

# Welcome

Thank you for choosing Freenove products!

## 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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## Attention

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.

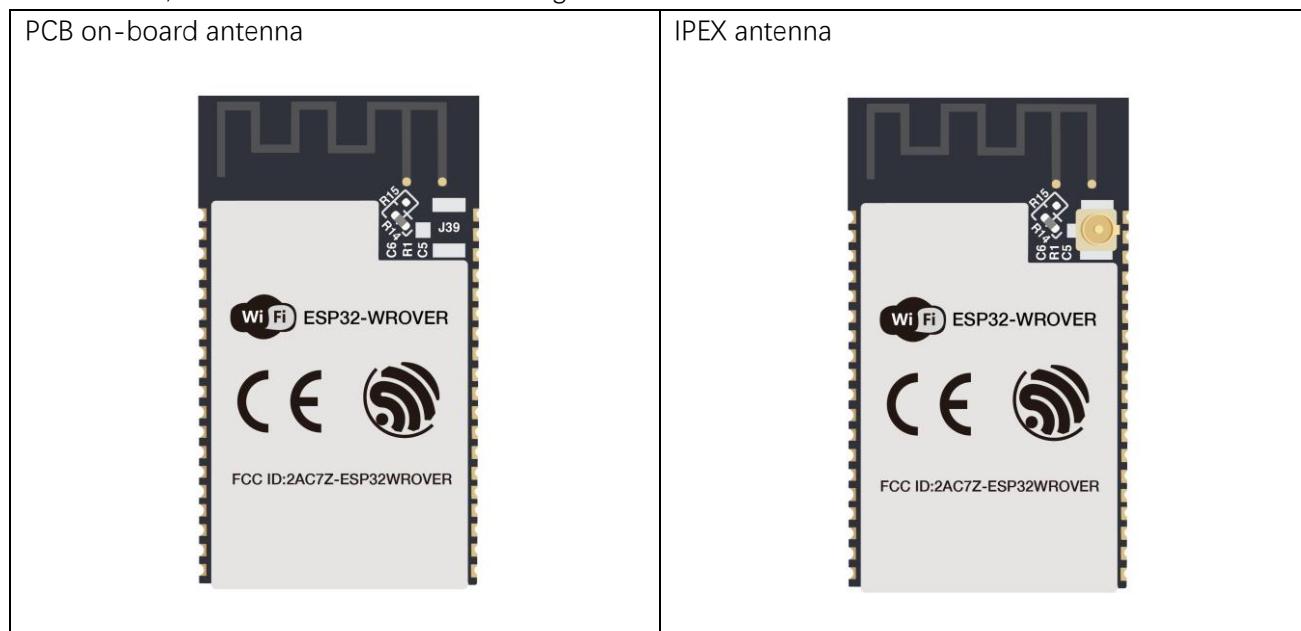
ESP32 can be developed both either with C/C++ language or micropython language. In this tutorial, we use micropython. With Micropython is as easy to learn as Python with little code, making it ideal for beginners. Moreover, the code of ESP32 is completely open-source, so beginners can quickly learn how 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.

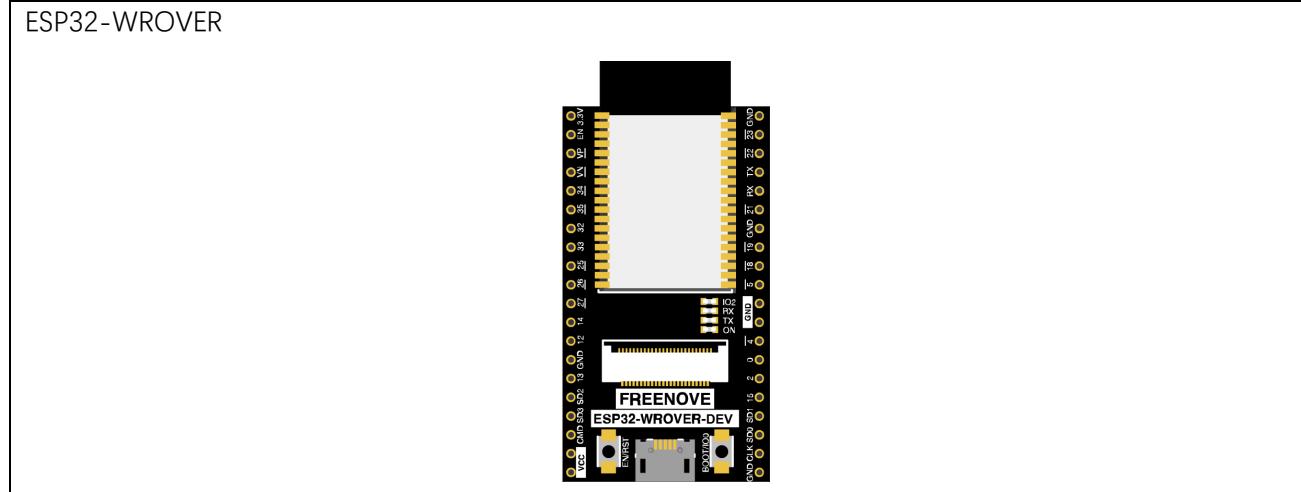
In addition, if you have any difficulties or questions with this tutorial or toolkit, feel free to ask for our quick and free technical support through [support@freenove.com](mailto:support@freenove.com)

## ESP32-WROVER

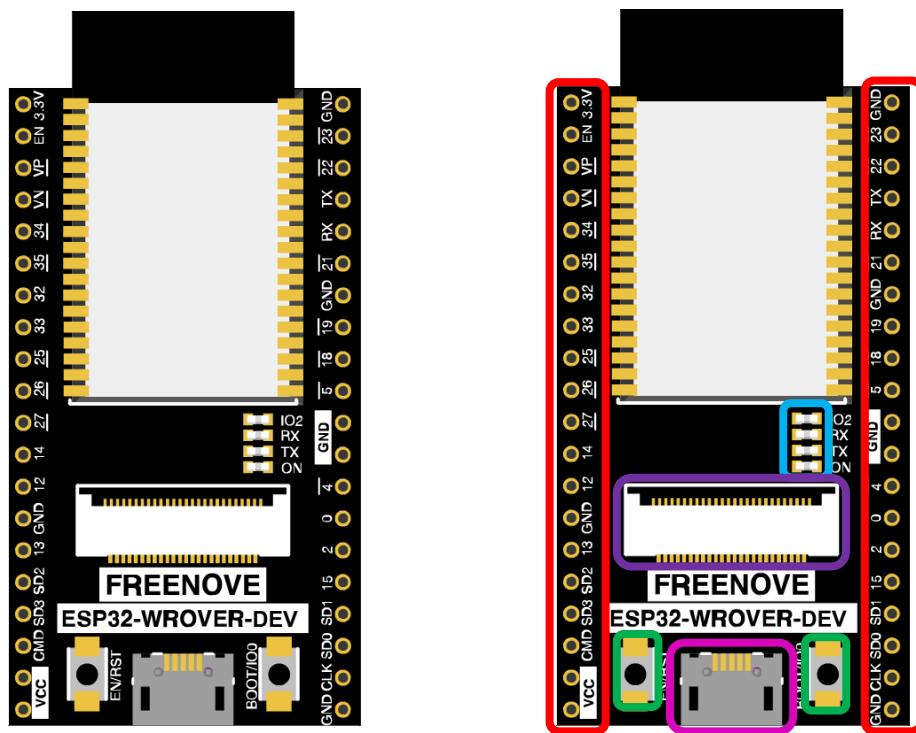
ESP32-WROVER has launched a total of two antenna packages, PCB on-board antenna and IPEX antenna respectively. The PCB on-board antenna is an integrated antenna in the chip module itself, so it is convenient to carry and design. The IPEX antenna is a metal antenna derived from the integrated antenna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



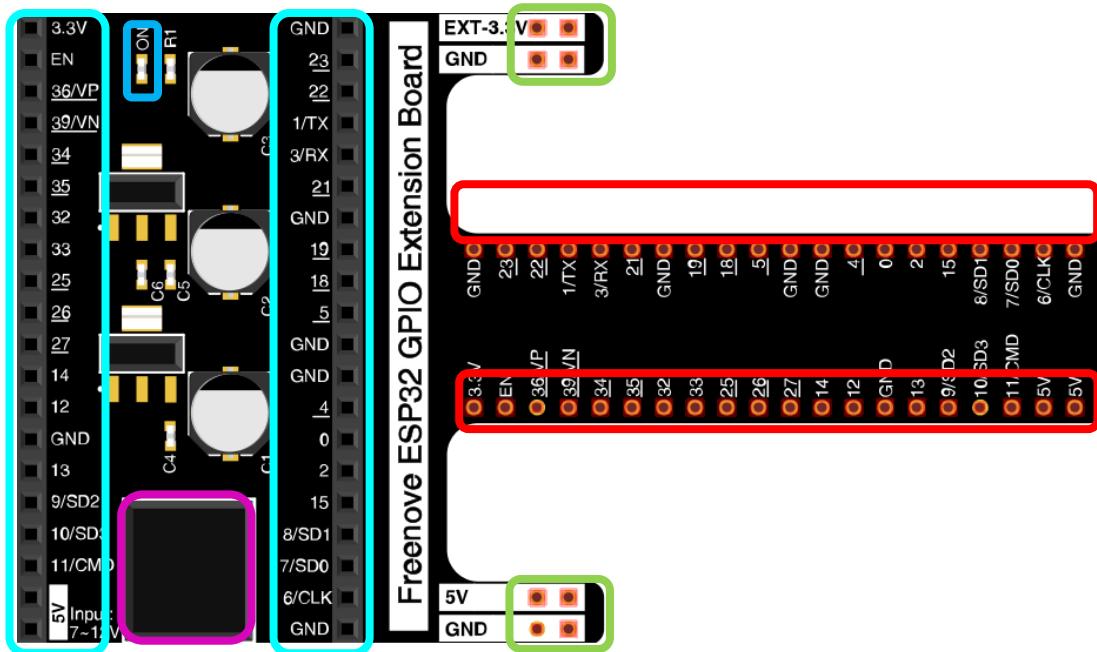
Compare the left and right images. We've boxed off the resources on the ESP32-WROVER in different colors to facilitate your understanding of the ESP32-WROVER.

| 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         |
|-----------|--|
| Red       | <b>GPIO pin</b>                              |
| Blue      | <b>LED indicator</b>                         |
| Green     | <b>GPIO interface of development board</b>   |
| Magenta   | <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)

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# 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.)

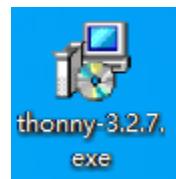
| Operating System | Download links/methods  |
|------------------|---|
| Windows          | <a href="https://github.com/thonny/thonny/releases/download/v3.2.7/thonny-3.2.7.exe">https://github.com/thonny/thonny/releases/download/v3.2.7/thonny-3.2.7.exe</a>   |
| Mac OS           | <a href="https://github.com/thonny/thonny/releases/download/v3.2.7/thonny-3.2.7.pk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

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

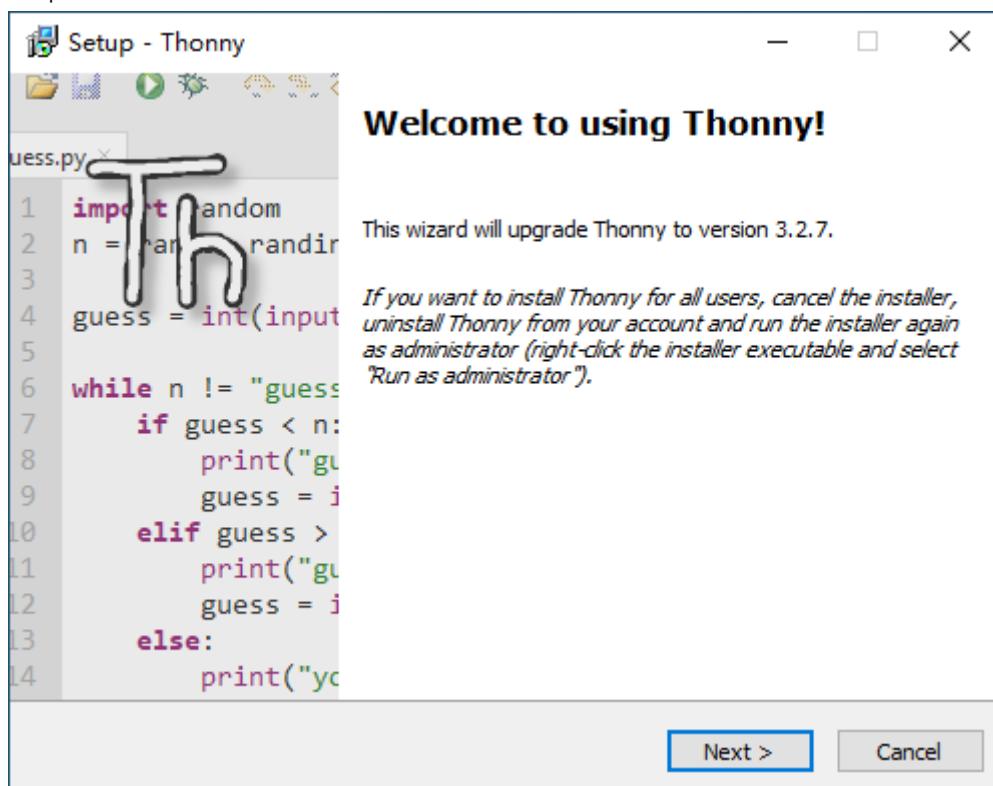


## Installing on Windows

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

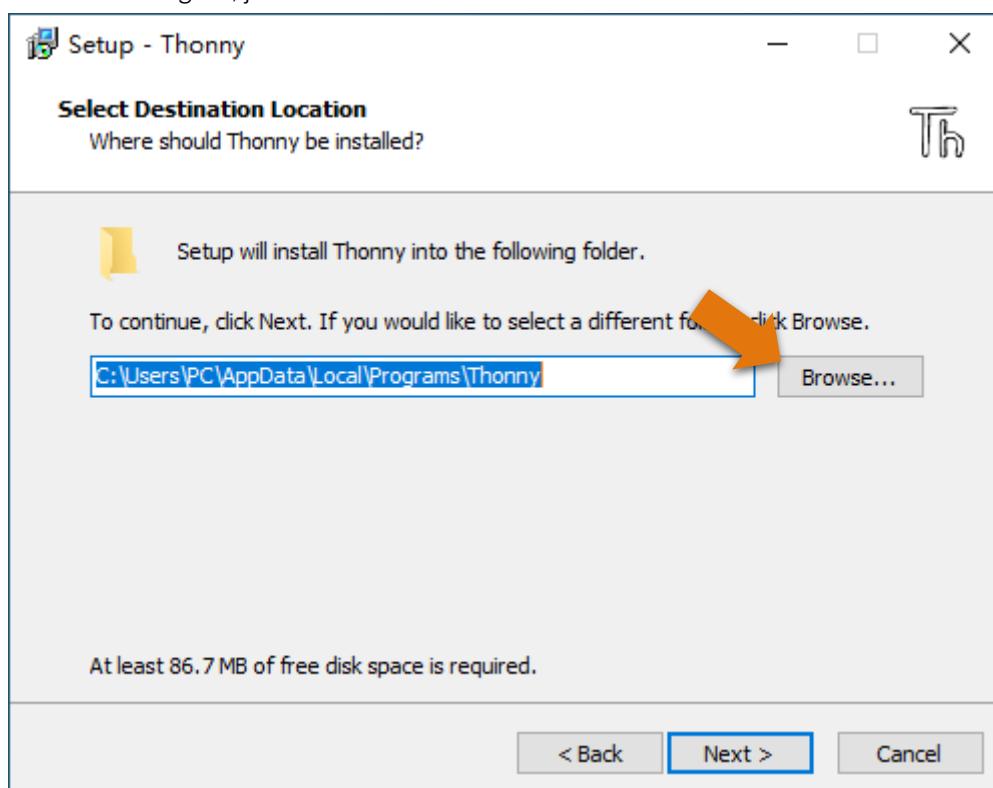


If you're not familiar with computer software installation, you can simply keep clicking "Next" until the installation completes.



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".





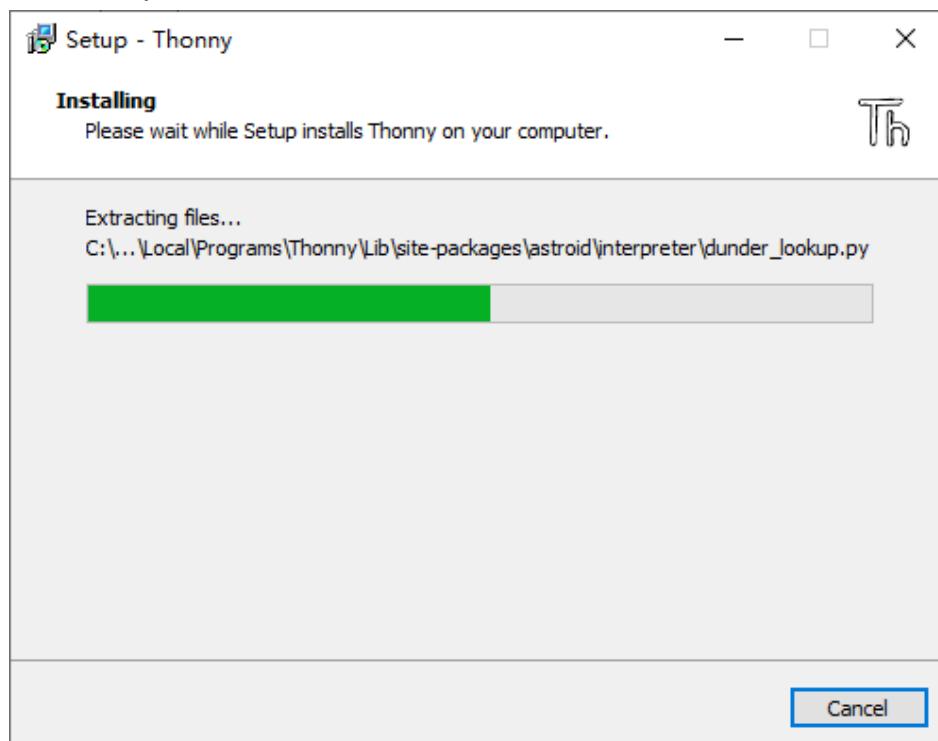
Check “Create desktop icon” and then it will generate a shortcut on your desktop to facilitate you to open Thonny later.



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.

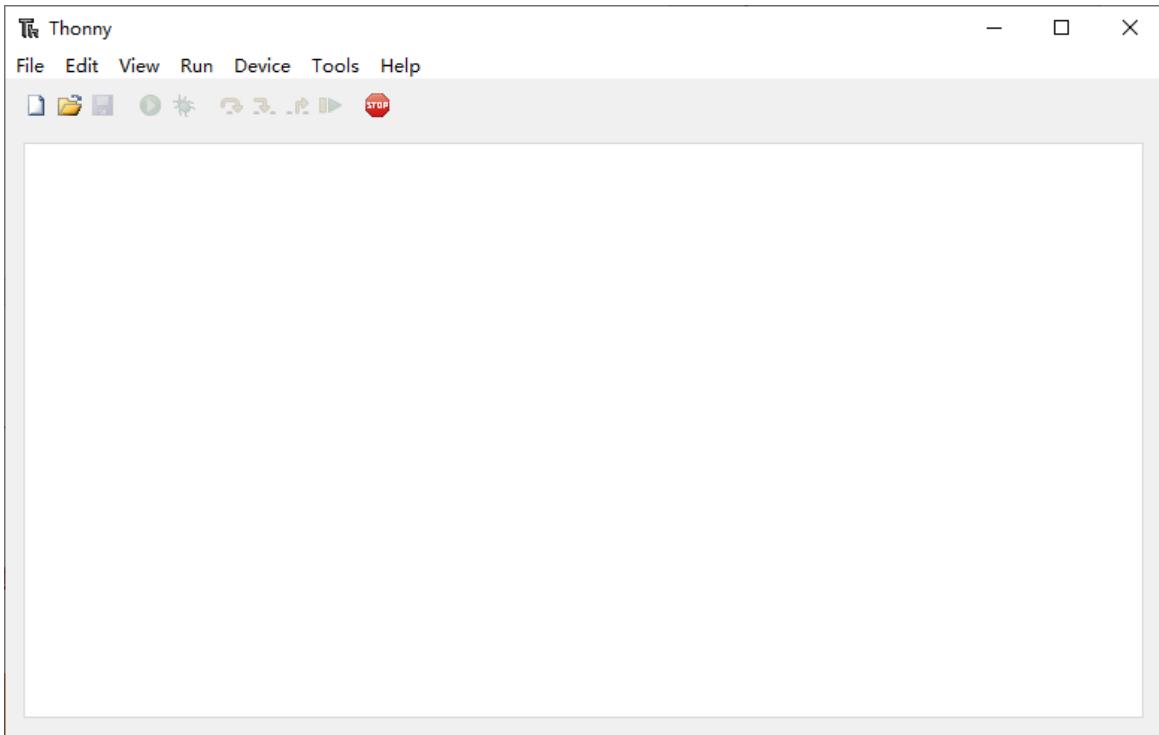


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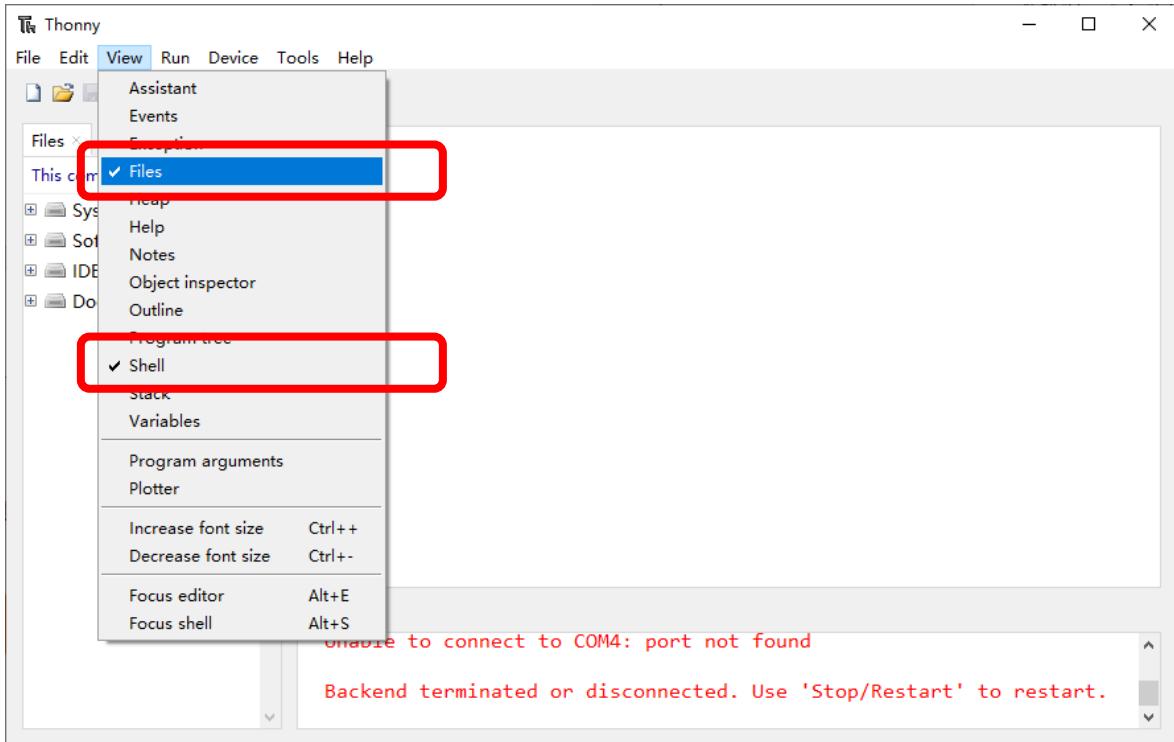


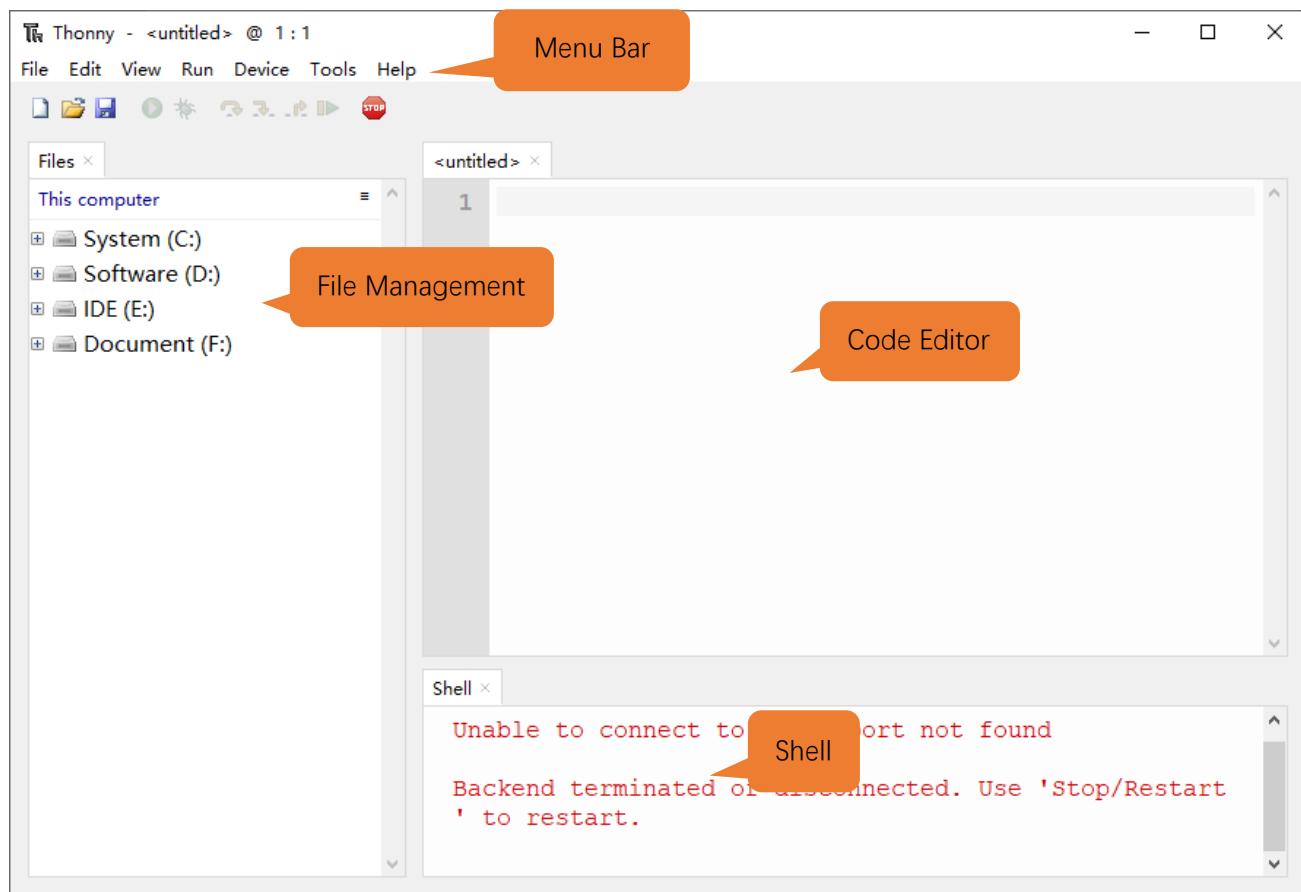
## 0.2 Basic Configuration of Thonny

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



Select "View" → "Files" and "Shell".







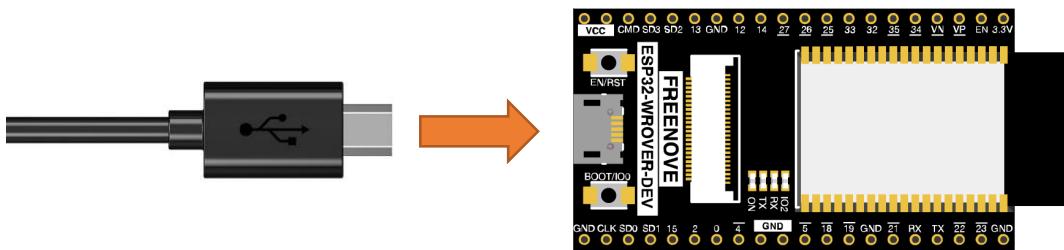
## 0.3 Installing CH340 (Important)

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

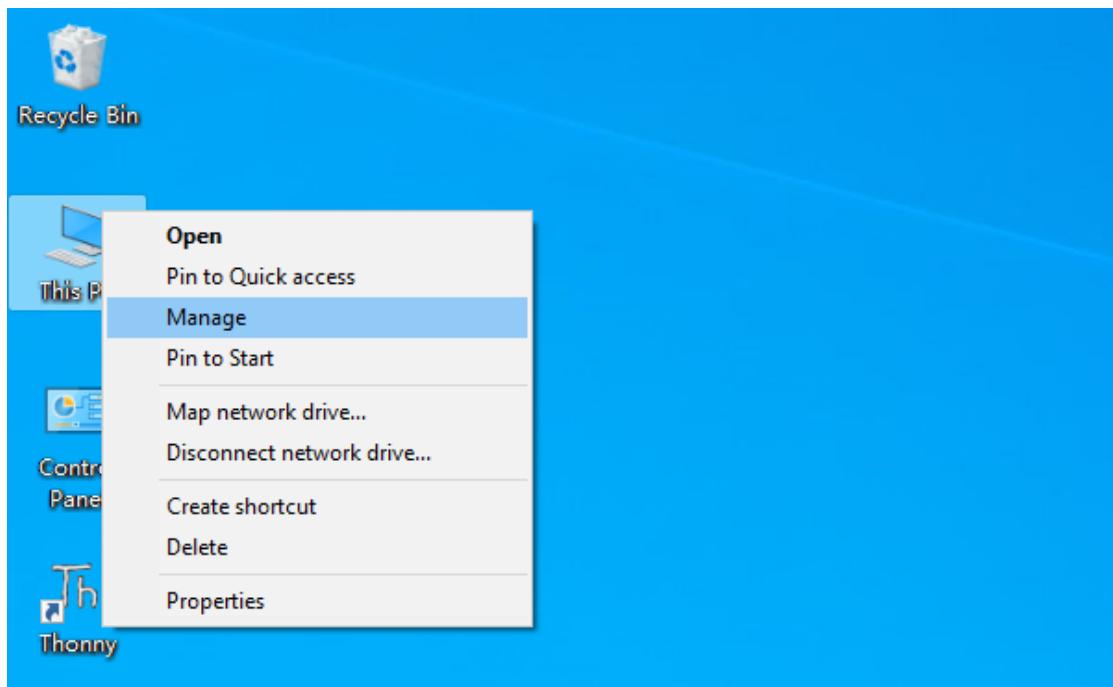
### Windows

Check whether CH340 has been installed

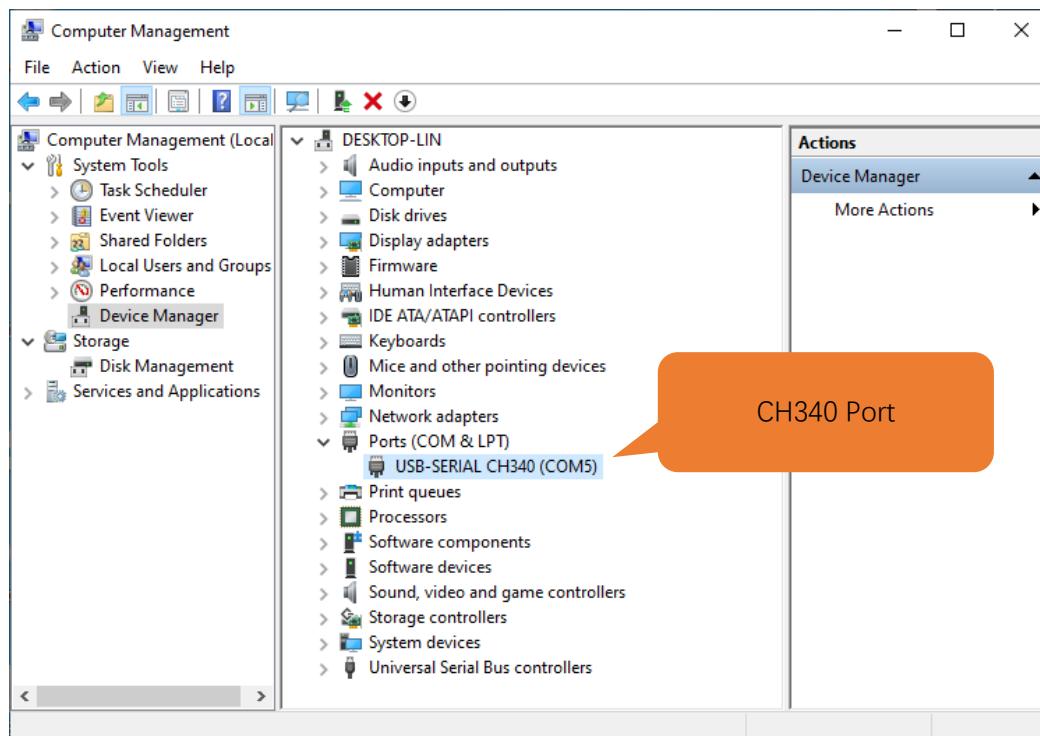
1. Connect your computer and ESP32 with a USB cable.



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

1. 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.

index / search / search CH340

All (14)

**Downloads (7)**

Products (4)

Application (2)

Video (1)

News (0)

**keyword CH340**

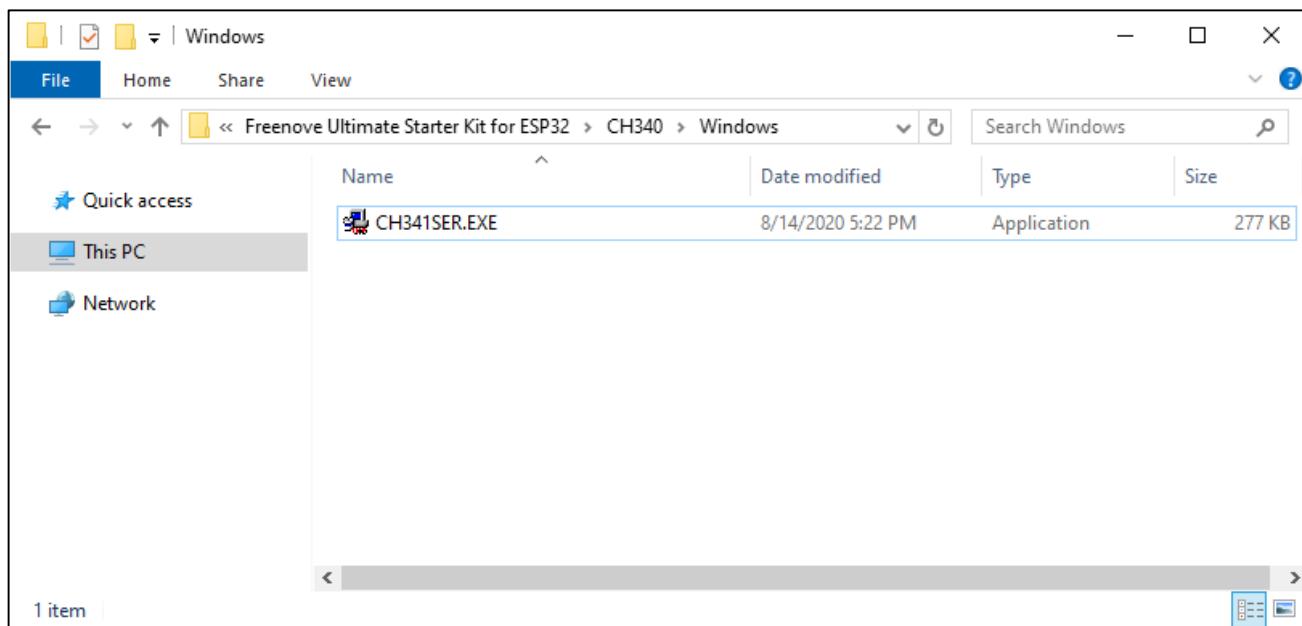
Downloads( 7 )

| file category | file content  | version | upload time |
|---------------|---|---------|-------------|
| Driver&Tools  | <b>Windows</b><br>CH341SER.EXE<br>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  |
|               | <b>CH341SER.ZIP</b><br>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  |
|               | <b>CH341SER_ANDROID...</b><br>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 (Java Driver), App Demo Example (USB to UART Device Driver) | 1.6     | 2019-04-19  |
|               | <b>CH341SER_LINUX...</b><br>CH340/CH341 USB to serial port LINUX driver   | 1.5     | 2018-03-18  |
|               | <b>CH341SER_MAC.ZI...</b><br>CH340/CH341 USB to serial port MAC OS driver   | 1.5     | 2018-07-05  |
| Others        |   |         |             |
|               | <b>PRODUCT_GUIDE.P...</b><br>Electronic selection of product selection manual, please refer to related product technical manual for more technical information.   | 1.4     | 2018-12-29  |
|               | <b>InstallNoteOn64...</b><br>Instructions for the driver after 18 years of August cannot be installed under some 64-bit WIN7 (English)  | 1.0     | 2019-01-10  |

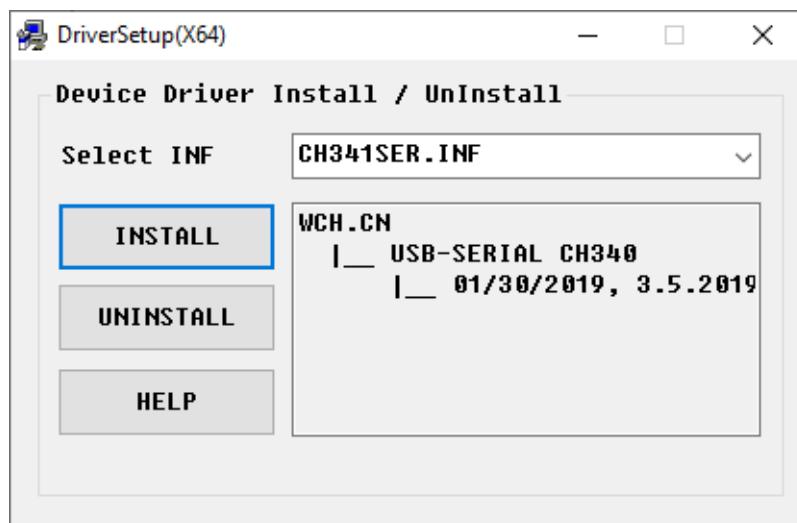
You can also open “**Freenove\_Super\_Starter\_Kit\_for\_ESP32/CH340**”, we have prepared the installation package.

| Name           | Date modified     | Type        | Size |
|----------------|-------------------|-------------|------|
| Linux          | 8/14/2020 5:24 PM | File folder |      |
| MAC            | 8/14/2020 5:23 PM | File folder |      |
| <b>Windows</b> | 8/14/2020 5:23 PM | File folder |      |

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

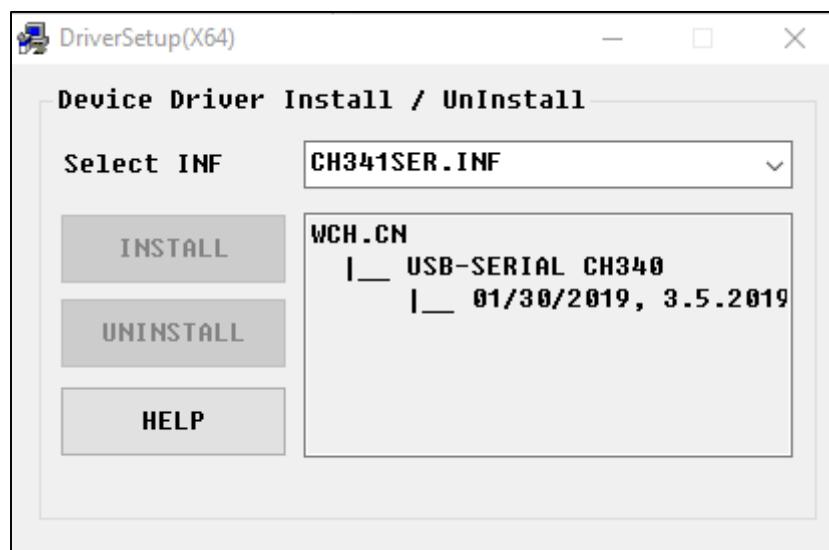


3. Double click “CH341SER.EXE”.

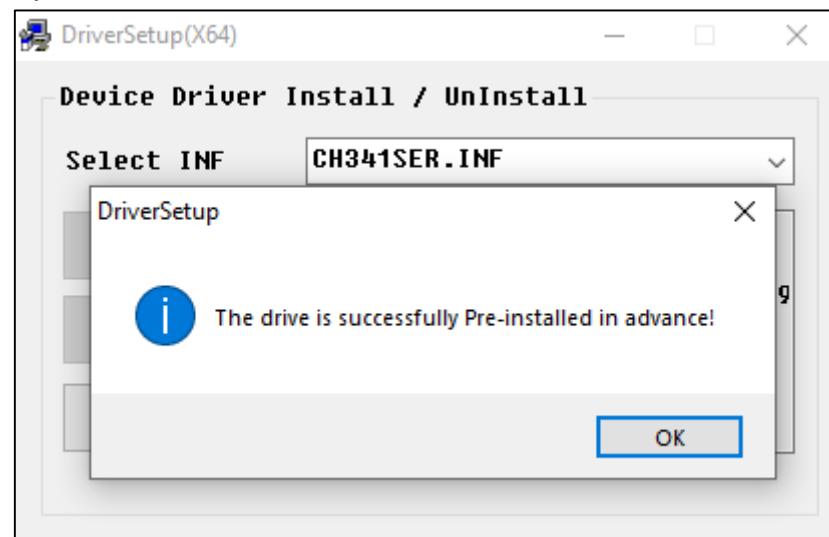




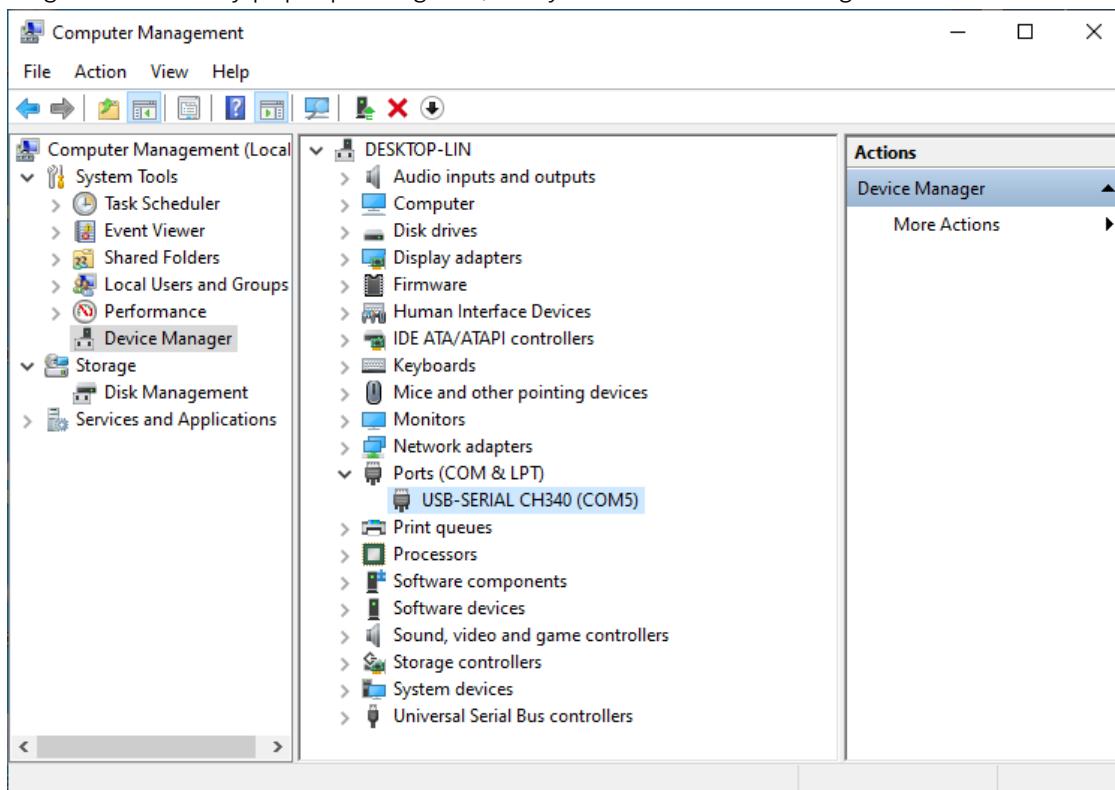
4. Click “INSTALL” and wait for the installation to complete.



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 orange callout boxes pointing to specific files: 'Windows' points to CH341SER.EXE, 'Linux' points to CH341SER\_LINUX..., and 'MAC' points to CH341SER\_MAC.ZIP. The table columns are file category, file content, version, and upload time.

| 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  |
|               | 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  |
|               | 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 (Java Driver), App Demo Examples, and STM32 Demo SDK. | 1.6     | 2019-04-19  |
|               | CH341SER_LINUX... CH340/CH341 USB to serial port LINUX driver   | 1.5     | 2018-03-18  |
|               | CH341SER_MAC.ZIP CH340/CH341 USB to serial port MAC OS driver   | 1.5     | 2018-07-05  |
| Others        |   |         |             |

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

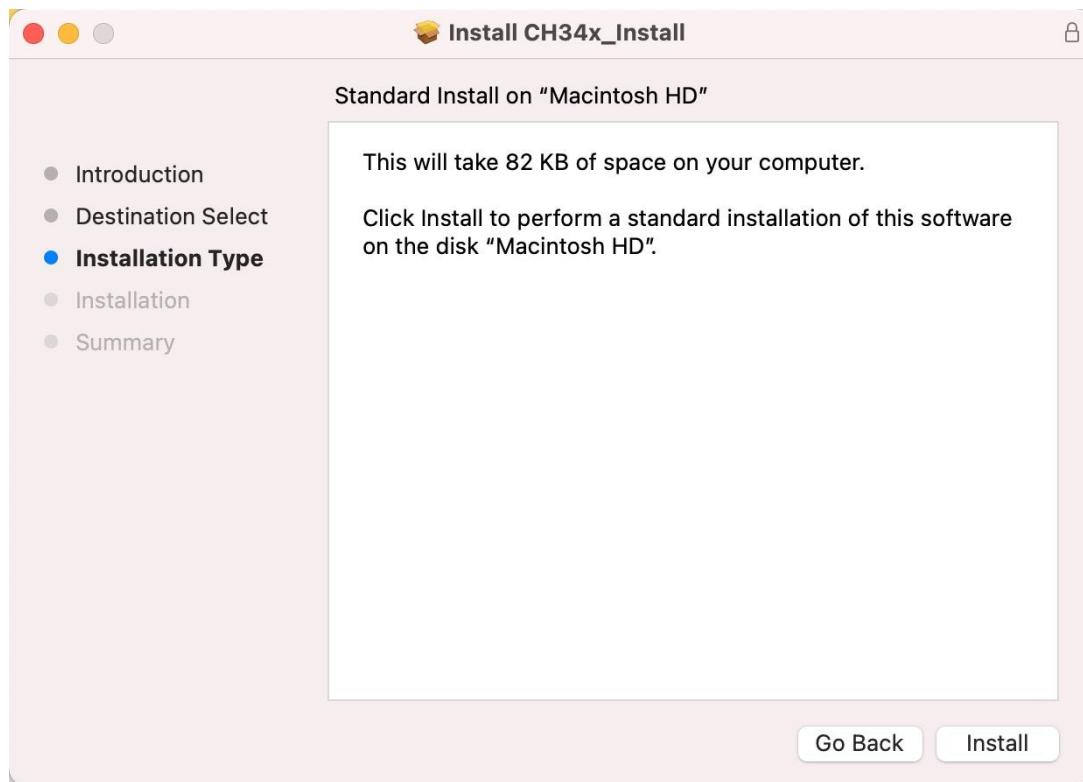
Second, open the folder "Freenove\_Super\_Starter\_Kit\_for\_ESP32/CH340/MAC/"



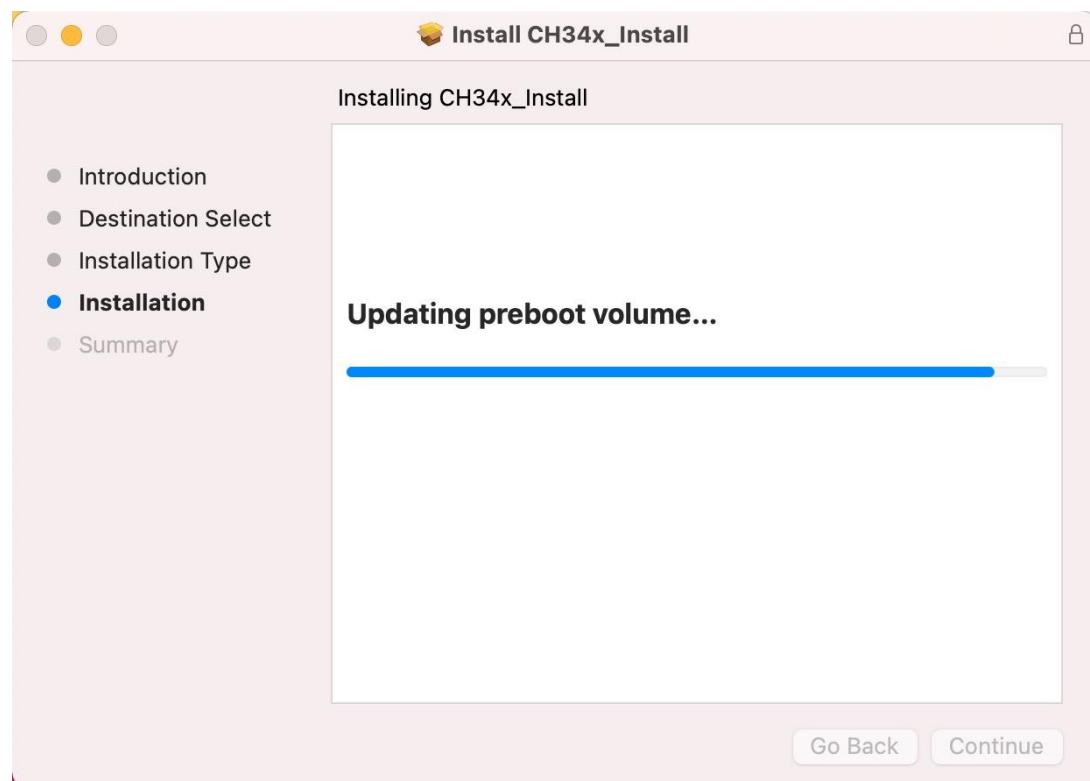
Third, click Continue.



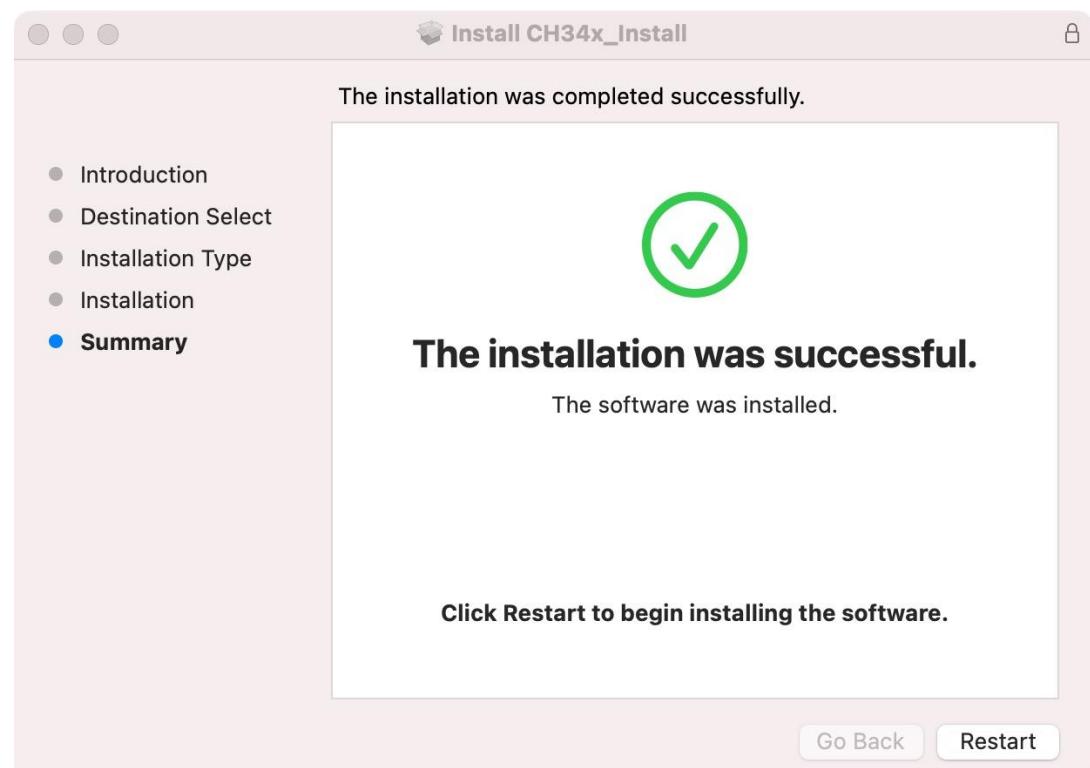
Fourth, click Install.



Then, waiting Finsh.

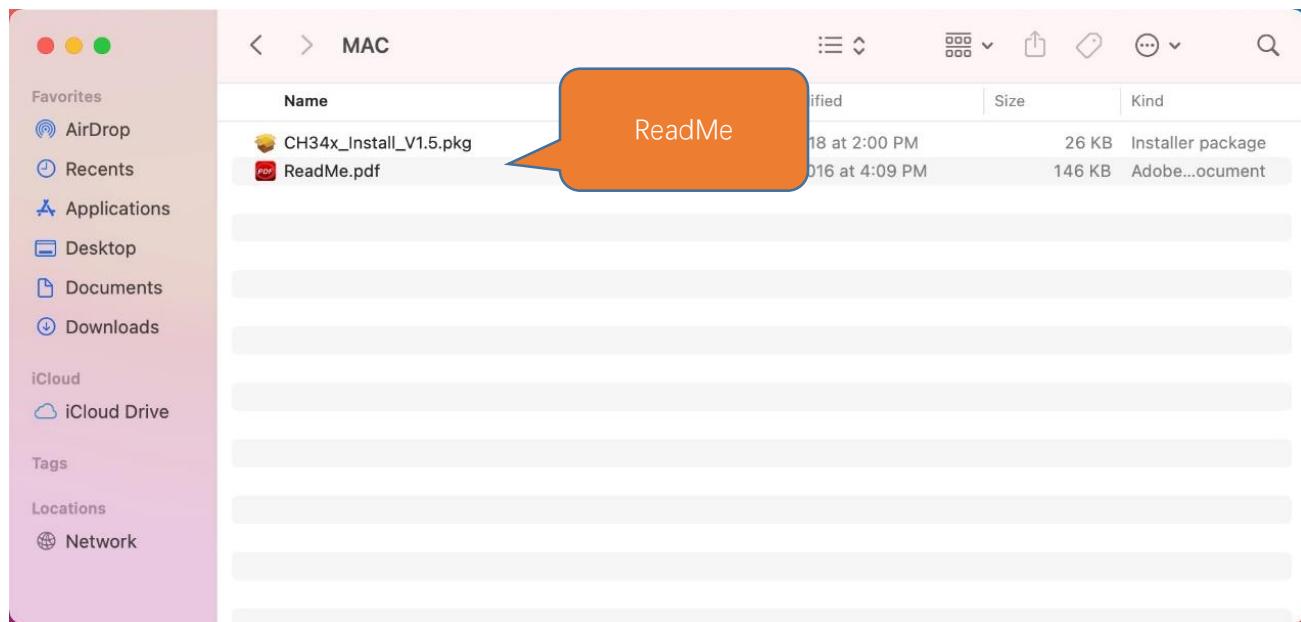


Finally, restart your PC.





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)

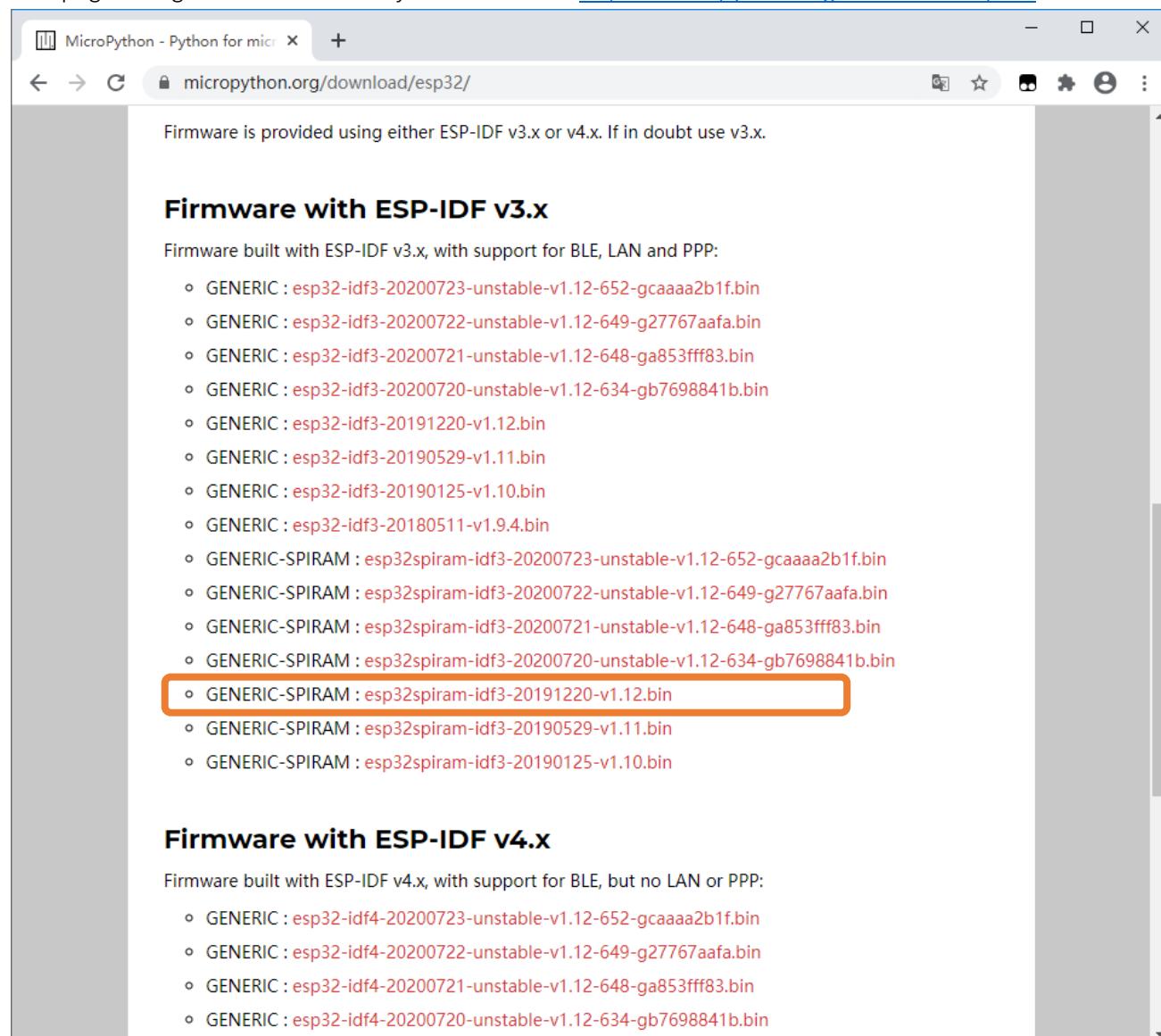
## 0.4 Burning Micropython Firmware (Important)

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](#)

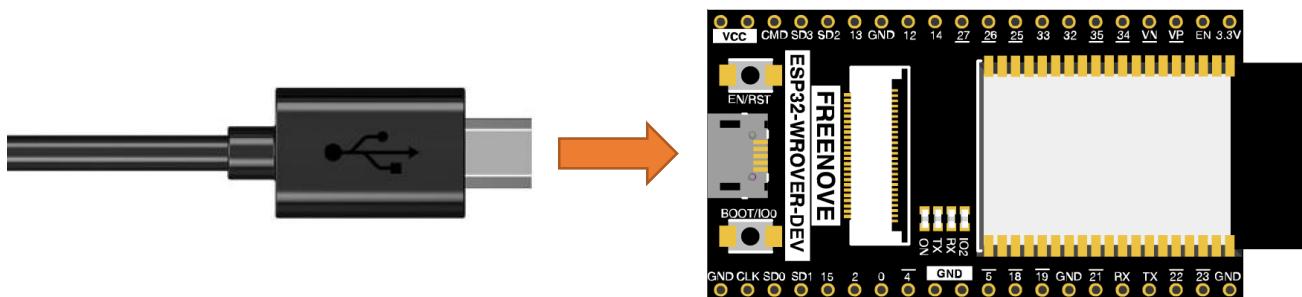
Firmware used in this tutorial is **esp32spiram-idf3-20191220-v1.12.bin**

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

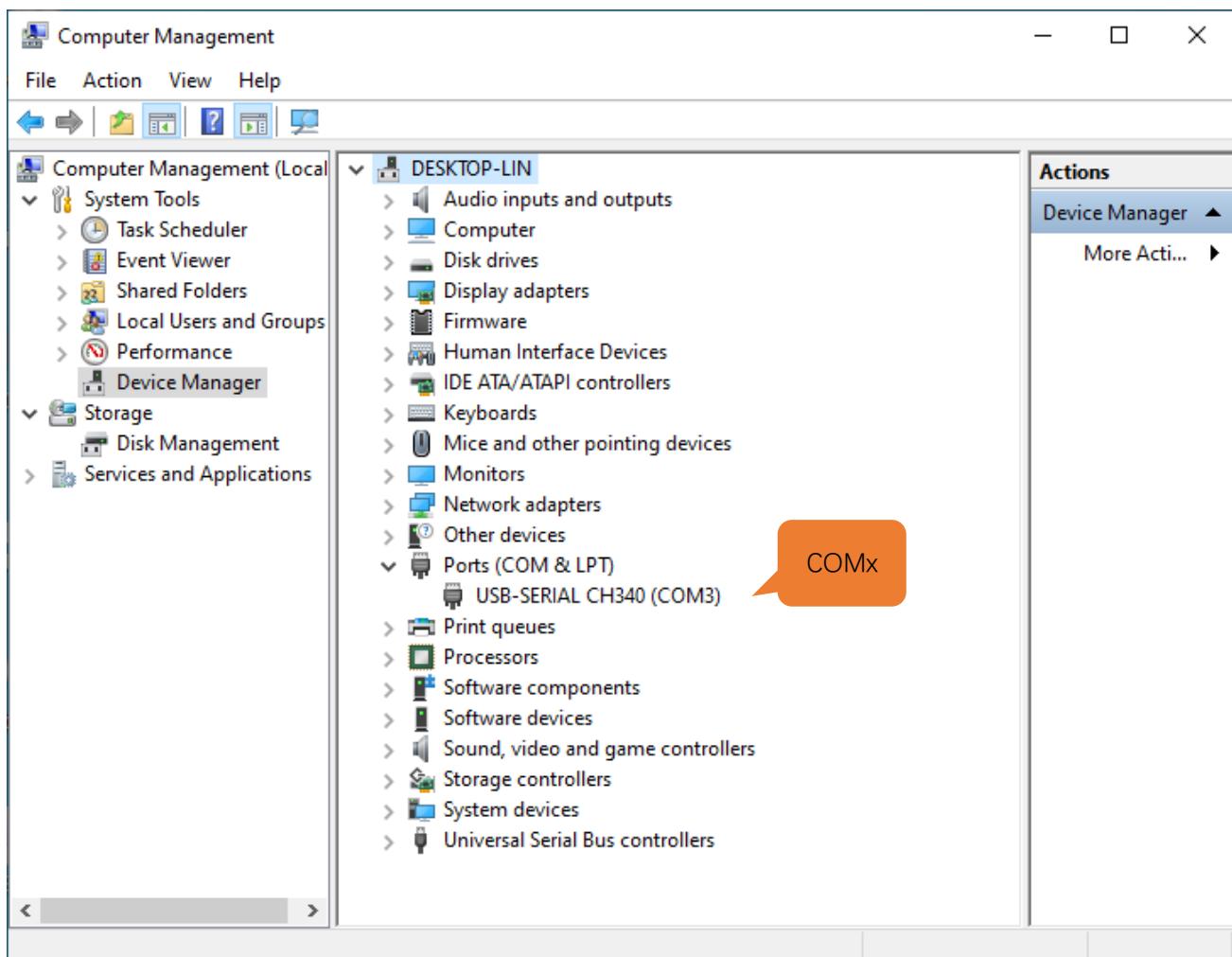
This file is also provided in our data folder "**Freenove\_Super\_Starter\_Kit\_for\_ESP32/Python/Python\_Firmware**".

# Burning a Micropython Firmware

Connect your computer and ESP32 with a USB cable.

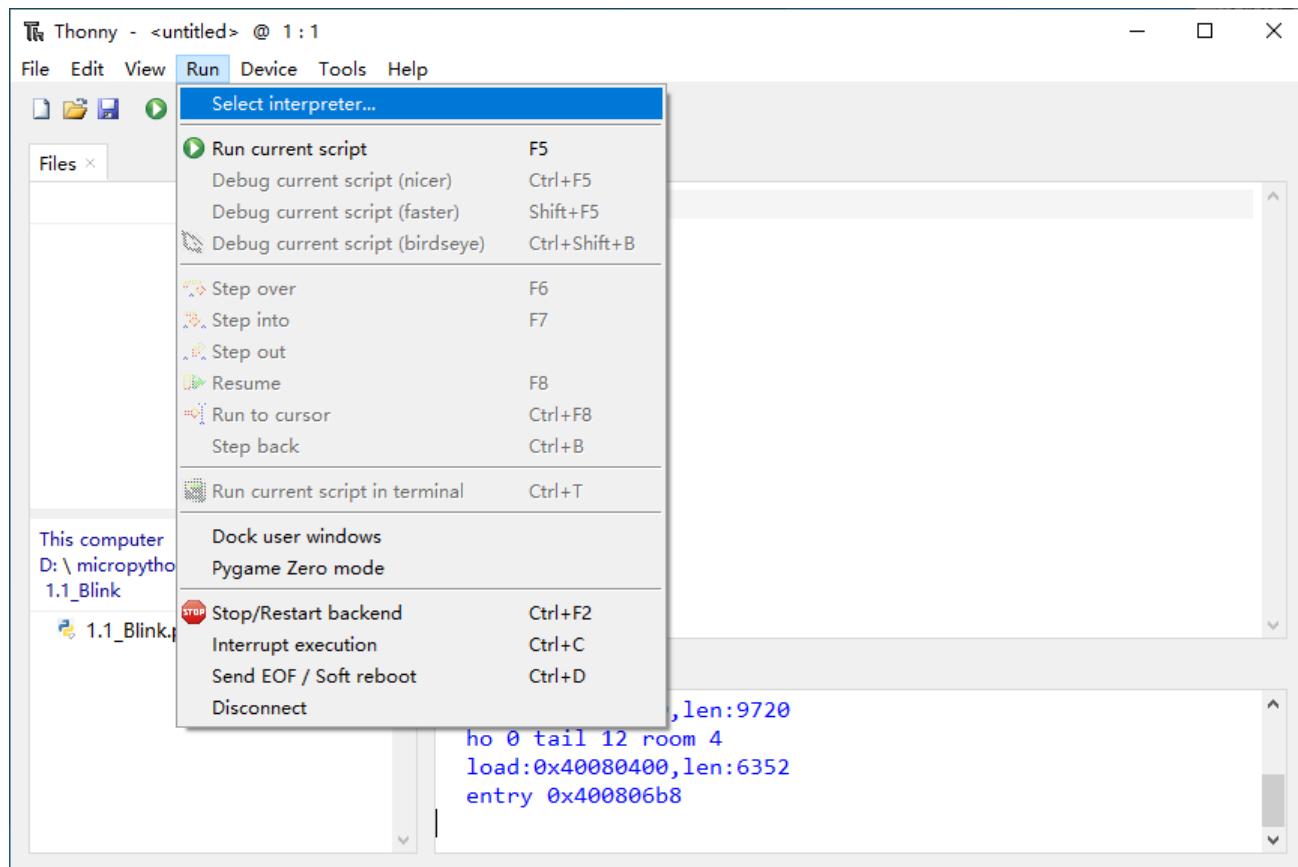


Make sure that the driver has been installed successfully and that it can recognize COM port correctly. Open device manager and expand “Ports”.



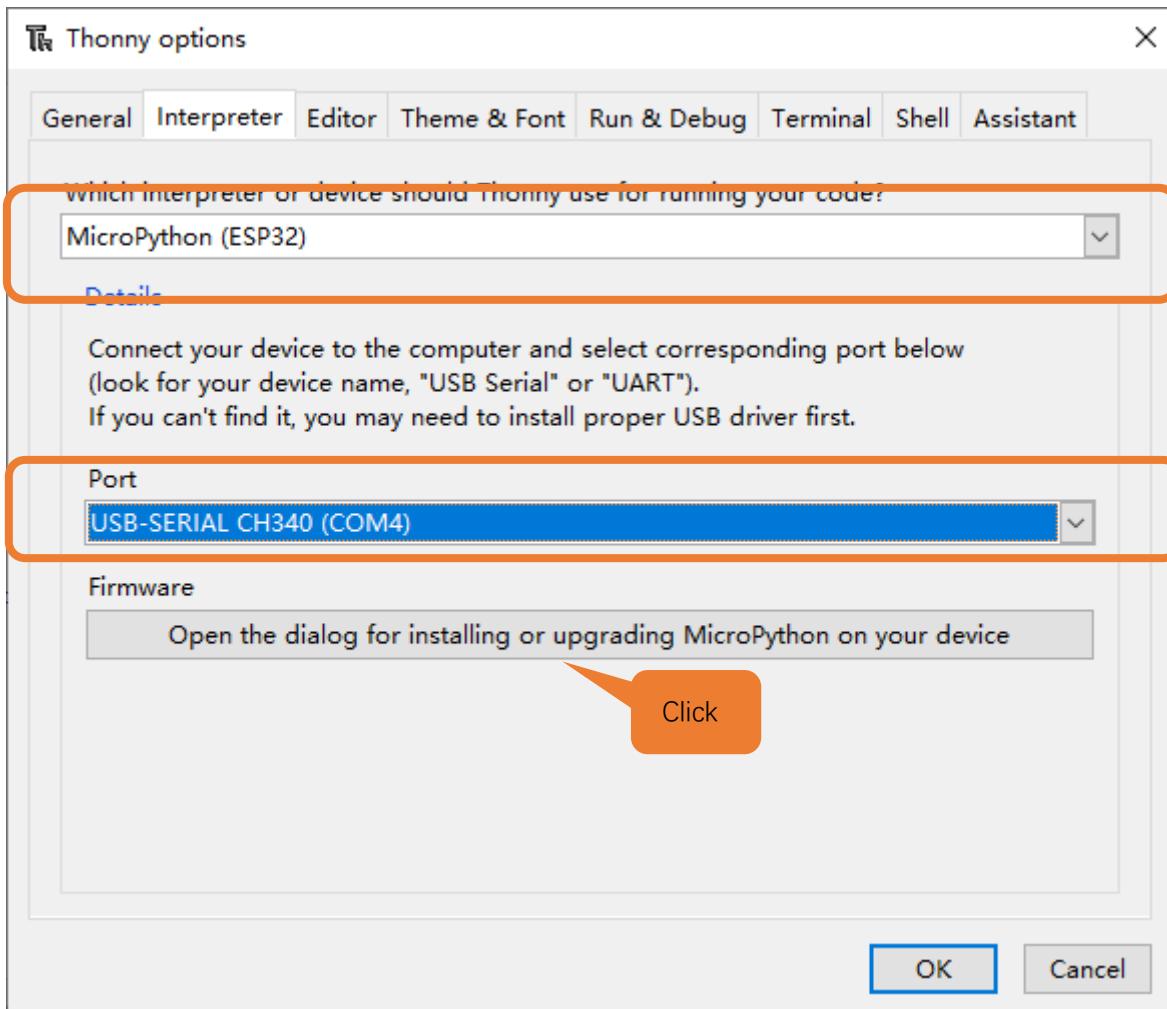
Note: the port of different people may be different, which is a normal situation.

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

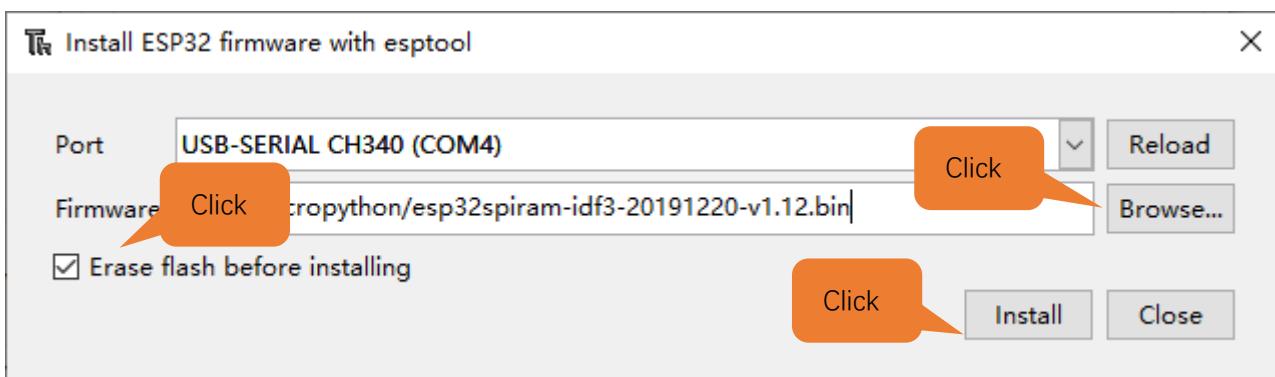




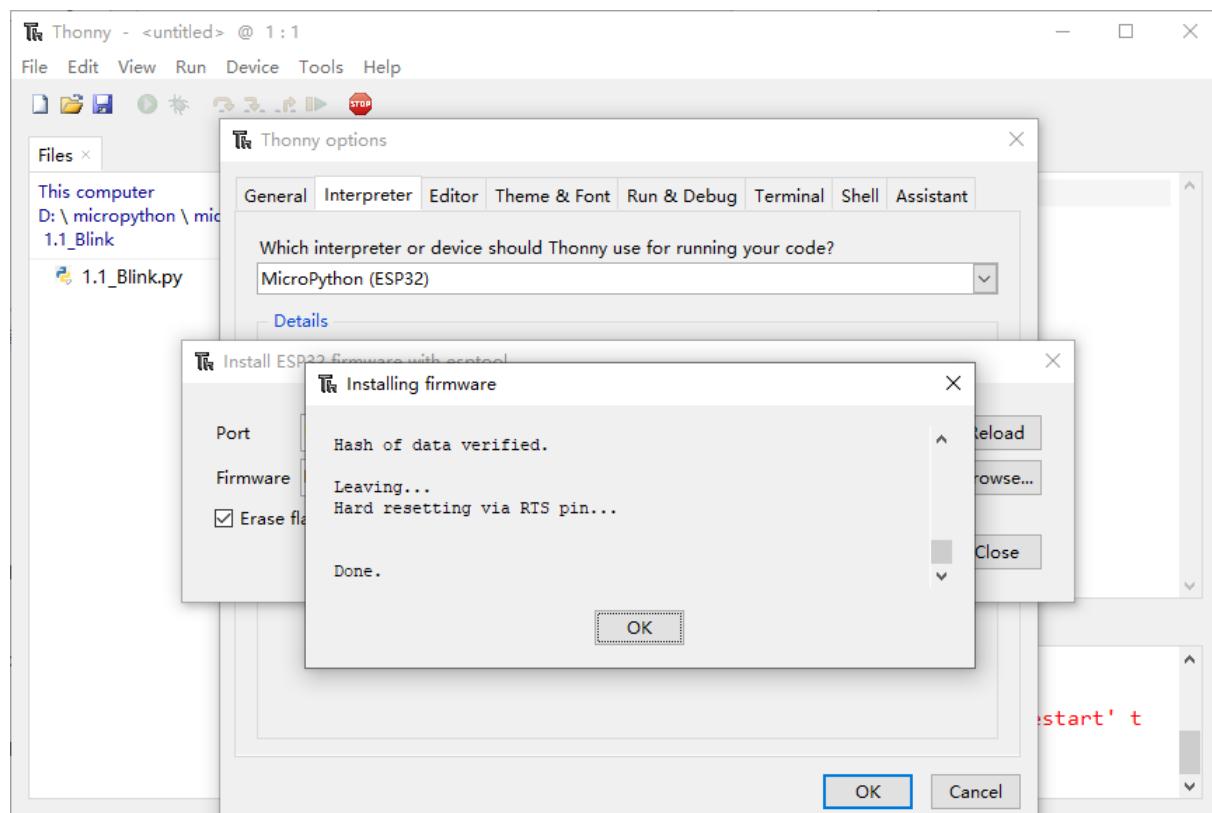
2. Select “Micropython (ESP32)”, select “USB-SERIAL CH340 (COM4)”, and then click the long button under “Firmware”.



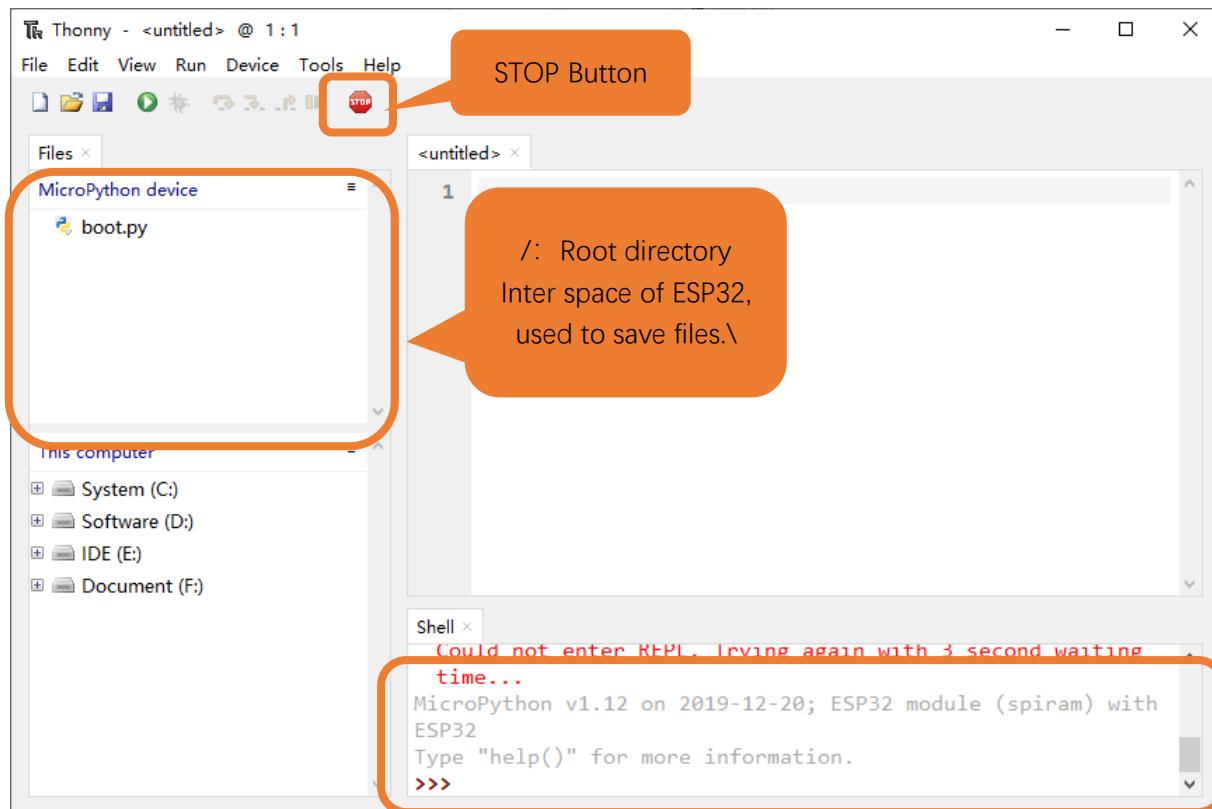
3. The following dialog box pops up. Select “USB-SERIAL CH340 (COM4)” for “Port” and then click “Browse...”. Select the previous prepared microPython firmware “**esp32spiram-idf3-20191220-v1.12.bin**”. Check “Erase flash before installing” and click “install” to wait for the prompt of finishing installation



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



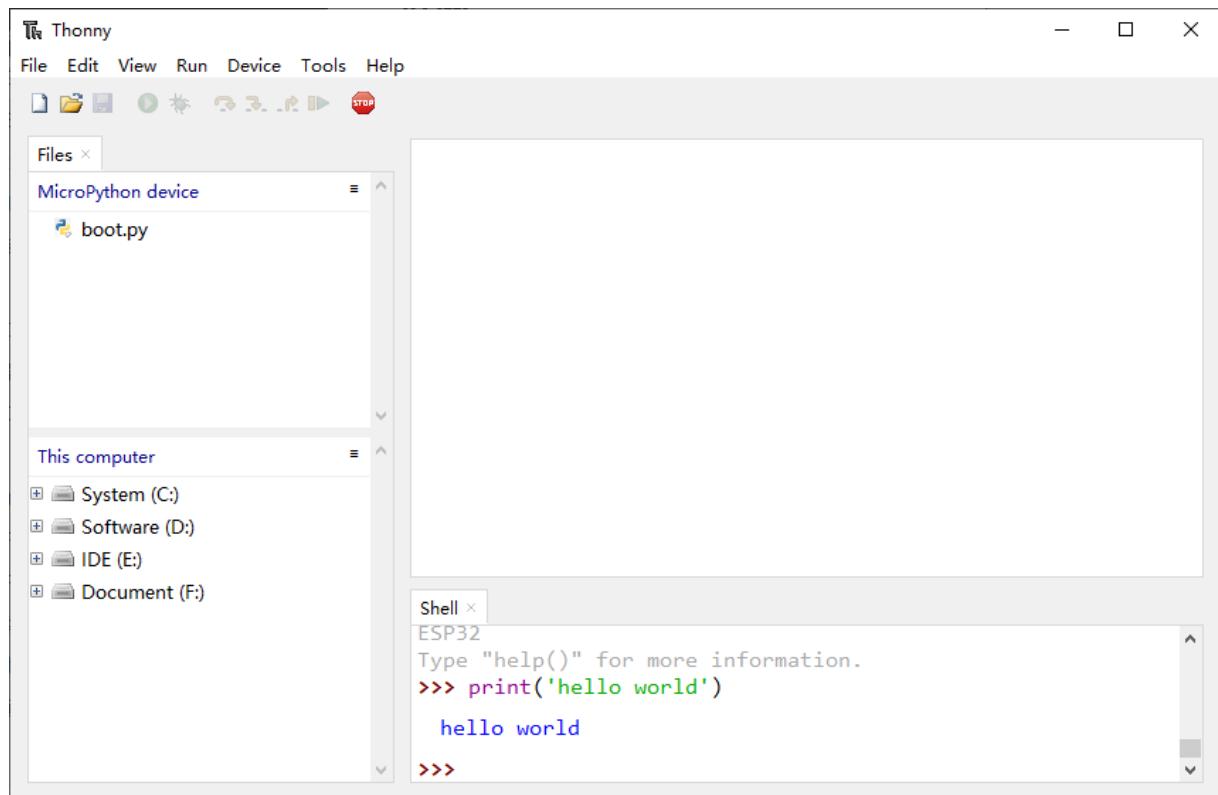
6. So far, all the preparations have been made.



## 0.5 Testing codes (Important)

### Testing Shell Command

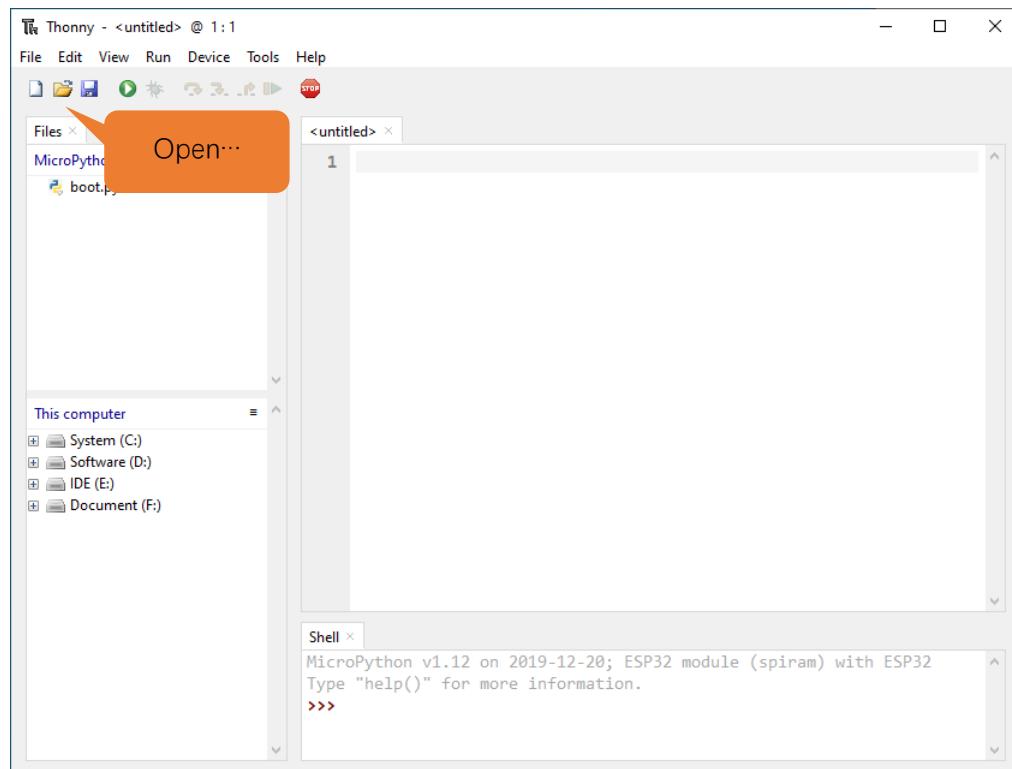
Enter “print('hello world')” in “Shell” and press Enter.



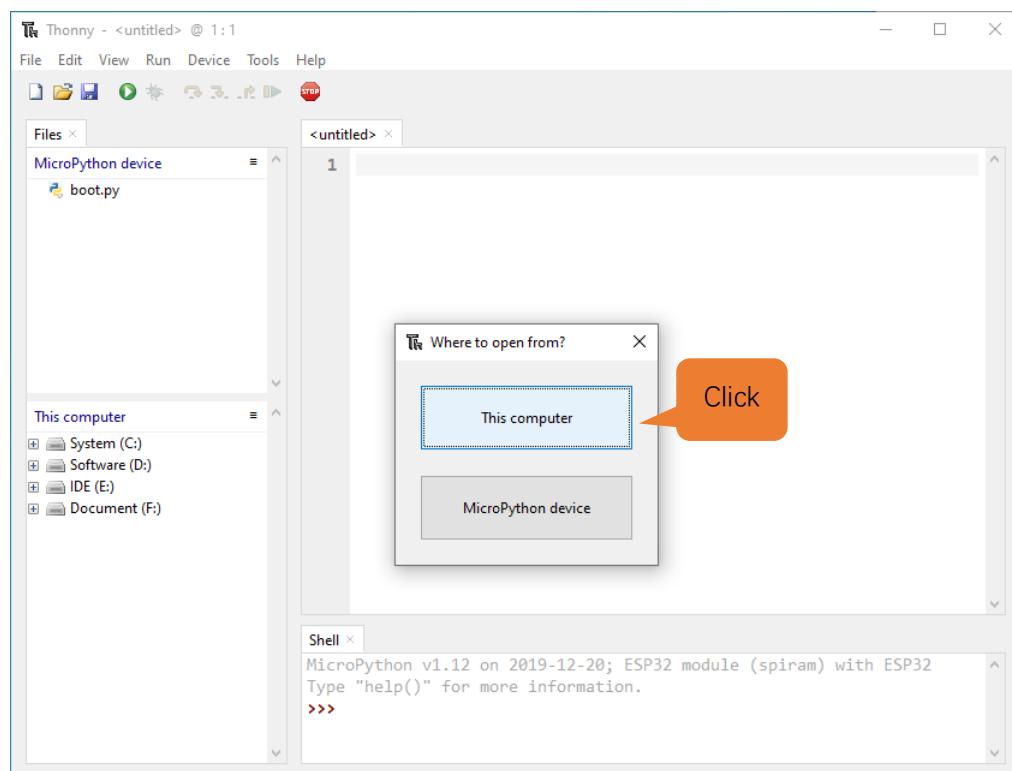
## Running Online

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

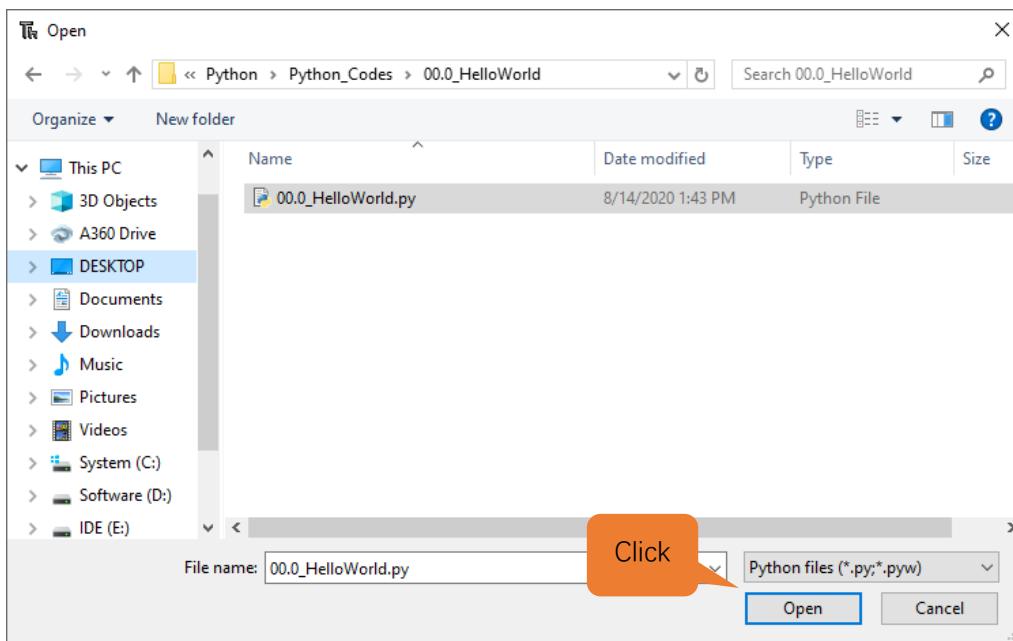
1. Open Thonny and click “Open…”.



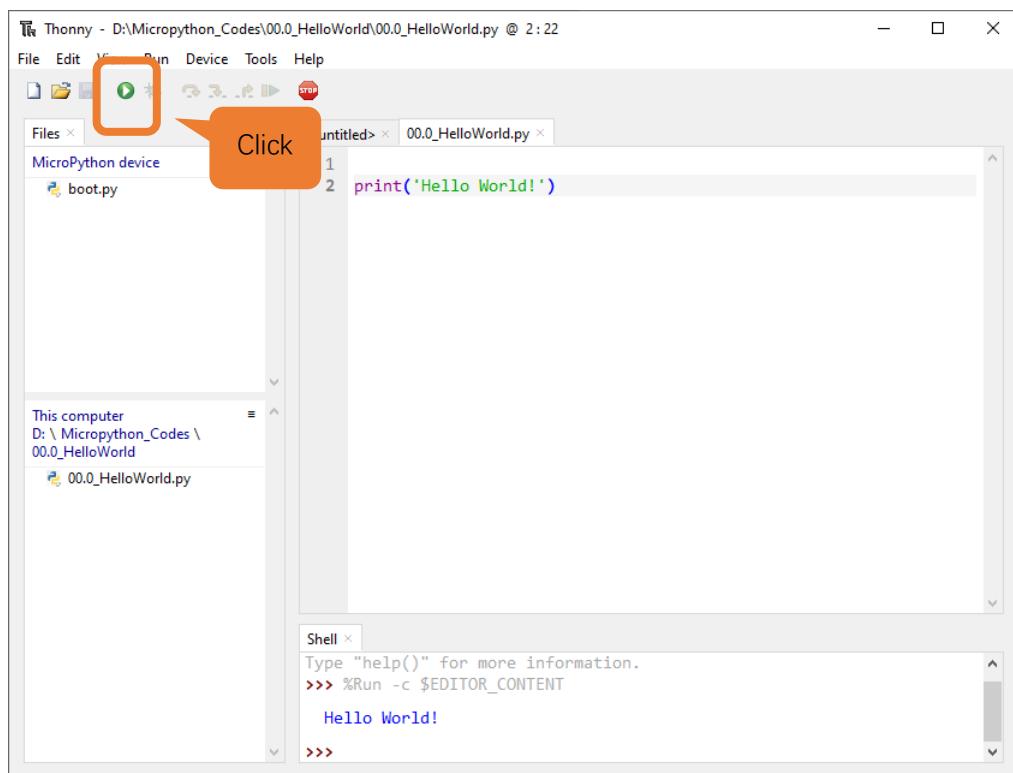
2. On the newly pop-up window, click “This computer”.



In the new dialog box, select “**00.0\_HelloWorld.py**” in “**Freenove\_Super\_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”.

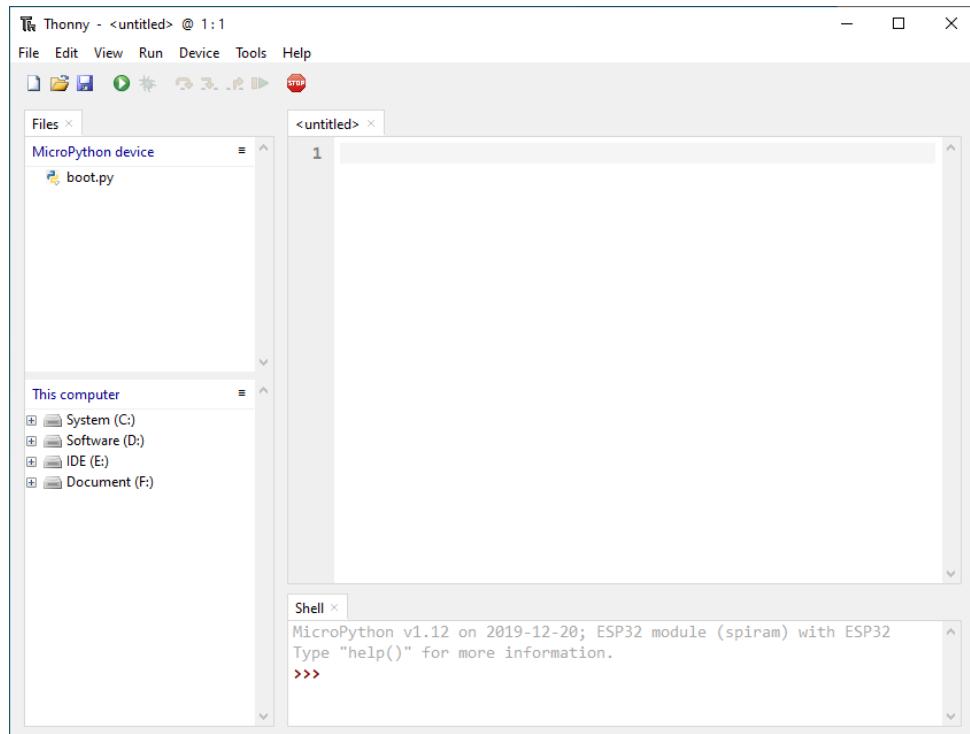


Note: When running online, if you press the reset key of ESP32, user's code will not be executed again. If you wish to run the code automatically after resetting the code, please refer to the following [Running Offline](#).

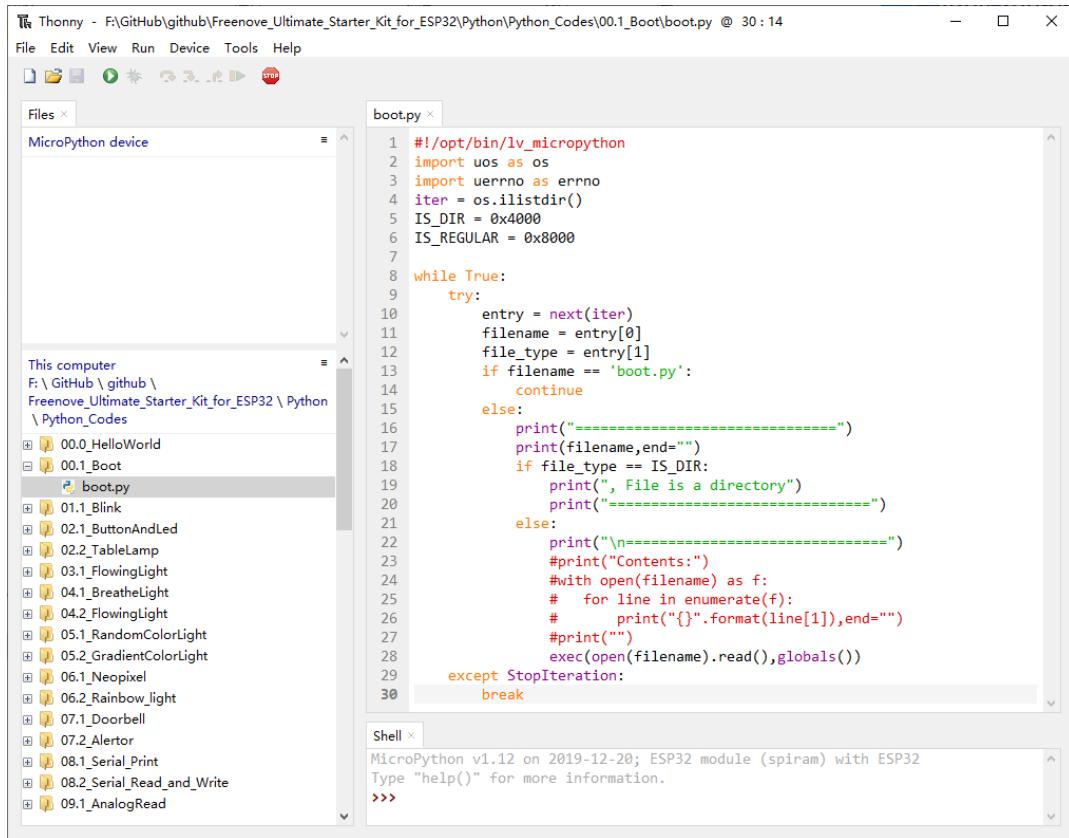
## Running Offline (Importance)

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.

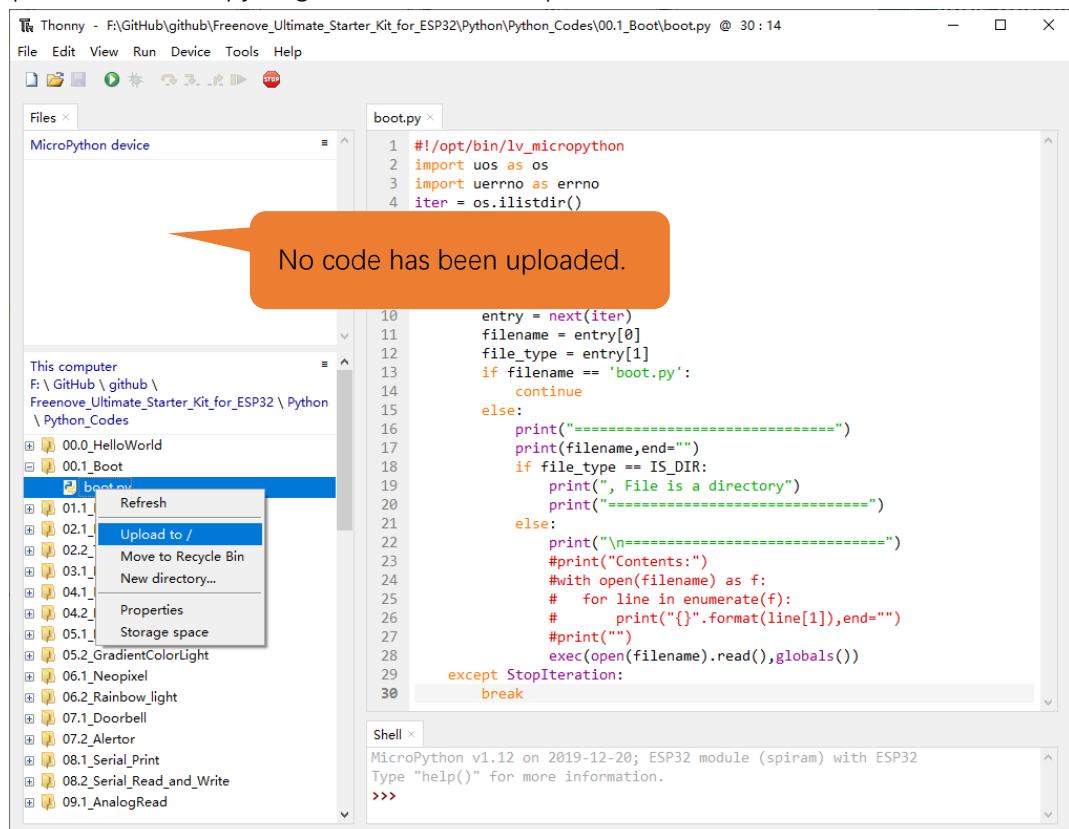
1. Move the program folder "**Freenove\_Super\_Starter\_Kit\_for\_ESP32/Python/Python\_Codes**" to disk(D) in advance with the path of "**D:/Micropython\_Codes**". Open "Thonny".



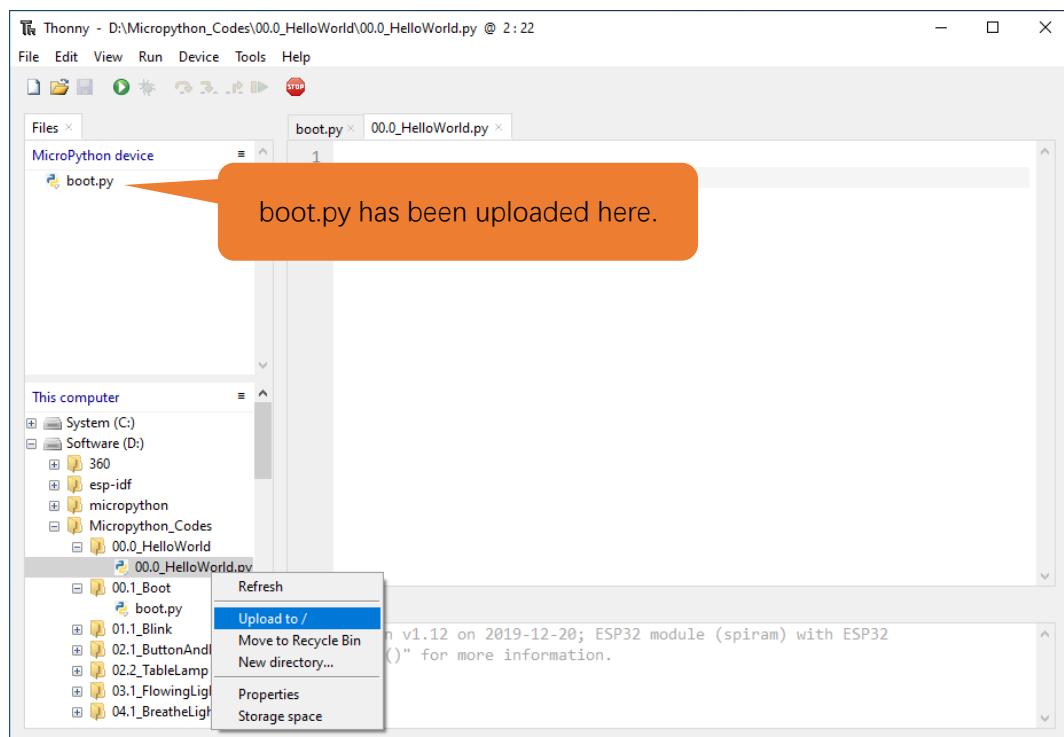
2. Expand "00.1\_Boot" in the "Micropython\_Codes" in the directory of disk(D), and double-click boot.py, which is provided by us to enable programs in "MicroPython device" to run offline.



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. On the left, the file tree displays a MicroPython device with files 00.0\_HelloWorld.py and boot.py. The main area shows the code for 00.0\_HelloWorld.py:

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

In the bottom right, the Shell window shows the execution results:

```
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!
```

An orange box highlights the "Hello World!" output line in the shell.

## 0.6 Thonny Common Operation

### Uploading Code to ESP32

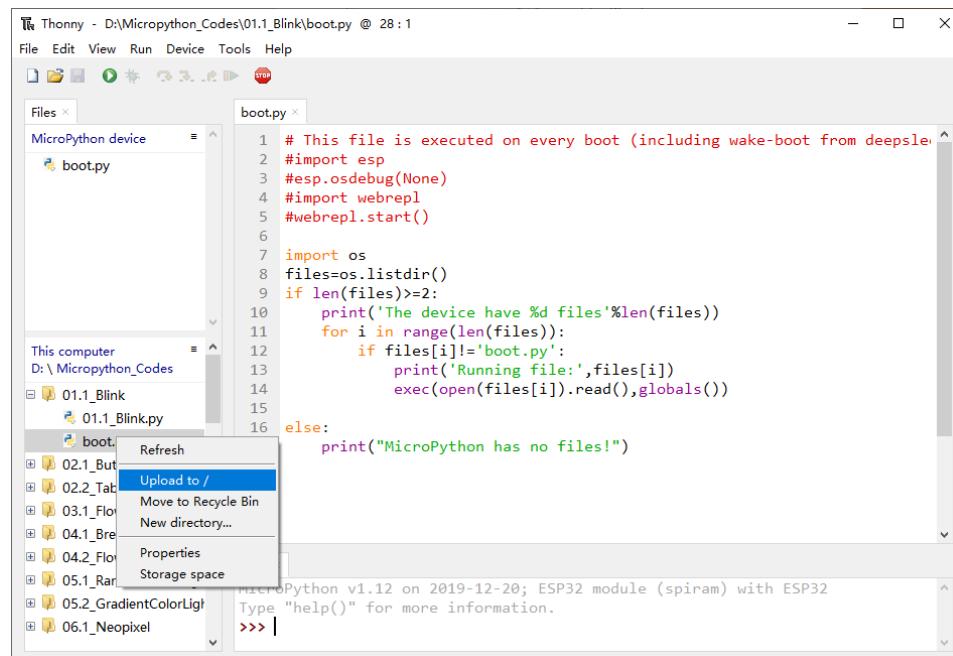
For convenience, we take the operation on “boot.py” as an example here. We have added “boot.py” to every code directory. Each time when ESP32 restarts, if there is a “boot.py” in the root directory, it will execute this code first.

```
# 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!")

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

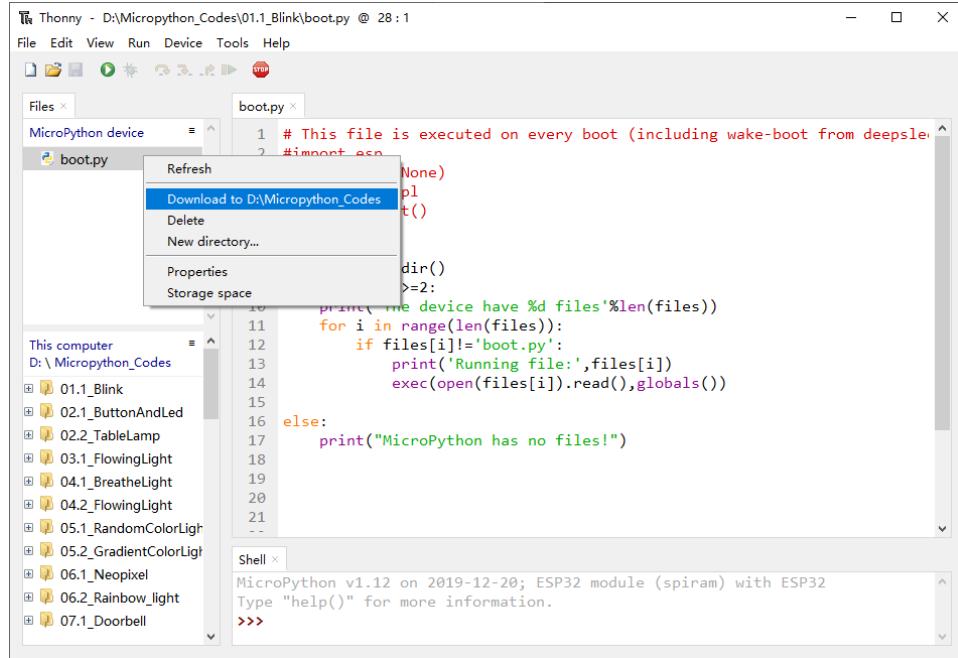
Select “boot.py” in “01.1\_Blink”, right-click your mouse and select “Upload to /” to upload code to ESP32’s root directory.





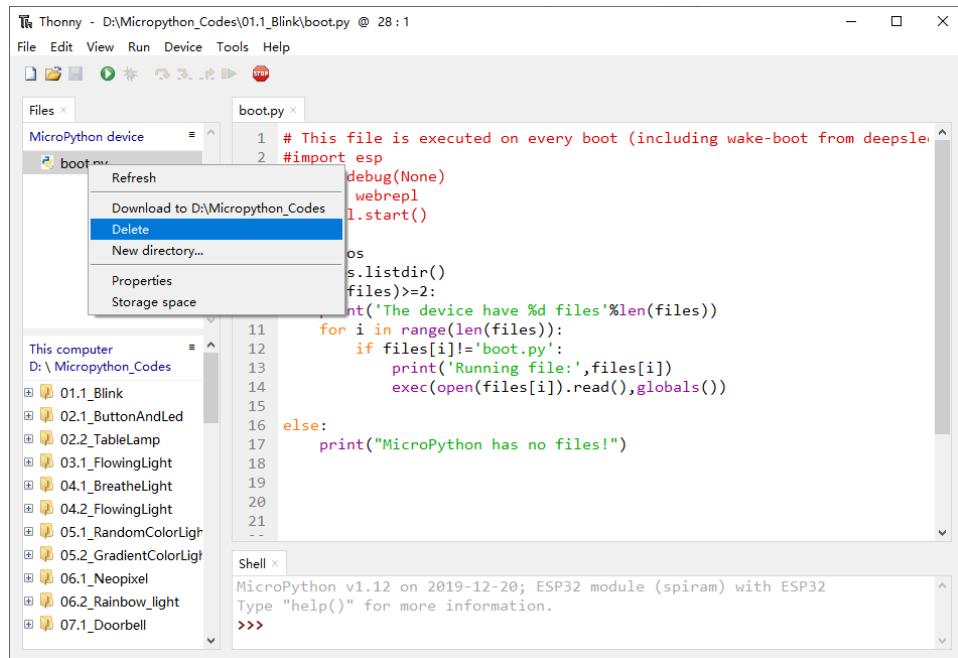
## Downloading Code to Computer

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



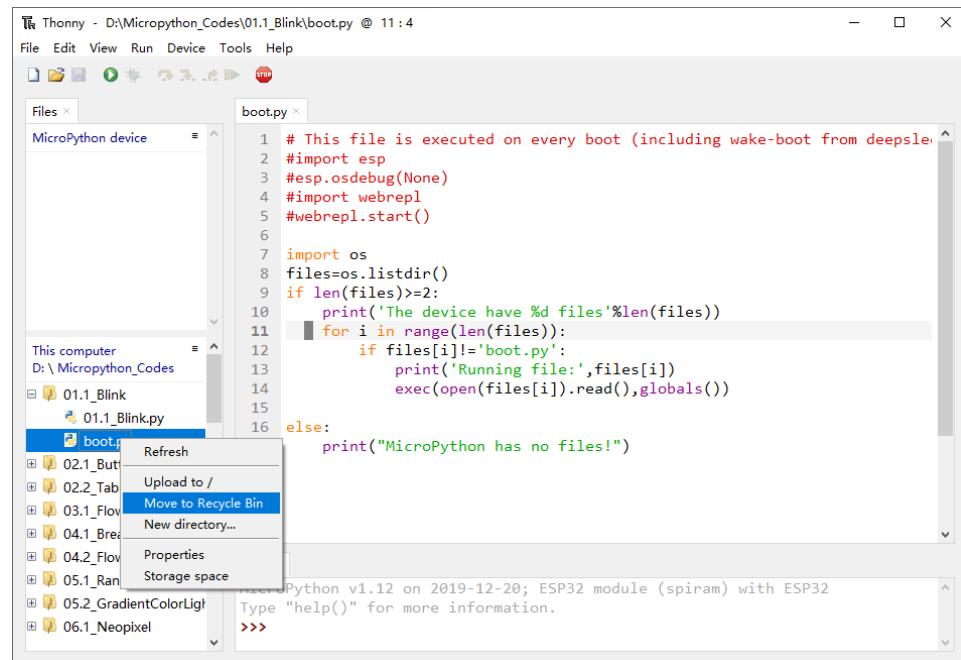
## Deleting Files from ESP32's Root Directory

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



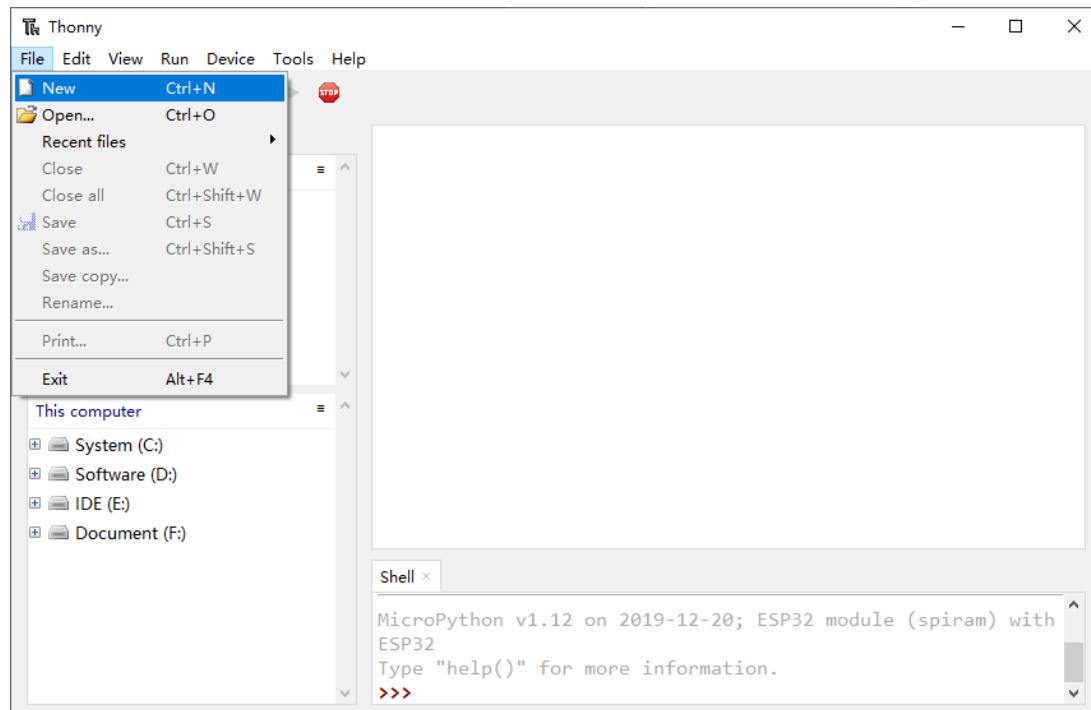
## Deleting Files from your Computer Directory

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.

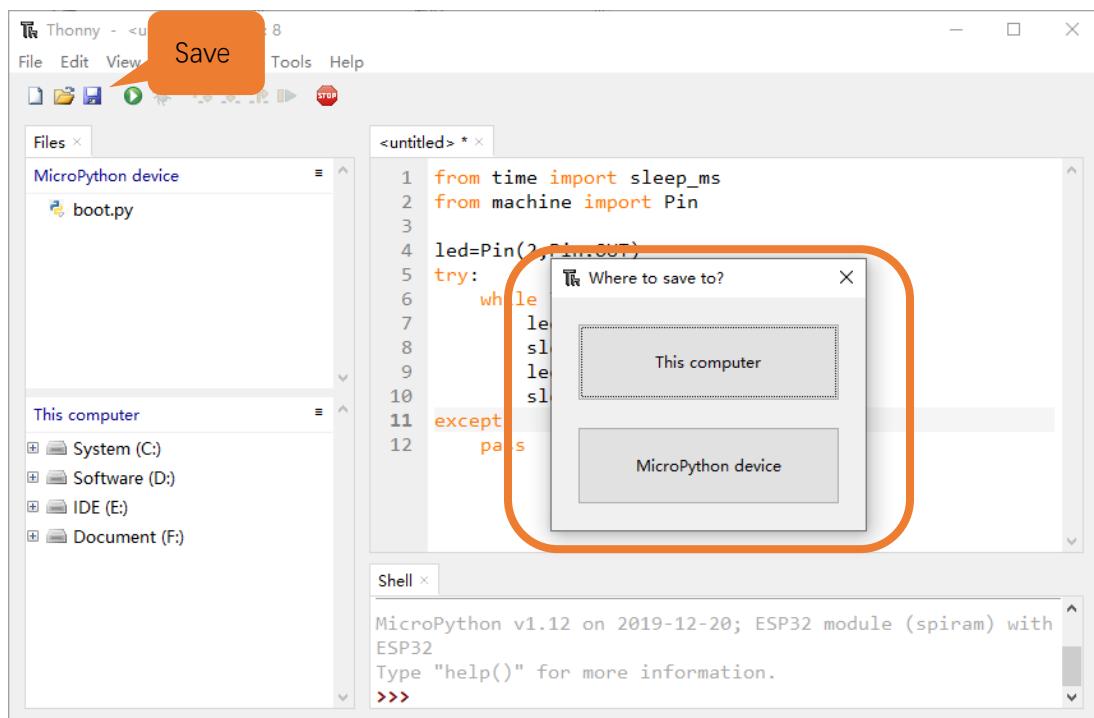


Enter codes in the newly opened file. Here we use codes of “01.1\_Blink.py” as an example.

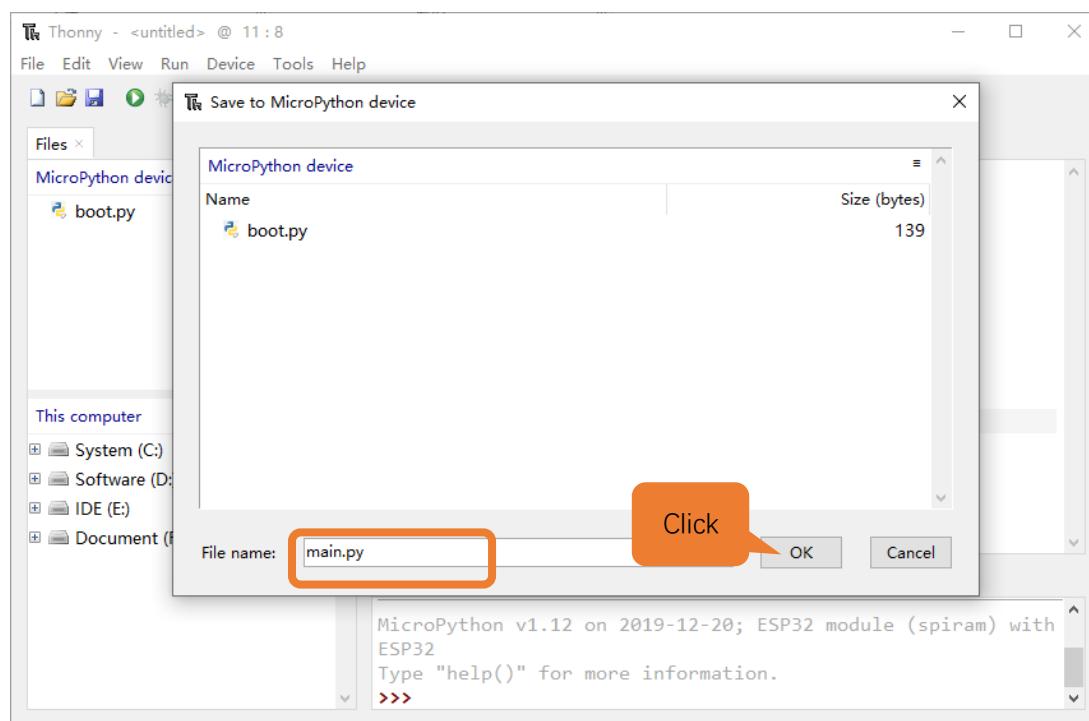
The screenshot shows the Thonny IDE interface. The menu bar includes File, Edit, View, Run, Device, Tools, and Help. The left sidebar shows a 'Files' tab with a 'MicroPython device' section containing a 'boot.py' file, and a 'This computer' section listing drives C:, D:, E:, and F:. The main code editor window titled '<untitled>' 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
```

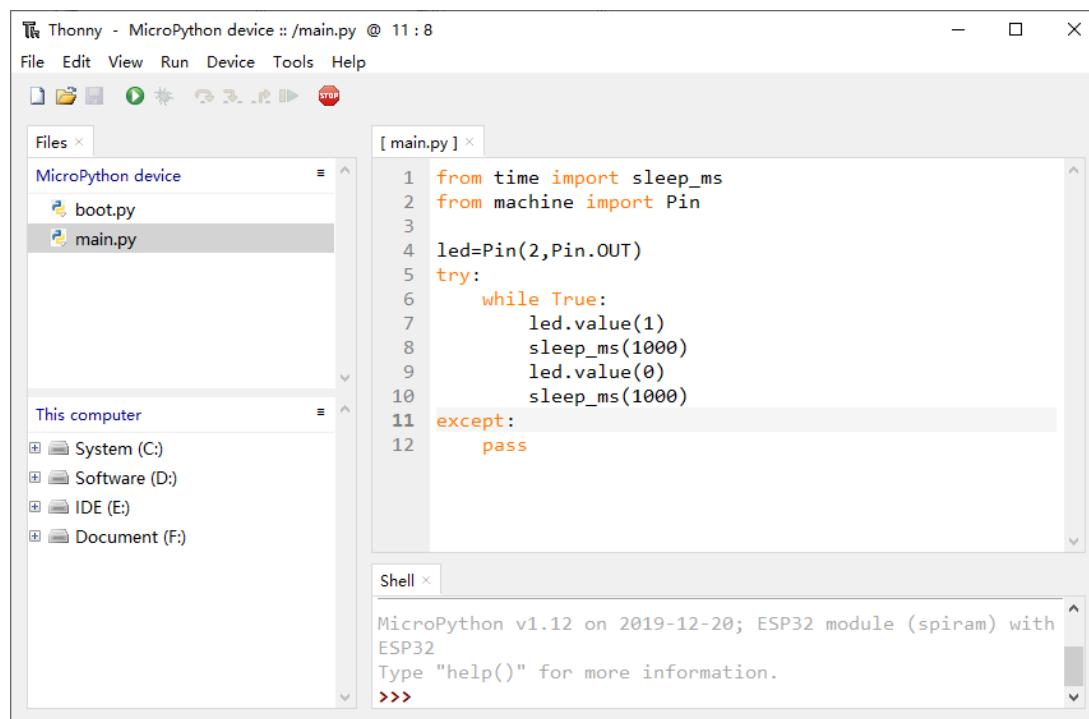
Click “Save” on the menu bar. You can save the codes either to your computer or to ESP32-WROVER.



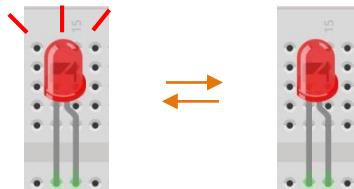
Select “MicroPython device”, enter “main.py” in the newly pop-up window and click “OK”.



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<br>Falling-edge Output | Falling-edge Sampling<br>Rising-edge Output | Rising-edge Sampling<br>Falling-edge Output | Rising-edge Sampling<br>Rising-edge Output |
| MTDO   | Pull-up   | 0  | 0   | 1   | 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.

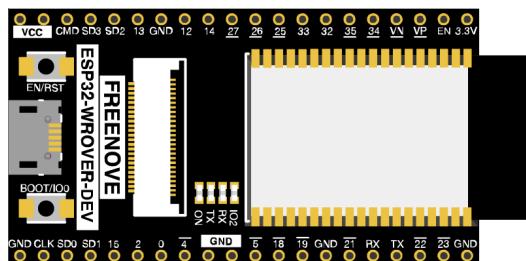
Because of external pull-up, MTDI pin is not suggested to be used as a touch sensor. For details, please refer to Peripheral Interface and Sensor chapter in "[ESP32 Data Sheet](#)".

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

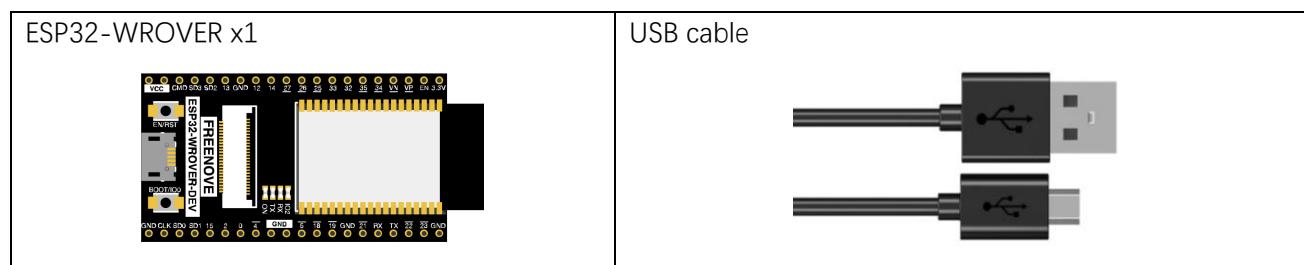
In this project, we will use ESP32 to control blinking a common LED.

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

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

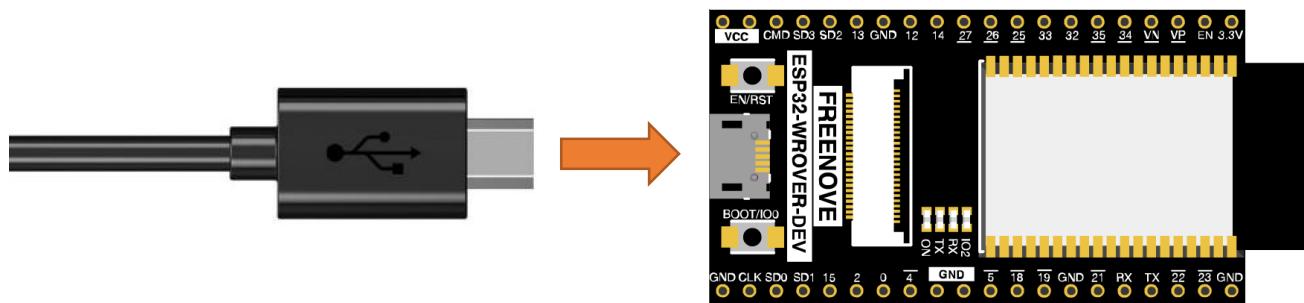
If you have not yet loaded Micropython Firmware, click [here](#).

## 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.

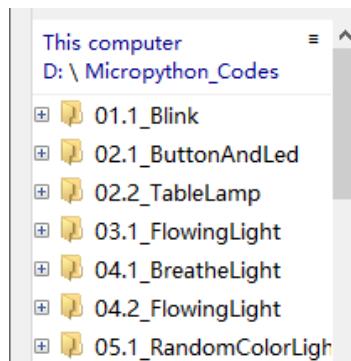
We can also use DC jack of extension board to power ESP32-WROVER. In this way, 5v and EXT 3.3v on extension board are provided by external power resource.

## Code

Codes used in this tutorial are saved in “**Freenove\_Super\_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.

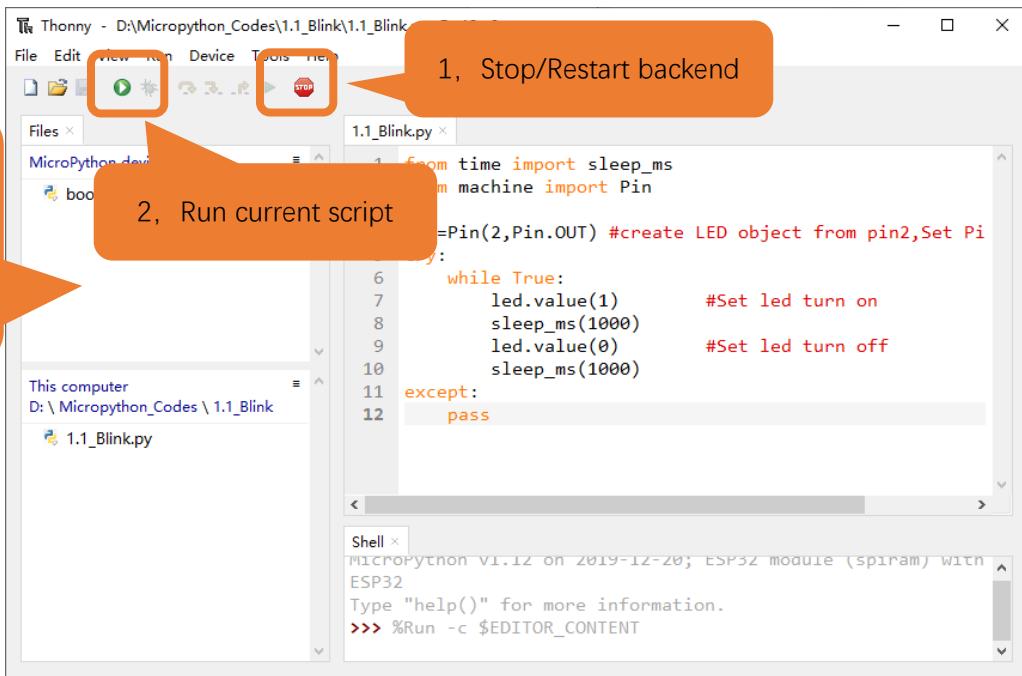
```

from time import sleep_ms
from machine import Pin

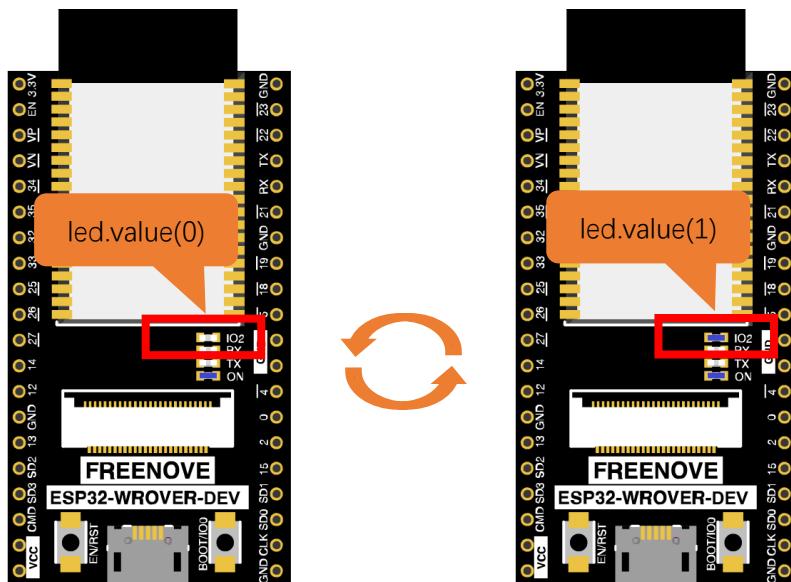
led=Pin(2,Pin.OUT) #create LED object from pin2,Set Pin2 to output
try:
    while True:
        led.value(1)      #Set led turn on
        sleep_ms(1000)
        led.value(0)      #Set led turn off
        sleep_ms(1000)
except:
    pass

```

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.



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

```

The 'Shell' pane at the bottom shows error messages related to connection issues:

```

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

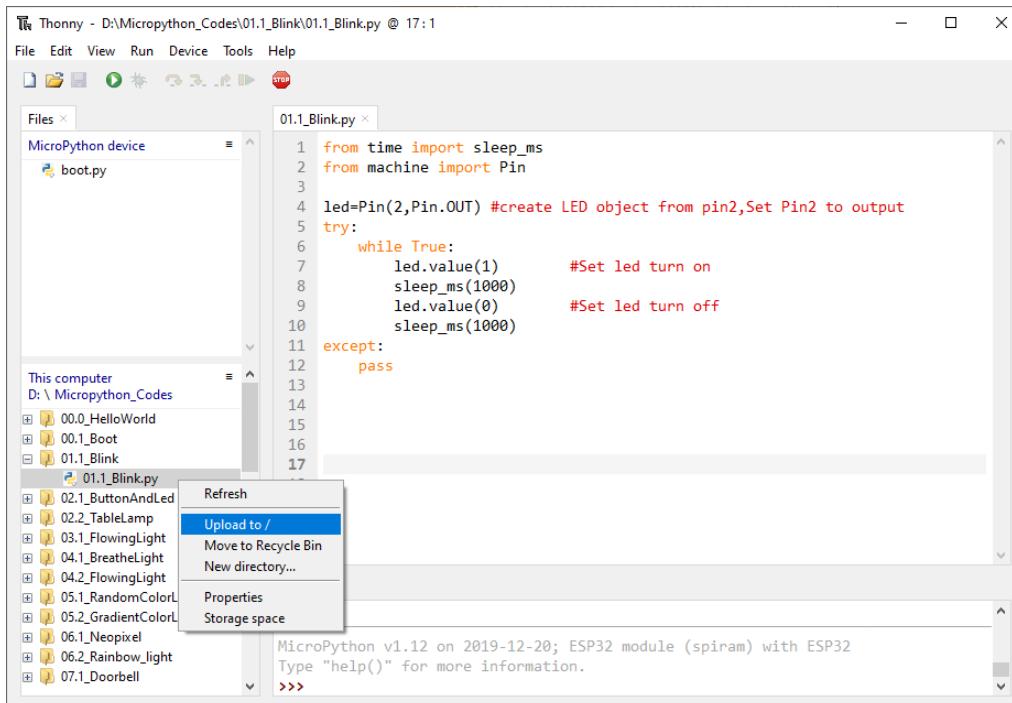
>>>
Connection lost (GetOverlappedResult failed (PermissionError(13, 'Access is denied.', None, 5)))

Use Stop/Restart to reconnect.

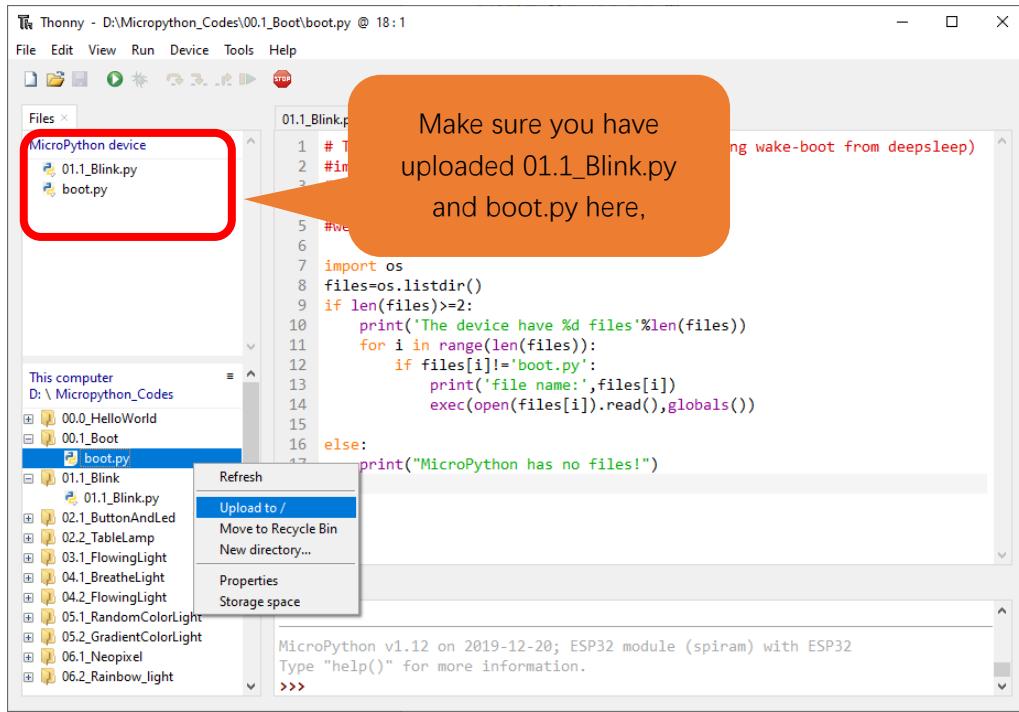
```

### Uploading code to ESP32

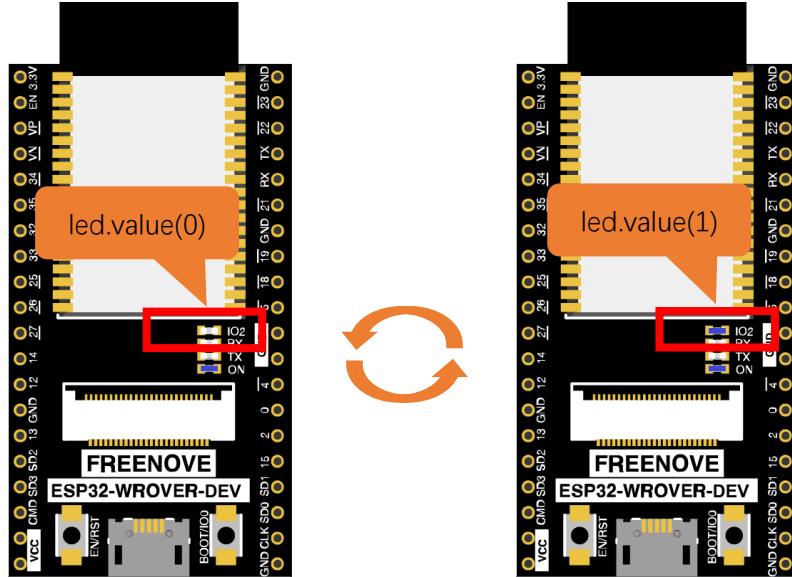
As shown in the following illustration, right-click the file 01.1\_Blink.py and select “Upload to /” to upload code to ESP32.



Upload boot.py in the same way.

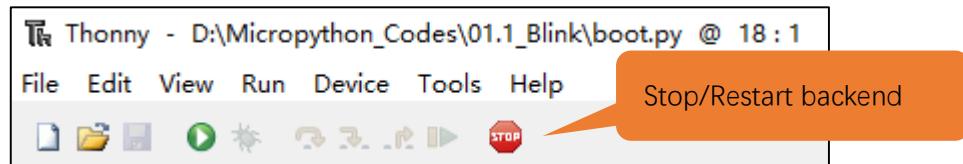


Press the reset key of ESP32 and you can see LED is ON for one second and then OFF for one second, which repeats in an endless loop.



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

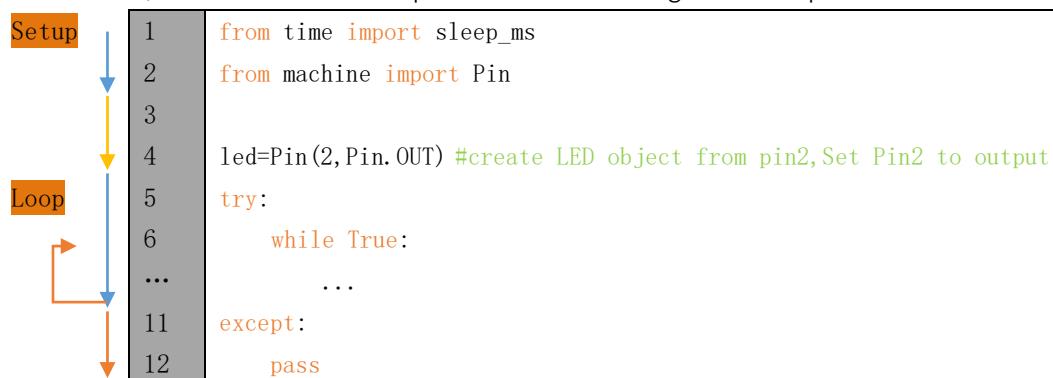
The following is the program code:

```

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().

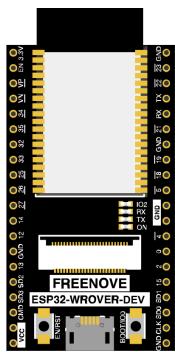
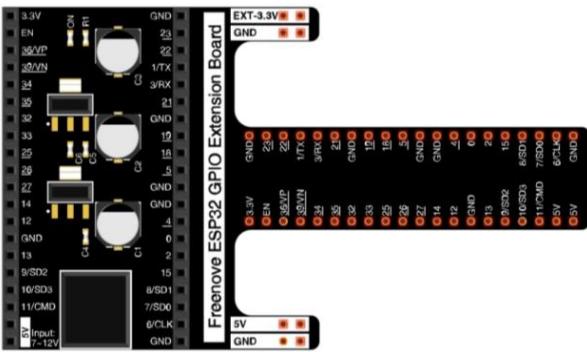
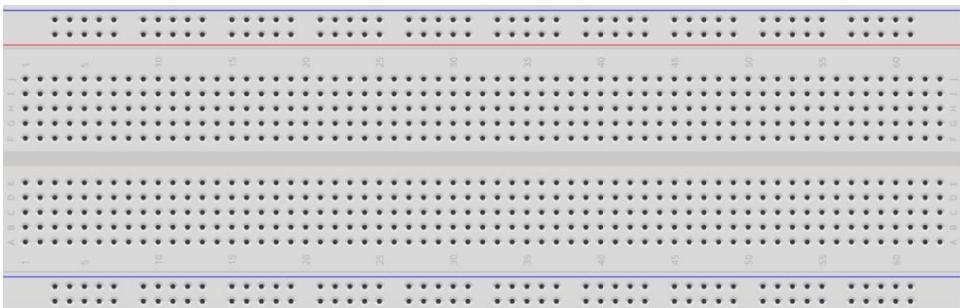
**old\_t:** Starting time

**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

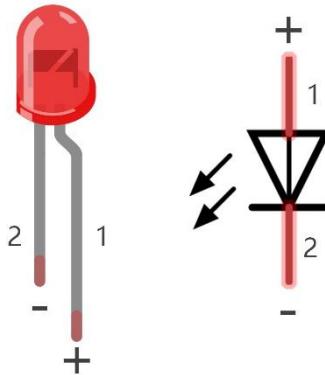
#### LED

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.



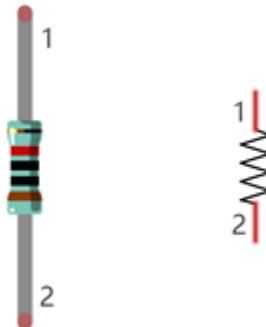
| LED  | Voltage  | Maximum current | Recommended current |
|--|----------|-----------------|---------------------|
| Red  | 1.9-2.2V | 20mA            | 10mA                |
| Green  | 2.9-3.4V | 10mA            | 5mA                 |
| Blue   | 2.9-3.4V | 10mA            | 5mA                 |
| 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).  $1M\Omega=1000k\Omega$ ,  $1k\Omega=1000\Omega$ .

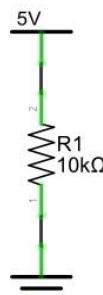
A resistor is a passive electrical component that limits or regulates the flow of current in an electronic circuit. On the left, we see a physical representation of a resistor, and the right is the symbol used to represent the presence of a resistor in a circuit diagram or schematic.



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:  $I=U/R=5V/10k\Omega=0.0005A=0.5mA$ .



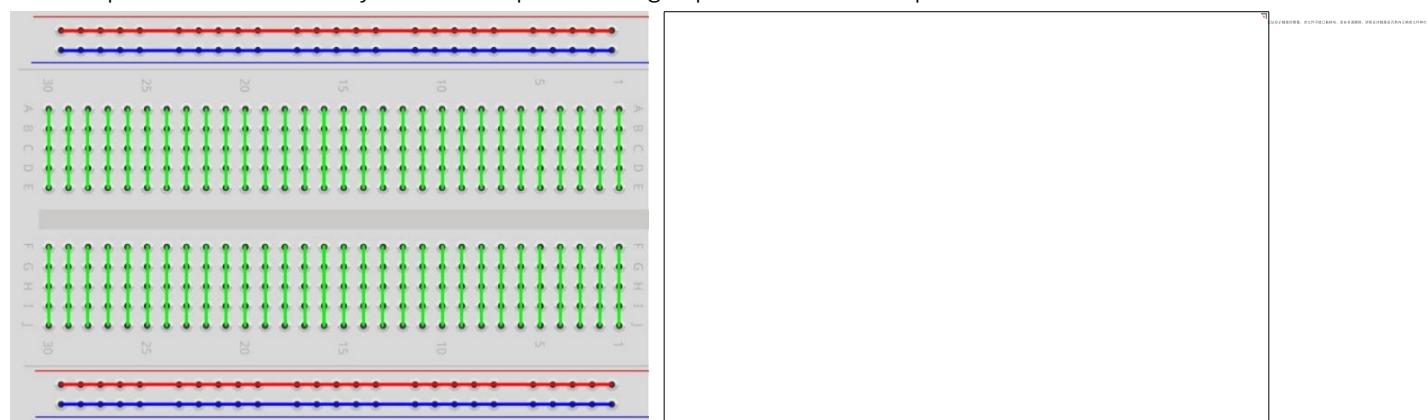
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**WARNING:** Never connect the two poles of a power supply with anything of low resistance value (i.e. a metal object or bare wire) this is a Short and results in high current that may damage the power supply and electronic components.

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)

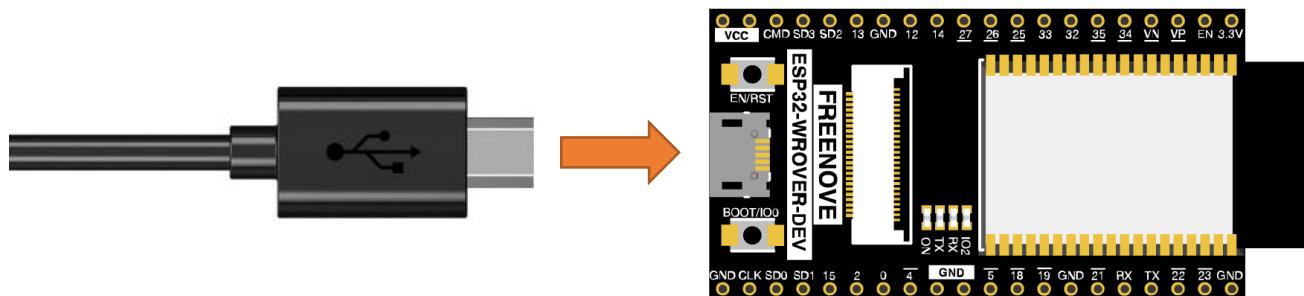
## Breadboard

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.

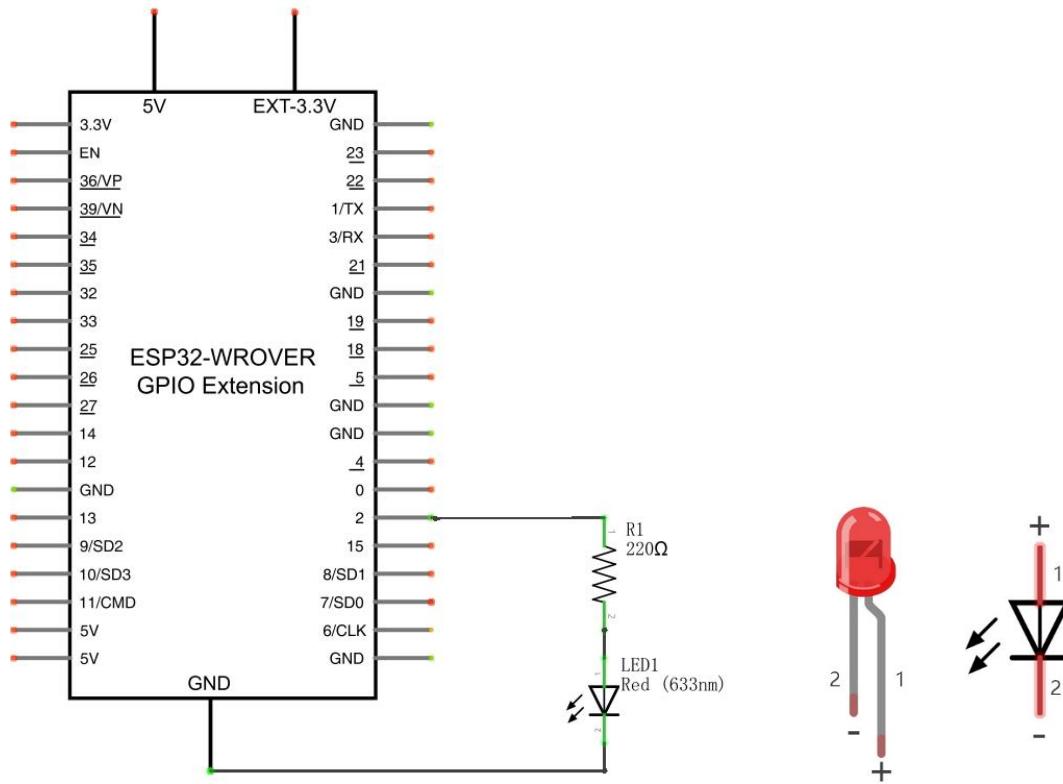
We can also use DC jack of extension board to power ESP32-WROVER. Then 5v and EXT 3.3v on extension board are from external power resource.

## Circuit

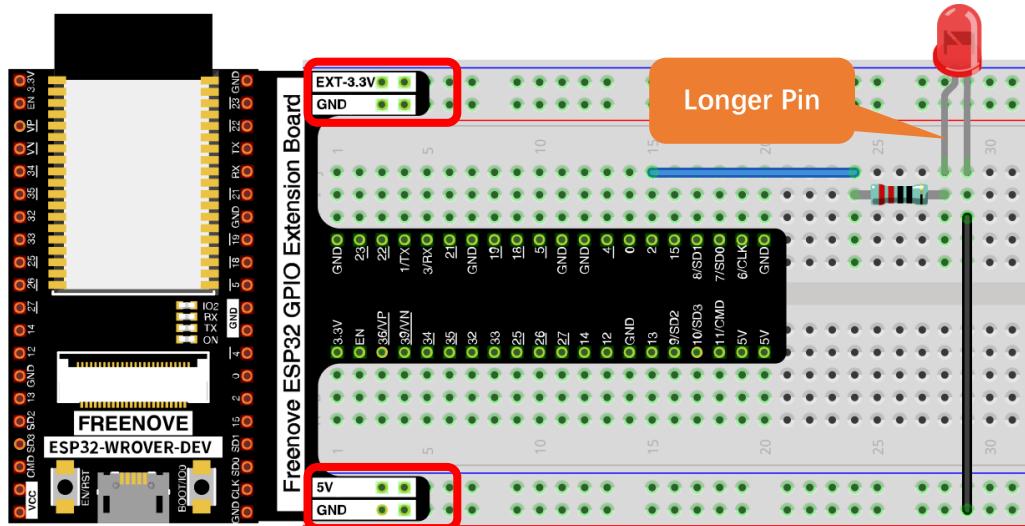
First, disconnect all power from the ESP32-WROVER. Then build the circuit according to the circuit and hardware diagrams. After the circuit is built and verified correct, connect the PC to ESP32-WROVER.

**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**



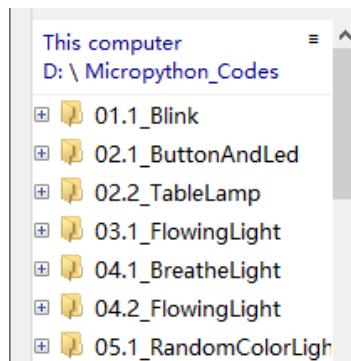
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## Code

Codes used in this tutorial are saved in “**Freenove\_Super\_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

```

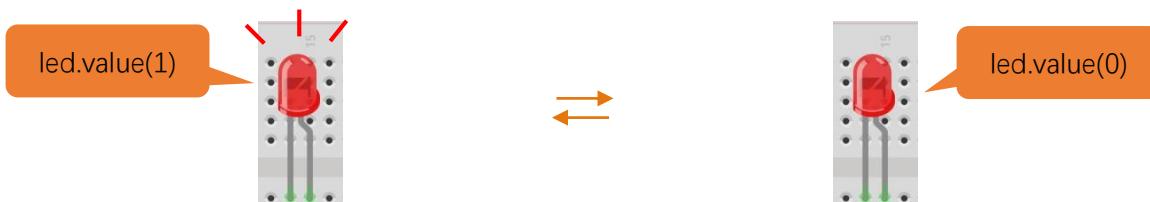
Make sure ESP32 has been connected with the computer with ESP32 correctly. Click “Stop/Restart backend” or press the reset button, and then wait to see what interface will show up.

```

1 from time import sleep_ms
2 import machine
3 led=Pin(2,Pin.OUT) #create LED object from pin2,Set Pin 2 as output
4
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

```

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 title bar indicates "Thonny - D:\Micropython\_Codes\01.1\_Blink\01.1\_Blink.py @ 18:1". The left sidebar lists files under "This computer" and "D:\Micropython\_Codes", including various examples like 00.0\_HelloWorld, 00.1\_Boot, and 01.1\_Blink. The main code editor window displays the following Python script:

```

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 bottom shell window shows error messages related to connection issues:

```

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

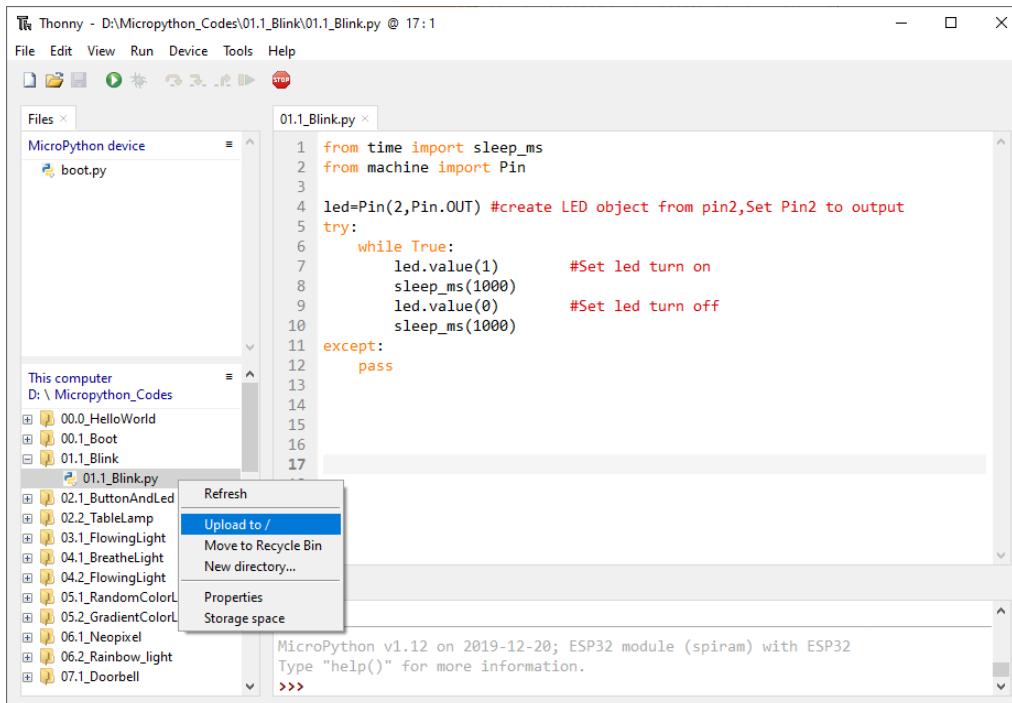
>>>
Connection lost (GetOverlappedResult failed (PermissionError(13, 'Access is denied.', None, 5)))

Use Stop/Restart to reconnect.

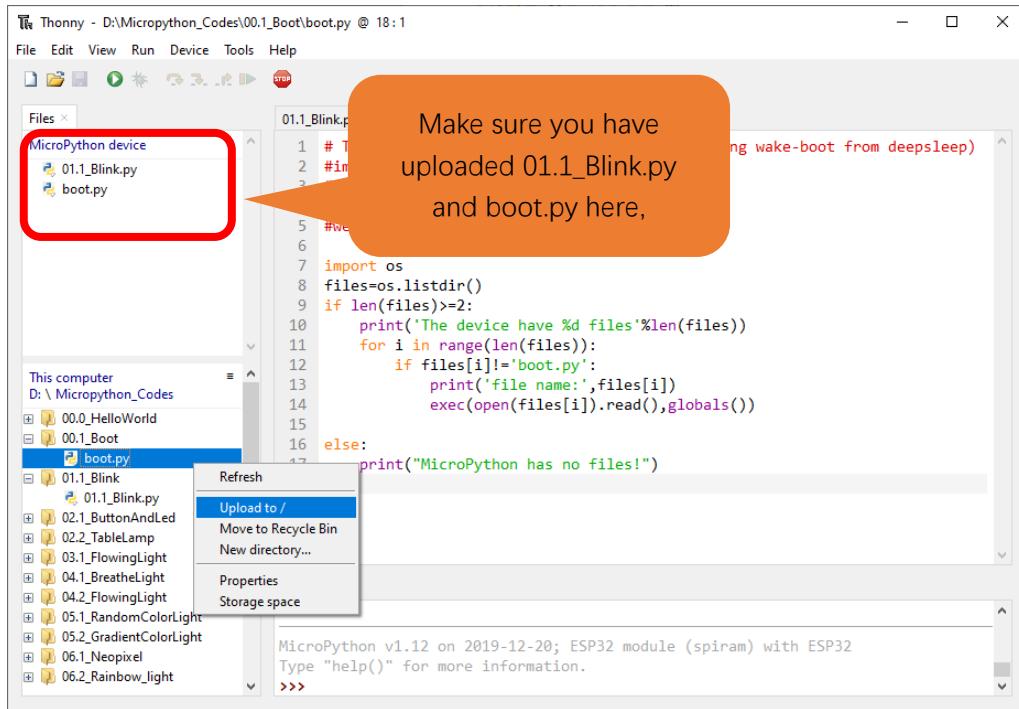
```

### Uploading code to ESP32

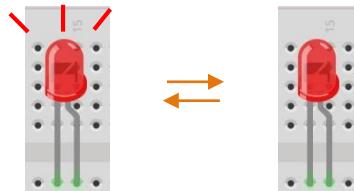
As shown in the following illustration, right-click the file 01.1\_Blink.py and select “Upload to /” to upload code to ESP32.



Upload boot.py in the same way.

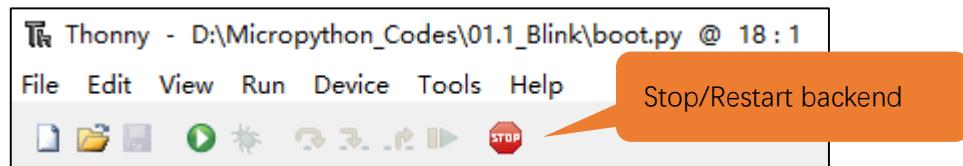


Press the reset key of ESP32 and you can see LED is ON for one second and then OFF for one second, which repeats in an endless loop.



Note:

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

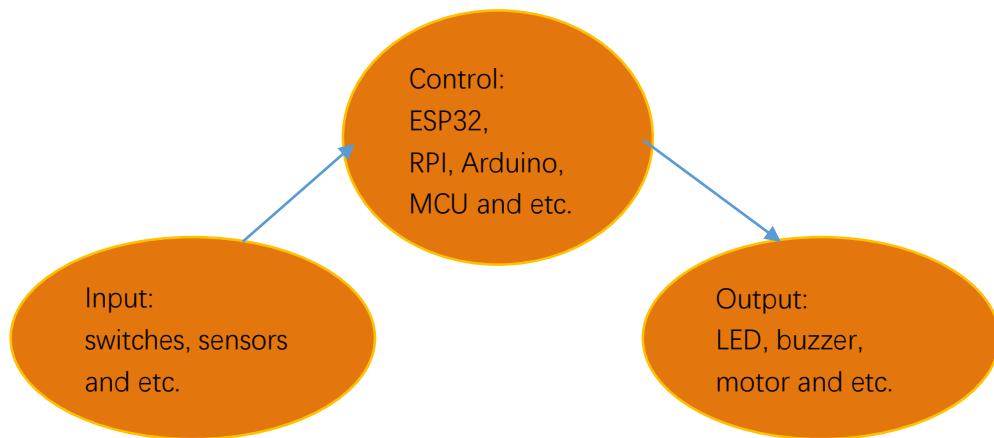


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# Chapter 2 Button & LED

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.

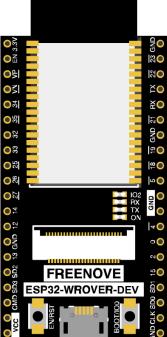
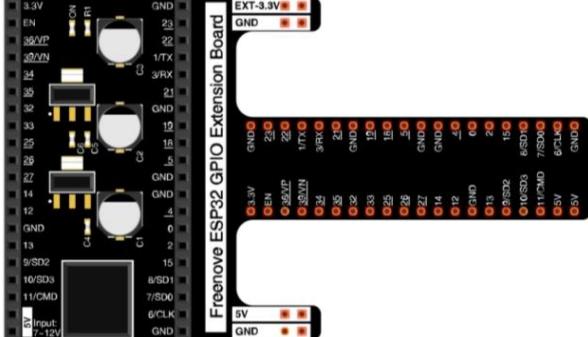
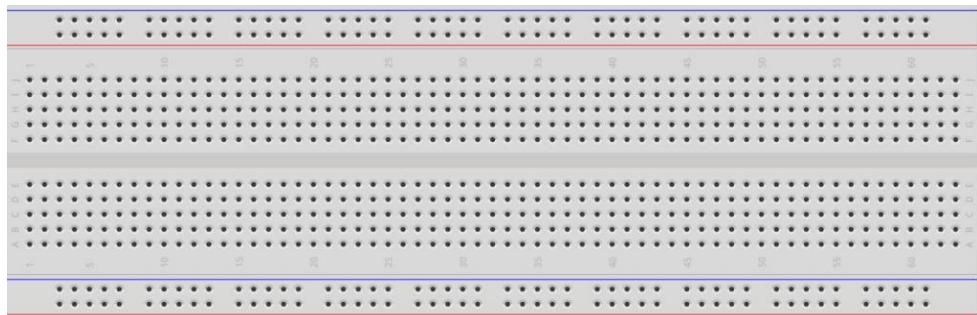


Next, we will build a simple control system to control an LED through a push button switch.

## 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.

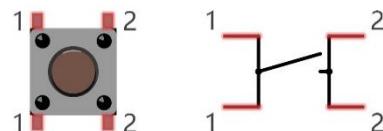
## Component List

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

## Component knowledge

### Push button

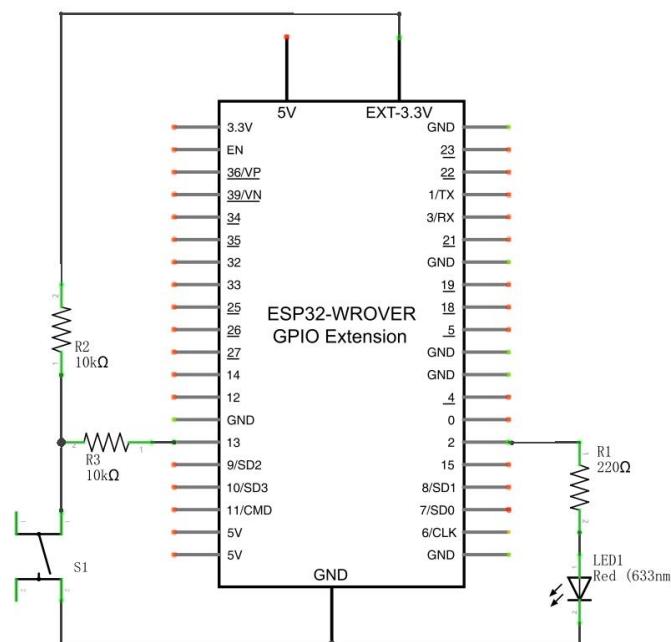
This type of Push Button Switch has 4 pins (2 Pole Switch). Two pins on the left are connected, and both left and right sides are the same per the illustration:



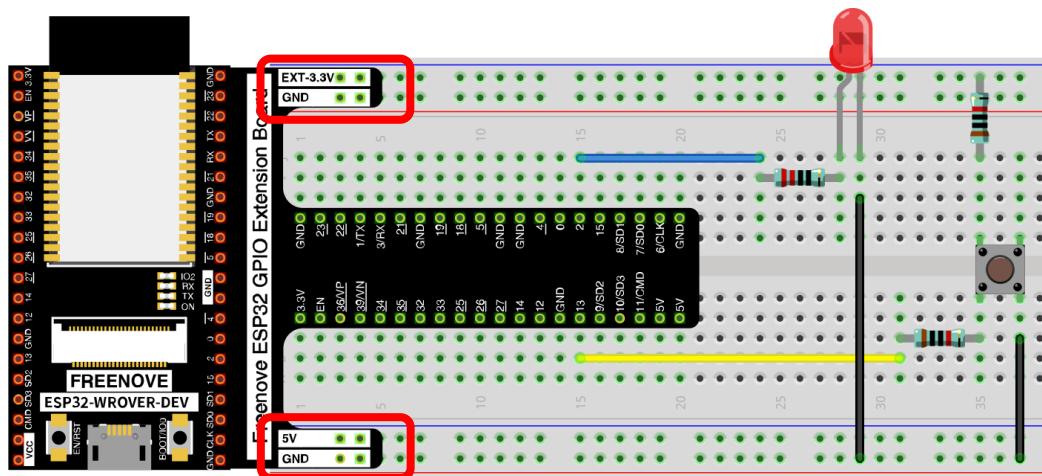
When the button on the switch is pressed, the circuit is completed (your project is Powered ON).

## 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)

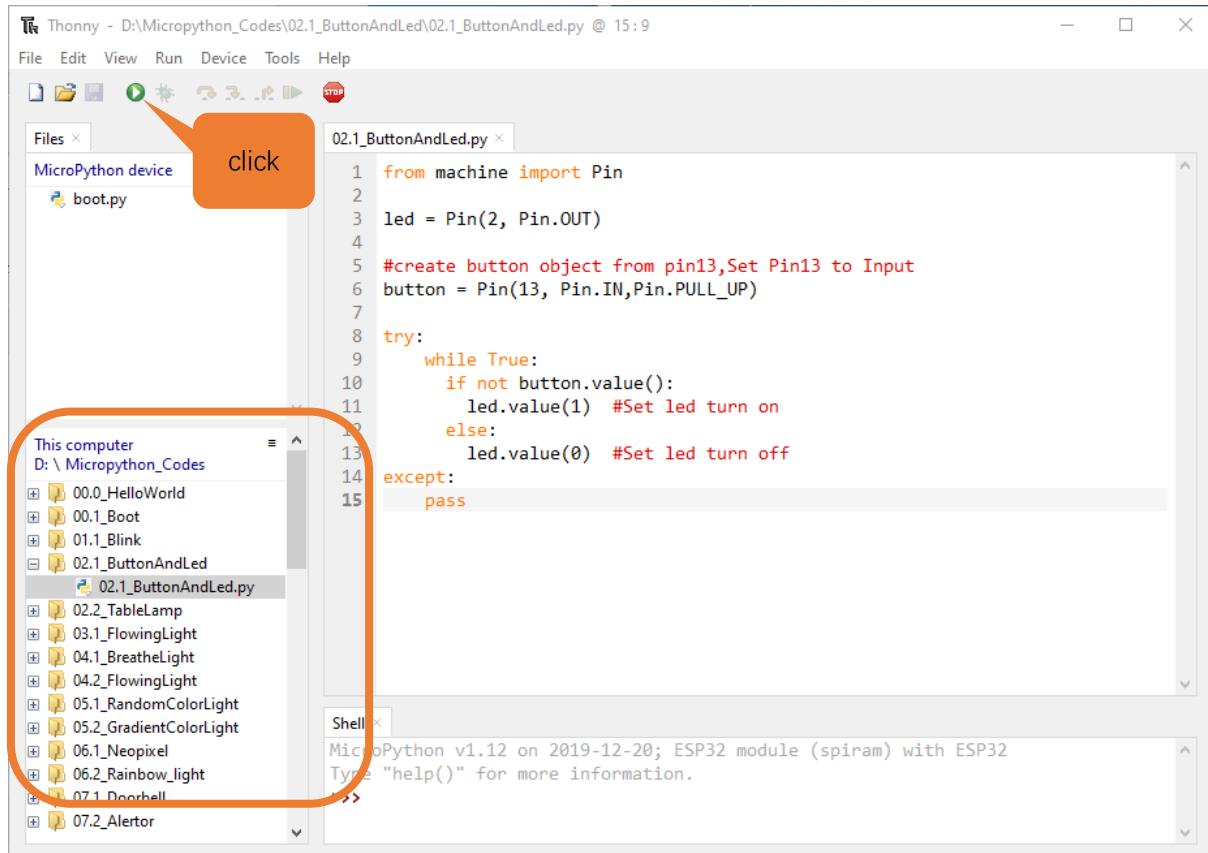
## Code

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\_Super\_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”.

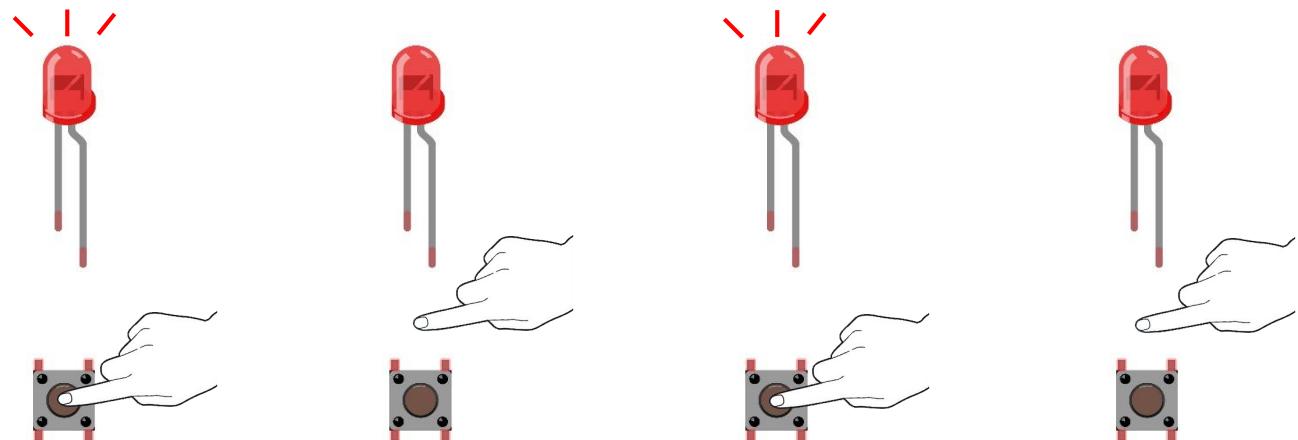
### 02.1\_ButtonAndLed



```

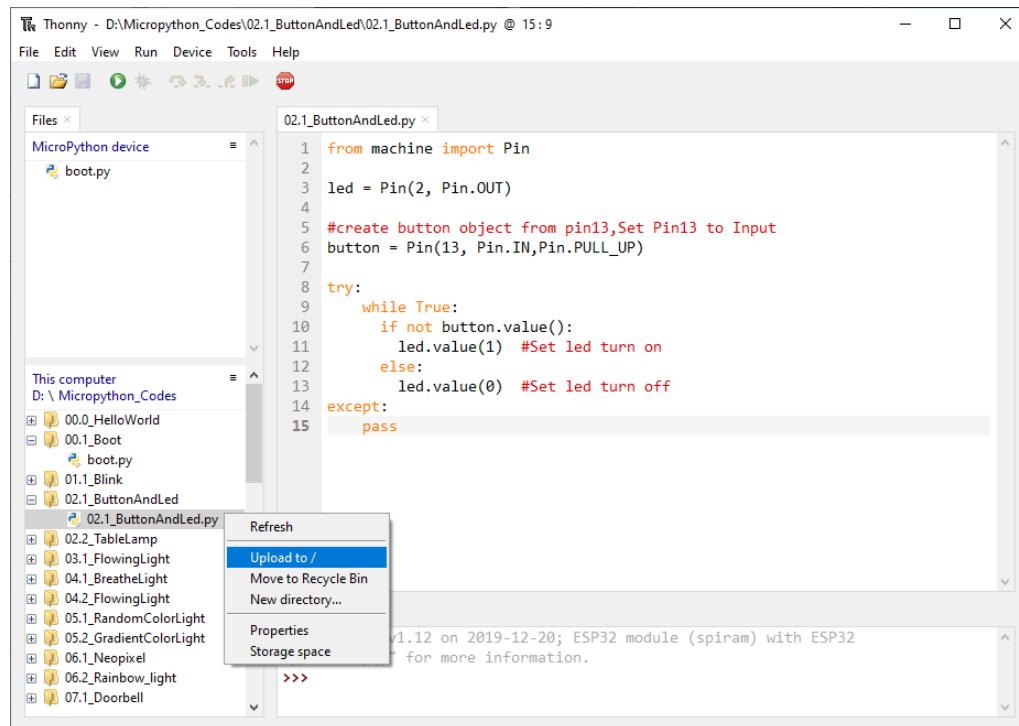
1 from machine import Pin
2
3 led = Pin(2, Pin.OUT)
4
5 #create button object from pin13,Set Pin13 to Input
6 button = Pin(13, Pin.IN,Pin.PULL_UP)
7
8 try:
9     while True:
10         if not button.value():
11             led.value(1) #Set led turn on
12         else:
13             led.value(0) #Set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

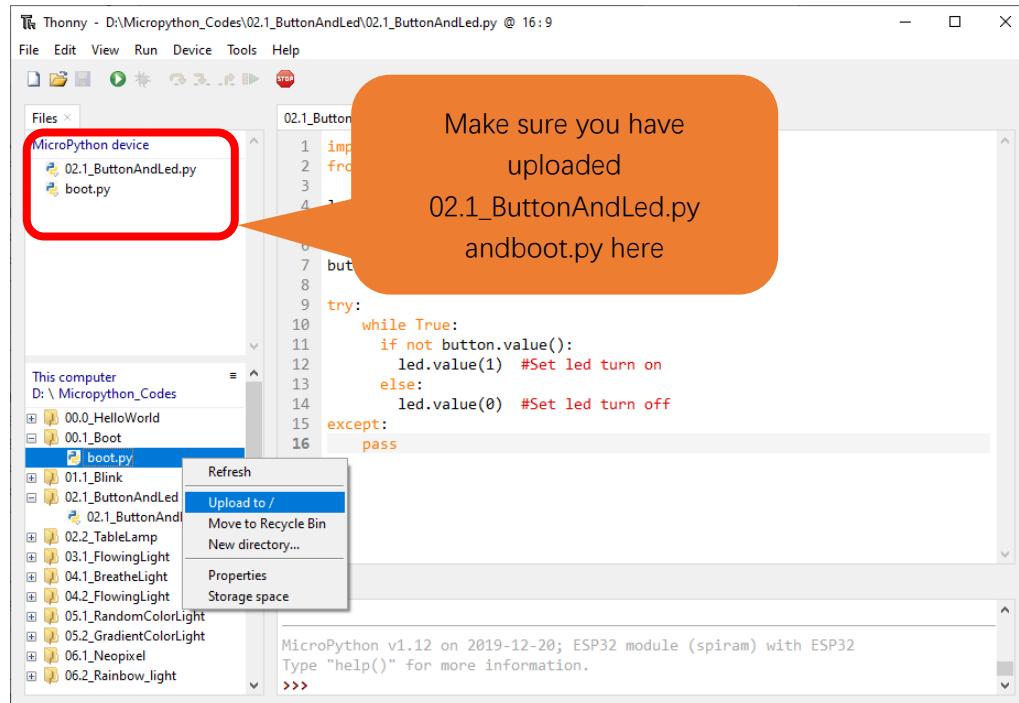


## Upload Code to ESP32

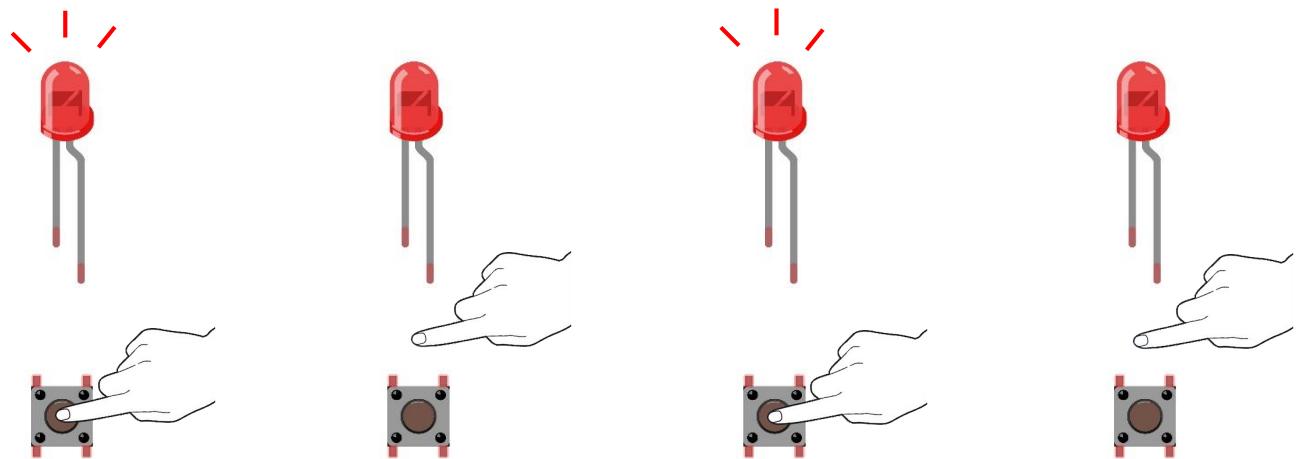
As shown in the following illustration, right-click file 02.1\_ButtonAndLed and select “Upload to /” to upload code to ESP32.



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      ...
```

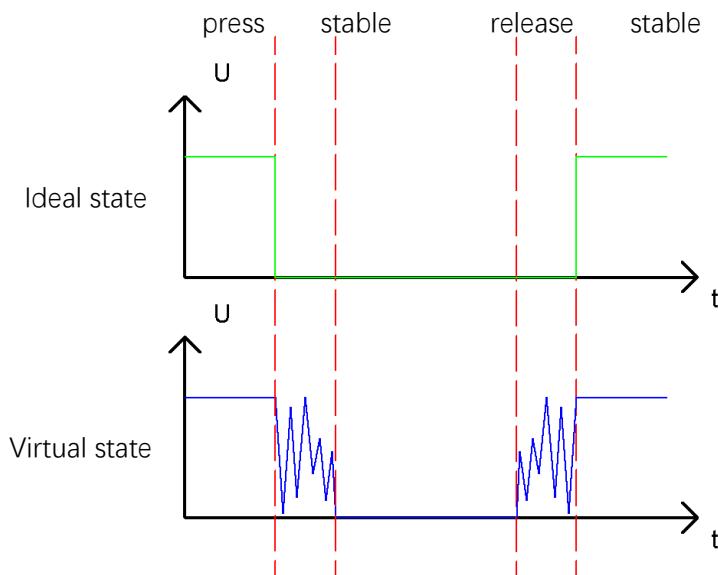
## Project 2.2 MINI table lamp

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).

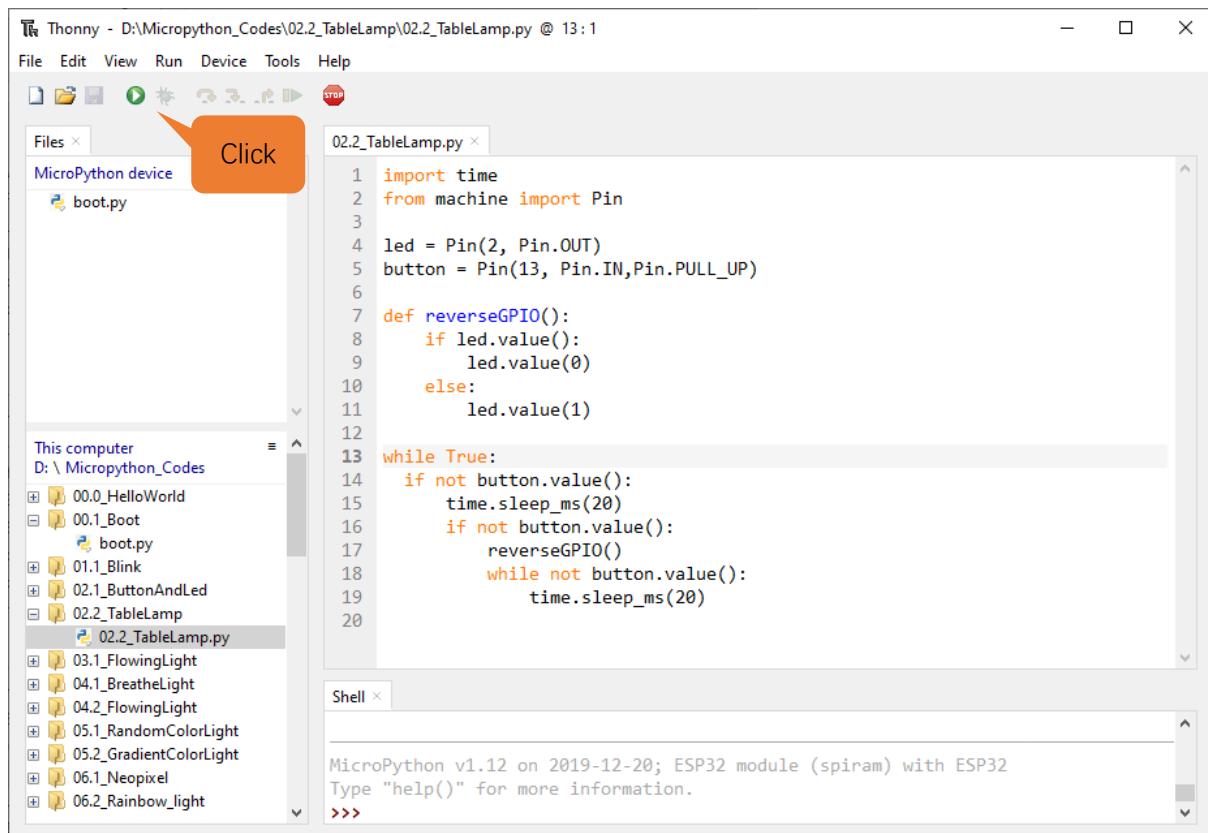
This project needs the same components and circuits as we used in the previous section.

## Code

### 02.2\_Tablelamp

Move the program folder “Freenove\_Super\_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”.



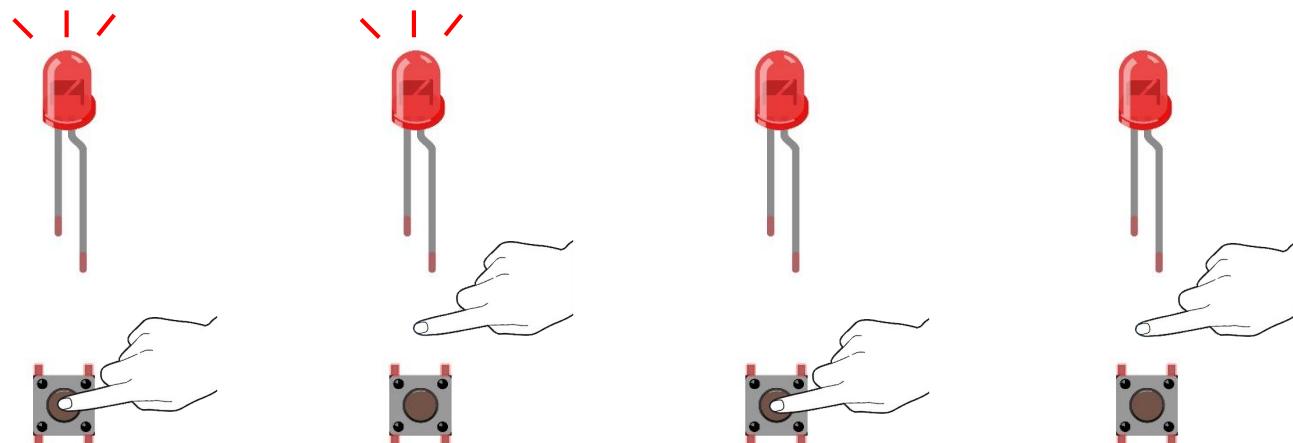
```

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.

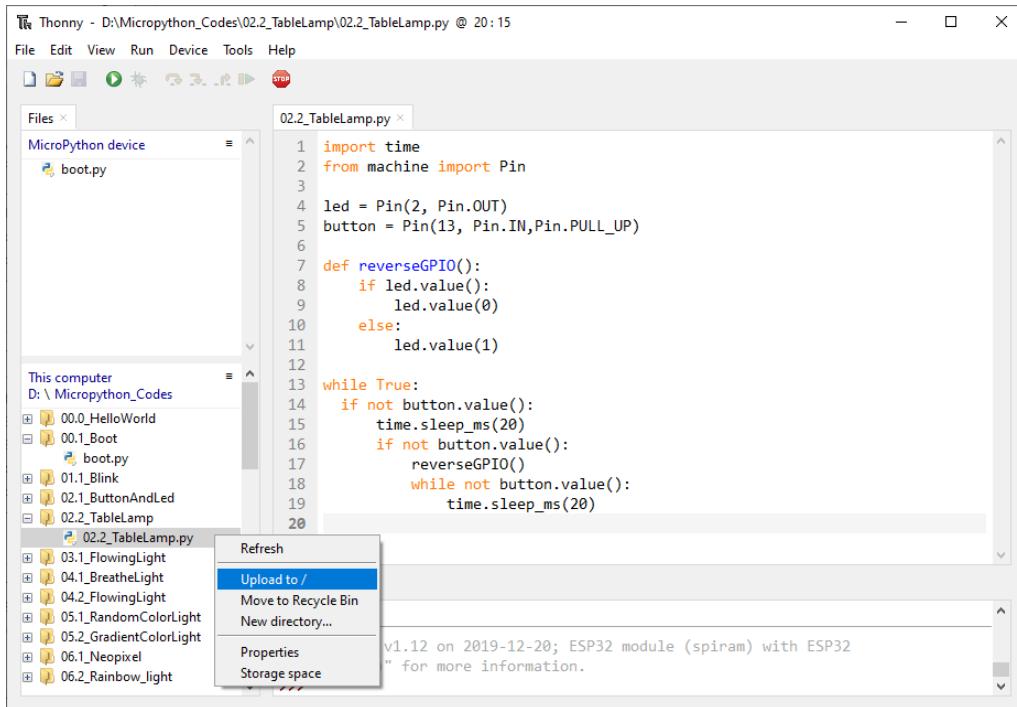


If you have any concerns, please contact us via: [support@freenove.com](mailto:support@freenove.com)

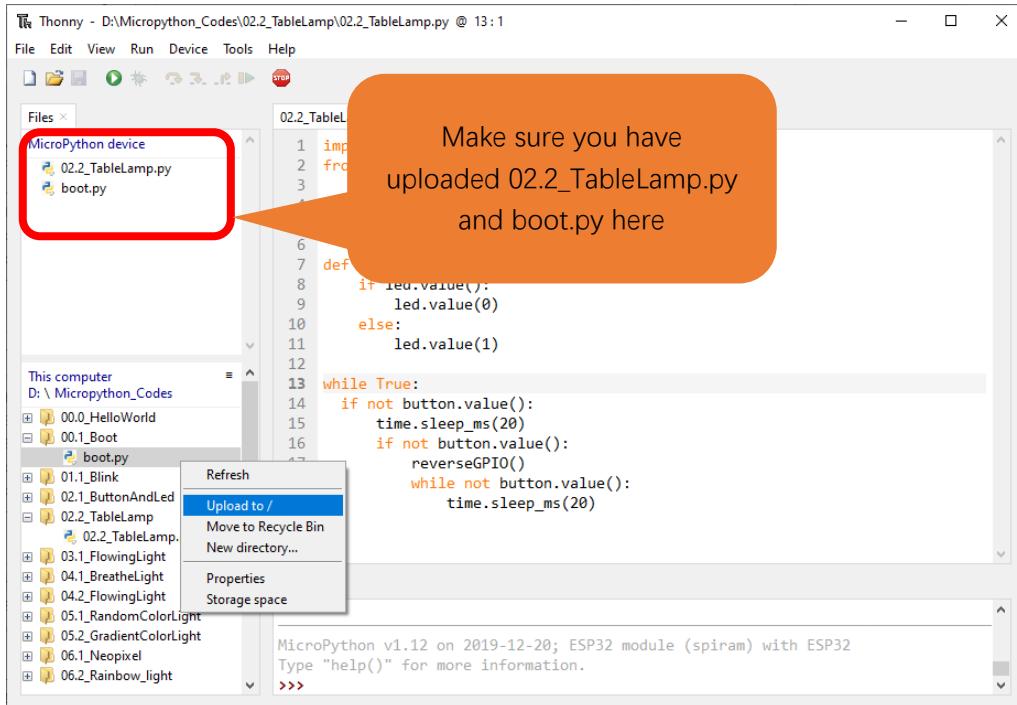
Any concerns? ✉ [support@freenove.com](mailto:support@freenove.com)

### Upload code to ESP32

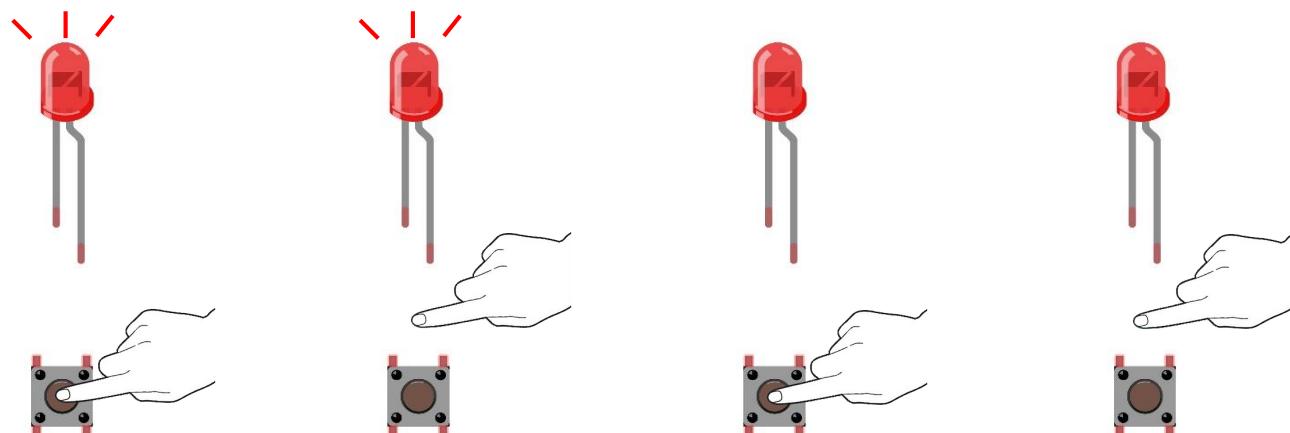
As shown in the following illustration, right-click file 02.2\_TableLamp and select “Upload to /” to upload code to ESP32.



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)
```

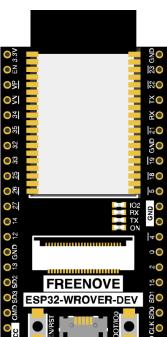
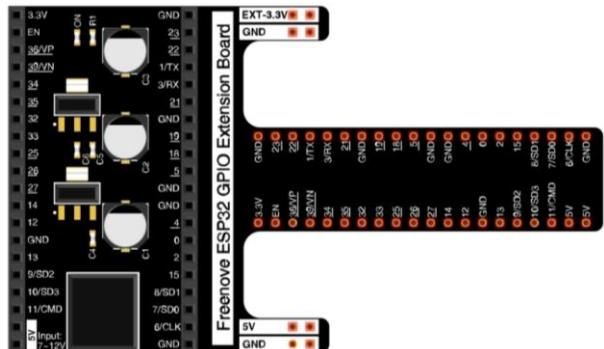
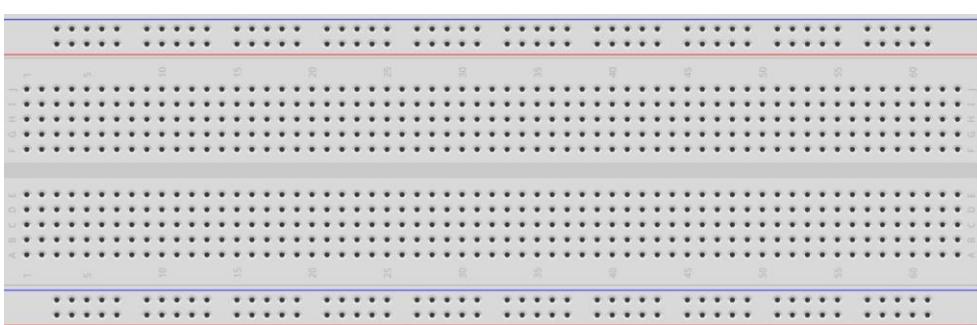
# Chapter 3 LED Bar

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   |
|   |  |

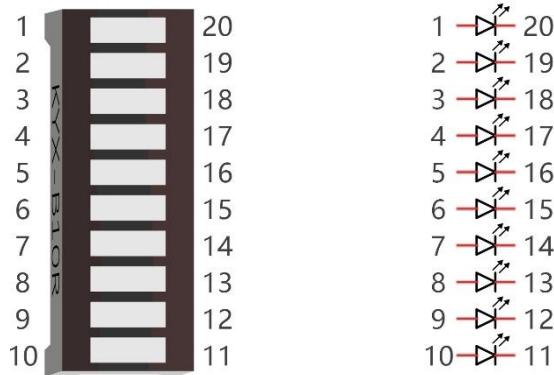


## Component knowledge

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

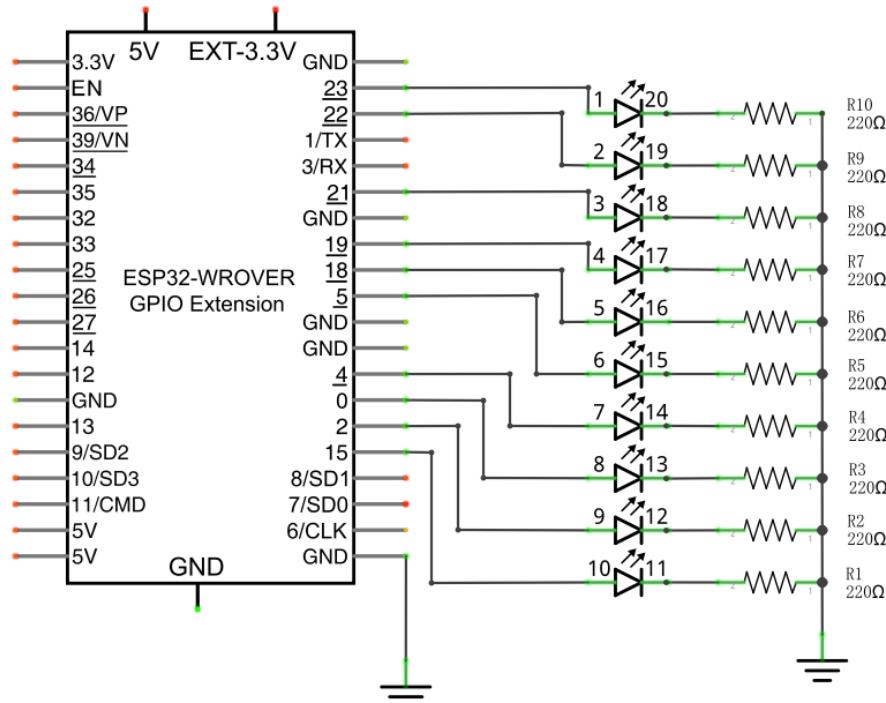
### LED bar

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.

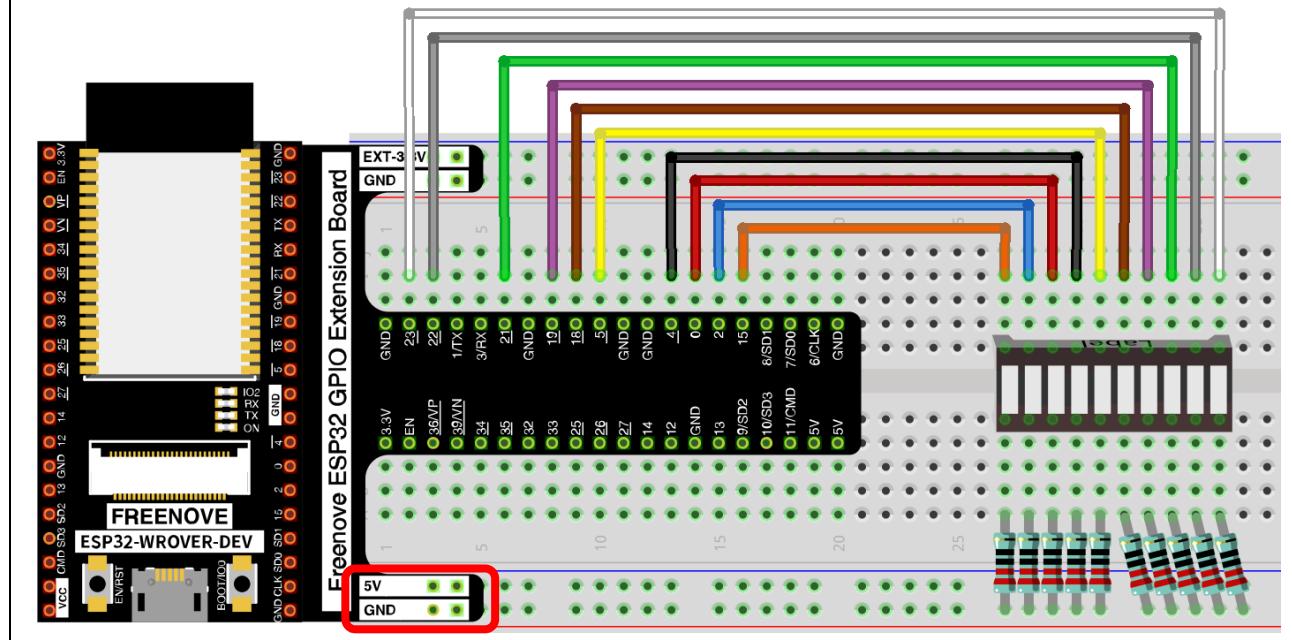


# Circuit

## 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 turned OFF. This process is repeated to achieve the “movements” of flowing water.

## 03.1\_FlowingLight

Move the program folder “**Freenove\_Super\_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”.

The screenshot shows the Thonny IDE interface. The title bar reads "Thonny - D:\Micropython\_Codes\03.1\_FlowingLight\03.1\_FlowingLight.py @ 21:1". The menu bar includes File, Edit, View, Run, Device, Tools, and Help. The toolbar has icons for file operations and a green play button. A red callout bubble points to the play button with the text "click". The left sidebar shows a file tree under "This computer" with several projects and their files, including "03.1\_FlowingLight.py" which is selected. The main code editor window displays the following Python script:

```
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()
21
```

The bottom shell window shows the MicroPython version and a prompt: "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

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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

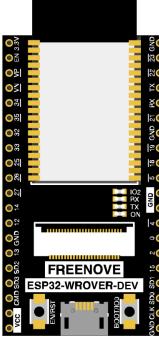
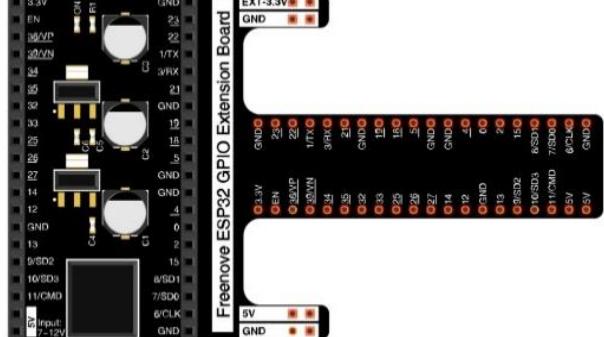
In previous study, we have known that one button has two states: pressed and released, and LED has light-on/off state, then how to enter a middle state? How to output an intermediate state to let LED "semi bright"? That's what we're going to learn.

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.

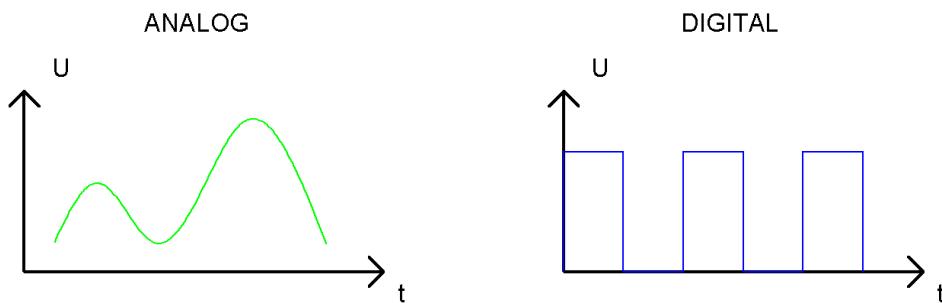
### Component List

|  |                         |               |
|--|-------------------------|---------------|
| 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.



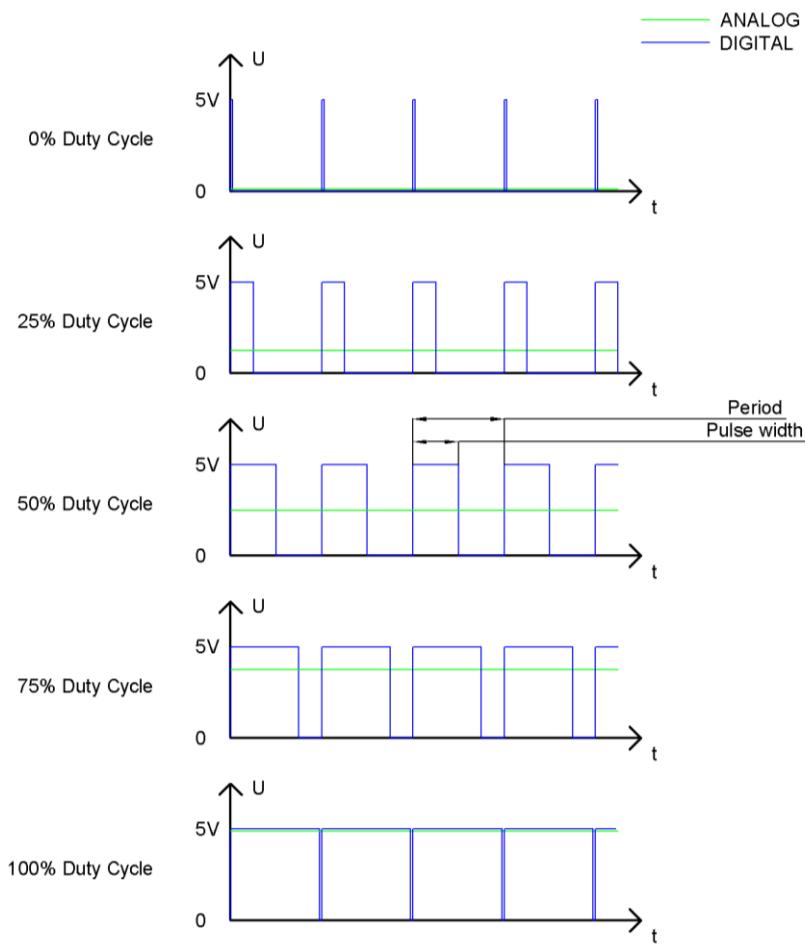
In practical application, we often use binary as the digital signal, that is a series of 0's and 1's. Since a binary signal only has two values (0 or 1), it has great stability and reliability. Lastly, both analog and digital signals can be converted into the other.

### 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.

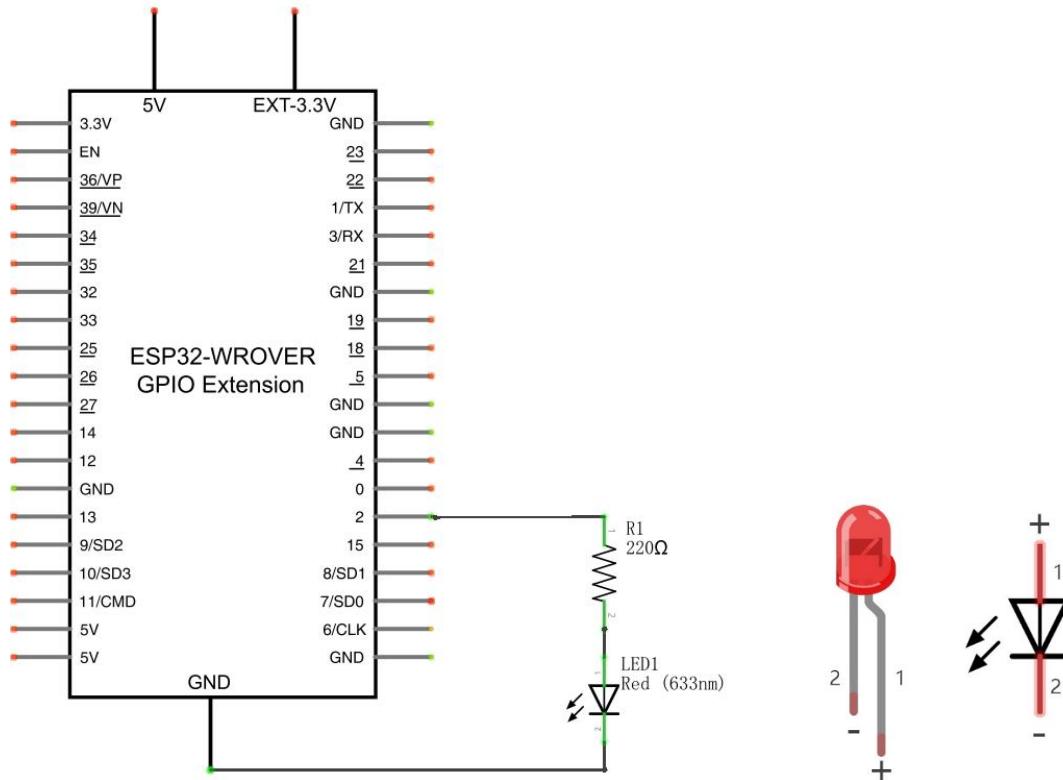
### ESP32 and PWM

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.

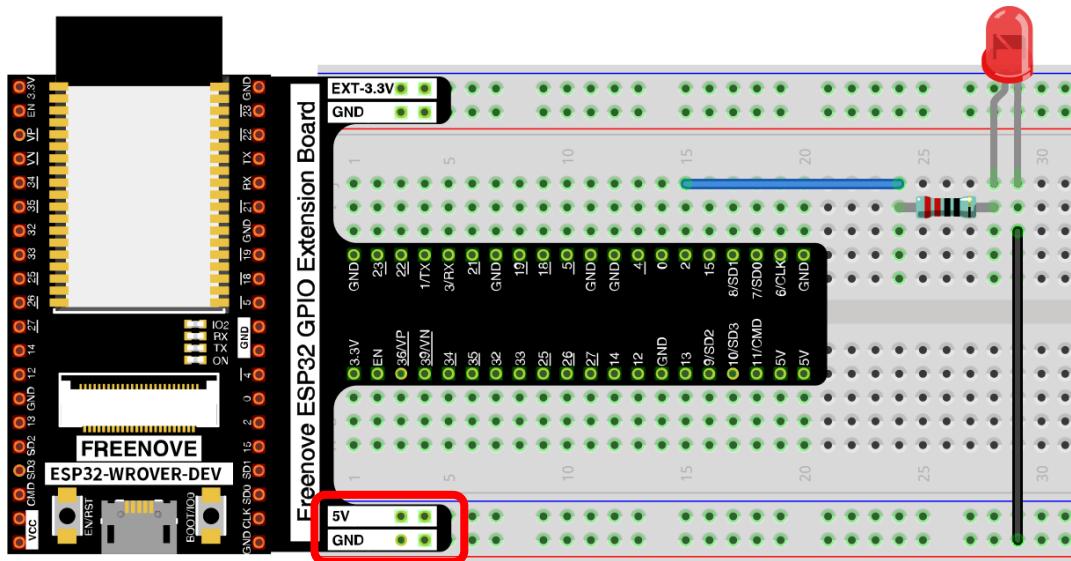
## Circuit

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

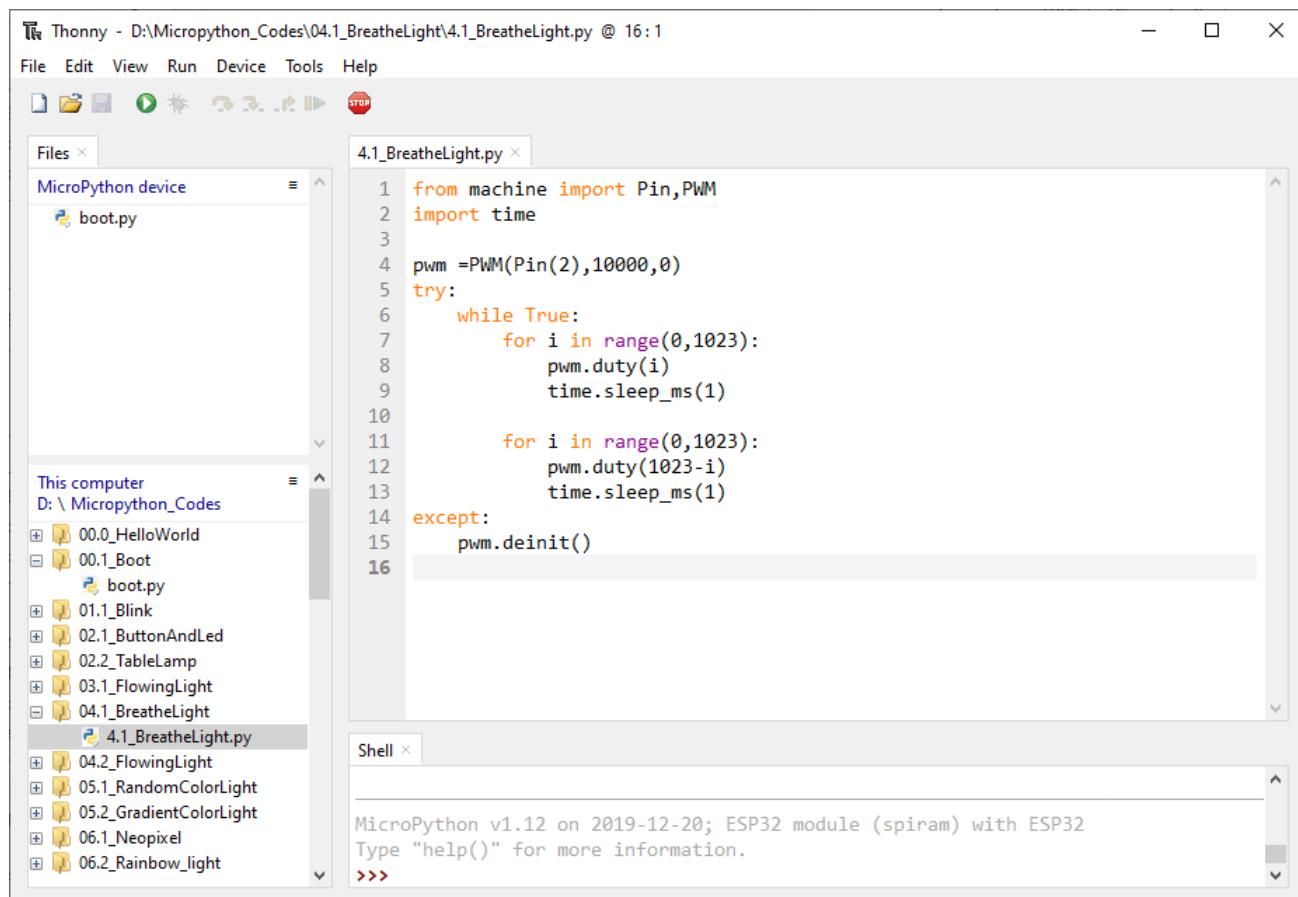
## Code

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\_Super\_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



```

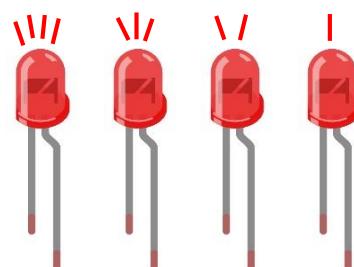
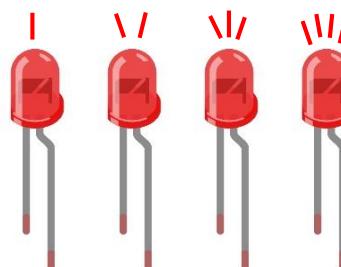
from machine import Pin,PWM
import time

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.

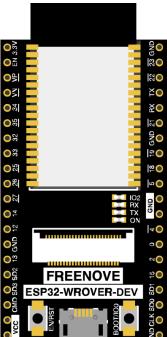
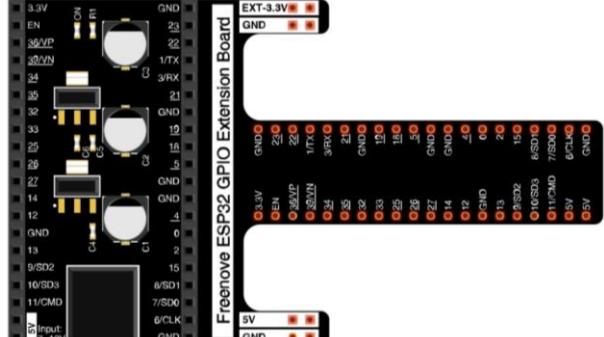
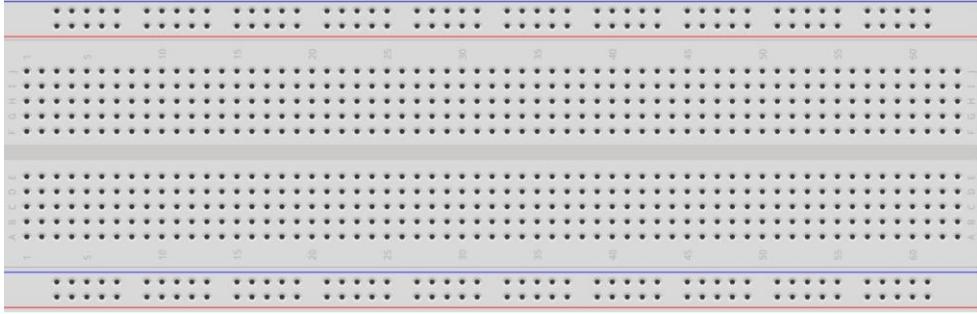
**PWM.duty([duty\_val])**: When there is no parameter, the function obtains and returns PWM duty cycle; When parameters are set, the function is used to set PWM duty cycle.

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

## Project 4.2 Meteor Flowing Light

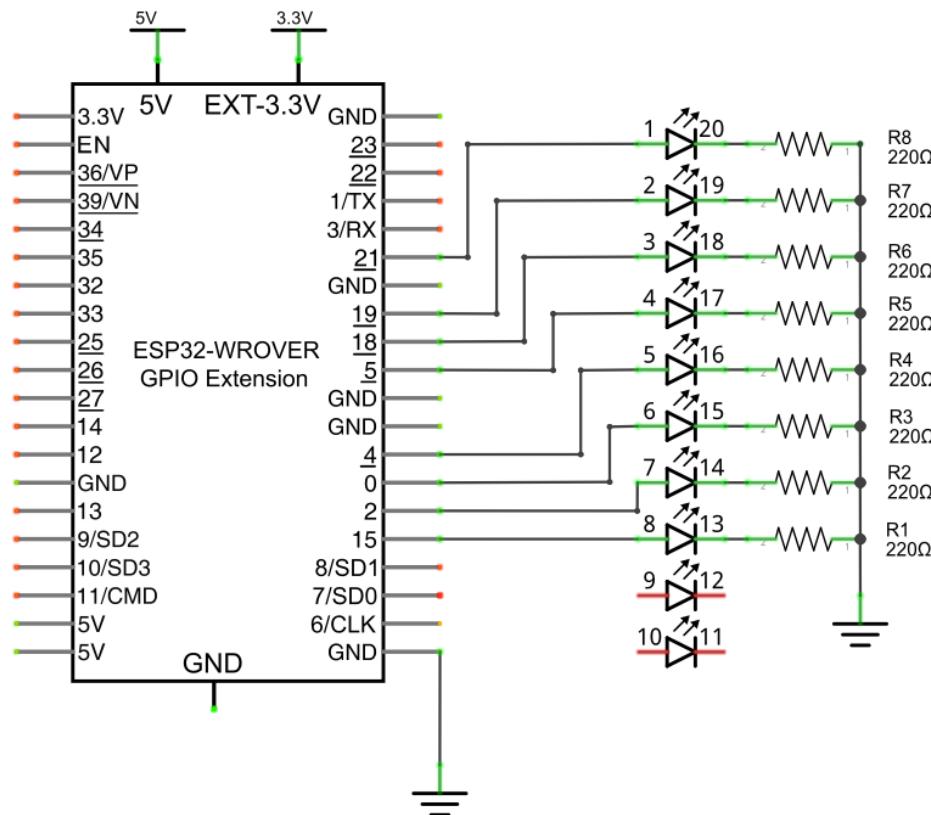
After learning about PWM, we can use it to control LED Bar Graph and realize a cooler Flowing Light.

### Component List

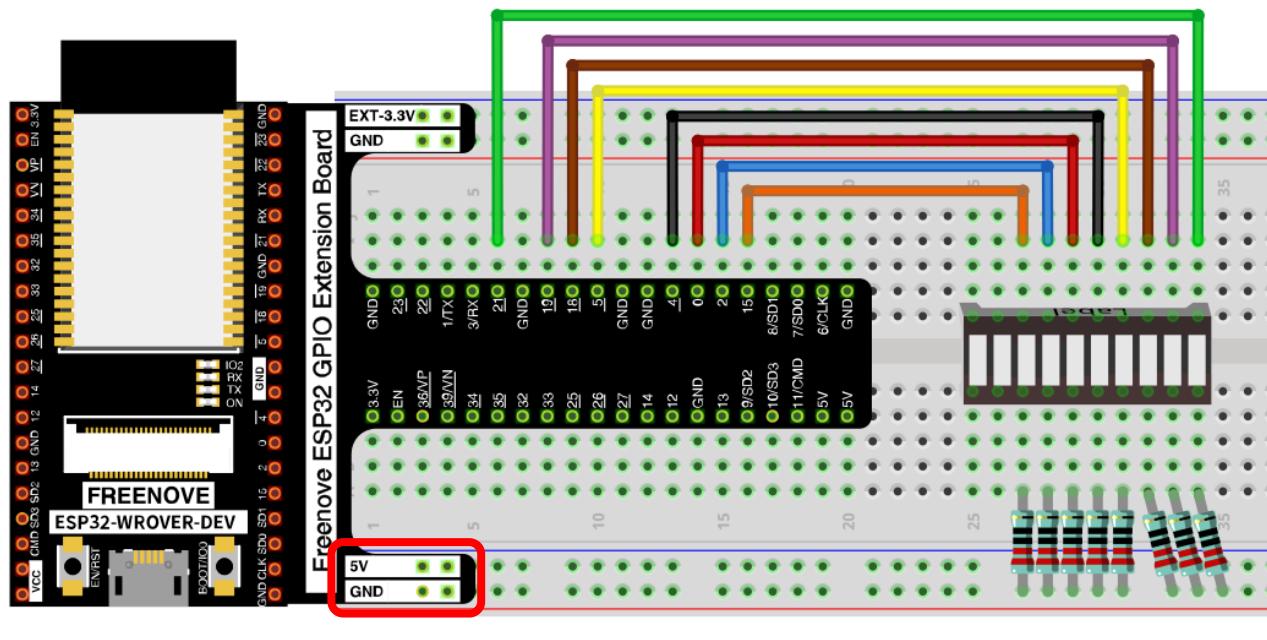
|  |  |
|--|--|
| <b>ESP32-WROVER x1</b><br>  | <b>GPIO Extension Board x1</b><br> |
| <b>Breadboard x1</b><br>  |  |
| <b>Jumper M/M x10</b><br> | <b>LED bar graph x1</b><br>       |
|  | <b>Resistor 220Ω x10</b><br>    |

## 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

The screenshot shows the Thonny IDE interface. The title bar says "Thonny - D:\Micropython\_Codes\04.2\_FlowingLight\04.2\_FlowingLight.py @ 17:1". 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 is titled "Files" and shows a tree view of the project structure:

- MicroPython device
- boot.py
- This computer
  - D:\Micropython\_Codes\04.2\_FlowingLight
  - 04.2\_FlowingLight.py
  - pwm.py

A context menu is open over the "pwm.py" entry in the "This computer" section, with options: Refresh, Upload to / (highlighted in blue), Move to Recycle Bin, New directory..., Properties, and Storage space.

The main editor window displays the code for "04.2\_FlowingLight.py":

```

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()

```

The bottom shell window shows the MicroPython version and a prompt:

```

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

```

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 |   |   |   |   |   |   |   |  |
|     | 2 | 2 | 2 | 2 | 2 | 2 | 2 |   | 2 | 6 | 8 |   |   |   |   |   |   |   |   |   |   |   |  |
|     | 3 | 3 | 3 | 3 | 3 | 3 | 3 |   | 3 |   |   |   |   |   |   |   |   |   |   |   |   |   |  |
| 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 is active, displaying the following code:

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

Annotations with orange callout boxes 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".

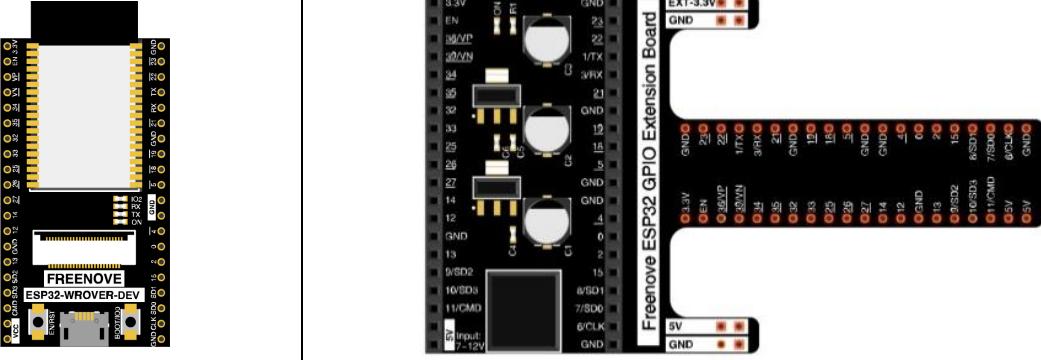
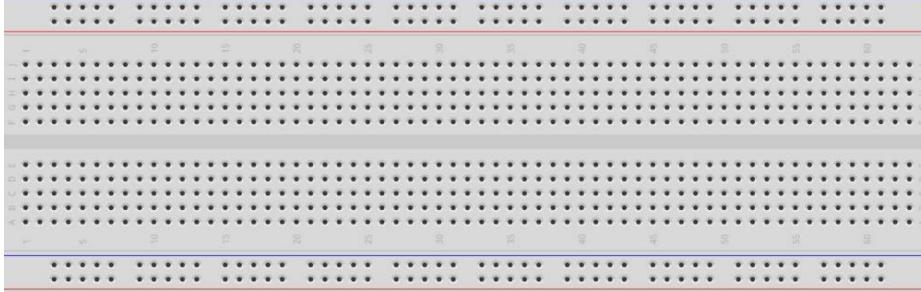
# Chapter 5 RGBLED

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.

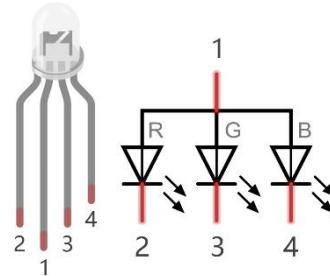
### Component List

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

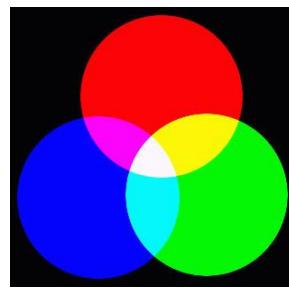
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## Related knowledge

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,



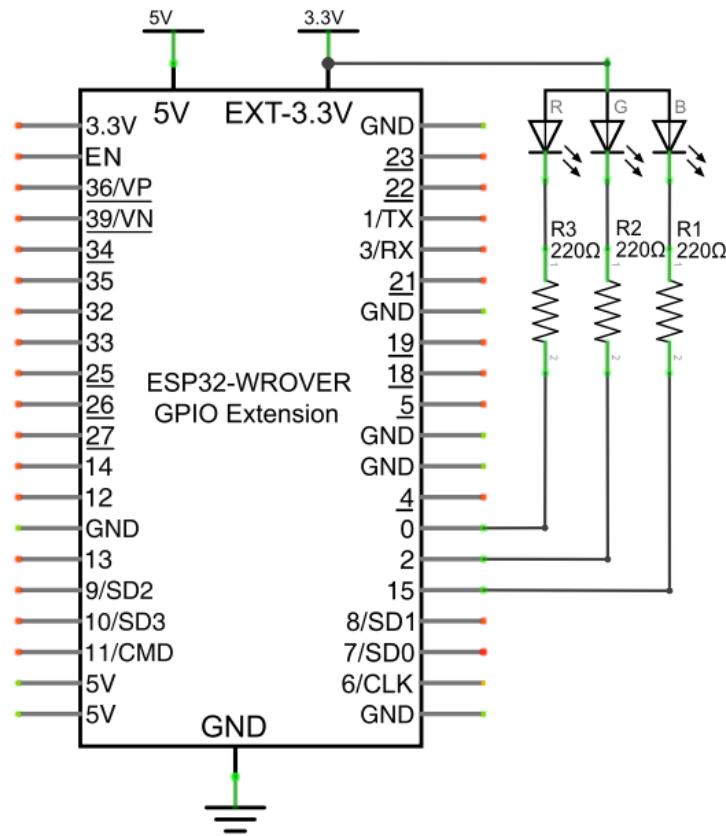
Red, green, and blue light are known as three primary colors. When you combine these three primary-color lights with different brightness, it can produce almost all kinds of visible lights. Computer screens, single pixel of cell phone screen, neon, and etc. are working under this principle.



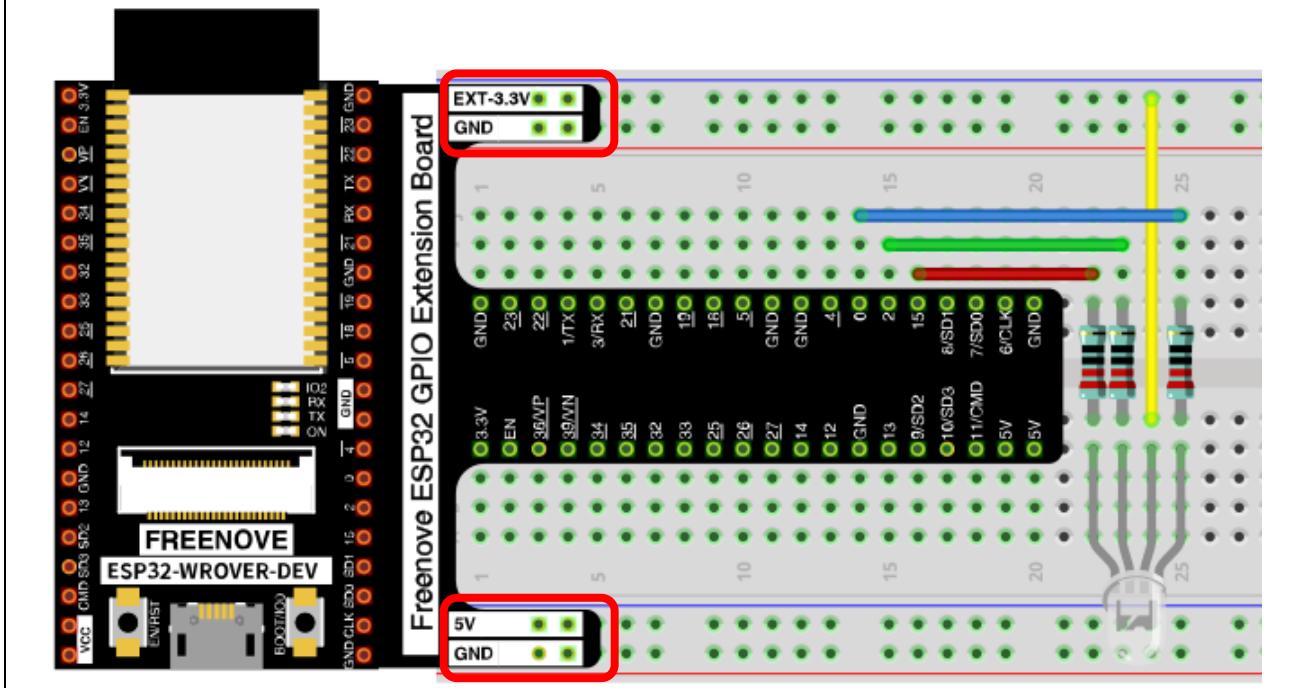
If we use three 10-bit PWM to control the RGBLED, in theory, we can create  $2^{10} * 2^{10} * 2^{10} = 1,073,741,824$ (1 billion) colors through different combinations.

## 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\_Super\_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

The screenshot shows the Thonny IDE interface. The title bar reads "Thonny - D:\Micropython\_Codes\05.1\_RandomColorLight\05.1\_RandomColorLight.py @ 26:18". The menu bar includes File, Edit, View, Run, Device, Tools, and Help. Below the menu is a toolbar with icons for file operations and a stop button. The left sidebar has a "Files" tab showing "MicroPython device" with "boot.py" and "This computer" with "D:\ Micropython\_Codes \ 05.1\_RandomColorLight" and "05.1\_RandomColorLight.py". The main area displays the Python code for "05.1\_RandomColorLight.py". The code initializes three PWM channels (pwm0, pwm1, pwm2) on pins 15, 2, and 0 respectively, with a frequency of 10000. It defines a "setColor" function that takes red, green, and blue values and sets the duty cycles of the PWM channels. A "try" block runs a loop where it generates random values for red, green, and blue, calls the "setColor" function, and sleeps for 200ms. The bottom right pane is a "Shell" window showing the MicroPython prompt: "MicroPython v1.12 on 2019-12-20; ESP32 module (spiram) with ESP32 Type "help()" for more information. >>>".

```
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)
    >>>
```

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

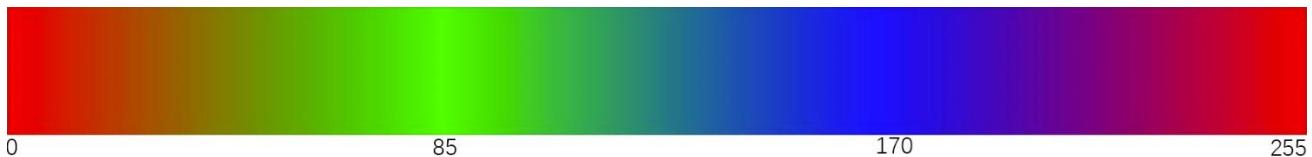


## Project 5.2 Gradient Color Light

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))
```

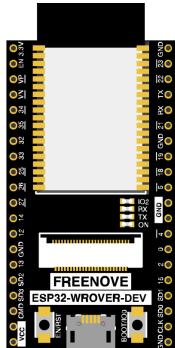
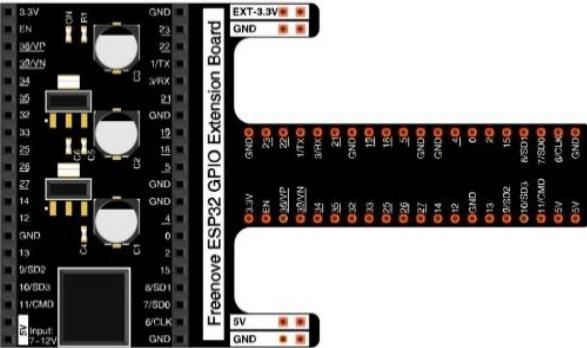
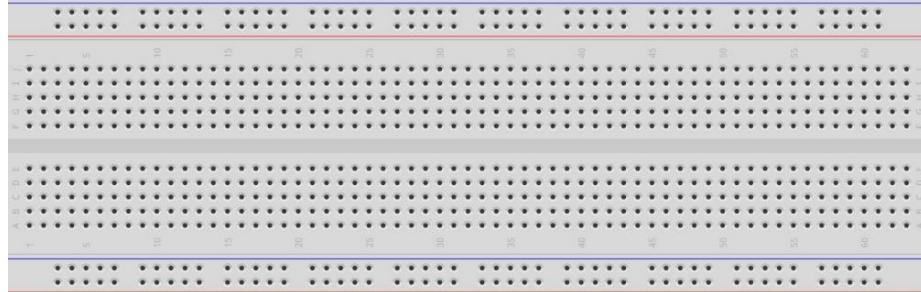
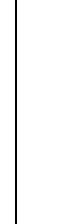
# Chapter 6 Buzzer

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

## Project 6.1 Doorbell

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

### Component List

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

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

## 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 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).

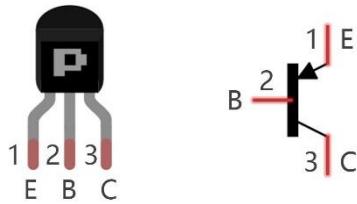


### Transistor

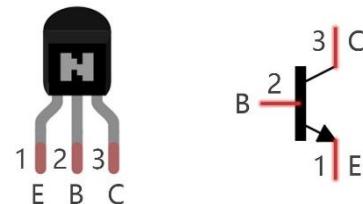
Because the buzzer requires such large current that GPIO of ESP32 output capability cannot meet the requirement, a transistor of NPN type is needed here to amplify the current.

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

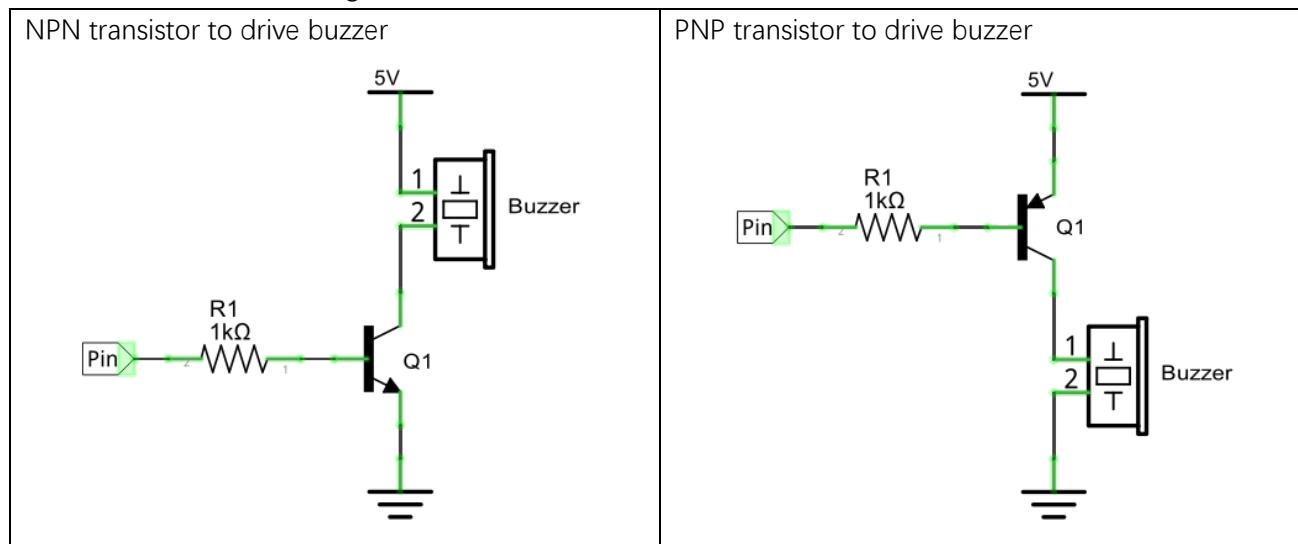


In our kit, the PNP transistor is marked with 8550, and the NPN transistor is marked with 8050.

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.

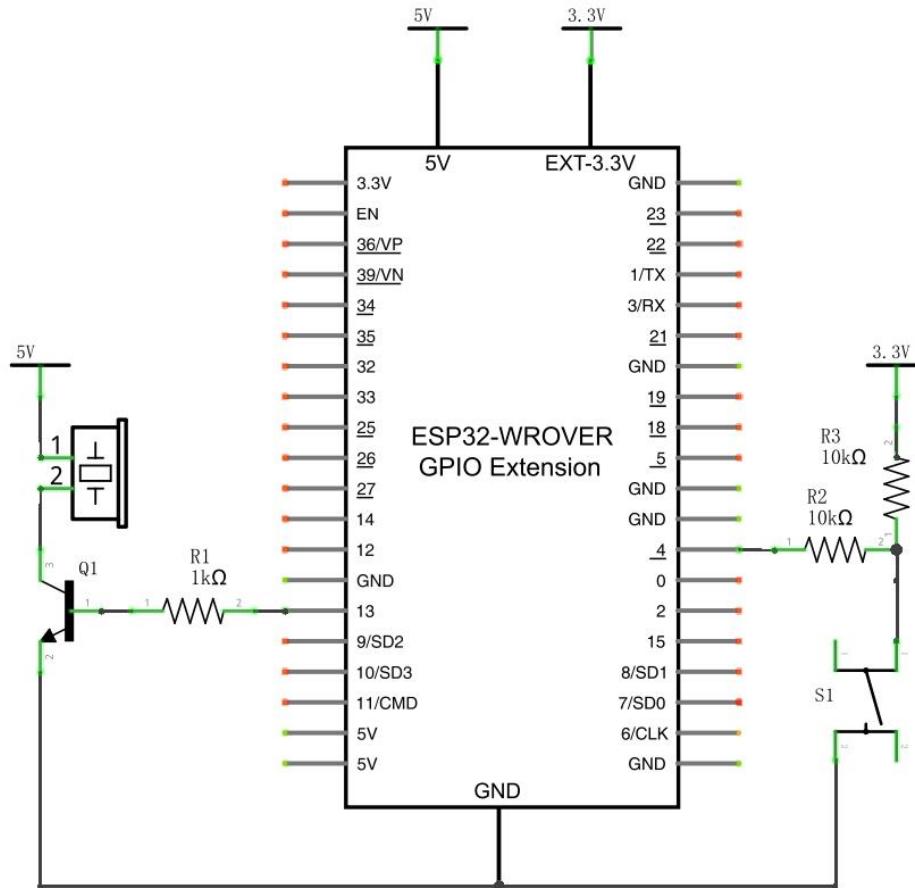
When using NPN transistor to drive buzzer, we often adopt the following method. If GPIO outputs high level, current will flow through R1, the transistor will get conducted, and the buzzer will sound. If GPIO outputs low level, no current flows through R1, the transistor will not be conducted, and buzzer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

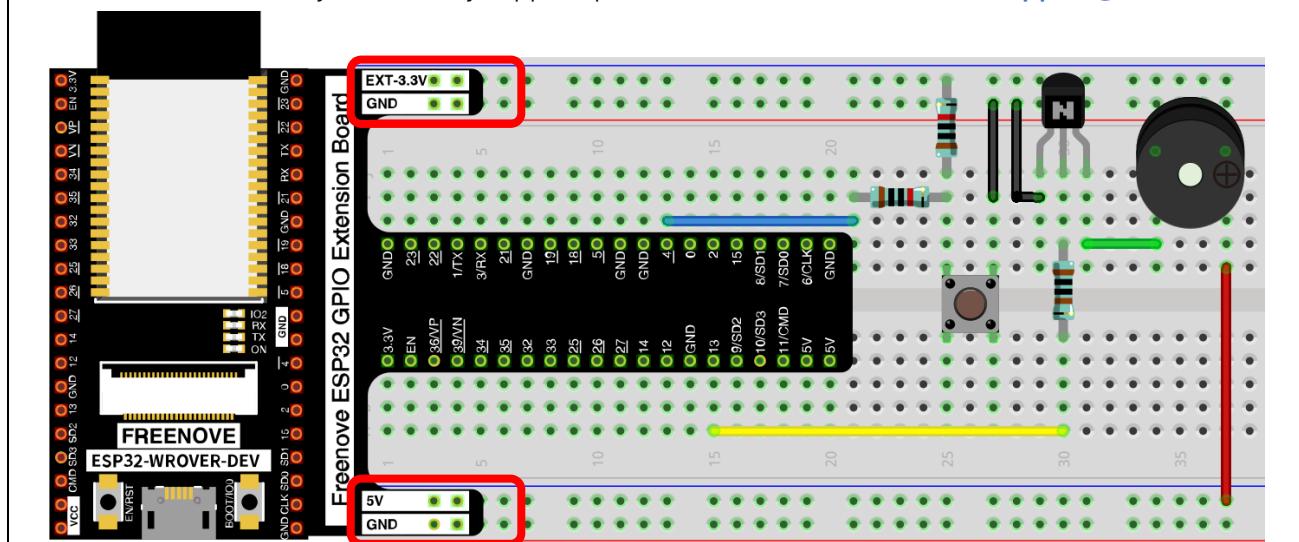


# Circuit

## 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.



## 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\_Super\_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\_Doorbell” and double click “06.1\_Doorbell.py”.

### 06.1\_Doorbell

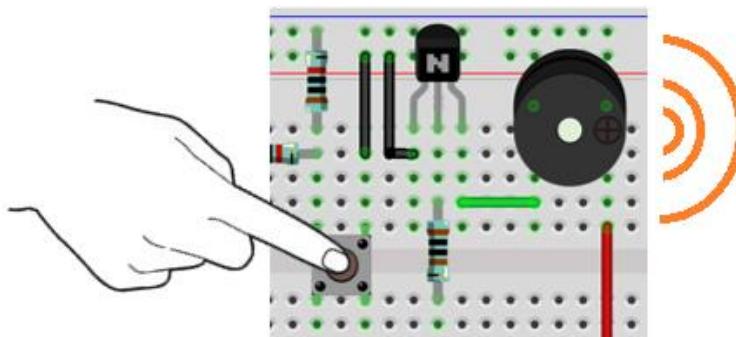
The screenshot shows the Thonny IDE interface. The title bar says "Thonny - D:\Micropython\_Codes\06.1\_Doorbell\06.1\_Doorbell.py @ 13:1". The menu bar includes File, Edit, View, Run, Device, Tools, and Help. Below the menu is a toolbar with icons for file operations like Open, Save, and Run. The left sidebar has a "Files" tab showing a tree view of files: "MicroPython device" (with "boot.py") and "This computer" (with "D:\ Micropython\_Codes \ 07.1\_Doorbell" and "07.1\_Doorbell.py" selected). The main area contains the 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)
```

At the bottom is a "Shell" tab showing the MicroPython environment:

```
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 6.2 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” → “06.2\_Alertor”, and double click “06.2\_Alertor.py”.

#### 06.2\_Alertor

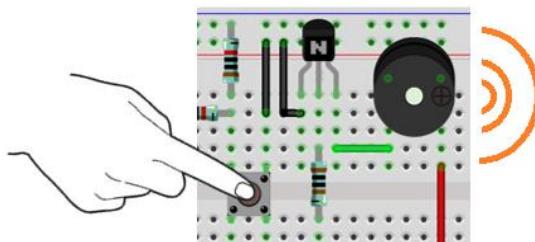
```

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()
23

```

The screenshot shows the Thonny IDE interface. The top menu bar includes File, Edit, View, Run, Device, Tools, and Help. The left sidebar shows a file tree with 'MicroPython device' containing 'boot.py' and 'This computer' containing 'D:\ Micropython\_Codes\06.2\_Alertor' with '06.2\_Alertor.py' selected. The main workspace shows the Python code for '06.2\_Alertor.py'. Below the code is a 'Shell' window displaying the MicroPython version and a prompt for commands.

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()
```



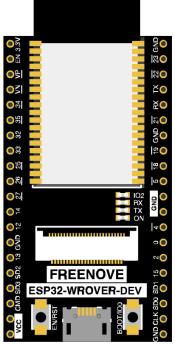
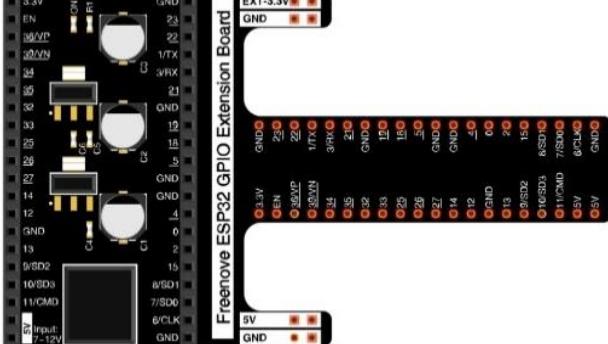
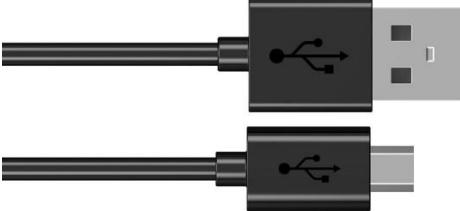
# Chapter 7 Serial Communication

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

## Project 7.1 Serial Print

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

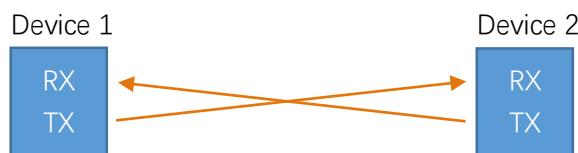
### Component List

|  |   |
|--|---|
| <b>ESP32-WROVER x1</b><br>     | <b>GPIO Extension Board x1</b><br> |
| <b>Micro USB Wire x1</b><br> |   |

## 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.

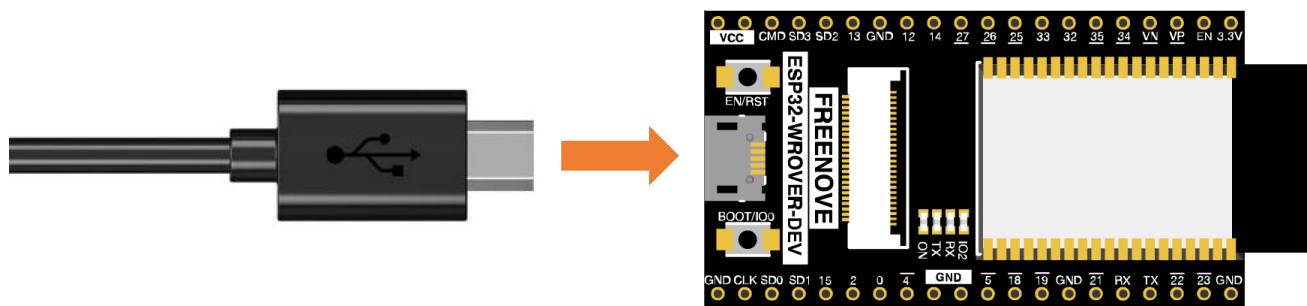
### Serial port on ESP32

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

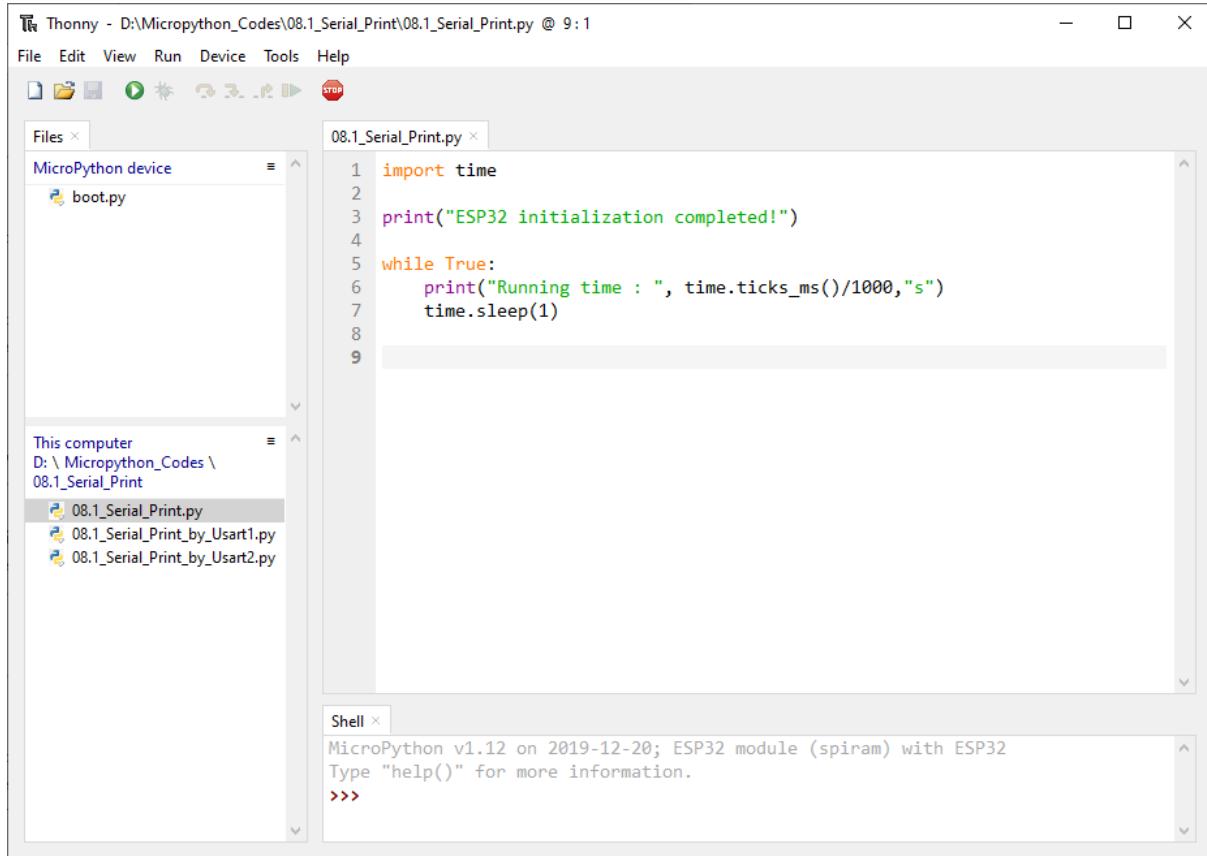


## Code

Move the program folder “**Freenove\_Super\_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\_Serial\_Print” and double “07.1\_Serial\_Print.py”.

### 07.1\_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.



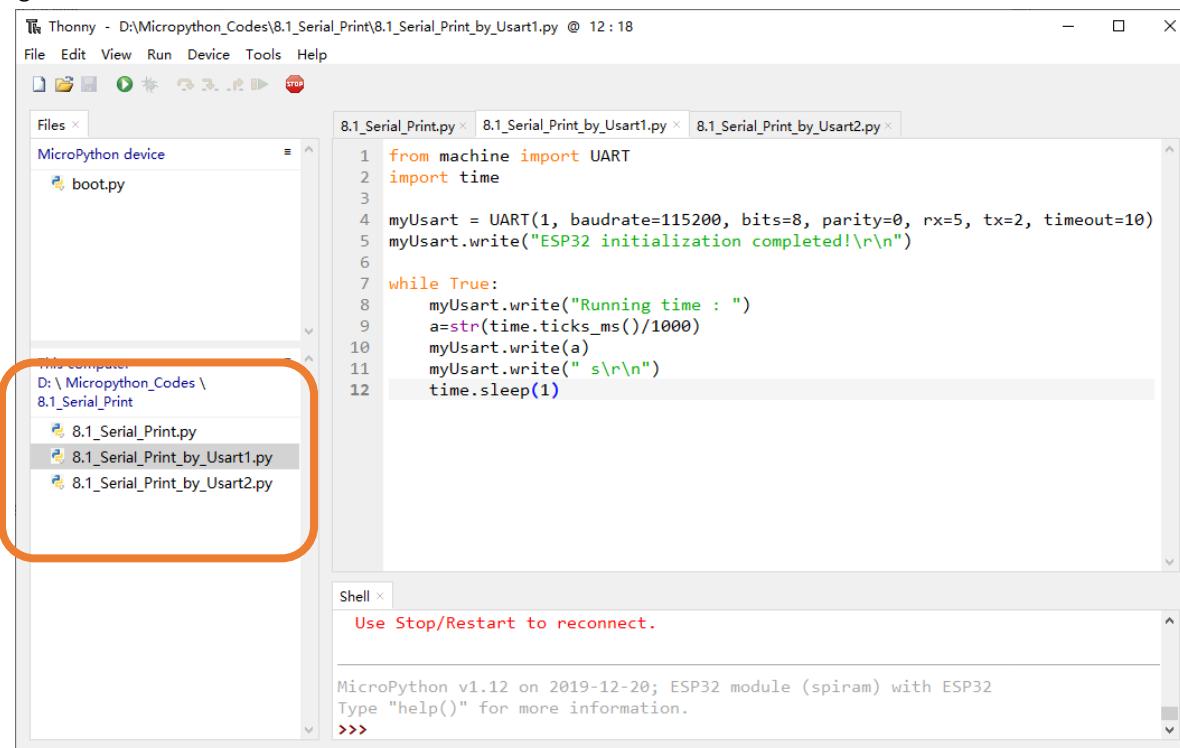
The following is the program code:

```

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.



## 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**: UAPTS'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)

$0 < \text{timeout} \leq 0x7FFF FFFF$  (decimal:  $0 < \text{timeout} \leq 2147483647$ )

**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 7.2 Serial Read and Write

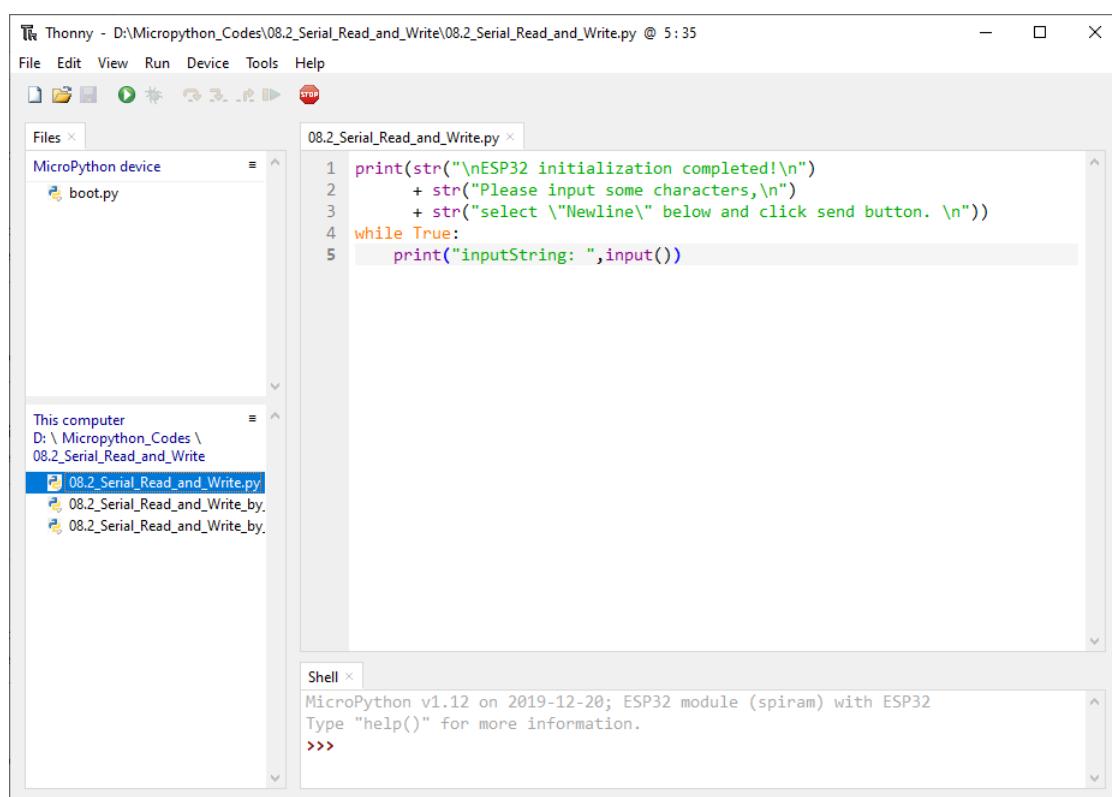
From last section, we use Serial port on Freenove ESP32 to send data to a computer, now we will use that to receive data from computer.

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

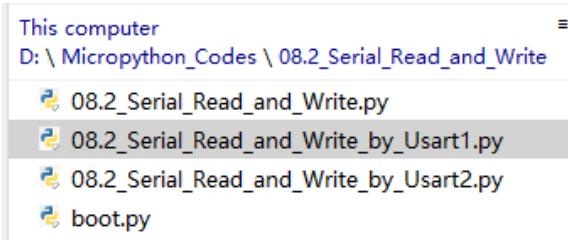
### Code

Open “Thonny”, click “This computer” → “D:” → “Micropython\_Codes” → “07.2\_Serial\_Read\_and\_Write” and double click “07.2\_Serial\_Read\_and\_Write.py”.

#### 07.2\_Serial\_Read\_and\_Write



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.



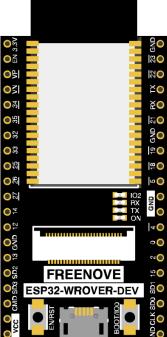
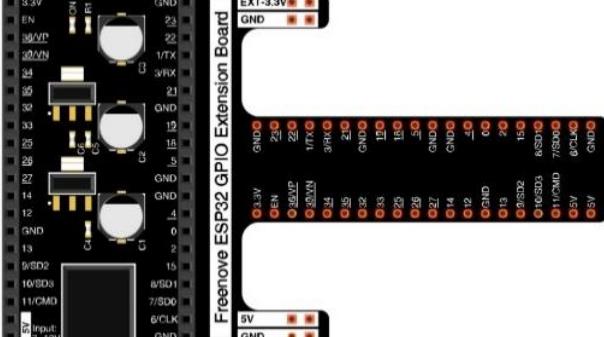
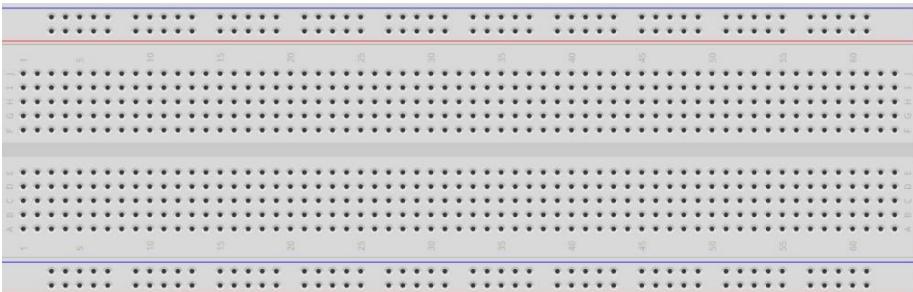
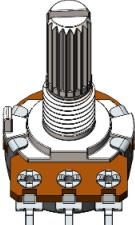
# Chapter 8 AD/DA Converter

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 8.1 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

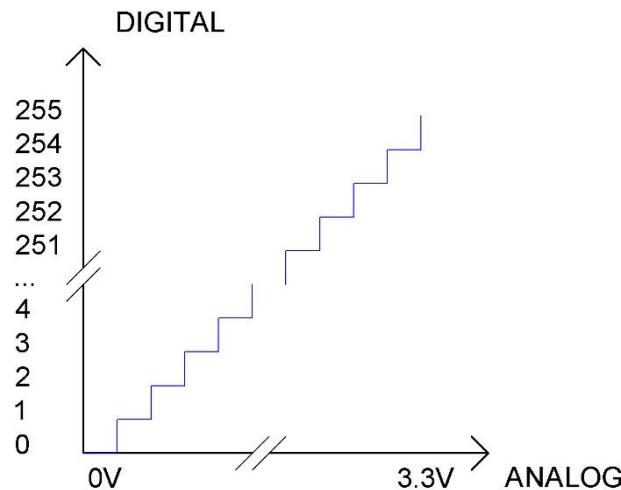
|  |   |   |  |
|--|---|---|--|
| ESP32-WROVER x1  | GPIO Extension Board x1   |   |  |
|    |  |   |  |
| Breadboard x1  |   |   |  |
|  |   |   |  |
| Rotary potentiometer x1  | Resistor 220Ω x1  | LED x1  | Jumper M/M x5  |
|   |  |  |  |

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

## 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 rang of 0V---3.3/4095 V corresponds to digital 0;

Subsection 2: the analog in rang 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:

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



### 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,

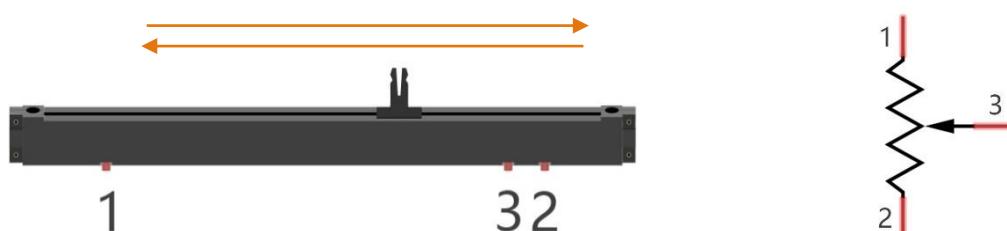
| Simulate pin number | GPIO number |
|---------------------|-------------|
| DAC1                | 25          |
| DAC2                | 26          |

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

## Component knowledge

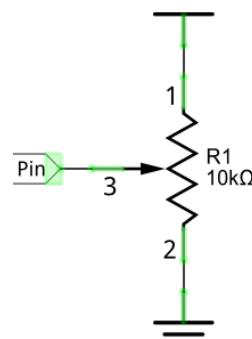
### Potentiometer

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.



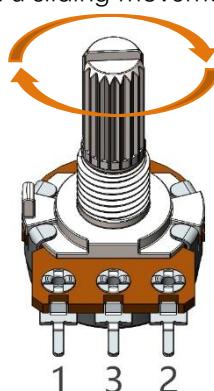
What between potentiometer pin 1 and pin 2 is the resistor body, and pins 3 is connected to brush. When brush moves from pin 1 to pin 2, the resistance between pin 1 and pin 3 will increase up to body resistance linearly, and the resistance between pin 2 and pin 3 will decrease down to 0 linearly.

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.



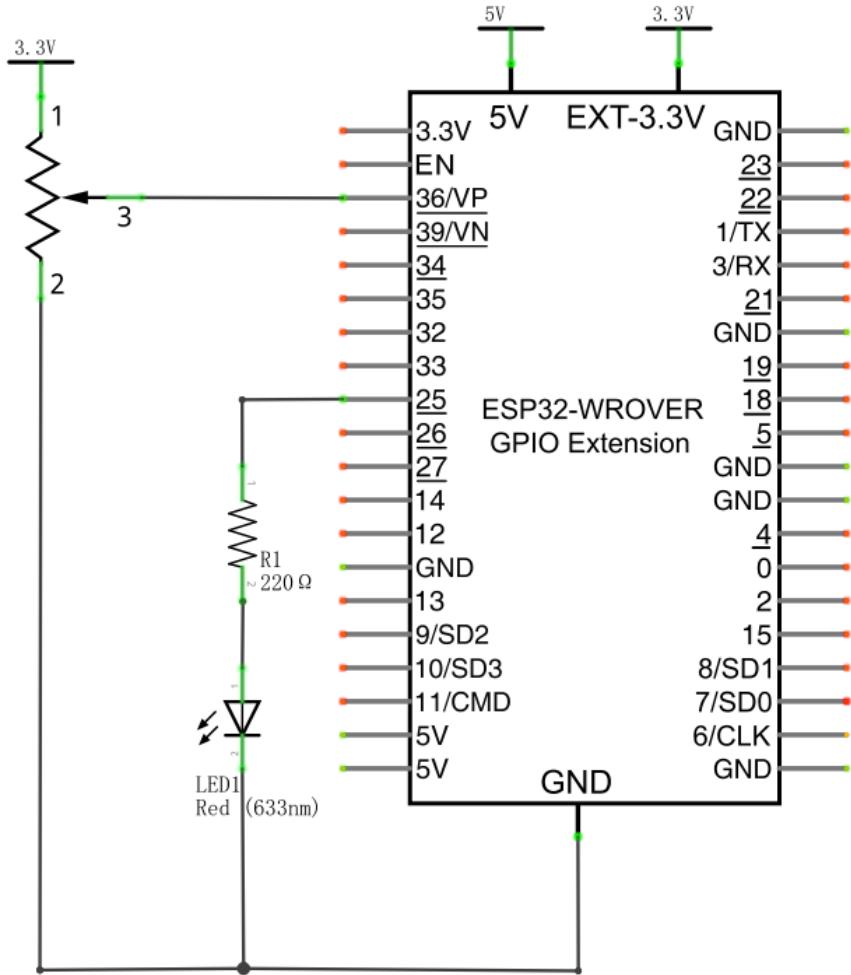
### Rotary potentiometer

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

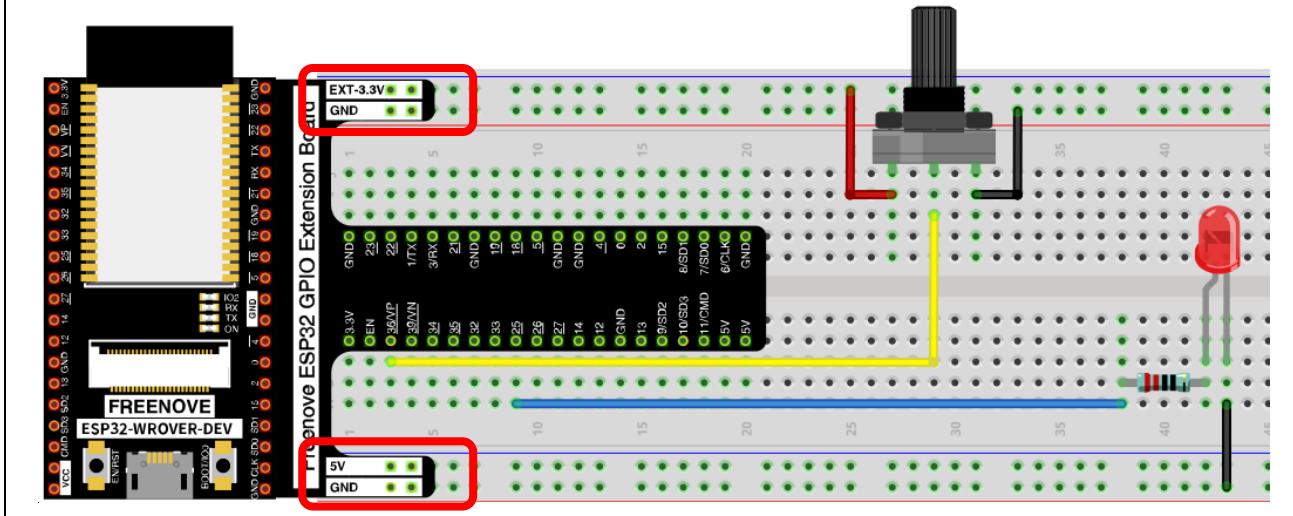


## Circuit

Schematic diagram



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



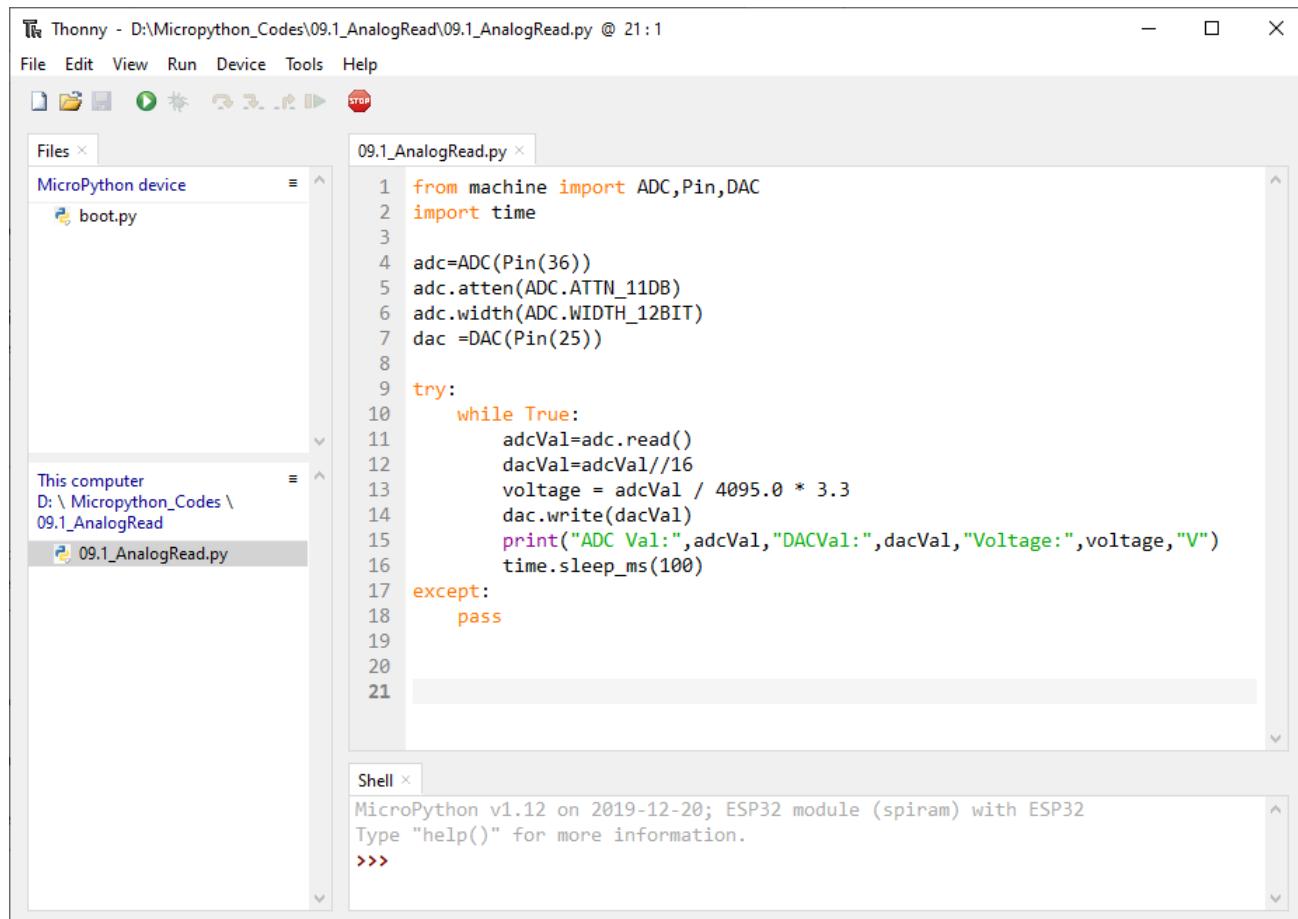
Any concerns? ✉ [support@freenove.com](mailto:support@freenove.com)

## Code

Move the program folder “**Freenove\_Super\_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\_AnalogRead” and then click “08.1\_AnalogRead.py”.

### 08.1\_AnalogRead



```

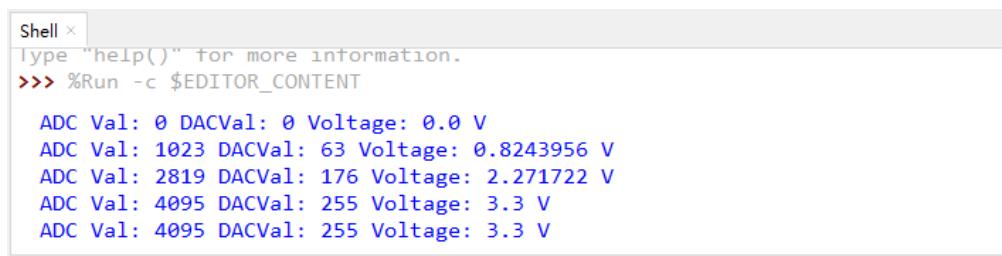
from machine import ADC,Pin,DAC
import time

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”.



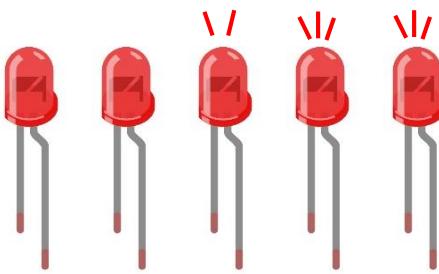
```

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

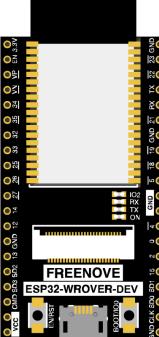
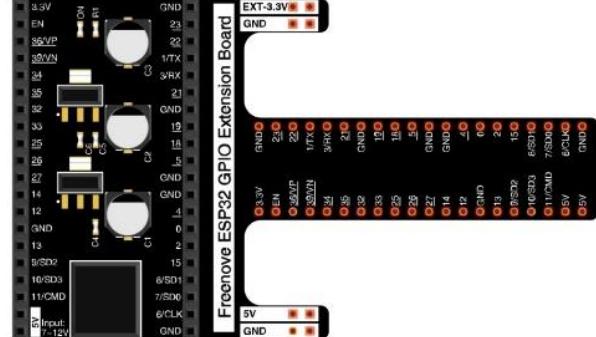
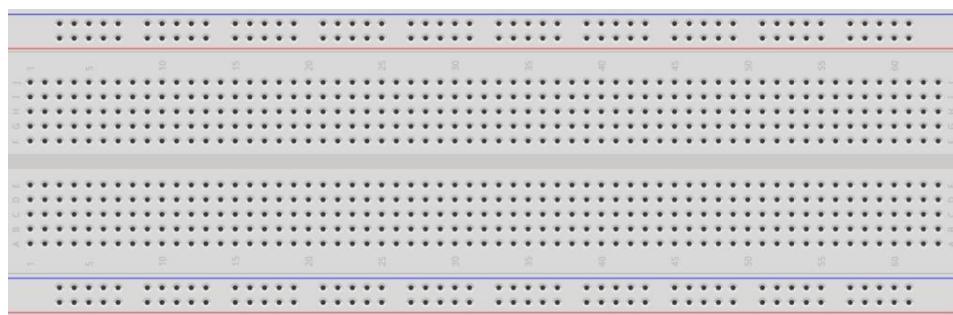
# Chapter 9 TouchSensor

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 9.1 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

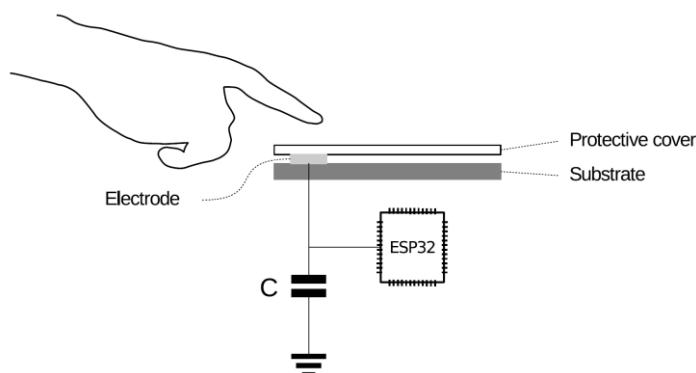
ESP32's touch sensor supports up to 7 GPIO channels as capacitive touch pins. Each pin can be used separately as an independent touch switch or be combined to produce multiple touch points. The following table is a list of available touch pins on ESP32.

| 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.

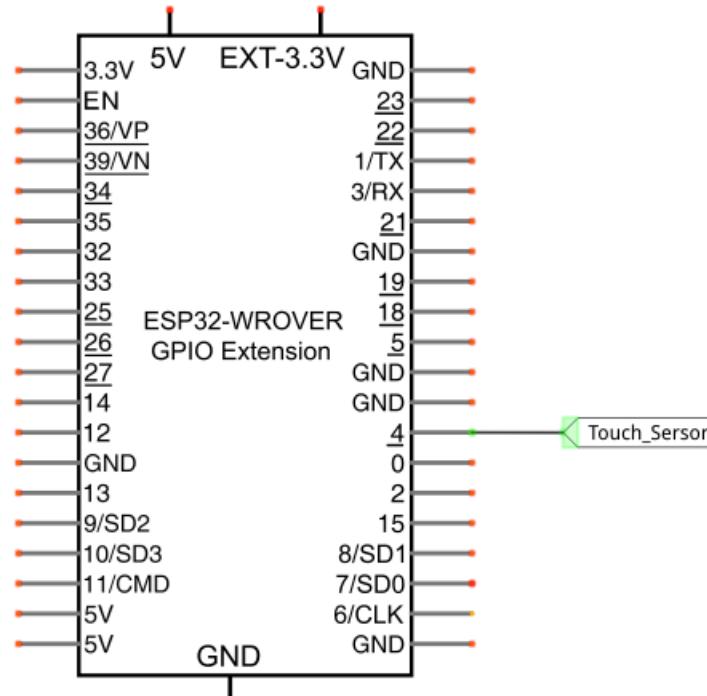
The electronic signals generated with the touch are analog, which are converted by the internal ADC. You may have found that all touch pins have featured with ADC.

The way to connect the hardware is as follows:

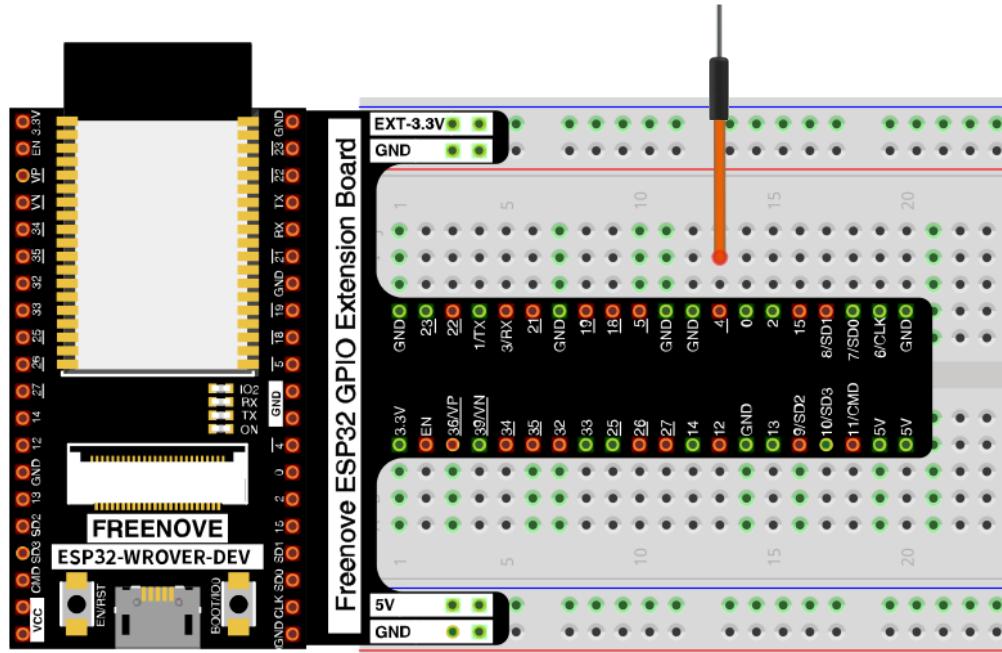


## Circuit

Schematic diagram



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

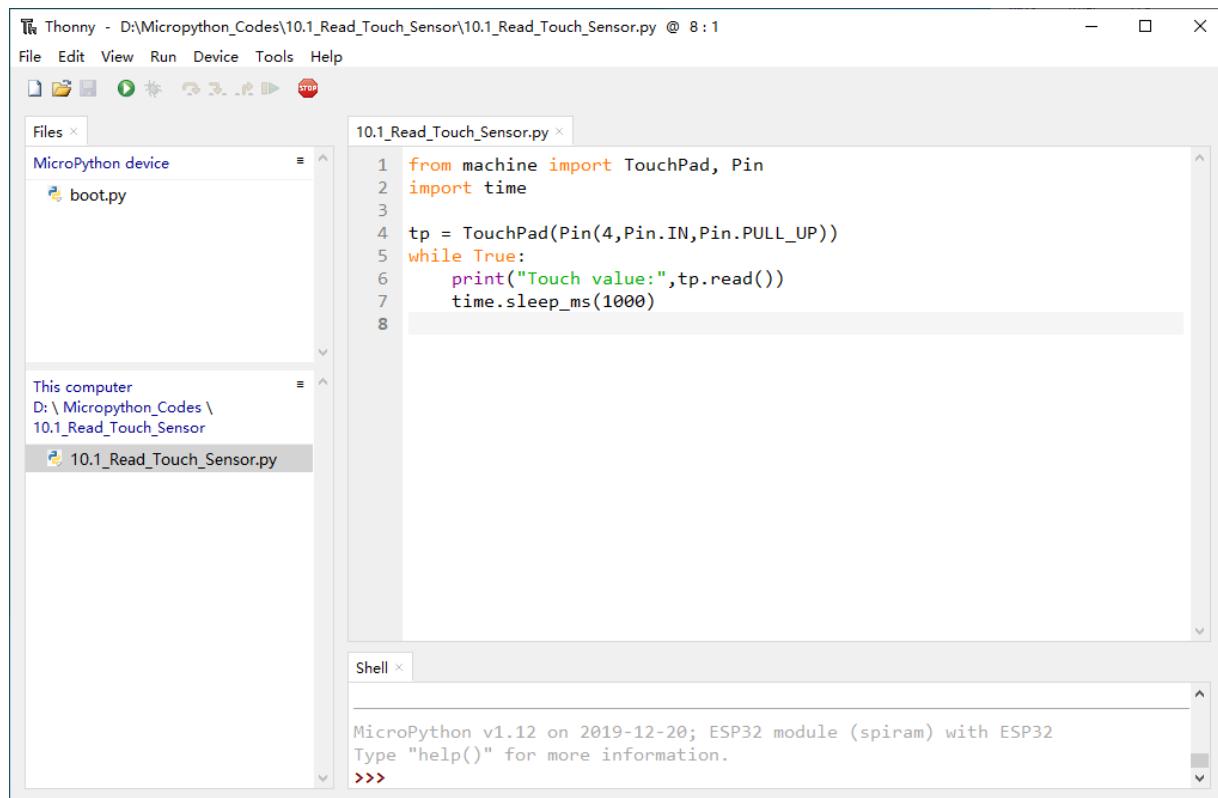


## Code

Move the program folder “**Freenove\_Super\_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\_Read\_Touch\_Sensor” and double click “09.1\_Read\_Touch\_Sensor.py”.

### 09.1\_Read\_Touch\_Sensor



The screenshot shows the Thonny IDE interface. The title bar says "Thonny - D:\Micropython\_Codes\09.1\_Read\_Touch\_Sensor\09.1\_Read\_Touch\_Sensor.py @ 8:1". The menu bar includes File, Edit, View, Run, Device, Tools, and Help. The left sidebar shows a file tree with "MicroPython device" expanded, showing "boot.py" and "10.1\_Read\_Touch\_Sensor.py". The main code editor window contains the following Python code:

```

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

```

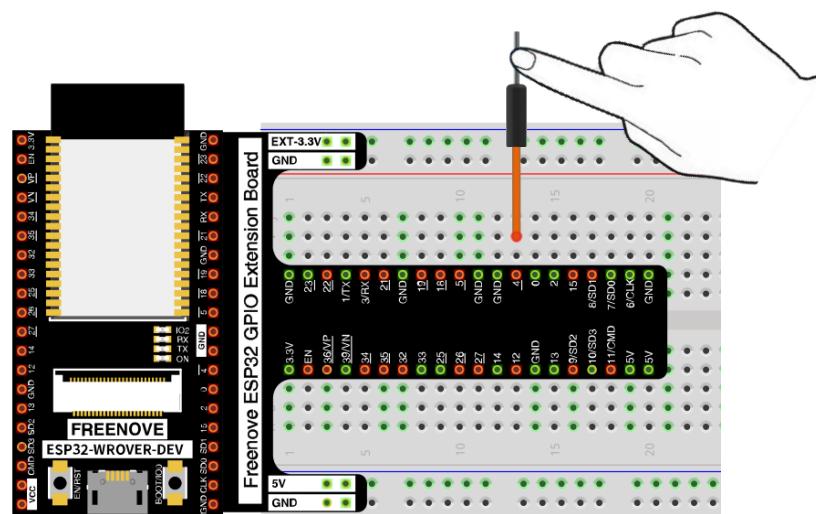
The bottom right pane is labeled "Shell" and displays the output of the MicroPython interpreter:

```

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 "File Edit View Run Device Tools 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 "MicroPython device" with "boot.py" selected. The main workspace shows a script named "10.1\_Read\_Touch\_Sensor.py" with the following code:

```

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

```

Below the code is a "Shell" window displaying the output of the script. It shows a series of touch values being printed every second:

```

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.

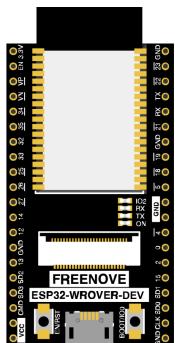
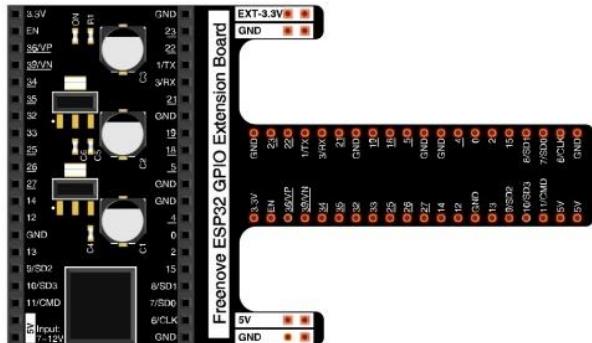
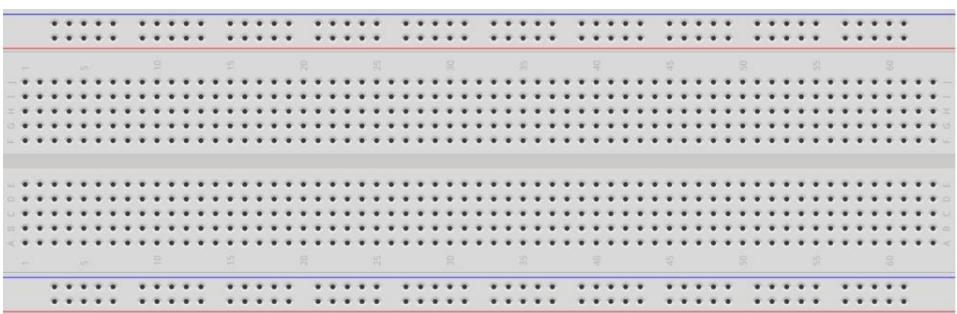
**pin**: Pin(4)、Pin(15)、Pin(13)、Pin(12)、Pin(14)、Pin(32)、Pin(33)

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

## Project 9.2 TouchLamp

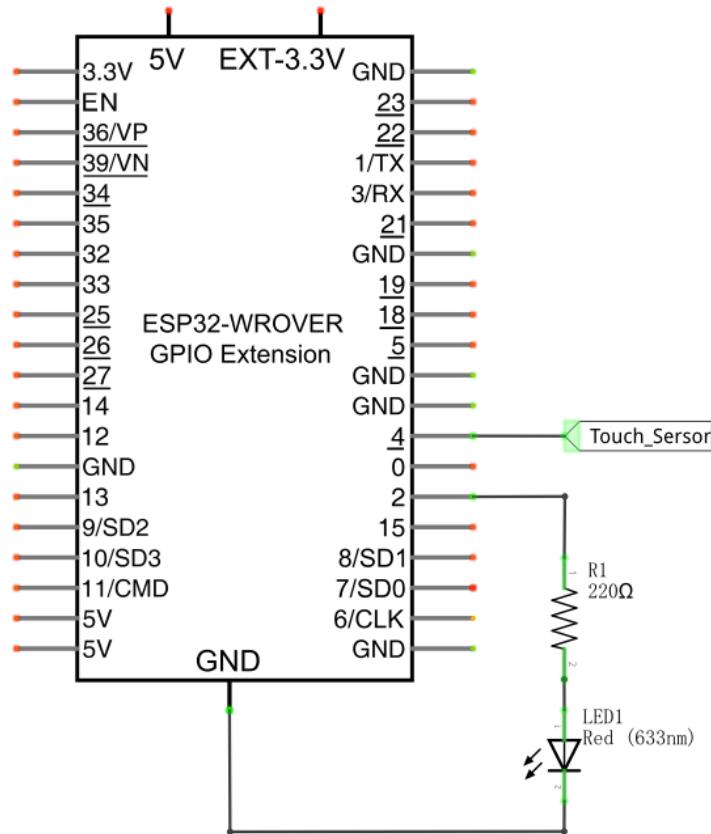
In this project, we will use ESP32's touch sensor to create a touch switch lamp.

### Component List

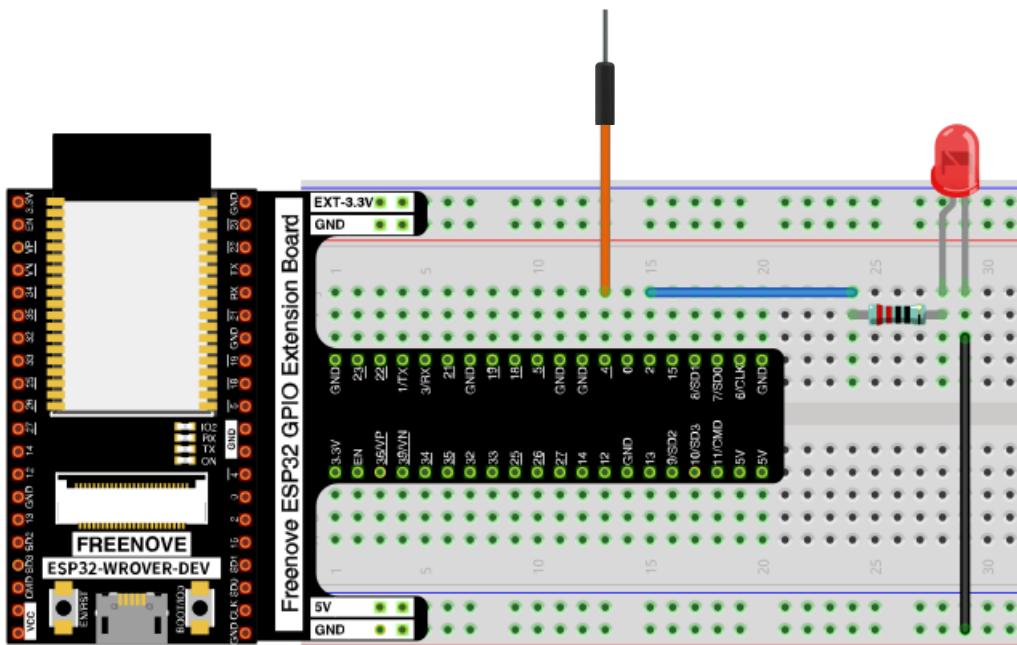
|   |  |   |
|---|--|---|
| ESP32-WROVER x1   | GPIO Extension Board x1  | Breadboard x1   |
|  |  |  |
| Jumper M/M x3   | LED x1   | Resistor 220Ω x1  |

## Circuit

Schematic diagram



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



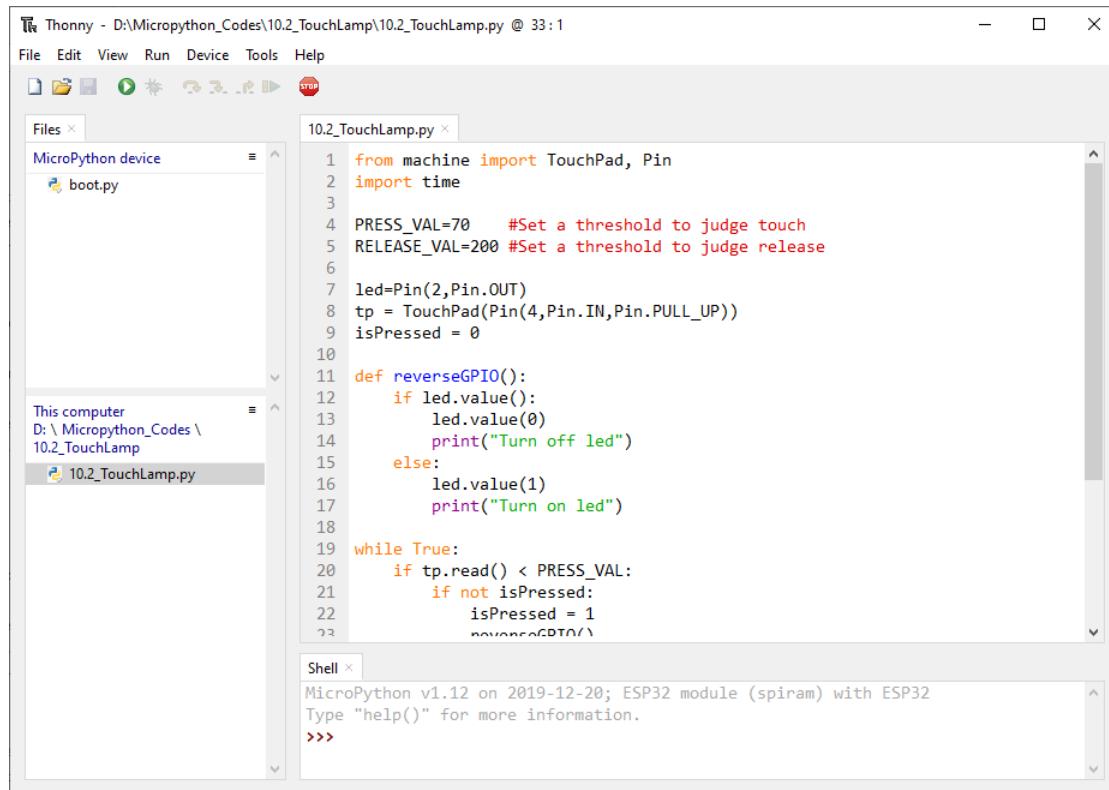
Any concerns? ✉ [support@freenove.com](mailto:support@freenove.com)

## Code

Move the program folder “**Freenove\_Super\_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” → “09.2\_TouchLamp” and double click “09.2\_TouchLamp.py”.

### 09.2\_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

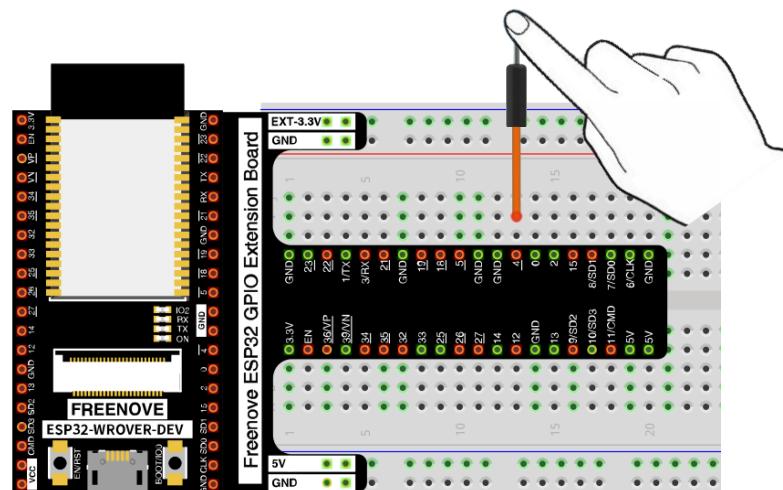
led=Pin(2,Pin.OUT)
tp = TouchPad(Pin(4,Pin.IN,Pin.PULL_UP))
isPressed = 0

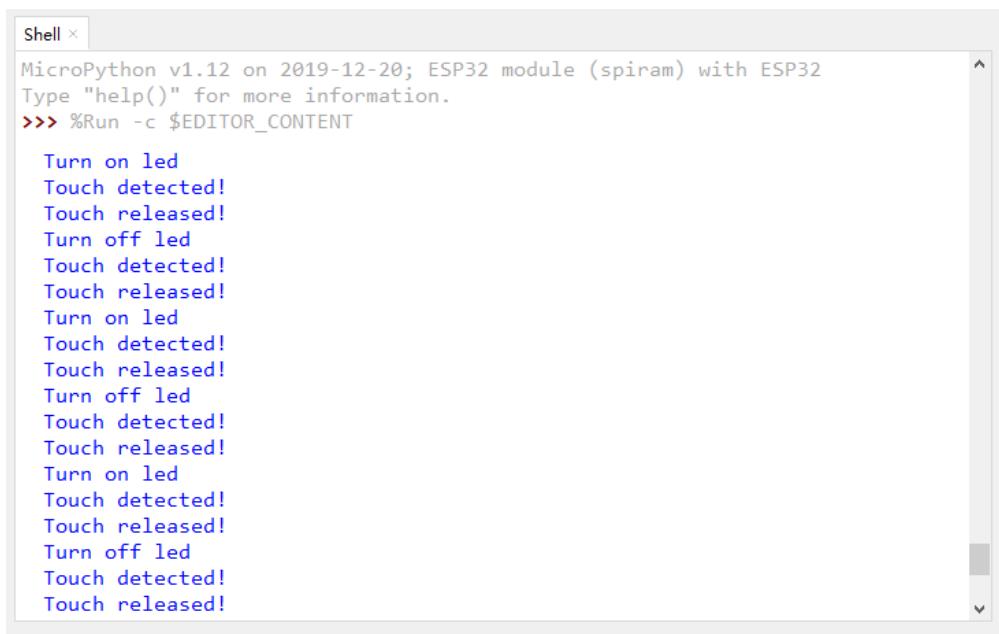
def reverseGPIO():
    if led.value():
        led.value(0)
        print("Turn off led")
    else:
        led.value(1)
        print("Turn on led")

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")

```

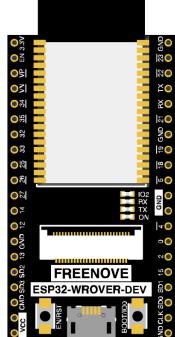
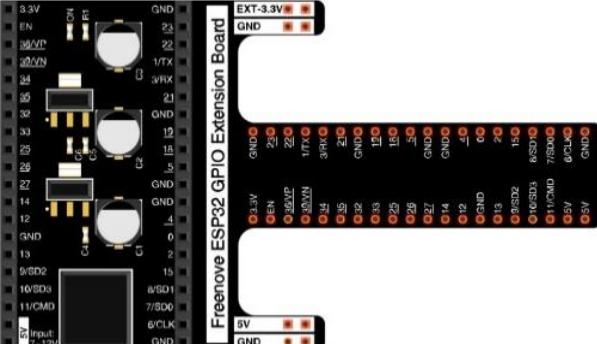
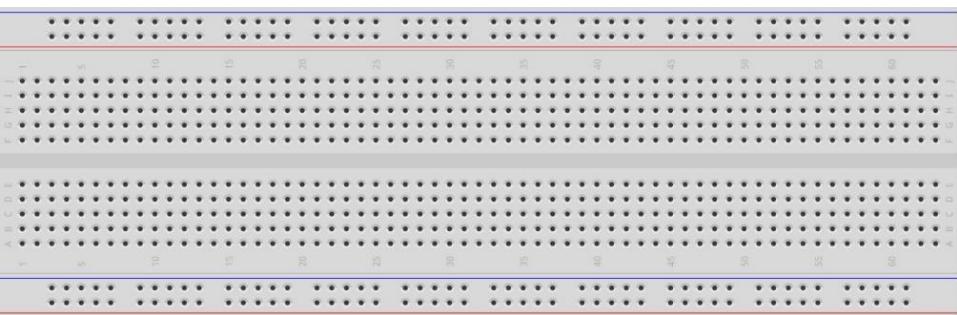
# Chapter 10 Potentiometer & LED

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 10.1 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.

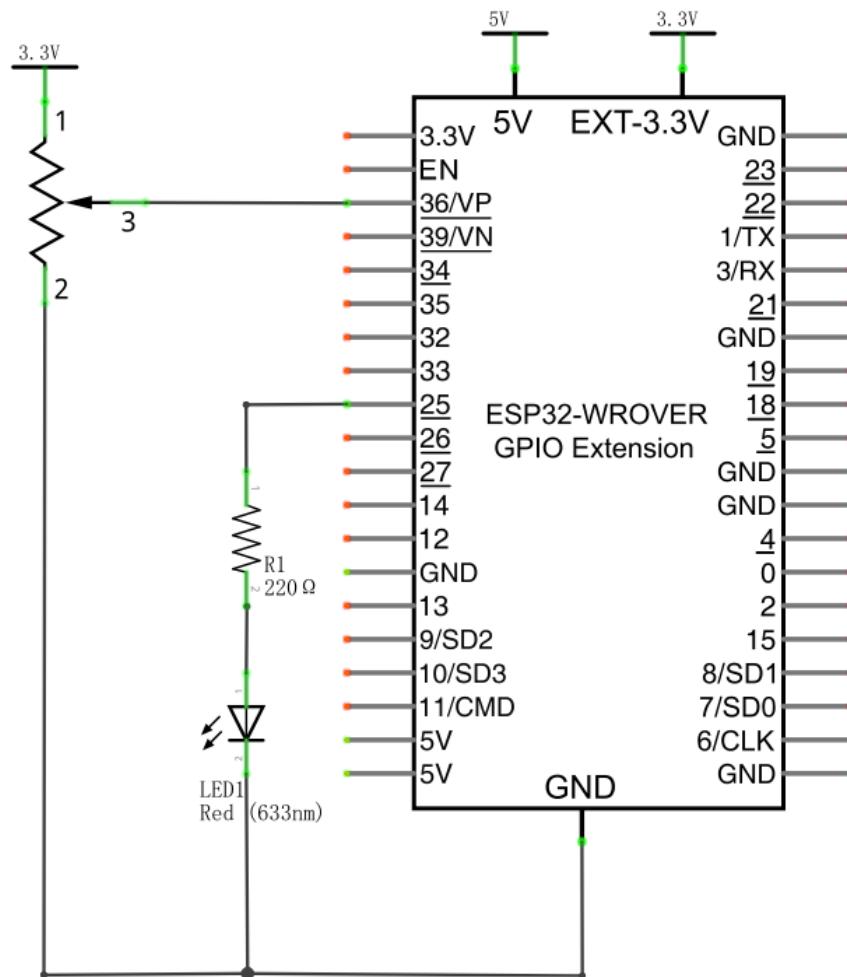
### Component List

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

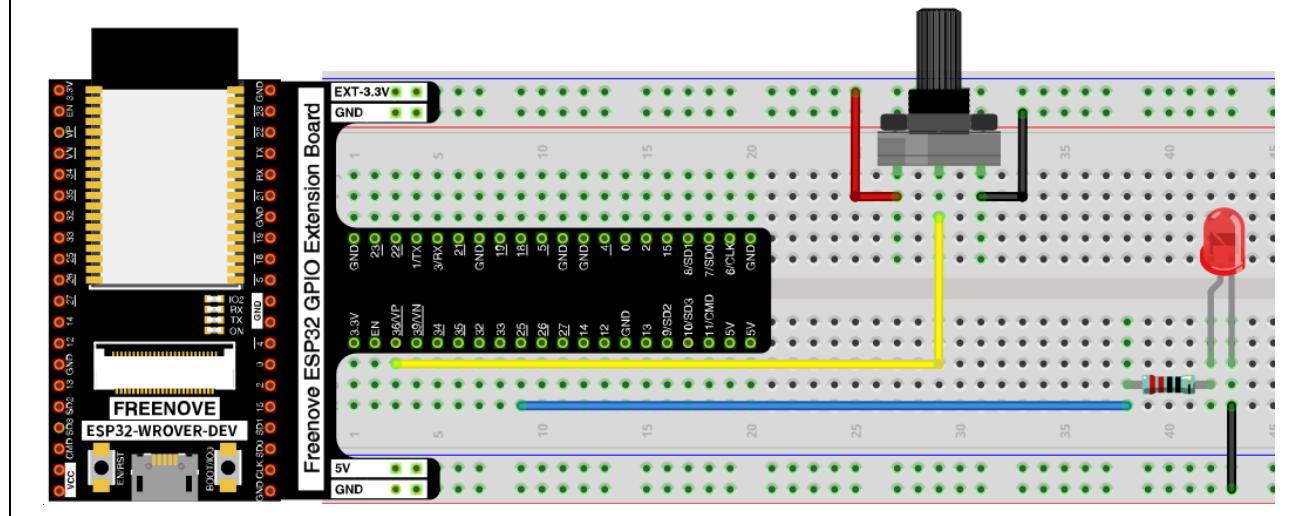
Any concerns? [✉ support@freenove.com](mailto:support@freenove.com)

## Circuit

Schematic diagram



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



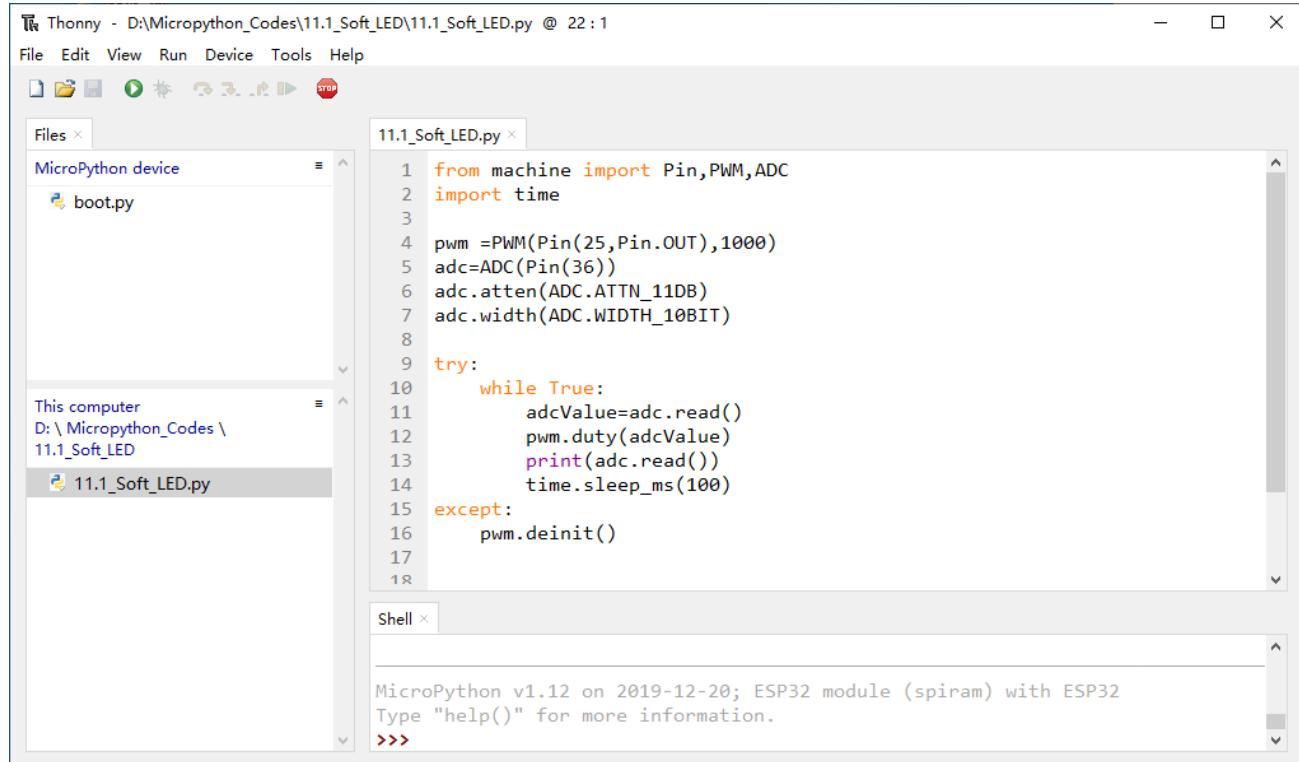
Any concerns? [✉ support@freenove.com](mailto:support@freenove.com)

## Code

Move the program folder “**Freenove\_Super\_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\_Soft\_LED” and double click “10.1\_Soft\_LED.py”.

### 10.1\_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 10.2 Soft Colorful Light

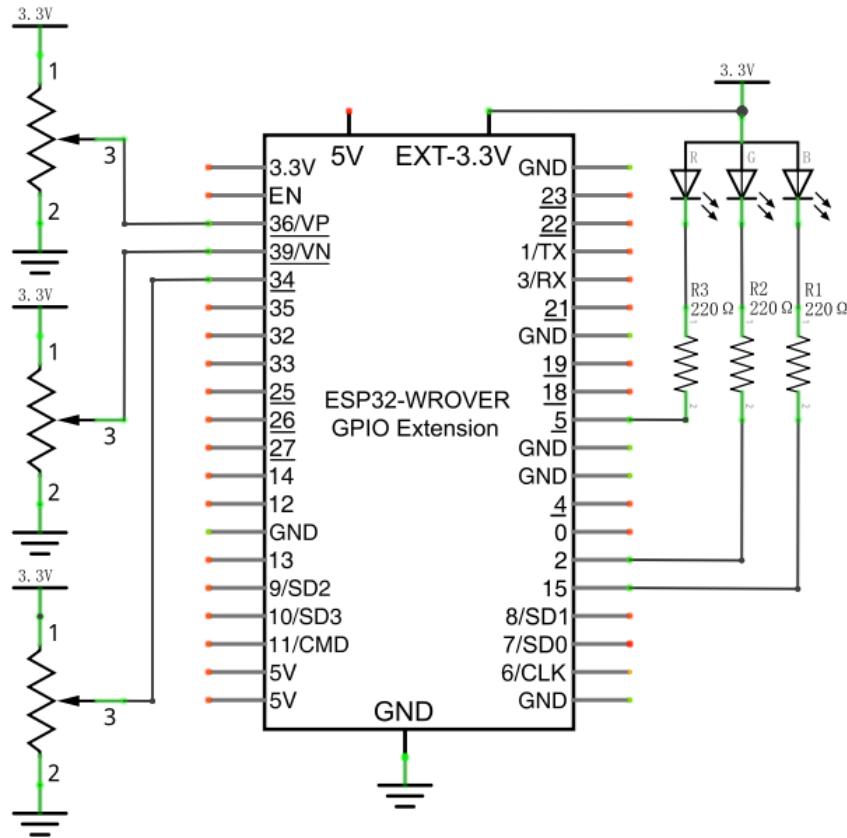
In this project, 3 potentiometers are used to control the RGB LED and in principle it is the same as the Soft Light project. Namely, read the voltage value of the potentiometer and then convert it to PWM used to control LED brightness. Difference is that the original project only controlled one LED,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

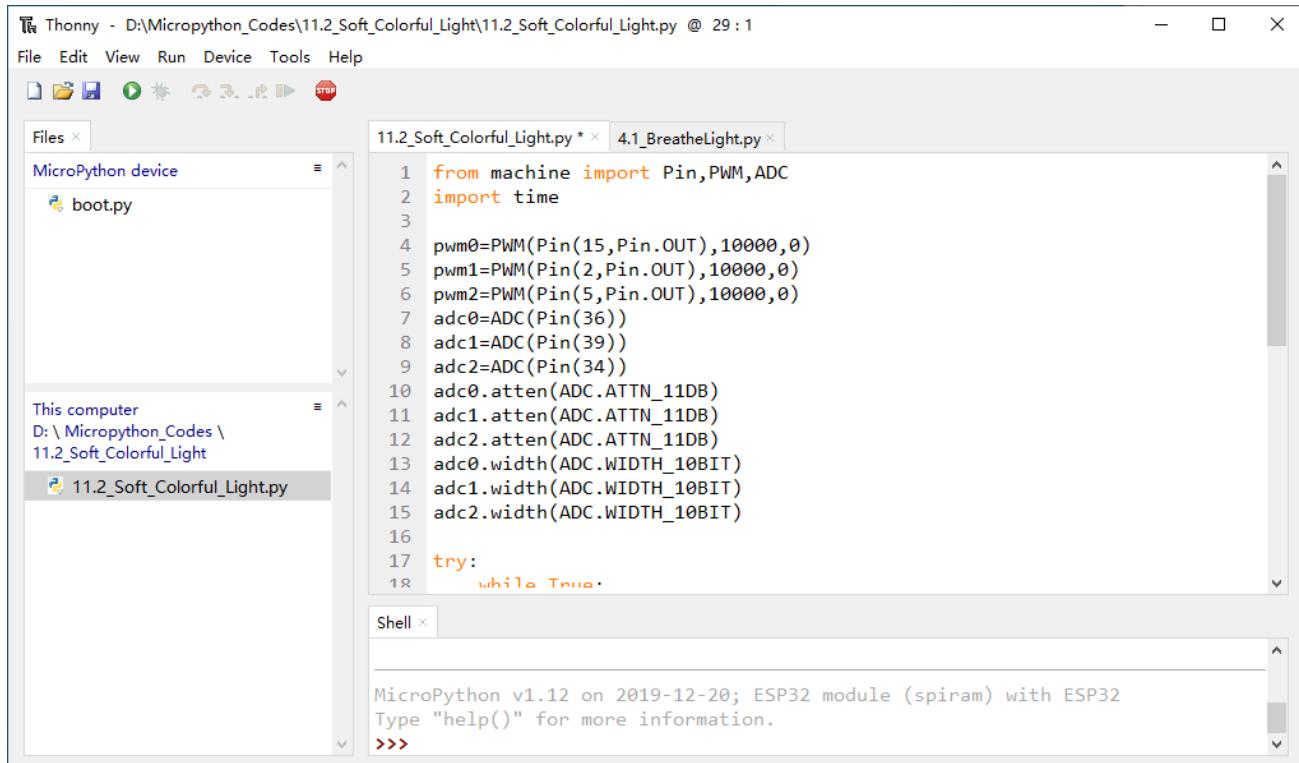
Schematic diagram



## Code

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

### 10.2\_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.



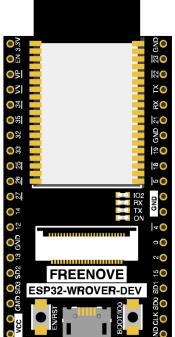
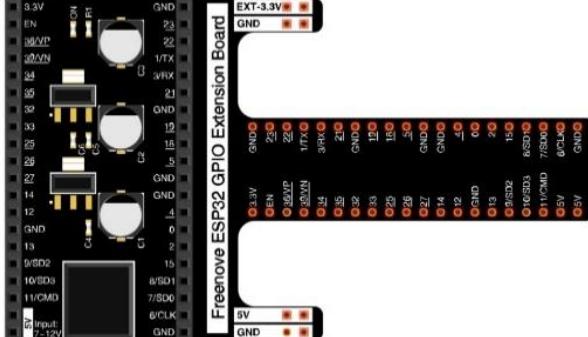
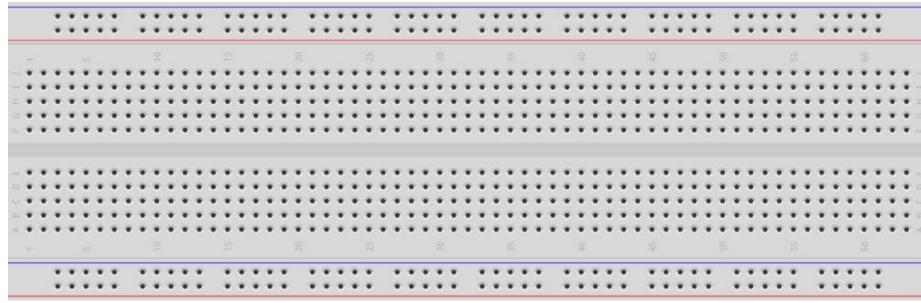
# Chapter 11 Photoresistor & LED

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

## Project 11.1 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

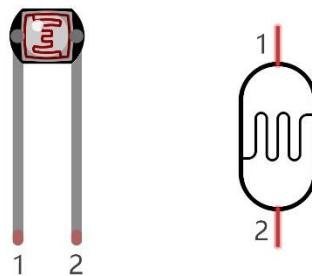
|   |                         |
|---|-------------------------|
| ESP32-WROVER x1   | GPIO Extension Board x1 |
|     |                         |
|    |                         |
| Breadboard x1   |                         |
|   |                         |
| Photoresistor x1  | Resistor             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

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

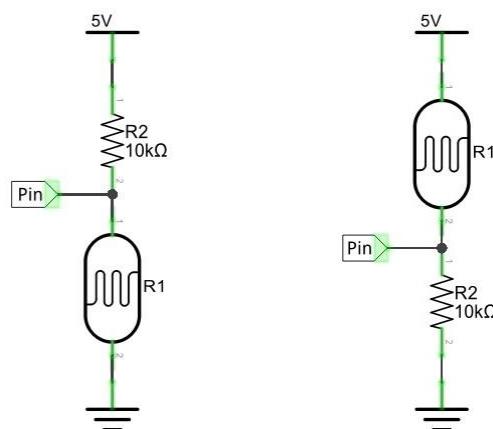
## Component knowledge

### 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:

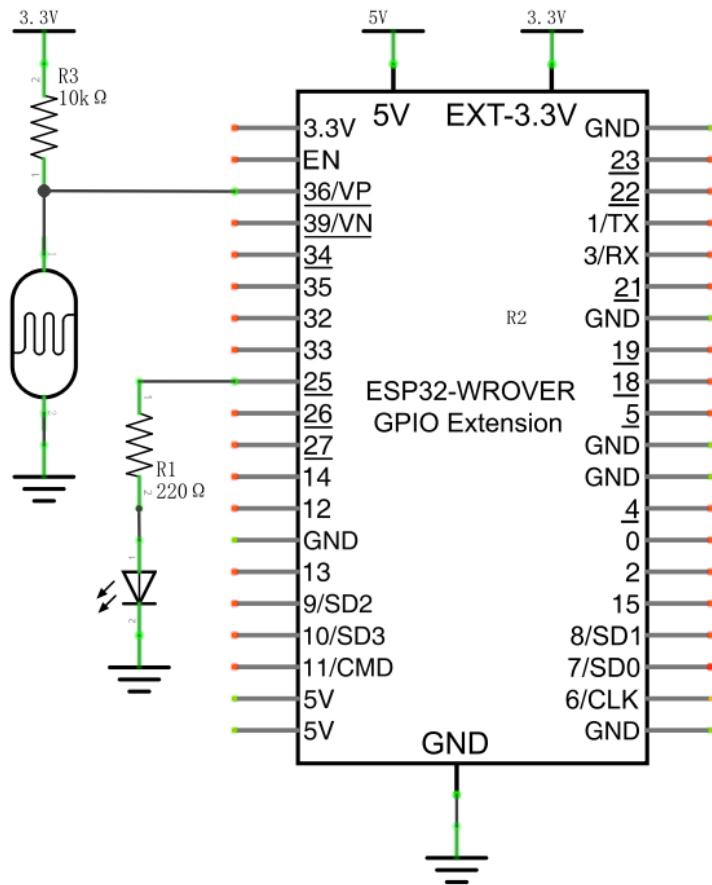


In the above circuit, when a Photoresistor's resistance value changes due to a change in light intensity, the voltage between the Photoresistor and Resistor R1 will also change. Therefore, the intensity of the light can be obtained by measuring this voltage.

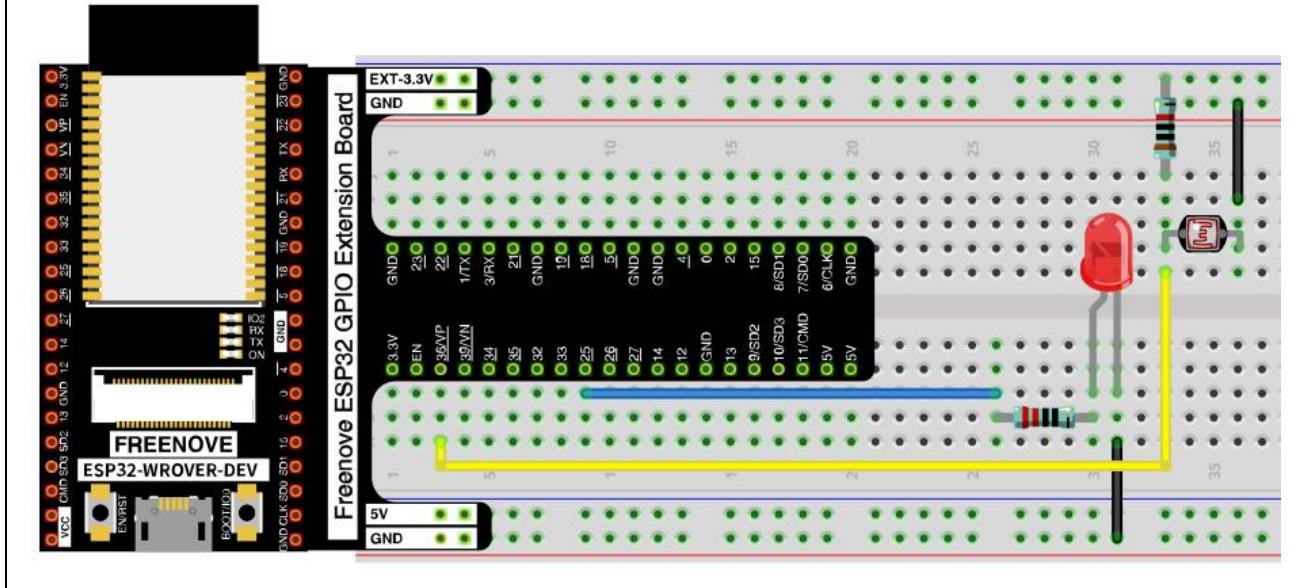
## Circuit

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)



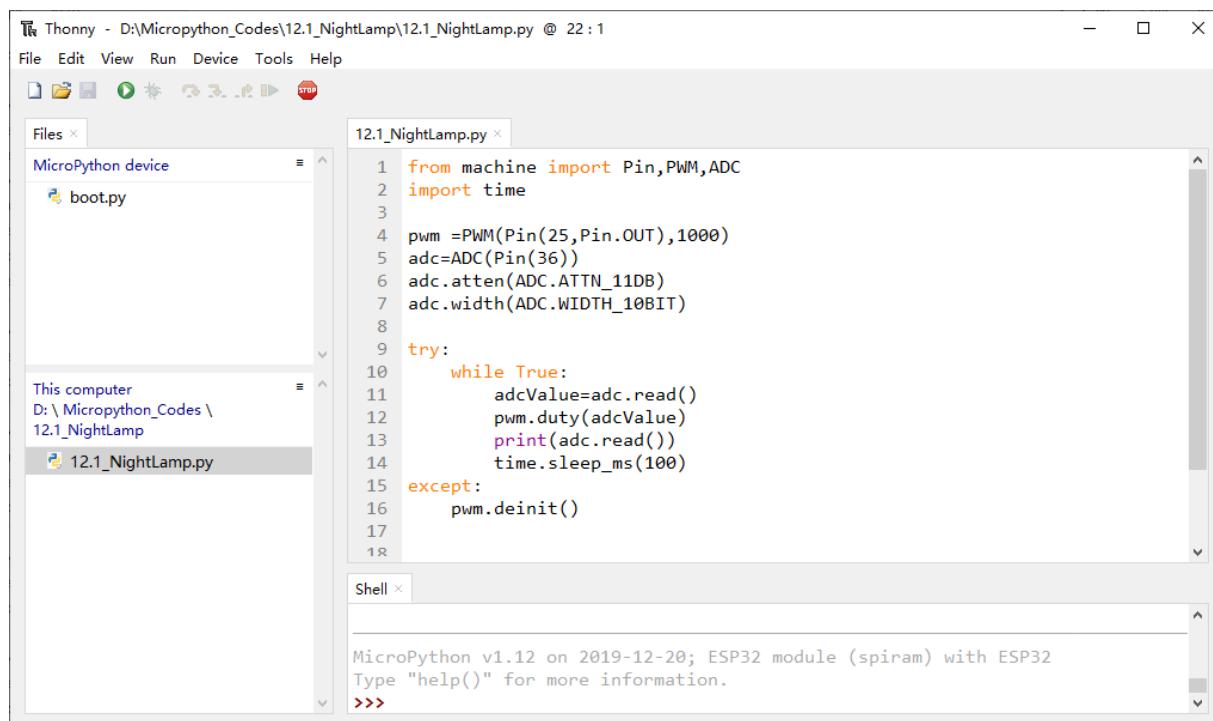
Any concerns? ✉ [support@freenove.com](mailto:support@freenove.com)

## Code

Move the program folder “**Freenove\_Super\_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](#).

### 11.1\_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()

```



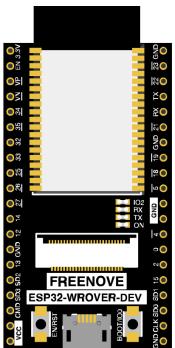
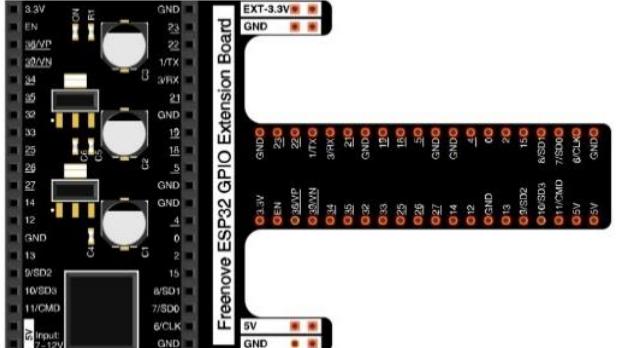
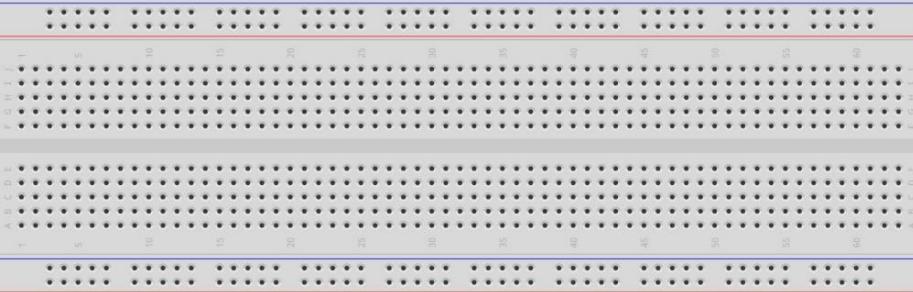
# Chapter 12 Thermistor

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

## Project 12.1 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.

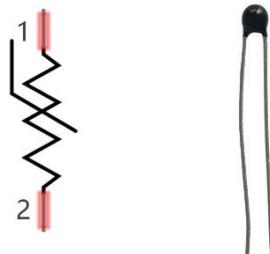
### Component List

|  |   |  |
|--|---|--|
| 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:

$R_t$  is the thermistor resistance under  $T_2$  temperature;

$R$  is the nominal resistance of thermistor under  $T_1$  temperature;

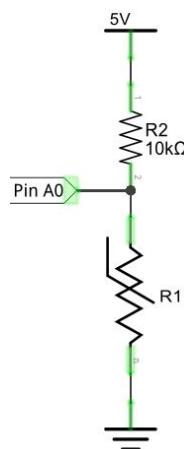
**EXP[n]** is nth power of e;

**B** is for thermal index;

$T_1, T_2$  is Kelvin temperature (absolute temperature). Kelvin temperature=273.15 + Celsius temperature.

For the parameters of the Thermistor, we use:  $B=3950$ ,  $R=10k$ ,  $T_1=25$ .

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.

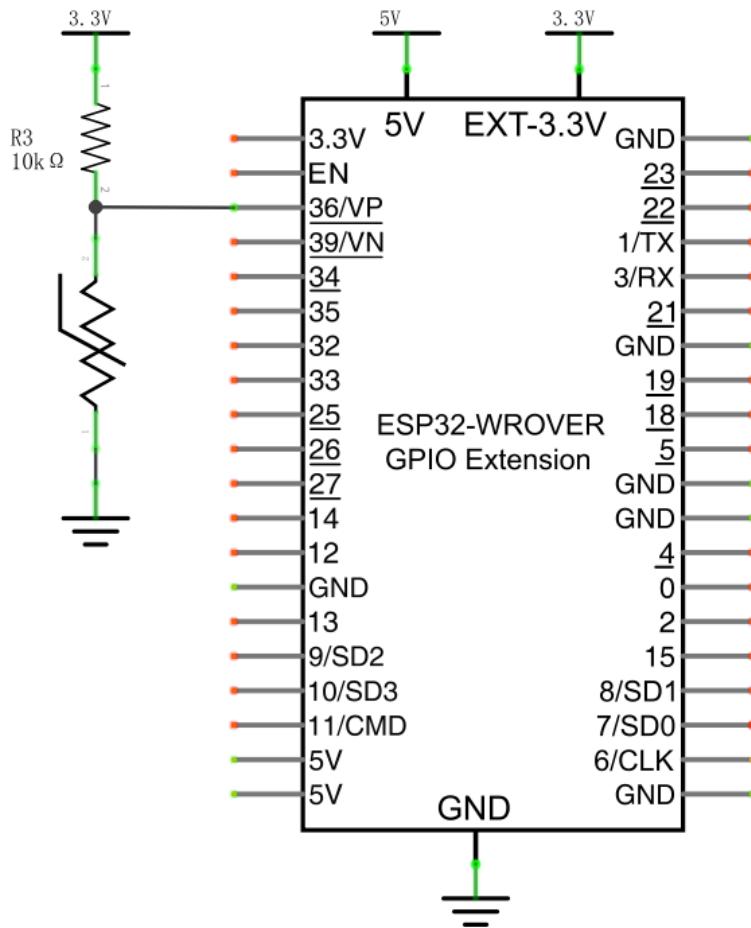
Therefore, the temperature formula can be derived as:

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

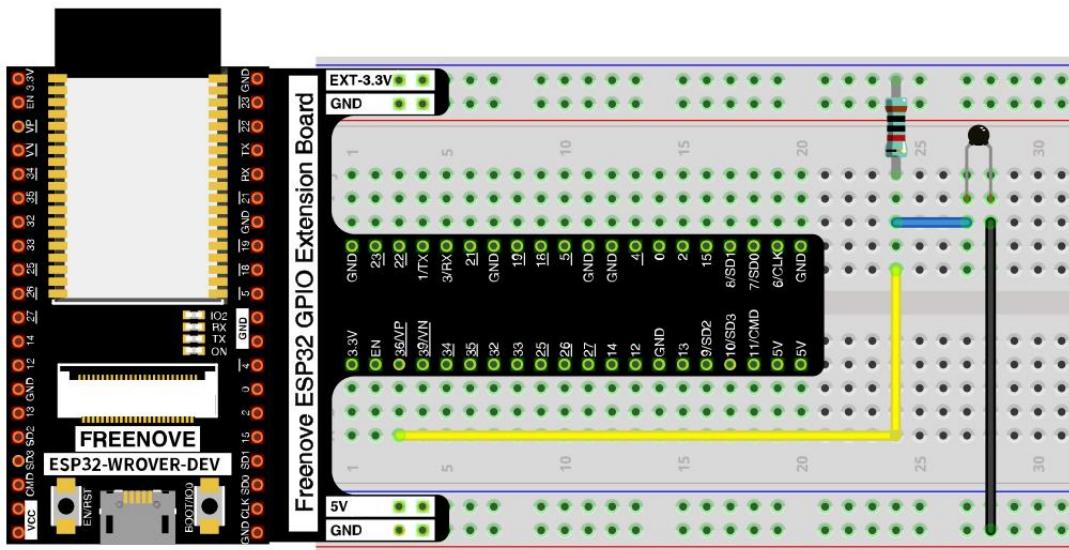
## Circuit

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)



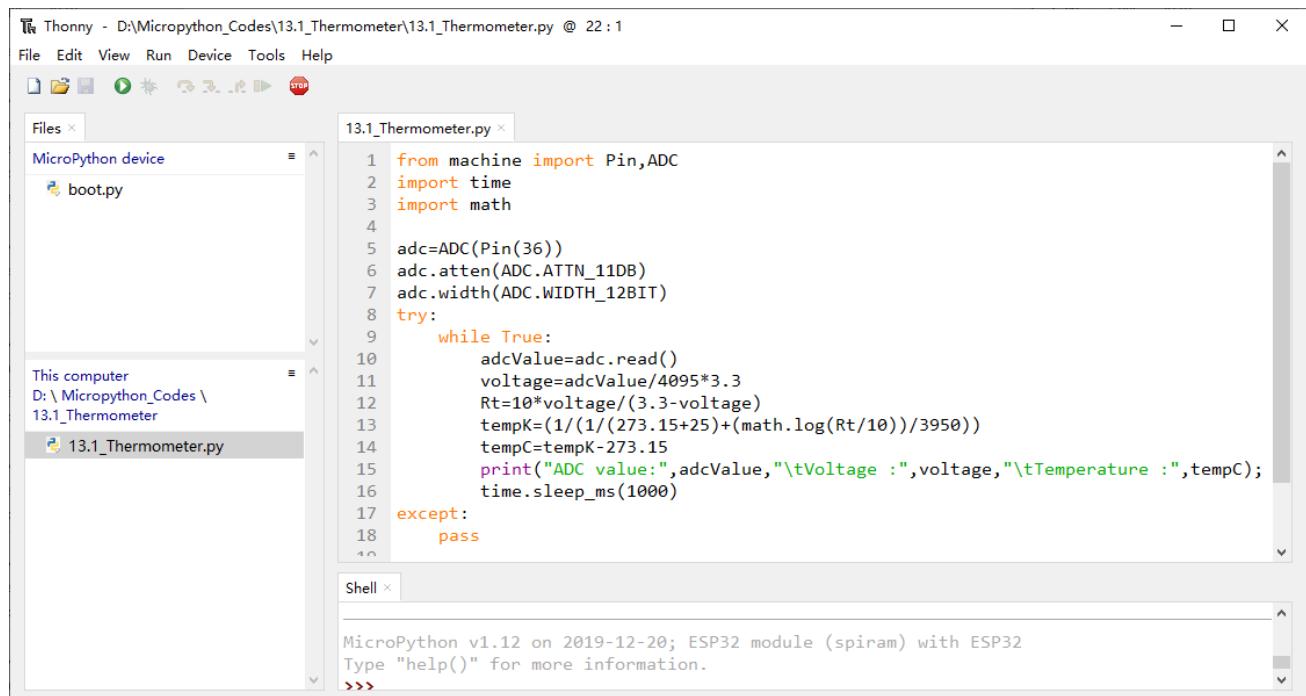
Any concerns? ✉ [support@freenove.com](mailto:support@freenove.com)

## Code

Move the program folder “**Freenove\_Super\_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” → “12.1\_Thermometer” and double click “12.1\_Thermometer.py”.

### 12.1\_Thermometer



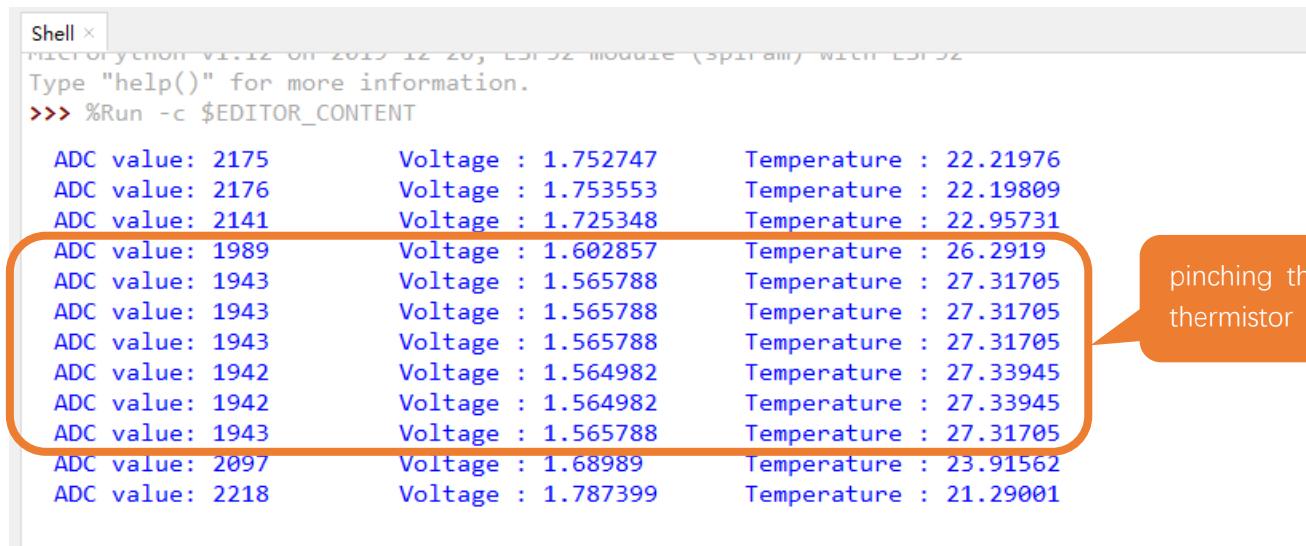
```

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 try:
9     while True:
10         adcValue=adc.read()
11         voltage=adcValue/4095*3.3
12         Rt=10*voltage/(3.3-voltage)
13         tempK=(1/(1/(273.15+25)+(math.log(Rt/10))/3950))
14         tempC=tempK-273.15
15         print("ADC value:",adcValue,"Voltage : ",voltage,"Temperature : ",tempC);
16         time.sleep_ms(1000)
17     except:
18         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

```

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,"\\tVoltage :",voltage,"\\tTemperature :",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.

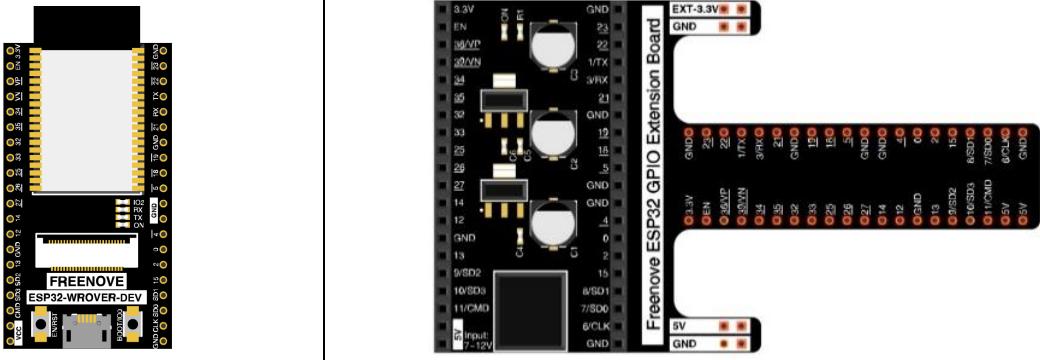
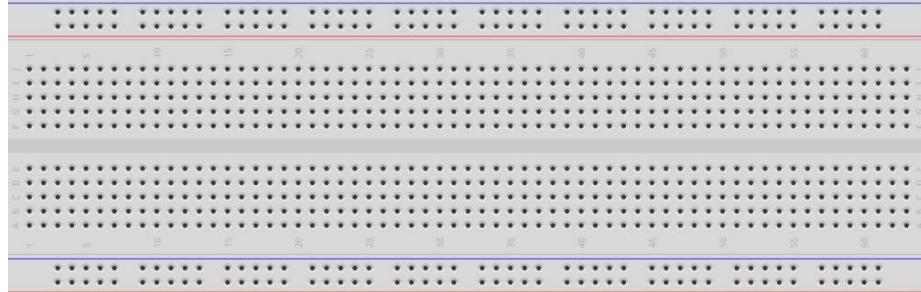
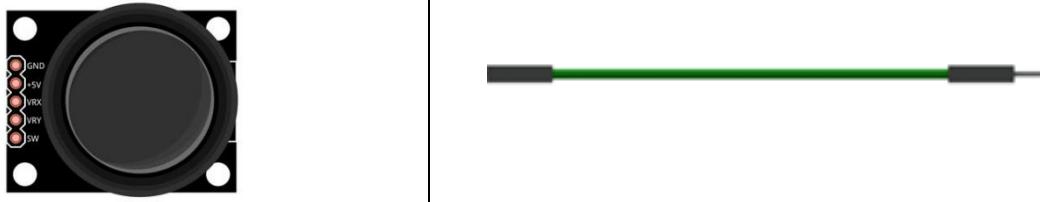
# Chapter 13 Joystick

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 13.1 Joystick

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

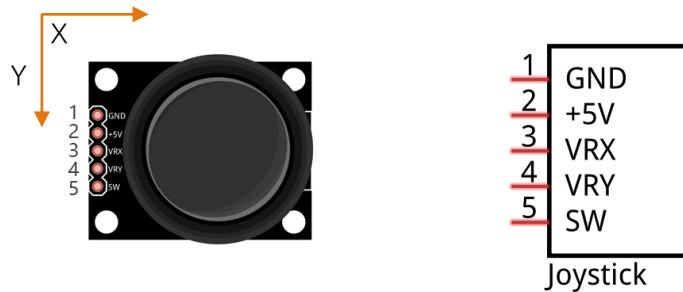
### Component List

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

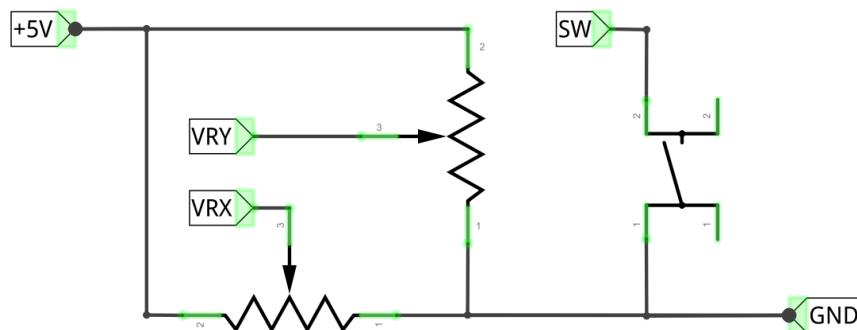
## Component knowledge

### 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).



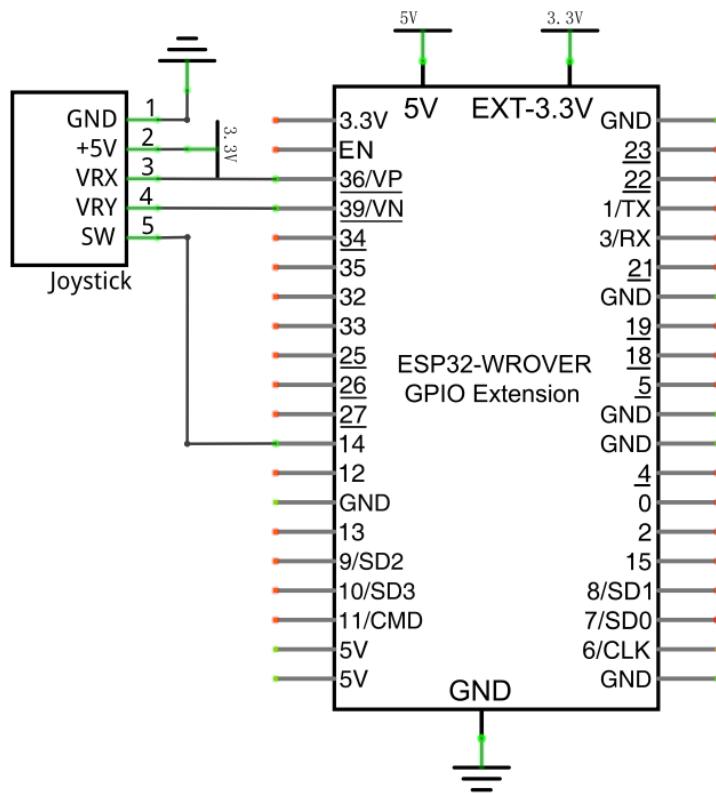
This is accomplished by incorporating two rotary potentiometers inside the Joystick Module at 90 degrees of each other, placed in such a manner as to detect shifts in direction in two directions simultaneously and with a Push Button Switch in the “vertical” axis, which can detect when a User presses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



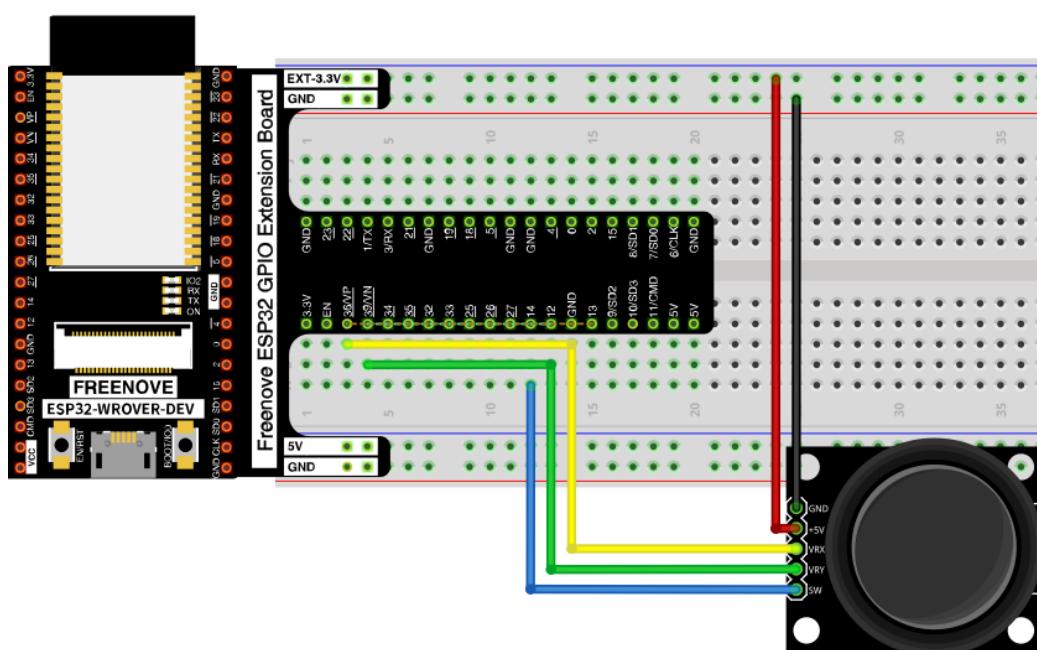
When the Joystick data is read, there are some differences between the axes: data of X and Y axes is analog, which needs to use the ADC. The data of the Z axis is digital, so you can directly use the GPIO to read this data or you have the option to use the ADC to read this.

## Circuit

Schematic diagram



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



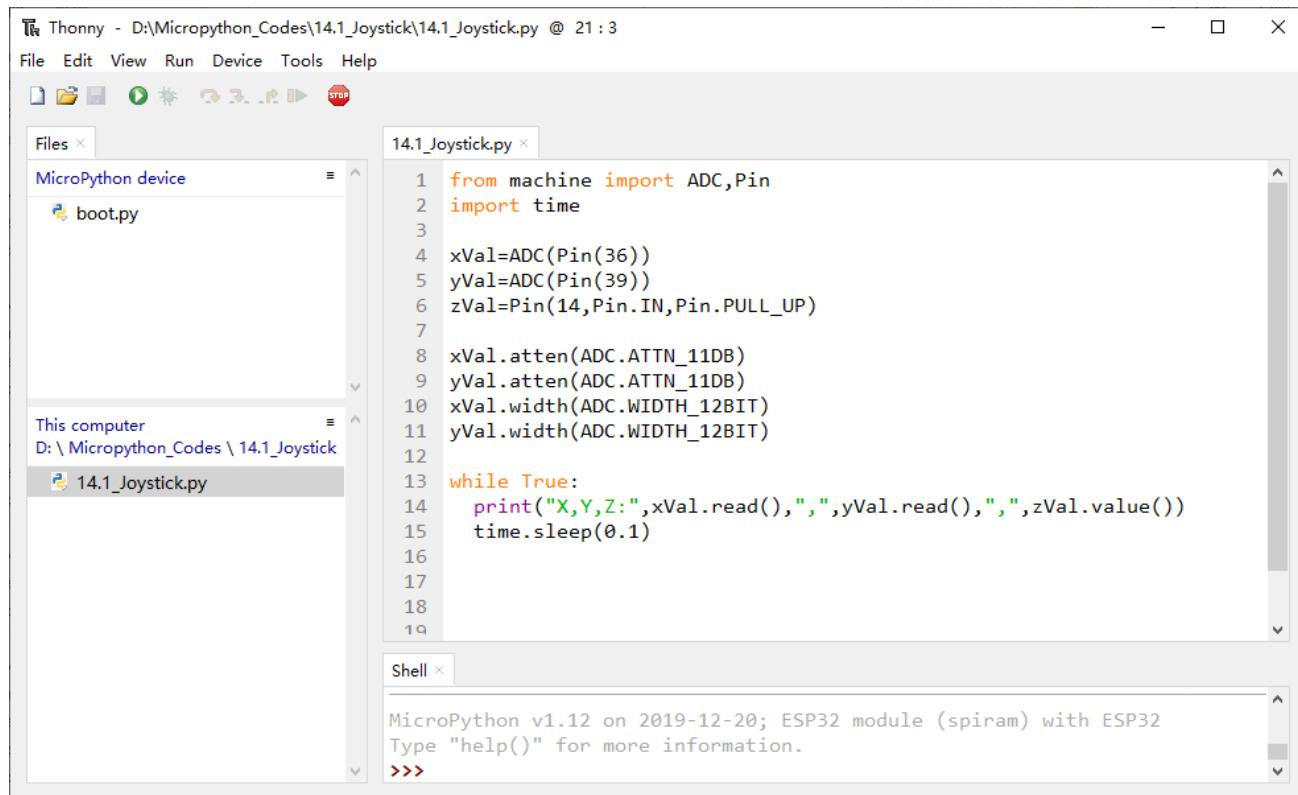
## Code

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\_Super\_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\_Joystick” and double click “13.1\_Joystick.py”.

### 13.1\_Joystick



```

from machine import ADC,Pin
import time

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

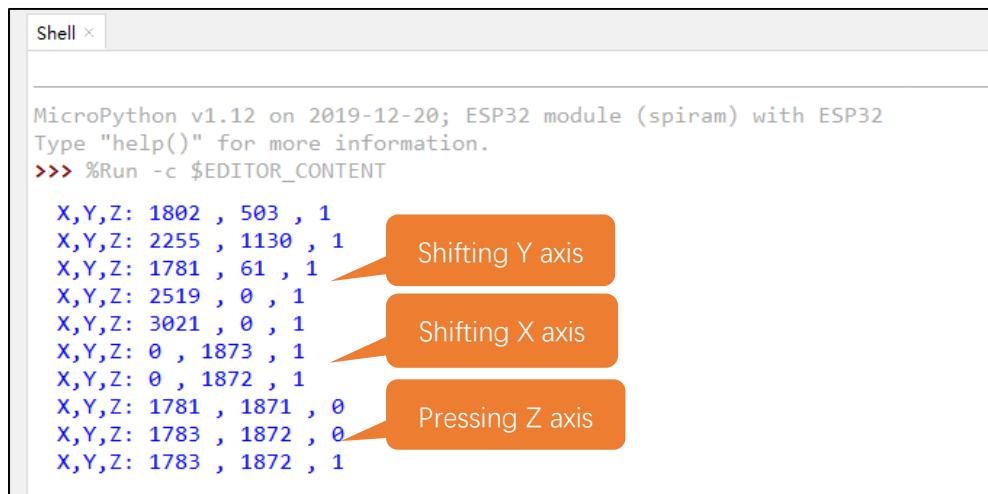
xVal.atten(ADC.ATTN_11DB)
yVal.atten(ADC.ATTN_11DB)
xVal.width(ADC.WIDTH_12BIT)
yVal.width(ADC.WIDTH_12BIT)

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

```

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

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 14 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 14.1 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

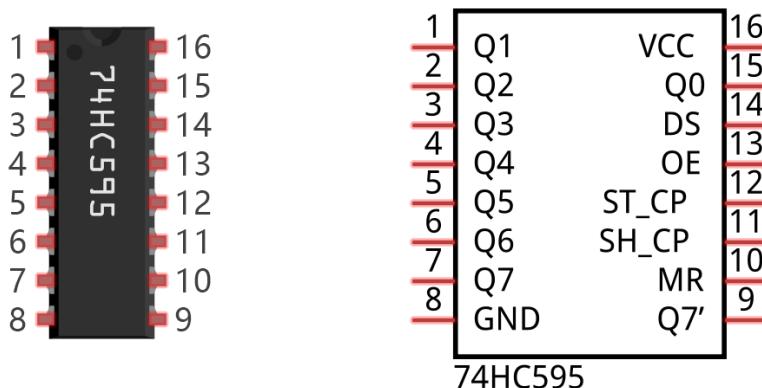
|                  |                         |
|------------------|-------------------------|
| ESP32-WROVER x1  | GPIO Extension Board x1 |
|                  |                         |
| Breadboard x1    |                         |
|                  |                         |
| 74HC595 x1      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

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

## 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.



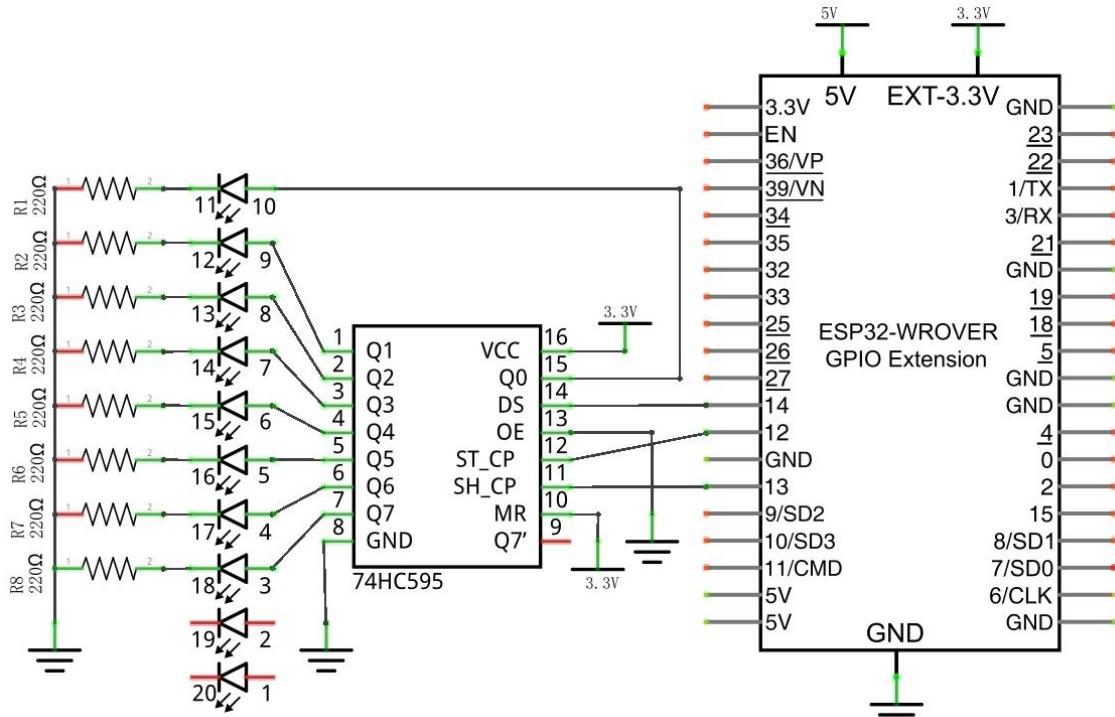
The ports of the 74HC595 chip are described as follows:

| 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,<br>When this pin is in high level, Q0-Q7 is in high resistance state<br>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.  |

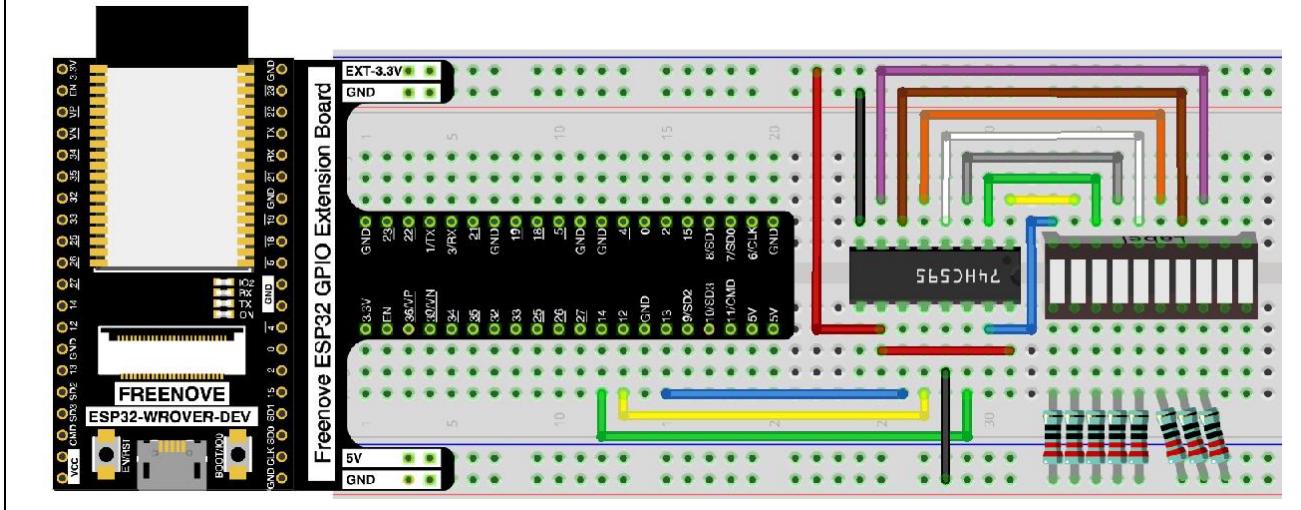
For more detail, please refer to the datasheet on the 74HC595 chip.

## 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\_Super\_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\_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 “14.1\_Flowing\_Water\_Light.py”.

### 14.1\_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 left sidebar shows a file tree with a MicroPython device section containing boot.py and my74HC595.py, and a This computer section containing 15.1\_Flowing\_Water\_Light, boot.py, and my74HC595.py. A context menu is open over my74HC595.py in the This computer section, with "Upload to /" highlighted. The main editor window displays the Python code for the 14.1\_Flowing\_Water\_Light script. The status bar at the bottom indicates the code was generated on 2019-12-20 for an ESP32 module with SPIRAM.

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..

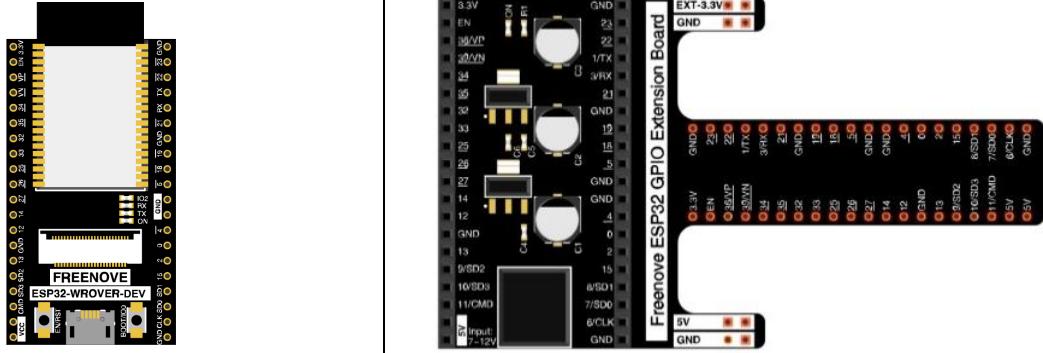
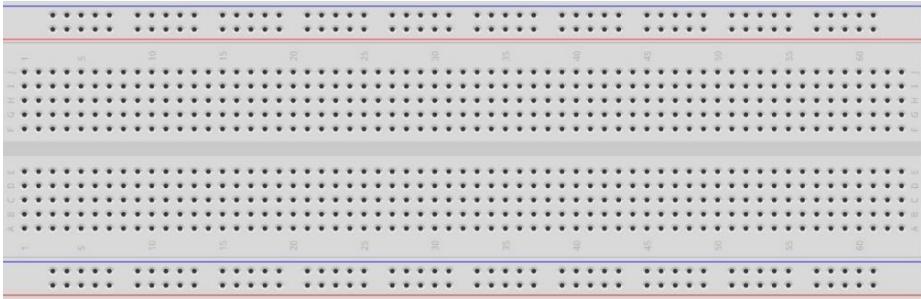
# Chapter 15 74HC595 & 7-Segment Display.

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

## Project 15.1 7-Segment Display.

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

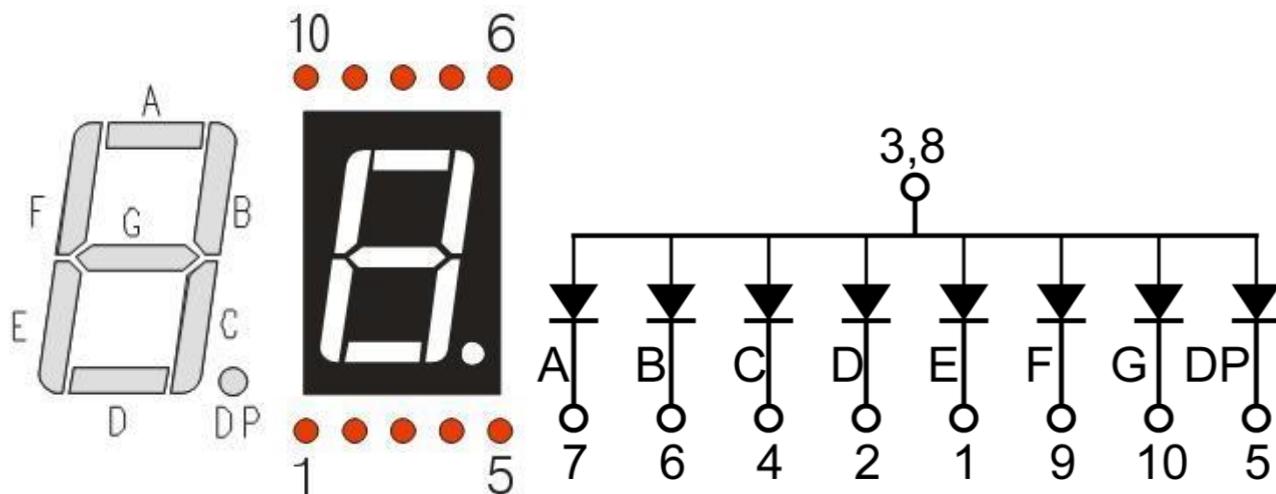
### Component List

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

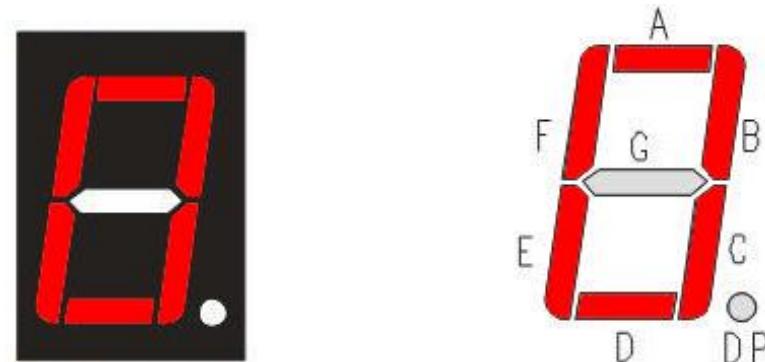
## Component knowledge

### 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.



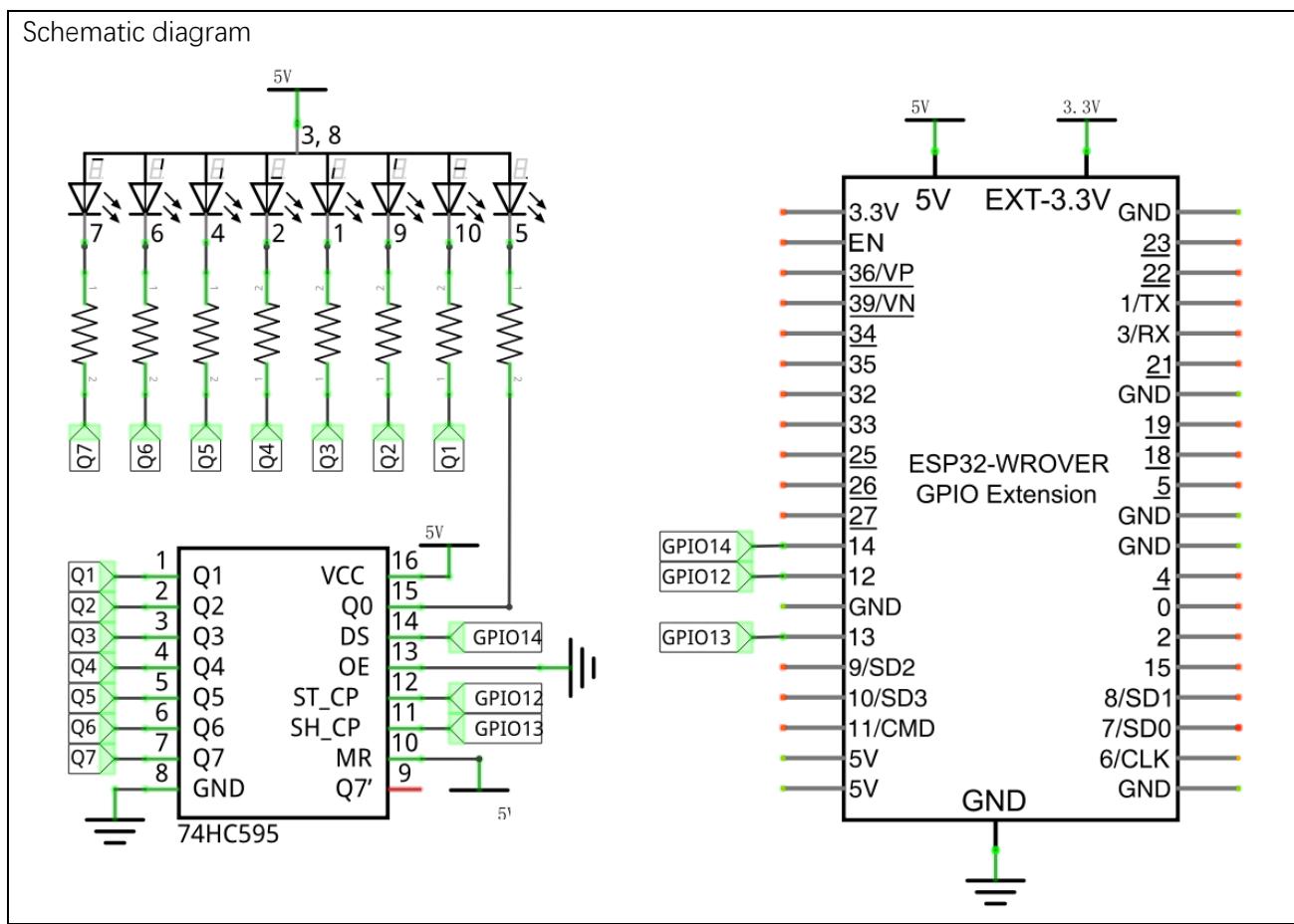
In this project, we will use a 7-Segment Display with a Common Anode. Therefore, when there is an input low level to an LED segment the LED will turn ON. Defining segment "A" as the lowest level and segment "DP" as the highest level, from high to low would look like this: "DP", "G", "F", "E", "D", "C",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



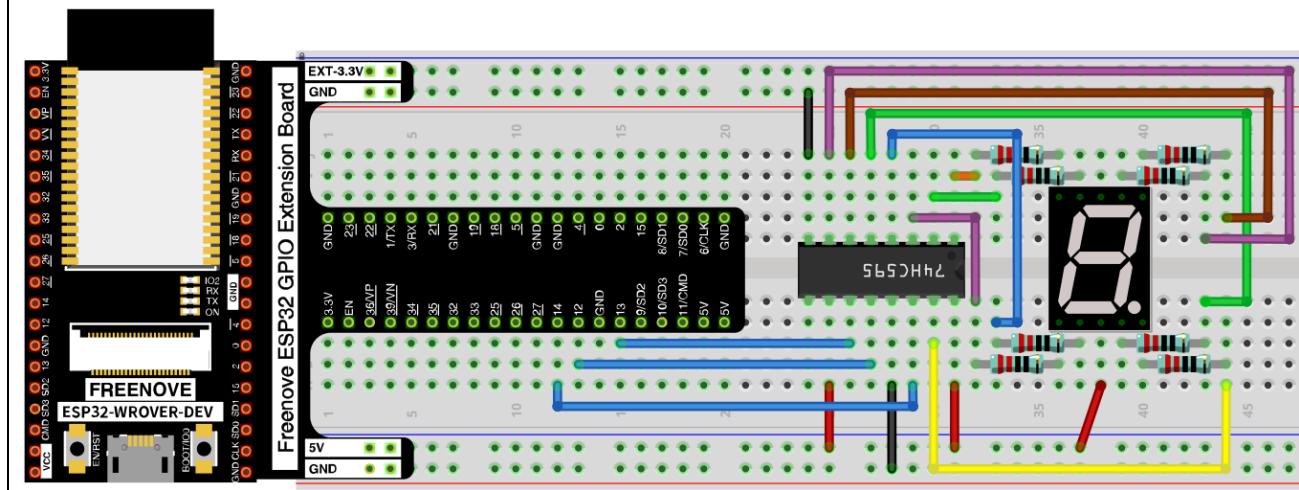
For detailed code values, please refer to the following table (common anode).

| 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

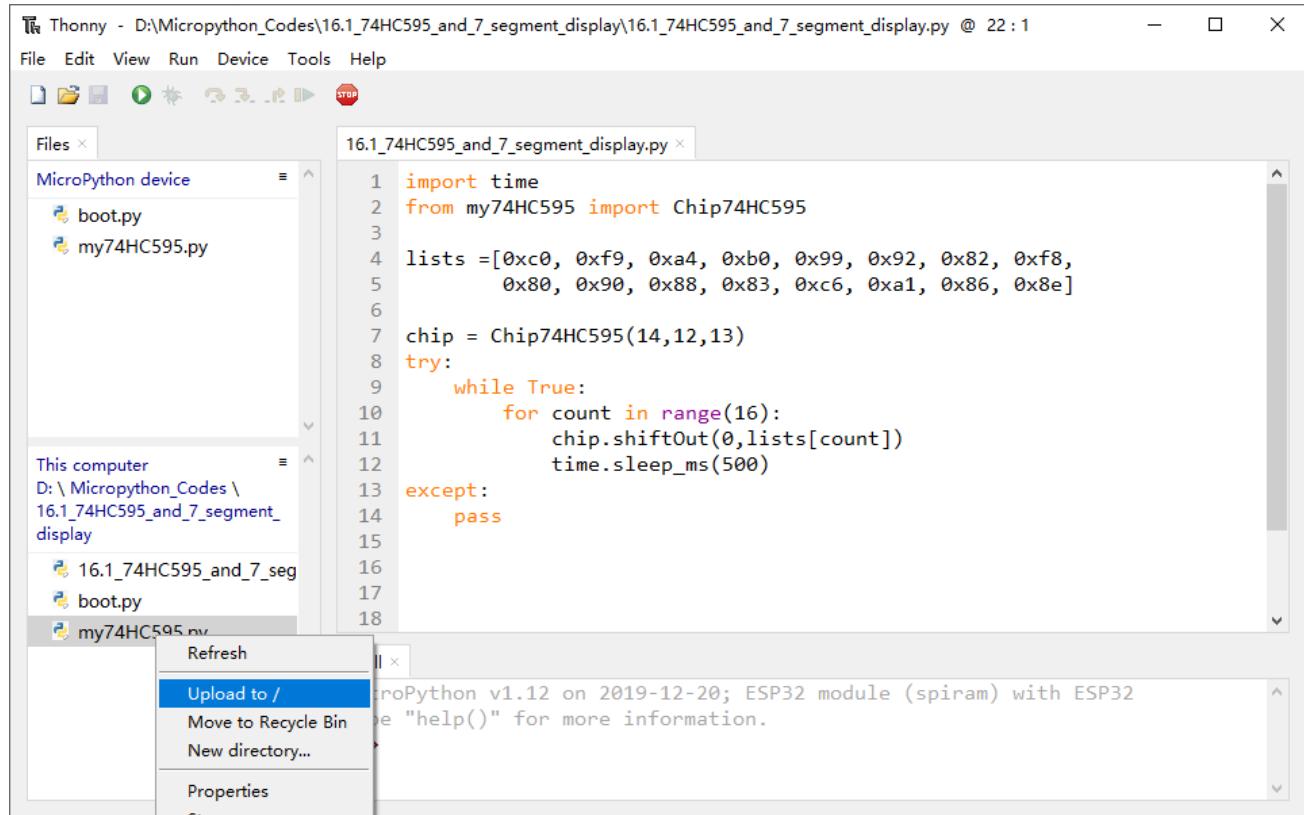
In this section, the 74HC595 is used in the same way as in the previous section, but with different values transferred. We can learn how to master the digital display by sending the code value of "0" - "F".

Move the program folder “**Freenove\_Super\_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\_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“15.1\_74HC595\_and\_7\_segment\_display.py”.

### 15.1\_74HC595\_and\_7\_segment\_display

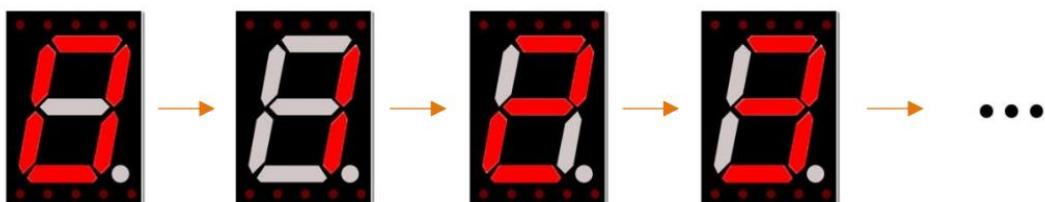


```

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
15
16
17
18

```

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])
```



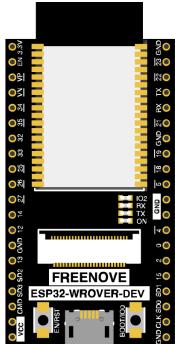
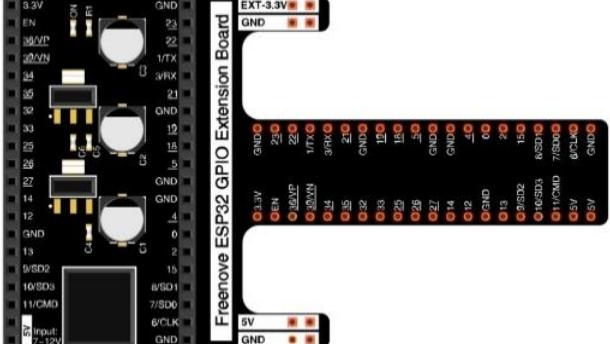
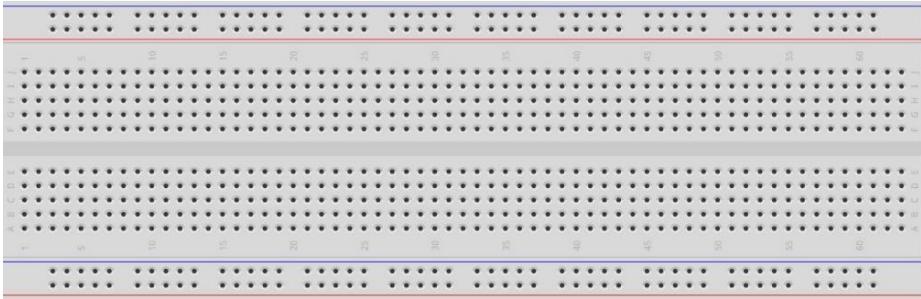
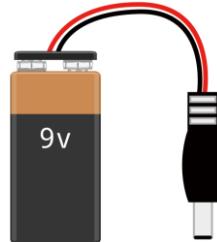
# Chapter 16 Relay & Motor

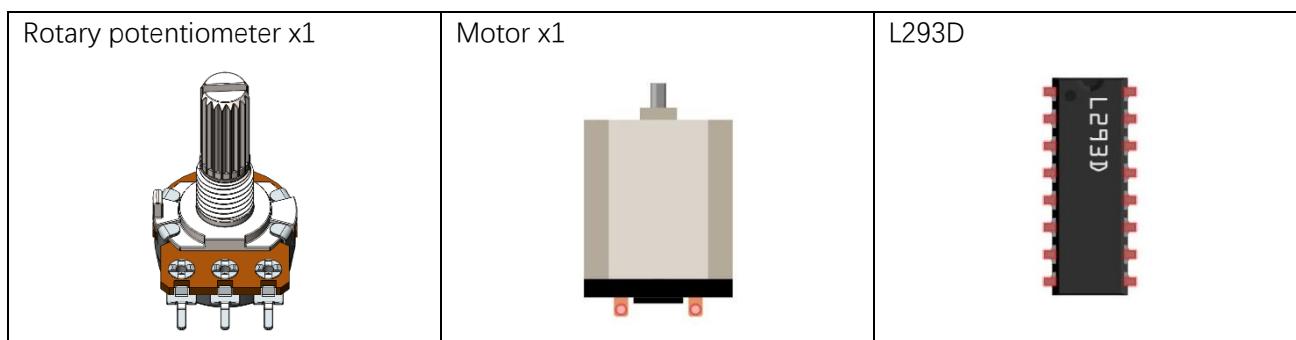
In this chapter, we will learn a kind of special switch module, Relay Module.

## Project 16.1 Control Motor with Potentiometer

Control the direction and speed of the motor with a potentiometer.

### Component List

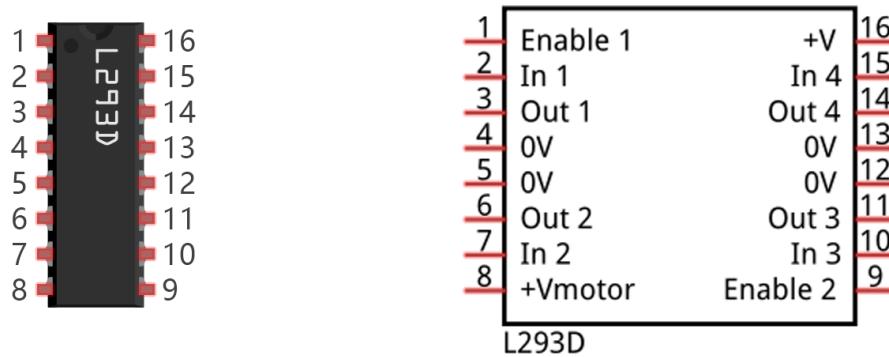
|  |   |                         |   |
|--|---|-------------------------|---|
| ESP32-WROVER x1                                  |     | GPIO Extension Board x1 |  |
| Breadboard x1                                    |   |                         |   |
| Jumper M/M                                       |    |                         |   |
| 9V battery (prepared by yourself) & battery line |  |                         |   |



## 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).



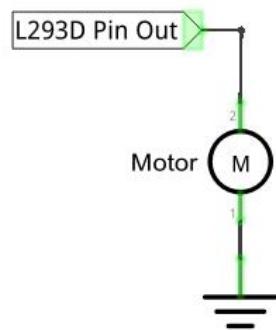
Port description of L293D module is as follows:

| 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 |

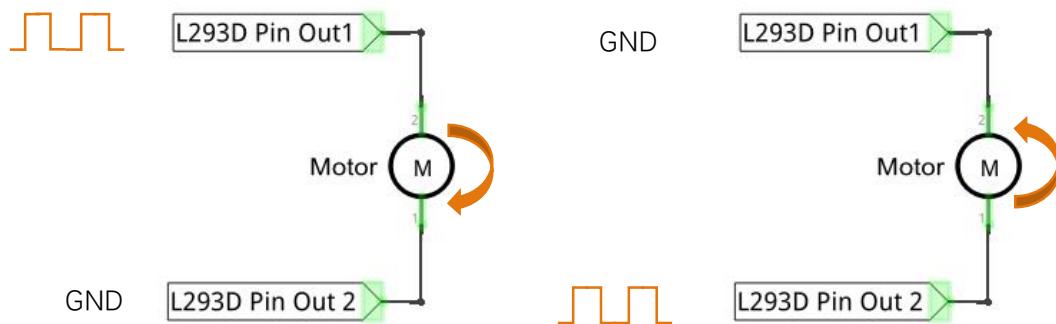
For more detail, please refer to the datasheet for this IC Chip.

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.



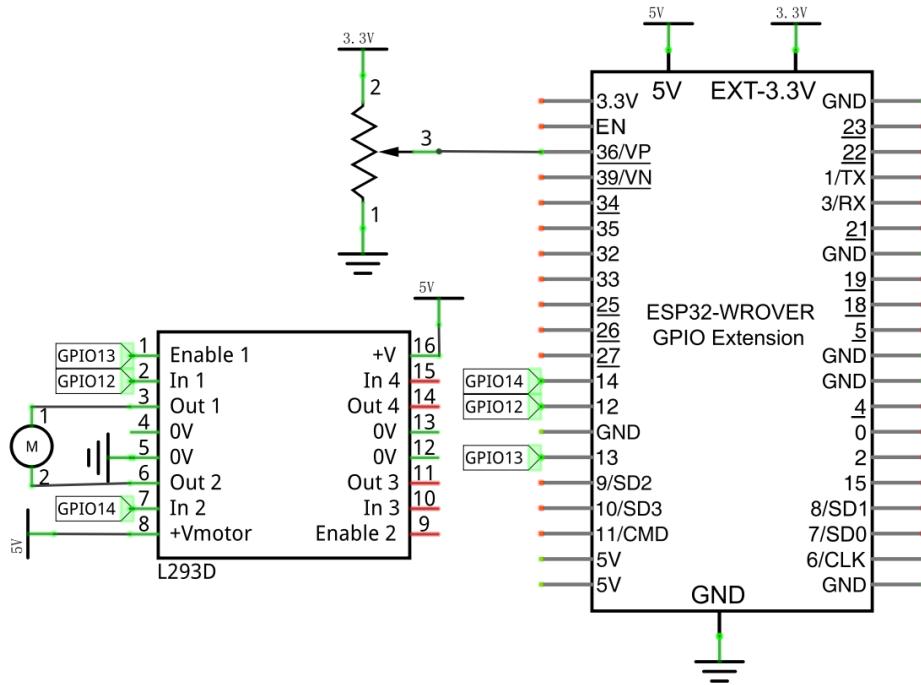
The following connection uses two channels of the L293D: one channel outputs the PWM wave, and the other channel connects to GND, therefore you can control the speed of the motor. When these two channel signals are exchanged, not only can they control the speed of motor, but also control the direction of the motor.



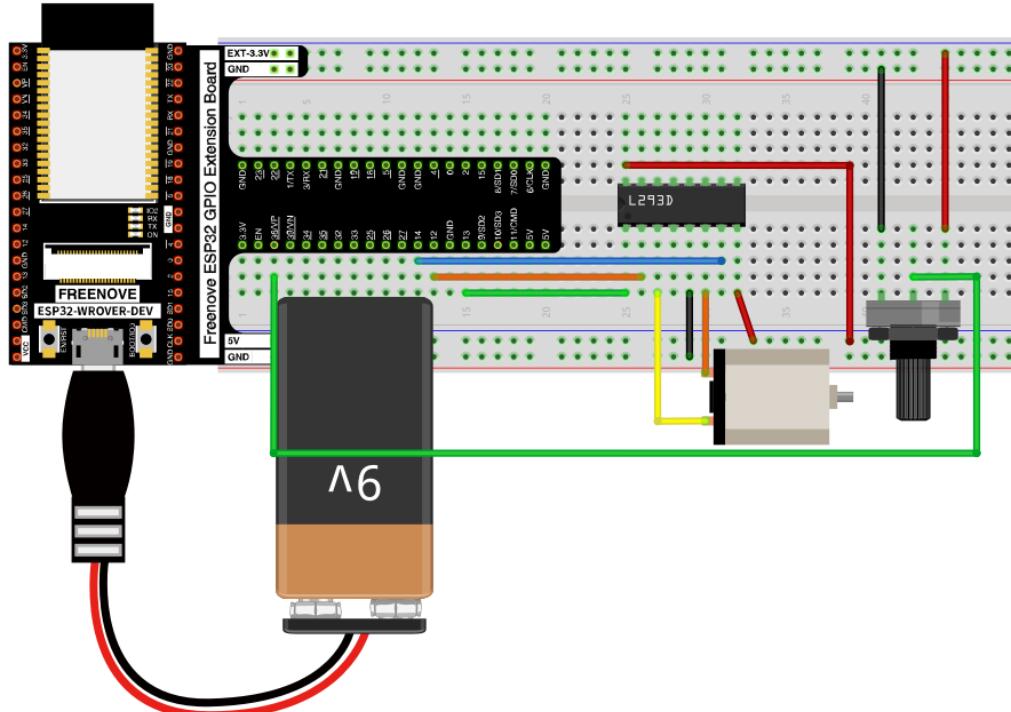
In practical use the motor is usually connected to channels 1 and 2 by outputting different levels to in1 and in2 to control the rotational direction of the motor, and output to the PWM wave to Enable1 port to control the motor's rotational speed. If the motor is connected to channel 3 and 4 by outputting 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\_Super\_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\_Motor\_And\_Driver” and double click “16.1\_Motor\_And\_Driver.py”.

### 16.1\_Motor\_And\_Driver

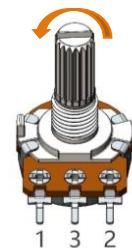
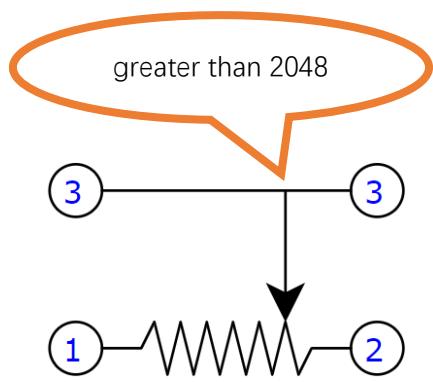
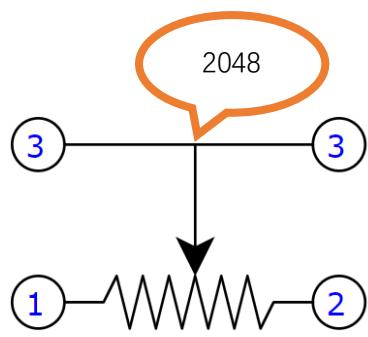
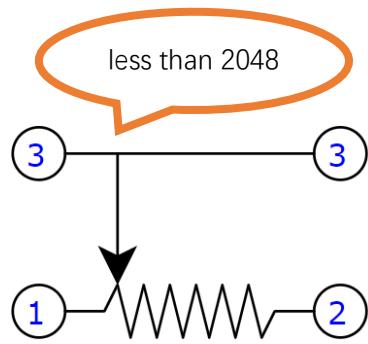
```

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
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)

```

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)

```

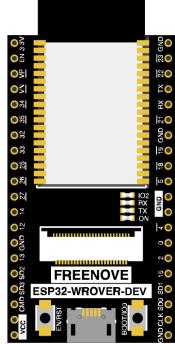
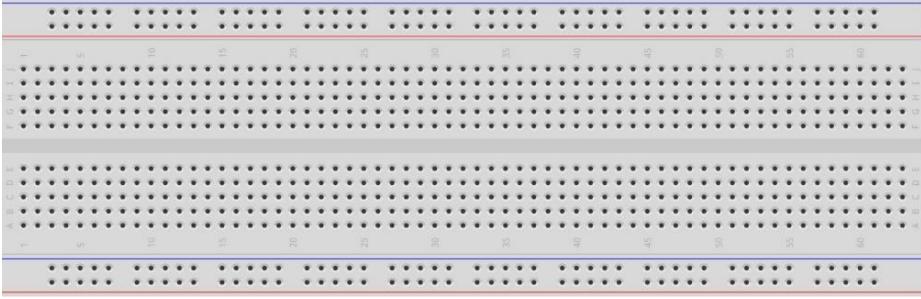
# Chapter 17 Servo

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 17.1 Servo Sweep

First, we need to learn how to make a Servo rotate.

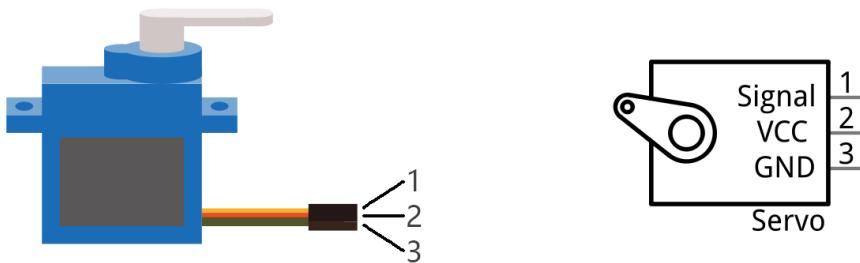
### Component List

|  |  |
|--|--|
| 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:

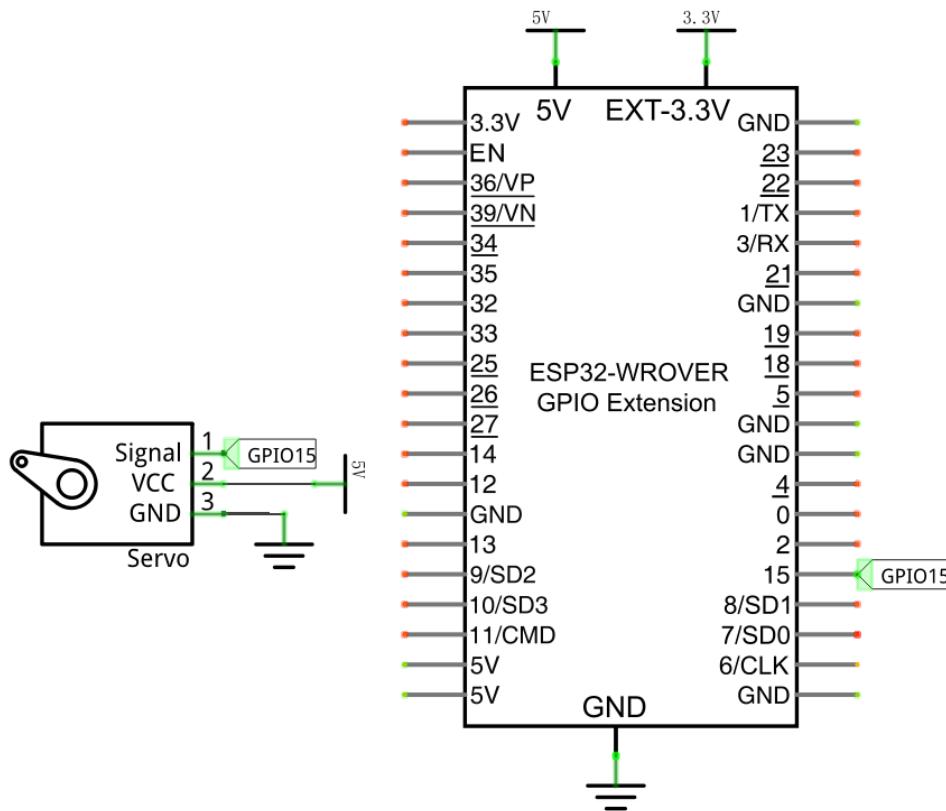
| High level time | Servo angle |
|-----------------|-------------|
| 0.5ms           | 0 degree    |
| 1ms             | 45 degree   |
| 1.5ms           | 0 degree    |
| 2ms             | 45 degree   |
| 2.5ms           | 180 degree  |

When you change the Servo signal value, the Servo will rotate to the designated angle.

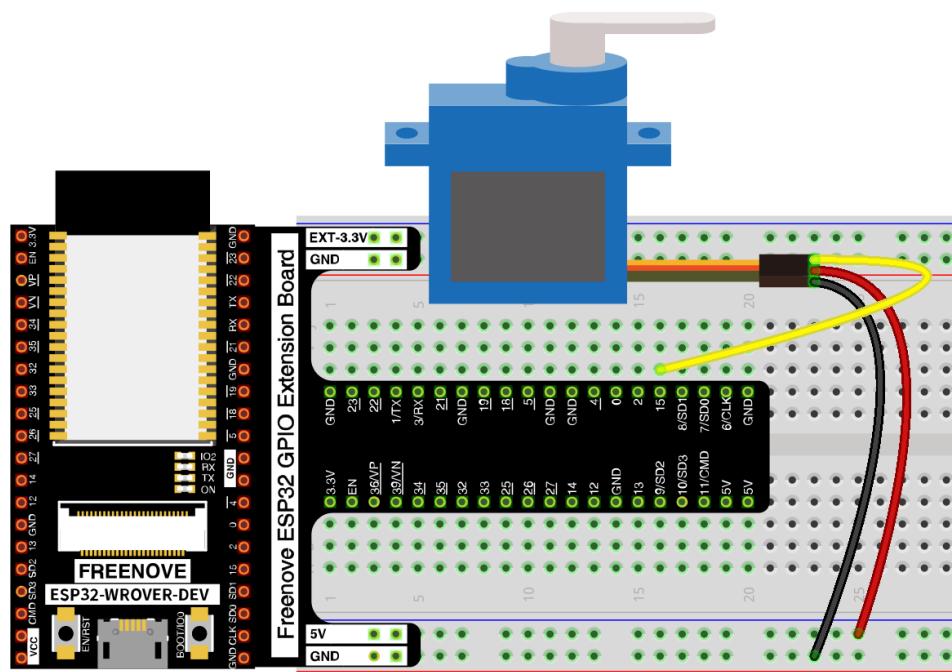
## Circuit

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)



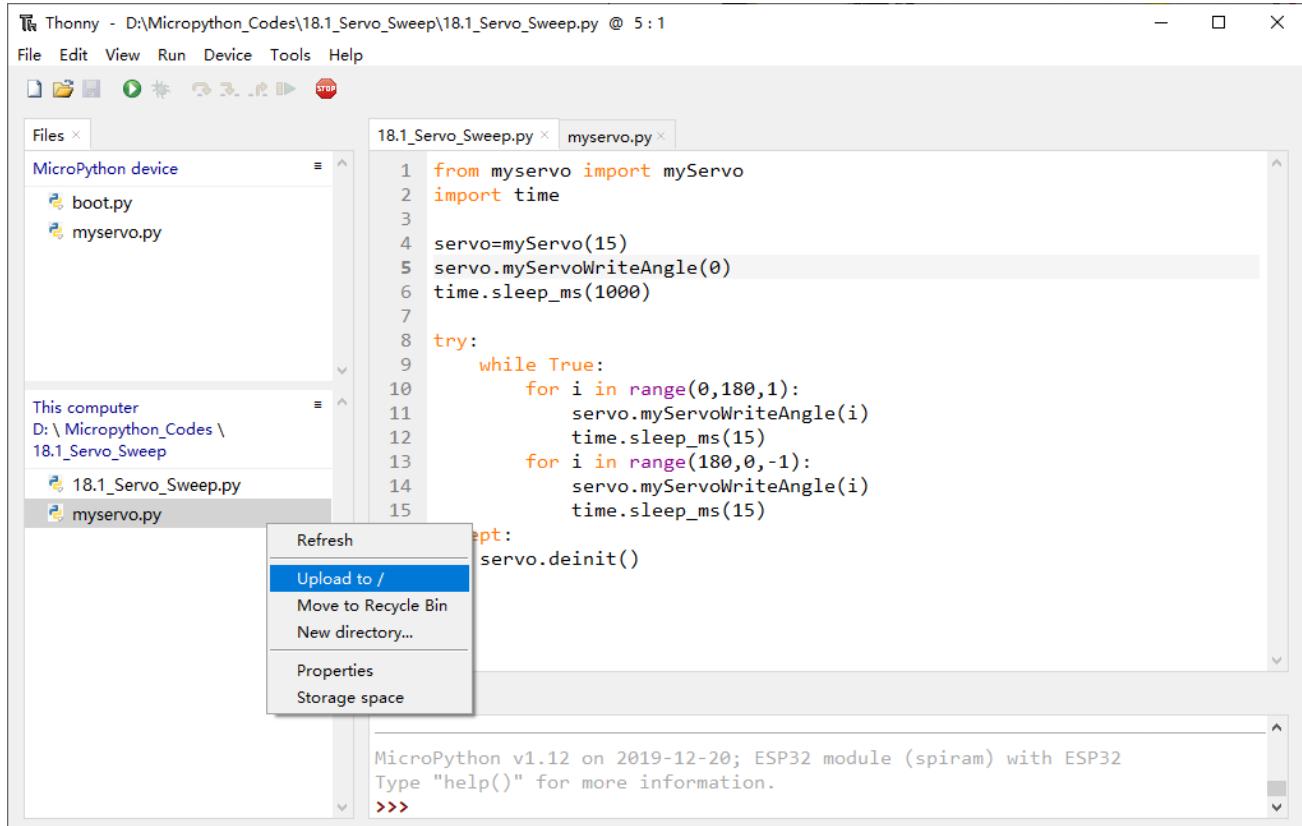
Any concerns? [✉ support@freenove.com](mailto:support@freenove.com)

## Code

Move the program folder “**Freenove\_Super\_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\_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 “17.1\_Servo\_Sweep.py”.

### 17.1\_Servo\_Sweep



```

from myservo import myServo
import time

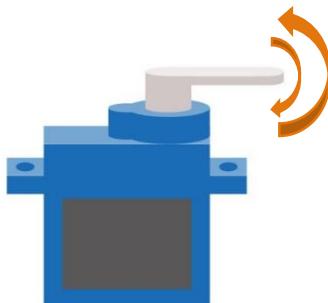
servo=myServo(15)
servo.myServoWriteAngle(0)
time.sleep_ms(1000)

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()

```

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

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.

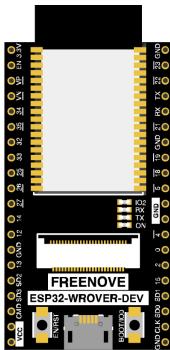
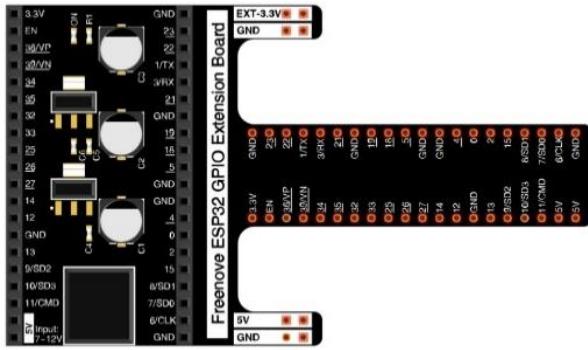
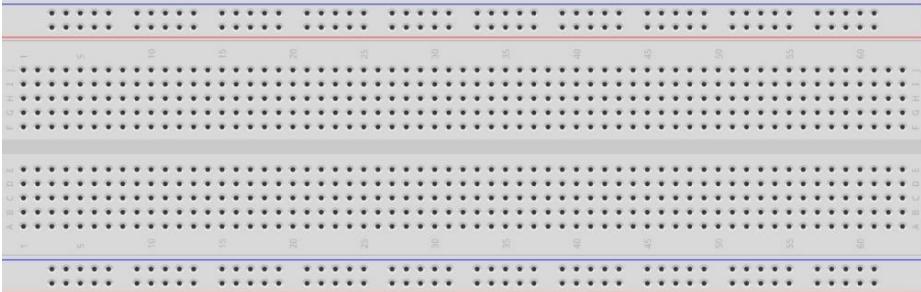
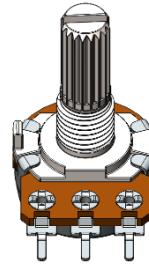
**myServoWriteTime(us)**: Writes time to control the servo.

**us**: Range from 500-2500, with 500 corresponding to the servo's 0 degree and 2500 corresponding to 180 degrees.

## Project 17.2 Servo Knop

Use a potentiometer to control the servo motor to rotate at any angle.

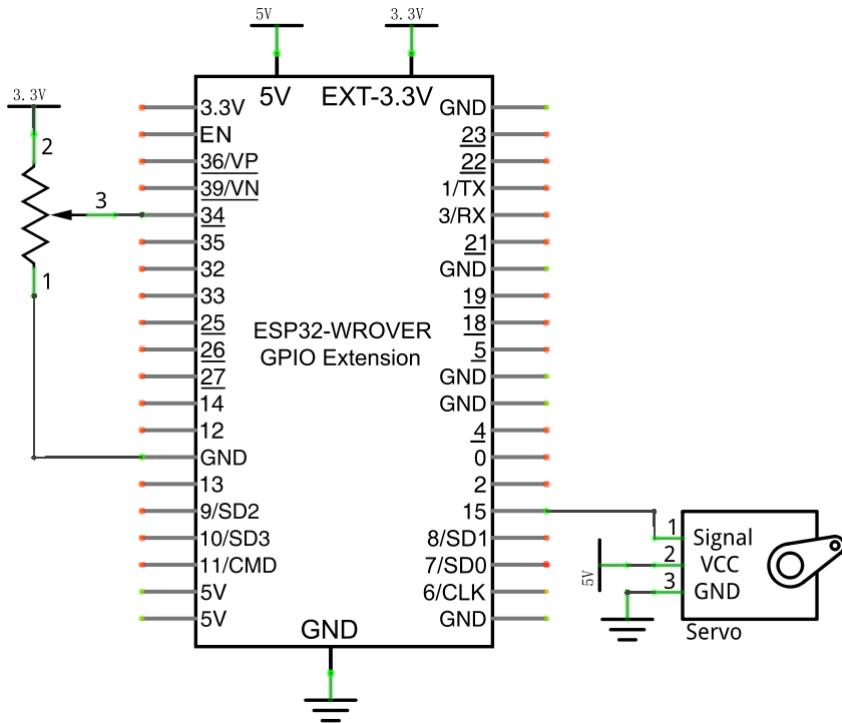
### Component List

|   |  |   |
|---|--|---|
| ESP32-WROVER x1   | GPIO Extension Board x1  |   |
|    |    |   |
| Breadboard x1   |   |   |
| Servo x1  | Jumper M/M x6  | Rotary potentiometer x1   |
|  |  |  |

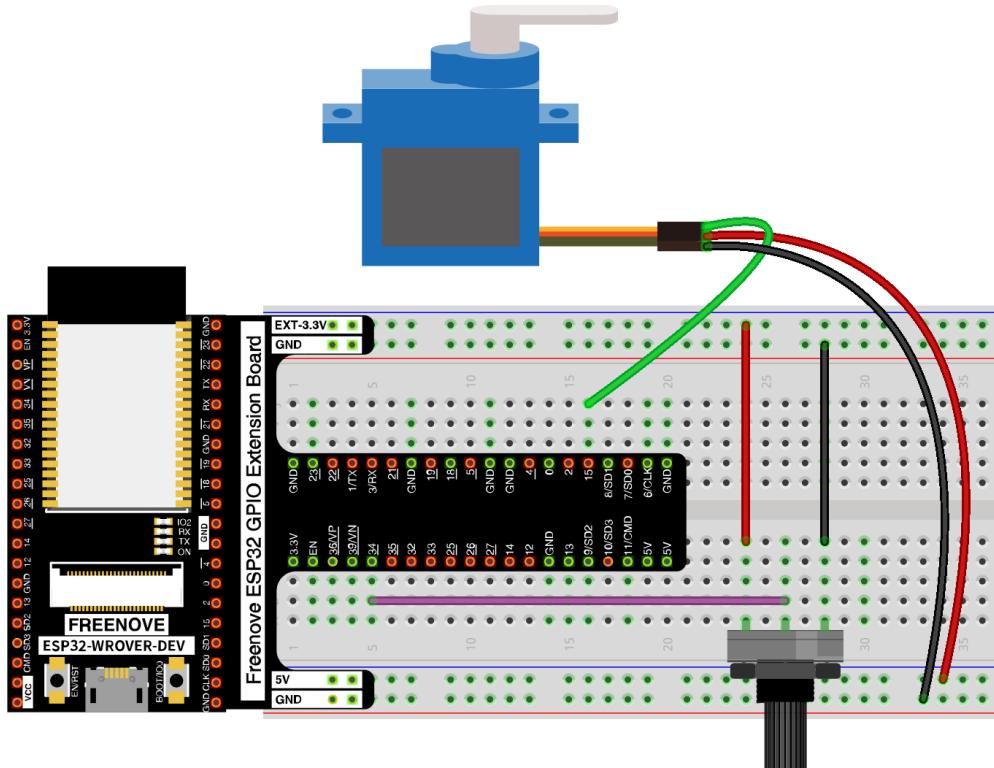
## Circuit

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)



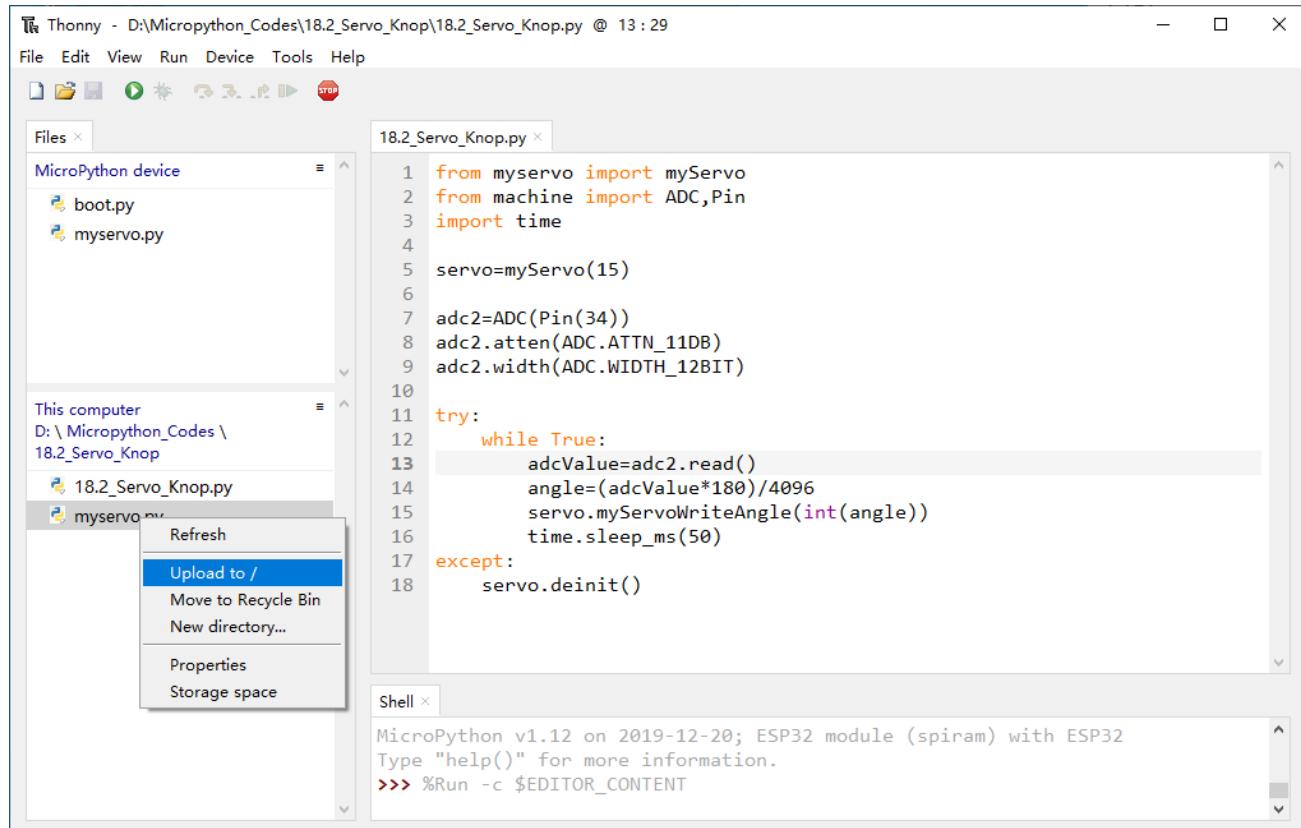
Any concerns? ✉ [support@freenove.com](mailto:support@freenove.com)

## Code

Move the program folder “**Freenove\_Super\_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\_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 “17.2\_Servo\_Knop.py”.

### 17.2\_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, Help. The toolbar has icons for file operations like Open, Save, Run, Stop, and Refresh. The left sidebar shows a "Files" tab with a tree view of files: "MicroPython device" contains "boot.py" and "myservo.py"; "This computer" shows "D:\Micropython\_Codes\18.2\_Servo\_Knop" containing "18.2\_Servo\_Knop.py" and "myservo.py". A context menu is open over "myservo.py" with options: Refresh, Upload to / (highlighted in blue), Move to Recycle Bin, New directory..., Properties, Storage space. The main code editor window displays the following Python 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()

```

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.

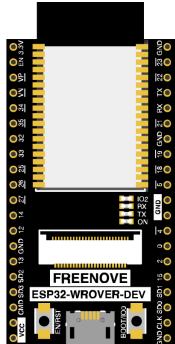
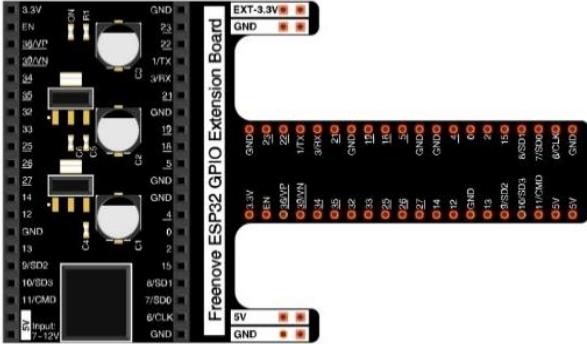
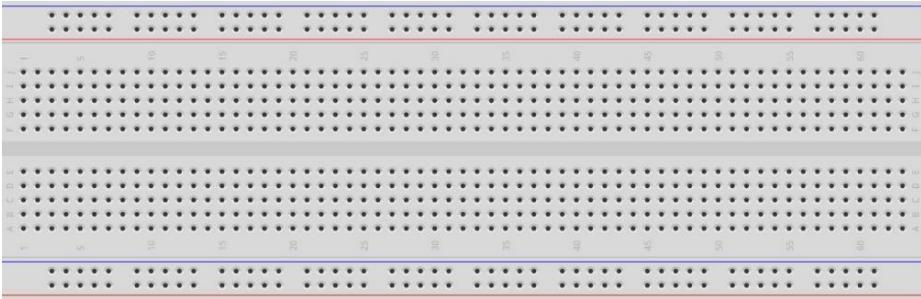
# Chapter 18 LCD1602

In this chapter, we will learn about the LCD1602 Display Screen

## Project 18.1 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  |



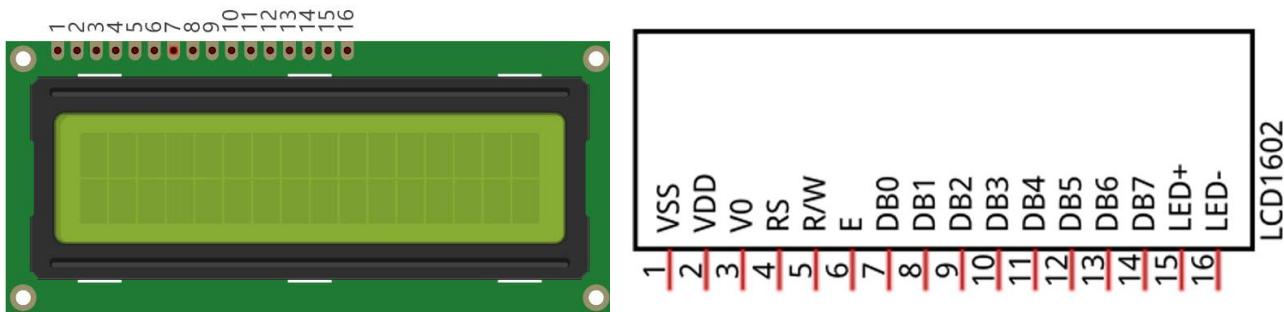
## Component knowledge

### I2C communication

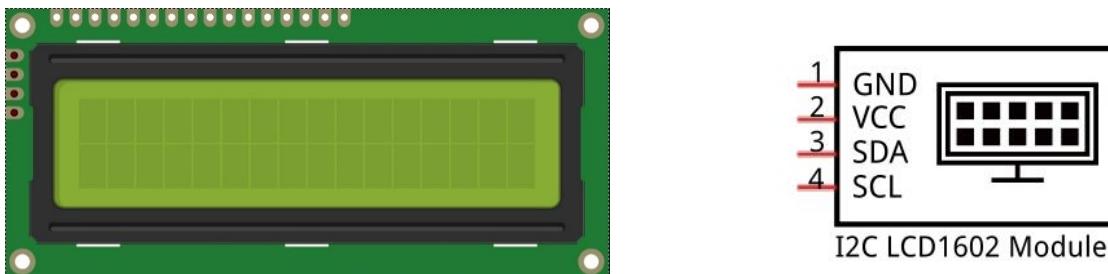
I2C (Inter-Integrated Circuit) is a two-wire serial communication mode, which can be used for the connection of micro controllers and their peripheral equipment. Devices using I2C communication must be connected to the serial data (SDA) line, and serial clock (SCL) line (called I2C bus). Each device 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

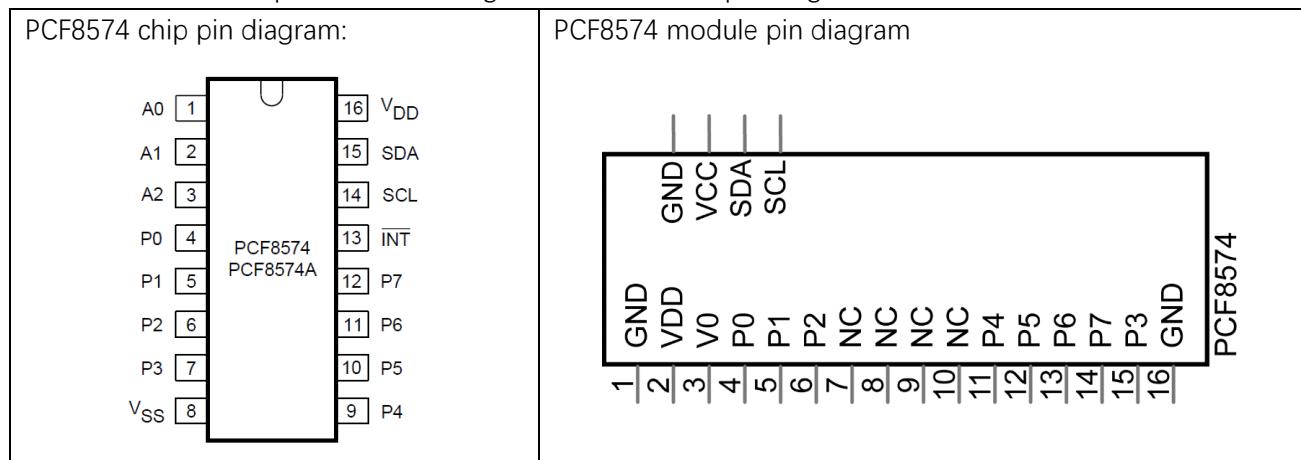


I2C LCD1602 Display Screen integrates an I2C interface, which connects the serial-input & parallel-output module to the LCD1602 Display Screen. This allows us to use only 4 lines to operate the LCD1602.

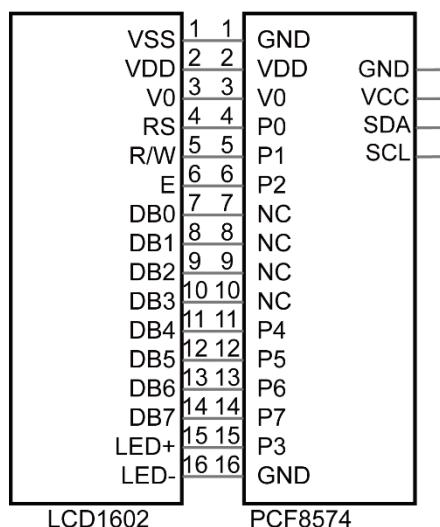


The serial-to-parallel IC chip used in this module is PCF8574T (PCF8574AT), and its default I2C address is 0x27(0x3F). You can also view the ESP32 bus on your I2C device address through command "i2cdetect -y 1".

Below is the PCF8574 pin schematic diagram and the block pin diagram:



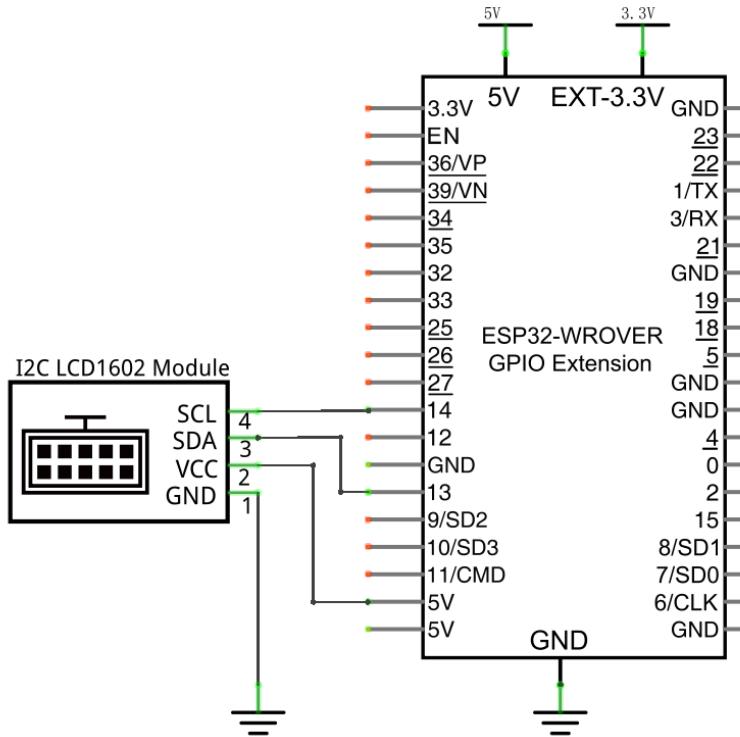
PCF8574 module pin and LCD1602 pin are corresponding to each other and connected with each other:



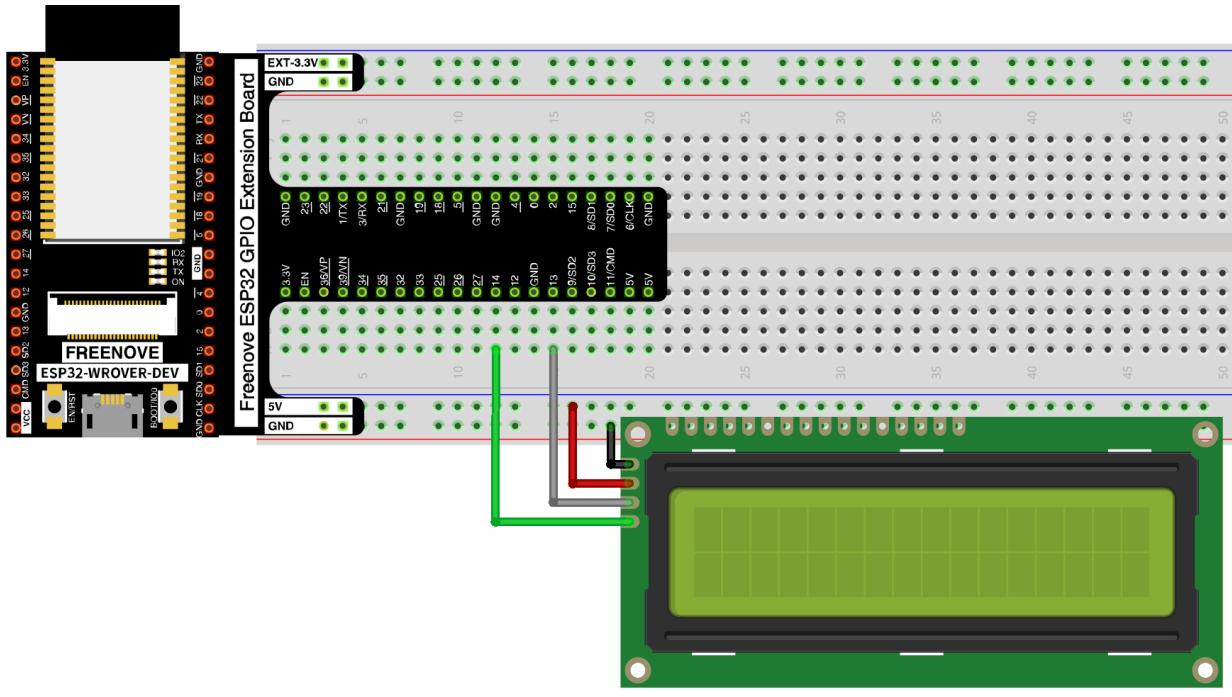
So we only need 4 pins to control the 16 pins of the LCD1602 Display Screen through the I<sub>2</sub>C interface. In this project, we will use the I<sub>2</sub>C LCD1602 to display some static characters and dynamic variables.

## Circuit

Schematic diagram



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

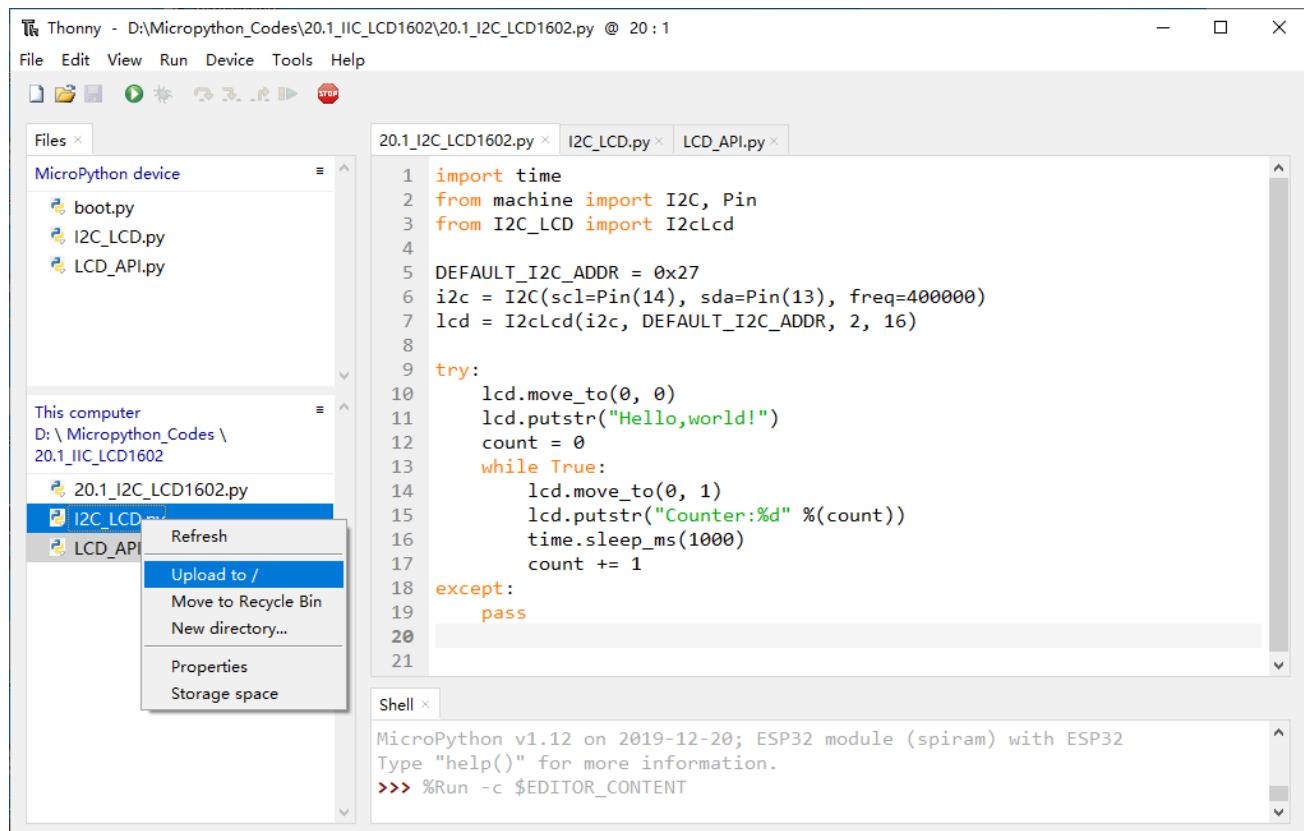


## Code

Move the program folder “**Freenove\_Super\_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\_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 “18.1\_I2C\_LCD1602.py”.

### 18.1\_I2C\_LCD1602



```

import time
from machine import I2C, Pin
from I2C_LCD import I2cLcd

DEFAULT_I2C_ADDR = 0x27
i2c = I2C(scl=Pin(14), sda=Pin(13), freq=400000)
lcd = I2cLcd(i2c, DEFAULT_I2C_ADDR, 2, 16)

try:
    lcd.move_to(0, 0)
    lcd.putstr("Hello,world!")
    count = 0
    while True:
        lcd.move_to(0, 1)
        lcd.putstr("Counter:%d" %(count))
        time.sleep_ms(1000)
        count += 1
except:
    pass

```

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 19 Ultrasonic Ranging

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

## Project 19.1 Ultrasonic Ranging

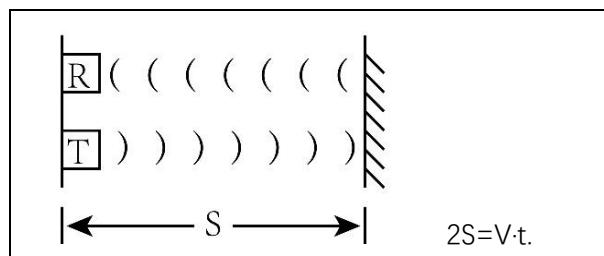
In this project, we use ultrasonic ranging module to measure distance, and print out the data in the terminal.

### Component List

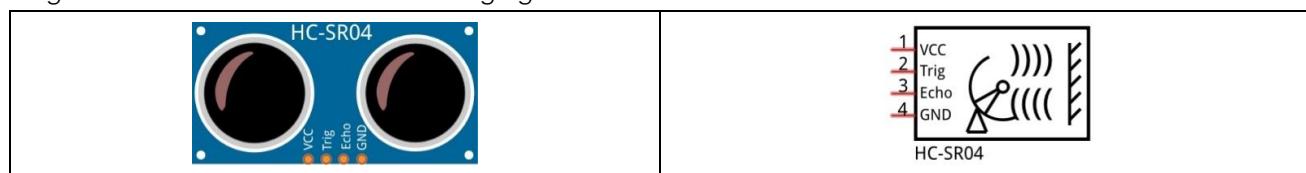
|                 |                         |
|-----------------|-------------------------|
| ESP32-WROVER x1 | GPIO Extension Board x1 |
|                 |                         |
| Breadboard x1   |                         |
| Jumper F/M x4   | HC SR04 x1              |

## 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:

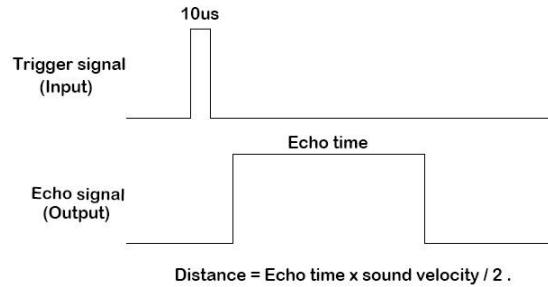
Working voltage: 5V

Working current: 12mA

Minimum measured distance: 2cm

Maximum measured distance: 200cm

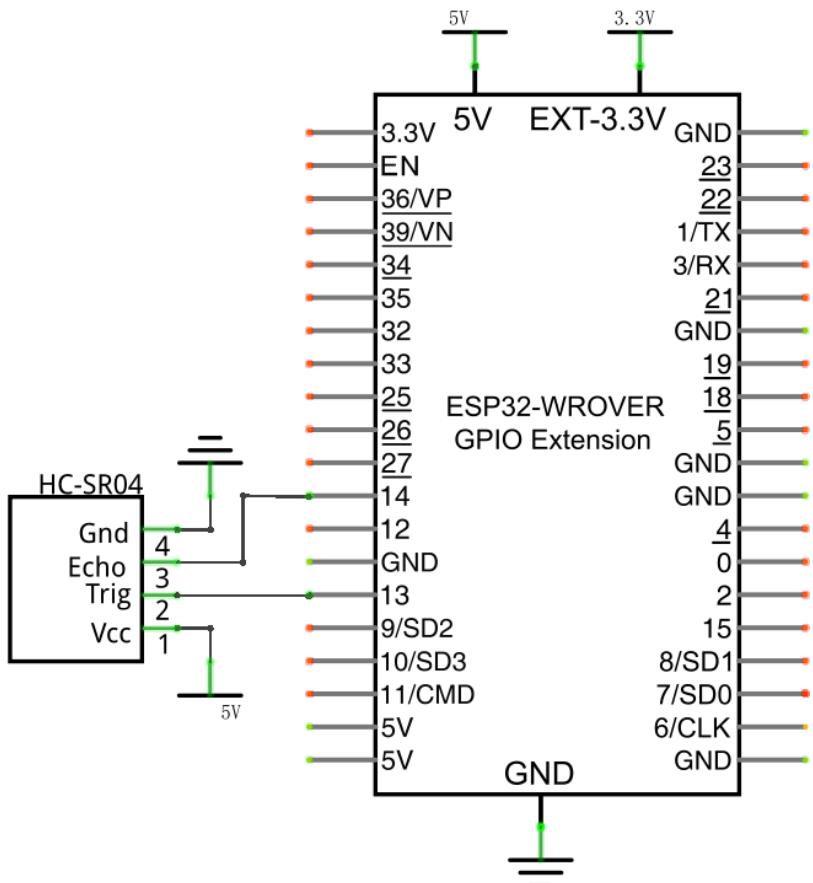
Instructions for Use: output a high-level pulse in Trig pin lasting for least 10us, the module begins to transmit ultrasonic waves. At the same time, the Echo pin is pulled up. When the module receives the returned ultrasonic waves from encountering an obstacle, the Echo pin will be pulled down. The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



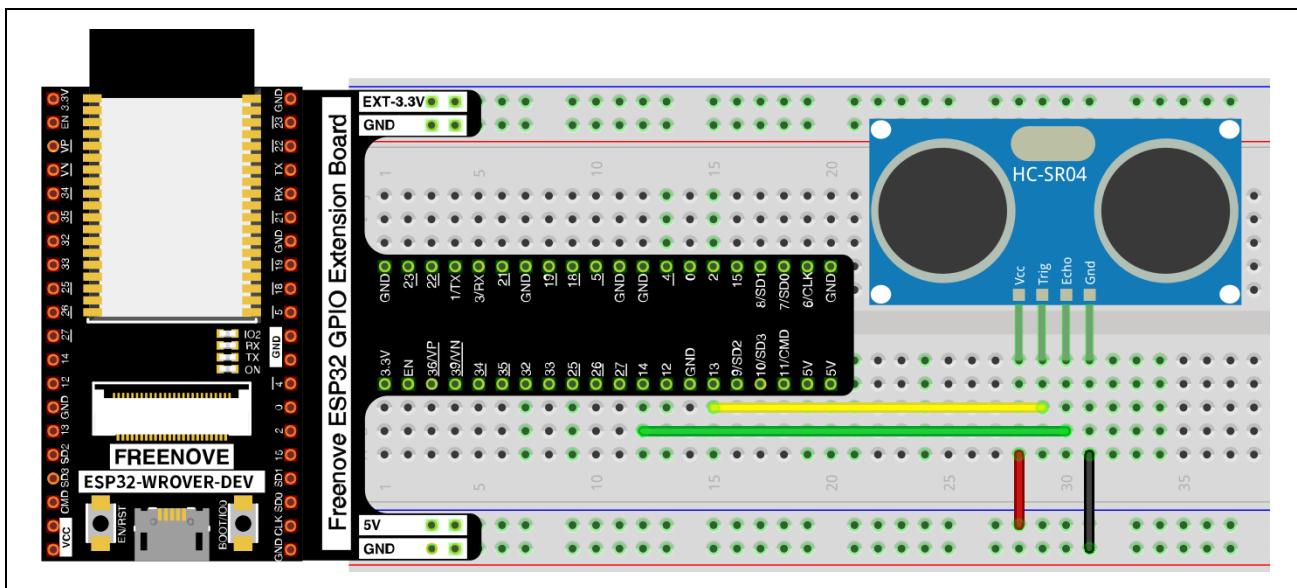
## Circuit

Note that the voltage of ultrasonic module is 5V in the circuit.

Schematic diagram



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



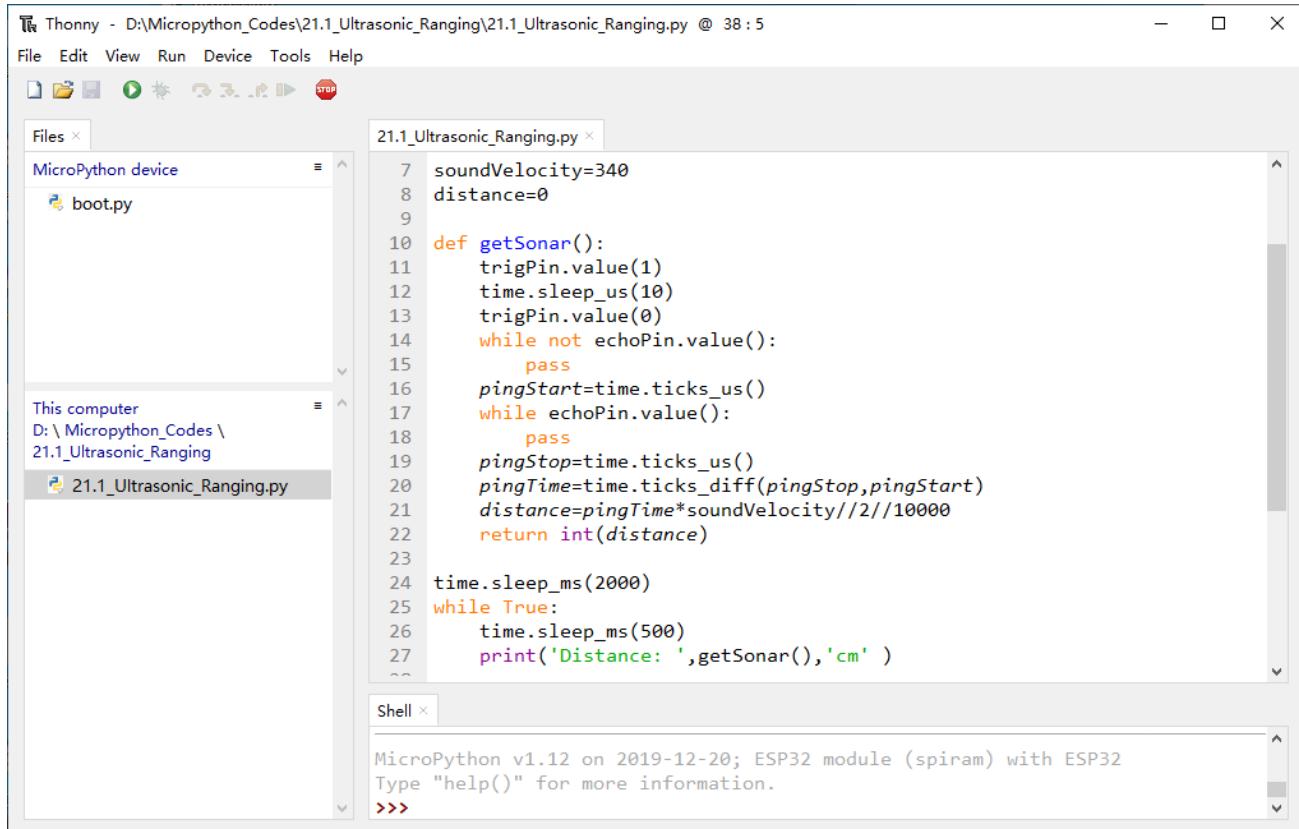
Any concerns?  support@freenove.com

## Code

Move the program folder “**Freenove\_Super\_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\_Ultrasonic\_Ranging” and double click “19.1\_Ultrasonic\_Ranging.py”.

### 19.1\_Ultrasonic\_Ranging



```

    Thonny - D:\Micropython_Codes\21.1_Ultrasonic_Ranging\21.1_Ultrasonic_Ranging.py @ 38 : 5
File Edit View Run Device Tools Help
Files x 21.1_Ultrasonic_Ranging.py x
MicroPython device
boot.py
This computer
D:\Micropython_Codes\
21.1_Ultrasonic_Ranging
21.1_Ultrasonic_Ranging.py
21.1_Ultrasonic_Ranging.py

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' )

```

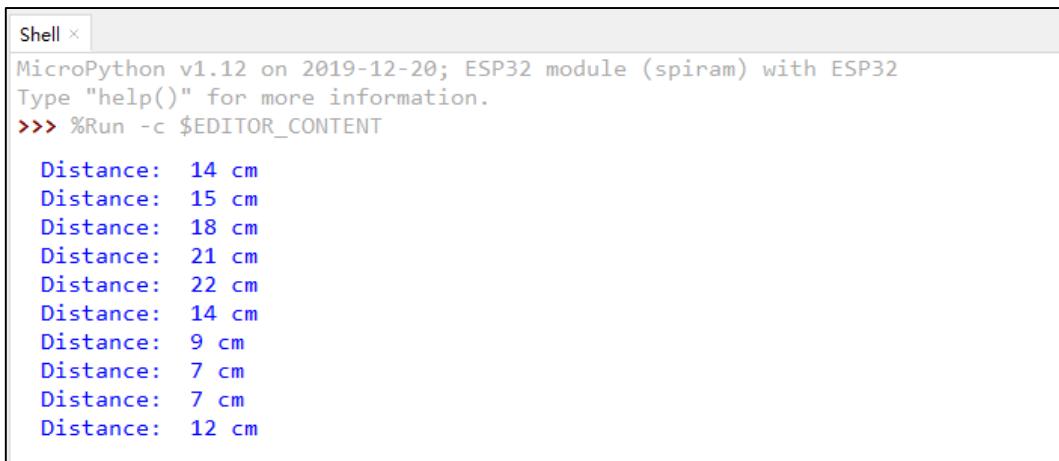
Shell x

```

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

```

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:



```

Shell x
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 19.2 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” → “19.2\_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 “19.2\_Ultrasonic\_Ranging.py”.

#### 19.2\_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 displays 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 right window is a "Shell" showing 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.



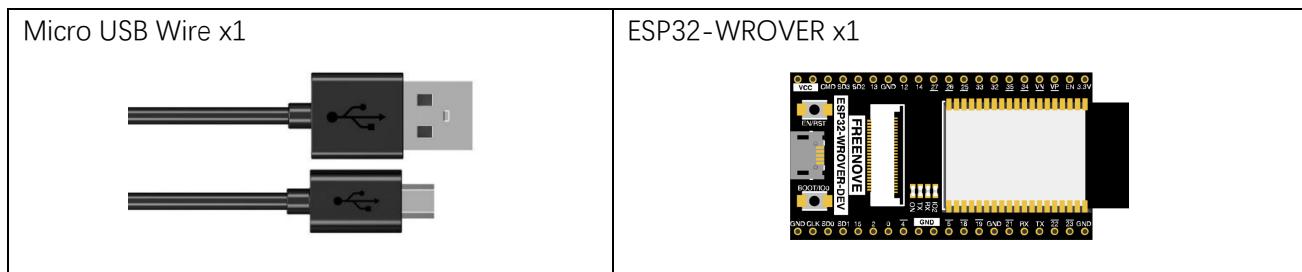
# Chapter 20 WiFi Working Modes

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 20.1 Station mode

### Component List



### Component knowledge

#### Station mode

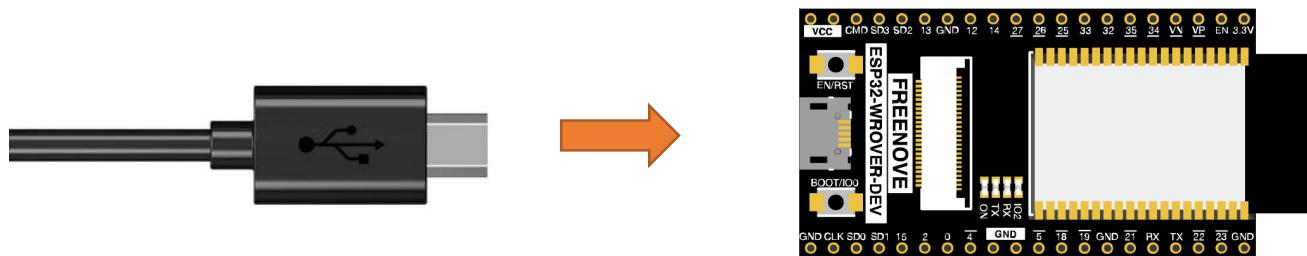
When ESP32 selects Station mode, it acts as a WiFi client. It can connect to the router network and communicate with other devices on the router via WiFi connection. As shown below, the PC is connected to the router, and if ESP32 wants to communicate with the PC, it needs to be connected to the router.



Any concerns? ✉ support@freenove.com

## Circuit

Connect Freenove ESP32 to the computer using the USB cable.



## Code

Move the program folder “**Freenove\_Super\_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\_Station\_mode” and double click “20.1\_Station\_mode.py”.

### 20.1\_Station\_mode

Enter the correct Router name and password.

```

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()

```

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)
```

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

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 20.2 AP mode

### Component List & Circuit

Component List & Circuit are the same as in Section 20.1.

### Component knowledge

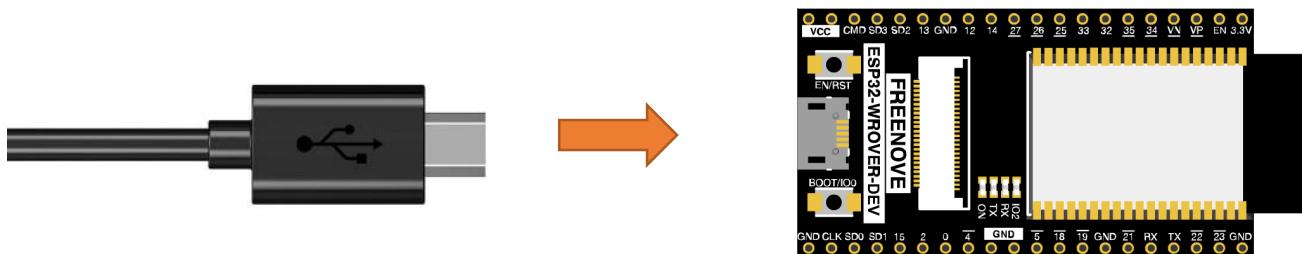
#### AP mode

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.



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

## Code

Move the program folder “**Freenove\_Super\_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” → “20.2\_AP\_mode”. and double click “20.2\_AP\_mode.py”.

### 20.2\_AP\_mode

```

Thonny - D:\Micropython_Codes\20.2_AP_mode\20.2_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.

```

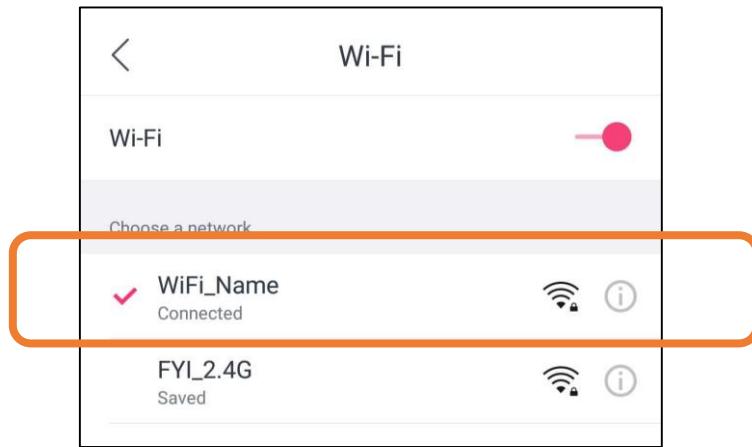
Shell x
MicroPython v1.12 on 2019-12-20; ESP32 module (spiram) with ESP32
Type "help()" for more information.
>>> %Run -c $EDITOR_CONTENT
Setting soft-AP ...
Success, IP address: ('192.168.1.10', '192.168.1.1', '255.255.255.0', '8.8.8.8')
Setup End

>>>

```



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

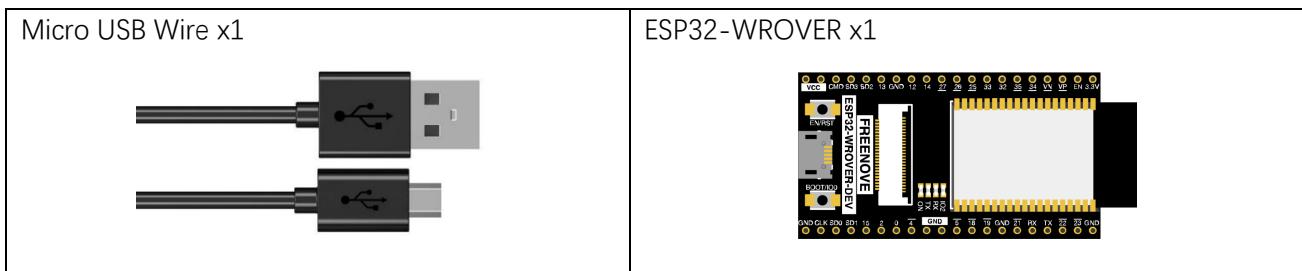
**DNS\_server**: DNS server

**disconnect()**: Disconnect from the currently connected wireless network

**status()**: Return the current status of the wireless connection

## Project 20.3 AP+Station mode

### Component List



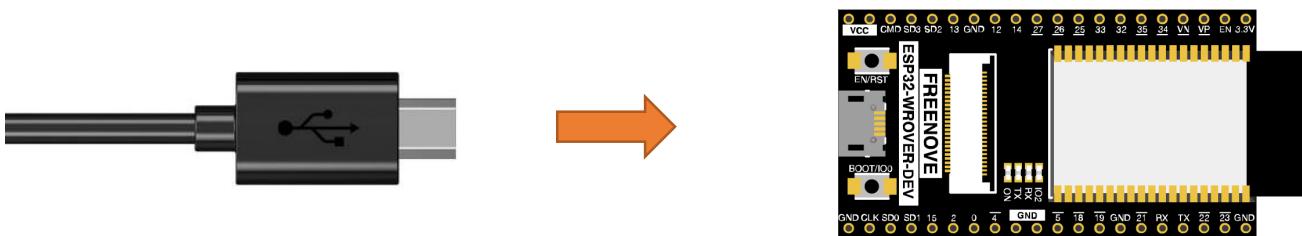
### Component knowledge

#### 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.

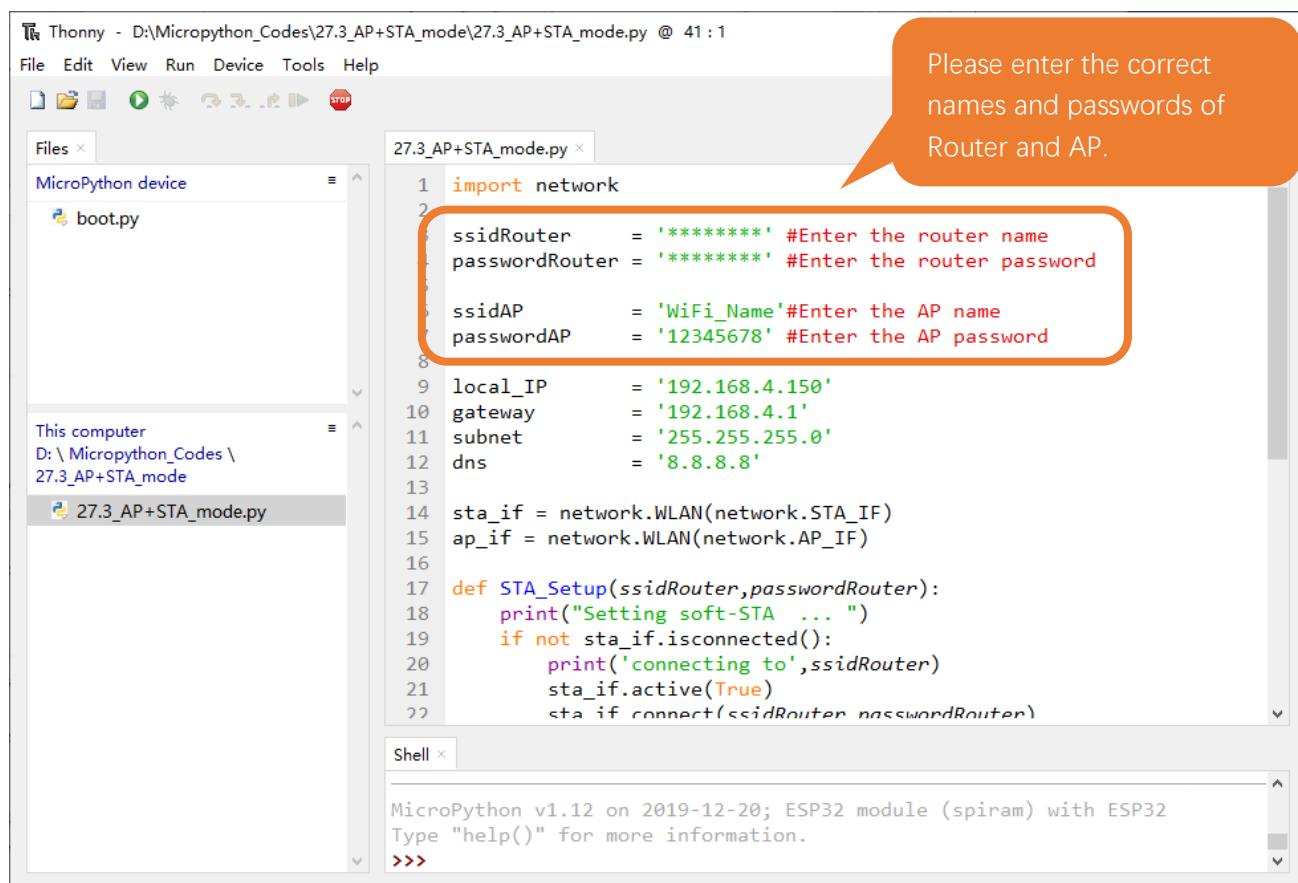


### Code

Move the program folder “**Freenove\_Super\_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” → “20.3\_AP+STA\_mode” and double click “20.3\_AP+STA\_mode.py”.

### 20.3 AP+STA mode



The screenshot shows the Thonny IDE interface. In the top menu bar, it says "Thonny - D:\Micropython\_Codes\27.3\_AP+STA\_mode\27.3\_AP+STA\_mode.py @ 41 : 1". Below the menu is a toolbar with icons for file operations. The left sidebar shows a "Files" tree with "MicroPython device" expanded, showing "boot.py". The main area has tabs for "27.3\_AP+STA\_mode.py" and "Shell". The code editor contains the following Python script:

```

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)

```

In the "Shell" tab, the output is:

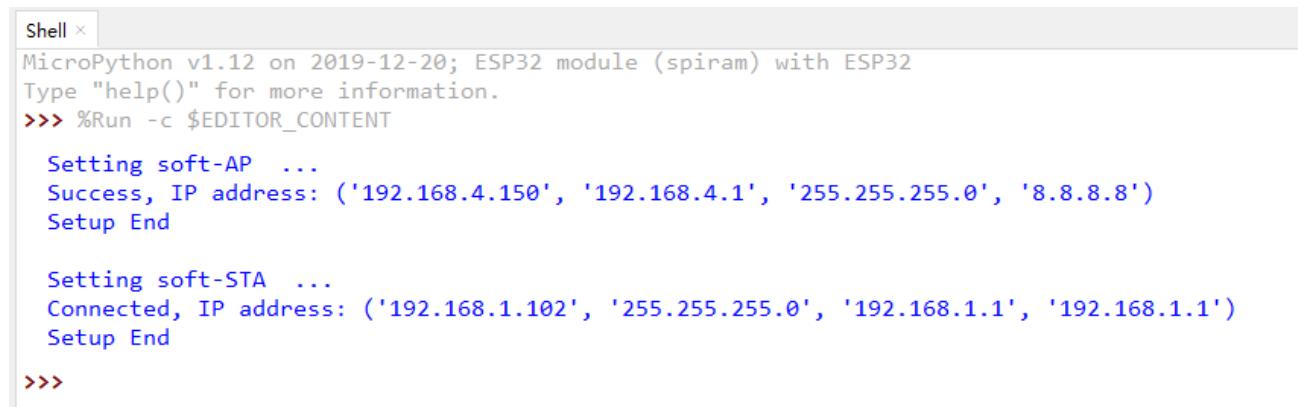
```

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

```

It is analogous to Project 20.1 and Project 20.2. 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:



The screenshot shows the MicroPython Shell window. The output is:

```

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

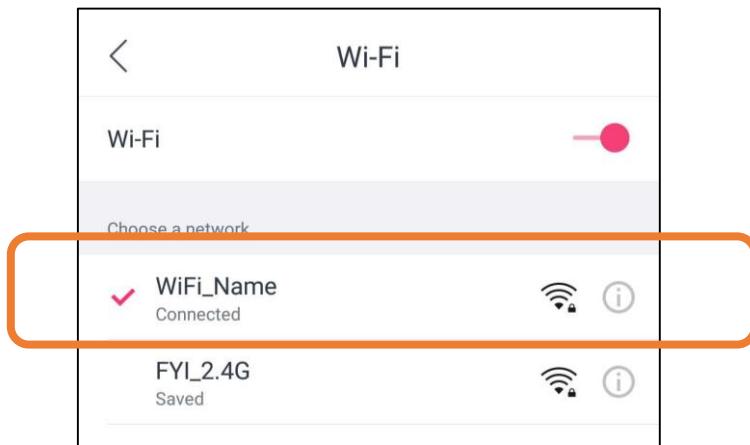
Setting soft-STA ...
Connected, IP address: ('192.168.1.102', '255.255.255.0', '192.168.1.1', '192.168.1.1')
Setup End

>>>

```



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 ... ")

```

Any concerns? ✉ support@freenove.com

```
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()
```

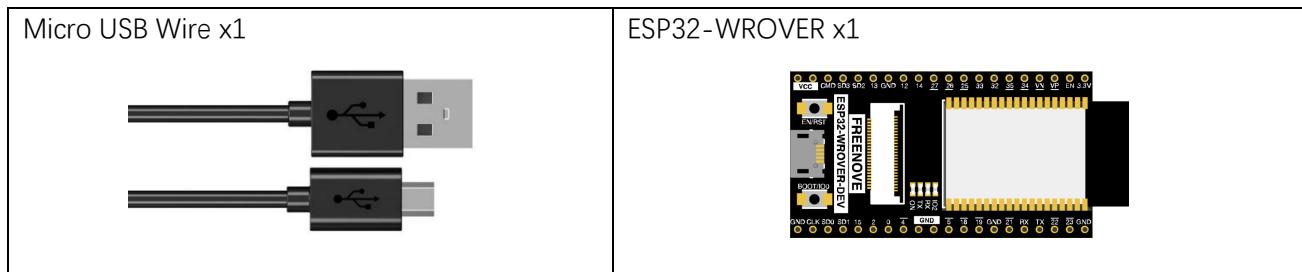
# Chapter 21 TCP/IP

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 21.1 As Client

In this section, ESP32 is used as Client to connect Server on the same LAN and communicate with it.

### Component List



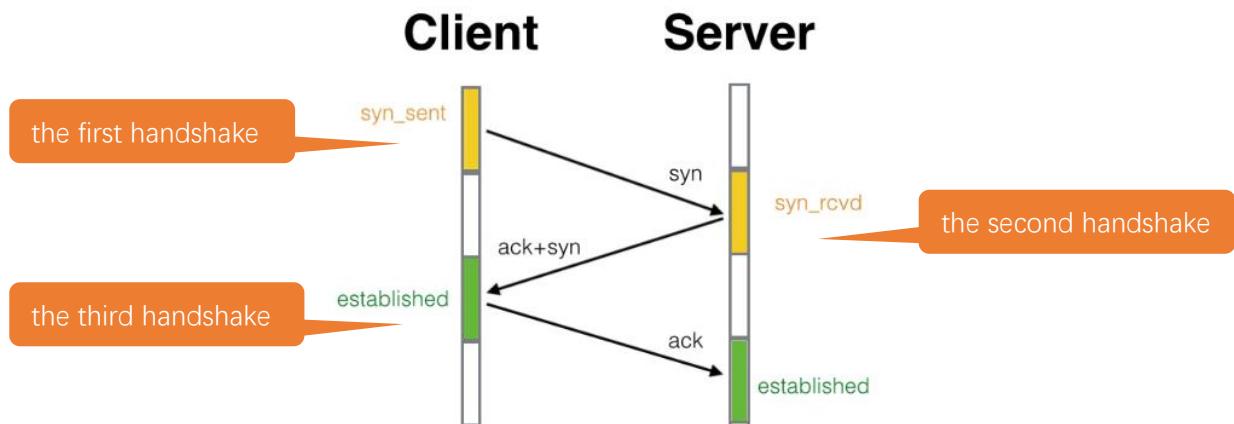
### Component knowledge

#### TCP connection

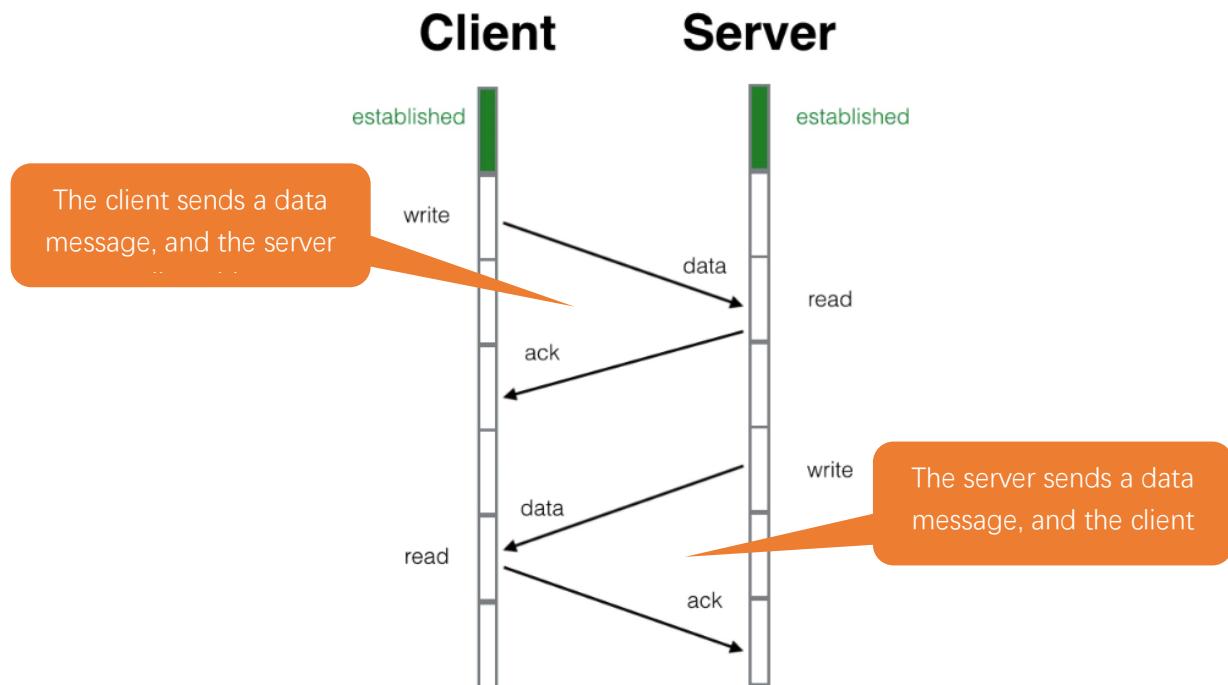
Before transmitting data, TCP needs to establish a logical connection between the sending end and the receiving end. It provides reliable and error-free data transmission between the two computers. In the TCP connection, the client and the server must be clarified. The client sends a connection request 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. At the top, there's a navigation bar with links for "Processing", "p5.js", "Processing.py", "Processing for Android", "Processing for Pi", and "Processing Foundation". Below the navigation bar is a large banner featuring the word "Processing" in a bold, white, sans-serif font, set against a dark background with a geometric, wireframe-like pattern. To the right of the banner is a search bar with a magnifying glass icon. On the left side of the main content area, there's a sidebar with links: "Cover", "Download", "Donate", "Exhibition", "Reference", "Libraries", "Tools", "Environment", "Tutorials", "Examples", "Books", "Overview", and "People". In the center, under the heading "Download Processing", it says "Processing is available for Linux, Mac OS X, and Windows. Select your choice to download the software below." Below this text is a large circular logo with a stylized "P" inside. To the right of the logo, it says "3.5.4 (17 January 2020)". Underneath, there are download links for "Windows 64-bit", "Windows 32-bit", "Linux 64-bit", and "Mac OS X".

Unzip the downloaded file to your computer. Click "processing.exe" as the figure below to run this software.

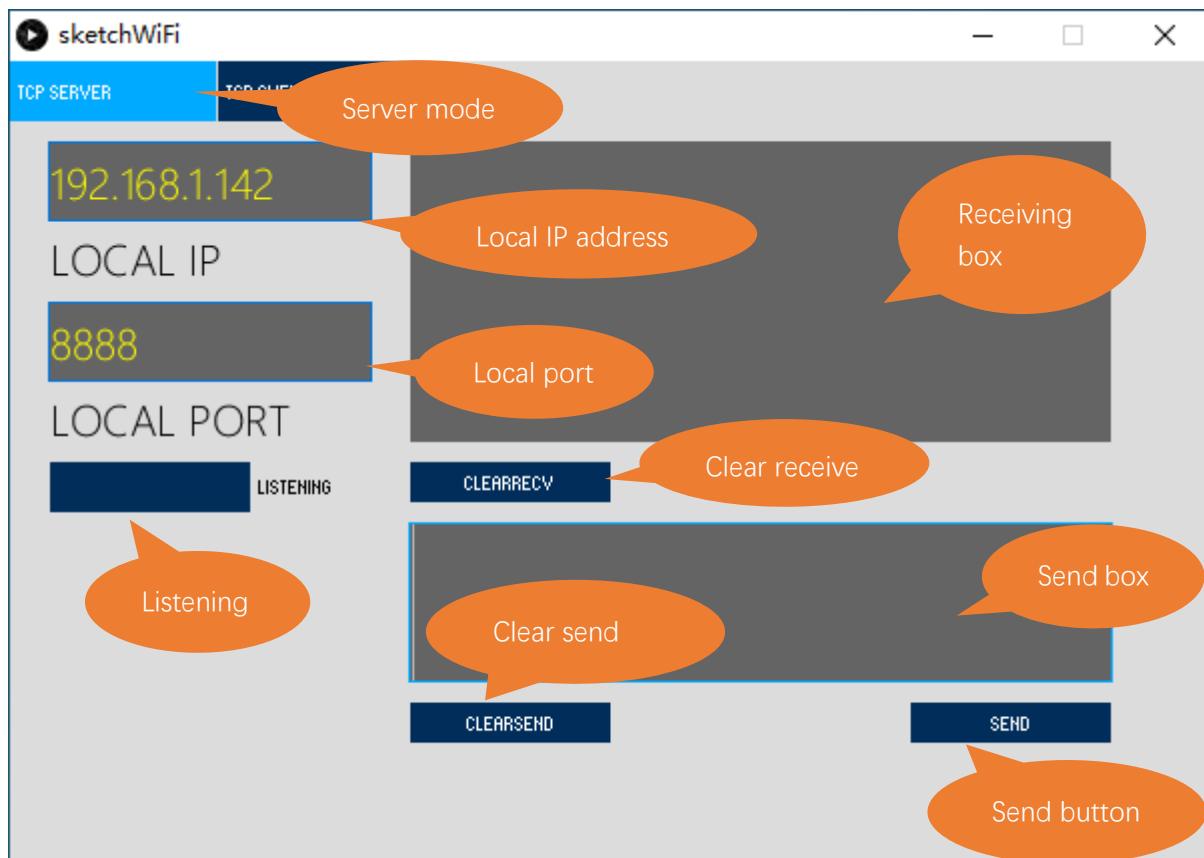
|                     |                 |
|---------------------|-----------------|
| core                | 2020/1/17 12:16 |
| java                | 2020/1/17 12:17 |
| lib                 | 2020/1/17 12:16 |
| modes               | 2020/1/17 12:16 |
| tools               | 2020/1/17 12:16 |
| processing.exe      | 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\_Super\_Starter\_Kit\_for\_ESP32/Codes/Micropython\_Codes/21.1\_TCP\_as\_Client/sketchWiFi/sketchWiFi.pde”. Click “Run”.

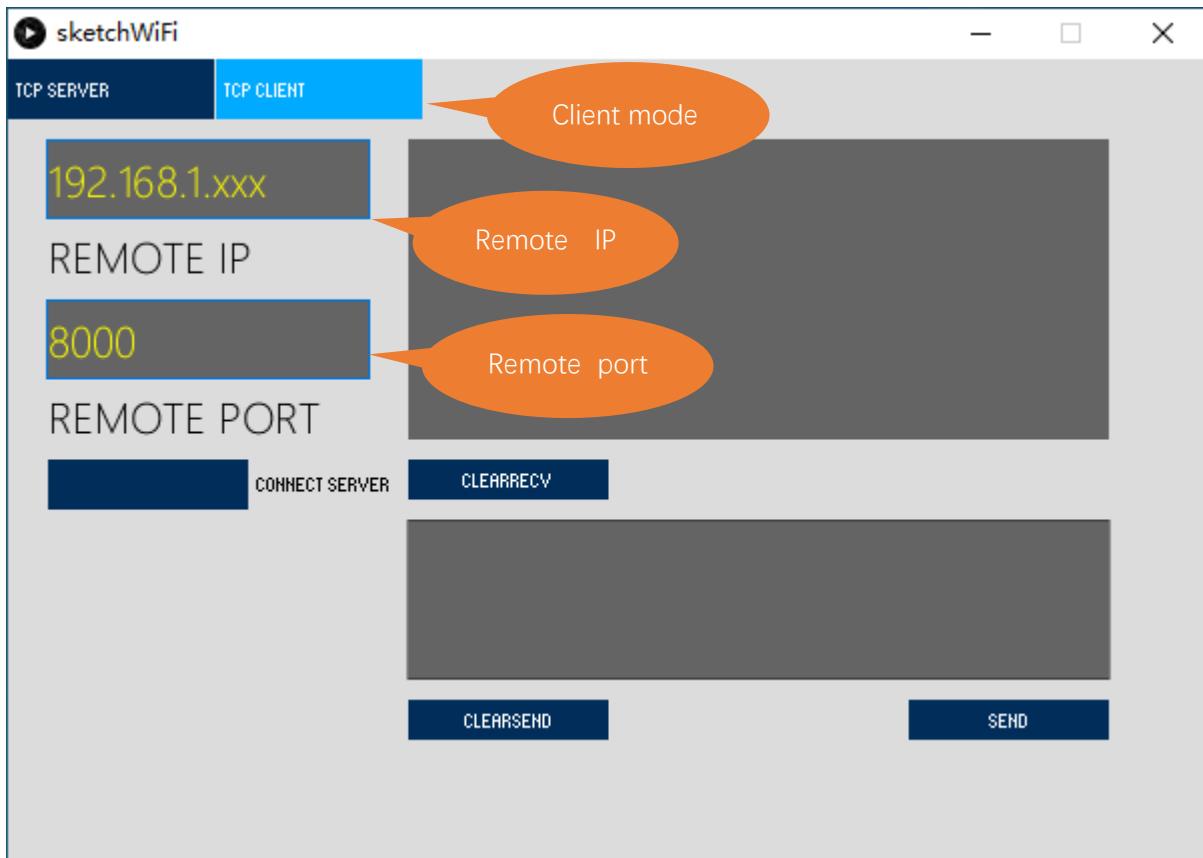


The new pop-up interface is as follows. If ESP32 is used as Client, select TCP SERVER mode for sketchWiFi.



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.

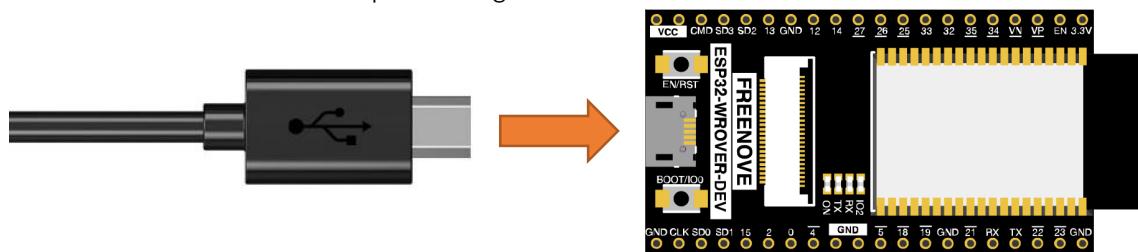
**clear receive:** clear out the content in the receiving text box

**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.

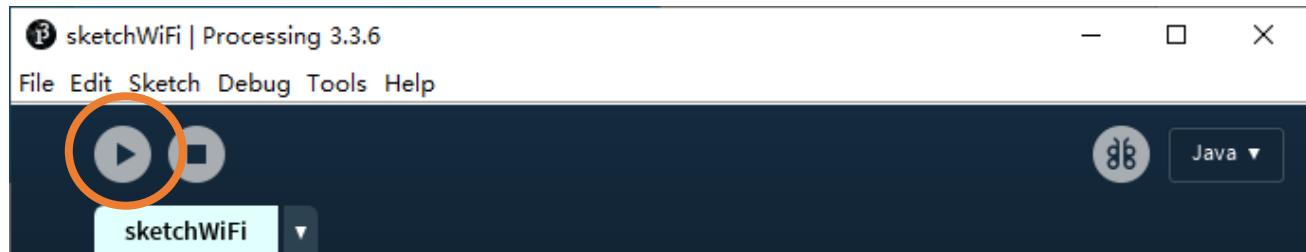
## Circuit

Connect Freenove ESP32 to the computer using USB cable.

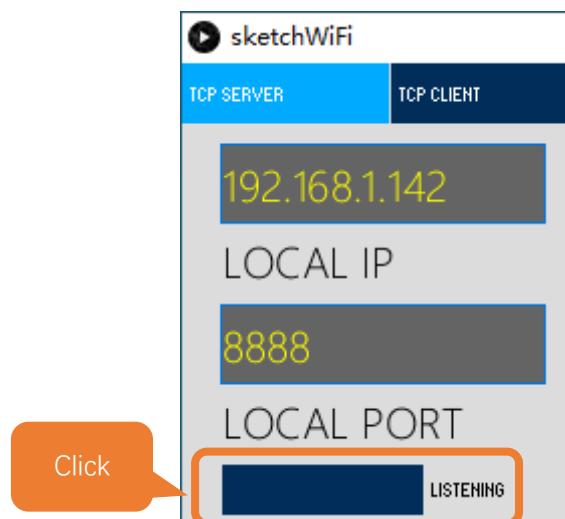


## Code

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\_Super\_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\_TCP\_as\_Client” and double click “21.1\_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:

## 21.1\_TCP\_as\_Client

```
Thonny - D:\Micropython_Codes\28.1_TCP_as_Client\28.1_TCP_as_Client.py @ 43 : 21
File Edit View Run Device Tools Help
Files x
MicroPython device
boot.py
This computer
D:\ Micropython_Codes \
28.1_TCP_as_Client
sketchWiFi
28.1_TCP_as_Client.py x
28.1_TCP_as_Client.py x
1 import network as n
2 import socket
3 import time
4
5 ssidRouter      = "*****"
6 passwordRouter = "*****"
7 host            = "192.168.1.142"
8 port            = 8888
9
10 wlan=None
11 s=None
12
13 def connectWifi(ssid,passwd):
14     global wlan
15     wlan=n.WLAN(n.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:
Shell x
MicroPython v1.12 on 2019-12-20; ESP32 module with ESP32
Type "help()" for more information.
>>>
```

Click “Run current script” and in “Shell”, you can see ESP32-WROVER automatically connects to sketchWiFi.

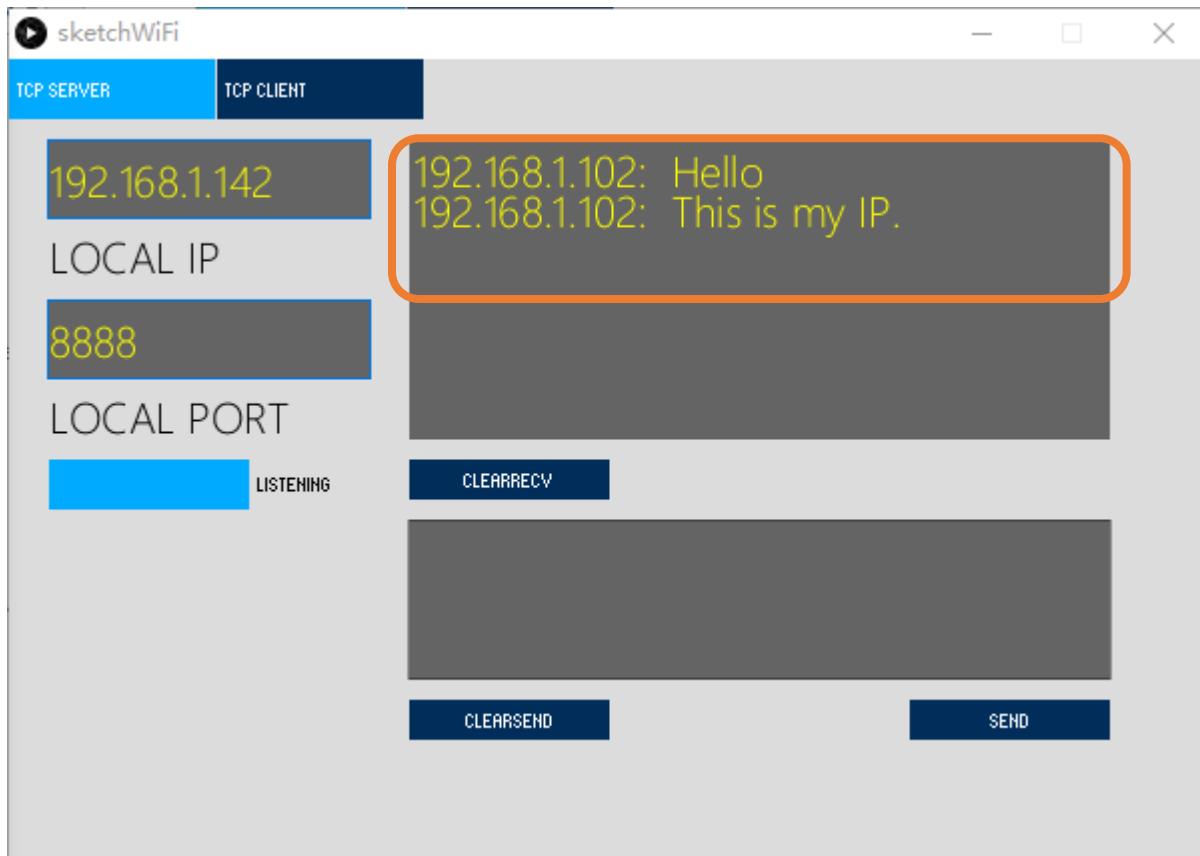
```
Shell x

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.

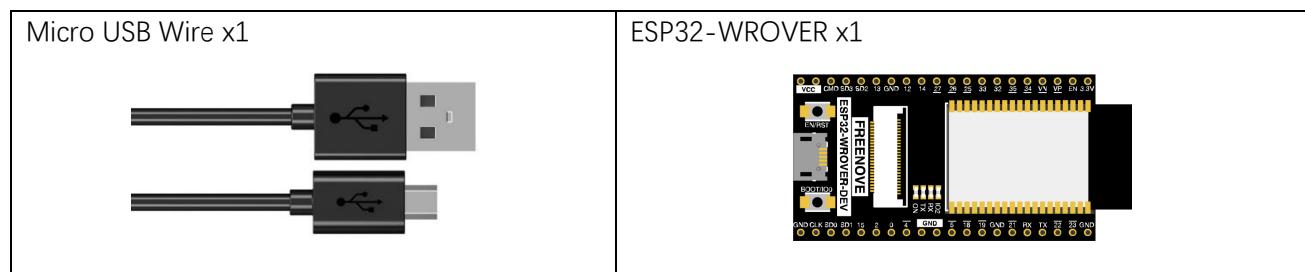
**close():** Close socket.

To learn more please visit: <http://docs.micropython.org/en/latest/>

## Project 21.2 As Server

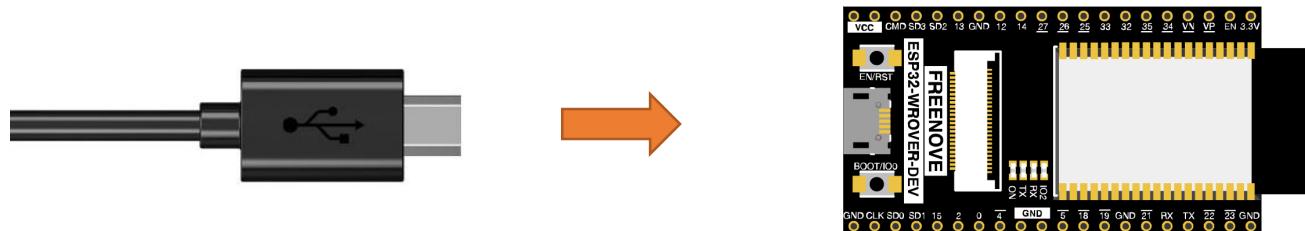
In this section, ESP32 is used as a Server to wait for the connection and communication with Client on the same LAN.

### Component List



### Circuit

Connect Freenove ESP32 to the computer using the USB cable.



## Code

Move the program folder “**Freenove\_Super\_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” → “21.2\_TCP\_as\_Server” and double click “21.2\_TCP\_as\_Server.py”.

Before clicking “Run current script”, please modify the name and password of your router shown in the box below.

### 21.2\_TCP\_as\_Server

```

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
9 wlan=None
10 listenSocket=None
11
12 def connectWifi(ssid,passwd):
13     global wlan
14     wlan=network.WLAN(network.STA_IF)
15     wlan.active(True)
16     wlan.disconnect()
17     wlan.connect(ssid,passwd)
18     while(wlan.ifconfig()[0]!='0.0.0.0'):

```

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.

```

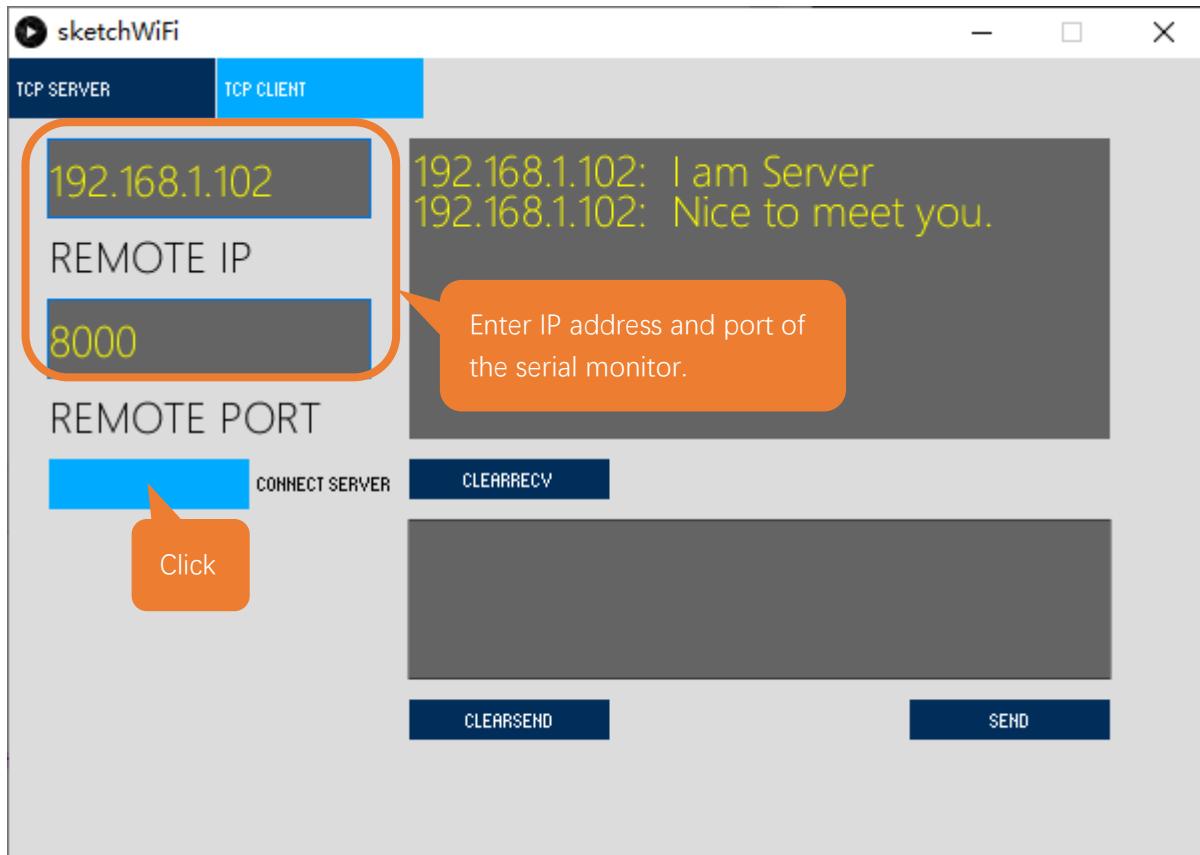
MicroPython v1.12 on 2019-12-20; ESP32 module (spiram) with ESP32
Type "help()" for more information.
>>> %Run -c $EDITOR_CONTENT
tcp waiting...
accepting....
Server IP: 192.168.1.102          Port: 8000

```

Processing:

Open the “Freenove\_Super\_Starter\_Kit\_for\_ESP32/Codes/MicroPython\_Codes/21.2\_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
```

Any concerns? ✉ support@freenove.com

```

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)

```



## 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 learn more about ESP32, you view our ultimate tutorial:

[https://github.com/Freenove/Freenove\\_Super\\_Starter\\_Kit\\_for\\_ESP32/archive/master.zip](https://github.com/Freenove/Freenove_Super_Starter_Kit_for_ESP32/archive/master.zip)

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.

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