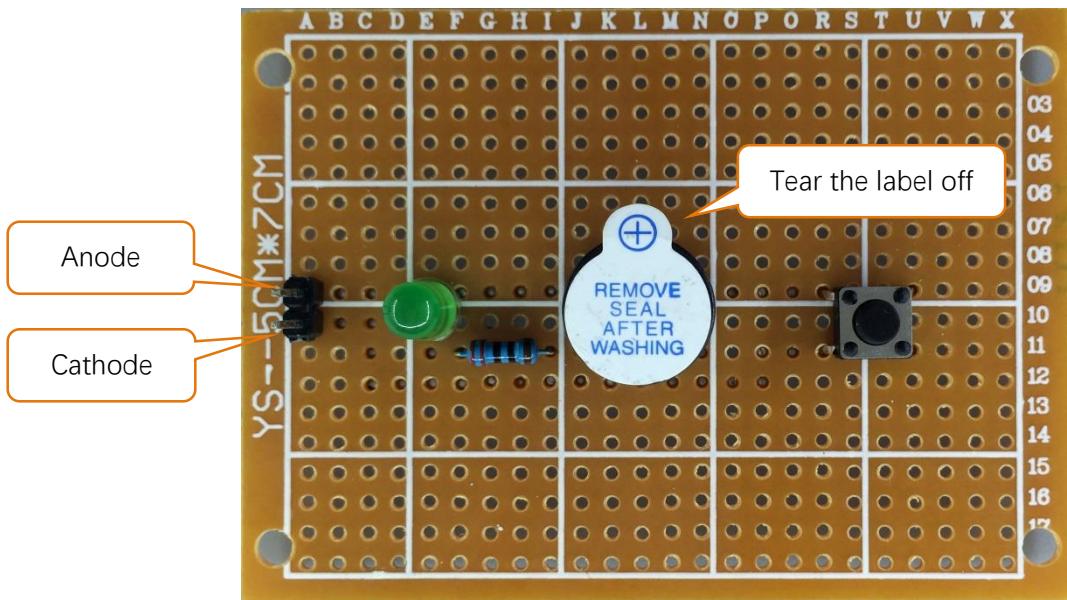


Rendering after soldering:



## Test circuit

Connect the circuit board to power supply (3~5V). You can use ESP32 board or battery box as the power supply.



Press the push button after connecting the power, and then the buzzer will make a sound.

## Project 29.2 Soldering a Flowing Water Light

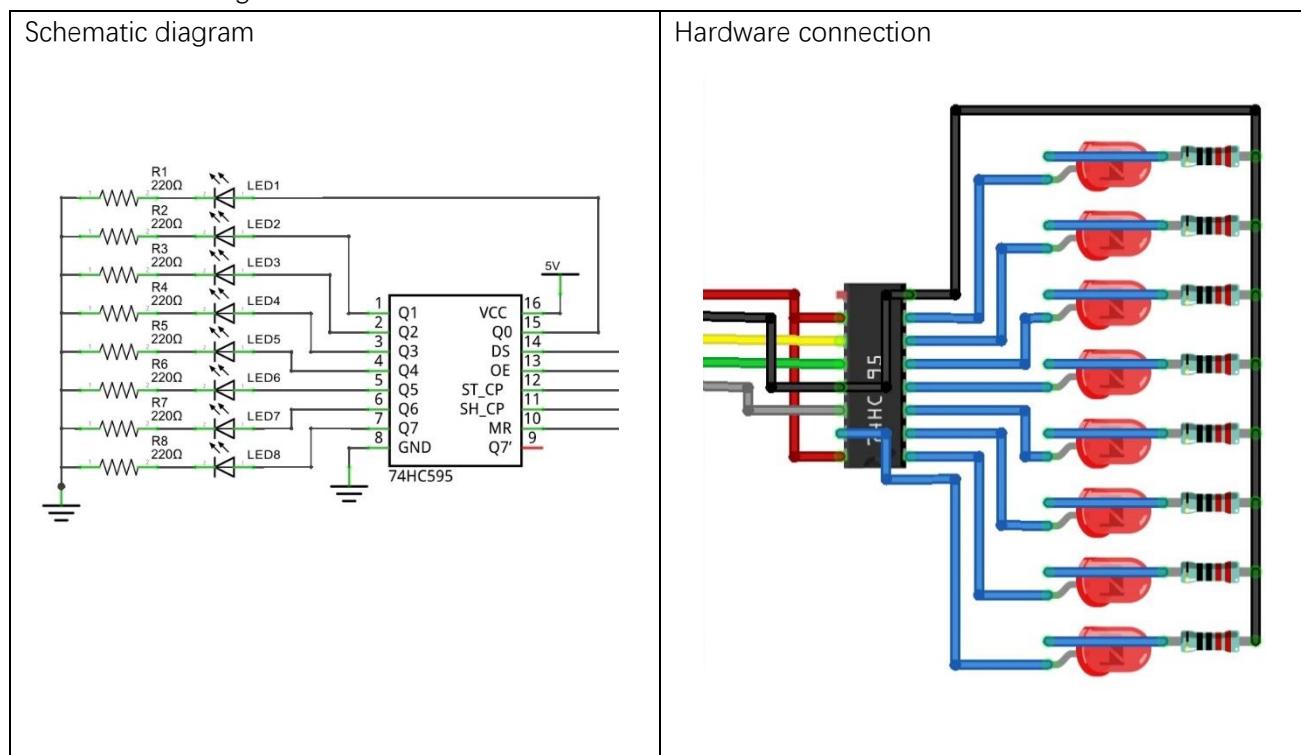
From previous chapter, we have learned to make a flowing water light with LED. Now, we will solder a circuit board, and use the improved code to make a more interesting flowing water light.

### Component List

Pin header x5	Resistor 220Ω x8	LED x1	74HC595 x1

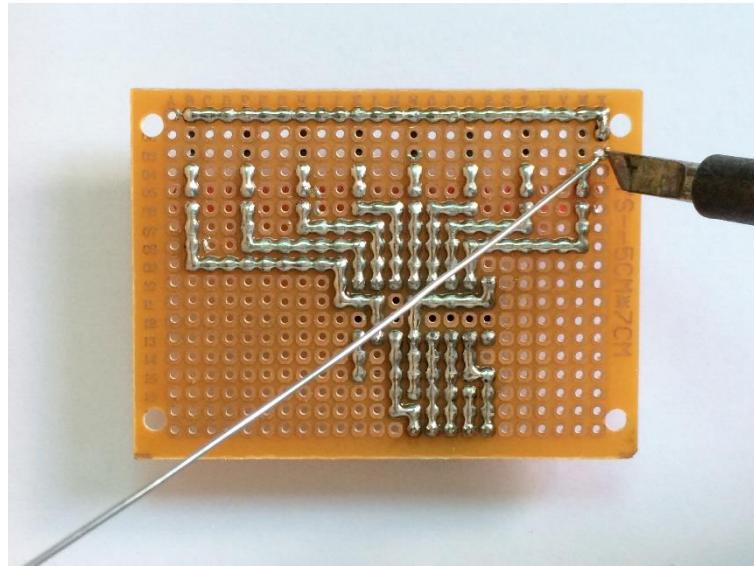
### Circuit

Solder the following circuit on the main board.

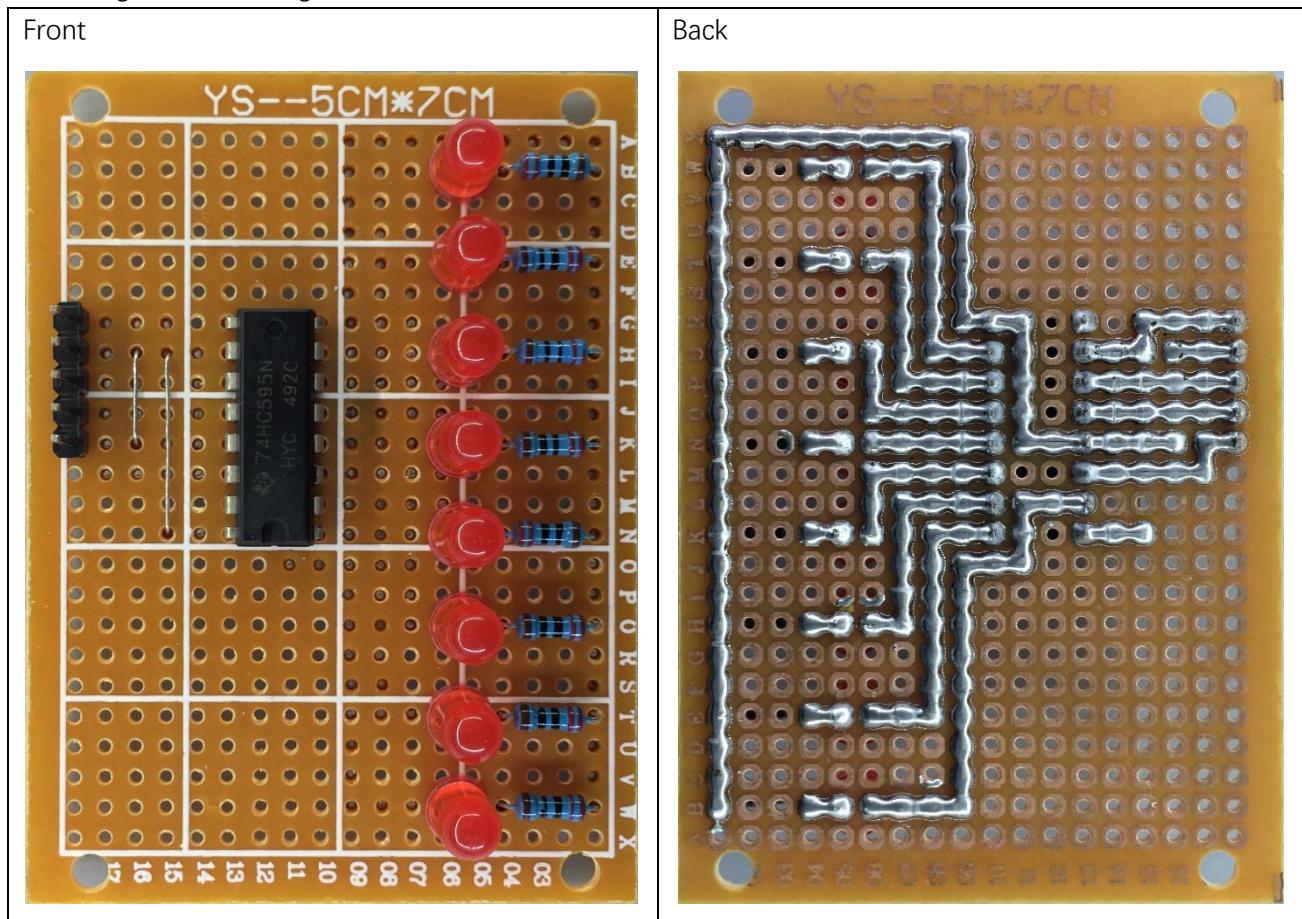


## Soldering the Circuit

Insert the components on the main board and solder the circuit on its back.

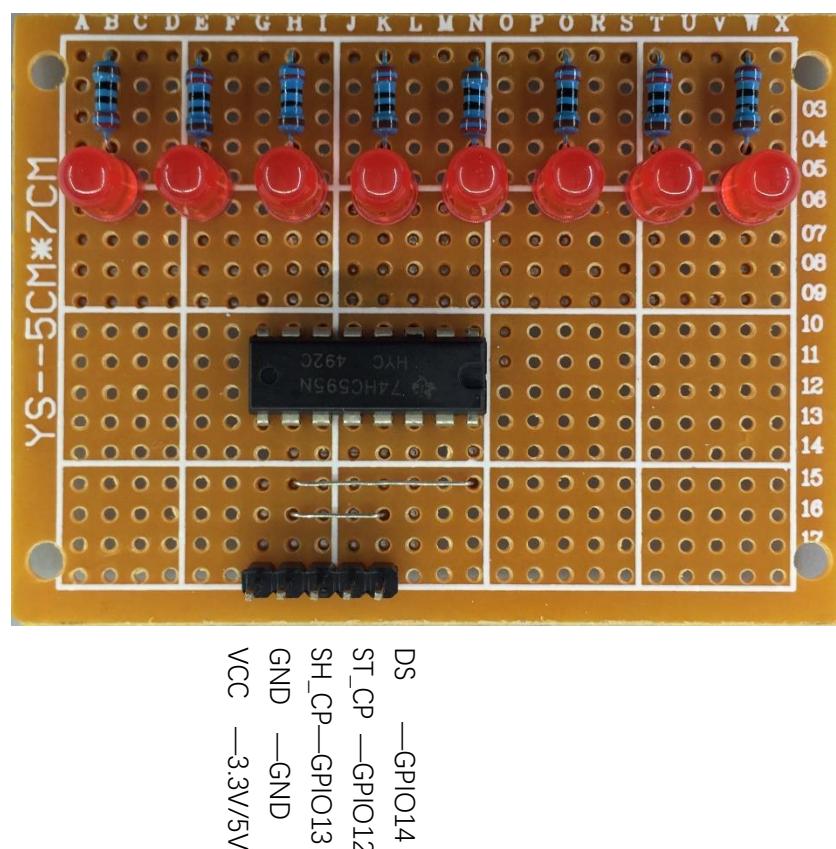


Rendering after soldering:



## Connect the Circuit

Connect the board to ESP32 with jumper wire in the following way.



## Code

The following is the program code:

```
1 import time
2 from my74HC595 import Chip74HC595
3
4 chip = Chip74HC595(14, 12, 13)
5 # ESP32-14: 74HC595-DS(14)
6 # ESP32-12: 74HC595-STCP(12)
7 # ESP32-13: 74HC595-SHCP(11)
8
9 while True:
10     x=0x01
11     for count in range(8):
12         chip.shiftOut(1,x) #High bit is sent first
13         x=x<<1
```

```
14     time.sleep_ms(300)
15     x=0x01
16     for count in range(8):
17         chip.shiftOut(0, x) #Low bit is sent first
18         x=x<<1
19         time.sleep_ms(300)
```

## 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](mailto:support@freenove.com)

We will check and correct it as soon as possible.

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/>

## End of the Tutorial

Thank you again for choosing Freenove products.