

# Important Information

Thank you for choosing Freenove products!

## Getting Started

First, please read the **Start Here.pdf** document in the unzipped folder you created.

If you have not yet downloaded the zip file, associated with this kit, please do so now and unzip it.

## Get Support and Offer Input

Freenove provides free and responsive product and technical support, including but not limited to:

- Product quality issues
- Product use and build issues
- Questions regarding the technology employed in our products for learning and education
- Your input and opinions are always welcome
- We also encourage your ideas and suggestions for new products and product improvements

For any of the above, you may send us an email to:

**[support@freenove.com](mailto:support@freenove.com)**

## Safety and Precautions

Please follow the following safety precautions when using or storing this product:

- Keep this product out of the reach of children under 6 years old.
- This product should be **used only when there is adult supervision present** as young children lack necessary judgment regarding safety and the consequences of product misuse.
- This product contains small parts and parts, which are sharp. This product contains electrically conductive parts. **Use caution with electrically conductive parts near or around power supplies, batteries and powered (live) circuits.**
- When the product is turned ON, activated or tested, some parts will move or rotate. **To avoid injuries to hands and fingers keep them away from any moving parts!**
- It is possible that an improperly connected or shorted circuit may cause overheating. **Should this happen, immediately disconnect the power supply or remove the batteries and do not touch anything until it cools down!** When everything is safe and cool, review the product tutorial to identify the cause.
- Only operate the product in accordance with the instructions and guidelines of this tutorial, otherwise parts may be damaged or you could be injured.
- Store the product in a cool dry place and avoid exposing the product to direct sunlight.
- After use, always turn the power OFF and remove or unplug the batteries before storing.

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



## About Freenove

Freenove provides open source electronic products and services worldwide.

Freenove is committed to assist customers in their education of robotics, programming and electronic circuits so that they may transform their creative ideas into prototypes and new and innovative products. To this end, our services include but are not limited to:

- Educational and Entertaining Project Kits for Robots, Smart Cars and Drones
- Educational Kits to Learn Robotic Software Systems for Arduino, Raspberry Pi and micro:bit
- Electronic Component Assortments, Electronic Modules and Specialized Tools
- **Product Development and Customization Services**

You can find more about Freenove and get our latest news and updates through our website:

<http://www.freenove.com>

[sale@freenove.com](mailto:sale@freenove.com)

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# Preface

ESP32-S3 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-S3 can be developed using the Arduino platform, which will definitely make it easier for people who have learned Arduino to master. Moreover, the code of ESP32-S3 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.

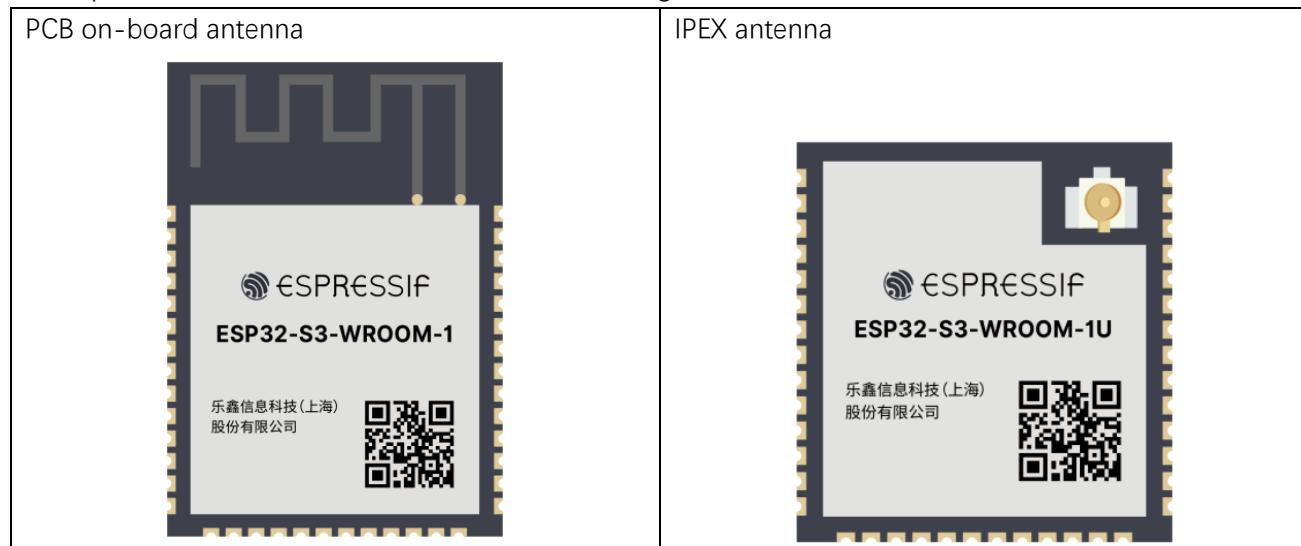
Generally, ESP32-S3 projects consist of code and circuits. Don't worry even if you've never learned code and circuits, because we will gradually introduce the basic knowledge of C programming language and electronic circuits, from easy to difficult. Our products contain all the electronic components and modules needed to complete these projects. It's especially suitable for beginners.

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 SEP32 and 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.

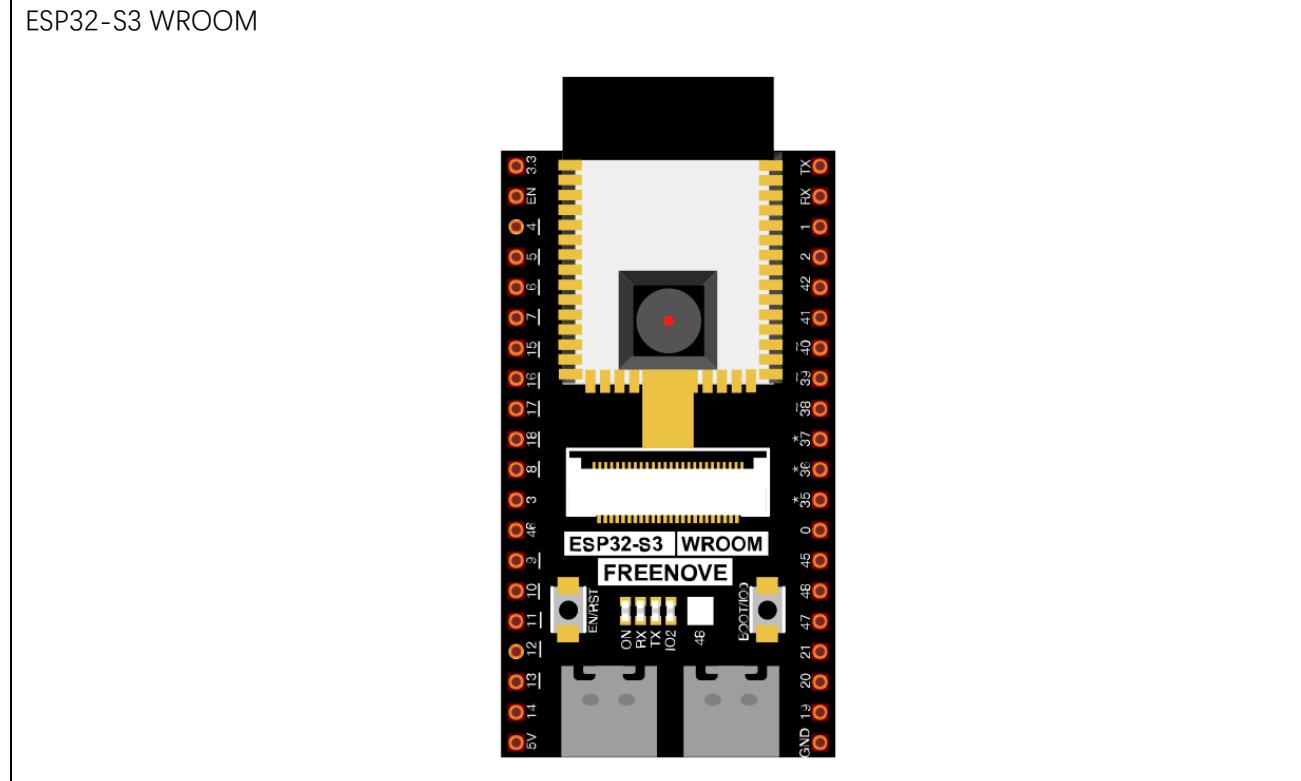
In addition, if you have any difficulties or questions with this tutorial or toolkit, feel free to ask for our quick and free technical support through [support@freenove.com](mailto:support@freenove.com)

## ESP32-S3 WROOM

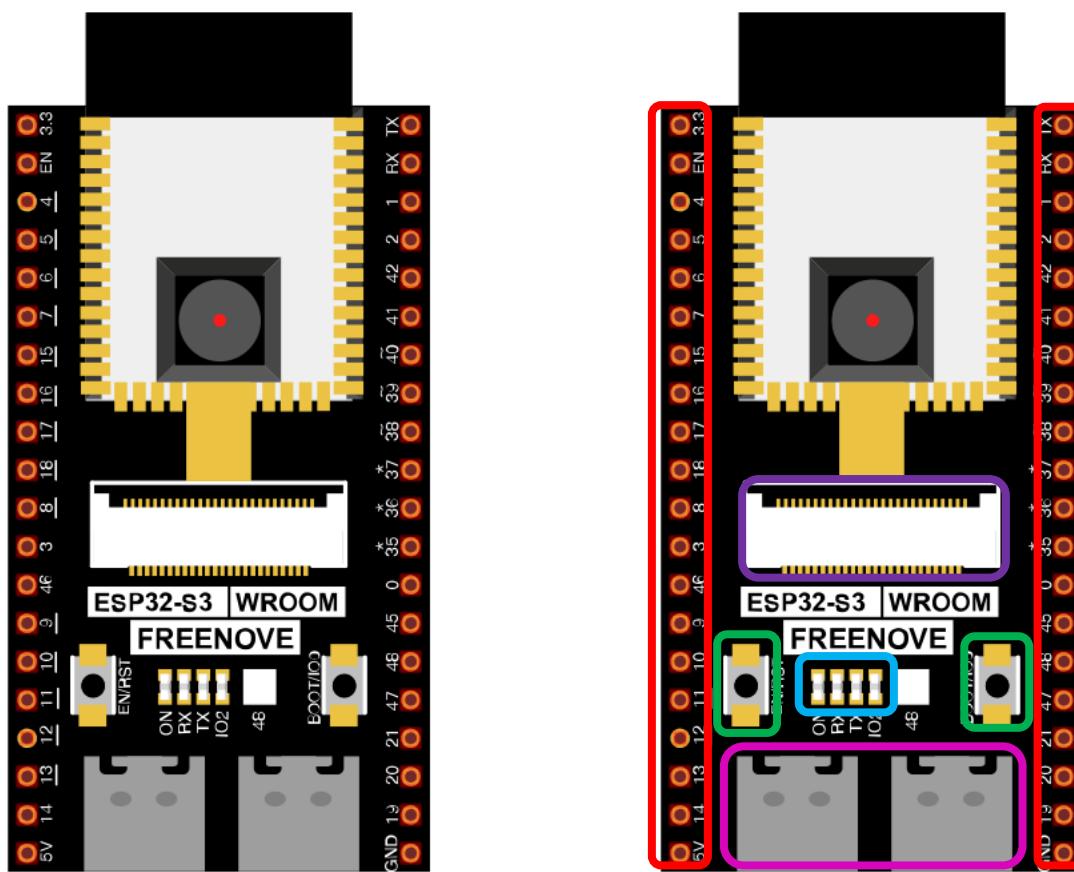
ESP32-S3-WROOM-1 has launched a total of two antenna packages, PCB on-board antenna and IPEX antenna respectively. The PCB on-board antenna is an integrated antenna in the chip module itself, so it is convenient to carry and design. The IPEX antenna is a metal antenna derived from the integrated antenna of the chip module itself, which is used to enhance the signal of the module.



In this tutorial, the ESP32-S3 WROOM is designed based on the PCB on-board antenna-packaged ESP32-S3-WROOM-1 module.



The hardware interfaces of ESP32-S3 WROOM are distributed as follows:



Compare the left and right images. We've boxed off the resources on the ESP32-S3 WROOM in different colors to facilitate your understanding of the ESP32-S3 WROOM.

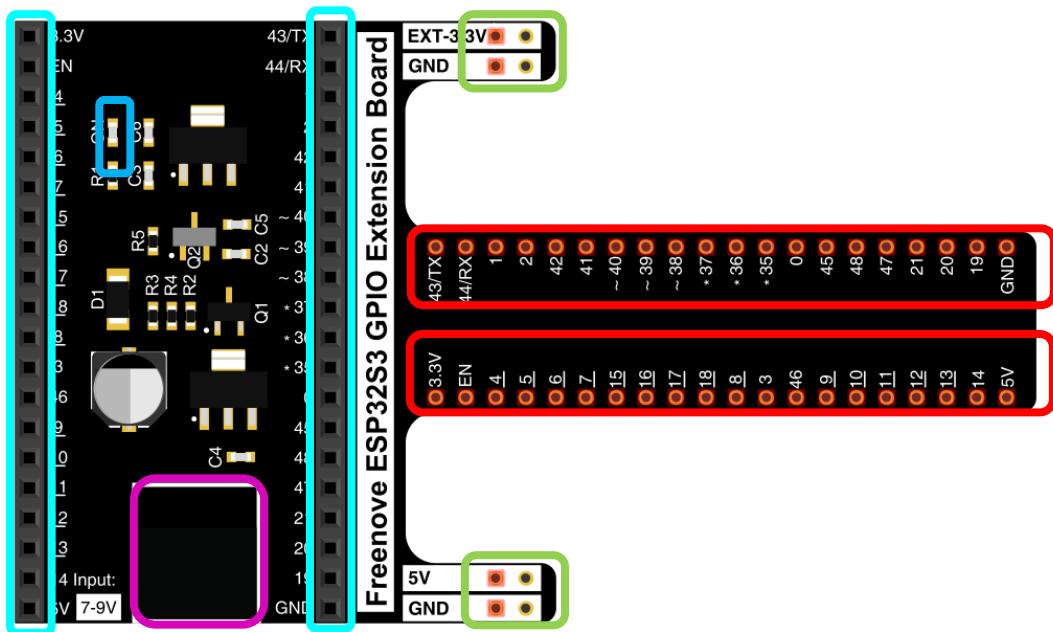
Box color	Corresponding resources introduction
	<b>GPIO pin</b>
	<b>LED indicator</b>
	<b>Camera interface</b>
	<b>Reset button, Boot mode selection button</b>
	<b>USB port</b>

For more information, please visit: [https://www.espressif.com.cn/sites/default/files/documentation/esp32-s3-wroom-1\\_wroom-1u\\_datasheet\\_en.pdf](https://www.espressif.com.cn/sites/default/files/documentation/esp32-s3-wroom-1_wroom-1u_datasheet_en.pdf).

## Extension board of the ESP32-S3 WROOM

And we also design an extension board, so that you can use the ESP32-S3 more easily in accordance with the circuit diagram provided. The followings are their photos.

The hardware interfaces of ESP32-S3 WROOM are distributed as follows:



We've boxed off the resources on the ESP32-S3 WROOM in different colors to facilitate your understanding of the ESP32-S3 WROOM.

Box color	Corresponding resources introduction
Red	GPIO pin
Cyan	LED indicator
Green	GPIO interface of development board
Magenta	power supplied by the extension board
	External power supply

In ESP32-S3, GPIO is an interface to control peripheral circuit.

In the following projects, we only use USB cable to power ESP32-S3 WROOM by default.

In the whole tutorial, we don't use T extension to power ESP32-S3 WROOM. So 5V and 3.3V (including EXT 3.3V) on the extension board are provided by ESP32-S3 WROOM.

We can also use DC jack of extension board to power ESP32-S3 WROOM. In this way, 5v and EXT 3.3V on extension board are provided by external power resource.

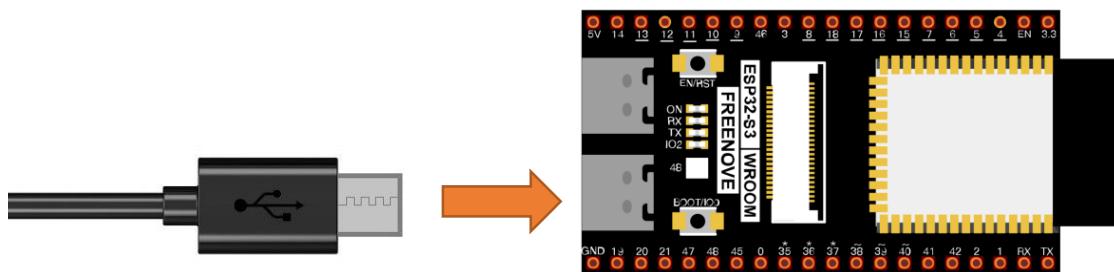
## CH343 (Importance)

ESP32-S3 WROOM uses CH343 to download codes. So before using it, we need to install CH343 driver in our computers.

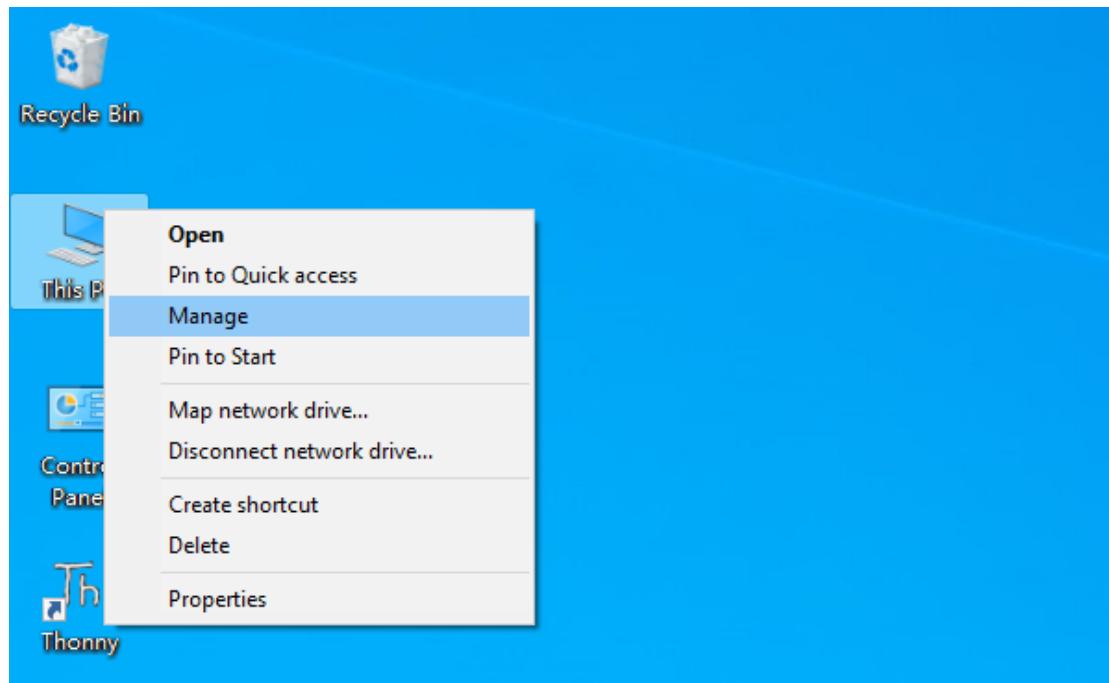
### Windows

Check whether CH343 has been installed

1. Connect your computer and ESP32-S3 WROOM with a USB cable.

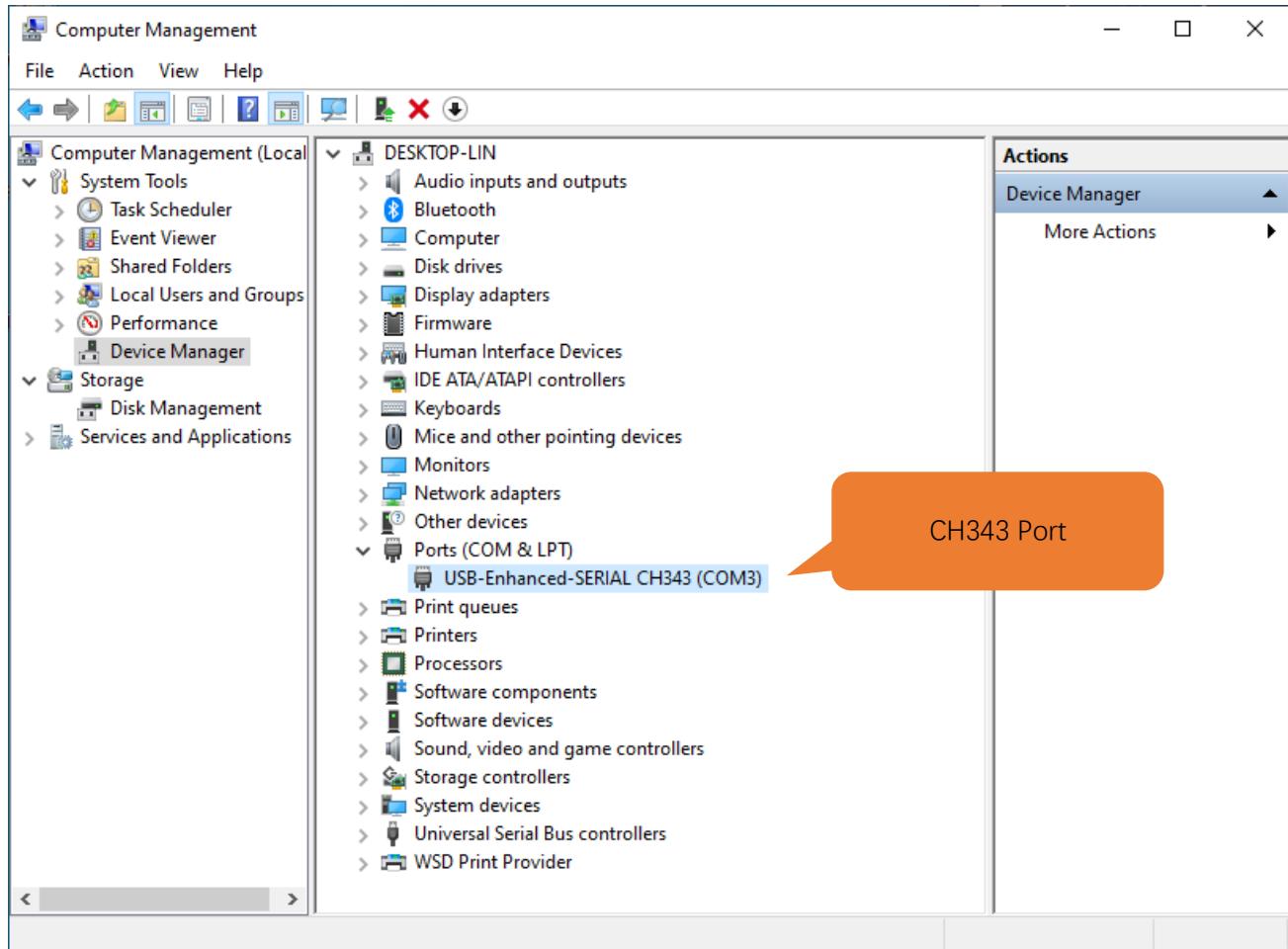


2. Turn to the main interface of your computer, select "This PC" and right-click to select "Manage".





3. Click "Device Manager". If your computer has installed CH343, you can see "USB-Enhanced-SERIAL CH343 (COMx)". And you can click [here](#) to move to the next step.



### Installing CH343

1. First, download CH343 driver, click <http://www.wch-ic.com/search?t=all&q=ch343> to download the appropriate one based on your operating system.

## keyword ch343

### Downloads( 8 )

file category	file content	version	upload time
DataSheet			
<a href="#">CH343DS1.PDF</a>	CH343 datasheet, USB to single serial port, supports up to 6M baud rate, serial port signals support 5V/3.3V/2.5V/1.8V, built-in crystal oscillator. CH343 supports built-in CDC driver in operating system or multi-functional high-speed VCP manufacture driver.	1.5	2021-11-18
Driver&Tools			
<a href="#">CH343SER.ZIP</a>	For CH342/CH343/CH344/CH347/CH9101/CH9102/CH9103/CH9143, USB to high-speed serial port VCP vendor driver, supports Windows 11/10/8.1/8/7/VISTA/XP/2000	1.61	2022-05-13
<a href="#">CH343CDC.ZIP</a>	For CH342/CH343/CH344/CH347/CH910X/CH9143/CH9340, USB to CDC serial port driver, supports Windows 11/10/8.1/8/7/VISTA/XP/2000	1.4	2022-05-13
<a href="#">CH343SER.EXE</a>	For CH342/CH343/CH344/CH347/CH9101/CH9102/CH9103/CH9143, USB to high-speed serial port VCP vendor driver, supports Windows 11/10/8.1/8/7/VISTA/XP/2000	1.61	2022-05-13
<a href="#">CH34XSER_MAC.ZIP</a>	For MAC, CH342/CH343/CH344/CH347/CH9101/CH9102/CH9103/CH9143, USB to serial port VCP vendor driver of macOS	1.7	2022-05-13
<a href="#">CH343CDC.EXE</a>	For CH342/CH343/CH344/CH347/CH910X/CH9143/CH9340, USB to CDC serial port driver, supports Windows 11/10/8.1/8/7/VISTA/XP/2000	1.4	2022-05-13
Application			
<a href="#">CH34xSerCfg.ZIP</a>	USB configuration tool of Windows for CH340/CH342/CH343/CH344/CH347/CH348/CH9101/CH9102/CH9103. Via this tool, the chip's Vendor ID, product ID, maximum current value, BCD version	1.2	2022-05-24

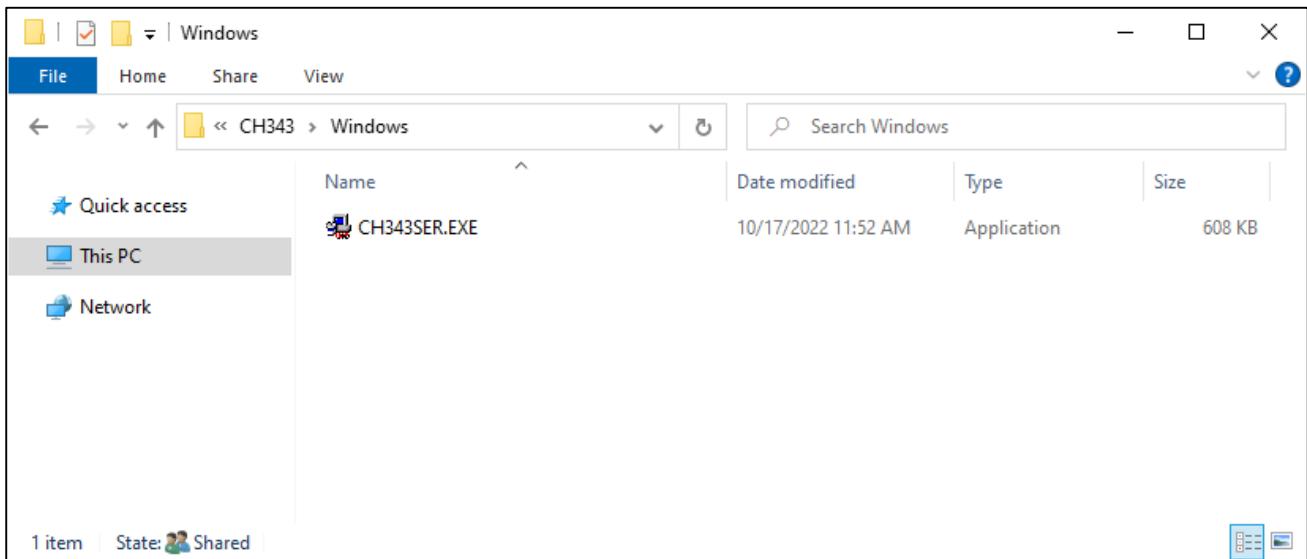
If you would not like to download the installation package, you can open

[“Freenove\\_Ultimate\\_Starter\\_Kit\\_for\\_ESP32\\_S3/CH343”](#), we have prepared the installation package.

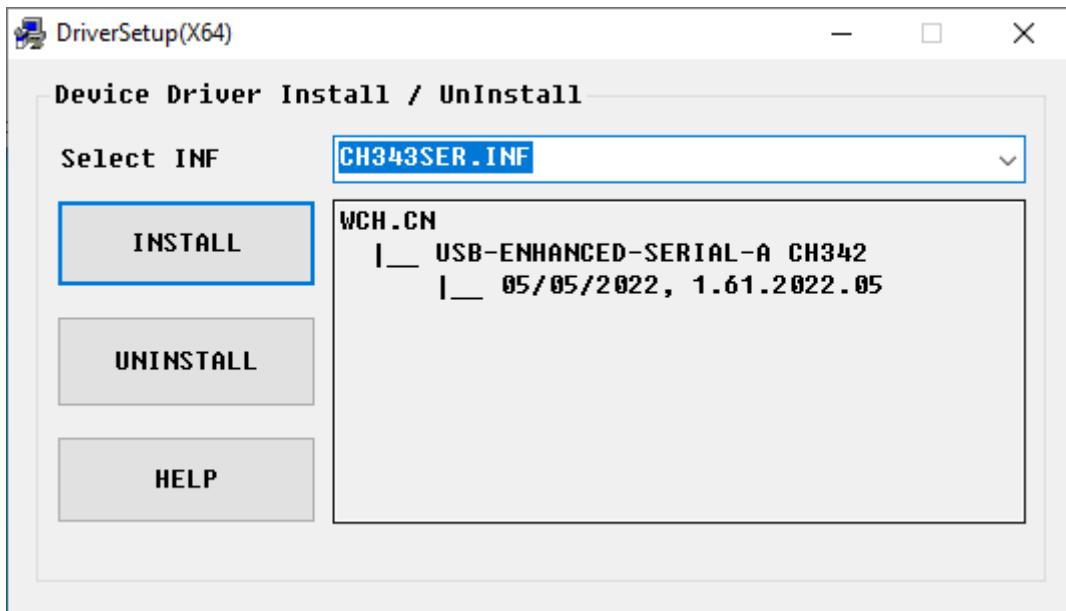
 Linux	10/17/2022 1:30 PM	File folder
 MAC	10/17/2022 1:30 PM	File folder
 Windows	10/17/2022 1:30 PM	File folder



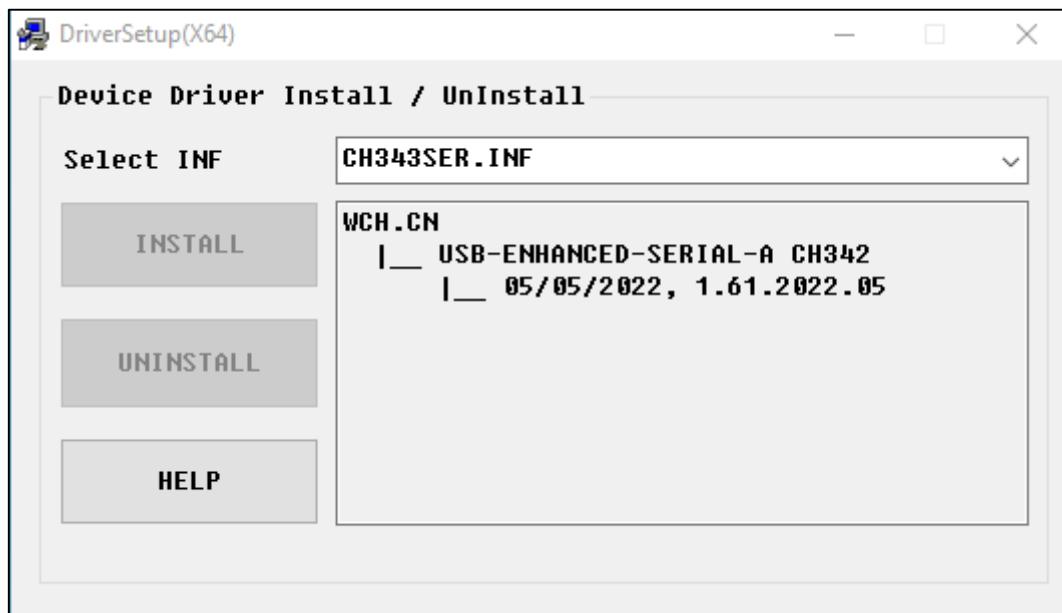
2. Open the folder “**Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32\_S3/CH343/Windows/**”



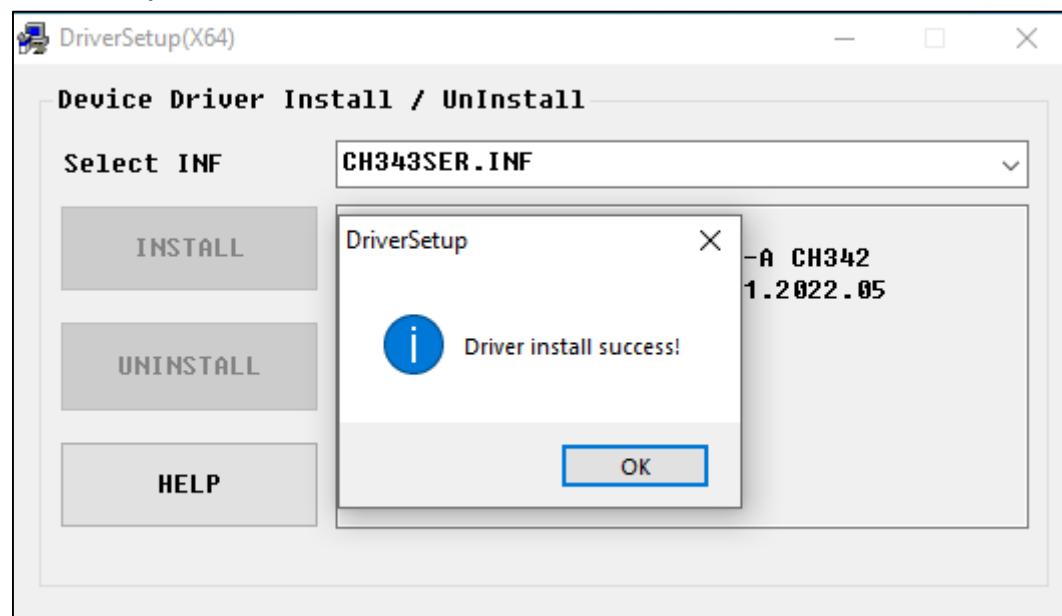
3. Double click “**CH343SER.EXE**”.



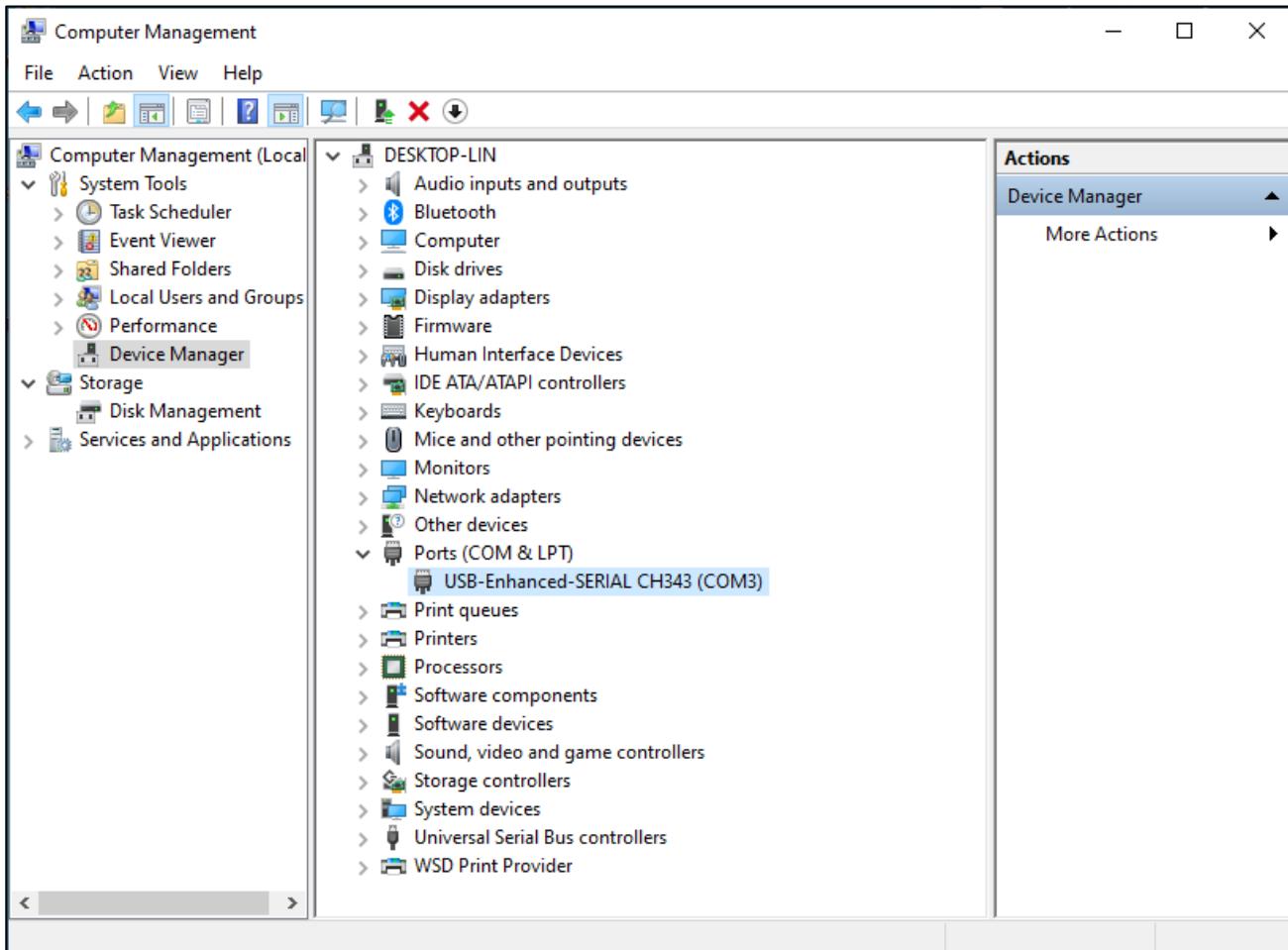
4. Click “INSTALL” and wait for the installation to complete.



5. Install successfully. Close all interfaces.



6. When ESP32-S3 WROOM 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, CH343 has been installed successfully. Close all dialog boxes.

## MAC

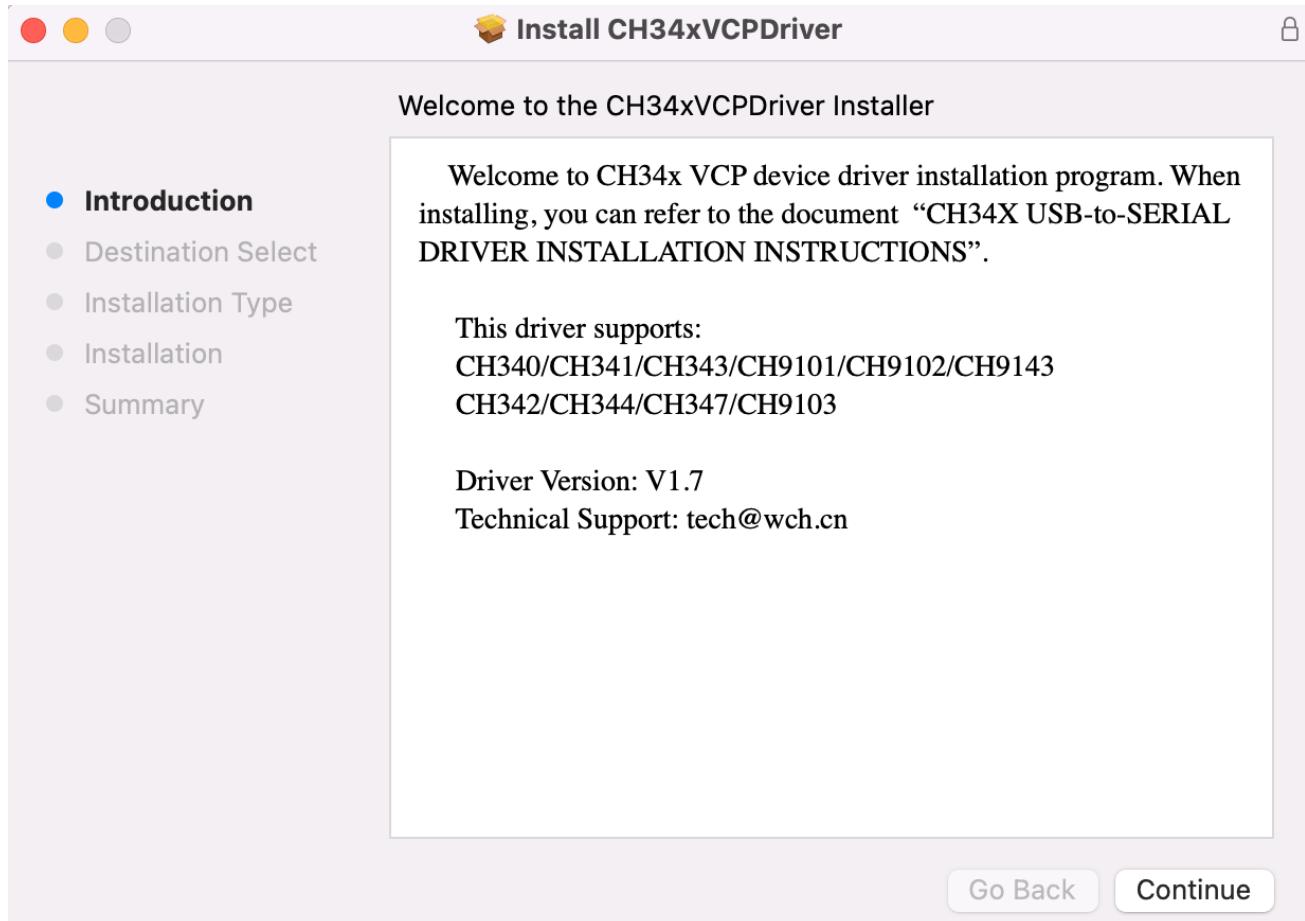
First, download CH343 driver, click <http://www.wch-ic.com/search?t=all&q=ch343> to download the appropriate one based on your operating system.

keyword ch343				
Downloads( 8 )				
file category	file content	version	upload time	
DataSheet				
	<a href="#">CH343DS1.PDF</a>	CH343 datasheet, USB to single serial port, supports up to 6M baud rate, serial port signals support 5V/3.3V/2.5V/1.8V, built-in crystal oscillator. CH343 supports built-in CDC driver in operating system or multi-functional high-speed VCP manufacture driver.	1.5	2021-11-18
Driver&Tools				
	<a href="#">CH343SER.ZIP</a>	For CH342/CH343/CH344/CH347/CH9101/CH9102/CH9103/CH9143, USB to high-speed serial port VCP vendor driver, supports Windows 11/10/8.1/8/7/VISTA/XP/2000	1.61	2022-05-13
	<a href="#">CH343CDC.ZIP</a>	For CH342/CH343/CH344/CH347/CH910X/CH9143/CH9340, USB to CDC serial port driver, supports Windows 11/10/8.1/8/7/VISTA/XP/2000	1.4	2022-05-13
	<a href="#">CH343SER.EXE</a>	For CH342/CH343/CH344/CH347/CH9101/CH9102/CH9103/CH9143, USB to high-speed serial port VCP vendor driver, supports Windows 11/10/8.1/8/7/VISTA/XP/2000	1.61	2022-05-13
	<a href="#">CH34XSER_MAC.ZI...</a>	For MAC CH342/CH343/CH344/CH347/CH9101/CH9102/CH9103/CH9143, USB to serial port VCP vendor driver of macOS	1.7	2022-05-13
	<a href="#">CH343CDC.EXE</a>	For CH342/CH343/CH344/CH347/CH910X/CH9143/CH9340, USB to CDC serial port driver, supports Windows 11/10/8.1/8/7/VISTA/XP/2000	1.4	2022-05-13
Application				
	<a href="#">CH34xSerCfg.ZIP</a>	USB configuration tool of Windows for CH340/CH342/CH343/CH344/CH347/CH348/CH9101/CH9102/CH9103. Via this tool, the chip's Vendor ID, product ID, maximum current value, BCD version	1.2	2022-05-24

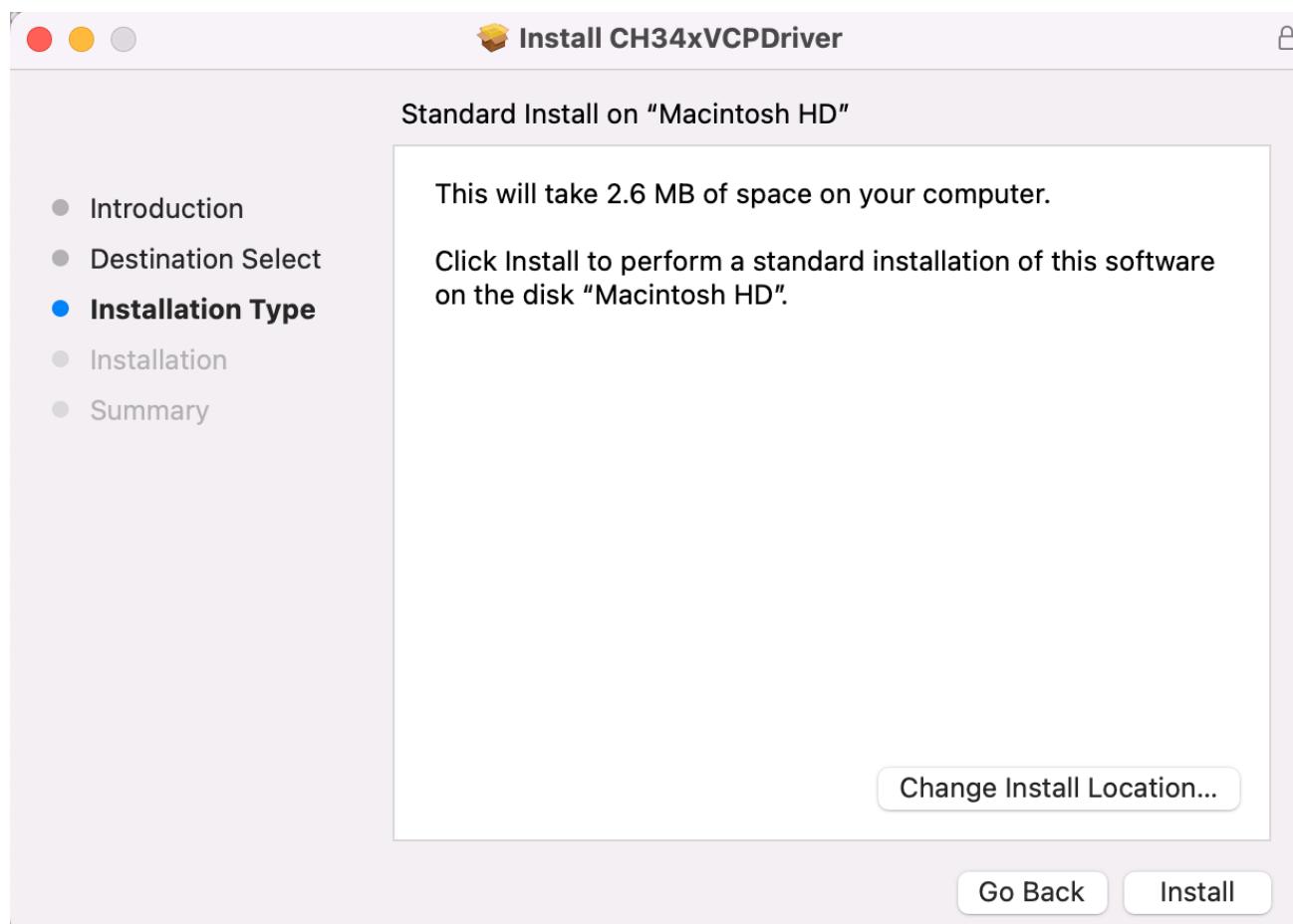
If you would not like to download the installation package, you can open “Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32\_S3/CH343”, we have prepared the installation package. Second, open the folder “Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32\_S3/CH343/MAC/”



Third, click Continue.

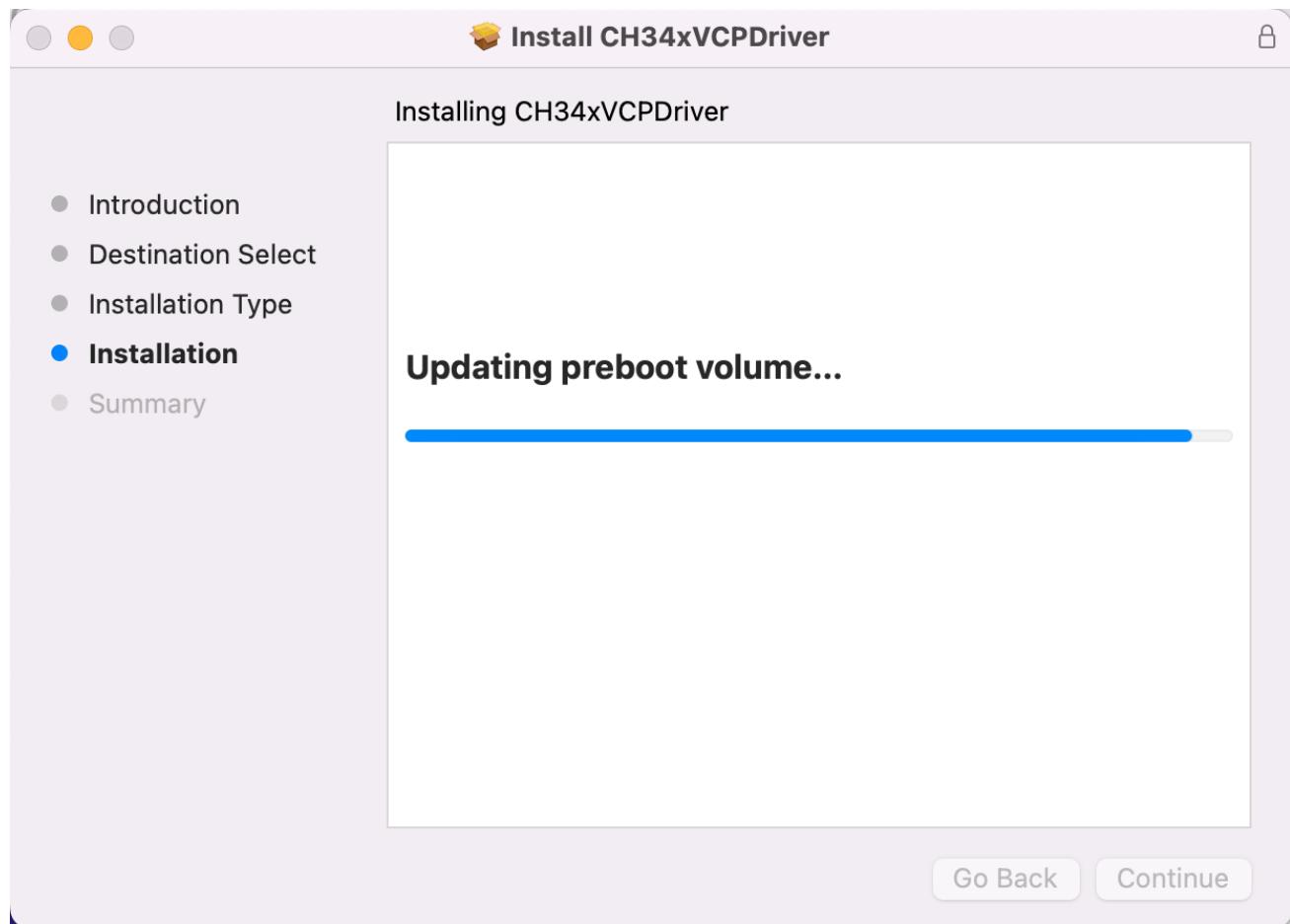


Fourth, click Install.

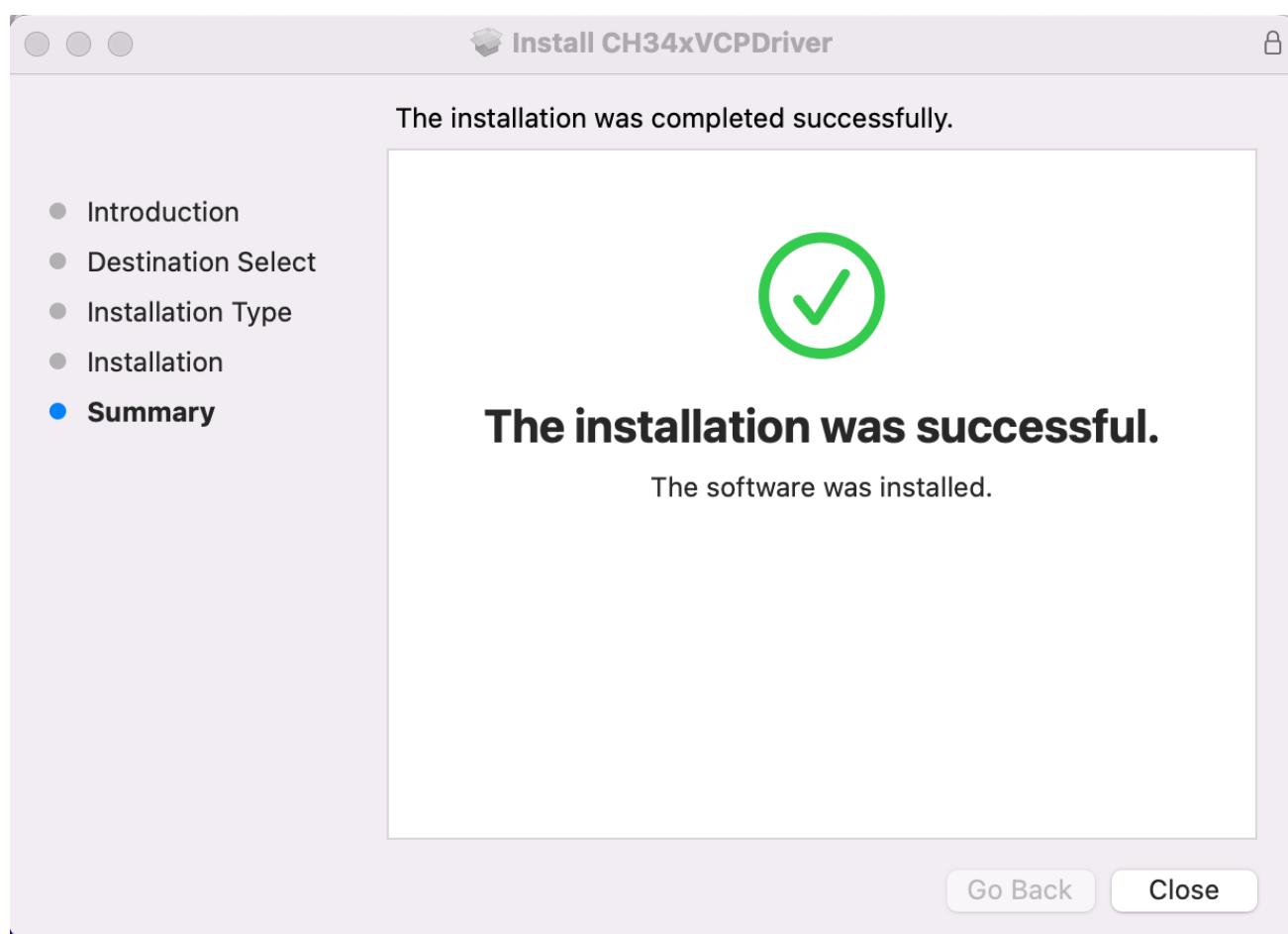




Then, waiting Finsh.

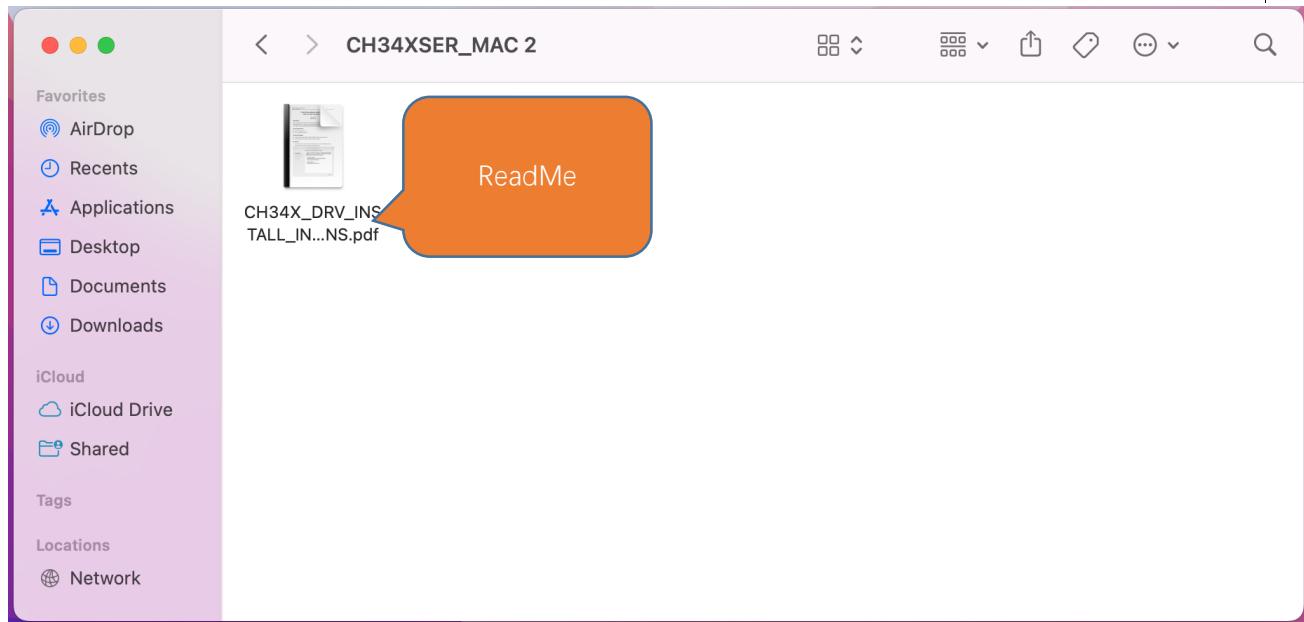


Finally, restart your PC.





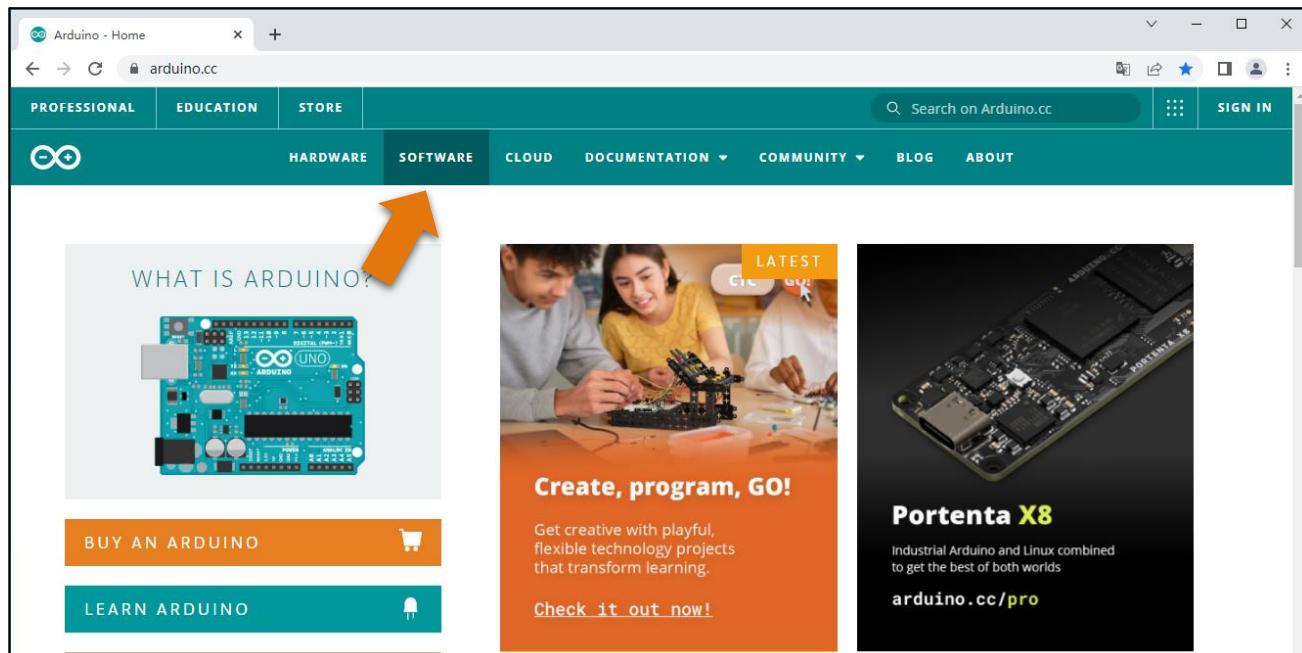
If you still haven't installed the CH340 by following the steps above, you can view `readme.pdf` to install it.



## Programming Software

Arduino Software (IDE) is used to write and upload the code for Arduino Board.

First, install Arduino Software (IDE): visit <https://www.arduino.cc>, click "Download" to enter the download page.



Select and download corresponding installer according to your operating system. If you are a windows user, please select the "Windows Installer" to download to install the driver correctly.

A screenshot of the Arduino website's Downloads page. The top navigation bar is identical to the homepage. The main content features a large image of the Arduino IDE 2.0.0 logo with the text "Arduino IDE 2.0.0". Below it is a brief description: "The new major release of the Arduino IDE is faster and even more powerful! In addition to a more modern editor and a more responsive interface it features autocompletion, code navigation, and even a live debugger." It also links to the "Arduino IDE 2.0 documentation". To the right, there's a "DOWNLOAD OPTIONS" section with links for Windows (Win 10 and newer, 64 bits; MSI installer; ZIP file), Linux (AppImage 64 bits (X86-64); ZIP file 64 bits (X86-64)), and macOS (10.14: "Mojave" or newer, 64 bits). An orange arrow points from the text above to the "DOWNLOAD OPTIONS" section.

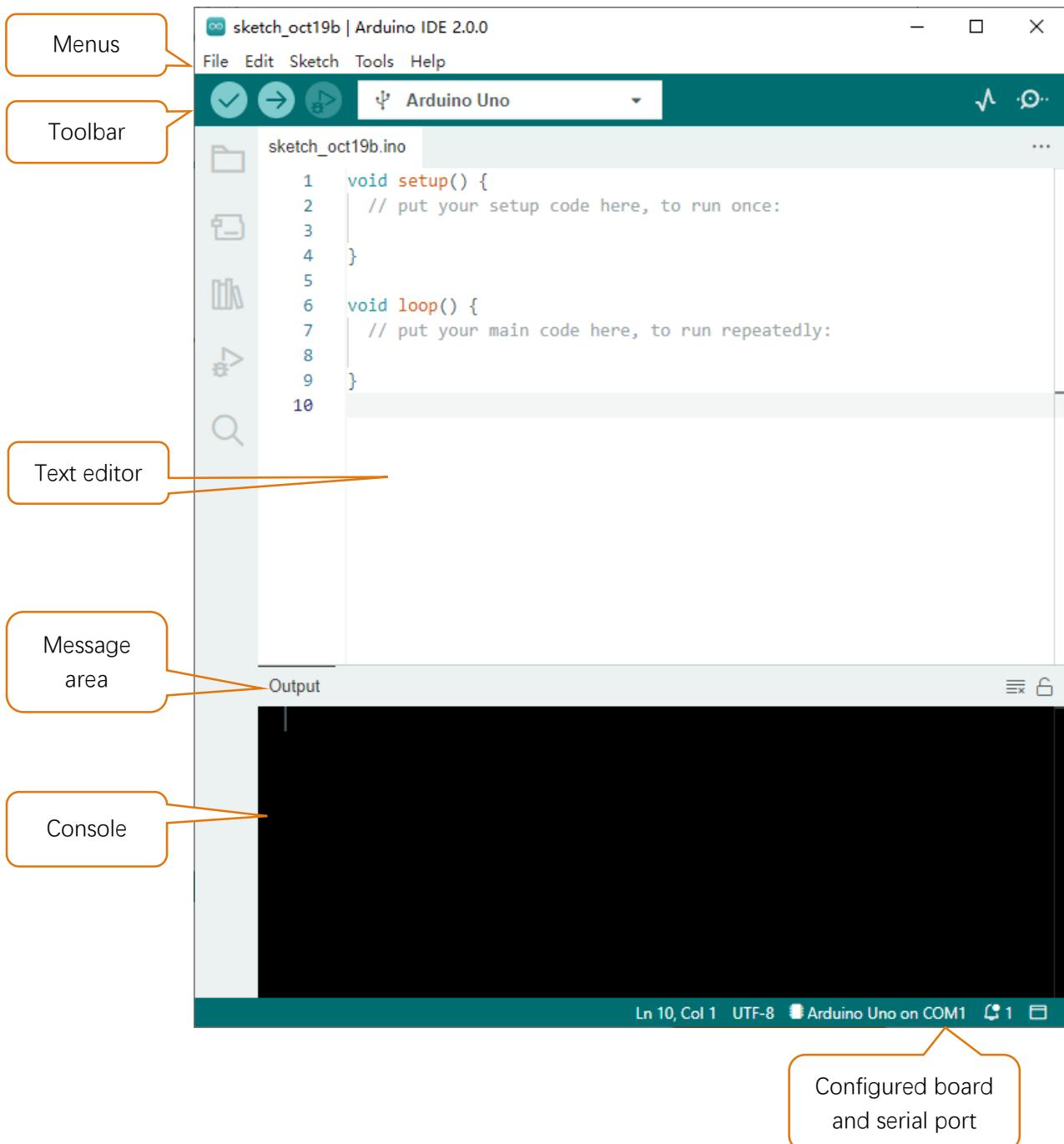
After the download completes, run the installer. For Windows users, there may pop up an installation dialog box of driver during the installation process. When it popes up, please allow the installation.

After installation is complete, an Arduino Software shortcut will be generated in the desktop. Run the Arduino Software.

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



The interface of Arduino Software is as follows:



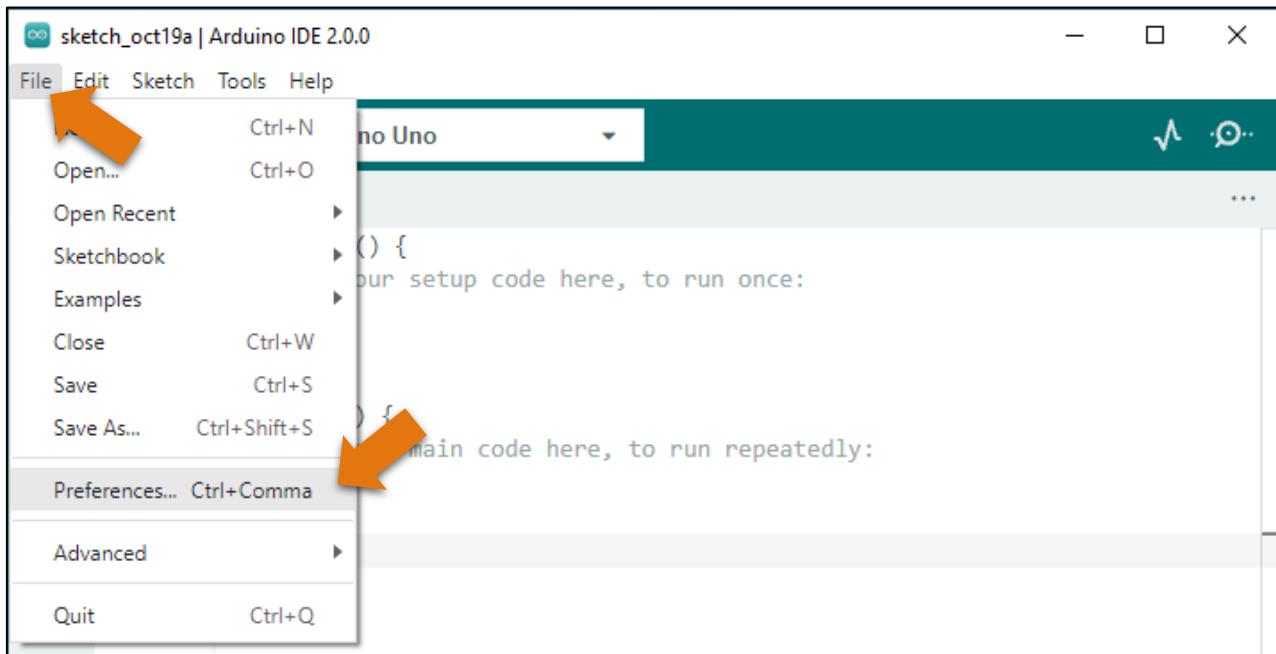
Programs written with Arduino Software (IDE) are called **sketches**. These sketches are written in the text editor and saved with the file extension.**.ino**. The editor has features for cutting/pasting and searching/replacing text. The message area gives feedback while saving and exporting and also displays errors. The console displays text output by the Arduino Software (IDE), including complete error messages and other information. The bottom right-hand corner of the window displays the configured board and serial port. The toolbar buttons allow you to verify and upload programs, create, open, and save sketches, and open the serial monitor.

	Verify Check your code for compile errors .
	Upload Compile your code and upload them to the configured board.
	Debug Debug code running on the board. (Some development boards do not support this function)
Arduino Uno	Development board selection Configure the support package and upload port of the development board.
	Serial Plotter Receive serial port data and plot it in a discounted graph.
	Serial Monitor Open the serial monitor.

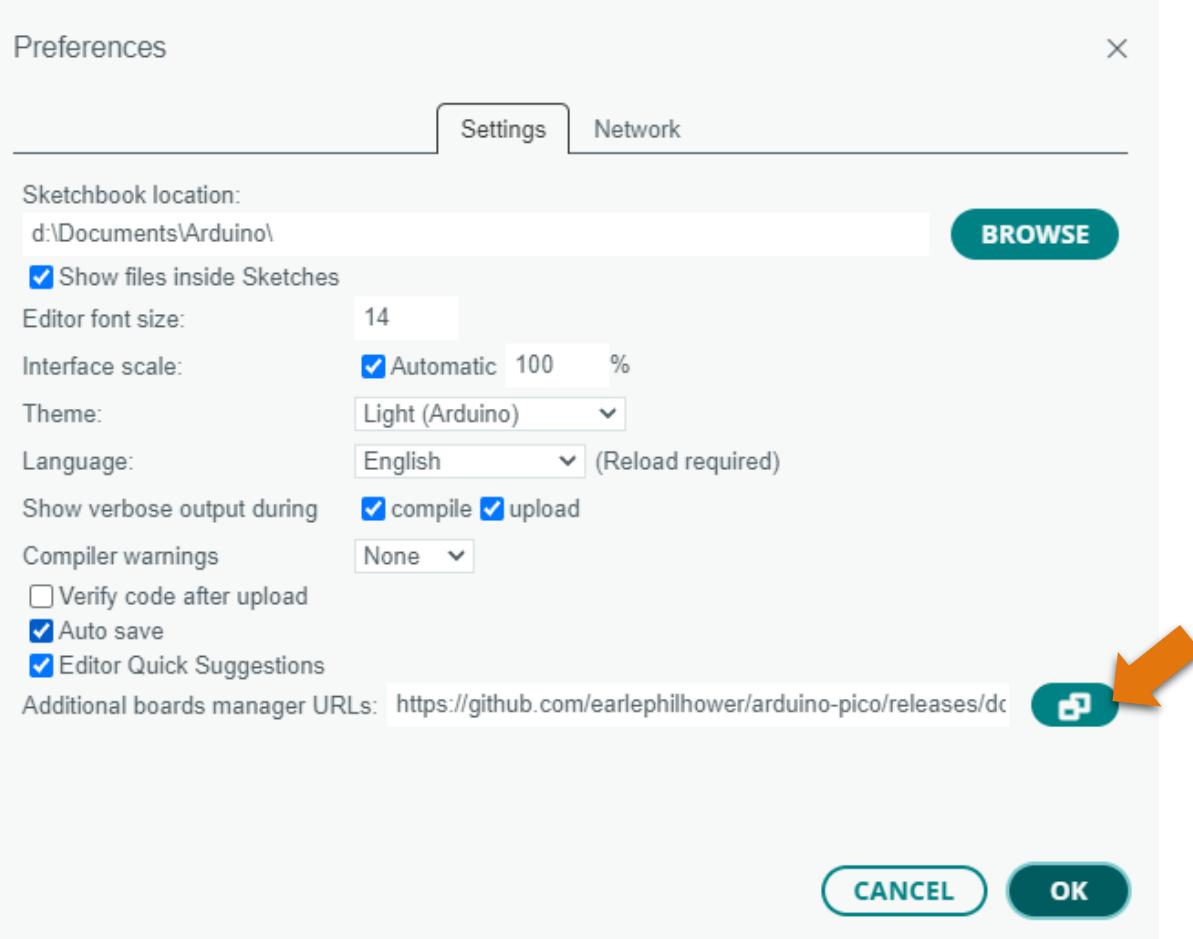
Additional commands are found within the five menus: File, Edit, Sketch, Tools, Help. The menus are context sensitive, which means only those items relevant to the work currently being carried out are available.

## Environment Configuration

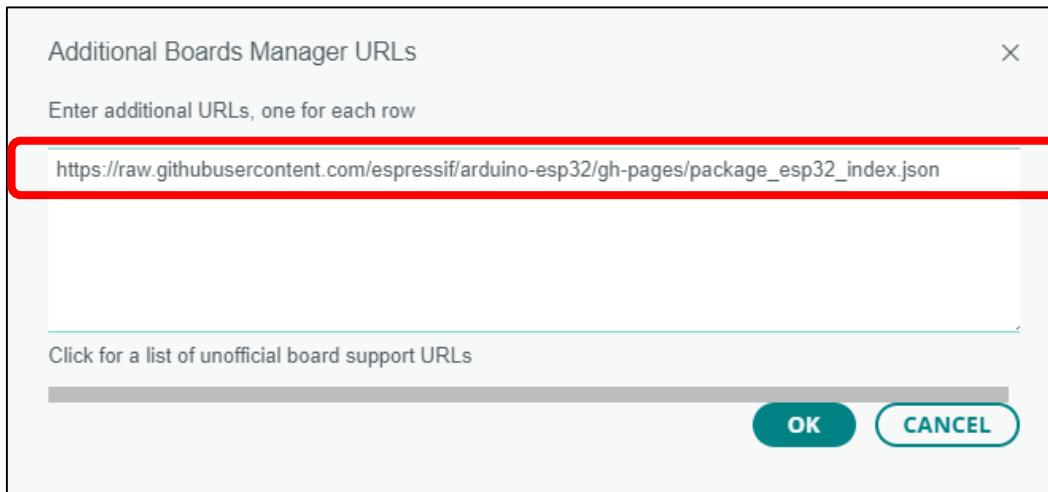
First, open the software platform arduino, and then click File in Menus and select Preferences.



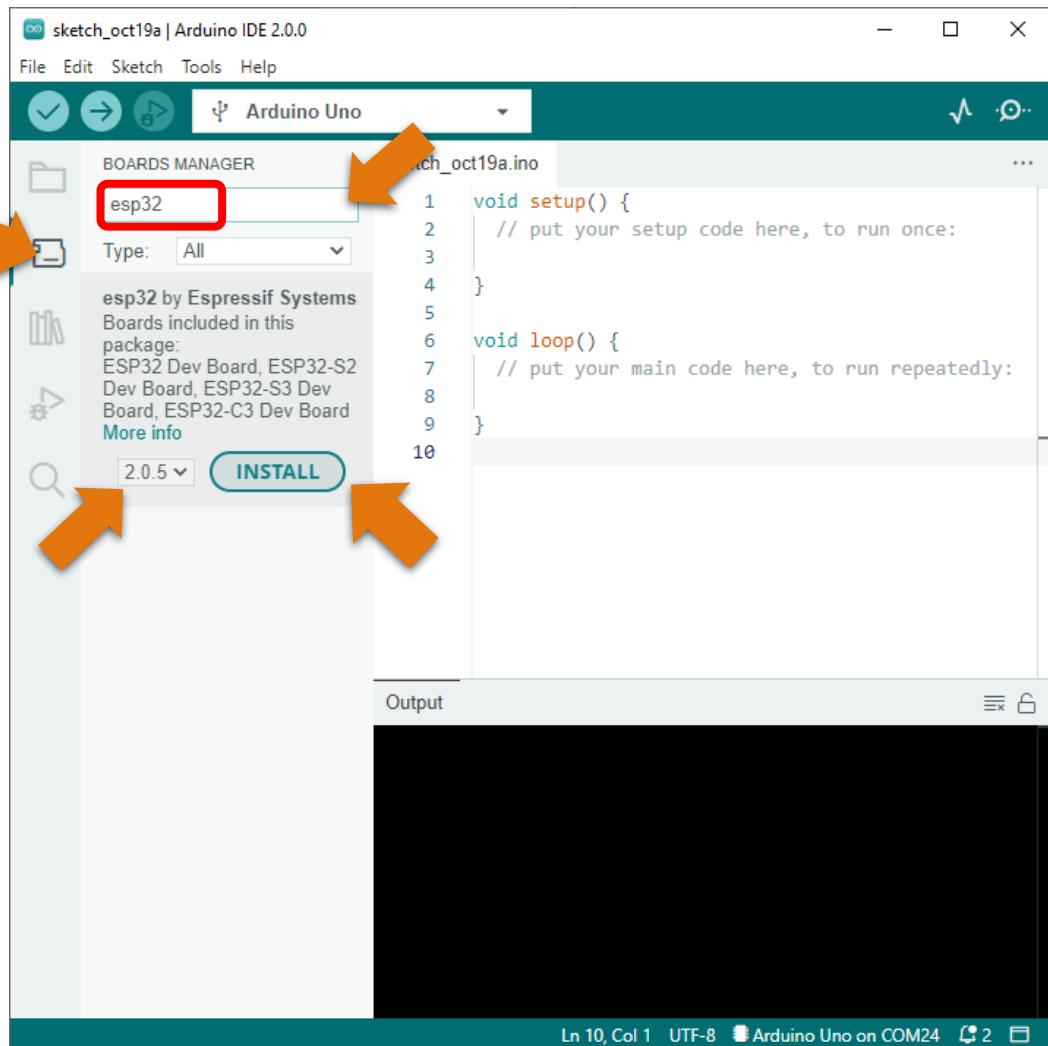
Second, click on the symbol behind "Additional Boards Manager URLs"



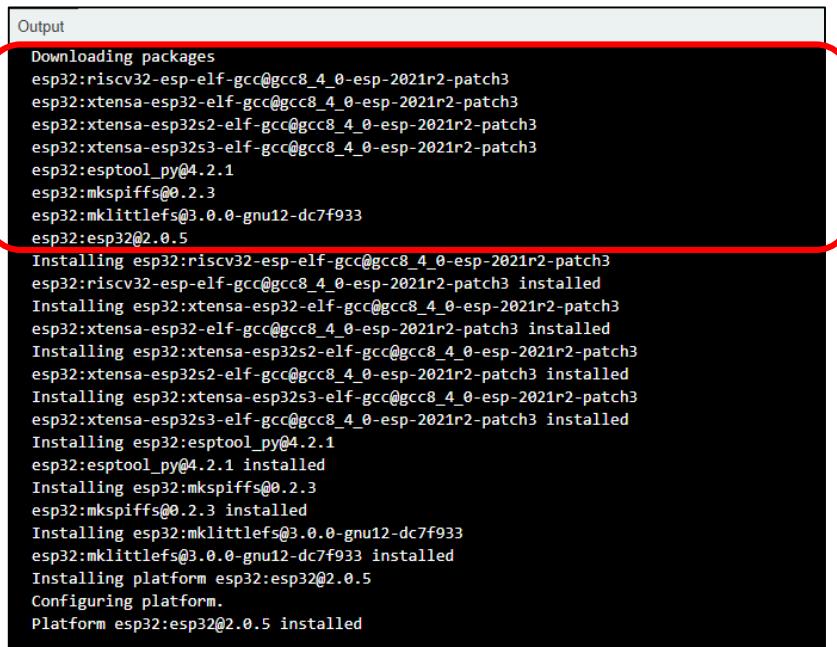
Third, fill in [https://raw.githubusercontent.com/espressif/arduino-esp32/gh-pages/package\\_esp32\\_index.json](https://raw.githubusercontent.com/espressif/arduino-esp32/gh-pages/package_esp32_index.json) in the new window, click OK, and click OK on the Preferences window again.



Fourth, click "Boards Manager". Enter "esp32" in Boards manager and select 2.0.5, Then click "INSTALL".



Arduinowill download these files automaticly. Wait for the installation to complete.

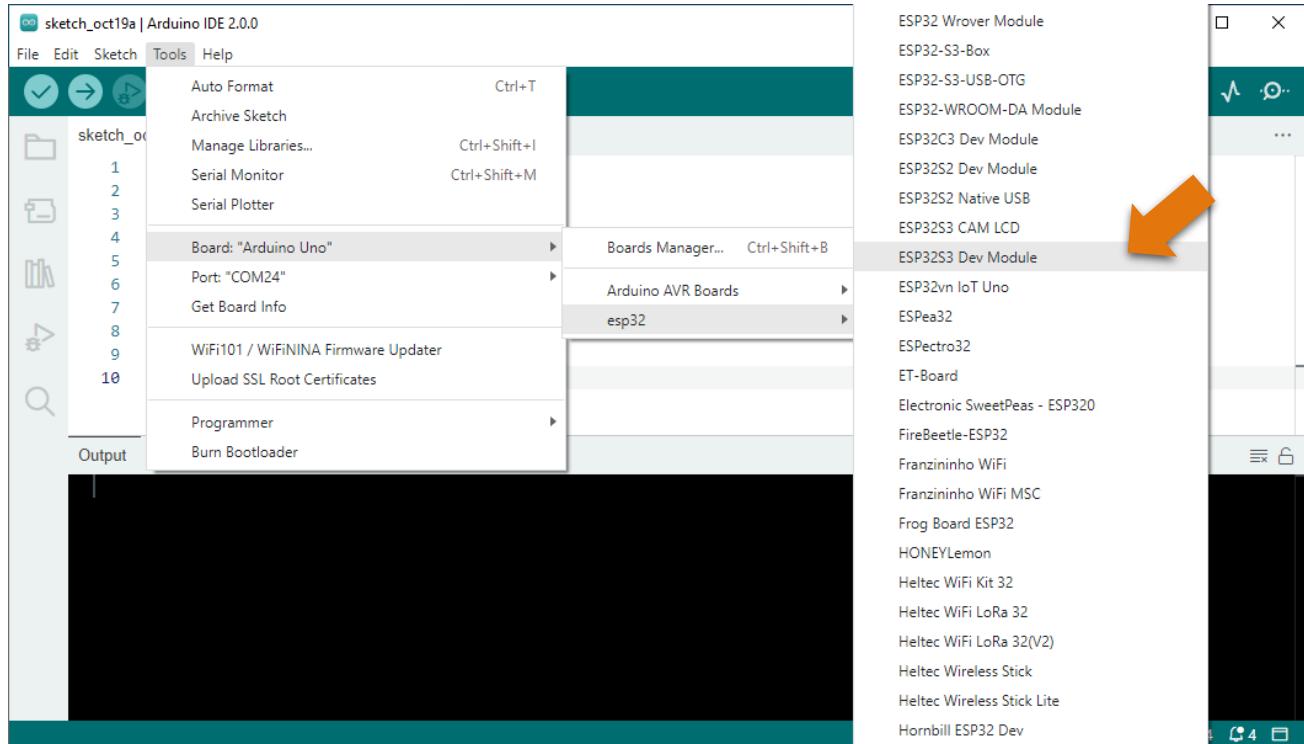


```

Output
Downloading packages
esp32:riscv32-esp-elf-gcc@gcc8_4_0-esp-2021r2-patch3
esp32:xtensa-esp32-elf-gcc@gcc8_4_0-esp-2021r2-patch3
esp32:xtensa-esp32s2-elf-gcc@gcc8_4_0-esp-2021r2-patch3
esp32:xtensa-esp32s3-elf-gcc@gcc8_4_0-esp-2021r2-patch3
esp32:esptool_py@4.2.1
esp32:mkspiffs@0.2.3
esp32:mklittlefs@3.0.0-gnu12-dc7f933
esp32:esp32@2.0.5

Installing esp32:riscv32-esp-elf-gcc@gcc8_4_0-esp-2021r2-patch3
esp32:riscv32-esp-elf-gcc@gcc8_4_0-esp-2021r2-patch3 installed
Installing esp32:xtensa-esp32-elf-gcc@gcc8_4_0-esp-2021r2-patch3
esp32:xtensa-esp32-elf-gcc@gcc8_4_0-esp-2021r2-patch3 installed
Installing esp32:xtensa-esp32s2-elf-gcc@gcc8_4_0-esp-2021r2-patch3
esp32:xtensa-esp32s2-elf-gcc@gcc8_4_0-esp-2021r2-patch3 installed
Installing esp32:xtensa-esp32s3-elf-gcc@gcc8_4_0-esp-2021r2-patch3
esp32:xtensa-esp32s3-elf-gcc@gcc8_4_0-esp-2021r2-patch3 installed
Installing esp32:esptool_py@4.2.1
esp32:esptool_py@4.2.1 installed
Installing esp32:mkspiffs@0.2.3
esp32:mkspiffs@0.2.3 installed
Installing esp32:mklittlefs@3.0.0-gnu12-dc7f933
esp32:mklittlefs@3.0.0-gnu12-dc7f933 installed
Installing platform esp32:esp32@2.0.5
Configuring platform.
Platform esp32:esp32@2.0.5 installed
  
```

When finishing installation, click Tools in the Menus again and select Board: "Arduino Uno", and then you can see information of ESP32. click "ESP32-S3 Dev Module" so that the ESP32-S3 programming development environment is configured.



## Notes for GPIO

### Strapping Pin

There are four Strapping pins for ESP32-S3: GPIO0、GPIO45、GPIO46、GPIO3。

With the release of the chip's system reset (power-on reset, RTC watchdog reset, undervoltage reset), the strapping pins sample the level and store it in the latch as "0" or "1", and keep it until the chip is powered off or turned off.

Each Strapping pin is connecting to internal pull-up/pull-down. Connecting to high-impedance external circuit or without an external connection, a strapping pin's default value of input level will be determined by internal weak pull-up/pull-down. To change the value of the Strapping, users can apply an external pull-down/pull-up resistor, or use the GPIO of the host MCU to control the level of the strapping pin when the ESP32-S3's power on reset is released.

**When releasing the reset, the strapping pin has the same function as a normal pin.**

The followings are default configurations of these four strapping pins at power-on and their functions under the corresponding configuration.

VDD_SPI Voltage			
Pin	Default	3.3 V	1.8 V
GPIO45	Pull-down	0	1
Booting Mode <sup>1</sup>			
Pin	Default	SPI Boot	Download Boot
GPIO0	Pull-up	1	0
GPIO46	Pull-down	Don't care	0
Enabling/Disabling ROM Messages Print During Booting <sup>2</sup>			
Pin	Default	Enabled	Disabled
GPIO46	Pull-down	See the 2nd note	See the 2nd note
JTAG Signal Selection			
Pin	Default	EFUSE_DIS_USB_JTAG = 0, EFUSE_DIS_PAD_JTAG = 0, EFUSE_STRAP_JTAG_SEL=1	
GPIO3	N/A	0: JTAG signal from on-chip JTAG pins 1: JTAG signal from USB Serial/JTAG controller	

#### Note:

1. The strapping combination of GPIO46 = 1 and GPIO0 = 0 is invalid and will trigger unexpected behavior.
2. By default, the ROM boot messages are printed over UART0 (UOTXD pin) and USB Serial/JTAG controller together. The ROM code printing can be disabled through configuration register and eFuse. For detailed information, please refer to Chapter [Chip Boot Control](#) in *ESP32-S3 Technical Reference Manual*.

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-s3-wroom-1\\_wroom-1u\\_datasheet\\_en.pdf](https://www.espressif.com/sites/default/files/documentation/esp32-s3-wroom-1_wroom-1u_datasheet_en.pdf)

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



## PSRAM Pin

The module on the ESP32-S3-WROOM board uses the ESP32-S3R8 chip with 8MB of external Flash. When we use the OPI PSRAM, please note that the GPIO35-GPIO37 on the ESP32-S3-WROOM board will not be available for other purposes. When OPI PSRAM is not used, GPIO35-GPIO37 on the board can be used as normal GPIO.

<b>ESP32-S3R8 / ESP32-S3R8V</b>	<b>In-package PSRAM (8 MB, Octal SPI)</b>
SPICLK	CLK
SPICS1	CE#
SPIID	DQ0
SPIQ	DQ1
SPIWP	DQ2
SPIHD	DQ3
GPIO33	DQ4
GPIO34	DQ5
GPIO35	DQ6
GPIO36	DQ7
GPIO37	DQS/DM

## SDcard Pin

An SDcard slot is integrated on the back of the ESP32-S3-WROOM board. We can use GPIO38-GPIO40 of ESP32-S3-WROOM to drive SD card.

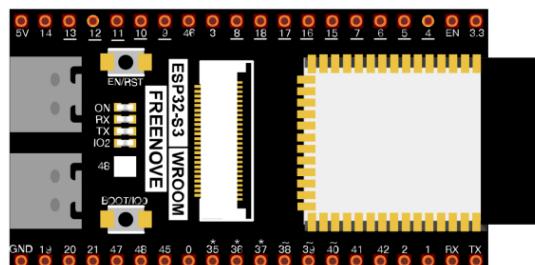
The SDcard of ESP32-S3-WROOM uses SDMMC, a 1-bit bus driving method, which has been integrated in the Arduino IDE, and we can call the "SD\_MMC.h" library to drive it. For details, see the SDcard chapter in this tutorial.

## USB Pin

In Micropython, GPIO19 and GPIO20 are used for the USB function of ESP32S3, so they cannot be used as other functions!

## Cam Pin

When using the camera of our ESP32-S3 WROOM, please check the pins of it. Pins with underlined numbers are used by the camera function, if you want to use other functions besides it, please avoid using them.



CAM_Pin	GPIO_pin
SIOD	GPIO4
SIOC	GPIO5
CSI_VSYNC	GPIO6
CSI_HREF	GPIO7
CSI_Y9	GPIO16
XCLK	GPIO15
CSI_Y8	GPIO17
CSI_Y7	GPIO18
CSI_PCLK	GPIO13
CSI_Y6	GPIO12
CSI_Y2	GPIO11
CSI_Y5	GPIO10
CSI_Y3	GPIO9
CSI_Y4	GPIO8

If you have any questions about the information of GPIO, you can click [here](#) to go back to ESP32-S3 WROOM to view specific information about GPIO.

or check: [https://www.espressif.com/sites/default/files/documentation/esp32-s3\\_datasheet\\_en.pdf](https://www.espressif.com/sites/default/files/documentation/esp32-s3_datasheet_en.pdf).

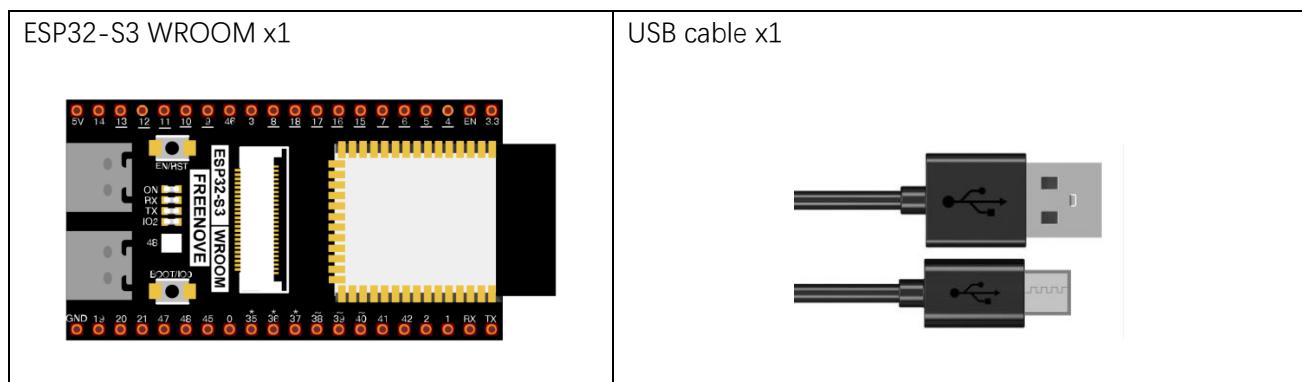
# Chapter 0 LED

This chapter is the Start Point in the journey to build and explore ESP32-S3 WROOM electronic projects. We will start with simple “Blink” project.

## Project 0.1 Blink

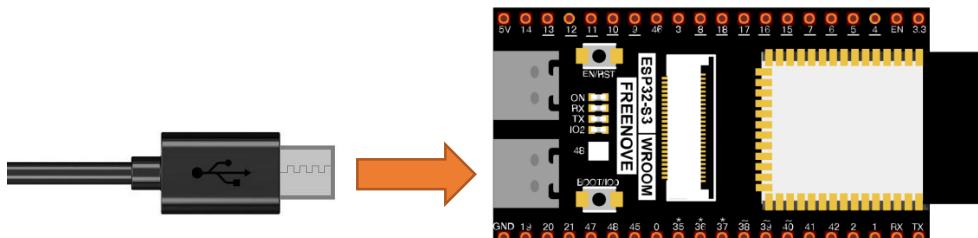
In this project, we will use ESP32-S3 WROOM to control blinking a common LED.

## Component List



### Power

ESP32-S3 WROOM needs 5v power supply. In this tutorial, we need connect ESP32-S3 WROOM 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-S3 WROOM by default.

In the whole tutorial, we don't use T extension to power ESP32-S3 WROOM. So 5V and 3.3V (including EXT 3.3V) on the extension board are provided by ESP32-S3 WROOM.

We can also use DC jack of extension board to power ESP32-S3 WROOM. In this way, 5v and EXT 3.3v on extension board are provided by external power resource.

## Sketch

According to the circuit, when the GPIO2 of ESP32-S3 WROOM output level is high, the LED turns ON. Conversely, when the GPIO2 ESP32-S3 WROOM output level is low, the LED turns OFF. Therefore, we can let GPIO2 circularly output high and low level to make the LED blink.

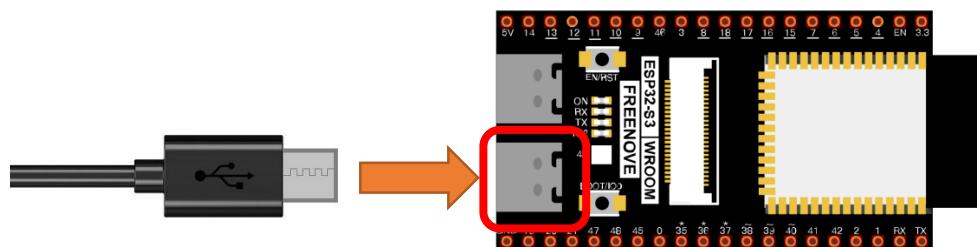
Upload the following Sketch:

**Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32\_S3\Sketches\Sketch\_01.1\_Blink.**

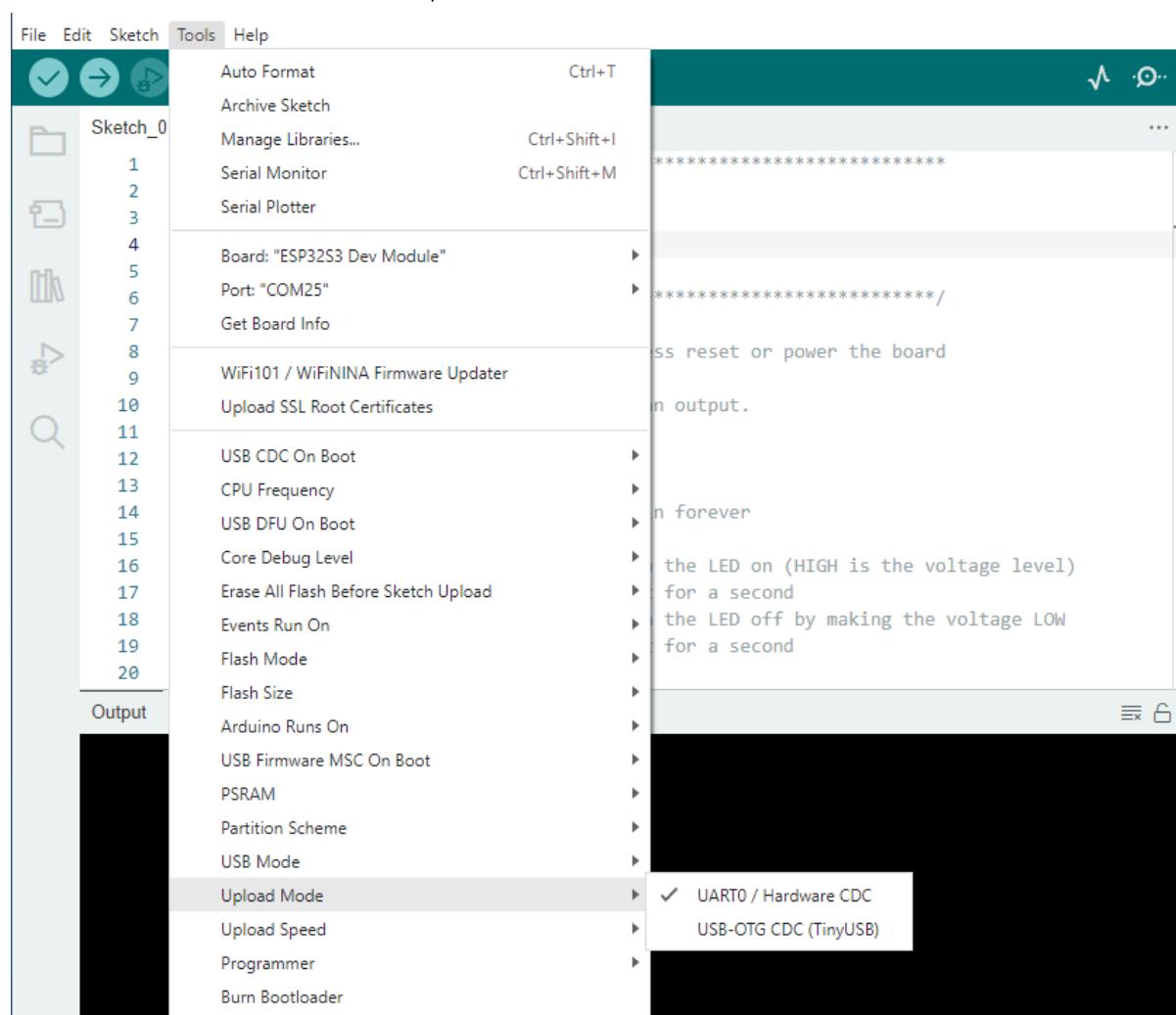
Next we will introduce two ways to upload code to ESP32-S3 WROOM.

**Option 1:**

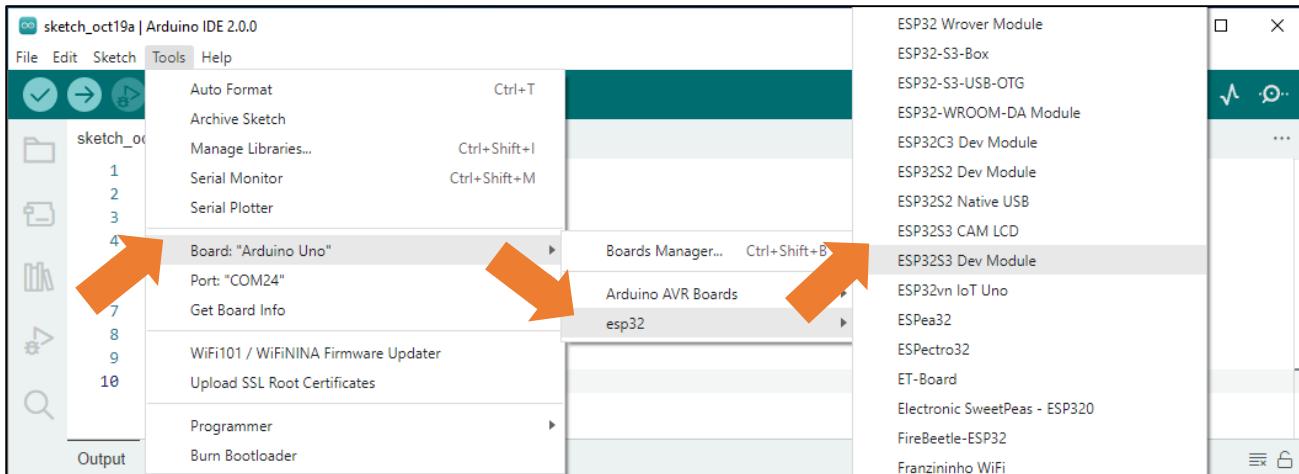
Connect ESP32-S3 WROOM to computer.



Open Arduino IDE 2.0.0. Click Tools->Upload Mode. Select UART0 / Hardware CDC.

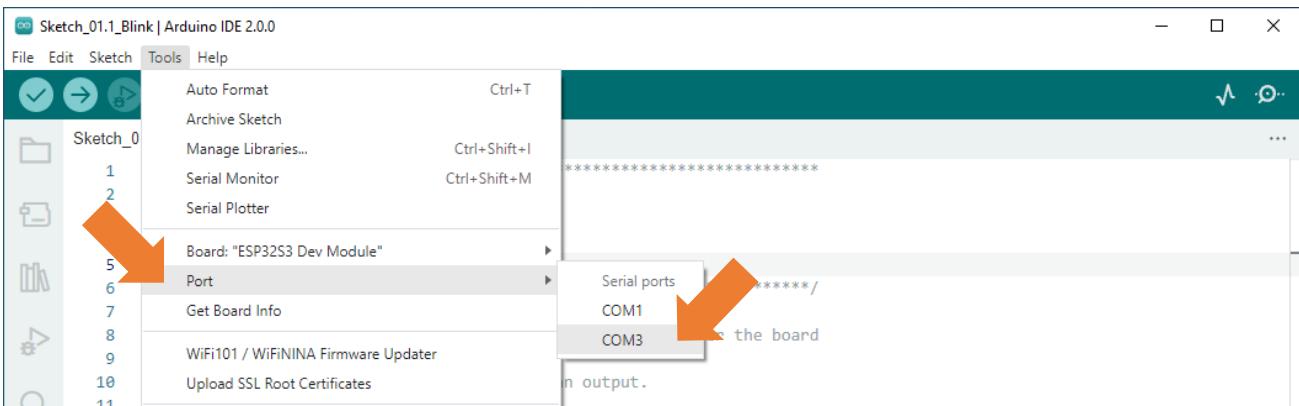


Before uploading the code, click "**Tools**", "**Board**" and select "**ESP32S3 Dev Module**".

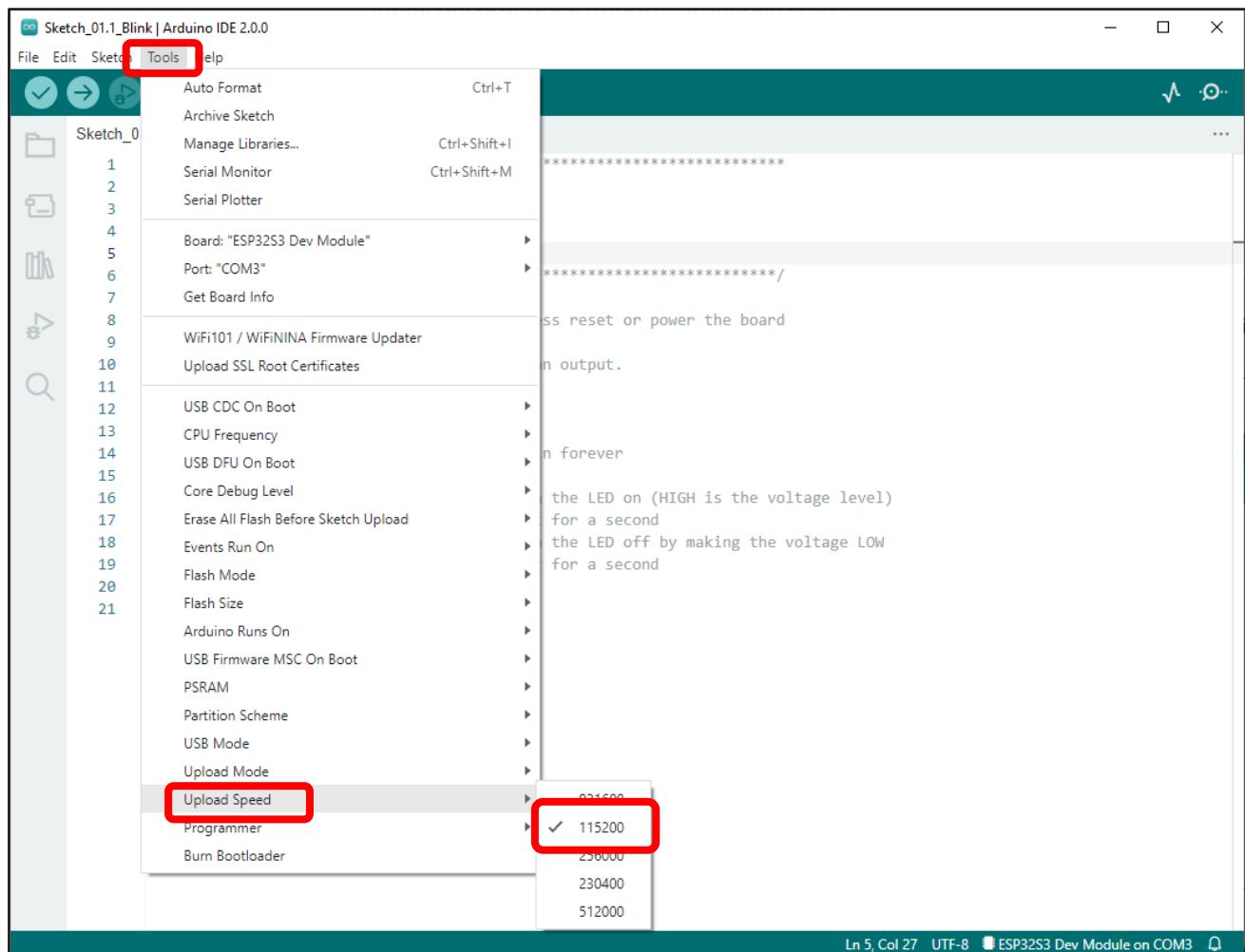


Select the serial port.

Note that the computer port number of each user may be different. Please select the correct serial port according to your computer. Taking the window system as an example, my computer recognizes that the communication interface of the ESP32-S3-WROOM is COM3, so I select COM3.



Note: For macOS users, if the uploading fails, please set the baud rate to 115200 before clicking “Upload Using Programmer”.





Click the Upload button and it will compile and upload the Sketch to the ESP32-S3-WROOM.

The screenshot shows the Arduino IDE interface with the following details:

- Title Bar:** Sketch\_01.1\_Blink | Arduino IDE 2.0.0
- Sketch Name:** Sketch\_01.1\_Blink.ino
- Board:** ESP32S3 Dev Module
- Code Content:**

```

1  // ****
2  * Filename   : Blink
3  * Description : Make an led blinking.
4  * Author     : www.freenove.com
5  * Modification: 2022/10/19
6  ****
7  #define LED_BUILTIN 2
8  // the setup function runs once when you press reset or power the board
9  void setup() {
10    // initialize digital pin LED_BUILTIN as an output.
11    pinMode(LED_BUILTIN, OUTPUT);
12 }
13
14 // the loop function runs over and over again forever
15 void loop() {
16    digitalWrite(LED_BUILTIN, HIGH);    // turn the LED on (HIGH is the voltage level)
17    delay(1000);                      // wait for a second
18    digitalWrite(LED_BUILTIN, LOW);     // turn the LED off by making the voltage LOW
19    delay(1000);                      // wait for a second
20 }
21

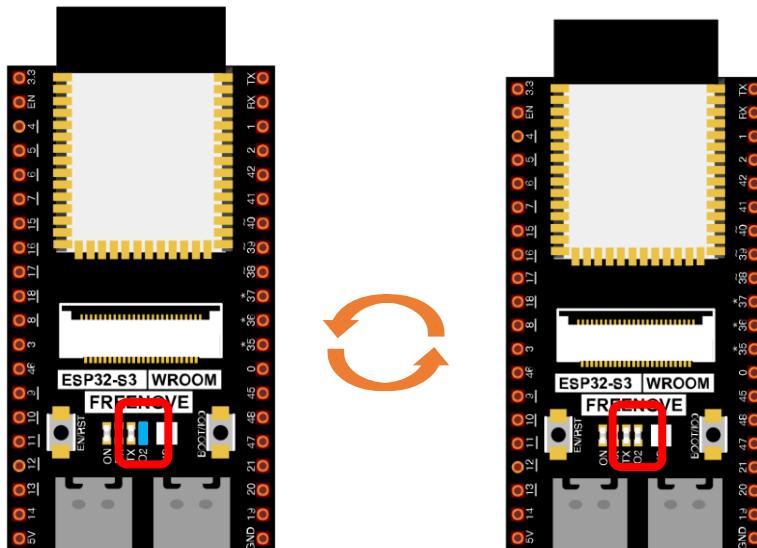
```
- Output Window:**

```

Wrote 8192 bytes (47 compressed) at 0x0000e000 in 0.2 seconds (effective 431.7 kbit/s)...
Hash of data verified.
Compressed 227968 bytes to 126986...
Writing at 0x00010000... (12 %)
Writing at 0x0001cdab... (25 %)
Writing at 0x00022890... (37 %)
Writing at 0x00027d25... (50 %)
Writing at 0x0002d247... (62 %)
Writing at 0x00034280... (75 %)
Writing at 0x0003dd05... (87 %)
Writing at 0x00043319... (100 %)

```
- Progress Bar:** Uploading... (progress bar is partially filled)
- Status Bar:** Ln 1, Col 1 UTF-8 ESP32S3 Dev Module on COM3

Wait for the Sketch upload to complete, and observe the ESP32-S3-WROOM. You can see that the blue LED (IO2) on the board flashes cyclically.

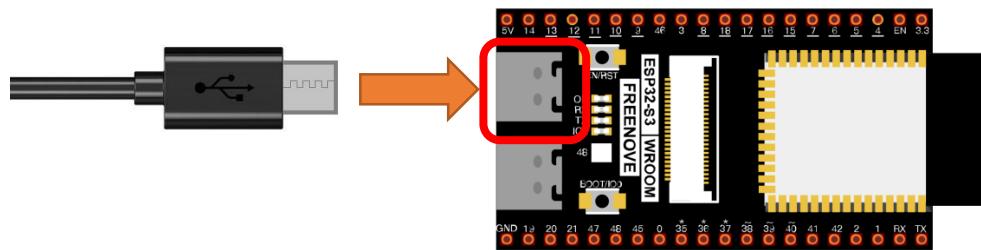


If you have any concerns, please contact us via: [support@freenove.com](mailto:support@freenove.com).

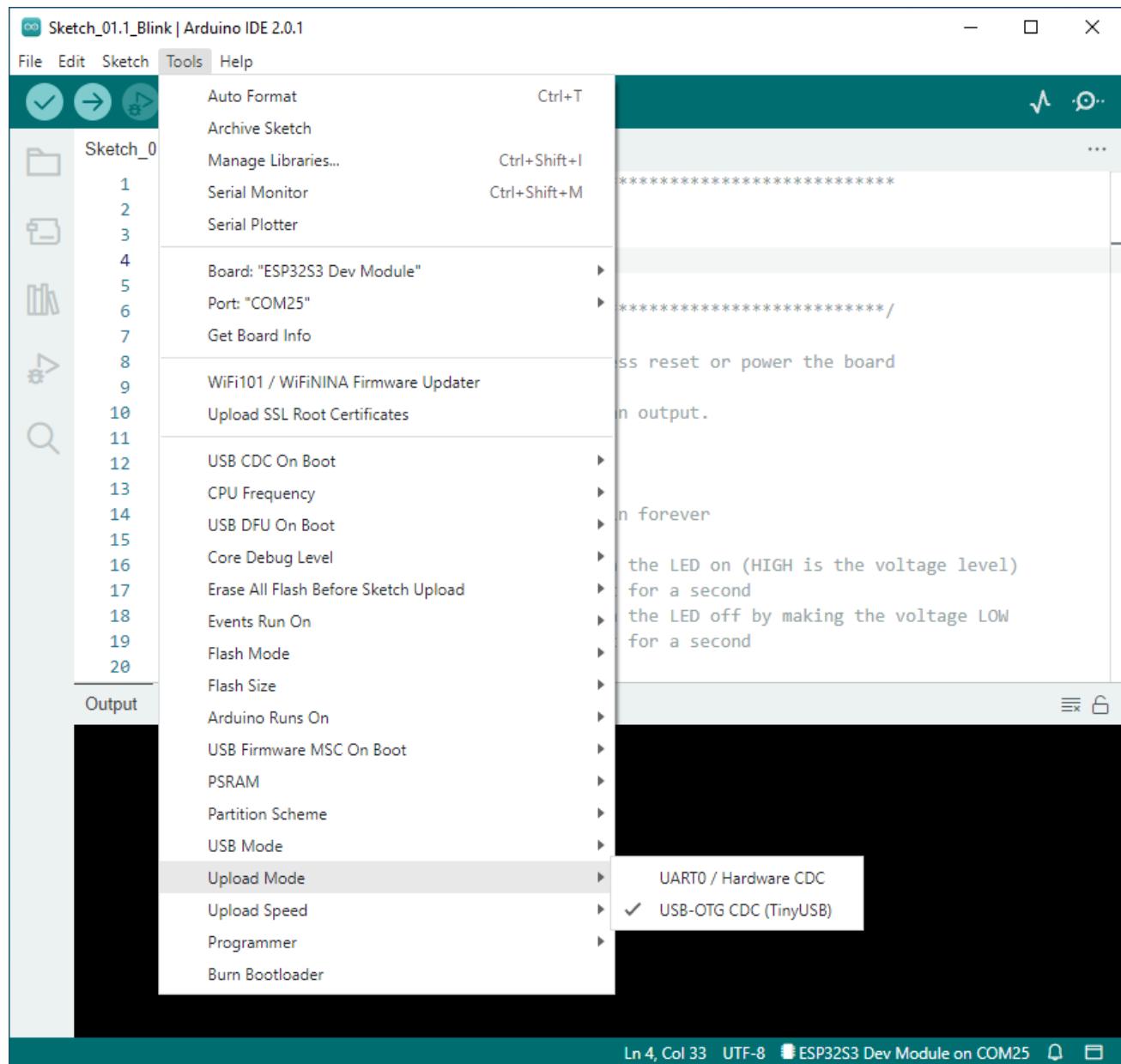
Any concerns? ✉ [support@freenove.com](mailto:support@freenove.com)

### Option 2:

Connect ESP32-S3 WROOM to computer.

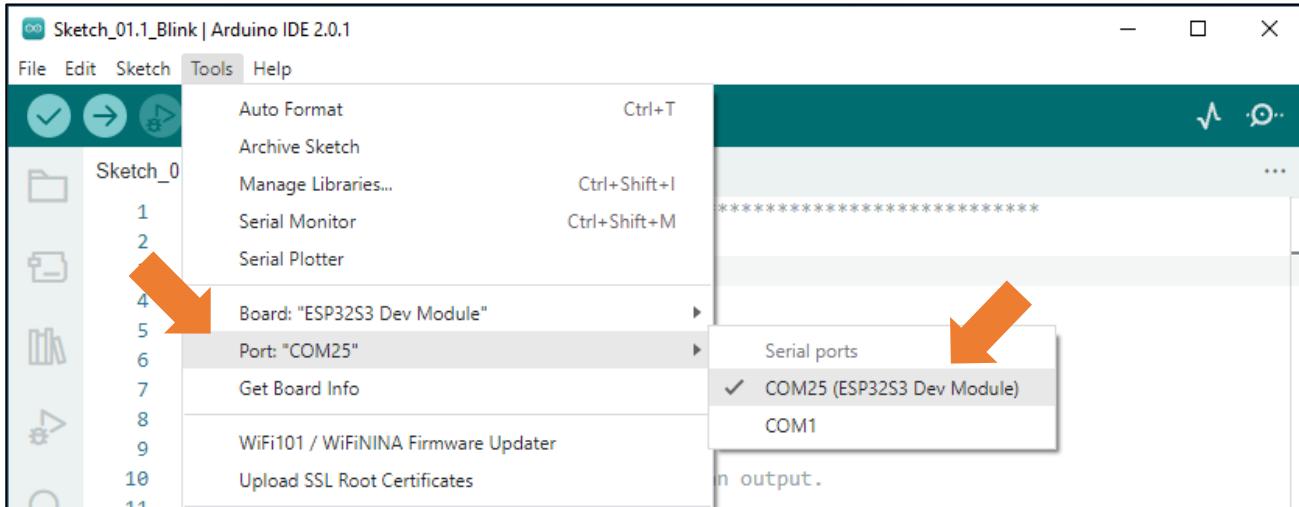


Open Arduino IDE 2.0.0. Click Tools->Upload Mode. Select USB-OTG CDC(TinyUSB).

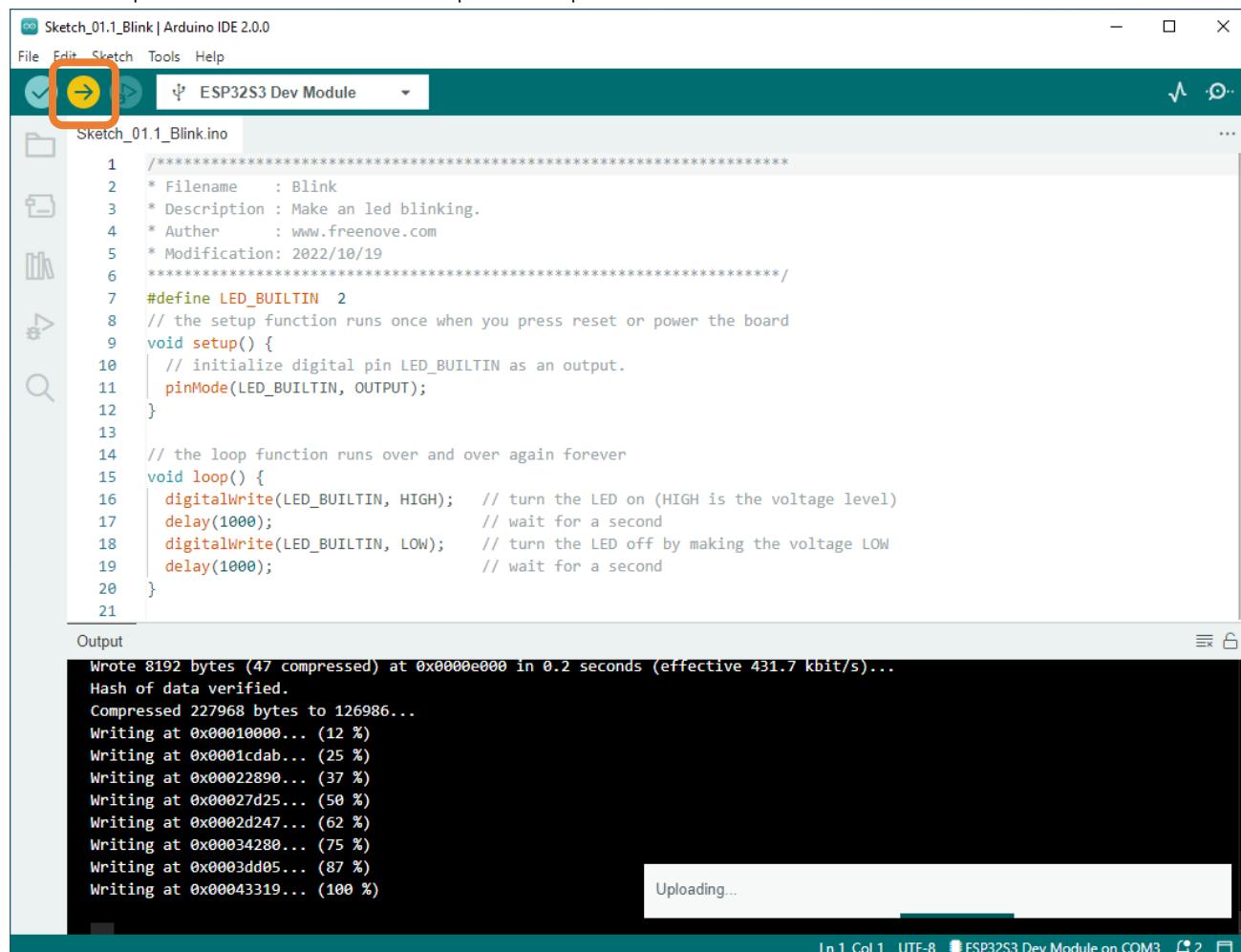


Select the serial port.

Note that the computer port number of each user may be different. Please select the correct serial port according to your computer. Taking the window system as an example, my computer recognizes that the communication interface of the ESP32-S3-WROOM is COM25, so I select COM25.



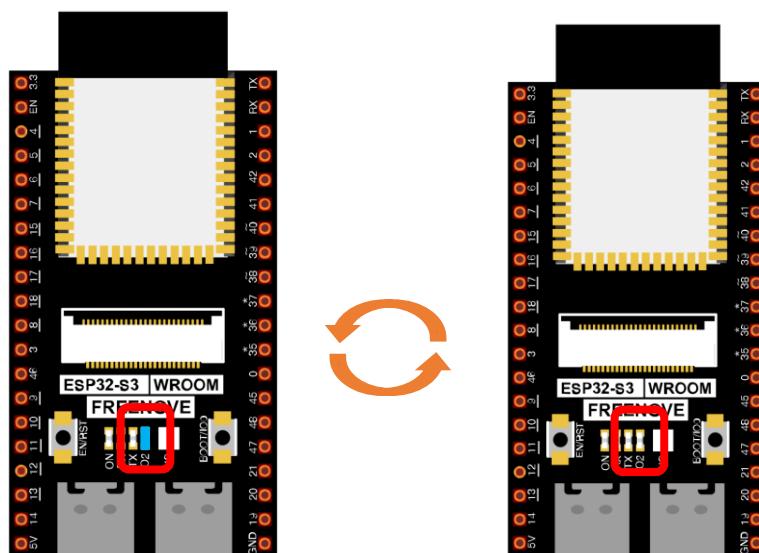
Click the Upload button and it will compile and upload the Sketch to the ESP32-S3-WROOM.



Wait for the Sketch upload to complete, and observe the ESP32-S3-WROOM. You can see that the blue

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

LED (IO2) on the board flashes cyclically.



### Sketch\_01.1\_Blink

The following is the program code:

```

1 #define LED_BUILTIN 2
2 // the setup function runs once when you press reset or power the board
3 void setup() {
4     // initialize digital pin LED_BUILTIN as an output.
5     pinMode(LED_BUILTIN, OUTPUT);
6 }
7
8 // the loop function runs over and over again forever
9 void loop() {
10    digitalWrite(LED_BUILTIN, HIGH);      // turn the LED on (HIGH is the voltage level)
11    delay(1000);                      // wait for a second
12    digitalWrite(LED_BUILTIN, LOW);       // turn the LED off by making the voltage LOW
13    delay(1000);                      // wait for a second
14 }
```

The Arduino IDE code usually contains two basic functions: void setup() and void loop().

After the board is reset, the setup() function will be executed firstly, and then the loop() function.

setup() function is generally used to write code to initialize the hardware. And loop() function is used to write code to achieve certain functions. loop() function is executed repeatedly. When the execution reaches the end of loop(), it will jump to the beginning of loop() to run again.

Reset	<pre> 1 // the setup function runs once when you press reset or power the board 2 void setup() { 3     ... 4 } 5 6 7 // the loop function runs over and over again forever </pre>
-------	---

Any concerns? ✉ support@freenove.com

```

8   void loop() {
...
13 }
```

**Reset**

Reset operation will lead the code to be executed from the beginning. Switching on the power, finishing uploading the code and pressing the reset button will trigger reset operation.

In the circuit, ESP32-S3 WROOM's GPIO2 is connected to the LED, so the LED pin is defined as 2.

```
1 #define LED_BUILTIN 2
```

This means that after this line of code, all LED\_BUILTIN will be treated as 2.

In the setup () function, first, we set the LED\_BUILTIN as output mode, which can make the port output high level or low level.

```

4 // initialize digital pin LED_BUILTIN as an output.
5 pinMode(LED_BUILTIN, OUTPUT);
```

Then, in the loop () function, set the LED\_BUILTIN to output high level to make LED light up.

```
10 digitalWrite(LED_BUILTIN, HIGH); // turn the LED on (HIGH is the voltage level)
```

Wait for 1000ms, that is 1s. Delay () function is used to make control board wait for a moment before executing the next statement. The parameter indicates the number of milliseconds to wait for.

```
11 delay(1000); // wait for a second
```

Then set the LED\_BUILTIN to output low level, and LED light off. One second later, the execution of loop () function will be completed.

```

12 digitalWrite(LED_BUILTIN, LOW); // turn the LED off by making the voltage LOW
13 delay(1000); // wait for a second
```

The loop() function is constantly being executed, so LED will keep blinking.

**Reference**

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

Configures the specified pin to behave either as an input or an output.

**Parameters**

pin: the pin number to set the mode of.

mode: INPUT, OUTPUT, INPUT\_PULLDOWN, or INPUT\_PULLUP.

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

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

For more related functions, please refer to <https://www.arduino.cc/reference/en/>

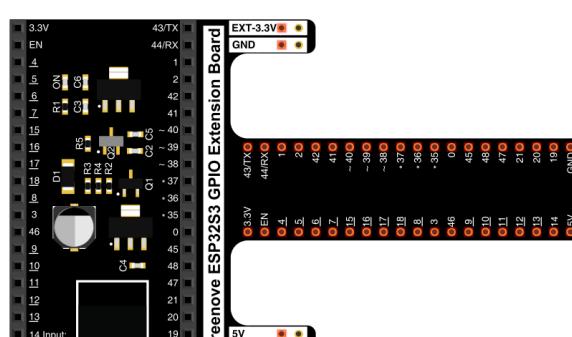
# Chapter 1 LED

This chapter is the Start Point in the journey to build and explore ESP32-S3 WROOM electronic projects. We will start with simple “Blink” project.

## Project 1.1 Blink

In this project, we will use ESP32-S3 WROOM to control blinking a common LED.

### Component List

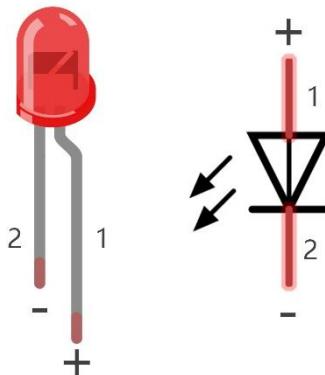
ESP32-S3 WROOM x1	GPIO Extension Board x1
	
Breadboard x1	
	LED x1
	Resistor 220Ω x1
	Jumper M/M x2

## Component knowledge

### LED

A LED is a type of diode. All diodes only work if current is flowing in the correct direction and have two poles. A 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 (GND). This type of component is known as “diodes” (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.



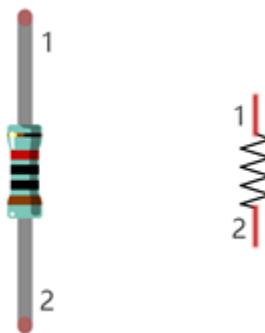
LED	Voltage	Maximum current	Recommended current
Red	1.9 - 2.2V	20mA	10mA
Green	2.9 - 3.4V	10mA	5mA
Blue	2.9 - 3.4V	10mA	5mA
Volt ampere characteristics conform to diode			

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 ( $R$ ).  $1M\Omega=1000k\Omega$ ,  $1k\Omega=1000\Omega$ .

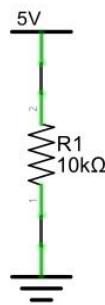
A resistor is a passive electrical component that limits or regulates the flow of current in an electronic circuit. On the left, we see a physical representation of a resistor, and the right is the symbol used to represent the presence of a resistor in a circuit diagram or schematic.



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

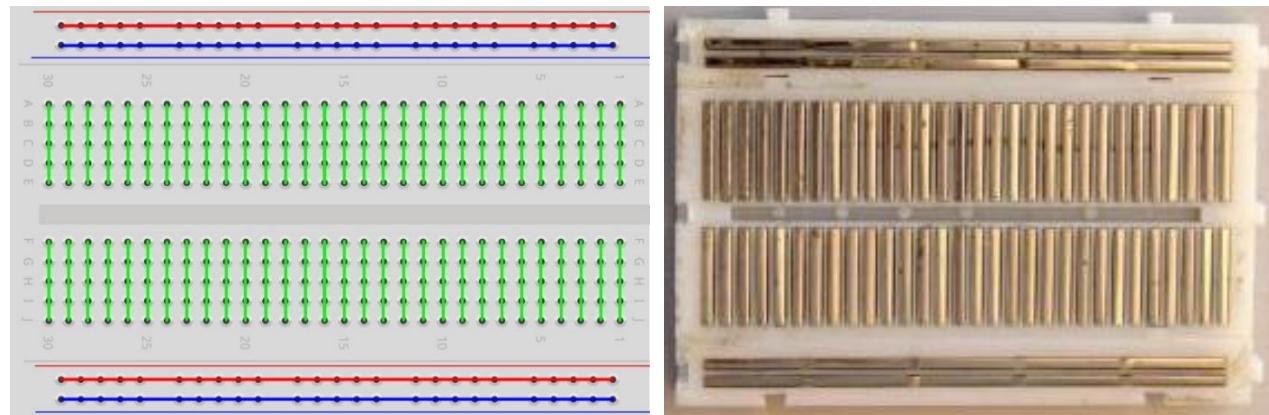


**WARNING:** Never connect the two poles of a power supply with anything of low resistance value (i.e. a metal object or bare wire) this is a Short and results in high current that may damage the power supply and electronic components.

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)

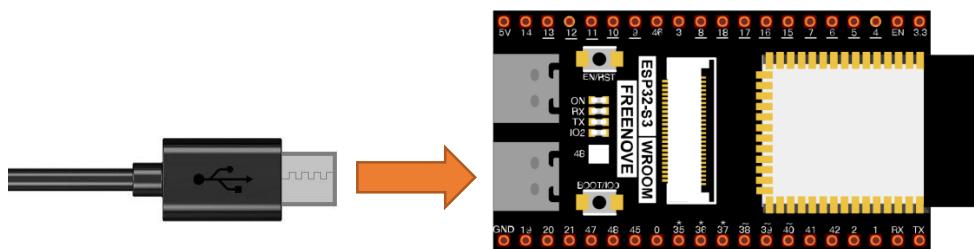
### Breadboard

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-S3 WROOM needs 5v power supply. In this tutorial, we need connect ESP32-S3 WROOM 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-S3 WROOM by default.

In the whole tutorial, we don't use T extension to power ESP32-S3 WROOM. So 5V and 3.3V (including EXT 3.3V) on the extension board are provided by ESP32-S3 WROOM.

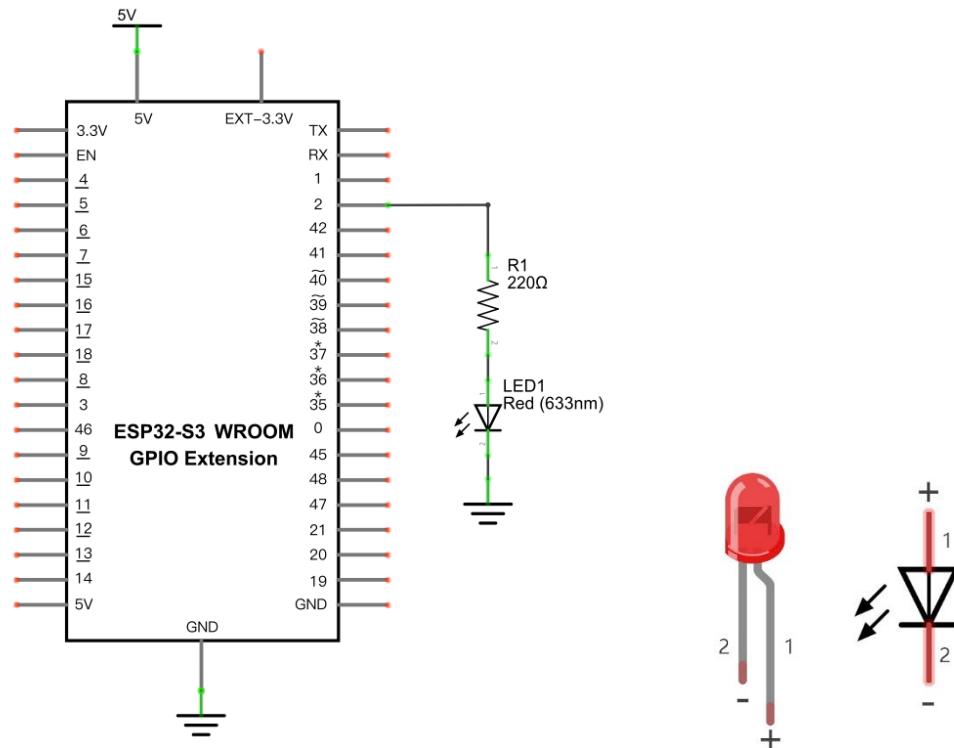
We can also use DC jack of extension board to power ESP32-S3 WROOM. In this way, 5v and EXT 3.3v on extension board are provided by external power resource.

## Circuit

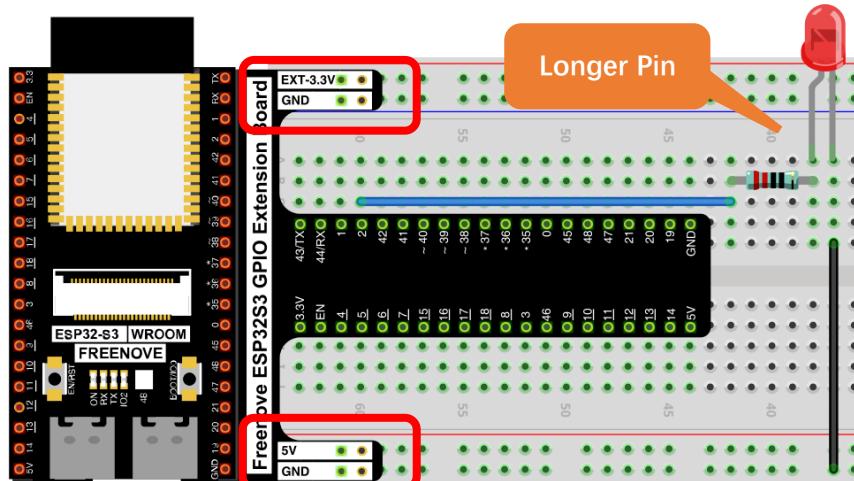
First, disconnect all power from the ESP32-S3 WROOM. Then build the circuit according to the circuit and hardware diagrams. After the circuit is built and verified correct, connect the PC to ESP32-S3 WROOM.

**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, generate excessive component heat and cause permanent damage to your hardware!

## Schematic diagram



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



**Don't rotate ESP32-S3 WROOM 180° for connection.**

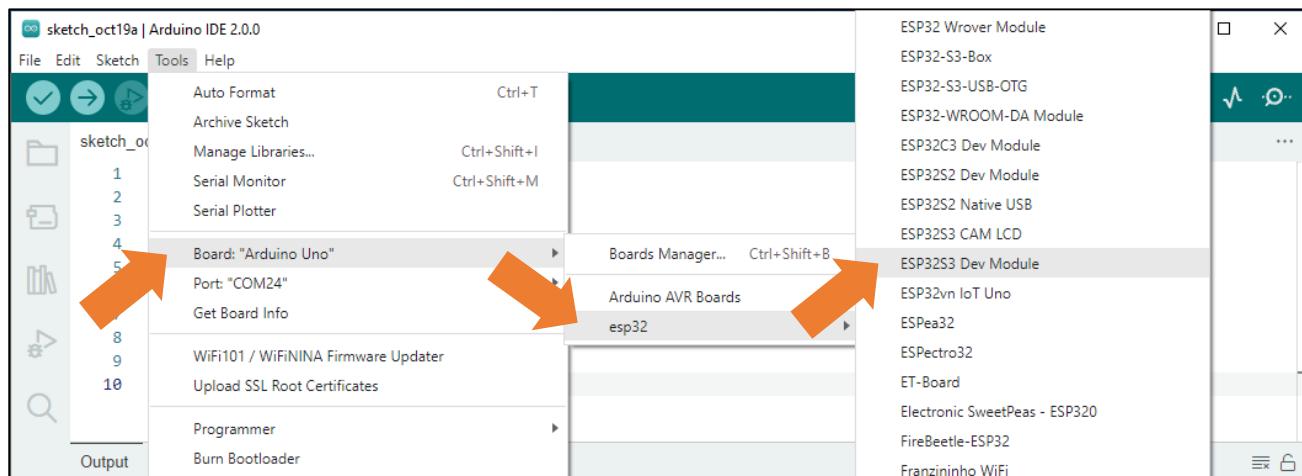
## Sketch

According to the circuit, when the GPIO2 of ESP32-S3 WROOM output level is high, the LED turns ON. Conversely, when the GPIO2 ESP32-S3 WROOM output level is low, the LED turns OFF. Therefore, we can let GPIO2 circularly output high and low level to make the LED blink.

Upload the following Sketch:

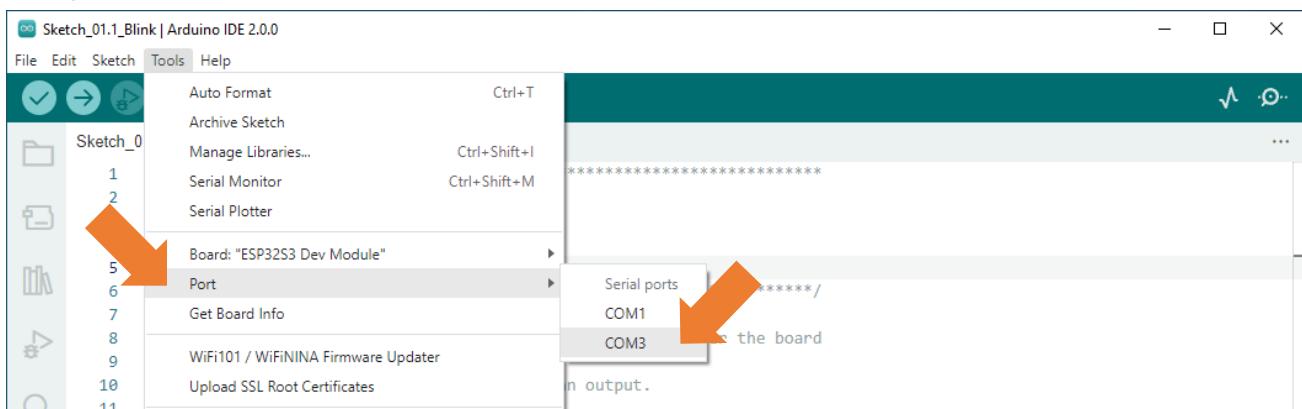
**Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32\_S3\Sketches\Sketch\_01.1\_Blink.**

Before uploading the code, click "Tools", "Board" and select "ESP32S3 Dev Module".

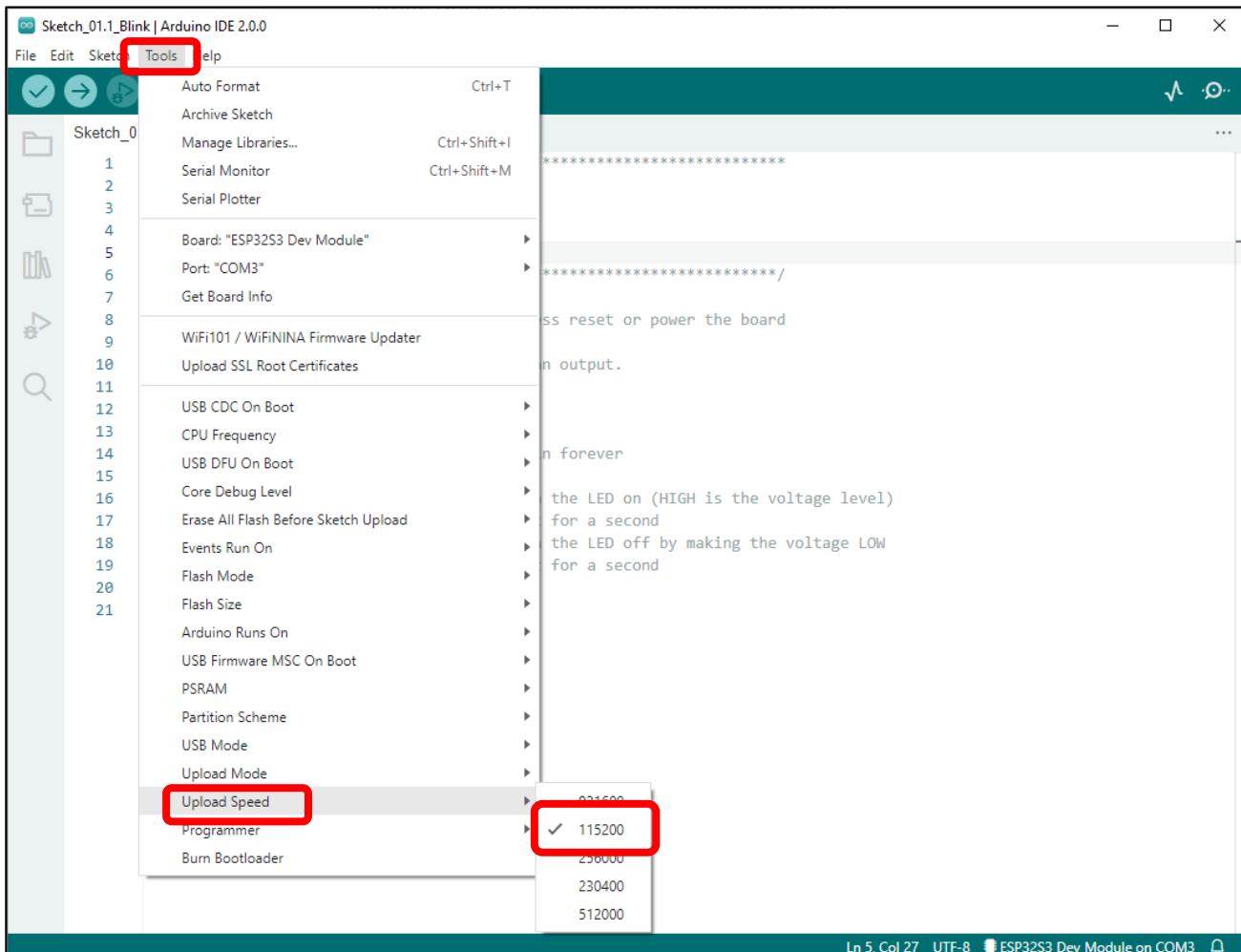


Select the serial port.

Note that the computer port number of each user may be different. Please select the correct serial port according to your computer. Taking the window system as an example, my computer recognizes that the communication interface of the ESP32-S3-WROOM is COM3, so I select COM3.



Note: For macOS users, if the uploading fails, please set the baud rate to 115200 before clicking “Upload Using Programmer”.



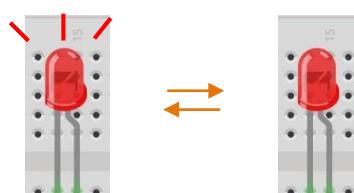
## Sketch\_01.1\_Blink

Click the Upload button and it will compile and upload the Sketch to the ESP32-S3-WROOM.

The screenshot shows the Arduino IDE interface with the following details:

- Title Bar:** Sketch\_01.1\_Blink | Arduino IDE 2.0.0
- File Menu:** File Edit Sketch Tools Help
- Tool Selection:** ESP32S3 Dev Module
- Code Area:** Displays the `Sketch_01.1_Blink.ino` file content, which is the standard Blink sketch for an LED connected to pin 15.
- Output Area:** Shows the upload progress:
  - Wrote 8192 bytes (47 compressed) at 0x0000e000 in 0.2 seconds (effective 431.7 kbit/s)...
  - Hash of data verified.
  - Compressed 227968 bytes to 126986...
  - Writing at 0x00010000... (12 %)
  - Writing at 0x0001cdab... (25 %)
  - Writing at 0x00022890... (37 %)
  - Writing at 0x00027d25... (50 %)
  - Writing at 0x0002d247... (62 %)
  - Writing at 0x00034280... (75 %)
  - Writing at 0x0003dd05... (87 %)
  - Writing at 0x00043319... (100 %)
- Status Bar:** Ln 1, Col 1 UTF-8 ESP32S3 Dev Module on COM3 2

Wait for the Sketch upload to complete, and observe the ESP32-S3 WROOM. You can see that the LED on breadboard flashes cyclically.



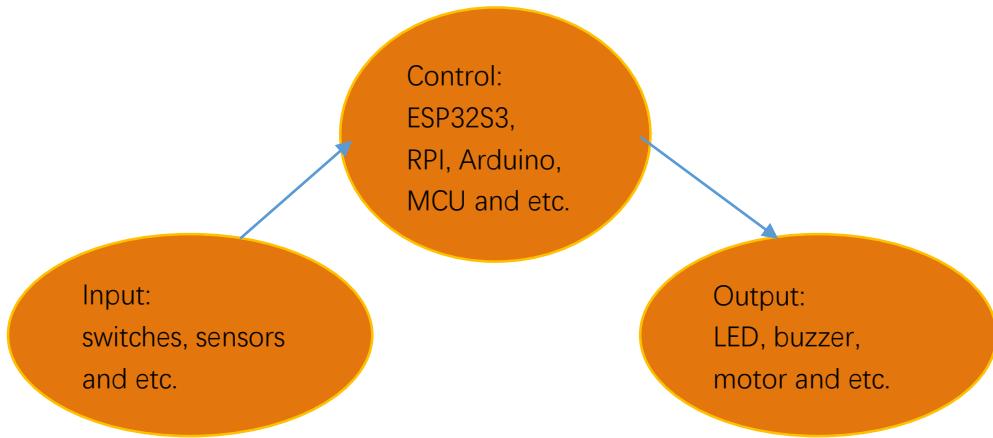
If you have any concerns, please contact us via: [support@freenove.com](mailto:support@freenove.com)

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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-S3 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.

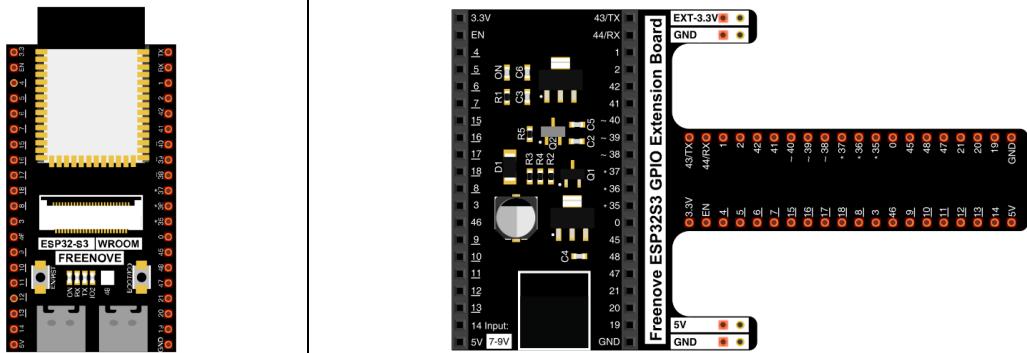
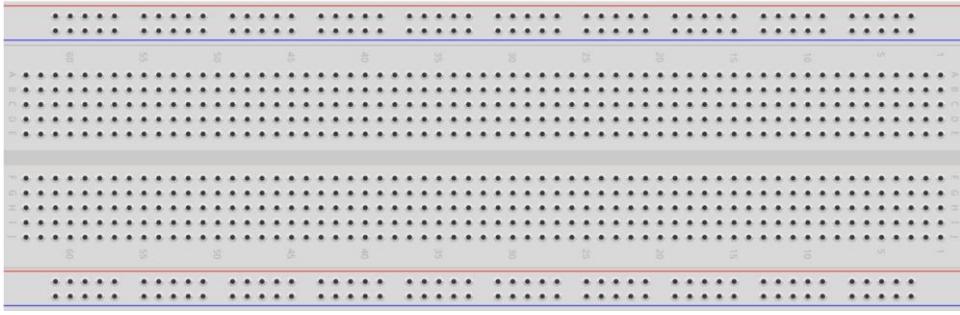
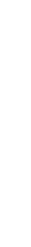


Next, we will build a simple control system to control a LED through a push button switch.

## 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.

## Component List

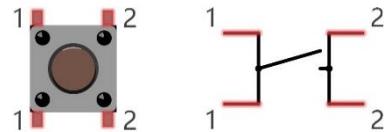
ESP32-S3 WROOM x1	GPIO Extension Board x1			
 <p>The image shows the ESP32-S3 WROOM module and the Freenove GPIO Extension Board. The ESP32-S3 WROOM is a small black square module with a yellow header and a white PCB underneath. The Freenove GPIO Extension Board is a larger black board with various components, capacitors, and a central chip. It has multiple pins labeled with numbers and letters, such as 3.3V, GND, 43/TX, 44/RX, EN, D1, R1, R2, R3, R4, C1, C2, C3, C4, C5, C6, Q1, and 5V.</p>				
Breadboard x1	 <p>A diagram of a breadboard, showing its grid of holes and power rails. The breadboard is a light grey color with red and blue horizontal power rails across the top and bottom. Vertical power rails are also present. The grid consists of a series of small circular holes arranged in a rectangular pattern.</p>			
Jumper M/M x4	LED x1	Resistor 220Ω x1	Resistor 10kΩ x2	Push button x1
				



## Component knowledge

### Push button

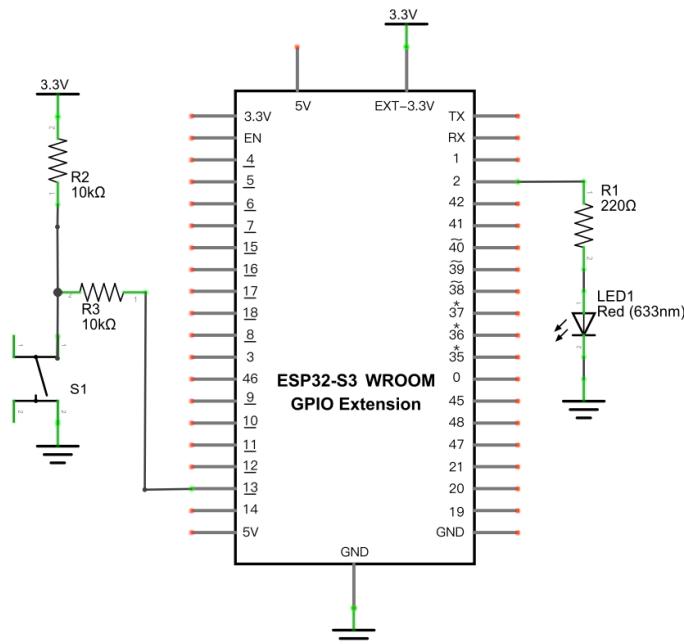
This type of push button switch has 4 pins (2 Pole Switch). Two pins on the left are connected, and both left and right sides are the same per the illustration:



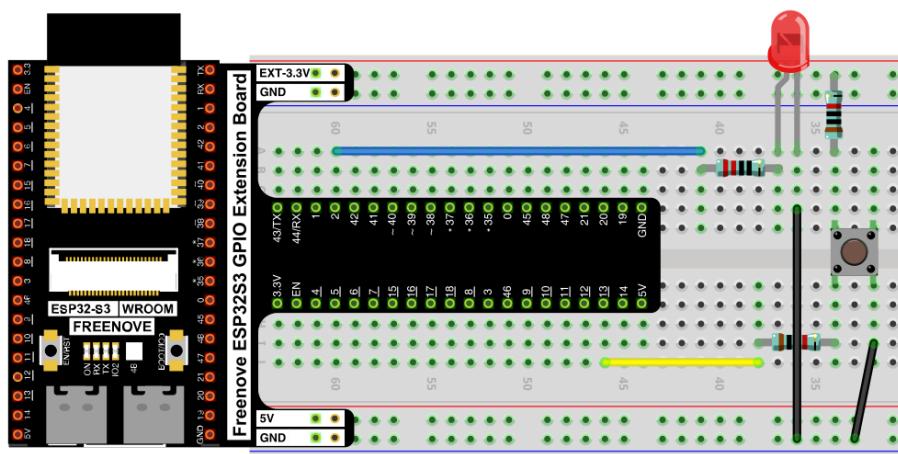
When the button on the switch is pressed, the circuit is completed (your project is powered ON).

## 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)

## Sketch

This project is designed for learning how to use push button switch to control a LED. We first need to read the state of switch, and then determine whether to turn the LED ON in accordance to the state of the switch. Upload following sketch:

**Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32\_S3\Sketches\Sketch\_02.1\_ButtonAndLed.**

**Sketch\_02.1\_ButtonAndLed**

The screenshot shows the Arduino IDE interface with the following details:

- Title Bar:** Sketch\_02.1\_ButtonAndLed | Arduino IDE 2.0.0
- Toolbar:** File Edit Sketch Tools Help
- Sketch Selection:** ESP32S3 Dev Module
- Code Area:**

```

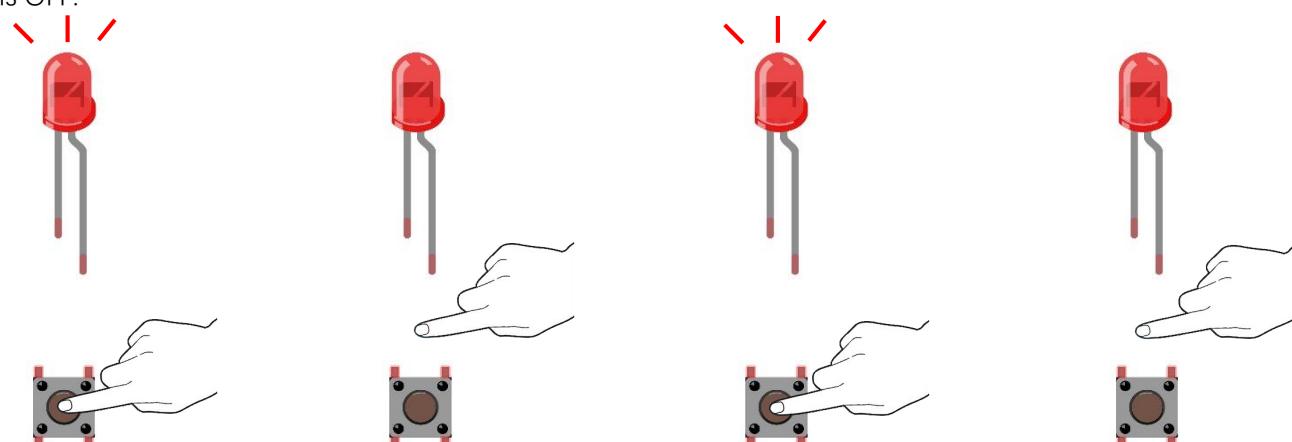
1  // ****
2  // Filename : ButtonAndLed
3  // Description : Control led by button.
4  // Author   : www.freenove.com
5  // Modification: 2022/10/19
6  ****
7  #define PIN_LED    2
8  #define PIN_BUTTON 13
9  // the setup function runs once when you press reset or power the board
10 void setup() {
11     // initialize digital pin PIN_LED as an output.
12     pinMode(PIN_LED, OUTPUT);
13     pinMode(PIN_BUTTON, INPUT);
14 }
15
16 // the loop function runs over and over again forever
17 void loop() {
18     if (digitalRead(PIN_BUTTON) == LOW) {
19         digitalWrite(PIN_LED,HIGH);
20     }else{
21         digitalWrite(PIN_LED,LOW);
22     }
23 }
```
- Output Area:**

```

Writing at 0x00027020... (50 %)
Writing at 0x0002d258... (62 %)
Writing at 0x00034260... (75 %)
Writing at 0x0003dd99... (87 %)
Writing at 0x0004332b... (100 %)
Wrote 228016 bytes (127023 compressed) at 0x00010000 in 3.2 seconds (effective 571.8 kbit/s)...
Hash of data verified.

Leaving...
Hard resetting via RTS pin...
```
- Status Bar:** Ln 19, Col 32 UTF-8 ESP32S3 Dev Module on COM3 2

Download the code to ESP32-S3 WROOM, then press the key, the LED turns ON, release the switch, the LED turns OFF.



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



The following is the program code:

```

1 #define PIN_LED    2
2 #define PIN_BUTTON 13
3 // the setup function runs once when you press reset or power the board
4 void setup() {
5     // initialize digital pin PIN_LED as an output.
6     pinMode(PIN_LED, OUTPUT);
7     pinMode(PIN_BUTTON, INPUT);
8 }
9
10 // the loop function runs over and over again forever
11 void loop() {
12     if (digitalRead(PIN_BUTTON) == LOW) {
13         digitalWrite(PIN_LED, HIGH);
14     }else{
15         digitalWrite(PIN_LED, LOW);
16     }
17 }
```

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

```

1 #define PIN_LED    2
2 #define PIN_BUTTON 13
```

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

```

11 void loop() {
12     if (digitalRead(PIN_BUTTON) == LOW) {
13         digitalWrite(PIN_LED, HIGH);
14     }else{
15         digitalWrite(PIN_LED, LOW);
16     }
17 }
```

### Reference

```
int digitalRead (int pin);
```

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

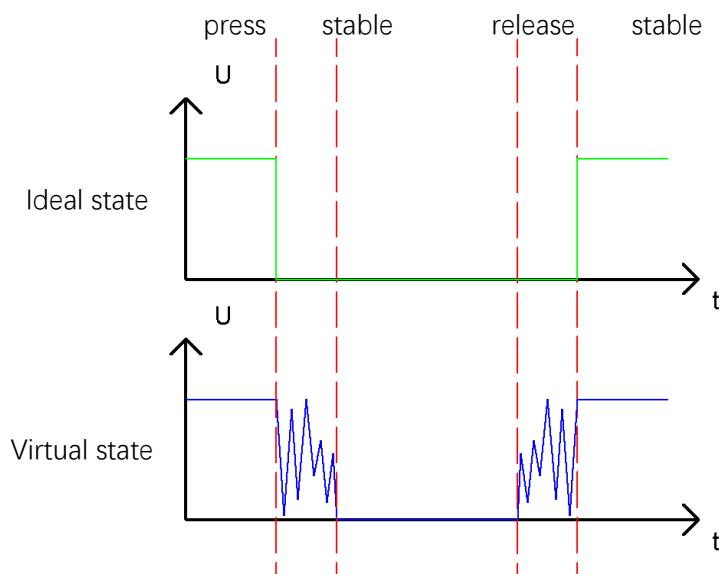
## Project 2.2 MINI table lamp

We will also use a push button switch, LED and ESP32-S3 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

The moment when a 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.



## Sketch

### Sketch\_02.2\_Tablelamp

The screenshot shows the Arduino IDE interface. The top menu bar includes File, Edit, Sketch, Tools, Help, and a dropdown for the board (ESP32S3 Dev Module). The central area displays the code for Sketch\_02.2\_TableLamp.ino. The code defines two pins: PIN\_LED (2) and PIN\_BUTTON (13). It sets up pin 2 as an output and pin 13 as an input. In the loop function, it checks if the button is pressed (LOW). If so, it delays 20ms, reads the button again, and if still LOW, it calls a reverseGPIO function. This creates a bouncy debouncing effect. The reverseGPIO function simply toggles the state of the LED pin. The serial monitor at the bottom shows the progress of writing the sketch to the ESP32-S3 Dev Module, reaching 100% completion and verifying the hash.

```

Sketch_02.2_TableLamp.ino
7  #define PIN_LED 2
8  #define PIN_BUTTON 13
9  // the setup function runs once when you press reset or power the board
10 void setup() {
11   // initialize digital pin PIN_LED as an output.
12   pinMode(PIN_LED, OUTPUT);
13   pinMode(PIN_BUTTON, INPUT);
14 }
15
16 // the loop function runs over and over again forever
17 void loop() {
18   if (digitalRead(PIN_BUTTON) == LOW) {
19     delay(20);
20     if (digitalRead(PIN_BUTTON) == LOW) {
21       reverseGPIO(PIN_LED);
22     }
23     while (digitalRead(PIN_BUTTON) == LOW);
24     delay(20);
25     //while (digitalRead(PIN_BUTTON) == LOW);
26   }
27 }
28
29 void reverseGPIO(int pin) {
30   digitalWrite(pin, !digitalRead(pin));
31 }
32

```

Output

```

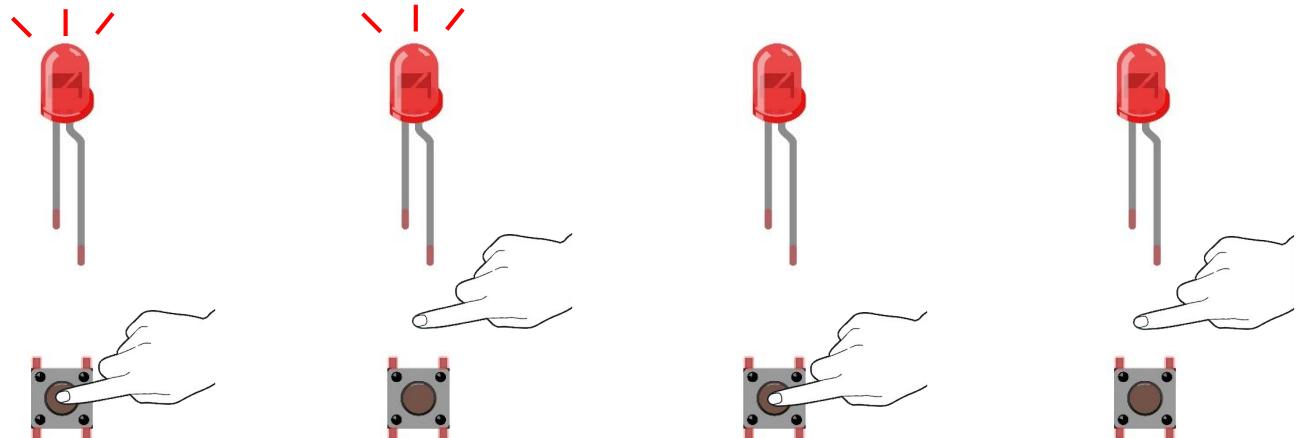
Writing at 0x00002700a... (50 %)
Writing at 0x00002d27e... (62 %)
Writing at 0x000034258... (75 %)
Writing at 0x00003dd27... (87 %)
Writing at 0x00004335b... (100 %)
Wrote 228112 bytes (127069 compressed) at 0x00010000 in 3.2 seconds (effective 571.4 kbit/s)...
Hash of data verified.

Leaving...
Hard resetting via RTS pin...

```

Ln 5, Col 27 UTF-8 ■ ESP32S3 Dev Module on COM3 2

Download the code to the ESP32-S3 WROOM, press the button, the LED turns ON, and press the button again, the LED turns OFF.



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

The following is the program code:

```

1 #define PIN_LED    2
2 #define PIN_BUTTON 13
3 // the setup function runs once when you press reset or power the board
4 void setup() {
5     // initialize digital pin PIN_LED as an output.
6     pinMode(PIN_LED, OUTPUT);
7     pinMode(PIN_BUTTON, INPUT);
8 }
9
10 // the loop function runs over and over again forever
11 void loop() {
12     if (digitalRead(PIN_BUTTON) == LOW) {
13         delay(20);
14         if (digitalRead(PIN_BUTTON) == LOW) {
15             reverseGPIO(PIN_LED);
16         }
17         while (digitalRead(PIN_BUTTON) == LOW);
18         delay(20);
19         while (digitalRead(PIN_BUTTON) == LOW);
20     }
21 }
22
23 void reverseGPIO(int pin) {
24     digitalWrite(pin, ! digitalRead(pin));
25 }
```

When judging the push button state, if it is detected as "pressed down", wait for a certain time to detect again to eliminate the effect of bounce. When confirmed, flip the LED on and off. Then it starts to wait for the pressed button to be released, and waits for a certain time to eliminate the effect of bounce after it is released.

```

12 if (digitalRead(PIN_BUTTON) == LOW) {
13     delay(20);
14     if (digitalRead(PIN_BUTTON) == LOW) {
15         reverseGPIO(PIN_LED);
16     }
17     while (digitalRead(PIN_BUTTON) == LOW);
18     delay(20);
19     while (digitalRead(PIN_BUTTON) == LOW);
20 }
```

The subfunction reverseGPIO() means reading the state value of the specified pin, taking the value back and writing it to the pin again to achieve the function of flipping the output state of the pin.

```

23 void reverseGPIO(int pin) {
24     digitalWrite(pin, ! digitalRead(pin));
25 }
```



# 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

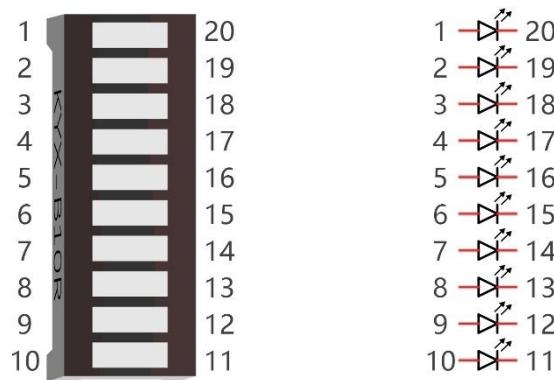
ESP32-S3 WROOM x1	GPIO Extension Board x1
Breadboard x1	
Jumper M/M x10	LED bar graph x1
	Resistor 220Ω x10

## Component knowledge

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

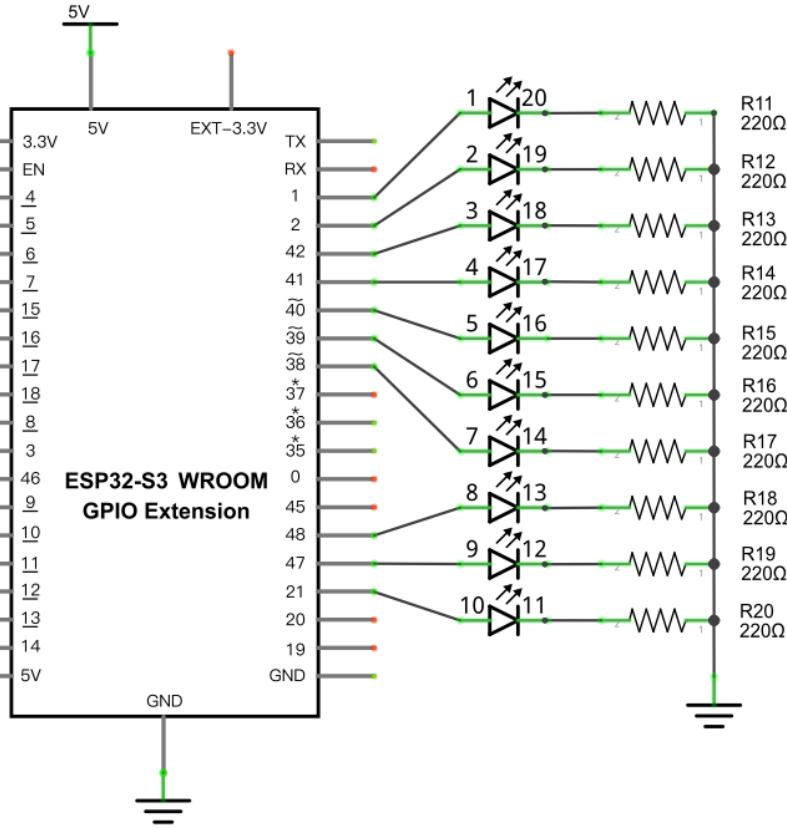
### LED bar

A LED bar graph 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.

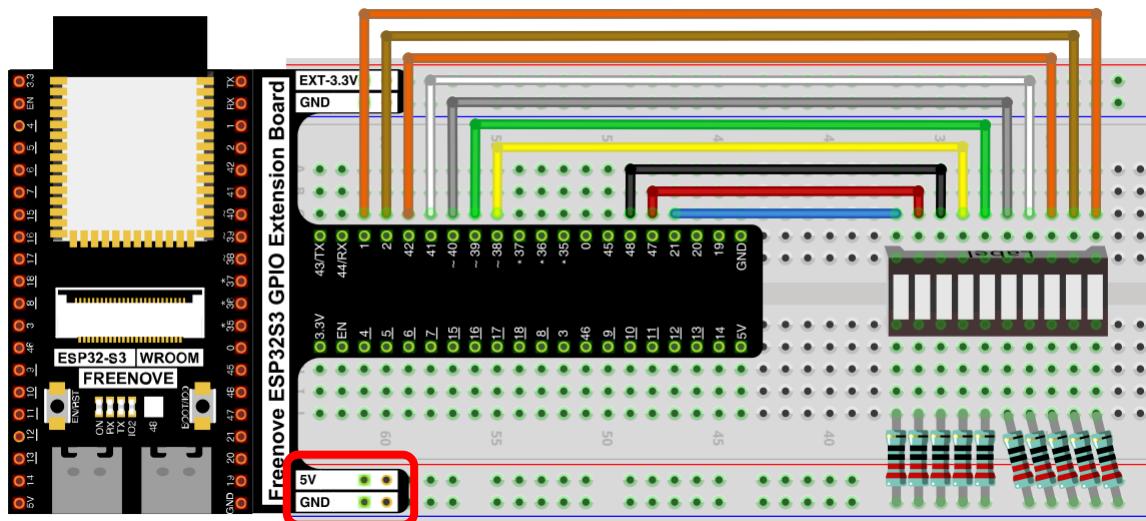


## Circuit

Schematic diagram



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



## Sketch

This project is designed to make a flowing water lamp. Which are these actions: First turn LED1 ON, then turn it OFF. Then turn LED2 ON, and then turn it OFF... and repeat the same to all 10 LEDs until the last LED is turns OFF. This process is repeated to achieve the “movements” of flowing water.

Upload following sketch:

**Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32\_S3\Sketches\Sketch\_03.1\_FlowingLight.**

**Sketch\_03.1\_FlowingLight**

The screenshot shows the Arduino IDE interface. The top bar displays "Sketch\_03.1\_FlowingLight | Arduino IDE 2.0.0". The menu bar includes File, Edit, Sketch, Tools, and Help. The toolbar has icons for file operations and a connection status. The main area shows the code for "Sketch\_03.1\_FlowingLight.ino". The code initializes an array of pins and sets them to OUTPUT mode. In the setup() function, it initializes the pin counts. In the loop() function, it alternates the state of each pin (HIGH then LOW) in a forward sequence from index 0 to ledCounts-1, and then in a reverse sequence back to index 0. The serial monitor window at the bottom shows the upload progress and the final message: "Wrote 234848 bytes (130729 compressed) at 0x00010000 in 2.5 seconds (effective 766.8 kbit/s)... Hash of data verified." followed by "Leaving..." and "Hard resetting via RTS pin...".

```

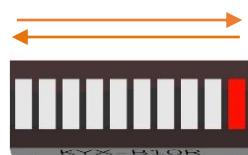
byte ledPins[] = {21, 47, 48, 38, 39, 40, 41, 42, 2, 1};
int ledCounts;

void setup() {
    ledCounts = sizeof(ledPins);
    for (int i = 0; i < ledCounts; i++) {
        pinMode(ledPins[i], OUTPUT);
    }
}

void loop() {
    for (int i = 0; i < ledCounts; i++) {
        digitalWrite(ledPins[i], HIGH);
        delay(100);
        digitalWrite(ledPins[i], LOW);
    }
    for (int i = ledCounts - 1; i > -1; i--) {
        digitalWrite(ledPins[i], HIGH);
        delay(100);
        digitalWrite(ledPins[i], LOW);
    }
}

```

Download the code to ESP32-S3 WROOM and LED bar graph will light up from left to right and from right to left.



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

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

The following is the program code:

```

1 byte ledPins[] = {21, 47, 48, 38, 39, 40, 41, 42, 2, 1};
2 int ledCounts;
3
4 void setup() {
5     ledCounts = sizeof(ledPins);
6     for (int i = 0; i < ledCounts; i++) {
7         pinMode(ledPins[i], OUTPUT);
8     }
9 }
10
11 void loop() {
12     for (int i = 0; i < ledCounts; i++) {
13         digitalWrite(ledPins[i], HIGH);
14         delay(100);
15         digitalWrite(ledPins[i], LOW);
16     }
17     for (int i = ledCounts - 1; i > -1; i--) {
18         digitalWrite(ledPins[i], HIGH);
19         delay(100);
20         digitalWrite(ledPins[i], LOW);
21     }
22 }
```

Use an array to define 10 GPIO ports connected to LED bar graph for easier operation.

```
1 byte ledPins[] = {21, 47, 48, 38, 39, 40, 41, 42, 2, 1};
```

In setup(), use sizeof() to get the number of array, which is the number of LEDs, then configure the GPIO port to output mode.

```

5 ledCounts = sizeof(ledPins);
6 for (int i = 0; i < ledCounts; i++) {
7     pinMode(ledPins[i], OUTPUT);
8 }
```

Then, in loop(), use two “for” loop to realize flowing water light from left to right and from right to left.

```

12 for (int i = 0; i < ledCounts; i++) {
13     digitalWrite(ledPins[i], HIGH);
14     delay(100);
15     digitalWrite(ledPins[i], LOW);
16 }
17 for (int i = ledCounts - 1; i > -1; i--) {
18     digitalWrite(ledPins[i], HIGH);
19     delay(100);
20     digitalWrite(ledPins[i], LOW);
21 }
```

# Chapter 4 Analog & PWM

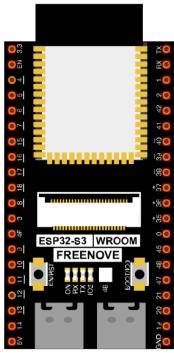
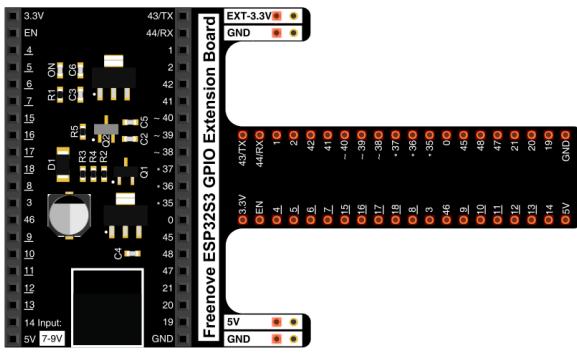
In previous study, we have known that one button has two states: pressed and released, and LED has light-on/off state, then how to enter a middle state? How to output an intermediate state to let LED "semi bright"? That's what we're going to learn.

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.

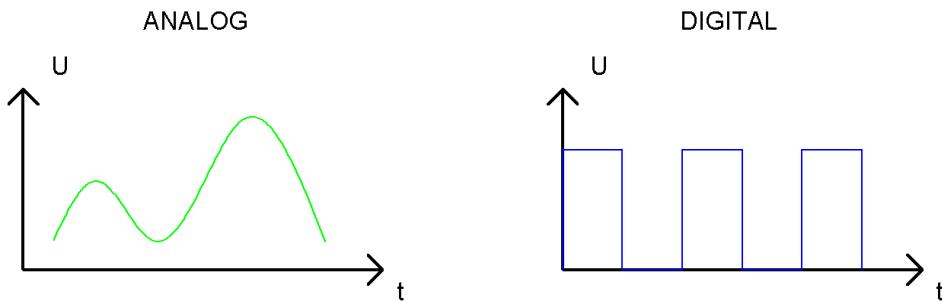
### Component List

ESP32-S3 WROOM 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.



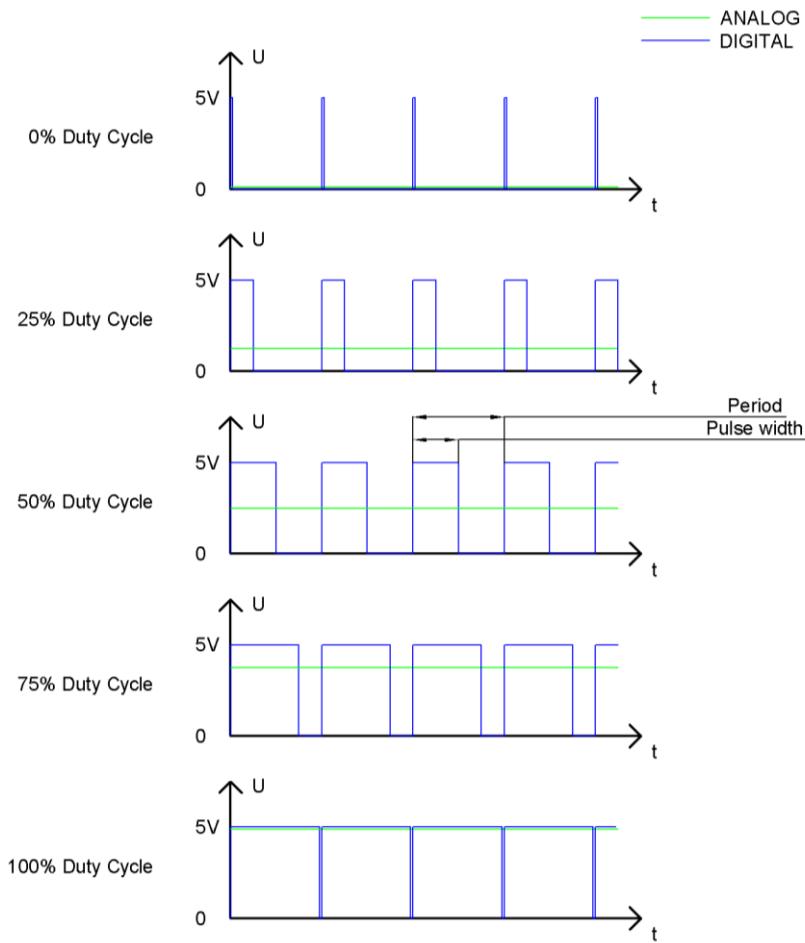
In practical application, we often use binary as the digital signal, that is a series of 0's and 1's. Since a binary signal only has two values (0 or 1), it has great stability and reliability. Lastly, both analog and digital signals can be converted into the other.

### 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 outputs 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 a 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. Therefore, we can control the output power of the LED and other output modules to achieve different effects.

### ESP32-S3 and PWM

On ESP32-S3, the LEDC(PWM) controller has 8 separate channels, each of which can independently control frequency, duty cycle, and even accuracy. Unlike traditional PWM pins, the PWM output pins of ESP32-S3 are configurable, with one or more PWM output pins per channel. The relationship between the maximum frequency and bit precision is shown in the following formula, where the maximum value of bit is 31.

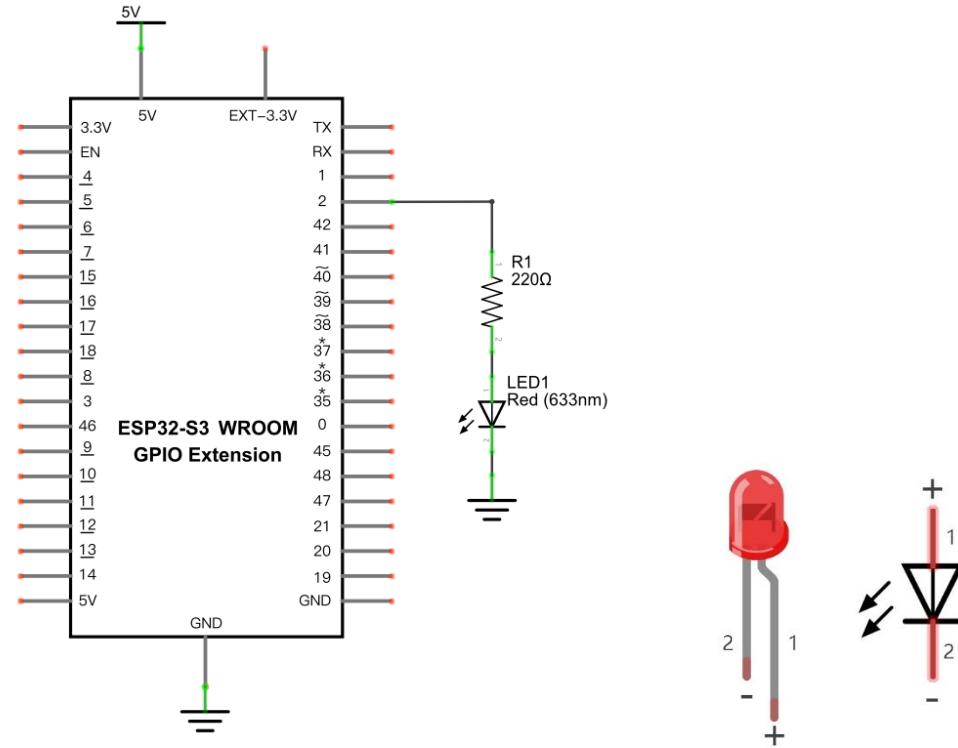
$$\text{Freq}_{\max} = \frac{80,000,000}{1 \ll \text{bit}}$$

For example, generate a PWM with an 8-bit precision ( $2^8=256$ . Values range from 0 to 255) with a maximum frequency of  $80,000,000/256 = 312,500\text{Hz}$ .

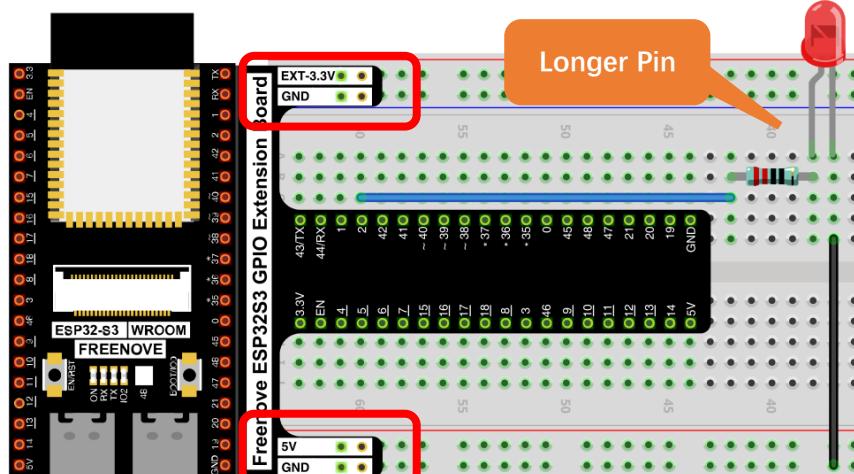
## Circuit

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

Schematic diagram



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

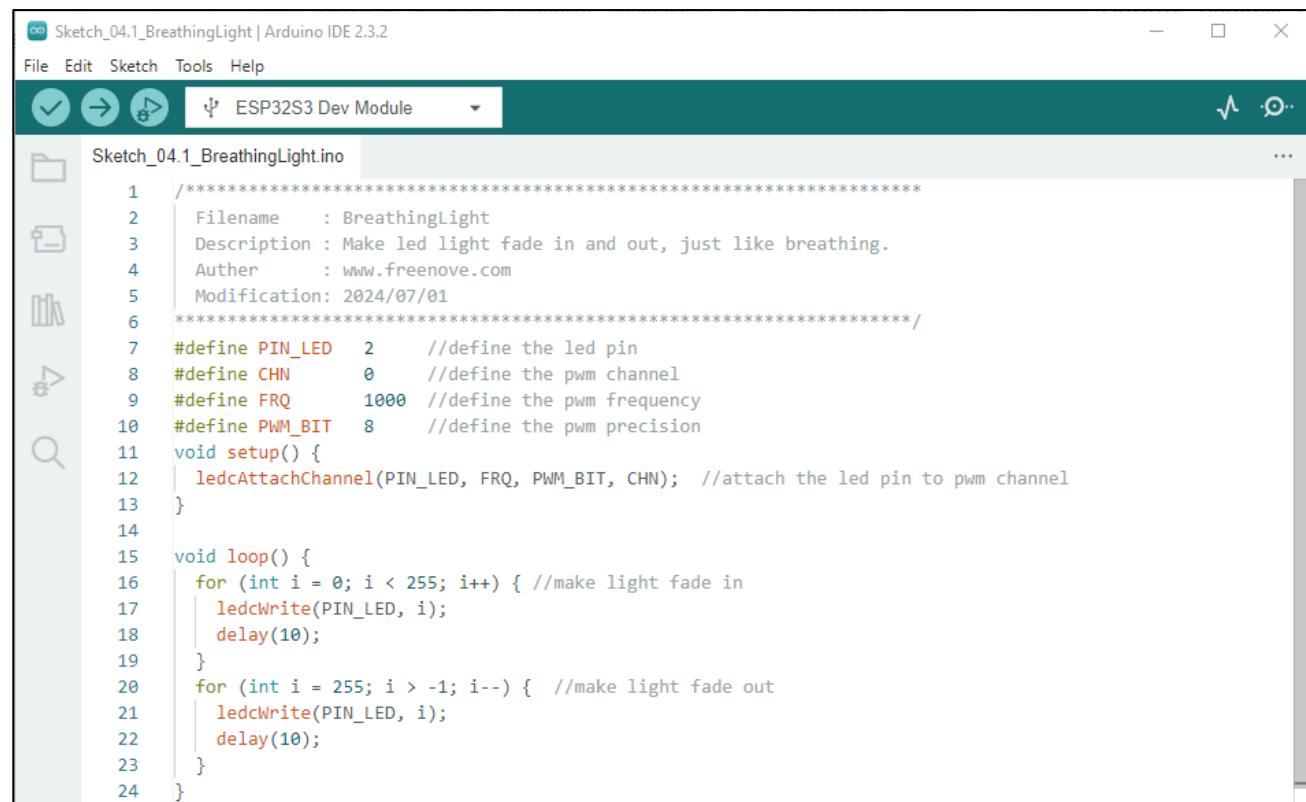


**Don't rotate ESP32-S3 WROOM 180° for connection.**

## Sketch

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.

### Sketch\_04.1\_BreathingLight



```

Sketch_04.1_BreathingLight | Arduino IDE 2.3.2
File Edit Sketch Tools Help
Sketch_04.1_BreathingLight.ino
1 //*****
2 |   Filename    : BreathingLight
3 |   Description : Make led light fade in and out, just like breathing.
4 |   Author      : www.freenove.com
5 |   Modification: 2024/07/01
6 *****/
7 #define PIN_LED 2      //define the led pin
8 #define CHN     0      //define the pwm channel
9 #define FRQ     1000   //define the pwm frequency
10 #define PWM_BIT 8     //define the pwm precision
11 void setup() {
12 |   ledcAttachChannel(PIN_LED, FRQ, PWM_BIT, CHN); //attach the led pin to pwm channel
13 }
14
15 void loop() {
16 |   for (int i = 0; i < 255; i++) { //make light fade in
17 |     ledcWrite(PIN_LED, i);
18 |     delay(10);
19 |   }
20 |   for (int i = 255; i > -1; i--) { //make light fade out
21 |     ledcWrite(PIN_LED, i);
22 |     delay(10);
23 |   }
24 }

```

Download the code to ESP32-S3 WROOM, and you'll see that LED is turned from on to off and then from off to on gradually like breathing.



The following is the program code:

1	#define PIN_LED 2 //define the led pin
2	#define CHN 0 //define the pwm channel
3	#define FRQ 1000 //define the pwm frequency
4	#define PWM_BIT 8 //define the pwm precision

```

5   void setup() {
6     ledcAttachChannel(PIN_LED, FRQ, PWM_BIT, CHN); //attach the led pin to pwm channel
7   }
8
9   void loop() {
10    for (int i = 0; i < 255; i++) { //make light fade in
11      ledcWrite(PIN_LED, i);
12      delay(10);
13    }
14    for (int i = 255; i > -1; i--) { //make light fade out
15      ledcWrite(PIN_LED, i);
16      delay(10);
17    }
18  }

```

The PWM pin output mode of ESP32-S3 is not the same as the traditional controller. It controls each parameter of PWM by controlling the PWM channel. Any number of GPIO can be connected with the PWM channel to output PWM. In `setup()`, you first configure a PWM channel and set the frequency and precision. Then the GPIO is associated with the PWM channel.

```

6   ledcAttachChannel(PIN_LED, FRQ, PWM_BIT, CHN); //attach the led pin to pwm channel

```

In the `loop()`, There are two “for” loops. The first makes the ledPin output PWM from 0% to 100% and the second makes the ledPin output PWM from 100% to 0%. This allows the LED to gradually light and extinguish.

```

11  for (int i = 0; i < 255; i++) { //make light fade in
12    ledcWrite(PIN_LED, i);
13    delay(10);
14  }
15  for (int i = 255; i > -1; i--) { //make light fade out
16    ledcWrite(PIN_LED, i);
17    delay(10);
18  }

```

You can also adjust the rate of the state change of LED by changing the parameters of the `delay()` function in the “for” loop.

```

void ledcAttachChannel (uint8_t pin, double freq, uint8_t bit_num, uint8_t channel);
void ledcDetachPin(uint8_t pin);

```

Set the frequency and accuracy of a PWM channel.

### Parameters

**chan**: channel index. Value range :0-7

**freq**: frequency, it could be a decimal.

**bit\_num**: precision of values.

**channel**: Bind/unbind a GPIO to a PWM channel.

```

void ledcWrite(uint8_t channel, uint32_t duty);

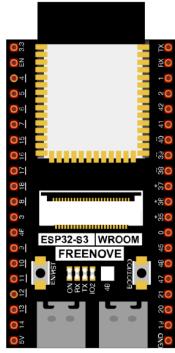
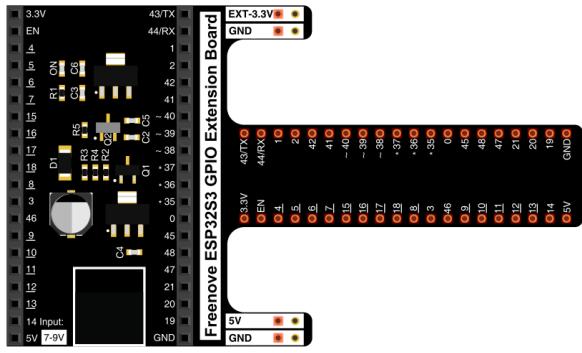
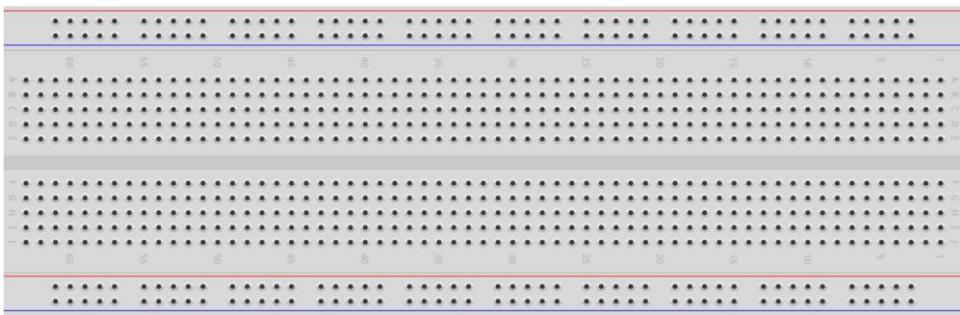
```

Writes the pulse width value to a PWM channel.

## Project 4.2 Meteor Flowing Light

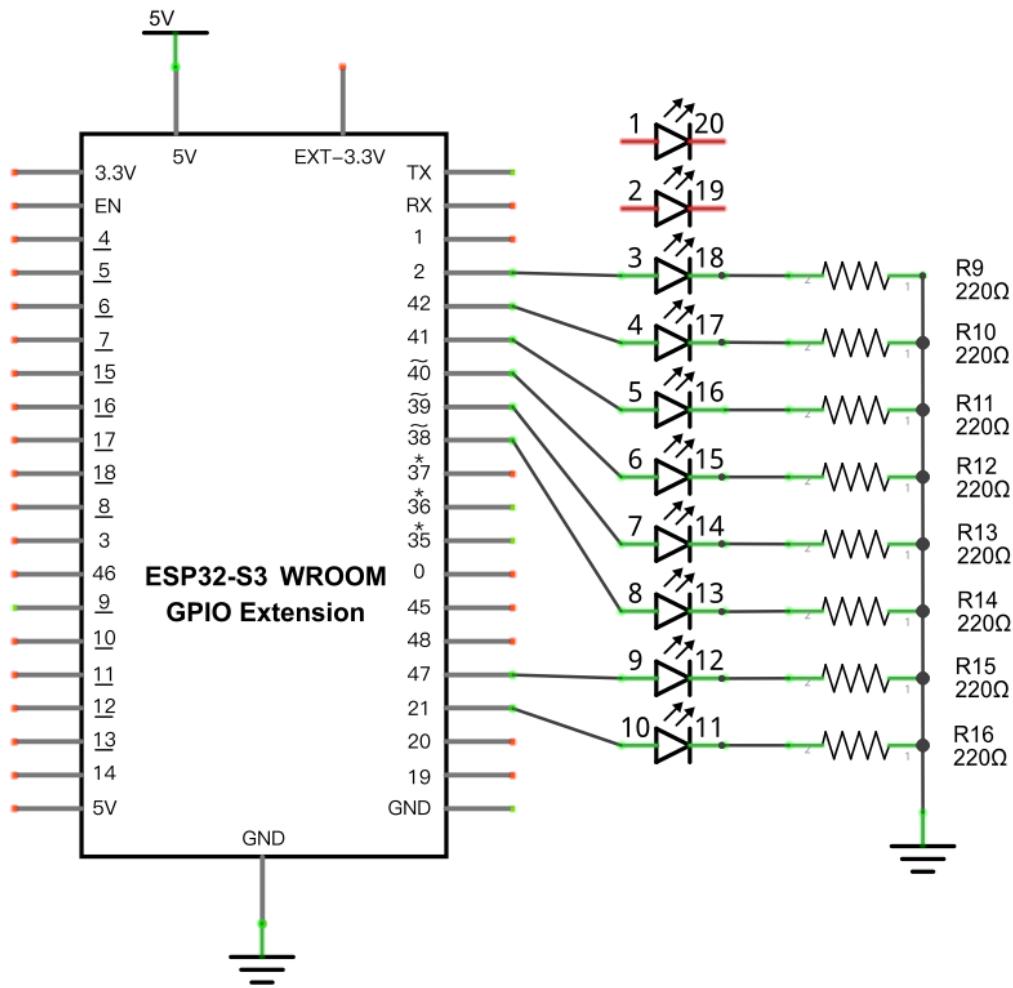
After learning about PWM, we can use it to control LED bar graph and realize a cooler flowing light. The component list, circuit, and hardware are exactly consistent with the project Flowing Light.

### Component List

ESP32-S3 WROOM x1	GPIO Extension Board x1	Breadboard x1
		
Jumper M/M x8	LED bar graph x1	Resistor 220Ω x8
		

## Circuit

Schematic diagram



## Sketch

Meteor flowing light will be implemented with PWM.

### Sketch\_04.2\_FlowingLight2

```

Sketch_04.2_FlowingLight2 | Arduino IDE 2.3.2
File Edit Sketch Tools Help
Sketch_04.2_FlowingLight2.ino
1 const byte ledPins[] = {21, 47, 38, 39, 40, 41, 42, 2}; //define led pins
2 const byte chns[] = {0, 1, 2, 3, 4, 5, 6, 7}; //define the pwm channels
3 const int dutys[] = {0, 0, 0, 0, 0, 0, 0, 0,
4 | 1023, 512, 256, 128, 64, 32, 16, 8,
5 | 0, 0, 0, 0, 0, 0, 0, 0
6 }; //define the pwm dutys
7 int ledCounts;
8 int delayTimes = 50; //flowing speed ,the smaller, the faster
9 void setup() {
10 | ledCounts = sizeof(ledPins); //get the led counts
11 | for (int i = 0; i < ledCounts; i++) { //setup the pwm channels
12 | | ledcAttachChannel(ledPins[i], 1000, 10, chns[i]);
13 | }
14 }
15
16 void loop() {
17 | for (int i = 0; i < 16; i++) { //flowing one side to other side
18 | | for (int j = 0; j < ledCounts; j++) {
19 | | | ledcWrite(ledPins[j], dutys[i + j]);
20 | | }
21 | | delay(delayTimes);
22 | }
23 | for (int i = 0; i < 16; i++) { //flowing one side to other side
24 | | for (int j = ledCounts - 1; j > -1; j--) {
25 | | | ledcWrite(ledPins[j], dutys[i + (ledCounts - 1 - j)]);
26 | | }
27 | | delay(delayTimes);
28 | }
29 | }
30 | }
31 | }
32 | }
33 | }
34 | }
35 }

```

Download the code to ESP32-S3 WROOM, 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 const byte ledPins[] = {21, 47, 38, 39, 40, 41, 42, 2}; //define led pins
2 const byte chns[] = {0, 1, 2, 3, 4, 5, 6, 7}; //define the pwm channels
3 const int dutys[] = {0, 0, 0, 0, 0, 0, 0, 0,
4 | 1023, 512, 256, 128, 64, 32, 16, 8,
5 | 0, 0, 0, 0, 0, 0, 0, 0
6 }; //define the pwm dutys
7 int ledCounts; //led counts
8 int delayTimes = 50; //flowing speed ,the smaller, the faster
9 void setup() {
10 | ledCounts = sizeof(ledPins); //get the led counts
11 | for (int i = 0; i < ledCounts; i++) { //setup the pwm channels
12 | | ledcAttachChannel(ledPins[i], 1000, 10, chns[i]);

```

```

13 }
14 }
15
16 void loop() {
17     for (int i = 0; i < 16; i++) {          //flowing one side to other side
18         for (int j = 0; j < ledCounts; j++) {
19             ledcWrite(ledPins[j], dutys[i + j]);
20         }
21         delay(delayTimes);
22     }
23     for (int i = 0; i < 16; i++) {          //flowing one side to other side
24         for (int j = ledCounts - 1; j > -1; j--) {
25             ledcWrite(ledPins[j], dutys[i + (ledCounts - 1 - j)]);
26         }
27         delay(delayTimes);
28     }
29 }
```

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

```

1 const byte ledPins[] = {21, 47, 38, 39, 40, 41, 42, 2};      //define led pins
2 const byte chns[] = {0, 1, 2, 3, 4, 5, 6, 7};                  //define the pwm channels
3 const int dutys[] = {0, 0, 0, 0, 0, 0, 0, 0,
4                         1023, 512, 256, 128, 64, 32, 16, 8,
5                         0, 0, 0, 0, 0, 0, 0, 0
6 };                //define the pwm dutys
```

In setup(), set the frequency of 8 PWM channels to 1000Hz, the accuracy to 10bits, and the maximum pulse width to 1023. Attach GPIO to these PWM channels.

```

11 for (int i = 0; i < ledCounts; i++) {    //setup the pwm channels
12     ledcAttachChannel(ledPins[i], 1000, 10, chns[i]);
13 }
```

In loop(), a nested for loop is used to control the pulse width of the PWM, and LED bar graph moves one grid after each 1 is added in the first for loop, gradually changing according to the values in the array duties. As shown in the table below, the value of the second row is the value in the array duties, and the 8 green squares in each row below represent the 8 LEDs on the LED bar graph. Every 1 is added to *i*, 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	7	8	9	1	1	1	1	1	1	1	1	1	2	2	2	2	2
d	0	0	0	0	0	0	0	0	1	5	2	1	6	3	1	8	0	0	0	0	0	0	0
i									0	1	5	2	4	2	6								
0																							
1																							
2																							
3																							
...																							
13																							
14																							
15																							

In the code, two nested for loops are used to achieve this effect.

```

17   for (int i = 0; i < 16; i++) {           //flowing one side to other side
18     for (int j = 0; j < ledCounts; j++) {
19       ledcWrite(ledPins[j], dutys[i + j]);
20     }
21     delay(delayTimes);
22   }
23   for (int i = 0; i < 16; i++) {           //flowing from one side to the other
24     for (int j = ledCounts - 1; j > -1; j--) {
25       ledcWrite(ledPins[j], dutys[i + (ledCounts - 1 - j)]);
26     }
27     delay(delayTimes);
28   }

```

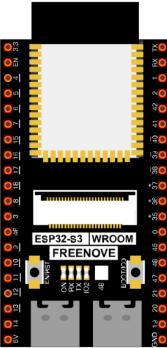
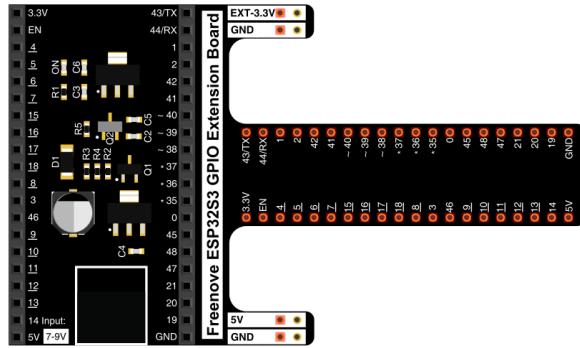
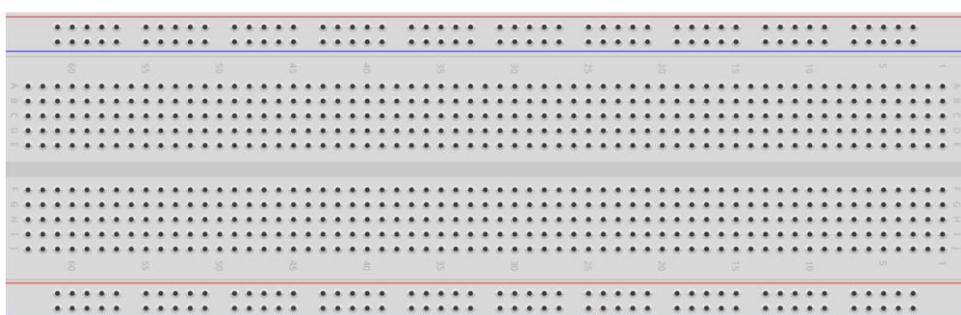
# Chapter 5 RGB LED

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

## Project 5.1 Random Color Light

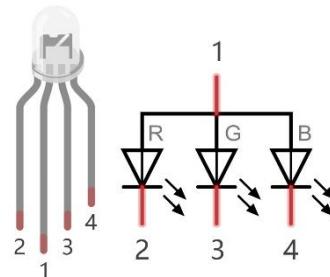
In this project, we will make a multicolored LED. And we can control RGB LED to switch different colors automatically.

### Component List

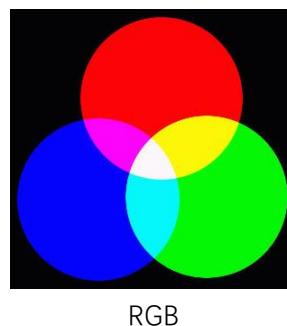
ESP32-S3 WROOM x1	GPIO Extension Board x1	
		
Breadboard x1		
RGBLED x1	Resistor 220Ω x3	Jumper M/M x4
		

## 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,



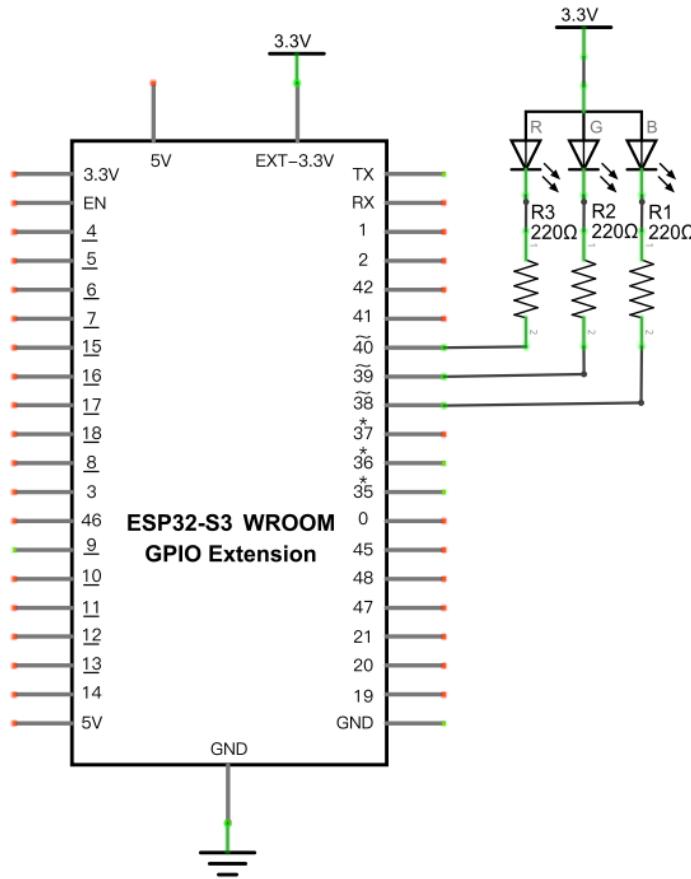
Red, green, and blue are known as three primary colors. When you combine these three primary-color lights with different brightness, it can produce almost all kinds of visible lights. Computer screens, single pixel of cell phone screen, neon, and etc. are working under this principle.



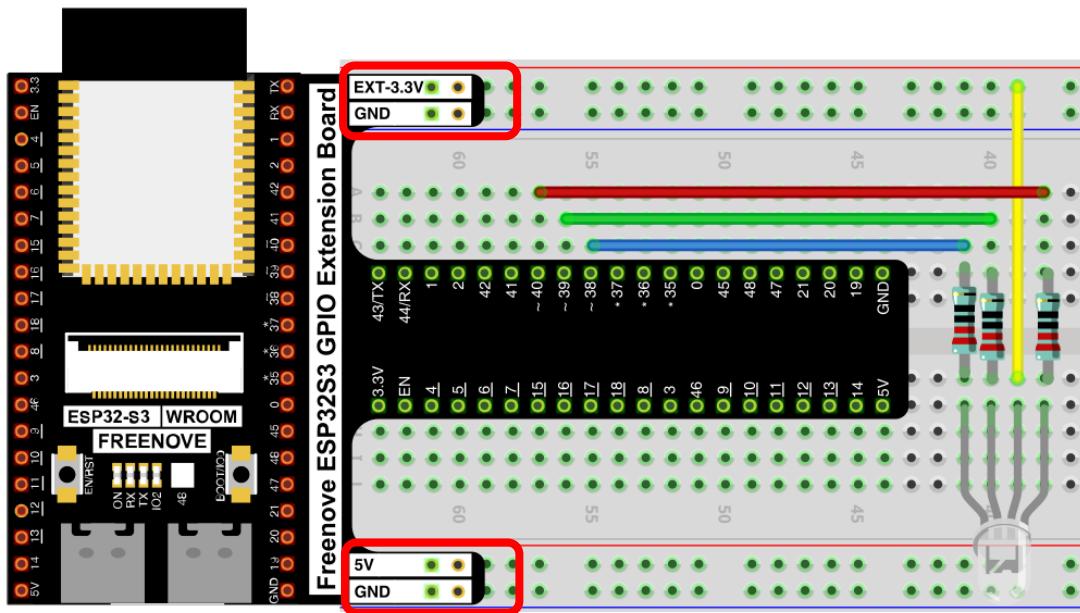
If we use three 8-bit PWMs to control the RGB LED, in theory, we can create  $2^8 \times 2^8 \times 2^8 = 16777216$  (16 million) colors through different combinations.

## Circuit

Schematic diagram



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

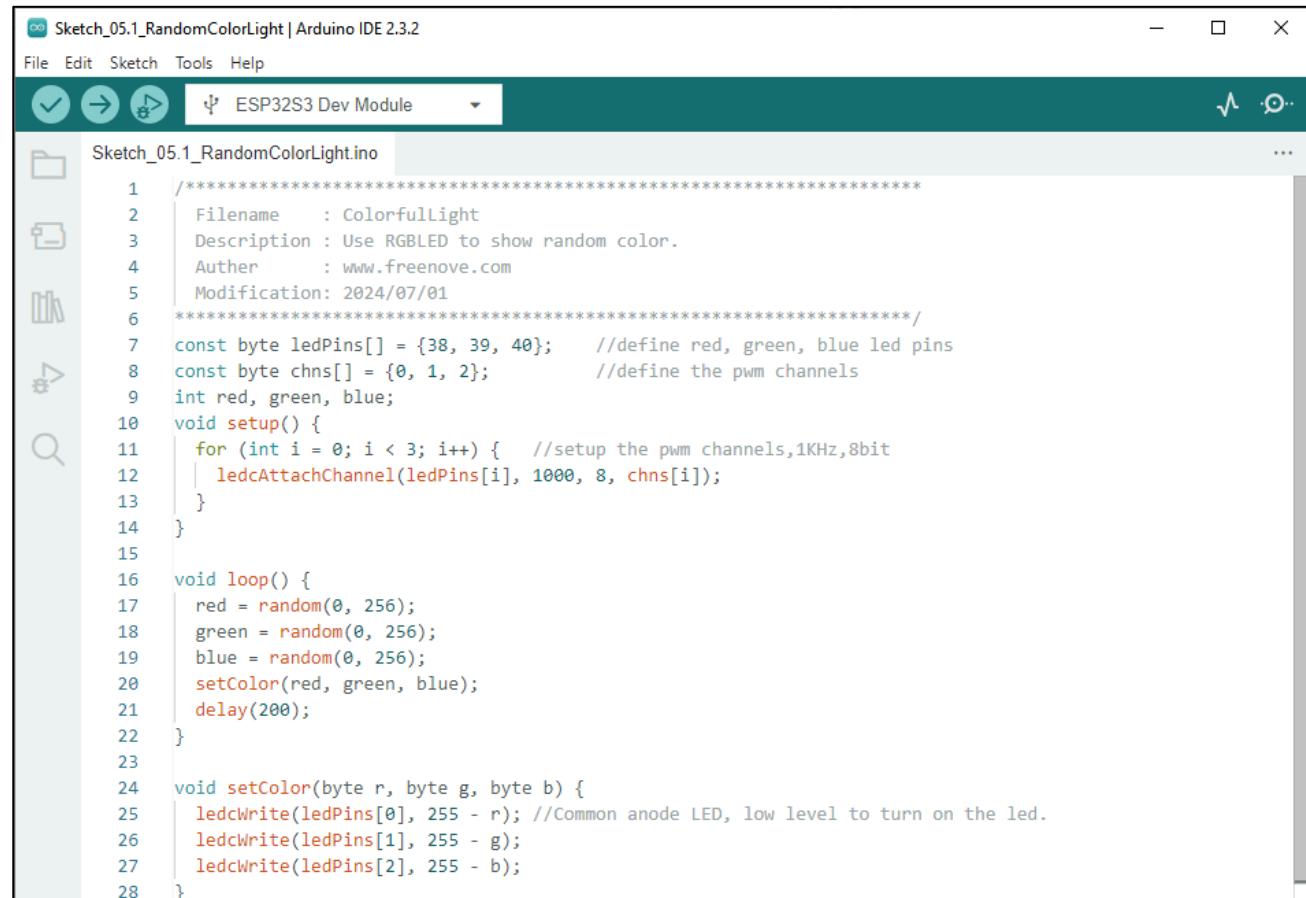


Any concerns? ✉ [support@freenove.com](mailto:support@freenove.com)

## Sketch

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

### Sketch\_05.1\_ColorfulLight



```

Sketch_05.1_RandomColorLight | Arduino IDE 2.3.2
File Edit Sketch Tools Help
Sketch_05.1_RandomColorLight.ino
1 //*****
2 Filename : ColorfullLight
3 Description : Use RGBLED to show random color.
4 Author : www.freenove.com
5 Modification: 2024/07/01
6 ****
7 const byte ledPins[] = {38, 39, 40}; //define red, green, blue led pins
8 const byte chns[] = {0, 1, 2}; //define the pwm channels
9 int red, green, blue;
10 void setup() {
11     for (int i = 0; i < 3; i++) { //setup the pwm channels,1KHz,8bit
12         ledcAttachChannel(ledPins[i], 1000, 8, chns[i]);
13     }
14 }
15
16 void loop() {
17     red = random(0, 256);
18     green = random(0, 256);
19     blue = random(0, 256);
20     setColor(red, green, blue);
21     delay(200);
22 }
23
24 void setColor(byte r, byte g, byte b) {
25     ledcWrite(ledPins[0], 255 - r); //Common anode LED, low level to turn on the led.
26     ledcWrite(ledPins[1], 255 - g);
27     ledcWrite(ledPins[2], 255 - b);
28 }

```

With the code downloaded to ESP32-S3 WROOM, RGB LED 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 const byte ledPins[] = {38, 39, 40}; //define red, green, blue led pins
2 const byte chns[] = {0, 1, 2}; //define the pwm channels
3 int red, green, blue;
4 void setup() {
5     for (int i = 0; i < 3; i++) { //setup the pwm channels,1KHz,8bit
6         ledcAttachChannel(ledPins[i], 1000, 8, chns[i]);
7     }
8 }
9
10 void loop() {
11     red = random(0, 256);
12     green = random(0, 256);
13     blue = random(0, 256);

```

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

```

14     setColor(red, green, blue);
15     delay(200);
16 }
17
18 void setColor(byte r, byte g, byte b) {
19     ledcWrite(ledPins[0], 255 - r); //Common anode LED, low level to turn on the led.
20     ledcWrite(ledPins[1], 255 - g);
21     ledcWrite(ledPins[2], 255 - b);
22 }
```

Define the PWM channel and associate it with the pin connected to RGB LED, and define the variable to hold the color value and initialize it in setup().

```

1 const byte ledPins[] = {38, 39, 40};      //define red, green, blue led pins
2 const byte chns[] = {0, 1, 2};           //define the pwm channels
3 int red, green, blue;
4 void setup() {
5     for (int i = 0; i < 3; i++) {        //setup the pwm channels, 1KHz, 8bit
6         ledcAttachChannel(ledPins[i], 1000, 8, chns[i]);
7     }
8 }
```

In setColor(), this function controls the output color of RGB LED by the given color value. Because the circuit uses a common anode, the LED lights up when the GPIO outputs low power. Therefore, in PWM, low level is the active level, so 255 minus the given value is necessary.

```

18 void setColor(byte r, byte g, byte b) {
19     ledcWrite(ledPins[0], 255 - r); //Common anode LED, low level to turn on the led.
20     ledcWrite(ledPins[1], 255 - g);
21     ledcWrite(ledPins[2], 255 - b);
22 }
```

In loop(), get three random Numbers and set them as color values.

```

11 red = random(0, 256);
12 green = random(0, 256);
13 blue = random(0, 256);
14 setColor(red, green, blue);
15 delay(200);
```

The related function of software PWM can be described as follows:

**long random(min, max);**

This function will return a random number(min --- max-1).

## Project 5.2 Gradient Color Light

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

Component list and the circuit are exactly the same as the 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 RGB LED will change colors along the model.

### Sketch\_05.2\_SoftColorfulLight

The following is the program code:

```
1 const byte ledPins[] = {38, 39, 40}; //define led pins
2 const byte chns[] = {0, 1, 2}; //define the pwm channels
3
4 void setup() {
5     for (int i = 0; i < 3; i++) { //setup the pwm channels
6         ledcAttachChannel(ledPins[i], 1000, 8, chns[i]);
7     }
8 }
9
10 void loop() {
11     for (int i = 0; i < 256; i++) {
12         setColor(wheel(i));
13         delay(20);
14     }
15 }
16
17 void setColor(long rgb) {
18     ledcWrite(ledPins[0], 255 - (rgb >> 16) & 0xFF);
19     ledcWrite(ledPins[1], 255 - (rgb >> 8) & 0xFF);
20     ledcWrite(ledPins[2], 255 - (rgb >> 0) & 0xFF);
21 }
22
23 long wheel(int pos) {
24     long WheelPos = pos % 0xff;
25     if (WheelPos < 85) {
26         return ((255 - WheelPos * 3) << 16) | ((WheelPos * 3) << 8);
27     } else if (WheelPos < 170) {
```

```
28     WheelPos -= 85;  
29     return (((255 - WheelPos * 3) << 8) | (WheelPos * 3));  
30 } else {  
31     WheelPos -= 170;  
32     return ((WheelPos * 3) << 16 | (255 - WheelPos * 3));  
33 }  
34 }
```

In `setColor()`, a variable represents the value of RGB, and a hexadecimal representation of color is a common representation, such as `0xAABBCC`, where AA represents the red value, BB represents the green value, and CC represents the blue value. The use of a variable can make the transmission of parameters more convenient, in the split, only a simple operation can take out the value of each color channel

```
18 void setColor(long rgb) {  
19     ledcWrite(ledPins[0], 255 - (rgb >> 16) & 0xFF);  
20     ledcWrite(ledPins[1], 255 - (rgb >> 8) & 0xFF);  
21     ledcWrite(ledPins[2], 255 - (rgb >> 0) & 0xFF);  
22 }
```

The `wheel()` function is the color selection method for the color model introduced earlier. The **pos** parameter ranges from 0 to 255 and outputs a color value in hexadecimal.

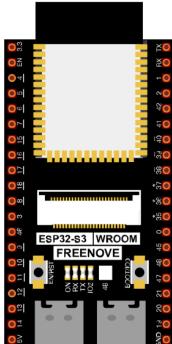
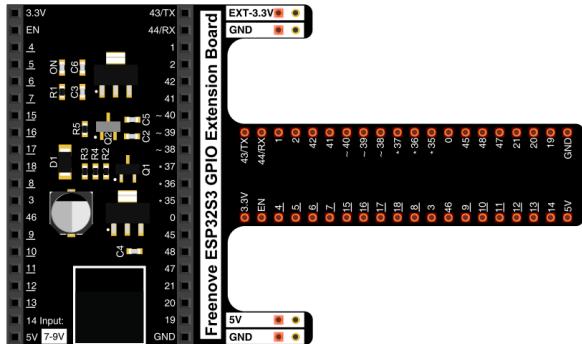
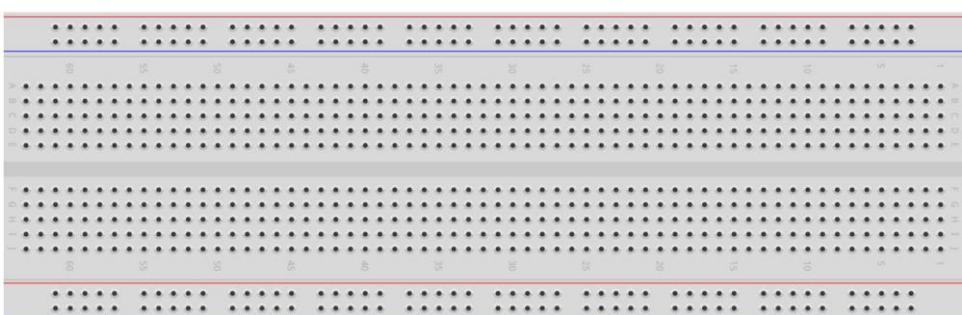
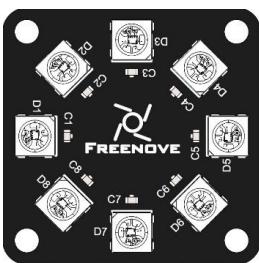
# Chapter 6 LEDPixel

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

## Project 6.1 LEDPixel

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

### Component List

ESP32-S3 WROOM x1	GPIO Extension Board x1
	
Breadboard x1	
Freenove 8 RGB LED Module x1	Jumper F/M x3
	

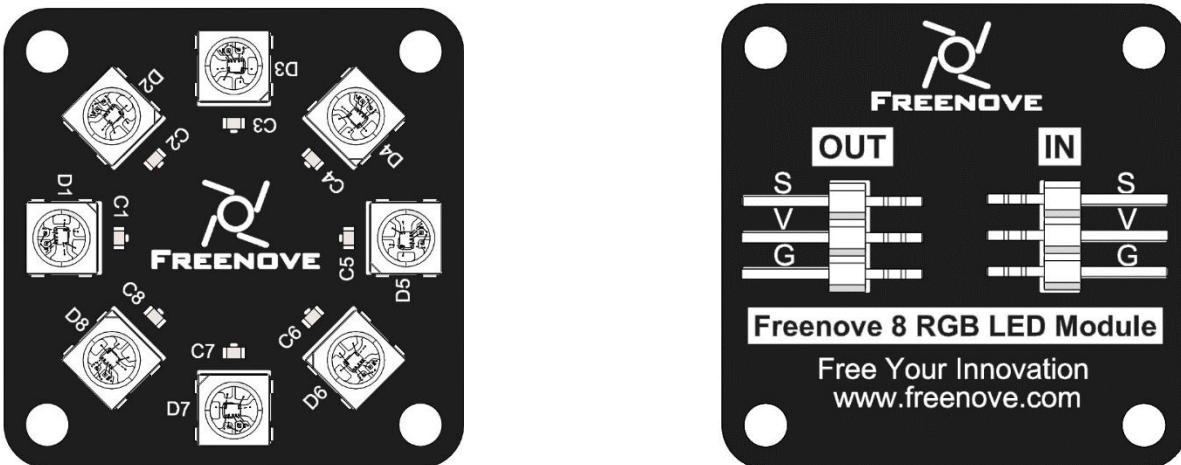
## Related knowledge

### Freenove 8 RGB LED Module

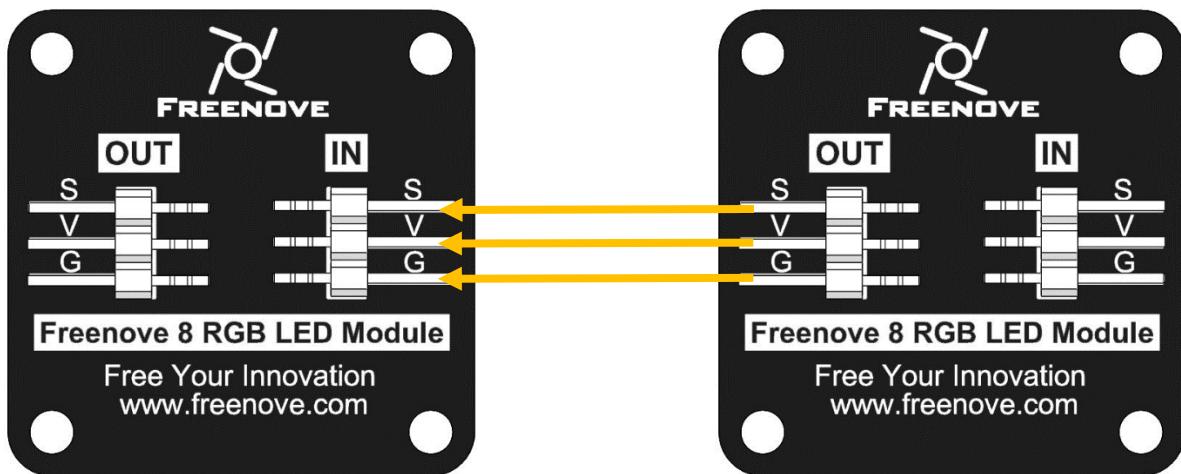
The Freenove 8 RGB LED Module is as below.

It consists of 8 WS2812, each of which requires only one pin to control and supports cascade. Each WS212 has integrated 3 LEDs, red, green and blue respectively, and each of them supports 256-level brightness adjustment, which means that each WS2812 can emit  $2^{24}=16,777,216$  different colors.

You can use only one data pin to control eight LEDs on the module. As shown below:



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

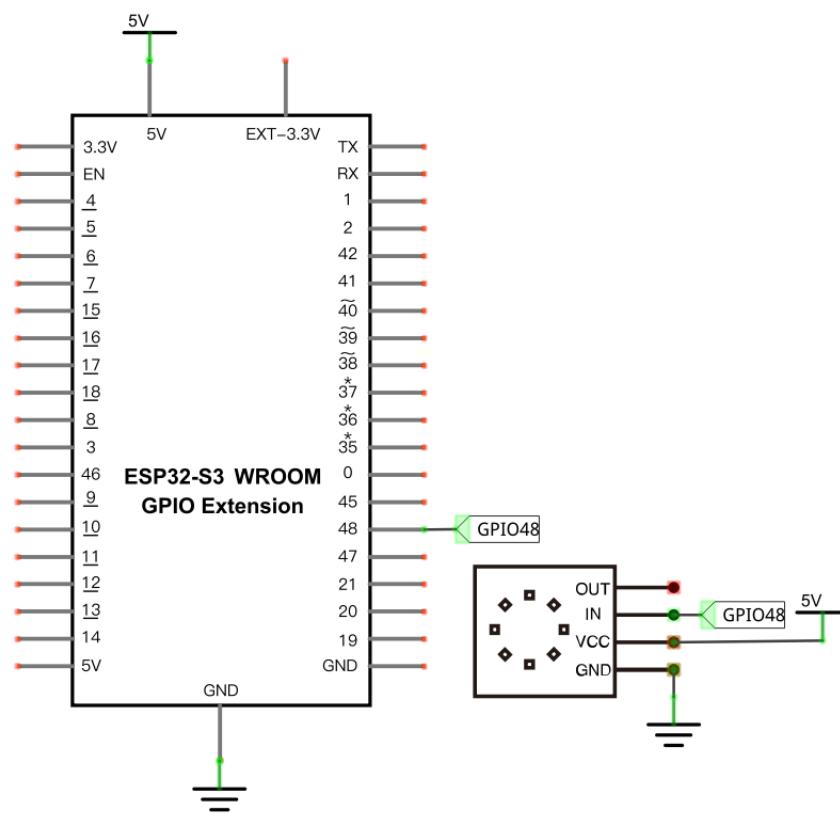


### Pin description:

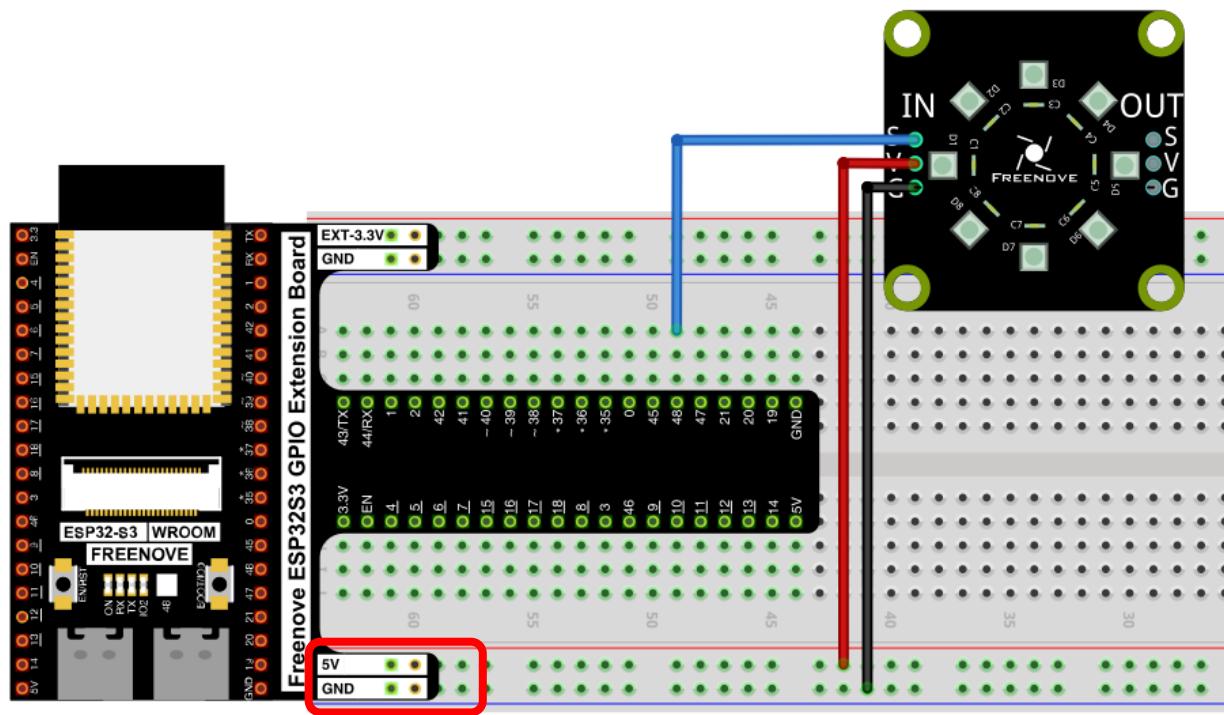
(IN)		(OUT)	
symbol	Function	symbol	Function
S	Input control signal	S	Output control signal
V	Power supply pin, +3.5V~5.5V	V	Power supply pin, +3.5V~5.5V
G	GND	G	GND

## Circuit

Schematic diagram



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



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



## Sketch

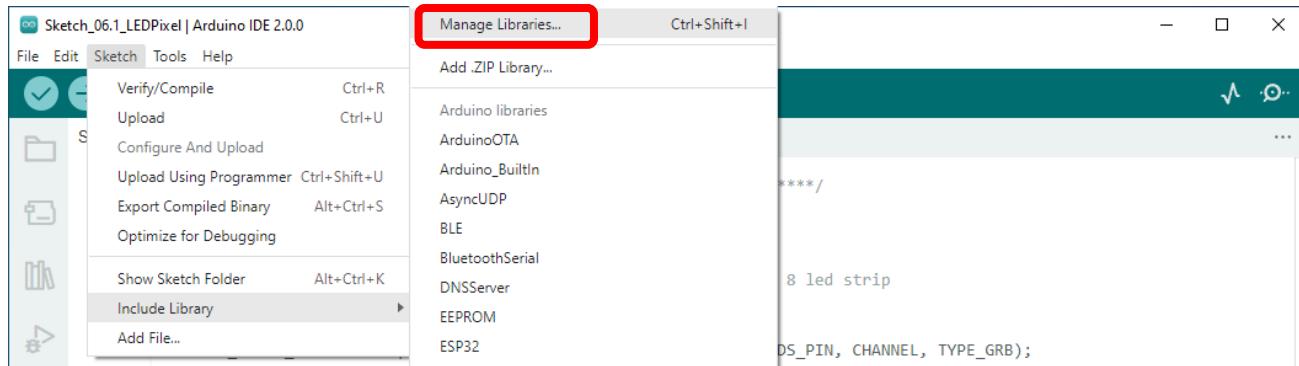
This code uses a library named "Freenove\_WS2812\_Lib\_for\_ESP32", if you have not installed it, please do so first.

Library is an important feature of the open source world, and we know that Arduino is an open source platform that everyone can contribute to. Libraries are generally licensed under the LGPL, which means you can use them for free to apply to your creations.

### How to install the library

There are two ways to add libraries.

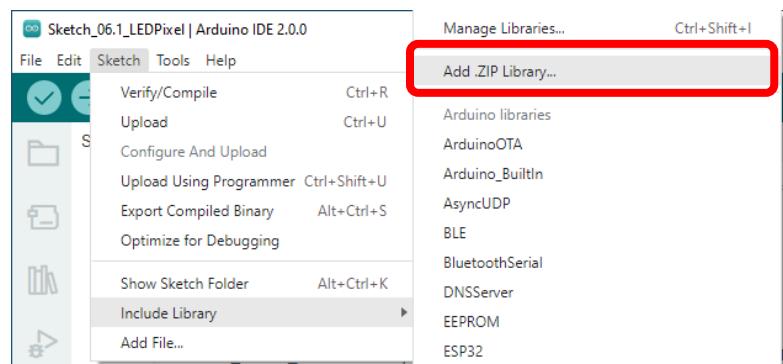
The first way, open the Arduino IDE, click Sketch → Include Library → Manager Libraries.



In the pop-up window, Library Manager, search for the name of the Library, "Freenove WS2812 Lib for ESP32". Then click Install.



The second way, open Arduino IDE, click Sketch→Include Library→Add .ZIP Library, In the pop-up window, find the file named ".Libraries/Freenove\_WS2812\_Lib\_for\_ESP32.Zip" which locates in this directory, and click OPEN.



### Sketch\_06.1\_LEDPixel

The screenshot shows the Arduino IDE 2.0.0 interface with the sketch 'Sketch\_06.1\_LEDPixel.ino' open. The code initializes an ESP32 WS2812 strip with 8 LEDs, connected to pin 48 via channel 0. It sets up the strip and enters a loop where it cycles through colors (red, green, blue, white, black) for each LED. The serial monitor output shows the progress of writing data to memory and a hash verification message.

```

Sketch_06.1_LEDPixel.ino
8 #include "Freenove_WS2812_Lib_for_ESP32.h"
9
10 #define LEDS_COUNT 8 // The number of led
11 #define LEDS_PIN 48 // define the pin connected to the Freenove 8 led strip
12 #define CHANNEL 0 // RMT module channel
13
14 Freenove_ESP32_WS2812 strip = Freenove_ESP32_WS2812(LEDS_COUNT, LEDS_PIN, CHANNEL, TYPE_GRB);
15
16 int m_color[5][3] = { {255, 0, 0}, {0, 255, 0}, {0, 0, 255}, {255, 255, 255}, {0, 0, 0} };
17 int delayval = 100;
18
19 void setup() {
20     strip.begin();
21     strip.setBrightness(10);
22 }
23 void loop() {
24     for (int j = 0; j < 5; j++) {
25         for (int i = 0; i < LEDS_COUNT; i++) {
26             strip.setLedColorData(i, m_color[j][0], m_color[j][1], m_color[j][2]); // Set color data.
27             strip.show(); // Send color data to LED, and display.
28             delay(delayval); // Interval time of each LED.
29         }
30         delay(500); // Interval time of each group of colors.
31     }
32 }

```

Output

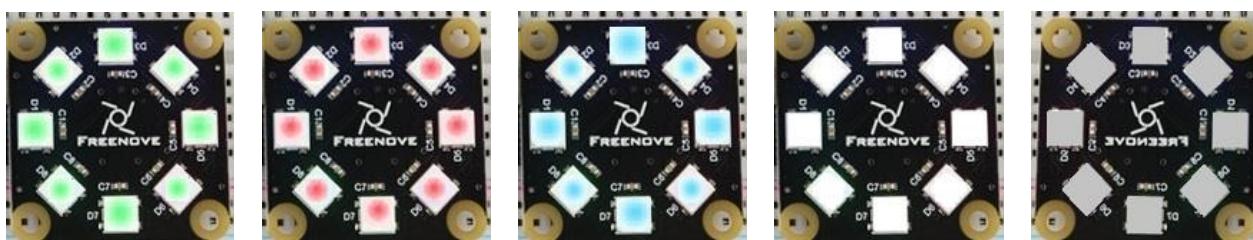
```

Writing at 0x0002cc18... (62 %)
Writing at 0x00033ceb... (75 %)
Writing at 0x0003d6f0... (87 %)
Writing at 0x00042ccb... (100 %)
Wrote 224592 bytes (125657 compressed) at 0x00010000 in 3.1 seconds (effective 581.9 kbit/s)...
Hash of data verified.

Leaving...
Hard resetting via RTS pin...

```

Download the code to ESP32-S3 WROOM and RGB LED begins to light up in red, green, blue, white and black.



The following is the program code:

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

```

1 #include "Freenove_WS2812_Lib_for_ESP32.h"
2
3 #define LEDS_COUNT 8 // The number of led
4 #define LEDS_PIN 48 // define the pin connected to the Freenove 8 led strip
5 #define CHANNEL 0 // RMT channel
6
7 Freenove_ESP32_WS2812 strip = Freenove_ESP32_WS2812(LEDS_COUNT, LEDS_PIN, CHANNEL, TYPE_GRB);
8
9 u8 m_color[5][3] = { {255, 0, 0}, {0, 255, 0}, {0, 0, 255}, {255, 255, 255}, {0, 0, 0} };
10 int delayval = 100;
11
12 void setup() {
13     strip.begin();
14     strip.setBrightness(10);
15 }
16 void loop() {
17     for (int j = 0; j < 5; j++) {
18         for (int i = 0; i < LEDS_COUNT; i++) {
19             strip.setLedColorData(i, m_color[j][0], m_color[j][1], m_color[j][2]);
20             strip.show();
21             delay(delayval);
22         }
23         delay(500);
24     }
25 }
```

To use some libraries, first you need to include the library's header file.

```
1 #include "Freenove_WS2812_Lib_for_ESP32.h"
```

Define the pins connected to the ring, the number of LEDs on the ring, and RMT channel values.

```

3 #define LEDS_COUNT 8 // The number of led
4 #define LEDS_PIN 48 // define the pin connected to the Freenove 8 led strip
5 #define CHANNEL 0 // RMT channel
```

Use the above parameters to create a LEDPixel object strip.

```
7 Freenove_ESP32_WS2812 strip = Freenove_ESP32_WS2812(LEDS_COUNT, LEDS_PIN, CHANNEL, TYPE_GRB);
```

Define the color values to be used, as red, green, blue, white, and black.

```
9 u8 m_color[5][3] = { {255, 0, 0}, {0, 255, 0}, {0, 0, 255}, {255, 255, 255}, {0, 0, 0} };
```

Define a variable to set the time interval for each led to light up. The smaller the value is, the faster it will light up.

```
10 int delayval = 50;
```

Initialize strip() in setup() and set the brightness.

```

13 strip.begin();
14 strip.setBrightness(10);
```

In the loop(), there are two “for” loops, the internal for loop to light the LED one by one, and the external for loop to switch colors. strip.setLedColorData() is used to set the color, but it does not change immediately. Only when strip.show() is called will the color data be sent to the LED to change the color.

```

17   for (int j = 0; j < 5; j++) {
18     for (int i = 0; i < LEDS_COUNT; i++) {
19       strip.setLedColorData(i, m_color[j][0], m_color[j][1], m_color[j][2]);
20       strip.show();
21       delay(delayval);
22     }
23     delay(500);
24   }

```

## Reference

**Freenove\_ESP32\_WS2812(u16 n = 8, u8 pin\_gpio = 2, u8 chn = 0, LED\_TYPE t = TYPE\_GRB)**

Constructor to create a LEDPixel object.

Before each use of the constructor, please add “#include "Freenove\_WS2812\_Lib\_for\_ESP32.h”

### Parameters

**n**: The number of led.

**pin\_gpio**: A pin connected to an led.

**Chn**: RMT channel, which uses channel 0 by default, has a total of eight channels, 0-7. This means that you can use eight LEDPixel modules for the display at the same time, and these modules do not interfere with each other

**t**: Types of LED.

**TYPE\_RGB**: The sequence of LEDPixel module loading color is red, green and blue.

**TYPE\_RBG**: The sequence of LEDPixel module loading color is red, blue and green.

**TYPE\_GRB**: The sequence of LEDPixel module loading color is green, red and blue.

**TYPE\_GBR**: The sequence of LEDPixel module loading color is green, blue and red.

**TYPE\_BRG**: The sequence of LEDPixel module loading color is blue, red and green.

**TYPE\_BGR**: The sequence of LEDPixel module loading color is blue, green and red.

**void begin(void);**

Initialize the LEDPixel object

```

void setLedColorData (u8 index, u8 r, u8 g, u8 b);
void setLedColorData (u8 index, u32 rgb);
void setLedColor (u8 index, u8 r, u8 g, u8 b);
void setLedColor (u8 index, u32 rgb);

```

Set the color of led with order number n.

**void show(void);**

Send the color data to the led and display the set color immediately.

**void setBrightness(uint8\_t);**

Set the brightness of the LED.

If you want to learn more about this library, you can visit the following website:

[https://github.com/Freenove/Freenove\\_WS2812\\_Lib\\_for\\_ESP32](https://github.com/Freenove/Freenove_WS2812_Lib_for_ESP32)



## Project 6.2 Rainbow Light

In the previous project, we have mastered the use of LEDPixel. This project will realize a slightly complicated rainbow light. The component list and the circuit are exactly the same as the project fashionable light.

### Sketch

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



#### Sketch\_06.2\_RainbowLight

```

Sketch_06.2_RainbowLight | Arduino IDE 2.0.0
File Edit Sketch Tools Help
ESP32S3 Dev Module
Sketch_06.2_RainbowLight.ino ...
1 #include "Freenove_WS2812_Lib_for_ESP32.h"
2
3 #define LEDS_COUNT 8
4 #define LEDS_PIN 48
5 #define CHANNEL 0
6
7 Freenove_ESP32_WS2812 strip = Freenove_ESP32_WS2812(LEDS_COUNT, LEDS_PIN, CHANNEL, TYPE_GRB);
8
9 void setup() {
10   strip.begin();
11   strip.setBrightness(20);
12 }
13
14 void loop() {
15   for (int j = 0; j < 255; j += 2) {
16     for (int i = 0; i < LEDS_COUNT; i++) {
17       strip.setLedColorData(i, strip.Wheel((i * 256 / LEDS_COUNT + j) & 255));
18     }
19     strip.show();
20     delay(5);
21   }
22 }
23
24
25
26
27
28 }
```

**Output**

```

Writing at 0x000270c1... (50 %)
Writing at 0x0002cbdc... (62 %)
Writing at 0x00033c33... (75 %)
Writing at 0x0003d6be... (87 %)
Writing at 0x00042c72... (100 %)
Wrote 224640 bytes (125742 compressed) at 0x00010000 in 3.1 seconds (effective 582.3 kbit/s)...
Hash of data verified.

Leaving...
Hard resetting via RTS pin...
```

Ln 29, Col 1 UTF-8 ESP32S3 Dev Module on COM3 2

Download the code to ESP32-S3 WROOM, and the Freenove 8 RGB LED Strip displays different colors and the color changes gradually.



The following is the program code:

```

1 #include "Freenove_WS2812_Lib_for_ESP32.h"
2
3 #define LEDS_COUNT 8 // The number of led
4 #define LEDS_PIN    48 // define the pin connected to the Freenove 8 led strip
5 #define CHANNEL     0 // RMT channel
6
7 Freenove_ESP32_WS2812 strip = Freenove_ESP32_WS2812(LEDS_COUNT, LEDS_PIN, CHANNEL, TYPE_GRB);
8
9 void setup() {
10   strip.begin();
11   strip.setBrightness(20);
12 }
13
14 void loop() {
15   for (int j = 0; j < 255; j += 1) {
16     for (int i = 0; i < LEDS_COUNT; i++) {
17       strip.setLedColorData(i, strip.Wheel((i * 256 / LEDS_COUNT + j) & 255));
18     }
19     strip.show(); // Send color data to LED, and display.
20     delay(5);
21   }
22 }
```

In the loop(), two “for” loops are used, the internal “for” loop(for-j) is used to set the color of each LED, and the external “for” loop(for-i) is used to change the color, in which the self-increment value in  $i+=1$  can be changed to change the color step distance. Changing the delay parameter changes the speed of the color change.  $\text{Wheel}(i * 256 / \text{LEDS\_COUNT} + j) \& 255$  will take color from the color model at equal intervals starting from i.

```

15 for (int j = 0; j < 255; j += 1) {
16   for (int i = 0; i < LEDS_COUNT; i++) {
17     strip.setLedColorData(i, strip.Wheel((i * 256 / LEDS_COUNT + j) & 255));
18   }
19   strip.show(); // Send color data to LED, and display.
20   delay(5);
21 }
```

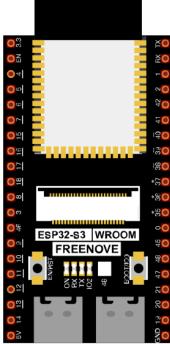
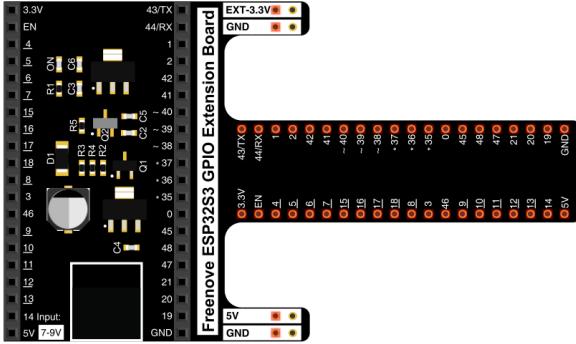
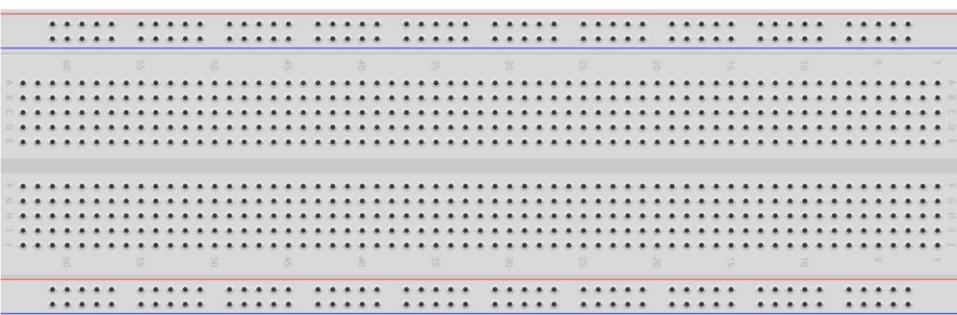
# Chapter 7 Buzzer

In this chapter, we will learn about buzzers that can make sounds.

## Project 7.1 Doorbell

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

### Component List

ESP32-S3 WROOM x1		GPIO Extension Board x1 
Breadboard x1		
		
Jumper M/M x6		
NPN transistor x1 (S8050)		Active buzzer x1 
Push button x1		Resistor 1kΩ x1 
Resistor 10kΩ x2		

## Component knowledge

### Buzzer

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



Active buzzer 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).

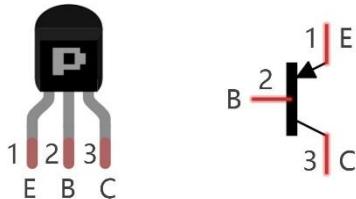


### Transistor

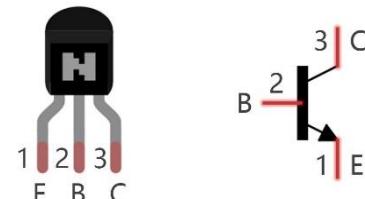
Because the buzzer requires such large current that GPIO of ESP32-S3 output capability cannot meet the requirement, a transistor of NPN type is needed here to amplify the current.

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

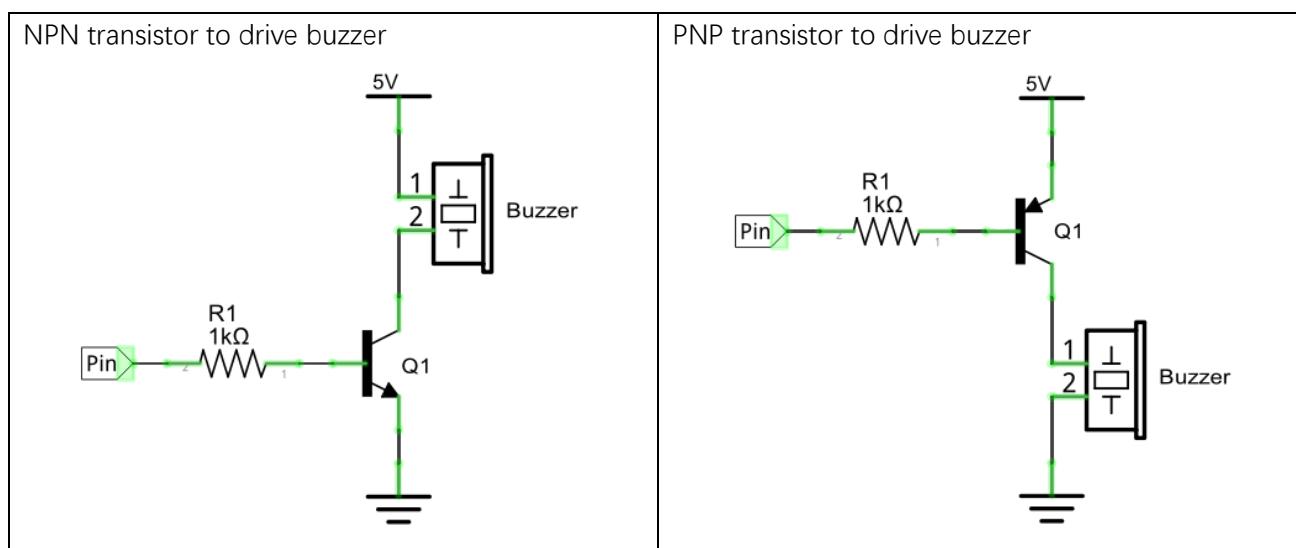


In our kit, the PNP transistor is marked with 8550, and the NPN transistor is marked with 8050.

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.

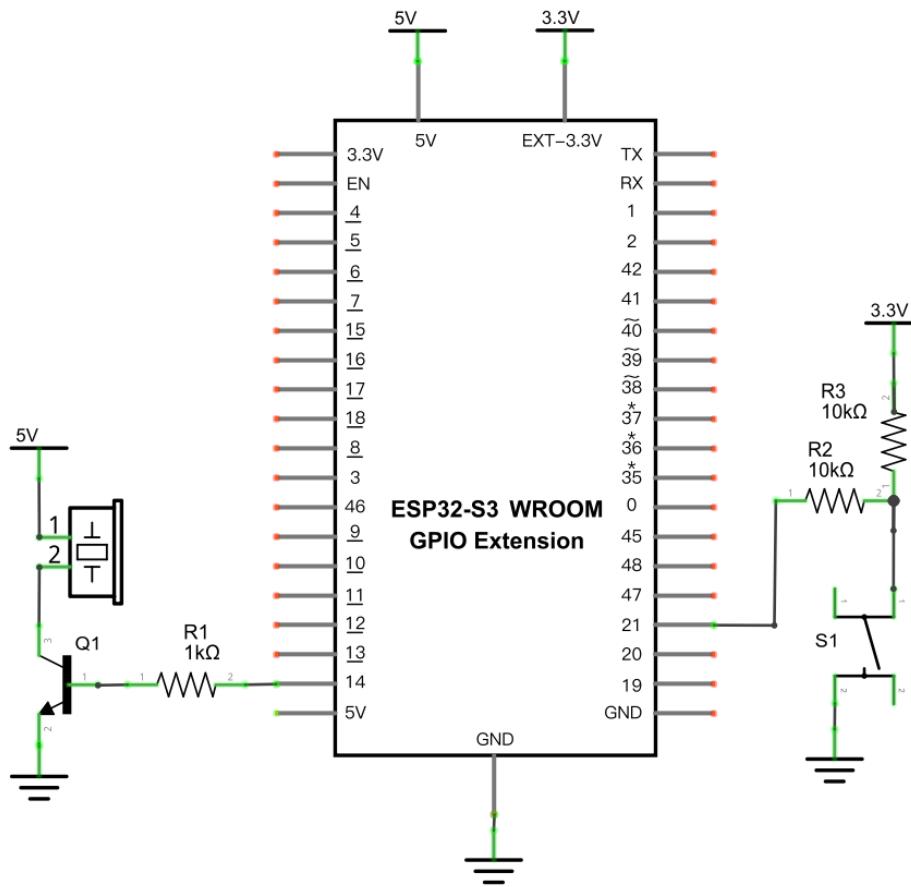
When use NPN transistor to drive buzzer, we often adopt the following method. If GPIO outputs high level, current will flow through R1, the transistor will get conducted, and the buzzer will sound. If GPIO outputs low level, no current flows through R1, the transistor will not be conducted, and buzzer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

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

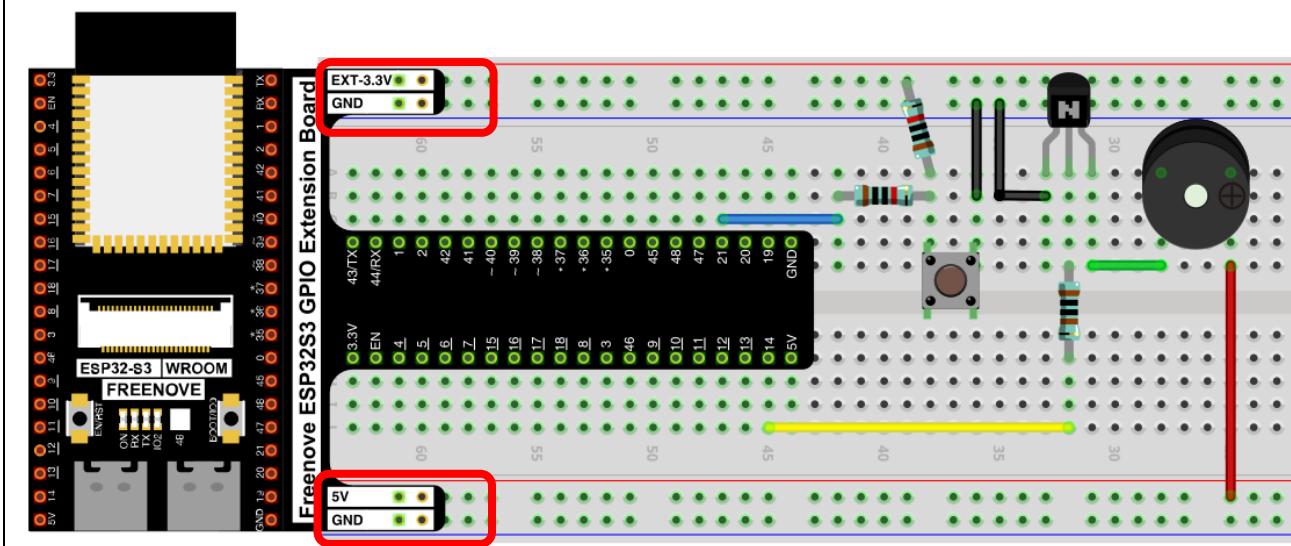


## Circuit

Schematic diagram



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



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

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



## Sketch

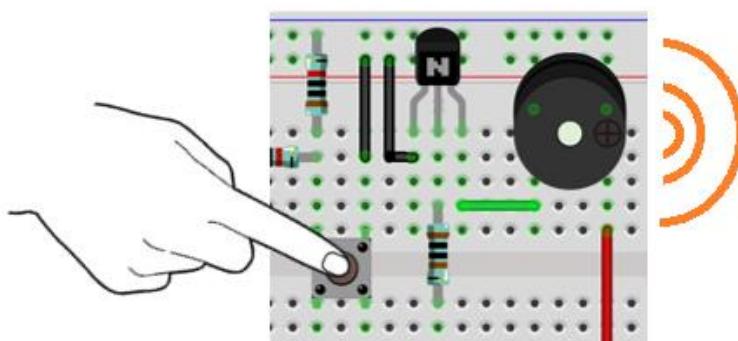
In this project, a buzzer will be controlled by a push button switch. When the button switch is pressed, the buzzer sounds and when the button is released, the buzzer stops. It is analogous to our earlier project that controlled a LED ON and OFF.

### Sketch\_07.1\_Doorbell

The screenshot shows the Arduino IDE interface with the title bar "Sketch\_07.1\_Doorbell | Arduino IDE 2.0.0". The menu bar includes File, Edit, Sketch, Tools, and Help. The toolbar has icons for save, upload, and refresh. The board selector dropdown shows "ESP32S3 Dev Module". The code editor displays the following sketch:

```
Sketch_07.1_Doorbell.ino
7 #define PIN_BUZZER 14
8 #define PIN_BUTTON 21
9
10 void setup() {
11     pinMode(PIN_BUZZER, OUTPUT);
12     pinMode(PIN_BUTTON, INPUT);
13 }
14
15 void loop() {
16     if (digitalRead(PIN_BUTTON) == LOW) {
17         digitalWrite(PIN_BUZZER,HIGH);
18     }else{
19         digitalWrite(PIN_BUZZER,LOW);
20     }
21 }
```

Download the code to ESP32-S3 WROOM, 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 #define PIN_BUZZER 14
2 #define PIN_BUTTON 21
3
4 void setup() {
```

```
5   pinMode(PIN_BUZZER, OUTPUT);
6   pinMode(PIN_BUTTON, INPUT);
7 }
8
9 void loop() {
10 if (digitalRead(PIN_BUTTON) == LOW) {
11     digitalWrite(PIN_BUZZER, HIGH);
12 } else{
13     digitalWrite(PIN_BUZZER, LOW);
14 }
15 }
```

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



## Project 7.2 Alertor

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

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

### Sketch

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. It is logically the same as using button to control LED, but in the control method, passive buzzer requires PWM of certain frequency to sound.

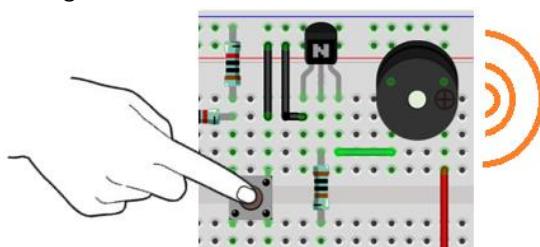
#### Sketch\_07.2\_Aleror

```

File Edit Sketch Tools Help
Sketch_07.2_Aleror.ino
ESP32S3 Dev Module
Sketch_07.2_Aleror.ino ...
1 #define PIN_BUZZER 14
2 #define PIN_BUTTON 21
3 #define CHN          0 //define the pwm channel
4
5 void setup() {
6     pinMode(PIN_BUTTON, INPUT);
7     pinMode(PIN_BUZZER, OUTPUT);
8     ledcAttachChannel(PIN_BUZZER, 1, 10, CHN); //attach the led pin to pwm channel
9     ledcWriteTone(PIN_BUZZER, 2000);           //Sound at 2KHz for 0.3 seconds
10    delay(300);
11 }
12
13 void loop() {
14     if (digitalRead(PIN_BUTTON) == LOW) {
15         alert();
16     } else {
17         ledcWriteTone(PIN_BUZZER, 0);
18     }
19 }
20
21 void alert() {
22     float sinVal;           // Define a variable to save sine value
23     int toneVal;            // Define a variable to save sound frequency
24     for (int x = 0; x < 360; x += 10) { // X from 0 degree->360 degree
25         sinVal = sin(x * (PI / 180)); // Calculate the sine of x
26         toneVal = 2000 + sinVal * 500; // Calculate sound frequency according to the sine of x
27         ledcWriteTone(PIN_BUZZER, toneVal);
28         delay(10);
29     }
30 }
31
32
33
34
35
36

```

Download the code to ESP32-S3 WROOM, press the button, then alarm sounds. And when the button is released, the alarm will stop sounding.



Any concerns? ✉ support@freenove.com

The following is the program code:

```
1 #define PIN_BUZZER 14
2 #define PIN_BUTTON 21
3 #define CHN      0 //define the pwm channel
4
5 void setup() {
6     pinMode(PIN_BUTTON, INPUT);
7     pinMode(PIN_BUZZER, OUTPUT);
8     ledcAttachChannel(PIN_BUZZER, 0, 10, CHN); //attach the led pin to pwm channel
9     ledcWriteTone(PIN_BUZZER, 2000);           //Sound at 2KHz for 0.3 seconds
10    delay(300);
11 }
12
13 void loop() {
14     if (digitalRead(PIN_BUTTON) == LOW) {
15         alert();
16     } else {
17         ledcWriteTone(PIN_BUZZER, 0);
18     }
19 }
20
21 void alert() {
22     float sinVal;          // Define a variable to save sine value
23     int toneVal;           // Define a variable to save sound frequency
24     for (int x = 0; x < 360; x += 10) { // X from 0 degree->360 degree
25         sinVal = sin(x * (PI / 180)); // Calculate the sine of x
26         toneVal = 2000 + sinVal * 500; //Calculate sound frequency according to the sine of x
27         ledcWriteTone(PIN_BUZZER, toneVal);
28         delay(10);
29     }
30 }
```

The code is the same as the active buzzer logically, but the way to control the buzzer is different. Passive buzzer requires PWM of certain frequency to control, so you need to create a PWM channel through ledcAttachChannel(). Here ledcWriteTone() is designed to generating square wave with variable frequency and duty cycle fixed to 50%, which is a better choice for controlling the buzzer.

```
8   ledcAttachChannel(PIN_BUZZER, 0, 10, CHN); //attach the led pin to pwm channel
9   ledcWriteTone(PIN_BUZZER, 2000);           //Sound at 2KHz for 0.3 seconds
```

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

```
21 void alert() {
22     float sinVal;           // Define a variable to save sine value
23     int toneVal;            // Define a variable to save sound frequency
24     for (int x = 0; x < 360; x += 10) {      // X from 0 degree->360 degree
25         sinVal = sin(x * (PI / 180));        // Calculate the sine of x
26         toneVal = 2000 + sinVal * 500;        //Calculate sound frequency according to the sine of x
27         ledcWriteTone(PIN_BUZZER, toneVal);
28         delay(10);
29     }
30 }
```

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

```
17 ledcWriteTone(PIN_BUZZER, 0);
```

#### Reference

```
double ledcWriteTone(uint8_t channel, double freq);
```

This updates the tone frequency value on the given channel.

This function has some bugs in the current version (V1.0.4): when the call interval is less than 20ms, the resulting PWM will have an exception. We will get in touch with the authorities to solve this problem and give solutions in the following two projects.

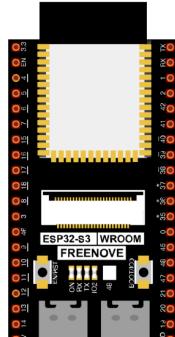
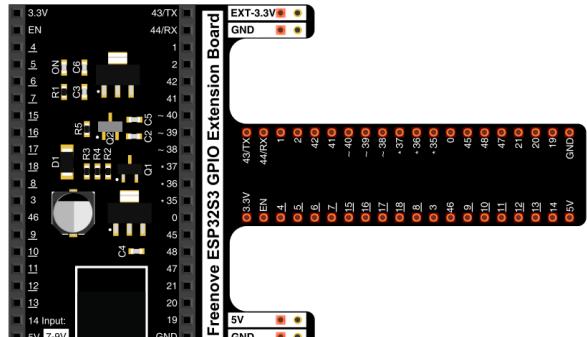
# Chapter 8 Serial Communication

Serial Communication is a means of communication between different devices/devices. This section describes ESP32-S3's Serial Communication.

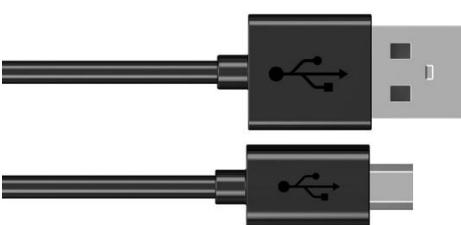
## Project 8.1 Serial Print

This project uses ESP32-S3's serial communicator to send data to the computer and print it on the serial monitor.

### Component List

ESP32-S3 WROOM x1	GPIO Extension Board x1
	

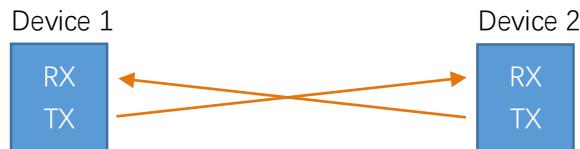
Micro USB Wire x1



## Related knowledge

### Serial communication

Serial communication generally refers to the Universal Asynchronous Receiver/Transmitter (UART), which is commonly used in electronic circuit communication. It has two communication lines, one is responsible for sending data (TX line) and the other for receiving data (RX line). The serial communication connections of two devices 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-S3

Freenove ESP32-S3 has integrated USB to serial transfer, so it could communicate with computer connecting to USB cable.

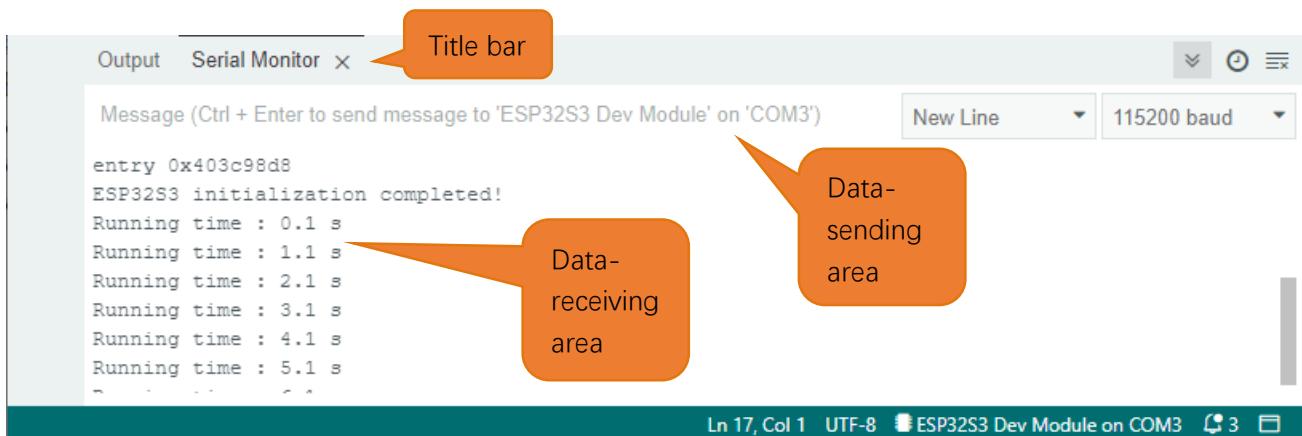


Arduino Software also uploads code to Freenove ESP32-S3 through the serial connection.

Your computer identifies serial devices connecting to it as COMx. We can use the Serial Monitor window of Arduino Software to communicate with Freenove ESP32-S3, connect Freenove ESP32-S3 to computer through the USB cable, choose the correct device, and then click the Serial Monitor icon to open the Serial Monitor window.



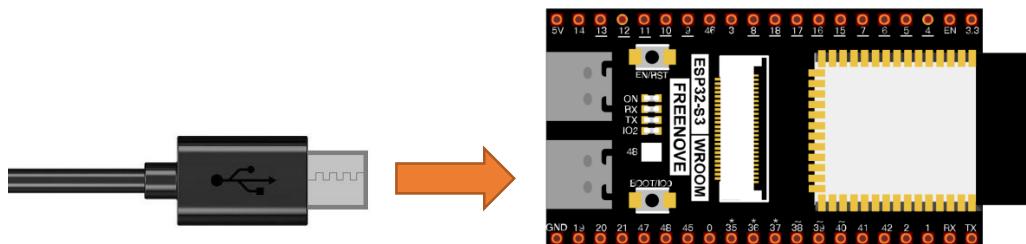
Interface of serial monitor window is as follows. If you can't open it, make sure Freenove ESP32-S3 has been connected to the computer, and choose the right serial port in the menu bar "Tools".



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

## Circuit

Connect Freenove ESP32-S3 to the computer with USB cable.



## Sketch

### Sketch\_08.1\_SerialPrinter

```

Sketch_08.1_SerialPrinter | Arduino IDE 2.0.0
File Edit Sketch Tools Help
ESP32S3 Dev Module
Sketch_08.1_SerialPrinter.ino
1 //*****
2   Filename    : SerialPrinter
3   Description : Use UART send some data to PC, and show them on serial monitor.
4   Author     : www.freenove.com
5   Modification: 2022/10/20
6 *****/
7
8 void setup() {
9   Serial.begin(115200);
10  Serial.println("ESP32S3 initialization completed!");
11 }
12
13 void loop() {
14   Serial.printf("Running time : %.1f s\n", millis() / 1000.0f);
15   delay(1000);
16 }

```

Download the code to ESP32-S3 WROOM, open the serial port monitor, set the baud rate to 115200, and press the reset button. As shown in the following figure:

```

Output Serial Monitor x
Message (Ctrl + Enter to send message to 'ESP32S3 Dev Module' on 'COM3')
load:0x403cc700,len:0x2a3c
entry 0x403c98d8
ESP32S3 initialization completed!
Running time : 0.1 s
Running time : 1.1 s
Running time : 2.1 s
Running time : 3.1 s
Running time : 4.1 s

```



As shown in the image above, "ESP32-S3 initialization completed! " The previous is the printing message when the system is started. The user program is then printed at a baud rate of 115200.

The following is the program code:

```

1 void setup() {
2     Serial.begin(115200);
3     Serial.println("ESP32S3 initialization completed!");
4 }
5
6 void loop() {
7     Serial.printf("Running time : %.1f s\n", millis() / 1000.0f);
8     delay(1000);
9 }
```

### Reference

<code>void begin(unsigned long baud, uint32_t config=SERIAL_8N1, int8_t rxPin=-1,            int8_t txPin=-1, bool invert=false, unsigned long timeout_ms = 20000UL);</code>
--

Initializes the serial port. Parameter baud is baud rate, other parameters generally use the default value.

<code>size_t println( arg );</code>
-------------------------------------

Print to the serial port and wrap. The parameter **arg** can be a number, a character, a string, an array of characters, etc.

<code>size_t printf(const char * format, ...) __attribute__((format (printf, 2, 3)));</code>
--

Print formatted content to the serial port in the same way as print in standard C.

<code>unsigned long millis();</code>
--------------------------------------

Returns the number of milliseconds since the current system was booted.

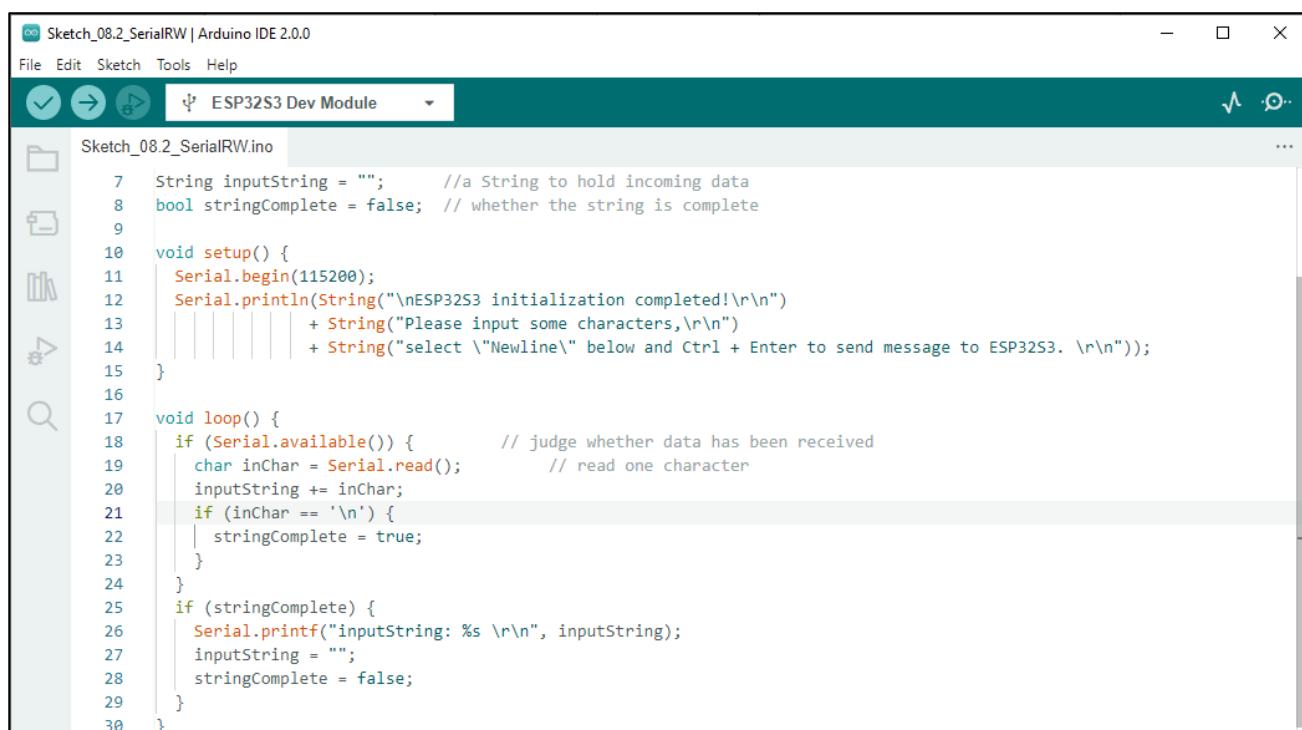
## Project 8.2 Serial Read and Write

From last section, we use serial port on Freenove ESP32-S3 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.

### Sketch

#### Sketch\_08.2\_SerialRW

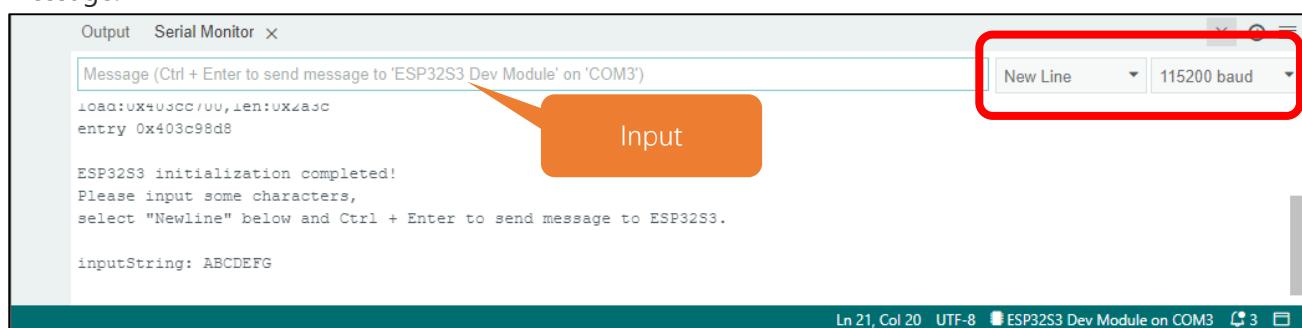


```

Sketch_08.2_SerialRW | Arduino IDE 2.0.0
File Edit Sketch Tools Help
ESP32S3 Dev Module
Sketch_08.2_SerialRW.ino
1 String inputString = ""; //a String to hold incoming data
2 bool stringComplete = false; // whether the string is complete
3
4 void setup() {
5     Serial.begin(115200);
6     Serial.println(String("\nESP32S3 initialization completed!\r\n")
7                     + String("Please input some characters,\r\n")
8                     + String("select \"Newline\" below and Ctrl + Enter to send message to ESP32S3. \r\n"));
9 }
10
11 void loop() {
12     if (Serial.available()) { // judge whether data has been received
13         char inChar = Serial.read(); // read one character
14         inputString += inChar;
15         if (inChar == '\n') {
16             stringComplete = true;
17         }
18     }
19     if (stringComplete) {
20         Serial.printf("inputString: %s \r\n", inputString);
21         inputString = "";
22         stringComplete = false;
23     }
24 }
25
26
27
28
29
30 }
```

Download the code to ESP32-S3 WROOM, open the serial monitor, and set the top right corner to **Newline**, **115200**. As shown in the following figure:

Then type characters like 'ABCDEFG' into the data sent at the top, and press Ctrl+Enter to send the message.



The following is the program code:

```

1  String inputString = "";      //a String to hold incoming data
2  bool stringComplete = false; // whether the string is complete
3
4  void setup() {
5      Serial.begin(115200);
6      Serial.println(String("\nESP32S3 initialization completed! \r\n")
7                      + String("Please input some characters, \r\n")
8                      + String("select \"Newline\" below and Ctrl + Enter to send message to
9 ESP32S3. \r\n"));
10 }
11
12 void loop() {
13     if (Serial.available()) { // judge whether data has been received
14         char inChar = Serial.read(); // read one character
15         inputString += inChar;
16         if (inChar == '\n') {
17             stringComplete = true;
18         }
19         if (stringComplete) {
20             Serial.printf("inputString: %s \n", inputString);
21             inputString = "";
22             stringComplete = false;
23         }
24     }
}

```

In loop(), determine whether the serial port has data, if so, read and save the data, and if the newline character is read, print out all the data that has been read.

### Reference

**String();**

Constructs an instance of the String class.

For more information, please visit

<https://www.arduino.cc/reference/en/language/variables/data-types/stringobject/>

**int available(void);**

Get the number of bytes (characters) available for reading from the serial port. This is data that's already arrived and stored in the serial receive buffer.

**Serial.read();**

Reads incoming serial data.

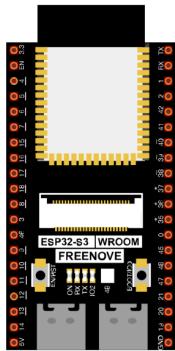
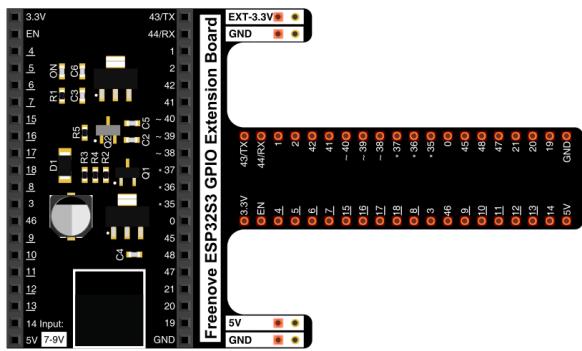
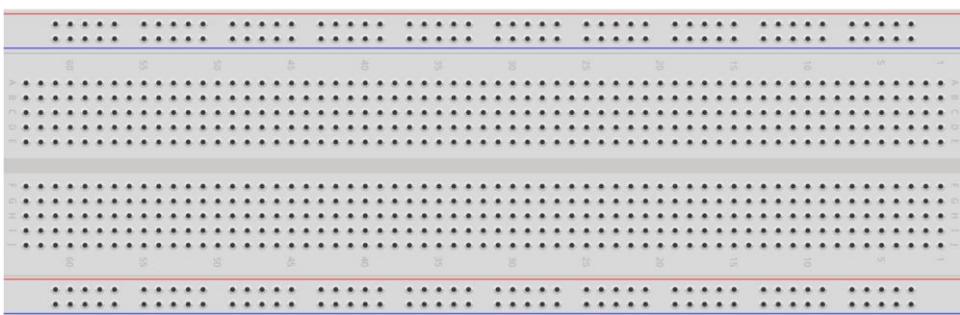
# Chapter 9 AD Converter

In this chapter, we will learn how to use ESP32-S3 to read analog signals.

## Project 9.1 Read the Voltage of Potentiometer

In this project, we will use the ADC function of ESP32-S3 to read the voltage value of the potentiometer and print it out through the serial monitor.

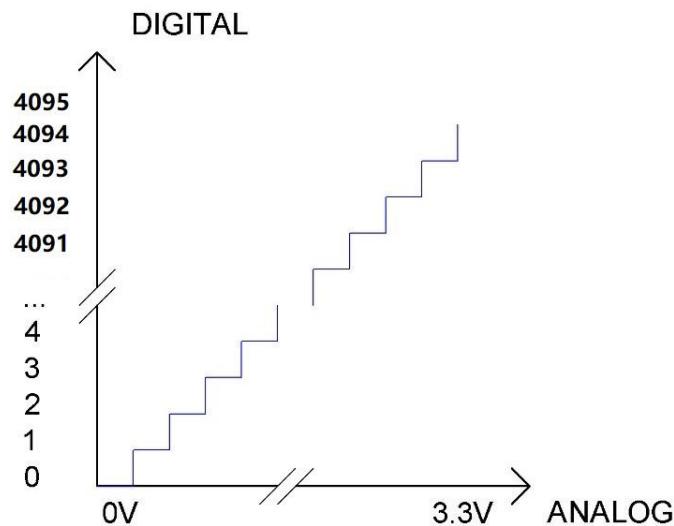
### Component List

ESP32-S3 WROOM x1	GPIO Extension Board x1
	
Breadboard x1	
Rotary potentiometer x1	Jumper M/M x3

## 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-S3 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:

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

### ADC on ESP32-S3

ESP32-S3 has two digital analog converters with successive approximations of 12-bit accuracy, and a total of 20 pins can be used to measure analog signals. GPIO pin sequence number and analog pin definition are shown in the following table.

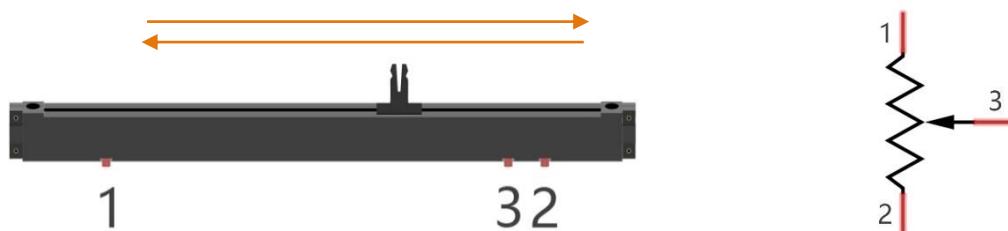
Pin number in Arduino	GPIO number	ADC channel
A0	GPIO 1	ADC1_CH0
A1	GPIO 2	ADC1_CH1
A2	GPIO 3	ADC1_CH2
A3	GPIO 4	ADC1_CH3
A4	GPIO 5	ADC1_CH4
A5	GPIO 6	ADC1_CH5
A6	GPIO 7	ADC1_CH6
A7	GPIO 8	ADC1_CH7
A8	GPIO 9	ADC1_CH8
A9	GPIO 10	ADC1_CH9
A10	GPIO 11	ADC2_CH0
A11	GPIO 12	ADC2_CH1
A12	GPIO 13	ADC2_CH2
A13	GPIO 14	ADC2_CH3
A14	GPIO 15	ADC2_CH4
A15	GPIO 16	ADC2_CH5
A16	GPIO 17	ADC2_CH6
A17	GPIO 18	ADC2_CH7
A18	GPIO 19	ADC2_CH8
A19	GPIO 20	ADC2_CH9

The analog pin number is also defined in ESP32-S3's code base. For example, you can replace GPIO1 with A0 in the code.

## Component knowledge

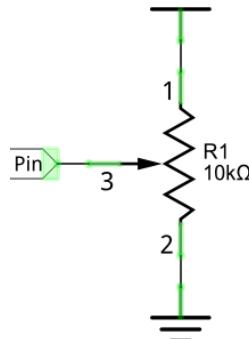
### Potentiometer

A potentiometer is a three-terminal resistor. 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.



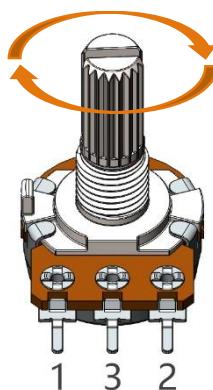
What between potentiometer pin 1 and pin 2 is the resistor body, and pins 3 is connected to brush. When brush moves from pin 1 to pin 2, the resistance between pin 1 and pin 3 will increase up to body resistance linearly, and the resistance between pin 2 and pin 3 will decrease down to 0 linearly.

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.



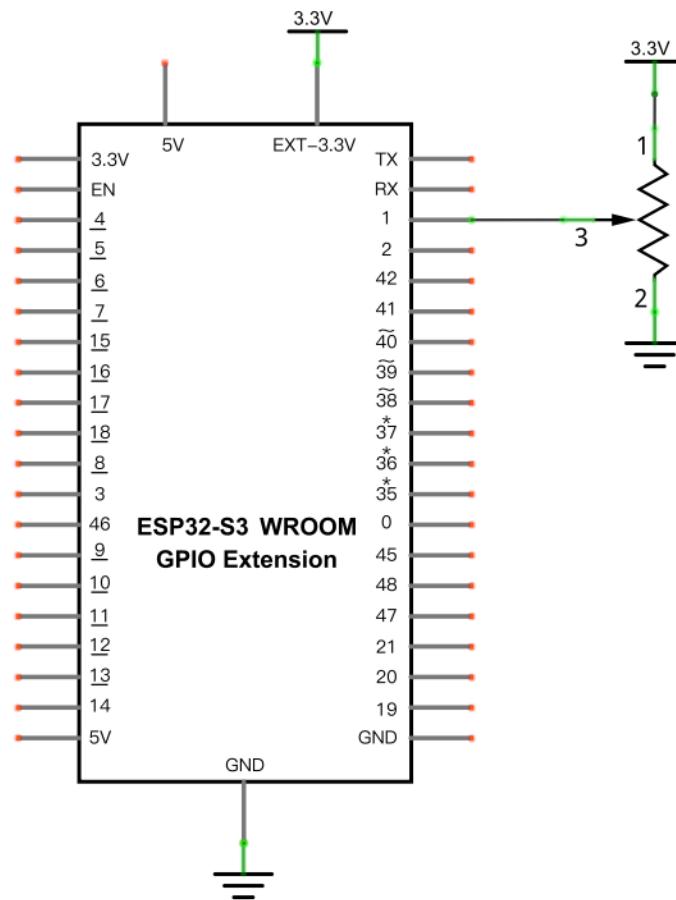
### Rotary potentiometer

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



# 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



## Sketch

### Sketch\_09.1\_ADC

The screenshot shows the Arduino IDE 2.0.0 interface with the following details:

- Title Bar:** Sketch\_09.1\_ADC | Arduino IDE 2.0.0
- Menu Bar:** File Edit Sketch Tools Help
- Toolbar:** Includes icons for Save, Run, Stop, and a dropdown for the connected board.
- Board Selector:** Set to "ESP32S3 Dev Module".
- Code Area:** Displays the `Sketch_09.1_ADC.ino` file content.

```

Sketch_09.1_ADC.ino

1  //*****
2  | Filename      : ADC_DAC
3  | Description   : Basic usage of ADC and DAC for esp32.
4  | Author        : www.freenove.com
5  | Modification  : 2022/10/20
6  *****/
7 #define PIN_ANALOG_IN 1
8 void setup() {
9 | Serial.begin(115200);
10 }
11
12 void loop() {
13 | int adcVal = analogRead(PIN_ANALOG_IN);
14 | double voltage = adcVal / 4095.0 * 3.3;
15 | Serial.printf("ADC Val: %d, \t Voltage: %.2fV\r\n", adcVal, voltage);
16 | delay(200);
17 }
```

Download the code to ESP32-S3 WROOM, open the serial monitor, and set the baud rate to 115200. As shown in the following figure.

The screenshot shows the Serial Monitor window with the following details:

- Text Input:** Message (Ctrl + Enter to send message to 'ESP32S3 Dev Module' on 'COM3')
- Output Area:**

```

ADC Val: 0,          Voltage: 0.00V
ADC Val: 0,          Voltage: 0.00V
ADC Val: 155,         Voltage: 0.12V
ADC Val: 613,         Voltage: 0.49V
ADC Val: 1303,        Voltage: 1.05V
ADC Val: 2297,        Voltage: 1.85V
ADC Val: 3307,        Voltage: 2.66V
ADC Val: 4095,        Voltage: 3.30V
ADC Val: 3107,         Voltage: 2.50V
ADC Val: 2341,         Voltage: 1.89V
ADC Val: 1727,         Voltage: 1.39V
ADC Val: 820,          Voltage: 0.66V
ADC Val: 0.           Voltage: 0.00V
    
```
- Settings:**
  - New Line dropdown: set to "New Line"
  - Baud Rate dropdown: set to "115200 baud"
- Bottom Status:**
  - indexing: 1/48
  - Ln 18, Col 1    UTF-8
  - ESP32S3 Dev Module on COM3
  - 2 messages

As shown in the picture above, as long as the handle of the potentiometer is rotated, the serial monitor will print out the ADC value, as well as the voltage value of the potentiometer.

The following is the code:

```
1 #define PIN_ANALOG_IN 1
2 void setup() {
3     Serial.begin(115200);
4 }
5
6 void loop() {
7     int adcVal = analogRead(PIN_ANALOG_IN);
8     double voltage = adcVal / 4095.0 * 3.3;
9     Serial.printf("ADC Val: %d, \t Voltage: %.2fV\n", adcVal, voltage);
10    delay(200);
11 }
```

In loop(), use the analogRead() function to obtain the input ADC value of the potentiometer, calculate the voltage value of the potentiometer according to the formula in the previous knowledge point, and print it out through the serial port.

```
7 int adcVal = analogRead(PIN_ANALOG_IN);
8 double voltage = adcVal / 4095.0 * 3.3;
9 Serial.printf("ADC Val: %d, \t Voltage: %.2fV\n", adcVal, voltage);
```

#### Reference

```
uint16_t analogRead(uint8_t pin);
```

Reads the value from the specified analog pin. Return the analog reading on the pin. (0-4095 for 12 bits).



# Chapter 10 Touch Sensor

ESP32-S3 offers up to 14 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-S3's built-in touch sensor. In addition, on the service life, the touch switch also has advantages that mechanical switch is completely incomparable.

## Project 10.1 Read Touch Sensor

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

### Component List

<b>ESP32-S3 WROOM x1</b> 	<b>GPIO Extension Board x1</b> 
<b>Breadboard x1</b> 	
<b>Jumper M/M x1</b> 	

## Related knowledge

### Touch sensor

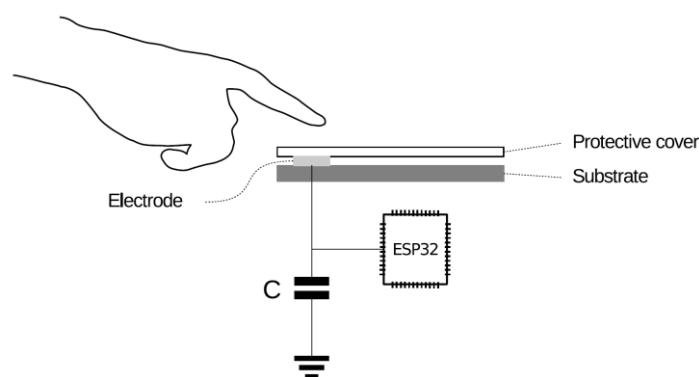
ESP32-S3's touch sensor supports up to 14 GPIO channels as capacitive touch pins. Each pin can be used separately as an independent touch switch or be combined to produce multiple touch points. The following table is a list of available touch pins on ESP32-S3.

Name of touch sensing signal	GPIO number
T1	GPIO1
T2	GPIO2
T3	GPIO3
T4	GPIO4
T5	GPIO5
T6	GPIO6
T7	GPIO7
T8	GPIO8
T9	GPIO9
T10	GPIO10
T11	GPIO11
T12	GPIO12
T13	GPIO13
T14	GPIO14

The touch pin number is already defined in ESP32-S3's code base. For example, in the code, you can use T1 to represent GPIO1.

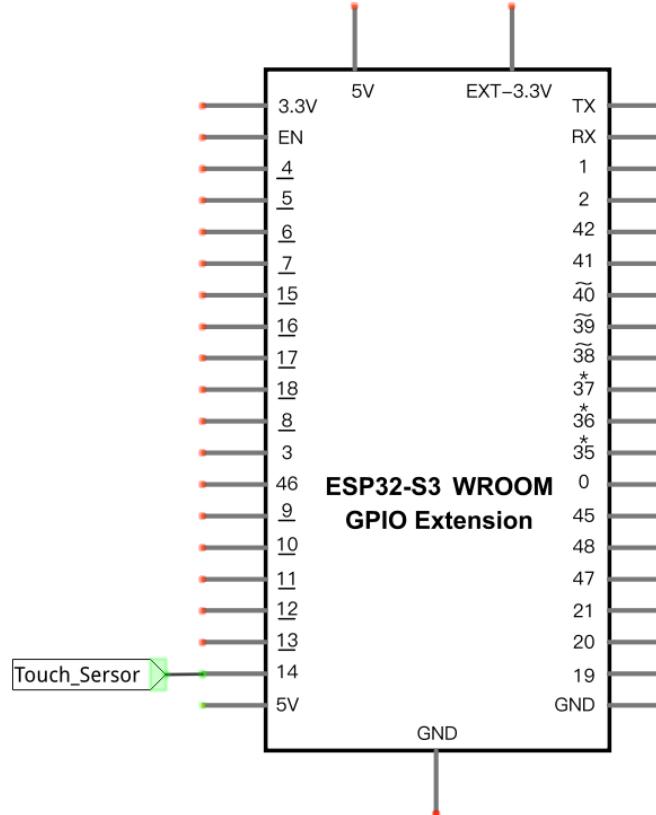
The electrical signals generated by touch are analog data, which are converted by an internal ADC converter. You may have noticed that all touch pins have ADC functionality.

The hardware connection method is shown in the following figure.

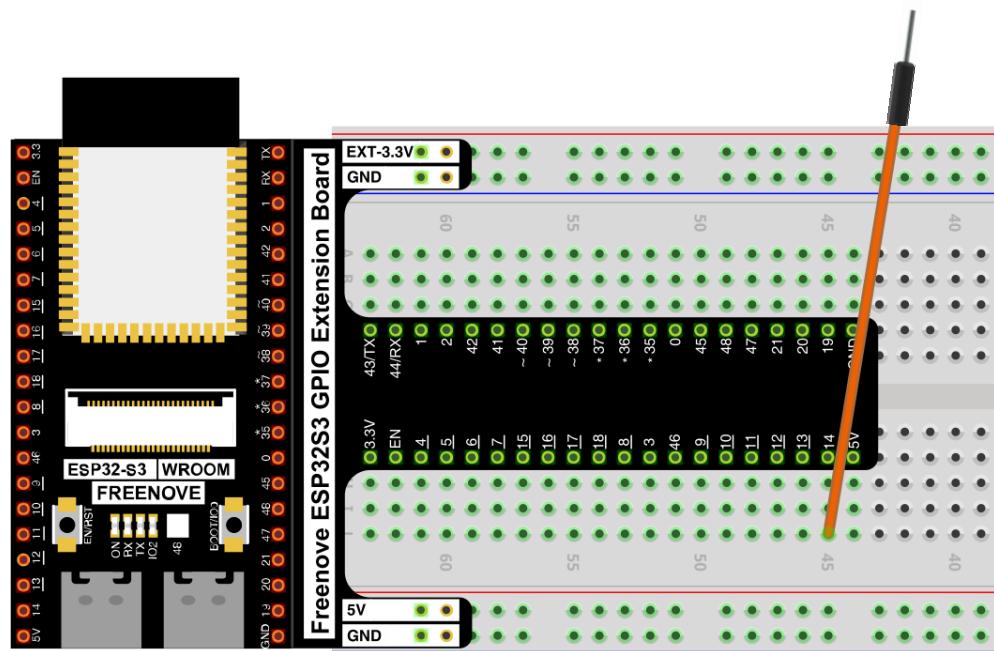


## Circuit

Schematic diagram



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



## Sketch

### Sketch\_10.1\_TouchRead

The screenshot shows the Arduino IDE interface with the following details:

- Title Bar:** Sketch\_10.1\_TouchRead | Arduino IDE 2.0.0
- Toolbar:** File, Edit, Sketch, Tools, Help
- Sketch Selection:** Sketch\_10.1\_TouchRead.ino (selected)
- Board Selection:** ESP32S3 Dev Module
- Code Area:**

```

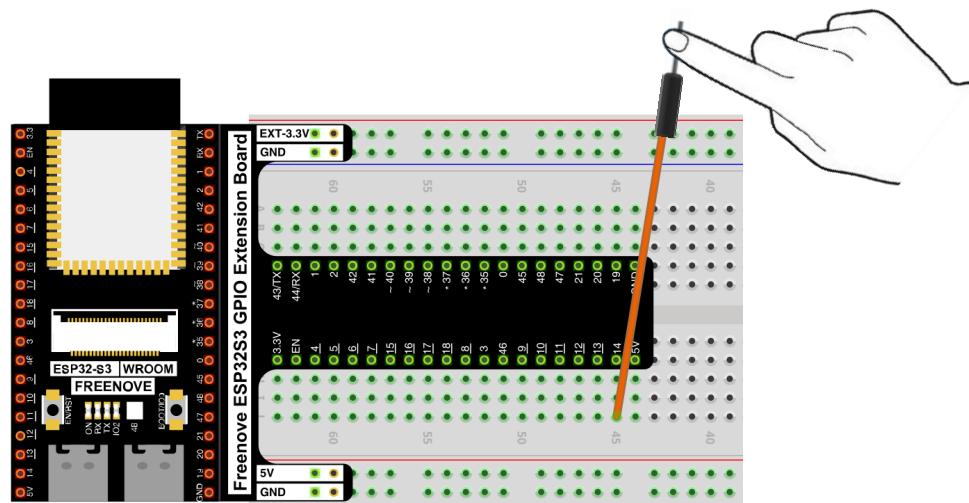
1  ****
2  Filename   : TouchRead
3  Description : Read touch sensor value.
4  Author     : www.freenove.com
5  Modification: 2022/10/21
6 ****
7
8 void setup()
9 {
10    Serial.begin(115200);
11 }
12
13 void loop()
14 {
15    Serial.printf("Touch value: %d \r\n",touchRead(T14)); // get value using T14 (GPIO14)
16    delay(1000);
17 }
```
- Output Area:**

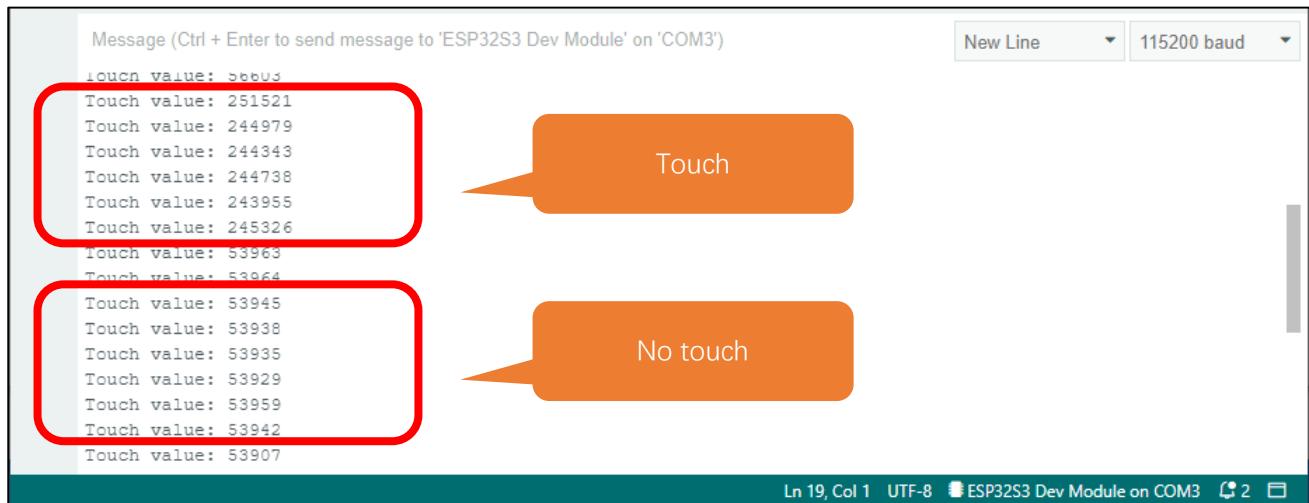
```

Writing at 0x0002e004... (55 %)
Writing at 0x00033008... (66 %)
Writing at 0x0003d407... (77 %)
Writing at 0x000441b6... (88 %)
Writing at 0x00049b64... (100 %)
Wrote 241312 bytes (134029 compressed) at 0x00010000 in 3.5 seconds (effective 546.7 kbit/s)...
Hash of data verified.

Leaving...
Hard resetting via RTS pin...
```
- Bottom Status Bar:** Ln 19, Col 1 UTF-8 ■ ESP32S3 Dev Module on COM3 4 2

Download the code to ESP32-S3 WROOM, open the serial monitor, and set the baud rate to 115200. Touch jumper with hand. As shown in the following figure,





### Reference

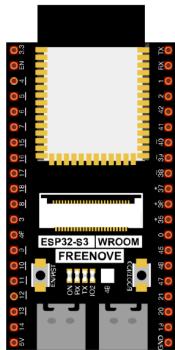
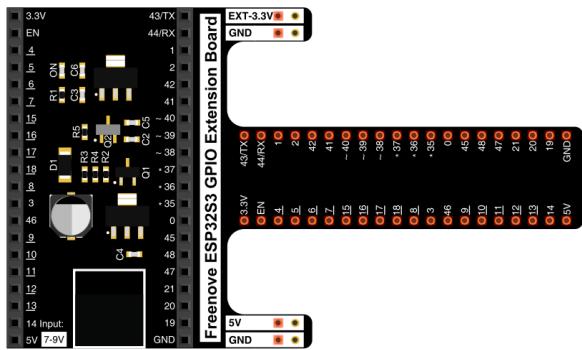
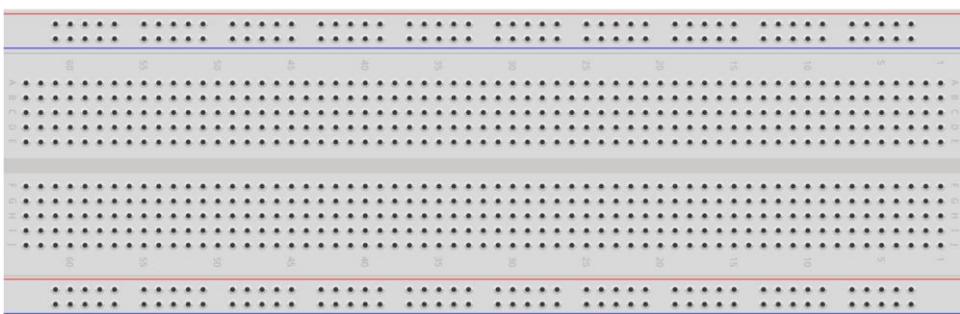
```
uint16_t touchRead(uint8_t pin);
```

Read touch sensor value. (values close to 0 mean touch detected)

## Project 10.2 Touch Lamp

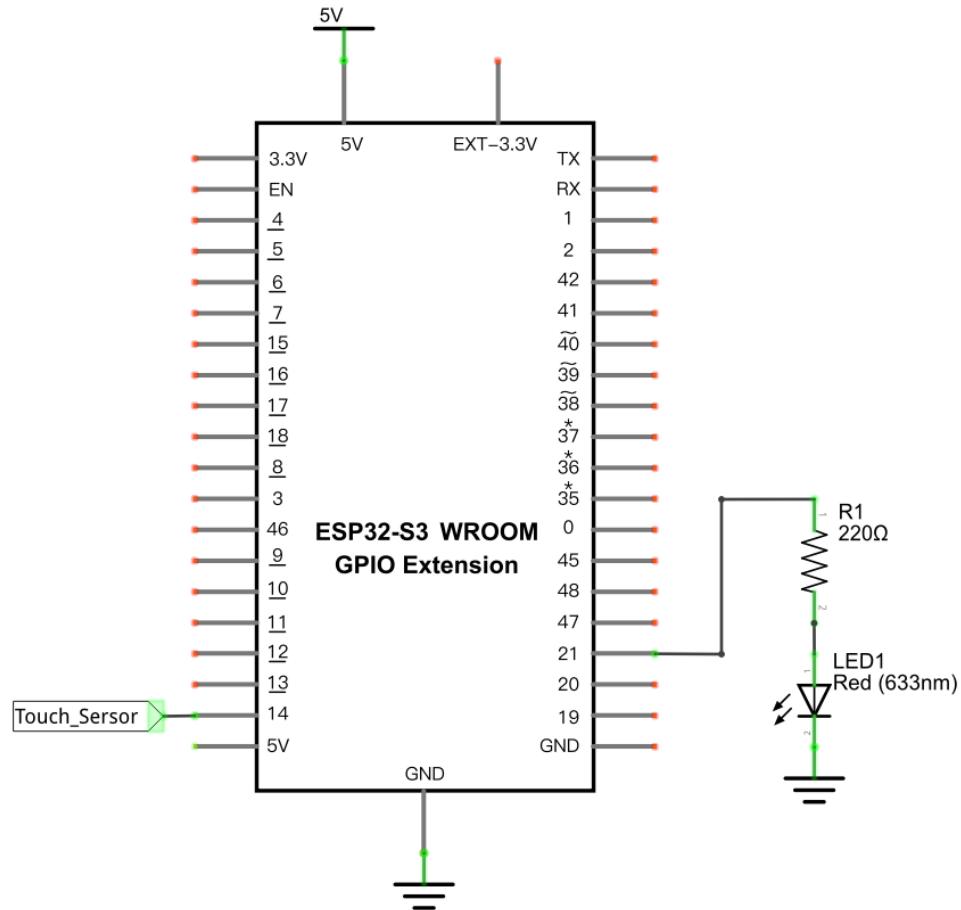
In this project, we will use ESP32-S3's touch sensor to create a touch switch lamp.

### Component List

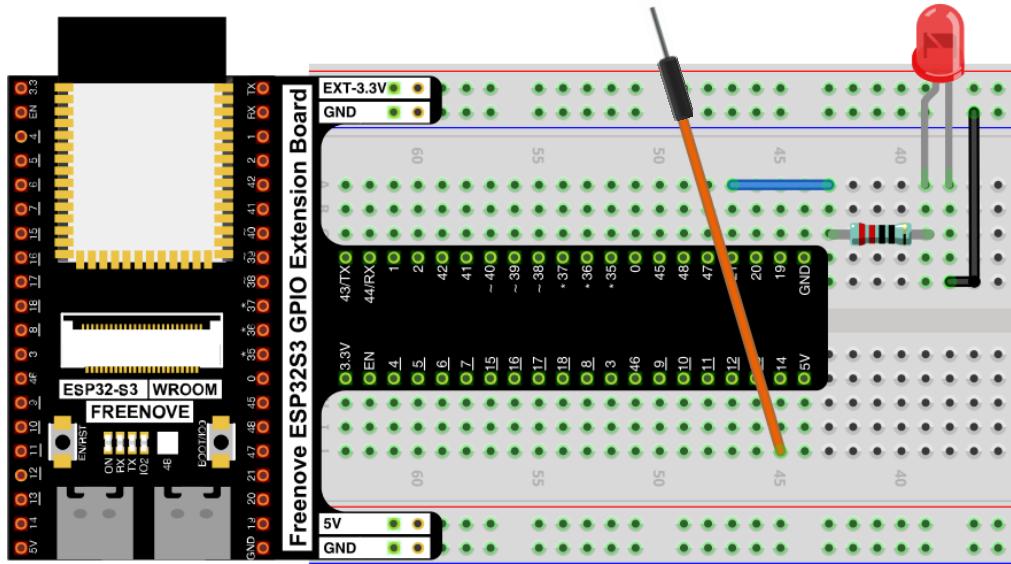
ESP32-S3 WROOM x1	GPIO Extension Board x1	Breadboard x1
		
Jumper M/M x3	LED x1	Resistor 220Ω x1

## Circuit

Schematic diagram



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



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

## Sketch

### Sketch\_10.2\_TouchLamp

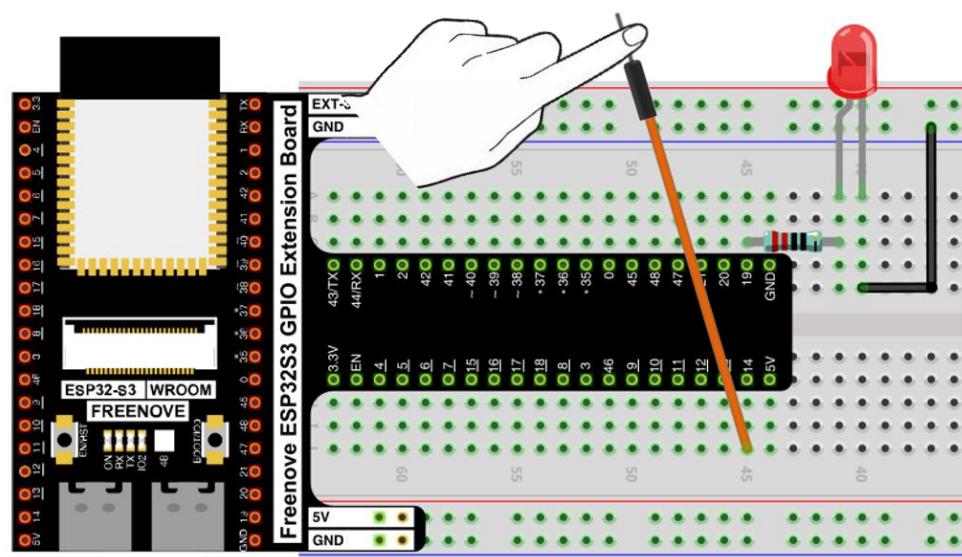


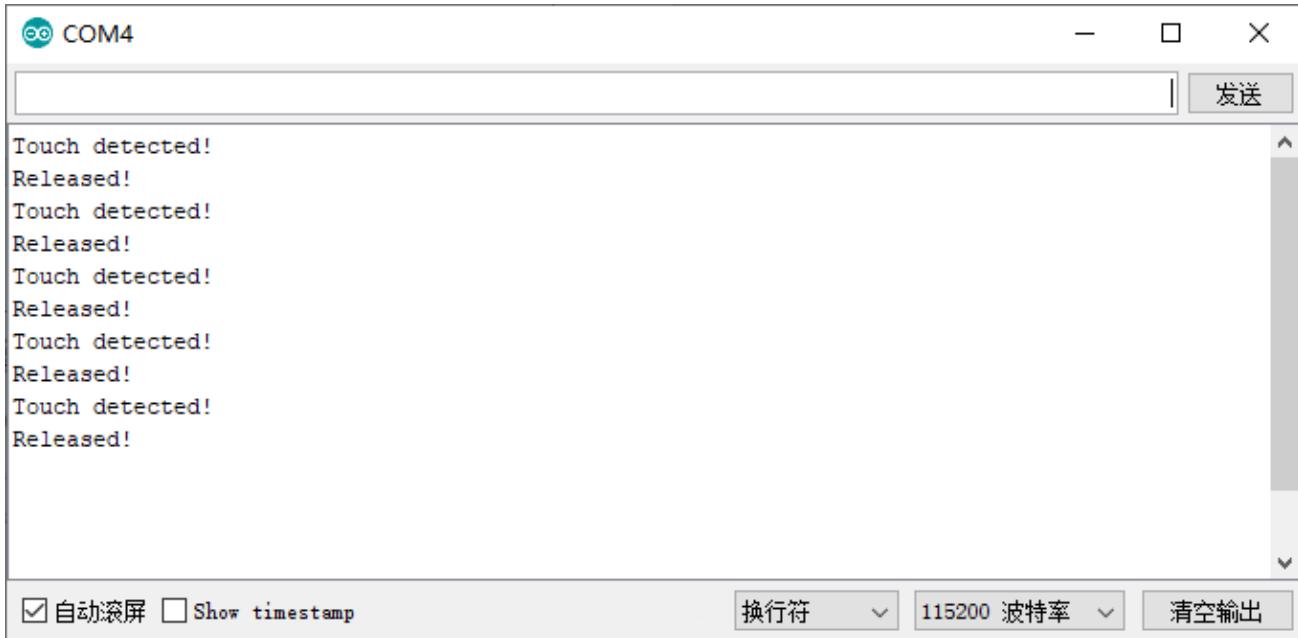
```

File Edit Sketch Tools Help
Sketch_10.2_TouchLamp.ino
1 #define PIN_LED      21
2 #define PRESS_VAL    200000 //Set a threshold to judge touch
3 #define RELEASE_VAL  60000 //Set a threshold to judge release
4
5 bool isProcessed = false;
6 void setup() {
7     Serial.begin(115200);
8     pinMode(PIN_LED, OUTPUT);
9 }
10 void loop() {
11     if (touchRead(T14) > PRESS_VAL) {
12         if (!isProcessed) {
13             isProcessed = true;
14             Serial.println("Touch detected! ");
15             reverseGPIO(PIN_LED);
16         }
17     }
18     if (touchRead(T14) < RELEASE_VAL) {
19         if (isProcessed) {
20             isProcessed = false;
21             Serial.println("Released! ");
22         }
23     }
24 }
25
26
27
28
29
30 }

```

Download the code to ESP32-S3 WROOM, open the serial monitor, and set the baud rate to 115200. Touch jumper with hand. As shown in the following figure,





With a touch pad, the state of the LED changes with each touch, and the detection state of the touch sensor is printed in the serial monitor.

The following is the program code:

```

1 #define PIN_LED      21
2 #define PRESS_VAL    200000 //Set a threshold to judge touch
3 #define RELEASE_VAL  60000 //Set a threshold to judge release
4
5 bool isProcessed = false;
6 void setup() {
7     Serial.begin(115200);
8     pinMode(PIN_LED, OUTPUT);
9 }
10 void loop() {
11     if (touchRead(T14) > PRESS_VAL) {
12         if (! isProcessed) {
13             isProcessed = true;
14             Serial.println("Touch detected! ");
15             reverseGPIO(PIN_LED);
16         }
17     }
18
19     if (touchRead(T14) < RELEASE_VAL) {
20         if (isProcessed) {
21             isProcessed = false;
22             Serial.println("Released! ");
23         }
24     }
}

```

```
25 }  
26  
27 void reverseGPIO(int pin) {  
28     digitalWrite(pin, ! digitalRead(pin));  
29 }
```

Due to different operating environments, the return value of the function touchRead() may not be the same or similar. Therefore, with the help of Project 10.1, we can know the return values of touchRead() in different states, and based on these return values, we can set a valid threshold range for the touch function.

For example, when touchRead() returns a value greater than 200000, we consider the touch function to be triggered by a human. Similarly, when the return value of touchRead() is less than 60000, we consider that the touch function has not been triggered by someone. Note that the threshold range here can be modified by users according to their own conditions

```
2 #define PRESS_VAL 200000 //Set a threshold to judge touch  
3 #define RELEASE_VAL 60000 //Set a threshold to judge release
```

In loop(), first determine whether the touch was detected. If yes, print some messages, flip the state of the LED, and set the flag bit **isProcessed** to true to avoid repeating the program after the touch was successful.

```
11 if (touchRead(T14) > PRESS_VAL) {  
12     if (! isProcessed) {  
13         isProcessed = true;  
14         Serial.println("Touch detected!");  
15         reverseGPIO(PIN_LED);  
16     }  
17 }
```

It then determines if the touch key is released, and if so, prints some messages and sets the **isProcessed** to false to avoid repeating the process after the touch release and to prepare for the next touch probe.

```
19 if (touchRead(T14) < RELEASE_VAL) {  
20     if (isProcessed) {  
21         isProcessed = false;  
22         Serial.println("Released!");  
23     }  
24 }
```

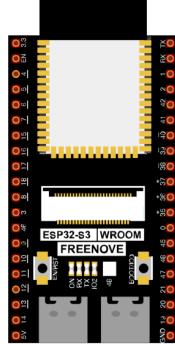
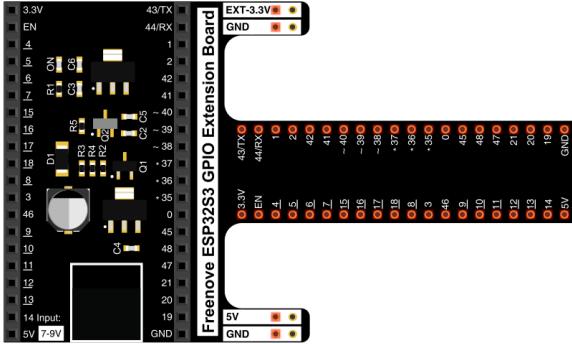
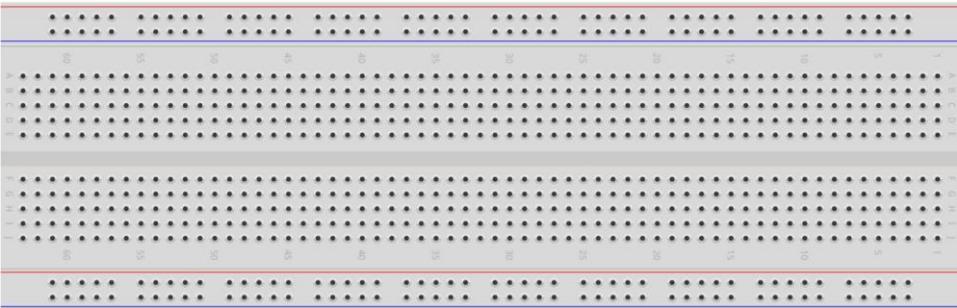
# Chapter 11 Potentiometer & LED

Earlier we have learned the use of ADC and PWM. In this chapter, we will learn how to use a potentiometer to control the brightness of an LED.

## Project 11.1 Soft Light

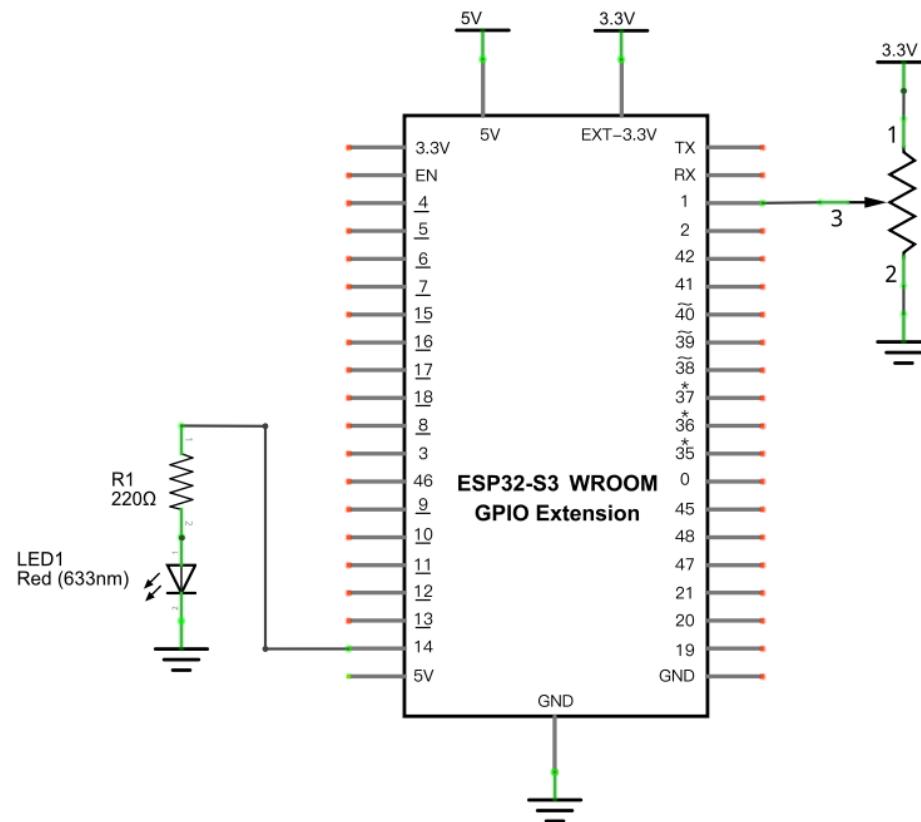
In this project, we will make a soft light. We will use an ADC Module to read ADC values of a potentiometer and map it to duty cycle of the PWM used to control the brightness of a LED. Then you can change the brightness of a LED by adjusting the potentiometer.

## Component List

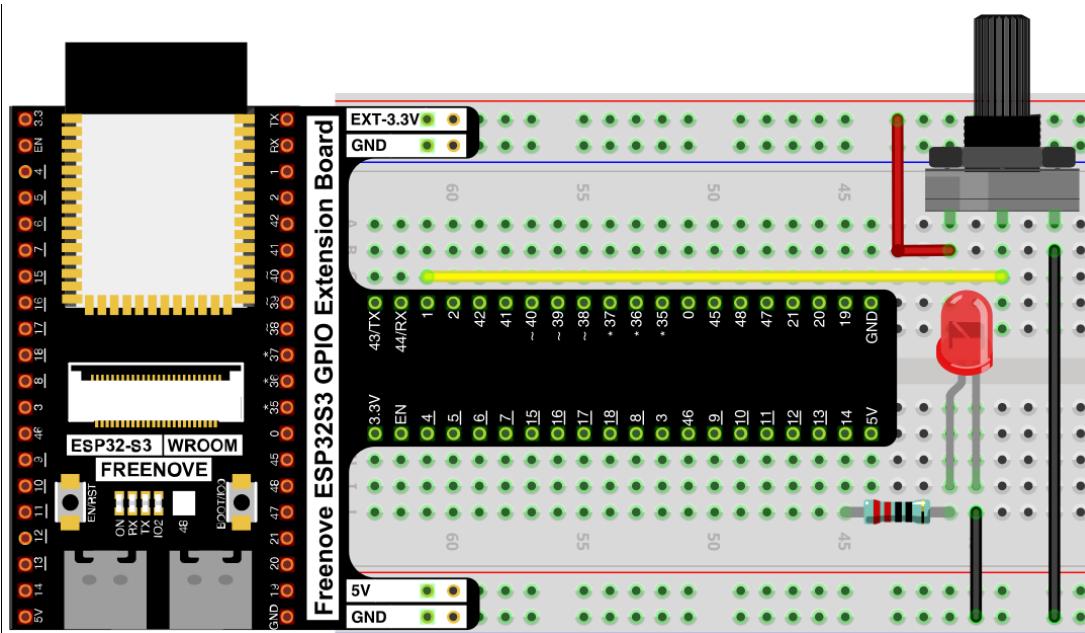
ESP32-S3 WROOM x1	GPIO Extension Board x1		
			
Breadboard x1			
			
Rotary potentiometer x1	Resistor 220Ω x1	LED x1	Jumper M/M x5
			

## Circuit

Schematic diagram



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



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## Sketch

### Sketch\_11.1\_Softlight

The screenshot shows the Arduino IDE interface with the following details:

- Title Bar:** Sketch\_11.1\_SoftLight | Arduino IDE 2.3.2
- Menu Bar:** File Edit Sketch Tools Help
- Toolbar:** Includes icons for Save, Run, Stop, and others.
- Board Selector:** Set to ESP32S3 Dev Module
- Code Area:** Displays the `Sketch_11.1_SoftLight.ino` file content.

```

Sketch_11.1_SoftLight.ino

1 #define PIN_ANALOG_IN    1
2 #define PIN_LED          14
3 #define CHAN              0
4 void setup() {
5     ledcAttachChannel(PIN_LED, 1000, 12, CHAN);
6 }
7
8 void loop() {
9     int adcVal = analogRead(PIN_ANALOG_IN); //read adc
10    int pwmVal = adcVal;           // adcVal re-map to pwmVal
11    ledcWrite(PIN_LED, pwmVal);   // set the pulse width.
12    delay(10);
13 }
```

Download the code to ESP32-S3 WROOM, by turning the adjustable resistor to change the input voltage of GPIO19, ESP32-S3 changes the output voltage of GPIO14 according to this voltage value, thus changing the brightness of the LED.

The following is the code:

```

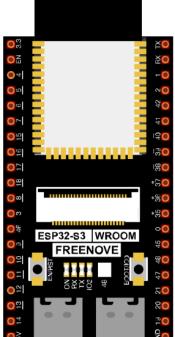
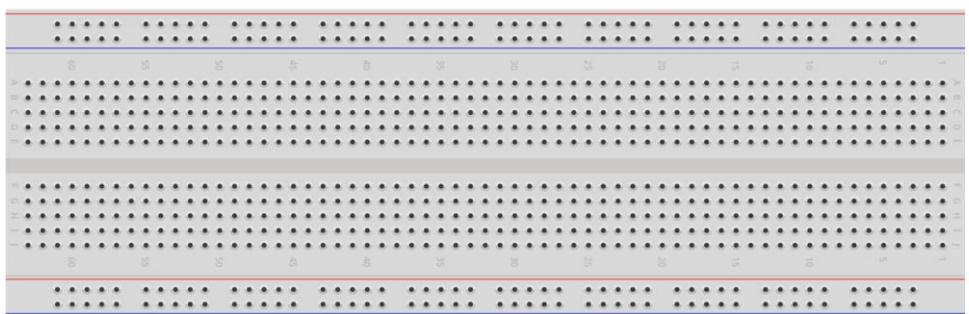
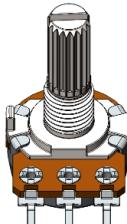
1 #define PIN_ANALOG_IN    1
2 #define PIN_LED          14
3 #define CHAN              0
4 void setup() {
5     ledcAttachChannel(PIN_LED, 1000, 12, CHAN);
6 }
7
8 void loop() {
9     int adcVal = analogRead(PIN_ANALOG_IN); //read adc
10    int pwmVal = adcVal;           // adcVal re-map to pwmVal
11    ledcWrite(PIN_LED, pwmVal);   // set the pulse width.
12    delay(10);
13 }
```

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

## Project 11.2 Soft Colorful Light

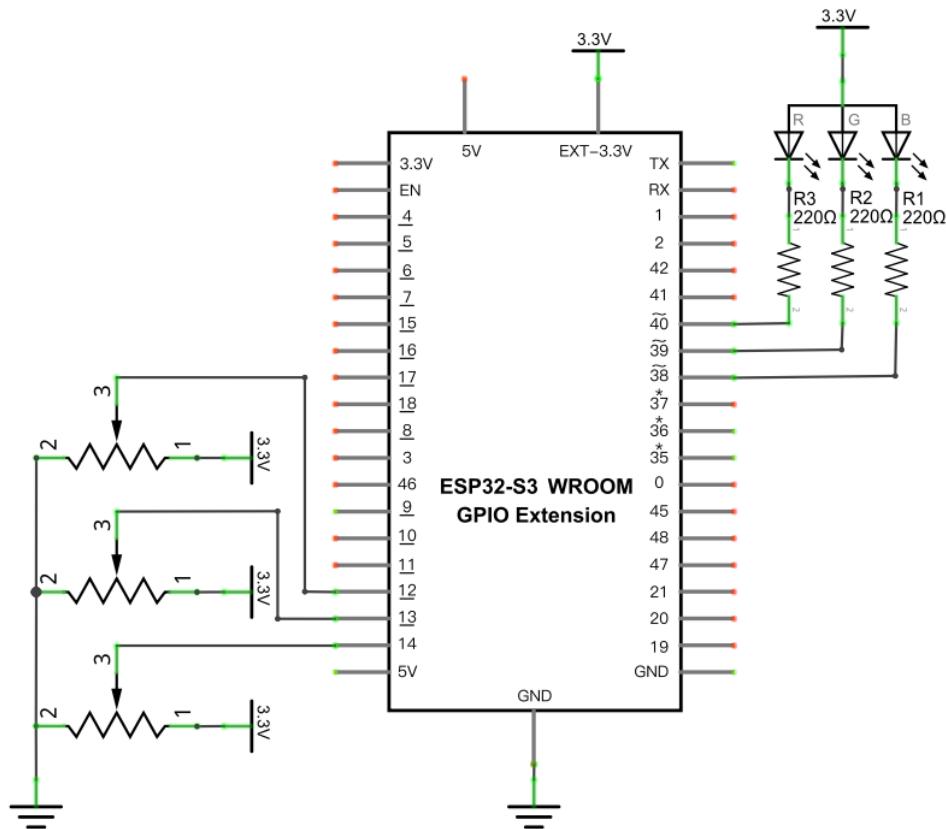
In this project, 3 potentiometers are used to control the RGB LED and in principle it is the same as the Soft Light project. Namely, read the voltage value of the potentiometer and then convert it to PWM used to control LED brightness. Difference is that the original project only controlled one LED,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

### Component List

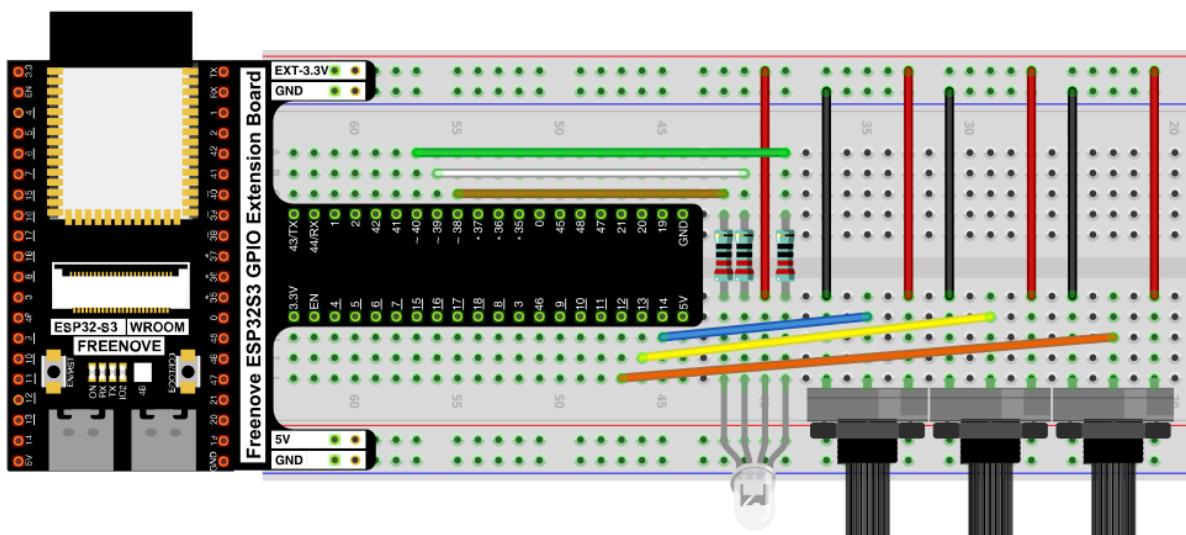
ESP32-S3 WROOM x1	GPIO Extension Board x1
	
Breadboard x1	
Rotary potentiometer x3	Resistor 220Ω x3
	
RGBLED x1	Jumper M/M x13
	

# Circuit

## Schematic diagram



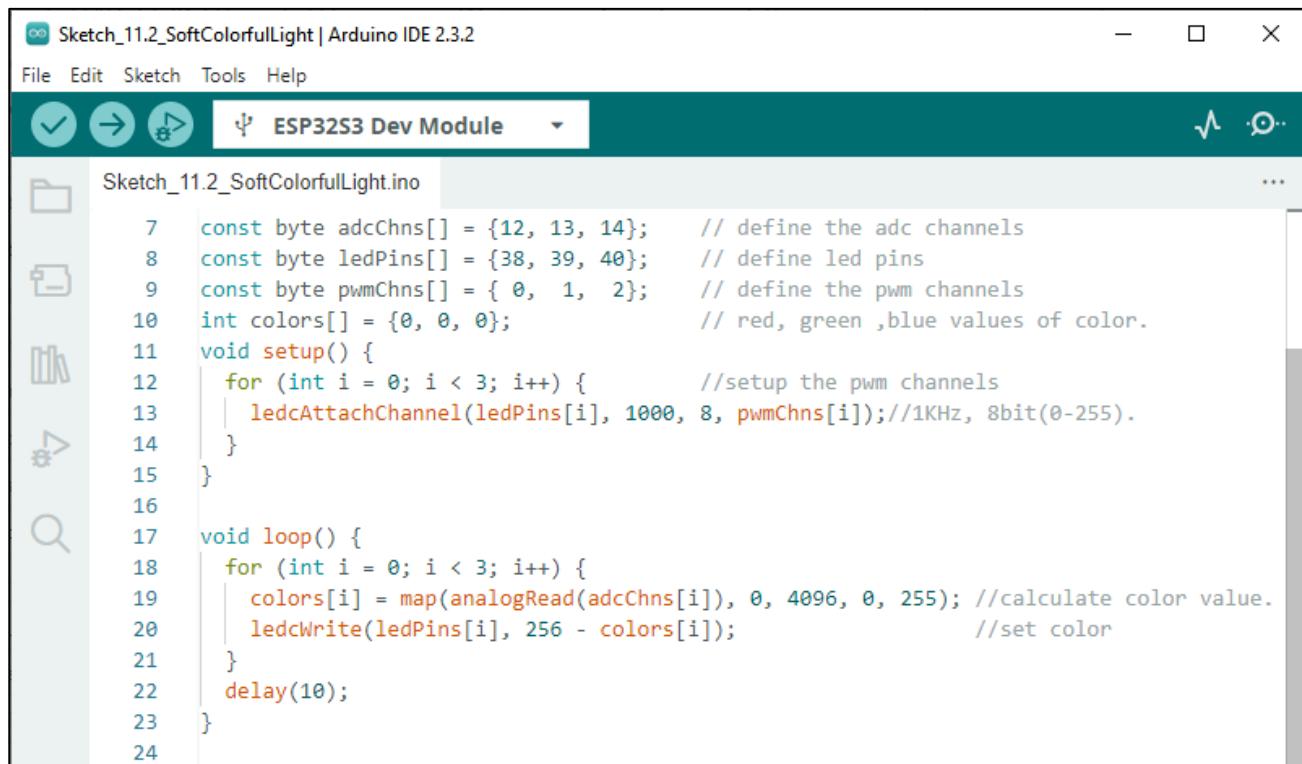
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## Sketch

### Sketch\_11.2\_SoftColorfullLight



The screenshot shows the Arduino IDE interface with the following details:

- Title Bar:** Sketch\_11.2\_SoftColorfullLight | Arduino IDE 2.3.2
- Menu Bar:** File Edit Sketch Tools Help
- Toolbar:** Includes icons for Save, Run, Stop, and a dropdown for the connected board: "ESP32S3 Dev Module".
- Code Editor:** Displays the following C++ code for "Sketch\_11.2\_SoftColorfullLight.ino":

```
const byte adcChns[] = {12, 13, 14};      // define the adc channels
const byte ledPins[] = {38, 39, 40};        // define led pins
const byte pwmChns[] = {0, 1, 2};          // define the pwm channels
int colors[] = {0, 0, 0};                  // red, green ,blue values of color.

void setup() {
    for (int i = 0; i < 3; i++) {           //setup the pwm channels
        ledcAttachChannel(ledPins[i], 1000, 8, pwmChns[i]); //1KHz, 8bit(0-255).
    }
}

void loop() {
    for (int i = 0; i < 3; i++) {
        colors[i] = map(analogReadadcChns[i]), 0, 4096, 0, 255); //calculate color value.
        ledcWrite(ledPins[i], 256 - colors[i]);                      //set color
    }
    delay(10);
}
```

Download the code to ESP32-S3 WROOM, rotate one of the potentiometers, then the color of RGB LED will change.

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The following is the program code:

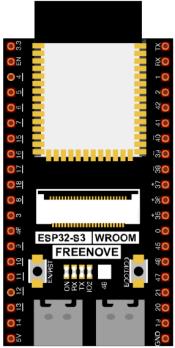
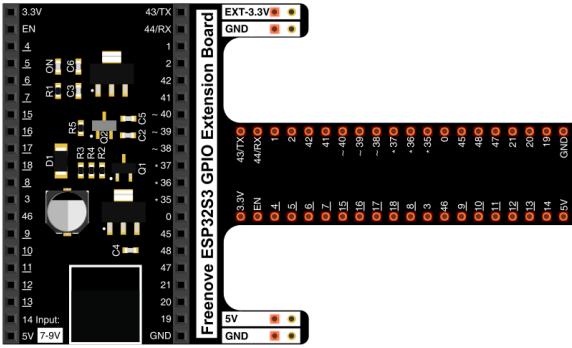
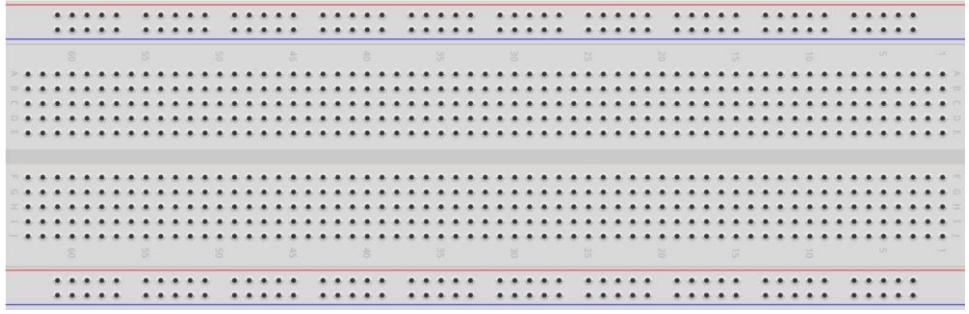
```
1 const byte adcChns[] = {12, 13, 14};      // define the adc channels
2 const byte ledPins[] = {38, 39, 40};        //define led pins
3 const byte chns[] = { 0, 1, 2};             //define the pwm channels
4 int colors[] = {0, 0, 0};                  // red, green,blue values of color.
5 void setup() {
6     for (int i = 0; i < 3; i++) {           //setup the pwm channels
7         ledcAttachChannel(ledPins[i], 1000, 8, chns[i]); //1KHz, 8bit(0-255).
8     }
9 }
10
11 void loop() {
12     for (int i = 0; i < 3; i++) {
13         colors[i] = map(analogReadadcChns[i]), 0, 4096, 0, 255); //calculate color
14         value.
15         ledcWrite(ledPins[i], 256 - colors[i]);                   //set color
16     }
17 }
```

In the code you can read the ADC values of the 3 potentiometers and map it into a PWM duty cycle to control the 3 LED elements to vary the color of their respective RGB LED.

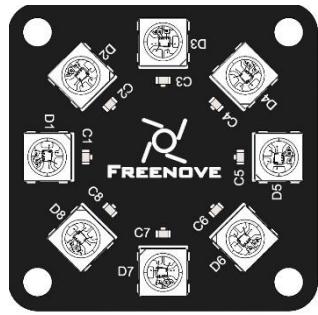
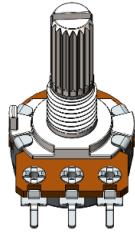
## Project 11.3 Soft Rainbow Light

In this project, we use potentiometer to control Freenove 8 RGB LED Module.

### Component List

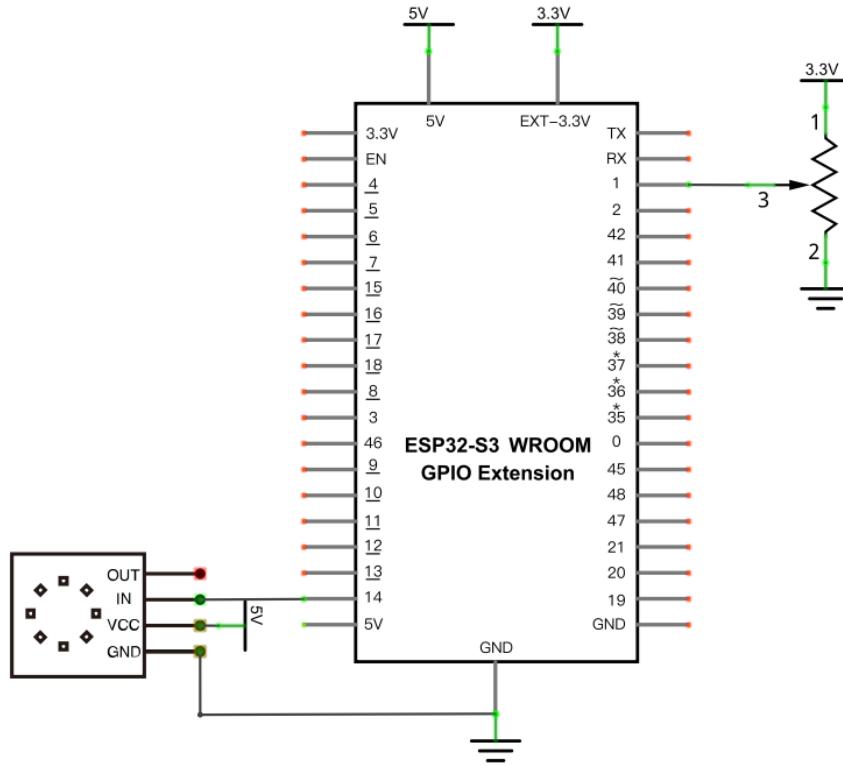
ESP32-S3 WROOM x1	GPIO Extension Board x1	Breadboard x1
		

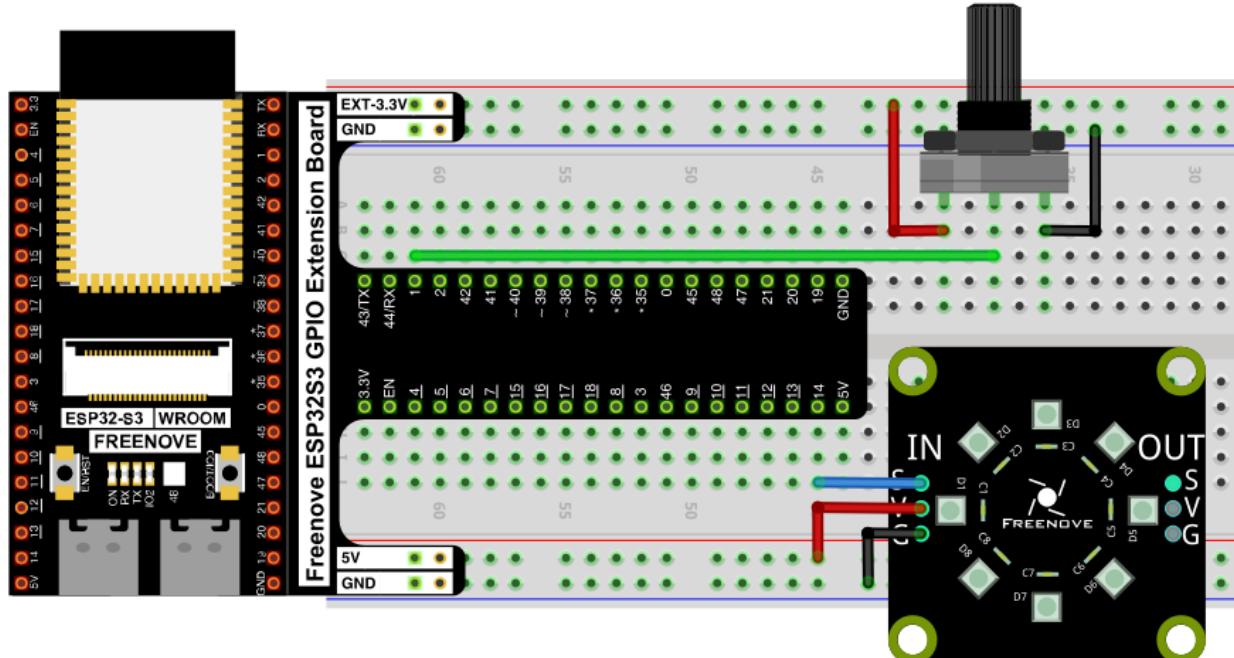
Freenove 8 RGB LED Module x1	Rotary potentiometer x1	Jumper F/M x3 Jumper M/M x3
		

## Circuit

Schematic diagram

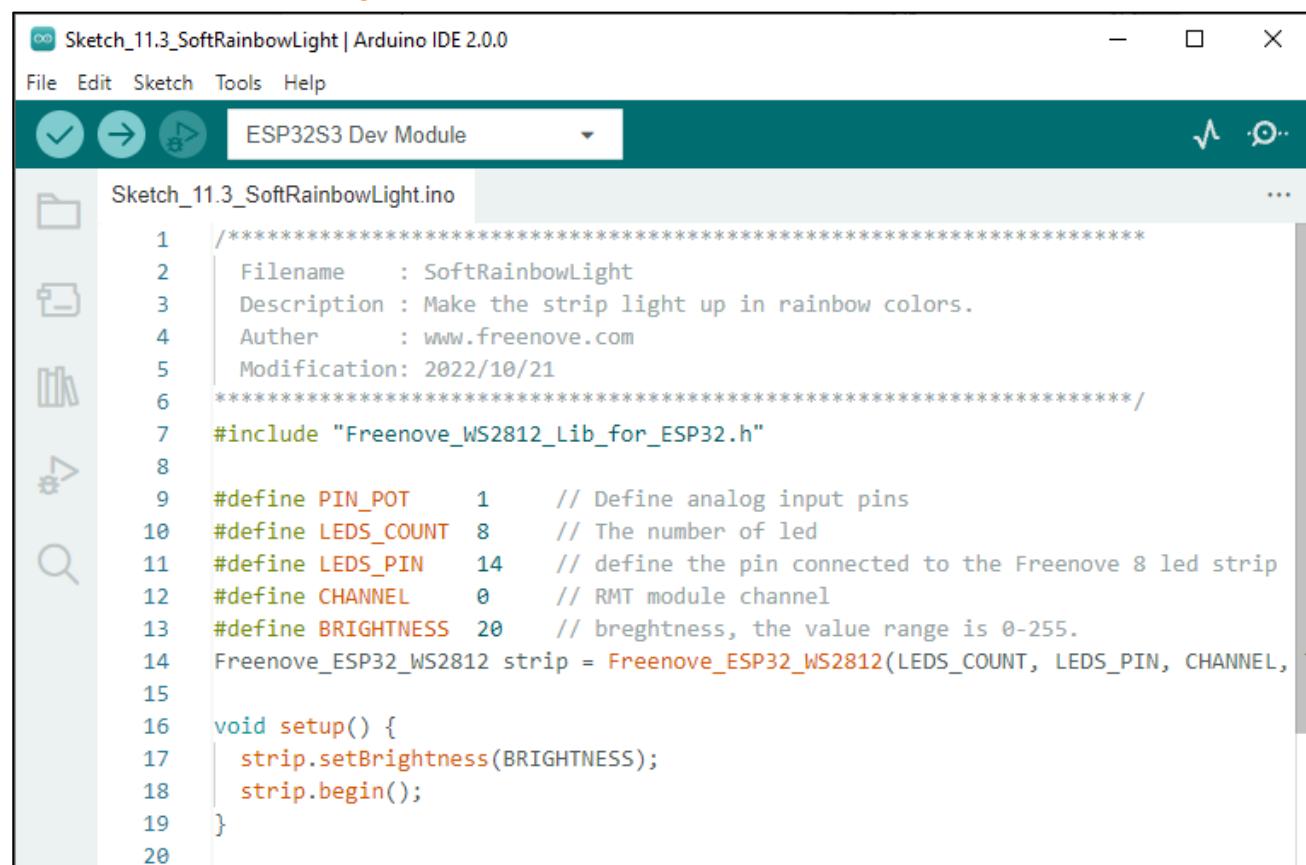


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## Sketch

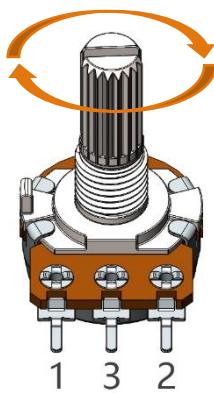
### Sketch\_11.3\_Soft\_Rainbow\_Light



The screenshot shows the Arduino IDE interface with the title bar "Sketch\_11.3\_SoftRainbowLight | Arduino IDE 2.0.0". The sketch name "Sketch\_11.3\_SoftRainbowLight.ino" is displayed in the center. The code itself is as follows:

```
1 //*****
2 // Filename : SoftRainbowLight
3 // Description : Make the strip light up in rainbow colors.
4 // Author : www.freenove.com
5 // Modification: 2022/10/21
6 *****/
7 #include "Freenove_WS2812_Lib_for_ESP32.h"
8
9 #define PIN_POT 1 // Define analog input pins
10 #define LEDS_COUNT 8 // The number of led
11 #define LEDS_PIN 14 // define the pin connected to the Freenove 8 led strip
12 #define CHANNEL 0 // RMT module channel
13 #define BRIGHTNESS 20 // brightness, the value range is 0-255.
14 Freenove_ESP32_WS2812 strip = Freenove_ESP32_WS2812(LEDS_COUNT, LEDS_PIN, CHANNEL, T
15
16 void setup() {
17     strip.setBrightness(BRIGHTNESS);
18     strip.begin();
19 }
20
```

Download the code to ESP32-S3 WROOM, rotate the handle of the potentiometer, and the color of the lamp ring will change.



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



The following is the program code:

```
1 #include "Freenove_WS2812_Lib_for_ESP32.h"
2
3 #define PIN_POT      1      // Define analog input pins
4 #define LEDS_COUNT   8      // The number of led
5 #define LEDS_PIN     14     // define the pin connected to the Freenove 8 led strip
6 #define CHANNEL      0      // RMT module channel
7 #define BRIGHTNESS   20     // brightness, the value range is 0~255.
8 Freenove_ESP32_WS2812 strip = Freenove_ESP32_WS2812(LEDS_COUNT, LEDS_PIN, CHANNEL, TYPE_GRB);
9
10 void setup() {
11     strip.setBrightness(BRIGHTNESS);
12     strip.begin();
13 }
14
15 void loop() {
16     int colorPos = map(analogRead(PIN_POT), 0, 4095, 0, 255);
17     for (int i = 0; i < LEDS_COUNT; i++) {
18         strip.setLedColorData(i, strip.Wheel(colorPos + i * 255 / 8)); // Set color data.
19     }
20     strip.show(); // Send color data to LED, and display.
21     delay(10);
22 }
```

The overall logical structure of the code is the same as the previous project rainbow light, except that the starting point of the color in this code is controlled by potentiometer.

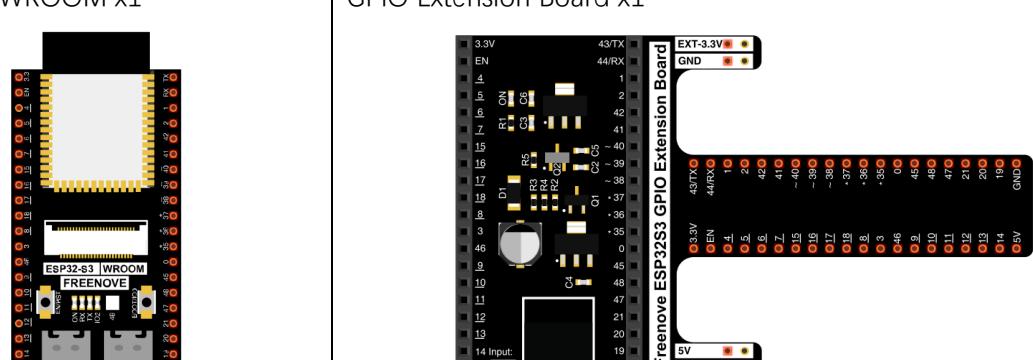
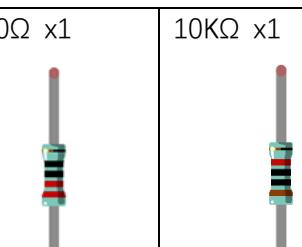
# Chapter 12 Photoresistor & LED

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

## Project 12.1 NightLamp

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

### Component List

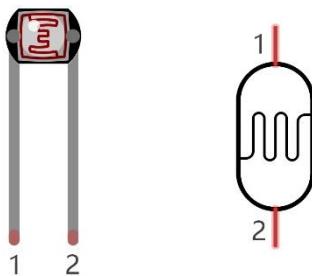
ESP32-S3 WROOM x1	GPIO Extension Board x1
	
Breadboard x1	
Photoresistor x1	Resistor
	220Ω x1      10KΩ x1
	
	LED x1
	
	Jumper M/M x4
	

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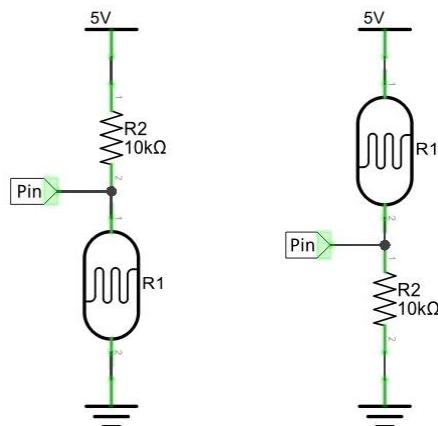
## Component knowledge

### Photoresistor

A 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. A 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:

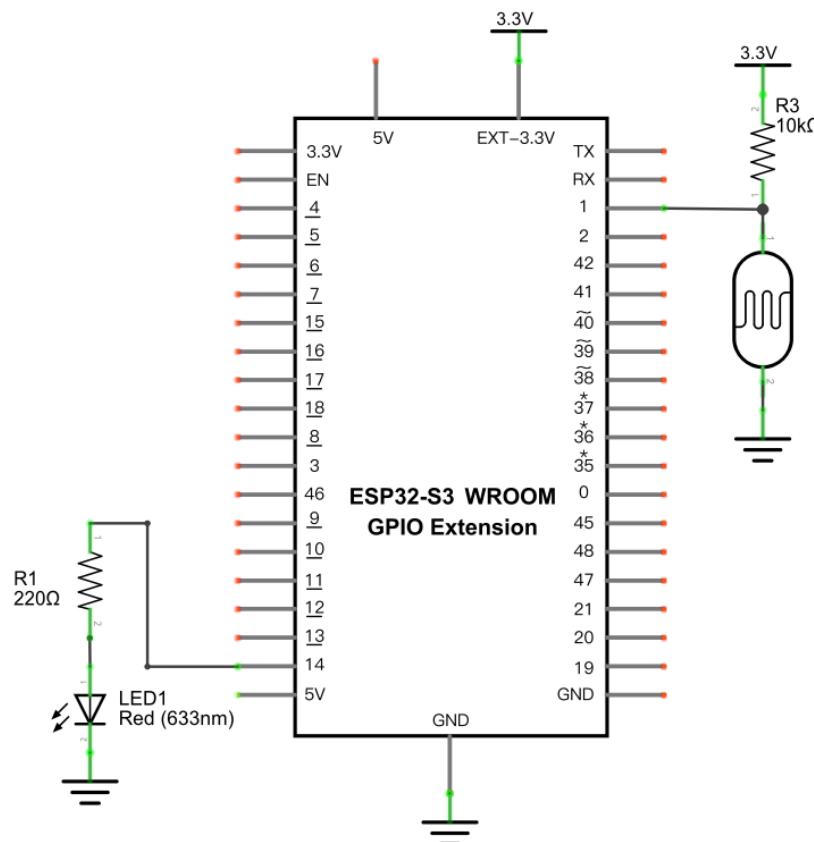


In the above circuit, when a photoresistor's resistance value changes due to a change in light intensity, the voltage between the photoresistor and resistor R1 will also change. Therefore, the intensity of the light can be obtained by measuring this voltage.

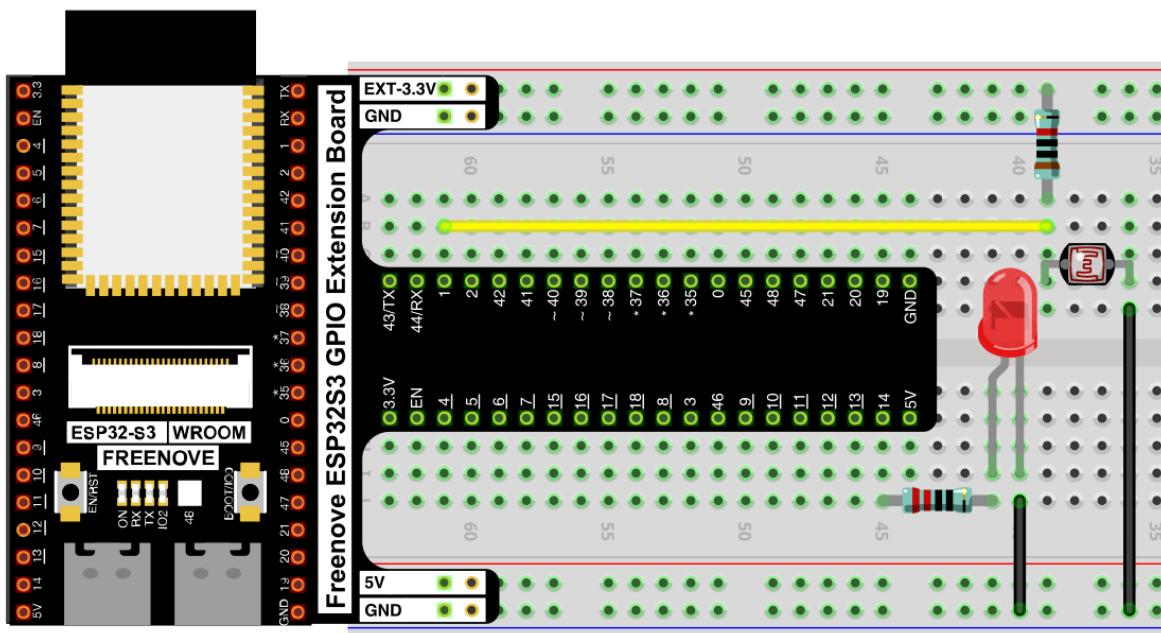
# Circuit

The circuit of this project is similar to project Soft Light. 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)



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## Sketch

The circuit used is similar to the project Soft Light. The only difference is that the input signal of the pin of ADC changes from a potentiometer to a combination of a photoresistor and a resistor.

### Sketch\_12.1\_Nightlamp

The screenshot shows the Arduino IDE interface with the title bar "Sketch\_12.1\_NightLamp | Arduino IDE 2.3.2". Below the title bar is a menu bar with File, Edit, Sketch, Tools, and Help. The main area displays the code for "Sketch\_12.1\_NightLamp.ino". The code uses the LEDC library to control an LED connected to pin 14 via pin 1. The analog input is read from pin 1 and mapped to a PWM value between 372 and 2048. The loop function then sets the LED brightness based on this value and adds a 10ms delay.

```
7 #define PIN_ANALOG_IN 1
8 #define PIN_LED 14
9 #define CHAN 0
10 #define LIGHT_MIN 372
11 #define LIGHT_MAX 2048
12 void setup() {
13     ledcAttachChannel(PIN_LED, 1000, 12, CHAN);
14 }
15
16 void loop() {
17     int adcVal = analogRead(PIN_ANALOG_IN); //read adc
18     // adcVal re-map to pwmVal
19     int pwmVal = map(constrain(adcVal, LIGHT_MIN, LIGHT_MAX), LIGHT_MIN, LIGHT_MAX, 0, 4095);
20     ledcWrite(PIN_LED, pwmVal); // set the pulse width.
21     delay(10);
22 }
```

Download the code to ESP32-S3 WROOM, if you cover the photoresistor or increase the light shining on it, the brightness of the LED changes accordingly.

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

The following is the program code:

```
1 #define PIN_ANALOG_IN 1
2 #define PIN_LED 14
3 #define CHAN 0
4 #define LIGHT_MIN 372
5 #define LIGHT_MAX 2048
6 void setup() {
7     ledcAttachChannel(PIN_LED, 1000, 12, CHAN);
8 }
9
10 void loop() {
11     int adcVal = analogRead(PIN_ANALOG_IN); //read adc
12     // adcVal re-map to pwmVal
13     int pwmVal = map(constrain(adcVal, LIGHT_MIN, LIGHT_MAX), LIGHT_MIN, LIGHT_MAX, 0,
14 4095);
15     ledcWrite(PIN_LED, pwmVal); // set the pulse width.
16     delay(10);
17 }
```

#### Reference

```
constrain(amt, low, high)
```

#define constrain(amt, low, high) ((amt)<(low)? (low) : ((amt)>(high)? (high) : (amt)))  
Constrain the value amt between low and high.

```
long map(long value, long fromLow, long fromHigh, long toLow, long toHigh);
```

Re-maps a number from one range to another. That is, a value of fromLow would get mapped to toLow, a value of fromHigh to toHigh, values in-between to values in-between, etc.



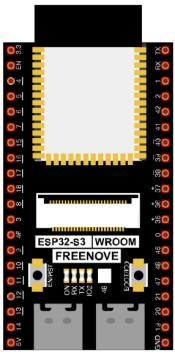
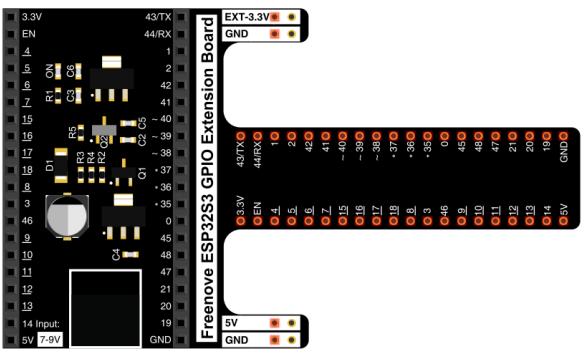
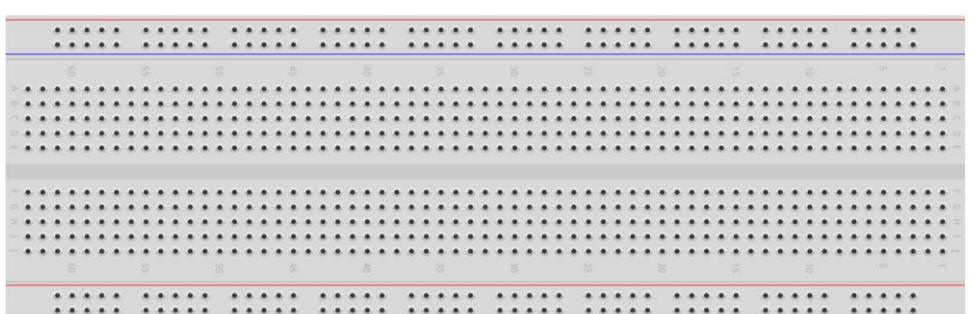
# Chapter 13 Thermistor

In this chapter, we will learn about thermistors which are another kind of resistor

## Project 13.1 Thermometer

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

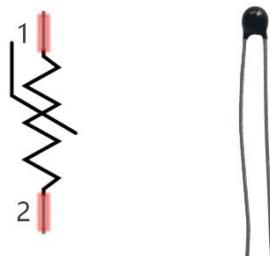
### Component List

ESP32-S3 WROOM x1	GPIO Extension Board x1
	
	
Breadboard x1	
	
Thermistor x1	Resistor 10kΩ x1
	
	

## 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;

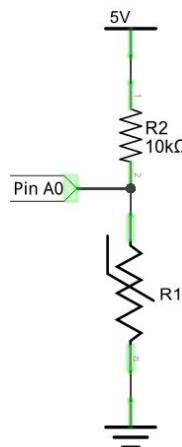
$\text{EXP}[n]$  is nth power of E;

$B$  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:

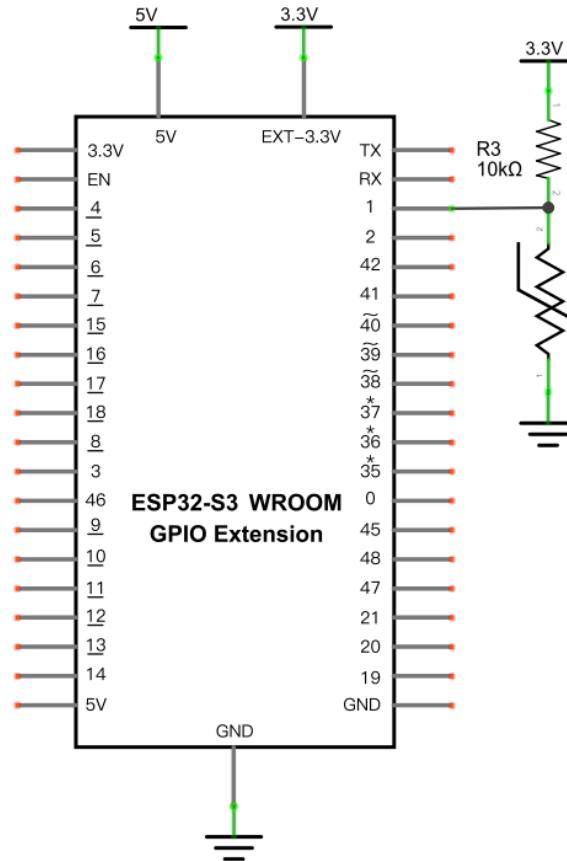
$$T_2 = 1 / \left( \frac{1}{T_1} + \ln \left( \frac{R_t}{R} \right) / B \right)$$



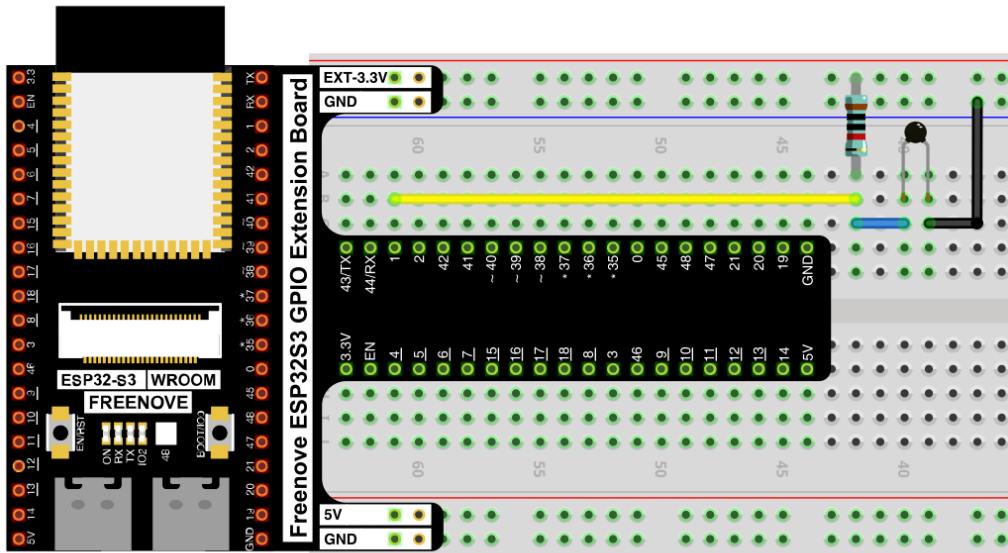
## Circuit

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

Schematic diagram



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



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## Sketch

### Sketch\_13.1\_Thermometer

```

Sketch_13.1_Thermometer | Arduino IDE 2.0.0
File Edit Sketch Tools Help
ESP32S3 Dev Module
Sketch_13.1_Thermometer.ino
1 //*****
2 Filename : Thermometer
3 Description : Making a thermometer by thermistor.
4 Author : www.freenove.com
5 Modification: 2022/10/21
6 ****
7 #define PIN_ANALOG_IN 1
8 void setup() {
9 | Serial.begin(115200);
10 }
11
12 void loop() {
13 | int adcValue = analogRead(PIN_ANALOG_IN); //read ADC pin
14 | double voltage = (float)adcValue / 4095.0 * 3.3; // calculate voltage
15 | double Rt = 10 * voltage / (3.3 - voltage); //calculate resistance value of thermistor
16 | double tempK = 1 / (1 / (273.15 + 25) + log(Rt / 10) / 3950.0); //calculate temperature (Kelvin)
17 | double tempC = tempK - 273.15; //calculate temperature (Celsius)
18 | Serial.printf("ADC value : %d,\nVoltage : %.2fV, \nTemperature : %.2fC\n", adcValue, voltage, tempC);
19 | delay(1000);
20 }

```

Download the code to ESP32-S3 WROOM, the terminal window will 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.

ADC value	Voltage	Temperature
1927	1.55V	27.00C
1930	1.56V	27.61C
1932	1.56V	27.56C
1935	1.56V	27.50C
1939	1.56V	27.41C
1935	1.56V	27.50C
1935	1.56V	27.50C
1939	1.56V	27.41C
1938	1.56V	27.43C
1934	1.56V	27.52C
1937	1.56V	27.45C
1933	1.56V	27.54C
1930	1.56V	27.50C

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The following is the code:

```
1 #define PIN_ANALOG_IN 1
2 void setup() {
3     Serial.begin(115200);
4 }
5
6 void loop() {
7     int adcValue = analogRead(PIN_ANALOG_IN);           //read ADC pin
8     double voltage = (float)adcValue / 4095.0 * 3.3;    // calculate voltage
9     double Rt = 10 * voltage / (3.3 - voltage);        //calculate resistance value of thermistor
10    double tempK = 1 / (1/(273.15 + 25) + log(Rt / 10)/3950.0); //calculate temperature (Kelvin)
11    double tempC = tempK - 273.15;                     //calculate temperature (Celsius)
12    Serial.printf("ADC value : %d, \tVoltage : %.2fV, \tTemperature : %.2fC\n", adcValue,
13    voltage, tempC);
14 }
```

In the code, GPIO1 is connected to the thermistor circuit. ESP32-S3 reads the ADC value of GPIO1, calculates the voltage and resistance value of the thermistor according to Ohm's law, and finally calculates the temperature value perceived by the thermistor according to the formula.

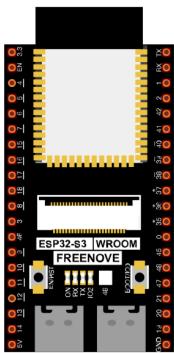
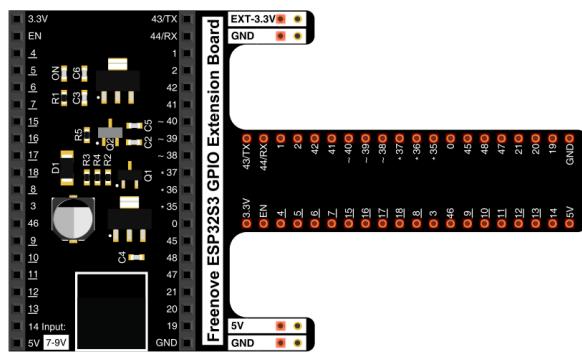
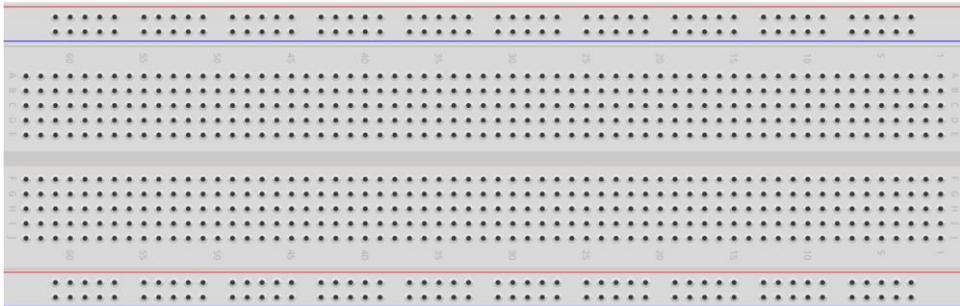
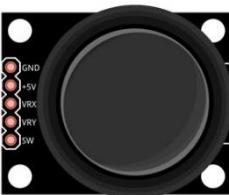
# Chapter 14 Joystick

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

## Project 14.1 Joystick

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

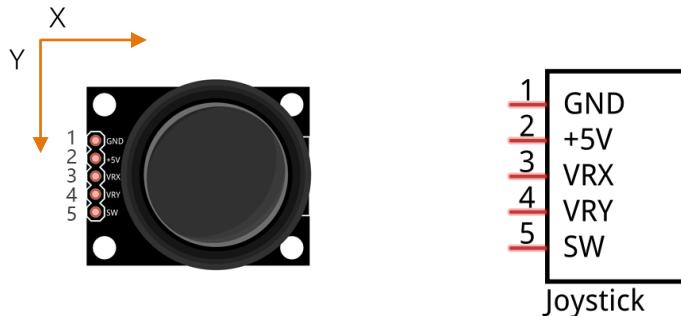
## Component List

ESP32-S3 WROOM x1	GPIO Extension Board x1
	
Breadboard x1	
Joystick x1	Jumper F/M x5
	

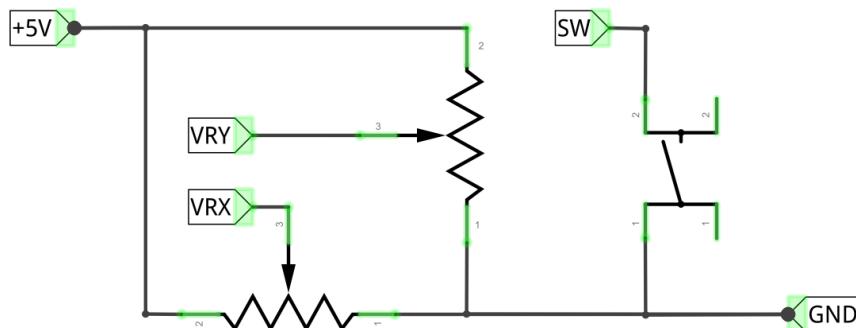
## Component knowledge

### 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).



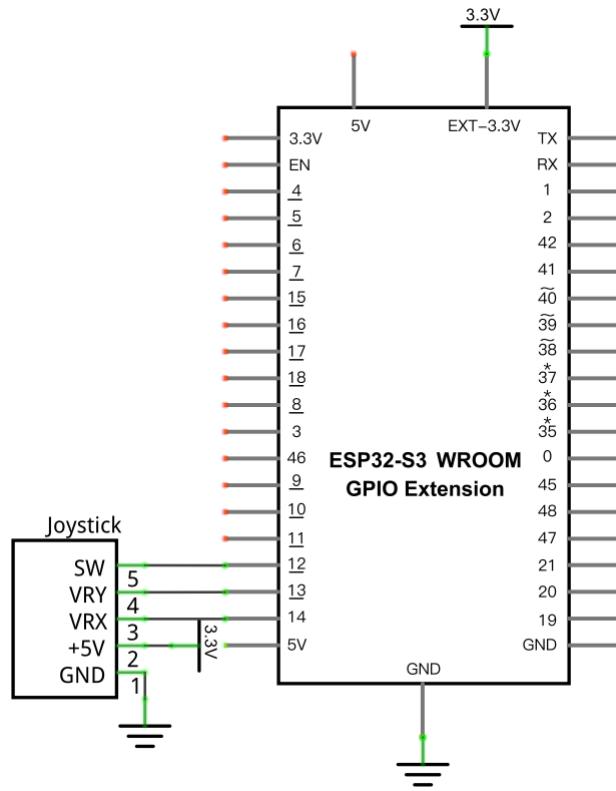
This is accomplished by incorporating two rotary potentiometers inside the joystick Module at 90 degrees of each other, placed in such a manner as to detect shifts in direction in two directions simultaneously and with a push button switch in the “vertical” axis, which can detect when a User presses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



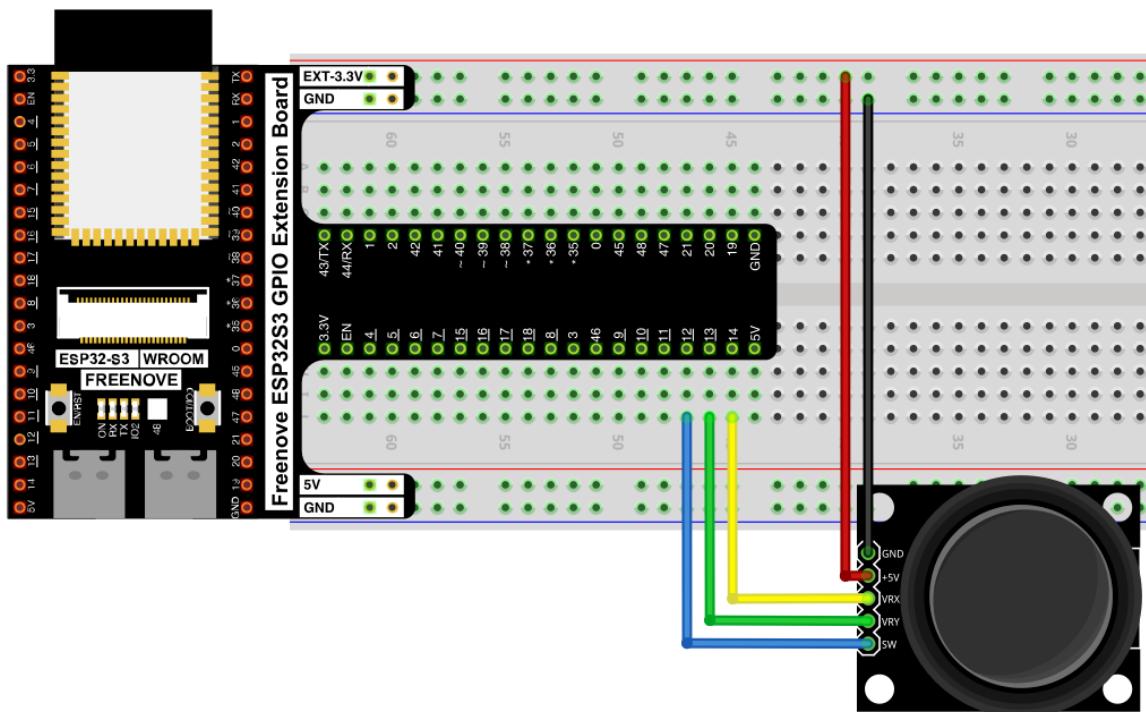
When the joystick data is read, there are some differences between the axes: data of X and Y axes is analog, which needs to use the ADC. The data of the Z axis is digital, so you can directly use the GPIO to read this data or you have the option to use the ADC to read this.

## Circuit

Schematic diagram



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



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## Sketch

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.

### Sketch\_14.1\_Joystick

```

Sketch_14.1_Joystick | Arduino IDE 2.0.0
File Edit Sketch Tools Help
    ✓ → ↻ ⚙ ESP32S3 Dev Module
Sketch_14.1_Joystick.ino ...
1 // *****
2   Filename : Joystick
3   Description : Read data from joystick.
4   Author : www.freenove.com
5   Modification: 2022/10/21
6 *****
7   int xyzPins[] = {14, 13, 12}; //x,y,z pins
8   void setup() {
9     Serial.begin(115200);
10    pinMode(xyzPins[2], INPUT_PULLUP); //z axis is a button.
11  }
12
13 void loop() {
14   int xVal = analogRead(xyzPins[0]);
15   int yVal = analogRead(xyzPins[1]);
16   int zVal = digitalRead(xyzPins[2]);
17   Serial.printf("X,Y,Z: %d,\t%d,\t%d\n", xVal, yVal, zVal);
18   delay(500);
19 }

```

Download the code to ESP32-S3 WROOM, open the serial port monitor, the baud rate is 115200, as shown in the figure below, shift (moving) the joystick or pressing it down will make the data change.

Output    Serial Monitor ▼ ⏴

Message (Ctrl + Enter to send message to 'ESP32S3 Dev Module' on 'COM3')    New Line    115200 baud

```

X,Y,Z: 2038,    2056,    1
X,Y,Z: 0,       2056,    1
X,Y,Z: 0,       2055,    1
X,Y,Z: 0,       2055,    1
X,Y,Z: 4095,    2060,    1
X,Y,Z: 4095,    2060,    1
X,Y,Z: 4095,    989,     1
X,Y,Z: 2041,    0,        1
X,Y,Z: 2041,    0,        1
X,Y,Z: 2427,    3479,    1
X,Y,Z: 2043,    4095,    1
X,Y,Z: 2038,    4095,    1
X,Y,Z: 1993,    2057,    1
X,Y,Z: 2035,    2057,    0
X,Y,Z: 1982,    2057,    0
X,Y,Z: 2027,    2056,    1
X,Y,Z: 1989,    2057,    1
X,Y,Z: 1995,    2057,    1
v v . 1000 2057 1

```

Ln 20, Col 1    UTF-8    ESP32S3 Dev Module on COM3    4

The following is the code:

```
1 int xyzPins[] = {14, 13, 12}; //x, y, z pins
2 void setup() {
3     Serial.begin(115200);
4     pinMode(xyzPins[2], INPUT_PULLUP); //z axis is a button.
5 }
6
7 void loop() {
8     int xVal = analogRead(xyzPins[0]);
9     int yVal = analogRead(xyzPins[1]);
10    int zVal = digitalRead(xyzPins[2]);
11    Serial.printf("X, Y, Z: %d, \t%d, \t%d\n", xVal, yVal, zVal);
12    delay(500);
13 }
```

In the code, configure xyzPins[2] to pull-up input mode. In loop(), use analogRead () to read the value of axes X and Y and use digitalWrite () to read the value of axis Z, then display them.

```
8 int xVal = analogRead(xyzPins[0]);
9 int yVal = analogRead(xyzPins[1]);
10 int zVal = digitalRead(xyzPins[2]);
11 Serial.printf("X, Y, Z: %d, \t%d, \t%d\n", xVal, yVal, zVal);
12 delay(500);
```



# Chapter 15 74HC595 & LED Bar Graph

We have used LED bar graph to make a flowing water light, in which 10 GPIO ports of ESP32-S3 is occupied. More GPIO ports mean that more peripherals can be connected to ESP32-S3, so GPIO resource is very precious. Can we make flowing water light with less GPIO? In this chapter, we will learn a component, 74HC595, which can achieve the target.

## Project 15.1 Flowing Water Light

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

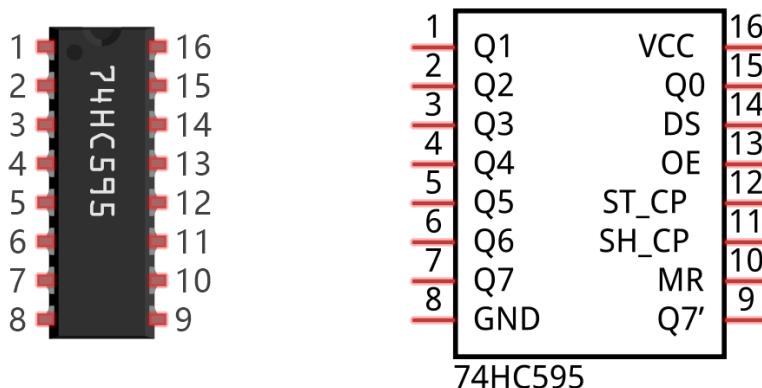
### Component List

ESP32-S3 WROOM x1	GPIO Extension Board x1		
Breadboard x1			
74HC595 x1	LED Bar Graph x1	Resistor 220Ω x8	Jumper M/M x15

## Related knowledge

### 74HC595

A 74HC595 chip is used to convert serial data into parallel data. A 74HC595 chip can convert the serial data of one byte into 8 bits, and send its corresponding level to each of the 8 ports correspondingly. With this characteristic, the 74HC595 chip can be used to expand the IO ports of a ESP32-S3. At least 3 ports are required to control the 8 ports of the 74HC595 chip.



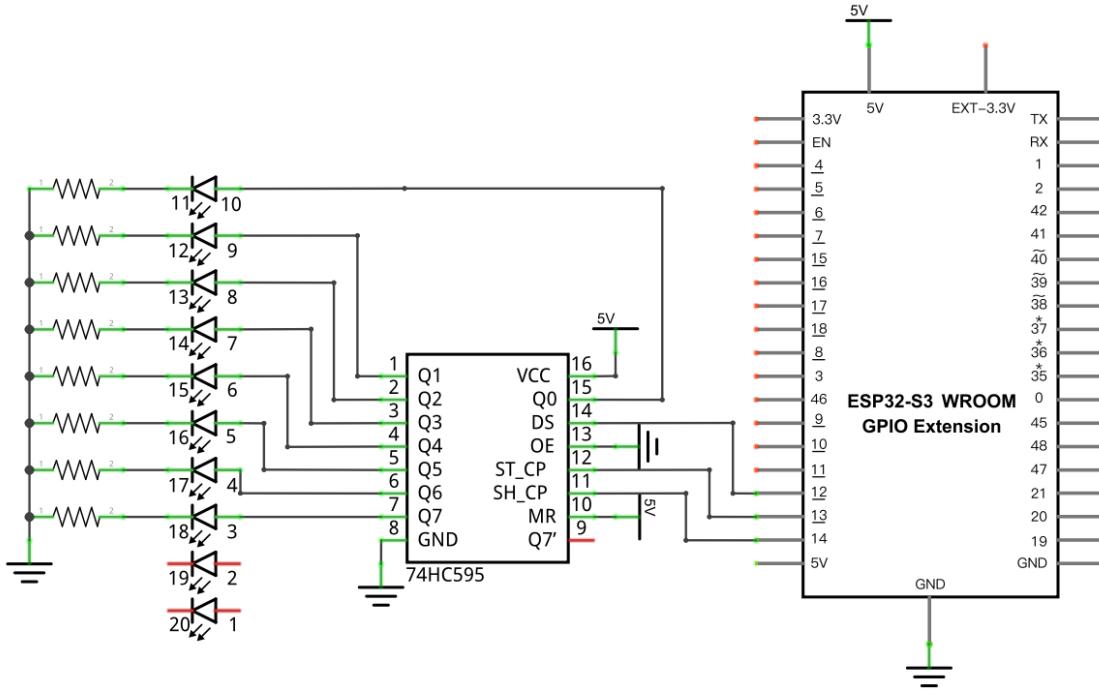
The ports of the 74HC595 chip are described as follows:

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

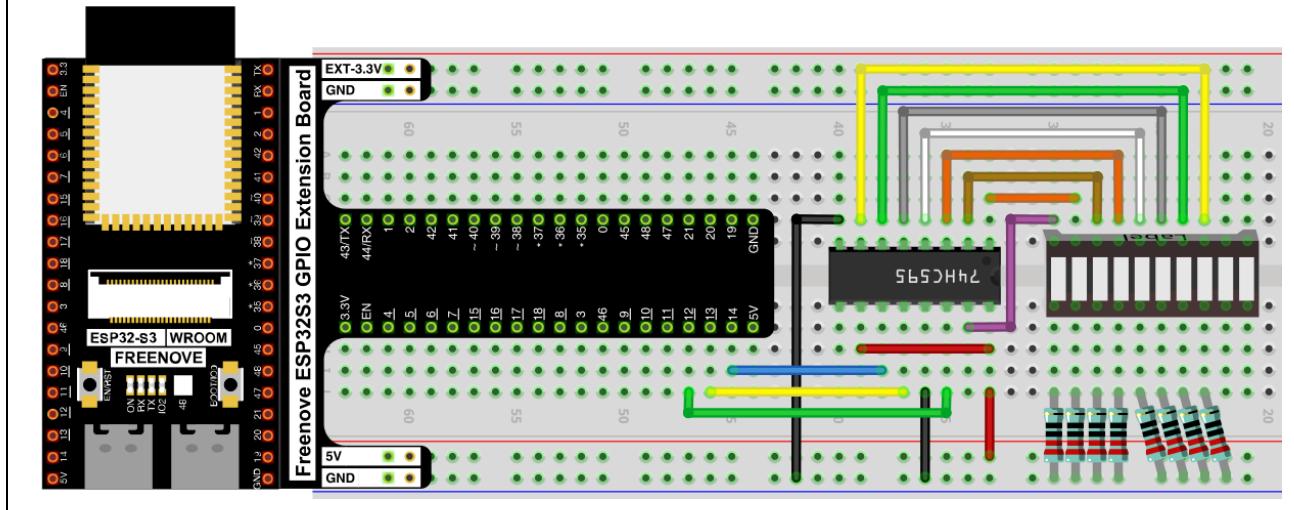
For more detail, please refer to the datasheet on the 74HC595 chip.

# Circuit

## Schematic diagram



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

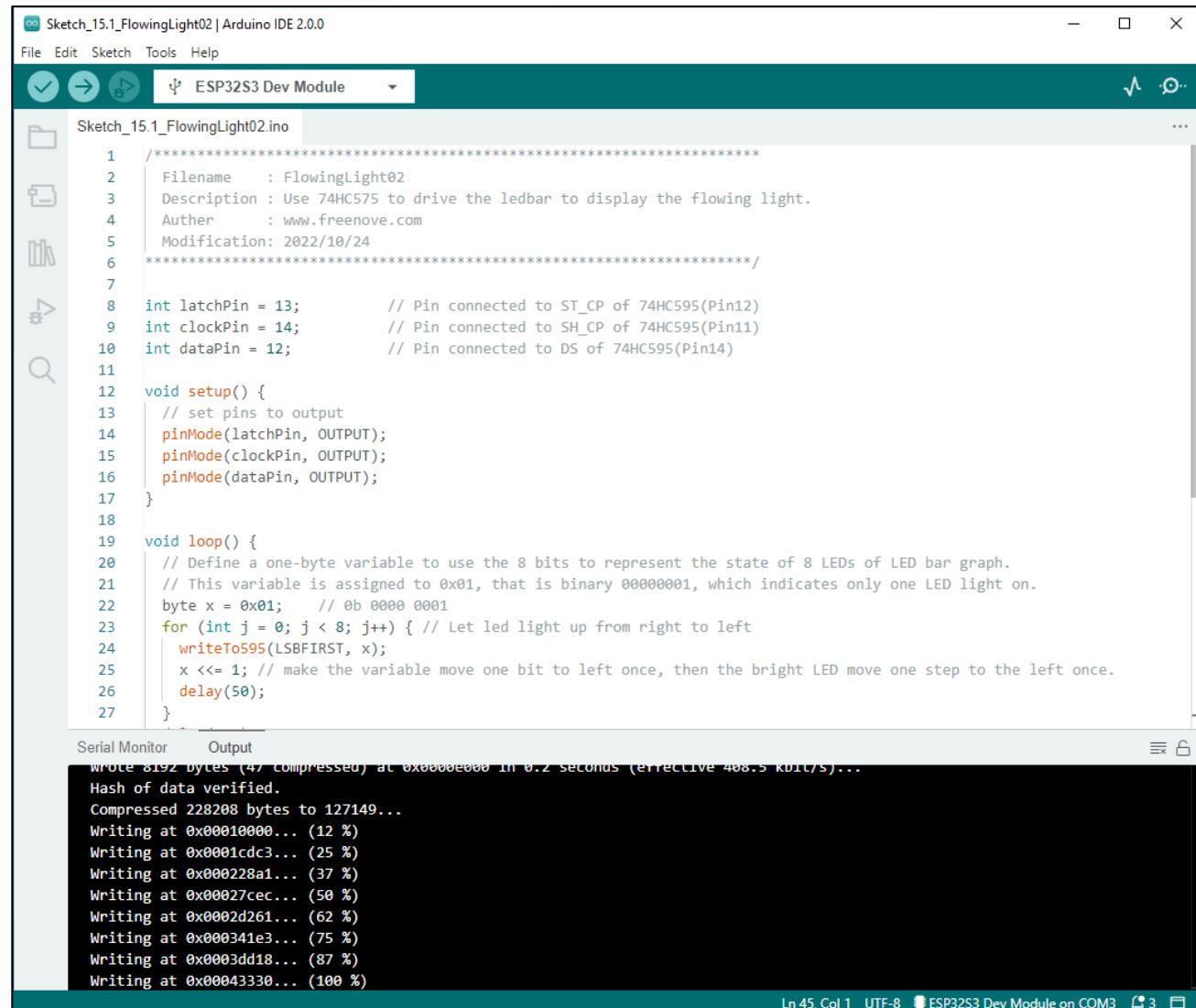


Any concerns?  support@freenove.com

## Sketch

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

### Sketch\_15.1\_FlowingLight2



```

Sketch_15.1_FlowingLight02 | Arduino IDE 2.0.0
File Edit Sketch Tools Help
ESP32S3 Dev Module
Sketch_15.1_FlowingLight02.ino
1 //*****
2   Filename    : FlowingLight02
3   Description : Use 74HC575 to drive the ledbar to display the flowing light.
4   Author     : www.freenove.com
5   Modification: 2022/10/24
6 *****/
7
8   int latchPin = 13;          // Pin connected to ST_CP of 74HC595(Pin12)
9   int clockPin = 14;          // Pin connected to SH_CP of 74HC595(Pin11)
10  int dataPin = 12;           // Pin connected to DS of 74HC595(Pin14)
11
12 void setup() {
13   // set pins to output
14   pinMode(latchPin, OUTPUT);
15   pinMode(clockPin, OUTPUT);
16   pinMode(dataPin, OUTPUT);
17 }
18
19 void loop() {
20   // Define a one-byte variable to use the 8 bits to represent the state of 8 LEDs of LED bar graph.
21   // This variable is assigned to 0x01, that is binary 00000001, which indicates only one LED light on.
22   byte x = 0x01;      // 0b 0000 0001
23   for (int j = 0; j < 8; j++) { // Let led light up from right to left
24     writeTo595(LSBFIRST, x);
25     x <= 1; // make the variable move one bit to left once, then the bright LED move one step to the left once.
26     delay(50);
27   }
}

```

Serial Monitor    Output

```

Wrote 6192 bytes (4) compressed at 0x00000000 in 0.2 seconds (effective 408.5 kbytes)...
Hash of data verified.
Compressed 228208 bytes to 127149...
Writing at 0x00010000... (12 %)
Writing at 0x0001cdc3... (25 %)
Writing at 0x000228a1... (37 %)
Writing at 0x00027cec... (50 %)
Writing at 0x0002d261... (62 %)
Writing at 0x000341e3... (75 %)
Writing at 0x0003dd18... (87 %)
Writing at 0x00043330... (100 %)

```

Ln 45, Col 1    UTF-8    ESP32S3 Dev Module on COM3    3

Download the code to ESP32-S3 WROOM. You will see that LED bar graph starts with the flowing water pattern flashing from left to right and then back from right to left.

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

The following is the program code:

```

1 int latchPin = 13;          // Pin connected to ST_CP of 74HC595(Pin12)
2 int clockPin = 14;          // Pin connected to SH_CP of 74HC595(Pin11)
3 int dataPin = 12;           // Pin connected to DS of 74HC595(Pin14)
4
5 void setup() {
6   // set pins to output
7   pinMode(latchPin, OUTPUT);

```

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```

8   pinMode(clockPin, OUTPUT);
9   pinMode(dataPin, OUTPUT);
10 }
11
12 void loop() {
13   // Define a one-byte variable to use the 8 bits to represent the state of 8 LEDs of LED bar
14   graph.
15   // This variable is assigned to 0x01, that is binary 00000001, which indicates only one LED
16   light on.
17   byte x = 0x01;    // 0b 0000 0001
18   for (int j = 0; j < 8; j++) { // Let led light up from right to left
19     writeTo595(LSBFIRST, x);
20     x <= 1; // make the variable move one bit to left once, then the bright LED move one step
21     to the left once.
22     delay(50);
23   }
24   delay(1000);
25   x = 0x80;      //0b 1000 0000
26   for (int j = 0; j < 8; j++) { // Let led light up from left to right
27     writeTo595(LSBFIRST, x);
28     x >= 1;
29     delay(50);
30   }
31   delay(1000);
32 }
33 void writeTo595(int order, byte _data) {
34   // Output low level to latchPin
35   digitalWrite(latchPin, LOW);
36   // Send serial data to 74HC595
37   shiftOut(dataPin, clockPin, order, _data);
38   // Output high level to latchPin, and 74HC595 will update the data to the parallel output
39   port.
40   digitalWrite(latchPin, HIGH);
41 }
```

In the code, we configure three pins to control the 74HC595 chip and define a one-byte variable to control the state of the 8 LEDs (in the LED bar graph Module) through the 8 bits of the variable. The LEDs light ON when the corresponding bit is 1. If the variable is assigned to 0x01, that is 00000001 in binary, there will be only one LED ON.

17	x=0x01;
----	---------

In the loop(), use "for" loop to send x to 74HC595 output pin to control the LED. In "for" loop, x will shift one bit to the LEFT in one cycle, then when data of x is sent to 74HC595, the LED that is turned ON will move one bit to the LEFT once.

```

18   for (int j = 0; j < 8; j++) { // Let led light up from right to left
19     writeTo595(LSBFIRST, x);
20     x <<= 1;
21     delay(50);
22   }

```

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

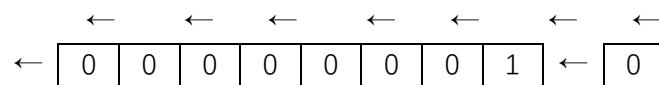
The subfunction `writeTo595()` is used to write data to 74HC595 and immediately output on the port of 74HC595.

### Reference

#### << operator

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

```
byte x = 1 << 1;
```

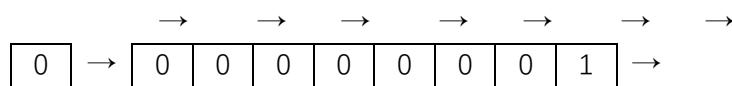


The result of x is 2 (binary 00000010) .



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

```
byte x = 1 >> 1;
```



The result of x is 0 (00000000) .



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

```
void shiftOut(uint8_t dataPin, uint8_t clockPin, uint8_t bitOrder, uint8_t val);
```

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

### Parameters

dataPin: the pin on which to output each bit. Allowed data types: int.

clockPin: the pin to toggle once the dataPin has been set to the correct value. Allowed data types: int.

bitOrder: which order to shift out the bits; either MSBFIRST or LSBFIRST. (Most Significant Bit First, or, Least Significant Bit First).

value: the data to shift out. Allowed data types: byte.

For more details about shift function, please refer to:

<https://www.arduino.cc/reference/en/language/functions/advanced-io/shiftdown/>

Any concerns? ✉ support@freenove.com

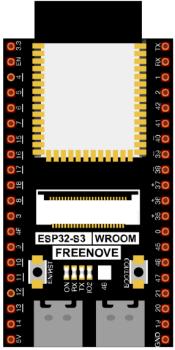
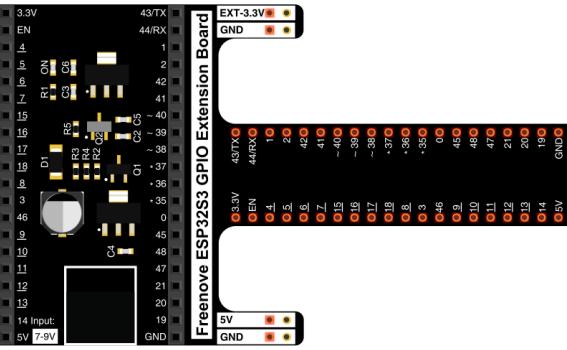
# Chapter 16 74HC595 & 7-Segment Display.

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

## Project 16.1 7-Segment Display.

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

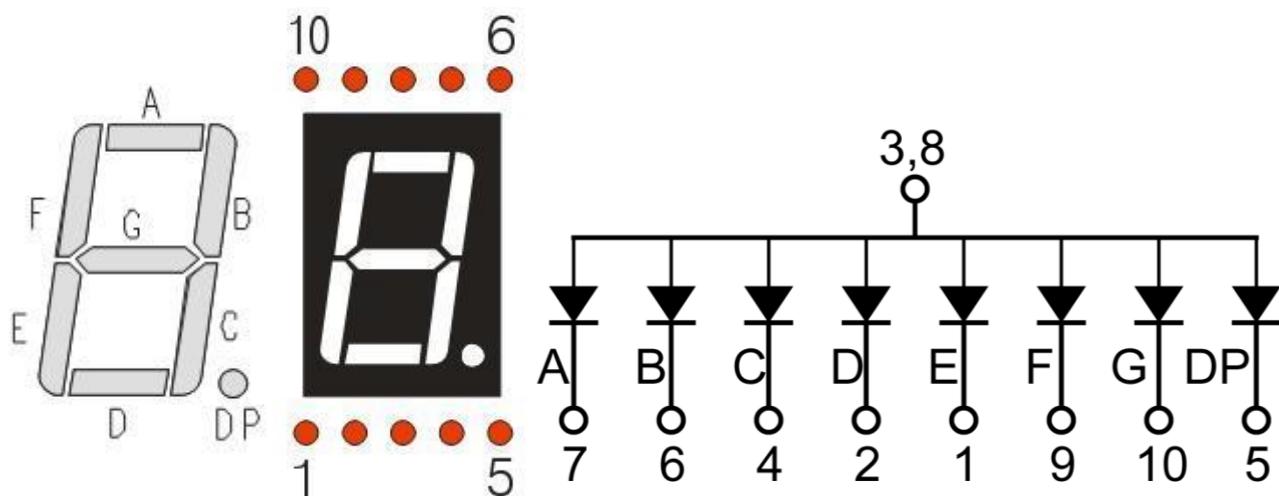
### Component List

ESP32-S3 WROOM x1	GPIO Extension Board x1		
			
Breadboard x1			
74HC595 x1	7-segment display x1	Resistor 220Ω x8	Jumper M/M

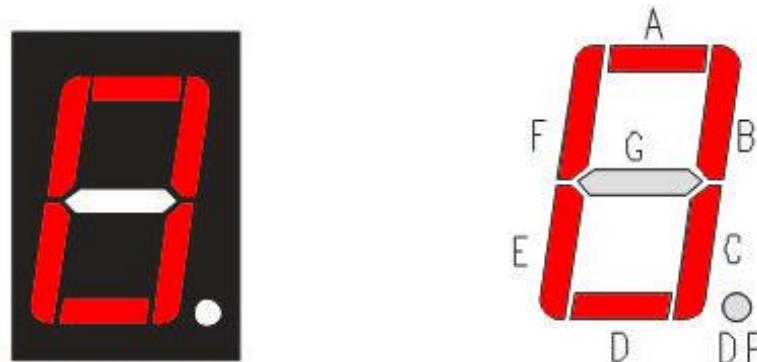
## Component knowledge

### 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 a 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:  $1100\ 0000_2 = 0xc0$ .

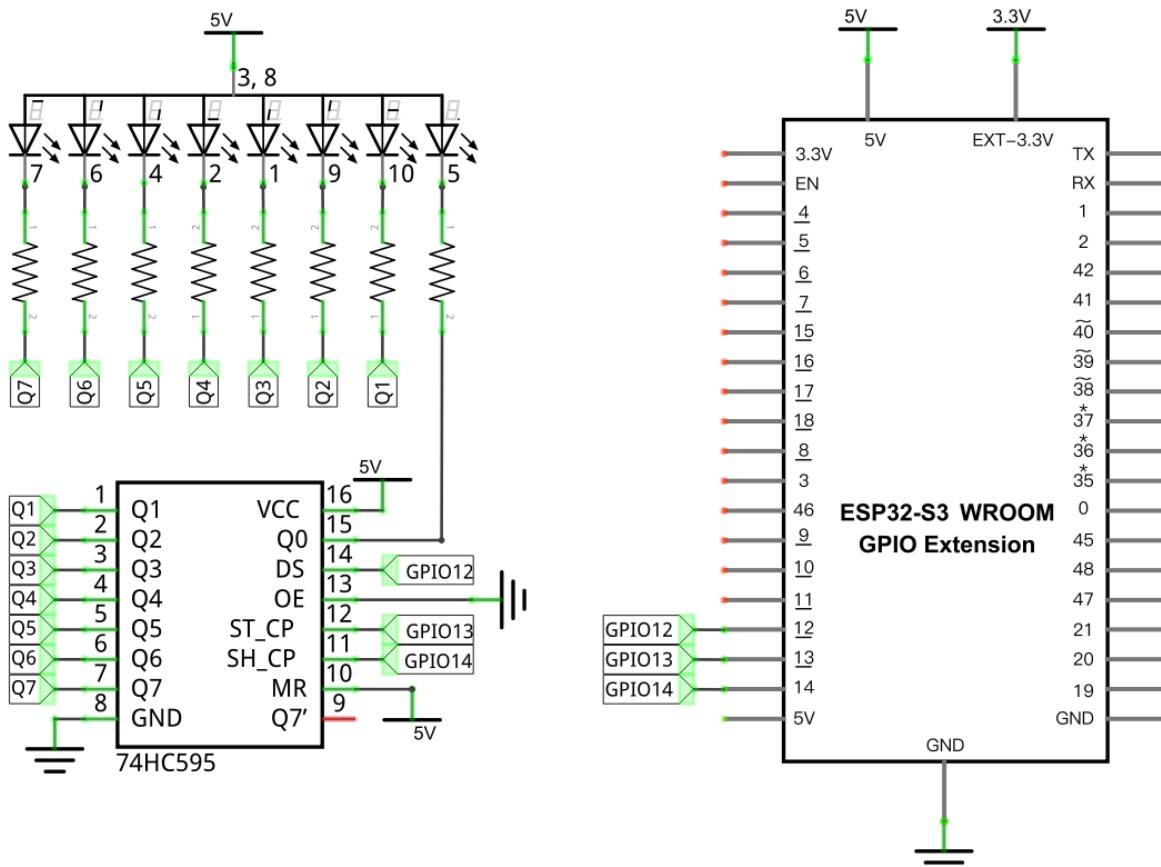


For detailed code values, please refer to the following table (common anode).

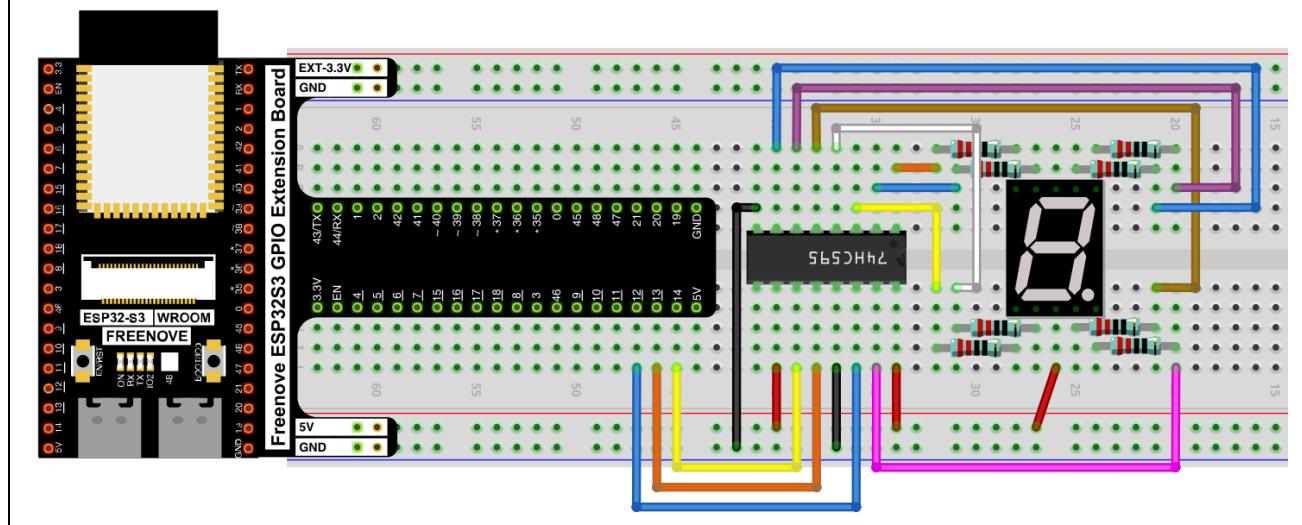
CHAR	DP	G	F	E	D	C	B	A	Hex	ASCII
0	1	1	0	0	0	0	0	0	0xc0	1100 0000
1	1	1	1	1	1	0	0	1	0xf9	1111 1001
2	1	0	1	0	0	1	0	0	0xa4	1010 0100
3	1	0	1	1	0	0	0	0	0xb0	1011 0000
4	1	0	0	1	1	0	0	1	0x99	1001 1001
5	1	0	0	1	0	0	1	0	0x92	1001 0010
6	1	0	0	0	0	0	1	0	0x82	1000 0010
7	1	1	1	1	1	0	0	0	0xf8	1111 1000
8	1	0	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

## 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



## Sketch

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 coded value of "0" - "F".

### Sketch\_16.1\_7\_Segment\_Display

```

Sketch_16.1_1_Digit_7-Segment_Display | Arduino IDE 2.0.0
File Edit Sketch Tools Help
ESP32S3 Dev Module
Sketch_16.1_1_Digit_7-Segment_Display.ino ...
1 //*****
2 Filename : 1 Digital 7 Segment Display
3 Description : Use 74HC595 to drive the digital display
4 Author : www.freenove.com
5 Modification: 2022/10/24
6 ****
7 int dataPin = 12;           // Pin connected to DS of 74HC595 (Pin14)
8 int latchPin = 13;          // Pin connected to ST_CP of 74HC595 (Pin12)
9 int clockPin = 14;          // Pin connected to SH_CP of 74HC595 (Pin11)
10
11 // Define the encoding of characters 0-F for the common-anode 7-Segment Display
12 byte num[] = {
13     0xc0, 0xf9, 0xa4, 0xb0, 0x99, 0x92, 0x82, 0xf8,
14     0x80, 0x90, 0x88, 0x83, 0xc6, 0xa1, 0x86, 0x8e
15 };
16
17 void setup() {
18     // set pins to output
19     pinMode(latchPin, OUTPUT);
20     pinMode(clockPin, OUTPUT);
21     pinMode(dataPin, OUTPUT);
22 }
23
24 void loop() {
25     // display 0-F on digital tube
26     for (int i = 0; i < 16; i++) {
27         writeData(num[i]); // Send data to 74HC595
28         delay(1000);       // delay 1 second
29         writeData(0xff);  // Clear the display content
30     }
31 }

```

Output

```

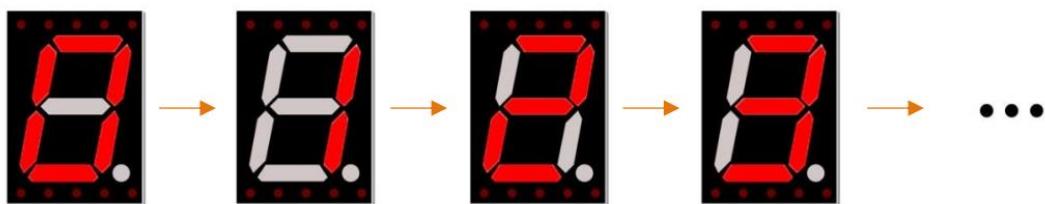
Writing at 0x00027cca... (50 %)
Writing at 0x0002d249... (62 %)
Writing at 0x000341e1... (75 %)
Writing at 0x0003dd01... (87 %)
Writing at 0x00043332... (100 %)
Wrote 228192 bytes (127137 compressed) at 0x00010000 in 3.2 seconds (effective 573.8 kbit/s)...
Hash of data verified.

Leaving...
Hard resetting via RTS pin...

```

Ln 41, Col 1 UTF-8 ESP32S3 Dev Module on COM3 3

Verify and upload the code, and you'll see a 1-bit, 7-segment display displaying 0-f in a loop.



The following is the program code:

```

1 int dataPin = 12;           // Pin connected to DS of 74HC595 (Pin14)
2 int latchPin = 13;          // Pin connected to ST_CP of 74HC595 (Pin12)
3 int clockPin = 14;          // Pin connected to SH_CP of 74HC595 (Pin11)
4 // Define the encoding of characters 0-F for the common-anode 7-Segment Display
5 byte num[] = {
6     0xc0, 0xf9, 0xa4, 0xb0, 0x99, 0x92, 0x82, 0xf8,
7     0x80, 0x90, 0x88, 0x83, 0xc6, 0xa1, 0x86, 0x8e
8 };
9
10 void setup() {
11     // set pins to output
12     pinMode(latchPin, OUTPUT);
13     pinMode(clockPin, OUTPUT);
14     pinMode(dataPin, OUTPUT);
15 }
16
17 void loop() {
18     // display 0-F on digital tube
19     for (int i = 0; i < 16; i++) {
20         writeData(num[i]); // Send data to 74HC595
21         delay(1000);      // delay 1 second
22         writeData(0xff); // Clear the display content
23     }
24 }
25
26 void writeData(int value) {
27     // Make latchPin output low level
28     digitalWrite(latchPin, LOW);
29     // Send serial data to 74HC595
30     shiftOut(dataPin, clockPin, LSBFIRST, value);
31     // Make latchPin output high level
32     digitalWrite(latchPin, HIGH);
33 }
```

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

```

4 // Define the encoding of characters 0-F for the common-anode 7-Segment Display
5 byte num[] = {
6     0xc0, 0xf9, 0xa4, 0xb0, 0x99, 0x92, 0x82, 0xf8,
7     0x80, 0x90, 0x88, 0x83, 0xc6, 0xa1, 0x86, 0x8e
8 };

```

Then, in the loop, we transfer the member of the “num” to 74HC595 by calling the writeData function, so that the digital tube displays what we want. After each display, “0xff” is used to eliminate the previous effect and prepare for the next display.

```

17 void loop() {
18     // display 0-F on digital tube
19     for (int i = 0; i < 16; i++) {
20         writeData(num[i]); // Send data to 74HC595
21         delay(1000);      // delay 1 second
22         writeData(0xff); // Clear the display content
23     }
24 }

```

In the shiftOut() function, whether to use LSBFIRST or MSBFIRST as the parameter depends on the physical situation.

```

26 void writeData(int value) {
27     // Make latchPin output low level
28     digitalWrite(latchPin, LOW);
29     // Send serial data to 74HC595
30     shiftOut(dataPin, clockPin, LSBFIRST, value);
31     // Make latchPin output high level, then 74HC595 will update data to parallel output
32     digitalWrite(latchPin, HIGH);
33 }

```

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

```

30 shiftOut(dataPin, clockPin, LSBFIRST, value & 0x7f);

```

## Project 16.2 4-Digit 7-Segment Display

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

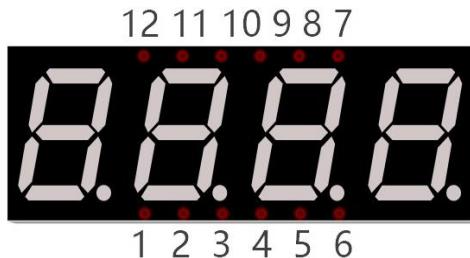
### Component List

ESP32-S3 WROOM x1	GPIO Extension Board x1
Breadboard x1	
74HC595 x1	7-segment display x1
Resistor 220Ω x8	Jumper M/M

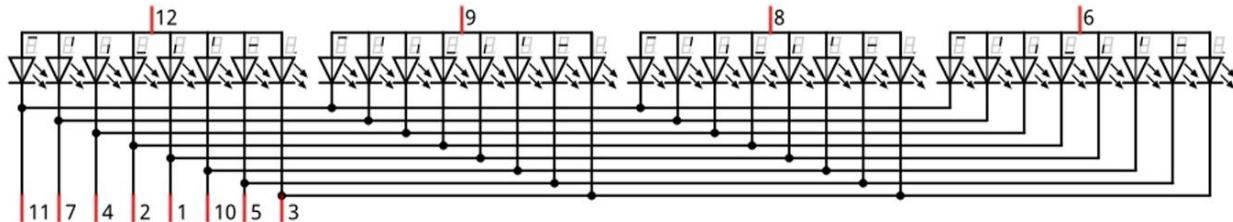
## Component knowledge

### 4 Digit 7-Segment Display

A 4 Digit 7-segment display integrates four 7-segment displays into one module, therefore it can display more characters. All of the LEDs contained have a common anode and individual cathodes. Its internal structure and pin designation diagram is shown below:



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

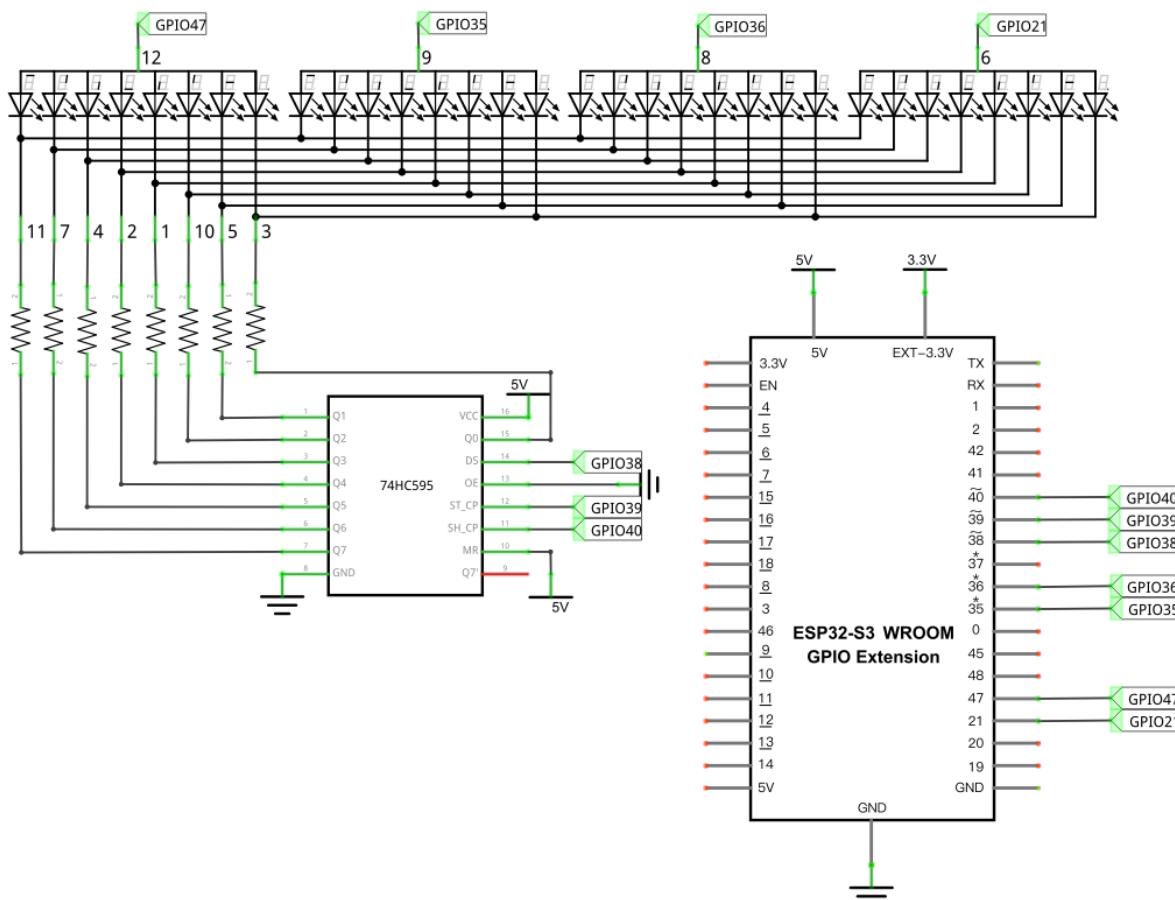


Display method of 4 digit 7-segment display is similar to 1 digit 7-segment display. The difference between them is that the 4-digit displays each Digit is visible in turn, one by one and not together. We need to first send high level to the common end of the first digit display, and send low level to the remaining three common ends, and then send content to 8 LED cathode pins of the first Digit Display. At this time, the first 7-segment display will show visible content and the remaining three will be OFF.

Similarly, the second, third and fourth 7-segment displays will show visible content in turn by scanning the display. Although the four number characters are displayed in turn separately, this process is so fast that it is imperceptible to the naked eye. This is due to the principle of optical afterglow effect and the vision persistence effect in human sight. This is how we can see all 4 number characters at the same time. However, if each number character is displayed for a longer period, you will be able to see that the number characters are displayed separately.

## Circuit

Schematic diagram





## Sketch

In this code, we use the 74HC595 IC chip to control the 4-digit 7-segment display, and use the dynamic scanning method to show the changing number characters.

### Sketch\_16.2\_4\_Digit\_7-Segment\_Display

The screenshot shows the Arduino IDE interface with the following details:

- Title Bar:** Sketch\_16.2\_4\_Digit\_7-Segment\_Display | Arduino IDE 2.0.0
- Menu Bar:** File Edit Sketch Tools Help
- Toolbar:** Includes icons for Save, Run, Stop, and others.
- Sketch Selection:** ESP32S3 Dev Module
- Code Area:** Displays the `Sketch_16.2_4_Digit_7-Segment_Display.ino` file content.

```
Sketch_16.2_4_Digit_7-Segment_Display.ino

1 // ****
2 Filename : 4 Digital 7 Segment Display
3 Description : Use 74HC595 to drive the digital display
4 Author : www.freenove.com
5 Modification: 2022/10/24
6 ****
7 int latchPin = 39;           // Pin connected to ST_CP of 74HC595 (Pin12)
8 int clockPin = 40;           // Pin connected to SH_CP of 74HC595 (Pin11)
9 int dataPin = 38;            // Pin connected to DS of 74HC595 (Pin14)
10 int comPin[] = {21,47,35,36}; // Common pin (anode) of 4 digit 7-segment display
11
12 // Define the encoding of characters 0-F of the common-anode 7-Segment Display
13 byte num[] = {0xc0, 0xf9, 0xa4, 0xb0, 0x99, 0x92, 0x82, 0xf8,
14 | | | | 0x80, 0x90, 0x88, 0x83, 0xc6, 0xa1, 0x86, 0x8e};
15
16 void setup() {
17     // set pins to output
18     pinMode(latchPin, OUTPUT);
19     pinMode(clockPin, OUTPUT);
20     pinMode(dataPin, OUTPUT);
21     for (int i = 0; i < 4; i++) {
22         pinMode(comPin[i], OUTPUT);
```

Compile and upload code to ESP32-S3 WROOM, then the digital tube displays as shown.



The following is the program code:

```
1 int latchPin = 39;           // Pin connected to ST_CP of 74HC595 (Pin12)
2 int clockPin = 40;           // Pin connected to SH_CP of 74HC595 (Pin11)
3 int dataPin = 38;            // Pin connected to DS of 74HC595 (Pin14)
4 int comPin[] = {47, 35, 36, 21};// Common pin (anode) of 4 digit 7-segment display
5
6 // Define the encoding of characters 0-F of the common-anode 7-Segment Display
7 byte num[] = {0xc0, 0xf9, 0xa4, 0xb0, 0x99, 0x92, 0x82, 0xf8,
8                 0x80, 0x90, 0x88, 0x83, 0xc6, 0xa1, 0x86, 0x8e};
9
10 void setup() {
11     // set pins to output
12     pinMode(latchPin, OUTPUT);
13     pinMode(clockPin, OUTPUT);
14     pinMode(dataPin, OUTPUT);
15     for (int i = 0; i < 4; i++) {
16         pinMode(comPin[i], OUTPUT);
17     }
18 }
19
20 void loop() {
21     for (int i = 0; i < 4; i++) {
22         // Select a single 7-segment display
23         selectDigitalDisplay (i);
24         // Send data to 74HC595
25         writeData(num[i]);
26         delay(5);
27         // Clear the display content
28         writeData(0xff);
29     }
30 }
31
32 void selectDigitalDisplay(byte com) {
33     // Close all single 7-segment display
34     for (int i = 0; i < 4; i++) {
35         digitalWrite(comPin[i], LOW);
36     }
37     // Open the selected single 7-segment display
38     digitalWrite(comPin[com], HIGH);
39 }
40
41 void writeData(int value) {
42     // Make latchPin output low level
43     digitalWrite(latchPin, LOW);
```

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```

44 // Send serial data to 74HC595
45 shiftOut(dataPin, clockPin, LSBFIRST, value); // Make latchPin output high level
46 // Make latchPin output high level, then 74HC595 will update data to parallel output
47 digitalWrite(latchPin, HIGH);
48 }

```

First, define the pin of 74HC595 and 7-segment display common end, character encoding.

```

1 int latchPin = 39;           // Pin connected to ST_CP of 74HC595 (Pin12)
2 int clockPin = 40;          // Pin connected to SH_CP of 74HC595 (Pin11)
3 int dataPin = 38;           // Pin connected to DS of 74HC595 (Pin14)
4 int comPin[] = {21, 47, 35, 36};// Common pin (anode) of 4 digit 7-segment display
5
6 // Define the encoding of characters 0-F of the common-anode 7-Segment Display
7 byte num[] = {0xc0, 0xf9, 0xa4, 0xb0, 0x99, 0x92, 0x82, 0xf8,
8                 0x80, 0x90, 0x88, 0x83, 0xc6, 0xa1, 0x86, 0x8e};

```

Second, initialize all the pins to output mode.

```

10 void setup() {
11     // set pins to output
12     pinMode(latchPin, OUTPUT);
13     pinMode(clockPin, OUTPUT);
14     pinMode(dataPin, OUTPUT);
15     for (int i = 0; i < 4; i++) {
16         pinMode(comPin[i], OUTPUT);
17     }
18 }

```

Then, since there are four digital tubes, we need to write a subfunction to control it to turn ON any digital tube. In order not to affect a new display, each time we want to turn ON a digital tube, we need to set the other digital tube OFF.

```

32 void selectDigitalDisplay(byte com) {
33     // Close all single 7-segment display
34     for (int i = 0; i < 4; i++) {
35         digitalWrite(comPin[i], LOW);
36     }
37     // Open the selected single 7-segment display
38     digitalWrite(comPin[com], HIGH);
39 }

```

The usage of the writeData function is the same as in the previous two sections, so it won't be covered again here.

```
41 void writeData(int value) {  
42     // Make latchPin output low level  
43     digitalWrite(latchPin, LOW);  
44     // Send serial data to 74HC595  
45     shiftOut(dataPin, clockPin, LSBFIRST, value);  
46     // Make latchPin output high level, then 74HC595 will update data to parallel output  
47     digitalWrite(latchPin, HIGH);  
48 }
```

In the loop function, because there are four digital tubes, a “for loop” is used to display the values of each one in turn. For example, when  $i = 0$ , turn ON the first digital tube to display the first value, then turn ON the second digital tube to display the second value, until all four digital tubes display their own values. Because the displaying time from the first number to the fourth number is so short, it may display many times in one second, but our eyes can't keep up with the speed of the digital tube, so we look as if the digital tube is displaying different Numbers at the same time.

```
20 void loop() {  
21     for (int i = 0; i < 4; i++) {  
22         // Select a single 7-segment display  
23         selectDigitalDisplay(i);  
24         // Send data to 74HC595  
25         writeData(num[i]);  
26         delay(5);  
27         // Clear the display content  
28         writeData(0xff);  
29     }  
30 }
```

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

```
45 shiftOut(dataPin, clockPin, LSBFIRST, value & 0x7f);
```

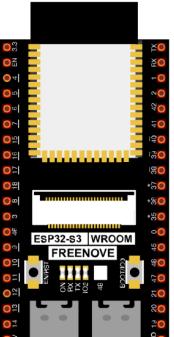
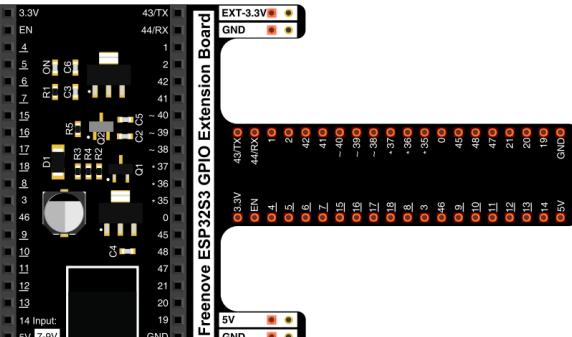
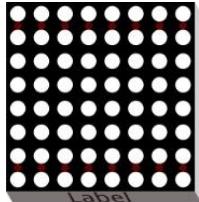
# Chapter 16 74HC595 & LED Matrix

Thus far we have learned how to use the 74HC595 IC chip to control the LED bar graph and the 7-segment display. We will now use 74HC595 IC chips to control a LED matrix.

## Project 16.3 LED Matrix

In this project, we will use two 74HC595 IC chips to control a monochrome (one color) (8X8) LED matrix to make it display both simple graphics and characters.

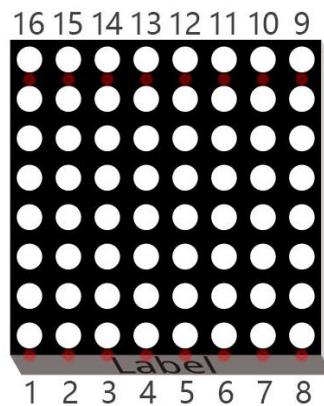
### Component List

ESP32-S3 WROOM x1	GPIO Extension Board x1		
			
Breadboard x1			
74HC595 x2	8*8 LEDMatrix x1	Resistor 220Ω x8	Jumper M/M
			

## Component knowledge

### LED Matrix

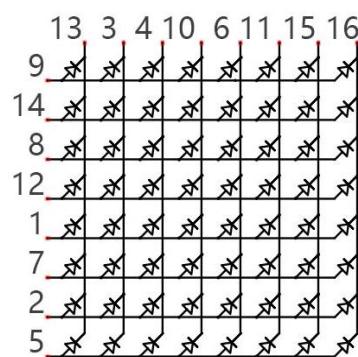
A LED matrix is a rectangular display module that consists of a uniform grid of LEDs. The following is an 8X8 monochrome (one color) LED matrix containing 64 LEDs (8 rows by 8 columns).



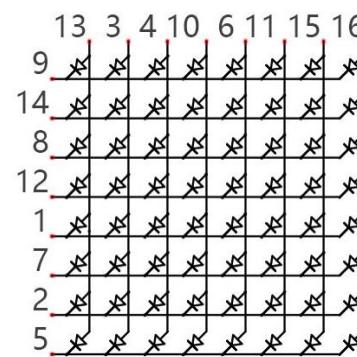
In order to facilitate the operation and reduce the number of ports required to drive this component, the positive poles of the LEDs in each row and negative poles of the LEDs in each column are respectively connected together inside the LED matrix module, which is called a common anode. There is another arrangement type. Negative poles of the LEDs in each row and the positive poles of the LEDs in each column are respectively connected together, which is called a common cathode.

The LED matrix that we use in this project is a common anode LED matrix.

Connection mode of common anode

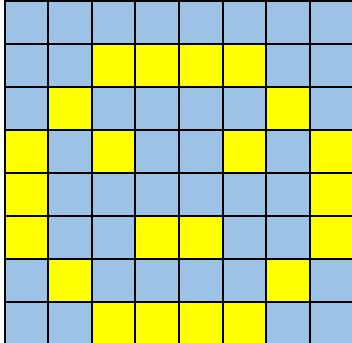


Connection mode of common cathode





Here is how a common anode LED matrix works. First, choose 16 ports on ESP32-S3 board to connect to the 16 ports of LED matrix. Configure one port in columns for low level, which makes that column the selected port. Then configure the eight port in the row to display content in the selected column. Add a delay value and then select the next column that outputs the corresponding content. This kind of operation by column is called scan. If you want to display the following image of a smiling face, you can display it in 8 columns, and each column is represented by one byte.



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

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

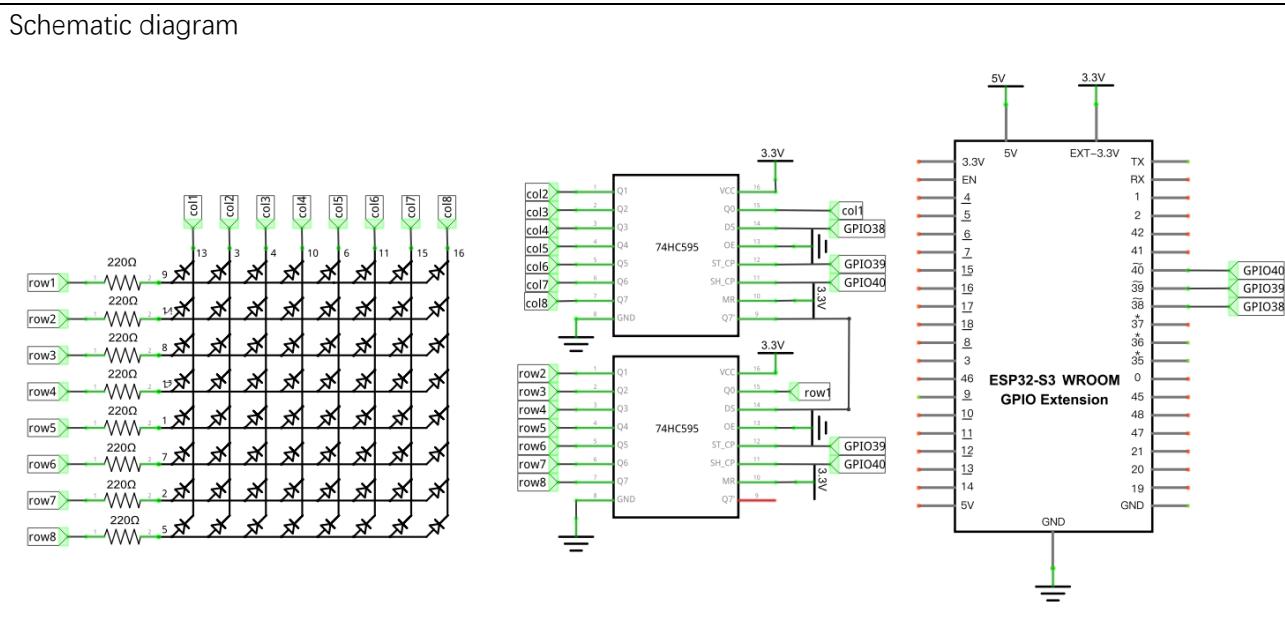
To begin, display the first column, then turn off the first column and display the second column. (and so on) .... turn off the seventh column and display the 8th column, and then start the process over from the first column again like the control of LED bar graph project. The whole process will be repeated rapidly in a loop. Due to the principle of optical afterglow effect and the vision persistence effect in human sight, we will see a picture of a smiling face directly rather than individual columns of LEDs turned ON one column at a time (although in fact this is the reality we cannot perceive).

Then, to save the number of GPIO, we use a 74HC595. When the first column is turned ON, set the lights that need to be displayed in the first column to "1", otherwise to "0", as shown in the above example, where the value of the first column is 0x1c. This value is sent to 74HC595 to control the display of the first column of the LED matrix. Following the above idea, turn OFF the display of the first column, then turn ON the second column, and then send the value of the second column to 74HC595 ..... Until each column is displayed, the LED matrix is displayed again from the first column.

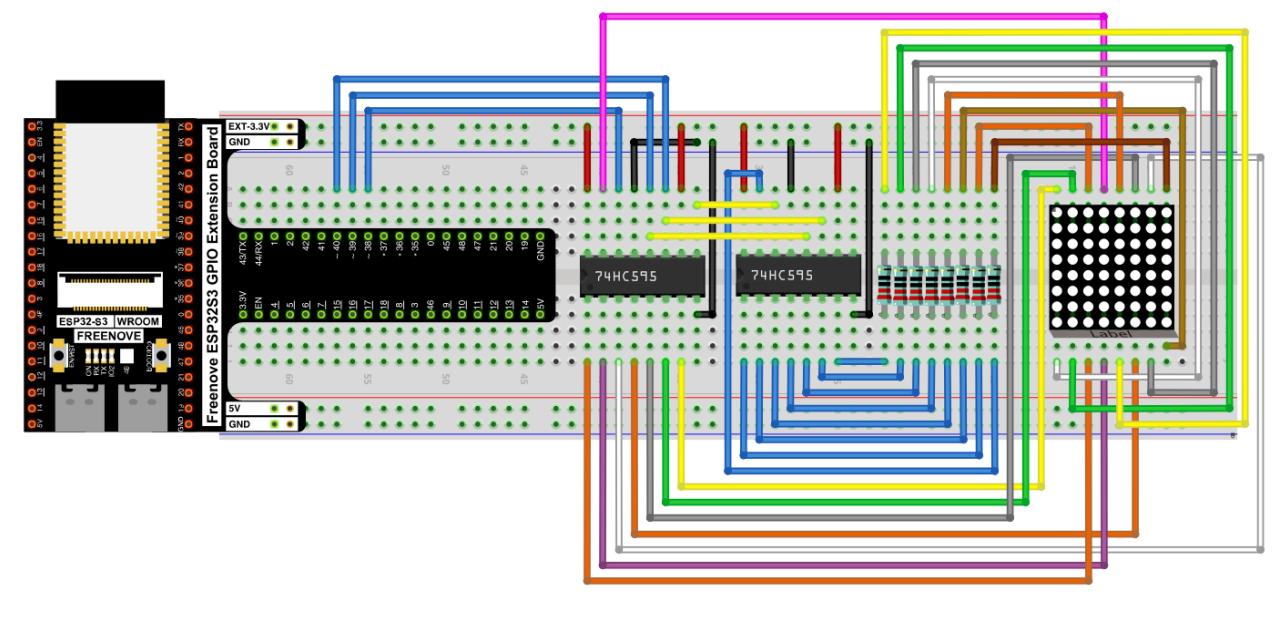
## Circuit

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

Schematic diagram

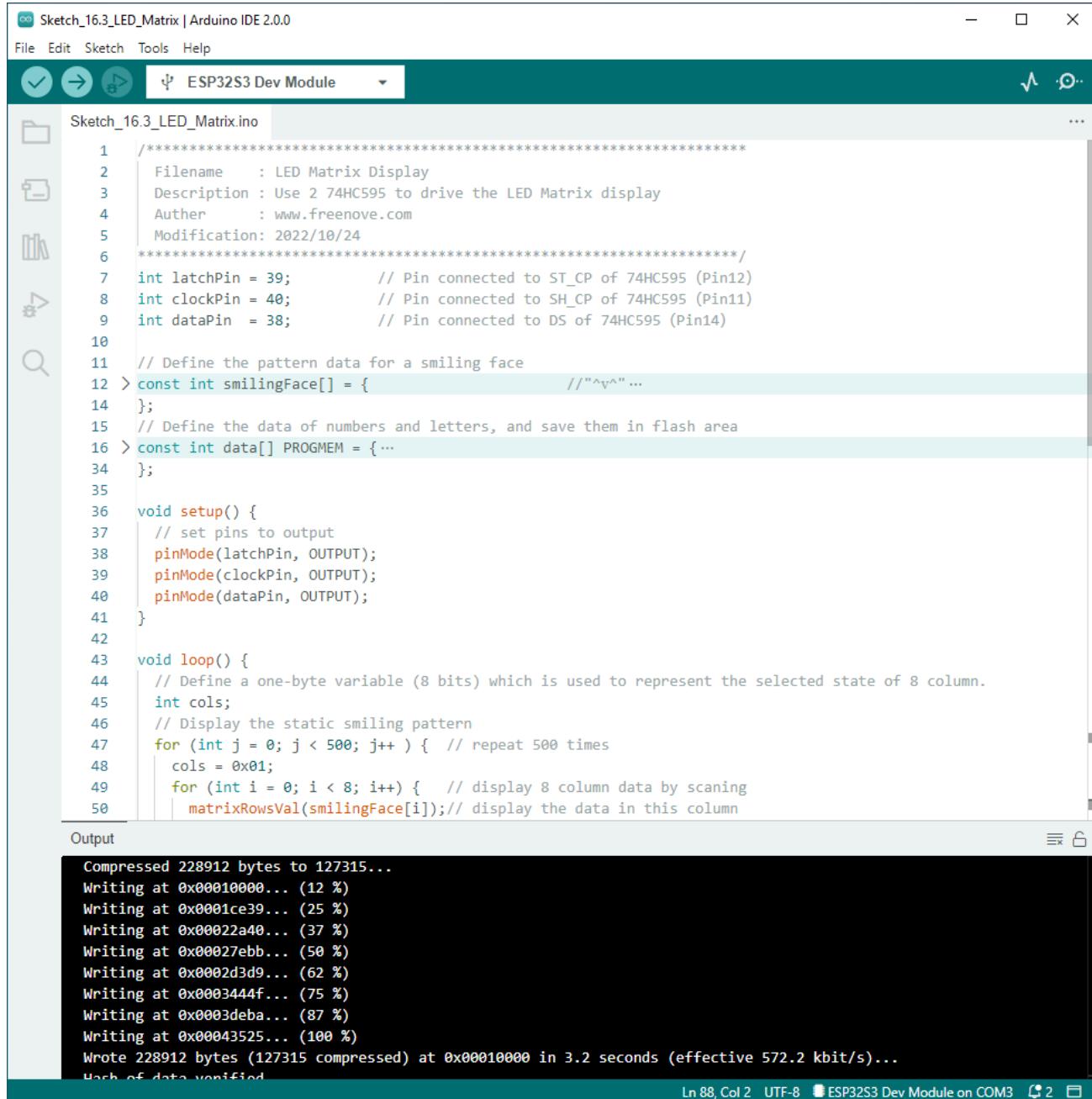


Hardware connection:



## Sketch

The following code will make LED matrix display a smiling face, and then display scrolling character "0-F".



```

Sketch_16.3_LED_Matrix | Arduino IDE 2.0.0
File Edit Sketch Tools Help
ESP32S3 Dev Module
Sketch_16.3_LED_Matrix.ino ...
1 // ****
2 Filename : LED Matrix Display
3 Description : Use 2 74HC595 to drive the LED Matrix display
4 Author : www.freenove.com
5 Modification: 2022/10/24
6 ****
7 int latchPin = 39;           // Pin connected to ST_CP of 74HC595 (Pin12)
8 int clockPin = 40;          // Pin connected to SH_CP of 74HC595 (Pin11)
9 int dataPin = 38;           // Pin connected to DS of 74HC595 (Pin14)
10
11 // Define the pattern data for a smiling face
12 > const int smilingFace[] = {           // "^\^"...
13 };
14 // Define the data of numbers and letters, and save them in flash area
15 > const int data[] PROGMEM = { ...
16 };
17
18 void setup() {
19     // set pins to output
20     pinMode(latchPin, OUTPUT);
21     pinMode(clockPin, OUTPUT);
22     pinMode(dataPin, OUTPUT);
23 }
24
25 void loop() {
26     // Define a one-byte variable (8 bits) which is used to represent the selected state of 8 column.
27     int cols;
28     // Display the static smiling pattern
29     for (int j = 0; j < 500; j++) { // repeat 500 times
30         cols = 0x01;
31         for (int i = 0; i < 8; i++) { // display 8 column data by scanning
32             matrixRowsVal(smilingFace[i]); // display the data in this column
33         }
34     }
35 }
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50

```

Output

```

Compressed 228912 bytes to 127315...
Writing at 0x00010000... (12 %)
Writing at 0x0001ce39... (25 %)
Writing at 0x00022a40... (37 %)
Writing at 0x00027ebb... (50 %)
Writing at 0x0002d3d9... (62 %)
Writing at 0x0003444f... (75 %)
Writing at 0x0003deba... (87 %)
Writing at 0x00043525... (100 %)
Wrote 228912 bytes (127315 compressed) at 0x00010000 in 3.2 seconds (effective 572.2 kbit/s)...
Hash of data verified

```

Ln 88, Col 2 UTF-8 ■ ESP32S3 Dev Module on COM3

Download the code to ESP32-S3 WROOM, and the LED matrix display a smiling face, and then display characters "0 to F" scrolling in a loop on the LED matrix.

### Sketch\_16.3\_LED\_Matrix

The following is the program code:

1	int latchPin = 39;           // Pin connected to ST_CP of 74HC595 (Pin12)
2	int clockPin = 40;          // Pin connected to SH_CP of 74HC595 (Pin11)

```
3 int dataPin = 38;           // Pin connected to DS of 74HC595 (Pin14)
4
5 // Define the pattern data for a smiling face
6 const int smilingFace[] = {                                // " ^ v ^ "
7     0x1C, 0x22, 0x51, 0x45, 0x45, 0x51, 0x22, 0x14
8 };
9 // Define the data of numbers and letters, and save them in flash area
10 const int data[] PROGMEM = {
11     0x00, 0x00, 0x00, 0x00, 0x00, 0x00, 0x00, // "
12     0x00, 0x00, 0x21, 0x7F, 0x01, 0x00, 0x00, 0x00, // "1"
13     0x00, 0x00, 0x23, 0x45, 0x49, 0x31, 0x00, 0x00, // "2"
14     0x00, 0x00, 0x22, 0x49, 0x49, 0x36, 0x00, 0x00, // "3"
15     0x00, 0x00, 0x0E, 0x32, 0x7F, 0x02, 0x00, 0x00, // "4"
16     0x00, 0x00, 0x79, 0x49, 0x49, 0x46, 0x00, 0x00, // "5"
17     0x00, 0x00, 0x3E, 0x49, 0x49, 0x26, 0x00, 0x00, // "6"
18     0x00, 0x00, 0x60, 0x47, 0x48, 0x70, 0x00, 0x00, // "7"
19     0x00, 0x00, 0x36, 0x49, 0x49, 0x36, 0x00, 0x00, // "8"
20     0x00, 0x00, 0x32, 0x49, 0x49, 0x3E, 0x00, 0x00, // "9"
21     0x00, 0x00, 0x3E, 0x41, 0x41, 0x3E, 0x00, 0x00, // "0"
22     0x00, 0x00, 0x3F, 0x44, 0x44, 0x3F, 0x00, 0x00, // "A"
23     0x00, 0x00, 0x7F, 0x49, 0x49, 0x36, 0x00, 0x00, // "B"
24     0x00, 0x00, 0x3E, 0x41, 0x41, 0x22, 0x00, 0x00, // "C"
25     0x00, 0x00, 0x7F, 0x41, 0x41, 0x3E, 0x00, 0x00, // "D"
26     0x00, 0x00, 0x7F, 0x49, 0x49, 0x41, 0x00, 0x00, // "E"
27     0x00, 0x00, 0x7F, 0x48, 0x48, 0x40, 0x00, 0x00 // "F"
28 };
29
30 void setup() {
31     // set pins to output
32     pinMode(latchPin, OUTPUT);
33     pinMode(clockPin, OUTPUT);
34     pinMode(dataPin, OUTPUT);
35 }
36
37 void loop() {
38     // Define a one-byte variable (8 bits) which is used to represent the selected state of 8
39     // column.
40     int cols;
41     // Display the static smiling pattern
42     for (int j = 0; j < 500; j++) { // repeat 500 times
43         cols = 0x01;
44         for (int i = 0; i < 8; i++) { // display 8 column data by scanning
45             matrixRowsVal(smilingFace[i]); // display the data in this column
46             matrixColsVal(~cols); // select this column
47         }
48     }
49 }
```



```

47     delay(1);                      // display them for a period of time
48     matrixRowsVal(0x00);           // clear the data of this column
49     cols <= 1;                     // shift "cols" 1 bit left to select the next column
50   }
51 }
52 // Display the dynamic patterns of numbers and letters
53 for (int i = 0; i < 128; i++) {
54   for (int k = 0; k < 10; k++) {    // repeat image of each frame 10 times.
55     cols = 0x01;                  // Assign binary 00000001. Means the first column is selected.
56     for (int j = i; j < 8 + i; j++) { // display image of each frame
57       matrixRowsVal(pgm_read_word_near(data + j)); // display the data in this column
58       matrixColsVal(~cols);          // select this column
59       delay(1);                   // display them for a period of time
60       matrixRowsVal(0x00);         // close the data of this column
61       cols <= 1;                  // shift "cols" 1 bit left to select the next column
62     }
63   }
64 }
65 }
66
67 void matrixRowsVal(int value) {
68   // make latchPin output low level
69   digitalWrite(latchPin, LOW);
70   // Send serial data to 74HC595
71   shiftOut(dataPin, clockPin, LSBFIRST, value);
72   // make latchPin output high level, then 74HC595 will update the data to parallel output
73   digitalWrite(latchPin, HIGH);
74 }
75
76
77 void matrixColsVal(int value) {
78   // make latchPin output low level
79   digitalWrite(latchPin, LOW);
80   // Send serial data to 74HC595
81   shiftOut(dataPin, clockPin, MSBFIRST, value);
82   // make latchPin output high level, then 74HC595 will update the data to parallel output
83   digitalWrite(latchPin, HIGH);
84 }
```

The first “for” loop in the “while” loop is used to display a static smile. Displaying column information from left to right, one column at a time with a total of 8 columns. This repeats 500 times to ensure sufficient display time.

```

40 int cols;
41 // Display the static smiling pattern
42 for (int j = 0; j < 500; j++) { // repeat 500 times
43 }
```

```

44     cols = 0x01; // Assign 0x01(binary 00000001) to the variable, which represents the first
45     column is selected.
46     for (int i = 0; i < 8; i++) { // display 8 column data by scanning
47         matrixRowsVal(smilingFace[i]); // display the data in this column
48         matrixColsVal(~cols); // select this column
49         delay(1); // display them for a period of time
50         cols <= 1; // shift "cols" 1 bit left to select the next column
51     }
}

```

The second “for” loop is used to display scrolling characters “0 to F”, for a total of  $17 \times 8 = 144$  columns. Displaying the 0-8 column, then the 1-9 column, then the 2-10 column..... and so on…128-136 column in consecutively to achieve the scrolling effect. The display of each frame is repeated a certain number of times and the more repetitions, the longer the single frame display will be and the slower the scrolling movement.

```

52 // Display the dynamic patterns of numbers and letters
53 for (int i = 0; i < 128; i++) {
54     for (int k = 0; k < 10; k++) { // repeat image of each frame 10 times.
55         cols = 0x01; // Assign binary 00000001. Means the first column is selected.
56         for (int j = i; j < 8 + i; j++) { // display image of each frame
57             matrixRowsVal(pgm_read_word_near(data + j)); // display the data in this column
58             matrixColsVal(~cols); // select this column
59             delay(1); // display them for a period of time
60             matrixRowsVal(0x00); // close the data of this column
61             cols <= 1; // shift "cols" 1 bit left to select the next column
62         }
63     }
64 }

```

The amount of pins of ESP32-S3 is limited, so you need to find ways to save pins. If you use ESP32-S3's GPIO to control the lattice without using 74HC595, you need 16 pins for the use of LED matrix. In this example, we use two 74HC595 to drive the LED matrix, requiring only three pins, so that we could save the rest of 13 pins.

# Chapter 17 Relay & Motor

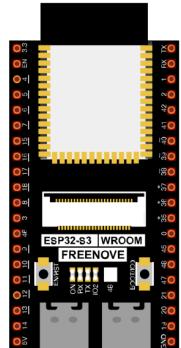
In this chapter, we will learn a kind of special switch module, relay module.

## Project 17.1 Relay & Motor

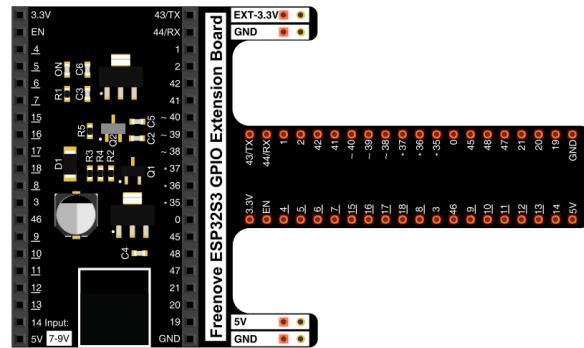
In this project, we will use a push button switch indirectly to control the motor via a relay.

### Component List

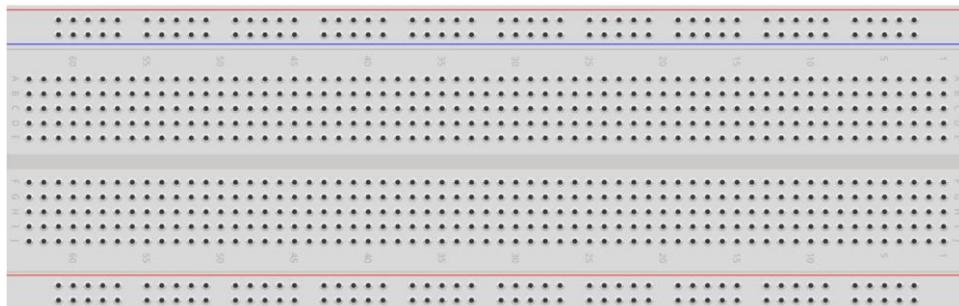
ESP32-S3 WROOM x1



GPIO Extension Board x1



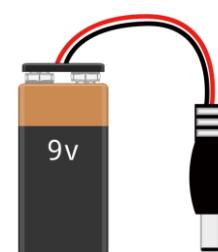
Breadboard x1

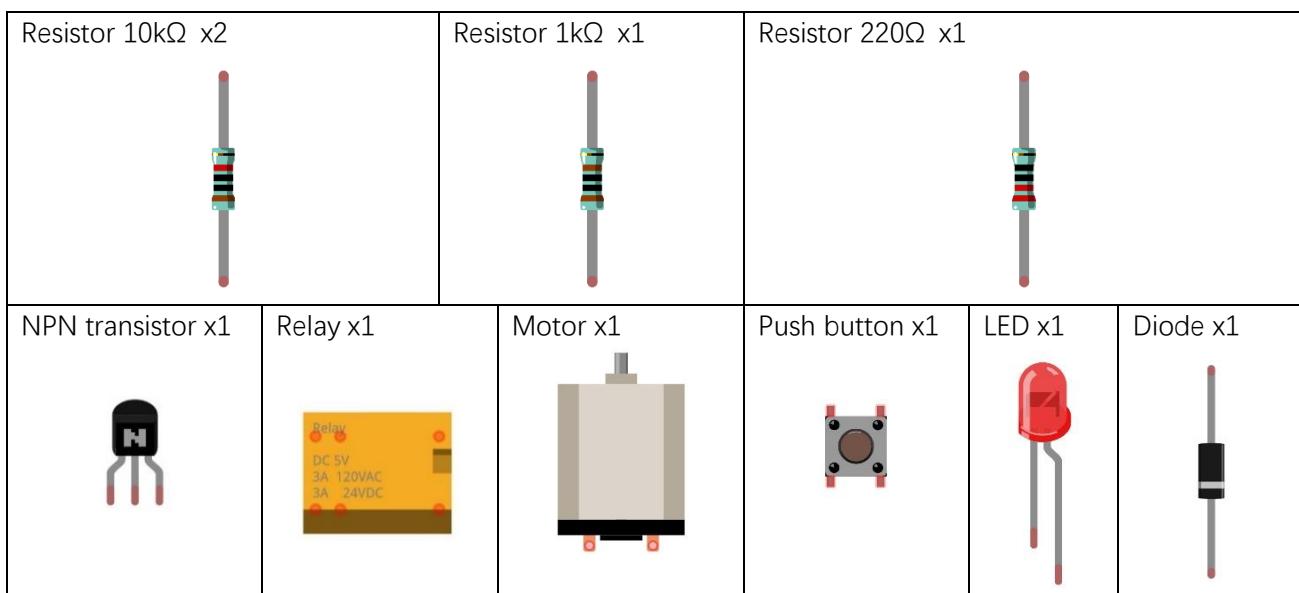


Jumper M/M



9V battery (prepared by yourself) & battery line



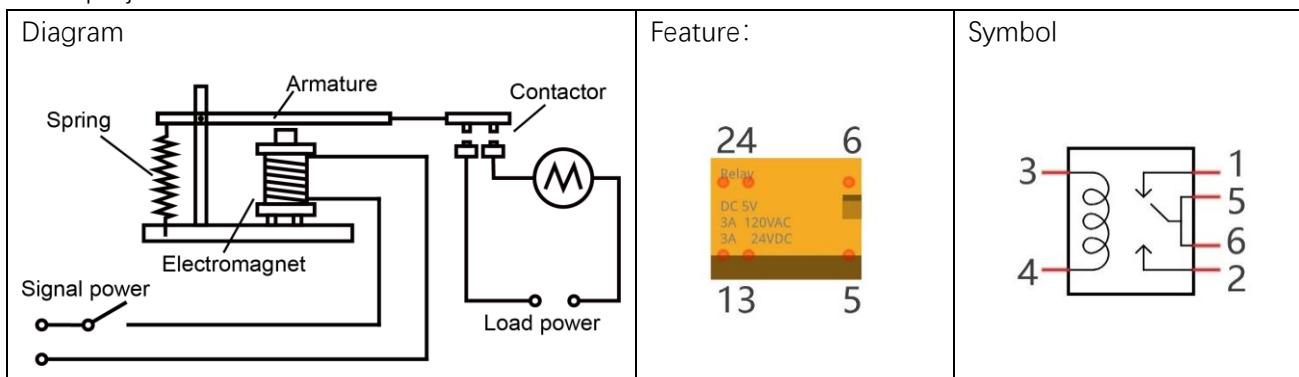


## Component knowledge

### Relay

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

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



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

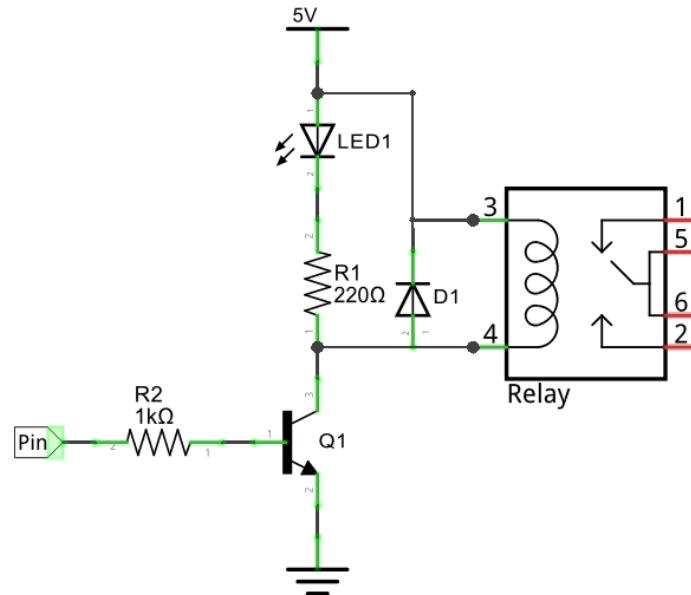
### Inductor

The symbol of Inductance is “L” and the unit of inductance is the “Henry” (H). Here is an example of how this can be encountered:  $1\text{H}=1000\text{mH}$ ,  $1\text{mH}=1000\mu\text{H}$ .

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

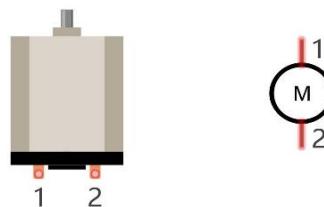


The reference circuit for relay is as follows. The coil of relays can be equivalent to that of inductors, when the transistor disconnects power supply of the relay, the current in the coil of the relay can't stop immediately, causing an impact on power supply. So a parallel diode will get connected to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

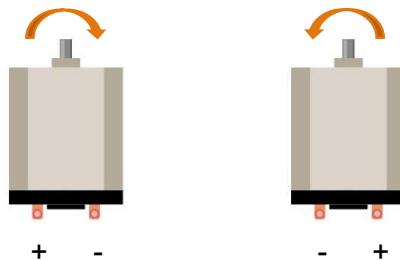


### Motor

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

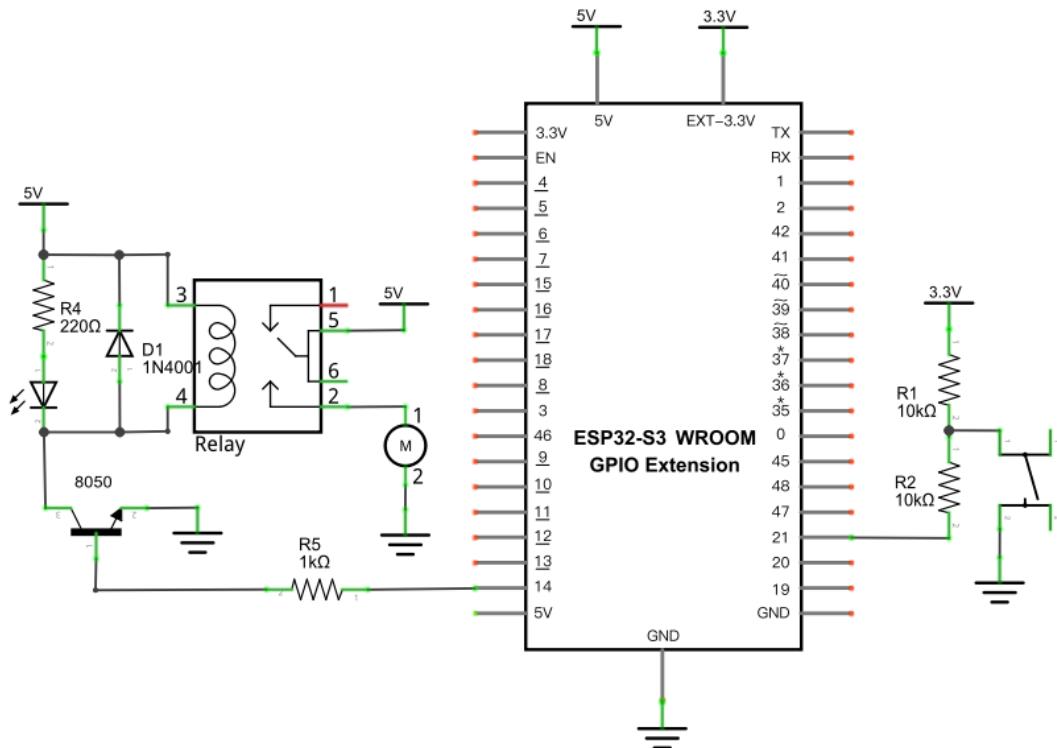


When a motor gets connected to the power supply, it will rotate in one direction. Reverse the polarity of power supply, then the motor rotates in opposite direction.

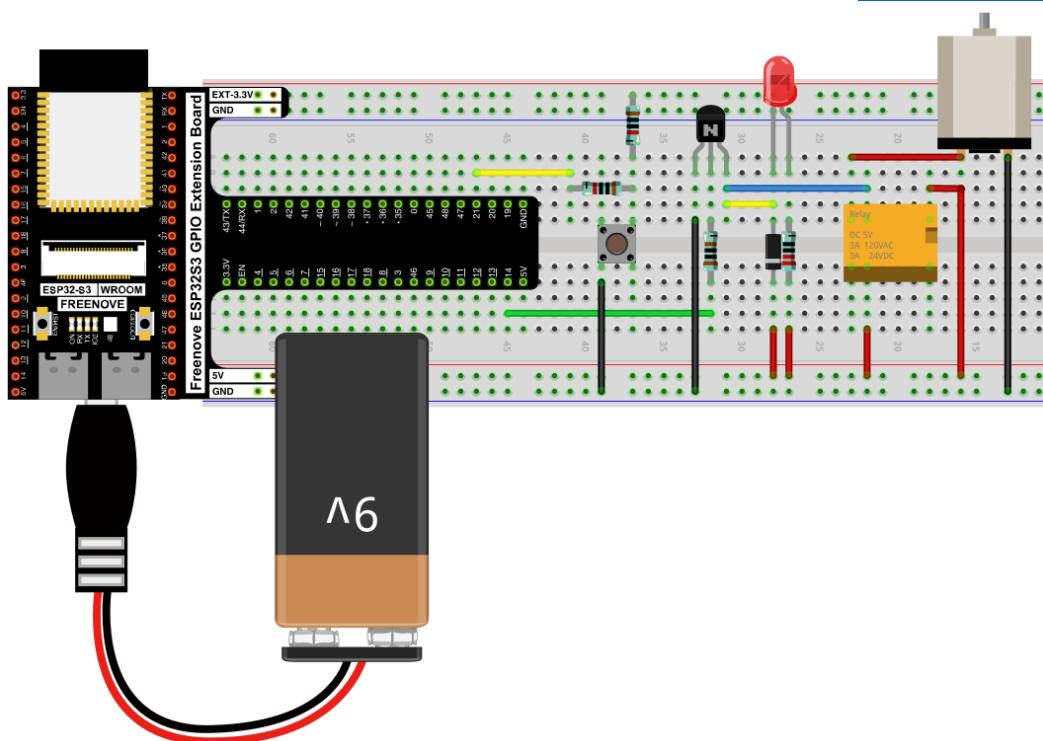


# Circuit

## Schematic diagram



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



Note: the motor circuit uses A large current, about 0.2-0.3A without load. We recommend that you use a 9V battery to power the extension board.

Any concerns?  support@freenove.com



## Sketch

Use buttons to control the relays and motors.

### Sketch\_17.1\_Control\_Motor\_by\_Relay

```
Sketch_17.1_Control_Motor_by_Relay | Arduino IDE 2.0.0
File Edit Sketch Tools Help
ESP32S3 Dev Module
Sketch_17.1_Control_Motor_by_Relay.ino
1 //*****
2 Filename : Control Motor by Relay
3 Description : Use relay to control motor.
4 Author : www.freenove.com
5 Modification: 2022/10/24
6 ****
7 int relayPin = 14; // the number of the relay pin
8 int buttonPin = 21; // the number of the push button pin
9
10 int buttonState = HIGH; // Record button state, and initial the state to high level
11 int relayState = LOW; // Record relay state, and initial the state to low level
12 int lastButtonState = HIGH; // Record the button state of last detection
13 long lastChangeTime = 0; // Record the time point for button state change
14
15 void setup() {
16     pinMode(buttonPin, INPUT_PULLUP); // Set push button pin into input mode
17     pinMode(relayPin, OUTPUT); // Set relay pin into output mode
18     digitalWrite(relayPin, relayState); // Set the initial state of relay into "off"
19 }
20 void loop() {
21     int nowButtonState = digitalRead(buttonPin); // Read current state of button pin
22     // If button pin state has changed, record the time point
23     if (nowButtonState != lastButtonState) {
24         lastChangeTime = millis();
25     }
26     // If button state changes, and stays stable for a while, then it should have skipped the bounce area
27     if (millis() - lastChangeTime > 10) {
28         if (buttonState != nowButtonState) { // Confirm button state has changed
29             buttonState = nowButtonState;
30             if (buttonState == LOW) { // Low level indicates the button is pressed
Output
Writing at 0x0002d729... (62 %)
Writing at 0x00033f7b... (75 %)
Writing at 0x0003e24d... (87 %)
Writing at 0x00043857... (100 %)
Wrote 234944 bytes (130834 compressed) at 0x00010000 in 2.5 seconds (effective 757.7 kbit/s)...
Hash of data verified.

Leaving...
Hard resetting via RTS pin...
Ln 38, Col 1  UTF-8  ESP32S3 Dev Module on COM24  2  
```

Download the code to ESP32-S3 WROOM. When the DC motor is connected to a power supply, it will rotate in one direction. If you reverse the polarity of the power supply, the DC motor will rotate in opposite direction.



The following is the program code:

```

1 int relayPin = 14;           // the number of the relay pin
2 int buttonPin = 21;          // the number of the push button pin
3
4 int buttonState = HIGH;      // Record button state, and initial the state to high level
5 int relayState = LOW;        // Record relay state, and initial the state to low level
6 int lastButtonState = HIGH; // Record the button state of last detection
7 long lastChangeTime = 0;     // Record the time point for button state change
8
9 void setup() {
10    pinMode(buttonPin, INPUT_PULLUP);           // Set push button pin into input mode
11    pinMode(relayPin, OUTPUT);                  // Set relay pin into output mode
12    digitalWrite(relayPin, relayState);         // Set the initial state of relay into "off"
13 }
14 void loop() {
15    int nowButtonState = digitalRead(buttonPin); // Read current state of button pin
16    // If button pin state has changed, record the time point
17    if (nowButtonState != lastButtonState) {
18        lastChangeTime = millis();
19    }
20    // If button state changes, and stays stable for a while, then it should have skipped the
21    // bounce area
22    if (millis() - lastChangeTime > 10) {
23        if (buttonState != nowButtonState) { // Confirm button state has changed
24            buttonState = nowButtonState;
25            if (buttonState == LOW) {        // Low level indicates the button is pressed
26                relayState = ! relayState;   // Reverse relay state
27                digitalWrite(relayPin, relayState); // Update relay state
28            }
29        }
30    }
31    lastButtonState = nowButtonState; // Save the state of last button
32 }
```



In Chapter 2, the pressing and releasing of the button will result in mechanical vibrating. If we don't solve this problem, some unexpected consequences may happen to the procedure. Click [here](#) to return to Chapter 2 Button & LED

To eliminate the vibrating, we record the electrical level of the button with nowButtonState, and the time point for the last change of pin level with lastChangeTime. If the state of the button changes, it will record the time point of the change.

```

15 int nowButtonState = digitalRead(buttonPin); // Read current state of button pin
16 // If button pin state has changed, record the time point
17 if (nowButtonState != lastButtonState) {
18     lastChangeTime = millis();
19 }
```

If the state of the pin changes and keeps stable for a period of time, it can be considered as a valid key state change, update the key state variable buttonState, and determine whether the key is pressed or released according to the current state.

```

15 // If button state changes, and stays stable for a while, then it should have skipped the
16 bounce area
17 if (millis() - lastChangeTime > 10) {
18     if (buttonState != nowButtonState) { // Confirm button state has changed
19         buttonState = nowButtonState;
20         if (buttonState == LOW) { // Low level indicates the button is pressed
21             relayState = ! relayState; // Reverse relay state
22             digitalWrite(relayPin, relayState); // Update relay state
23         }
24     }
25 }
26 lastButtonState = nowButtonState; // Save the state of last button
```

# Chapter 17.2 Motor & Driver

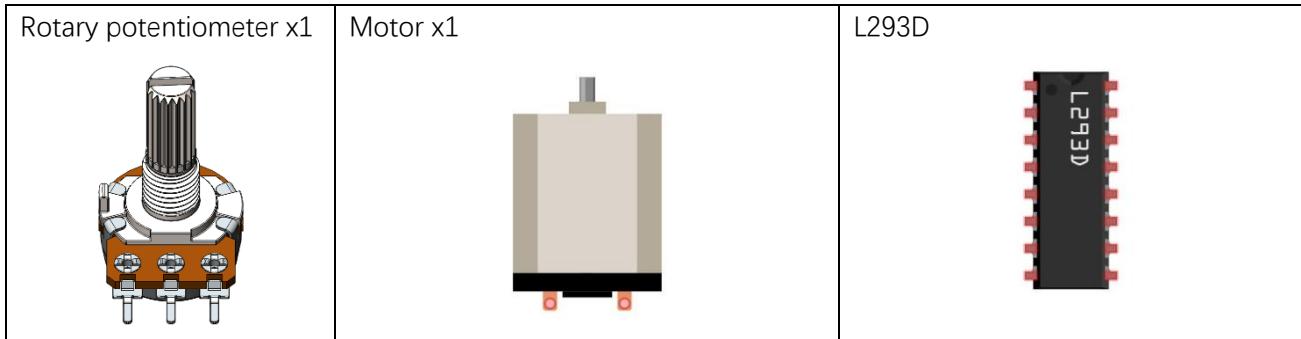
In this chapter, we will learn about DC motors and DC motor drivers and how to control the speed and direction of a DC motor.

## Project 17.2 Control Motor with Potentiometer

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

### Component List

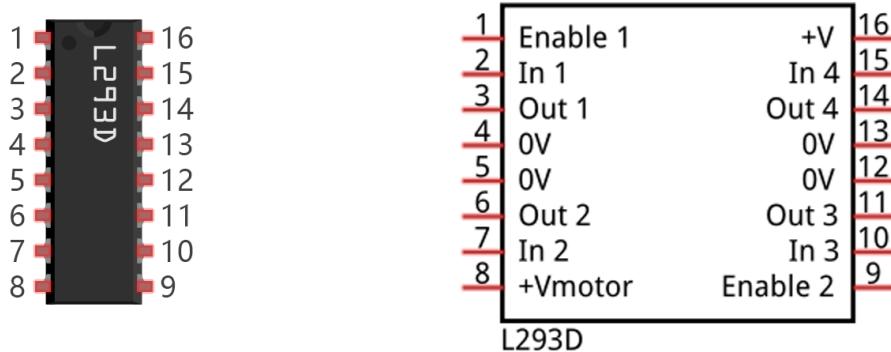
ESP32-S3 WROOM x1		GPIO Extension Board x1	
Breadboard x1			
Jumper M/M			
9V battery (prepared by yourself) & battery line			



## 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).



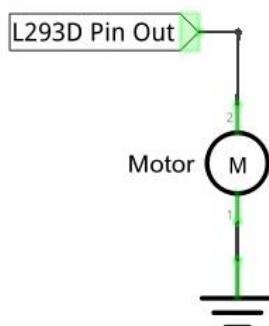
Port description of L293D module is as follows:

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

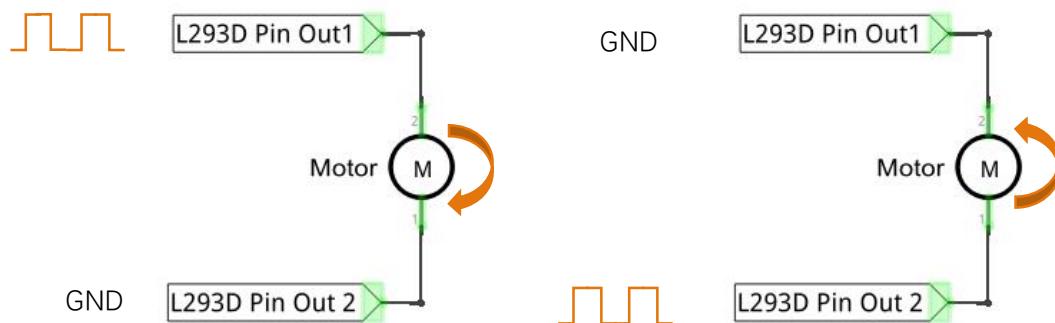
For more detail, please refer to the datasheet for this IC Chip.

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 controls the speed of motor, but also can control the steering of the motor.

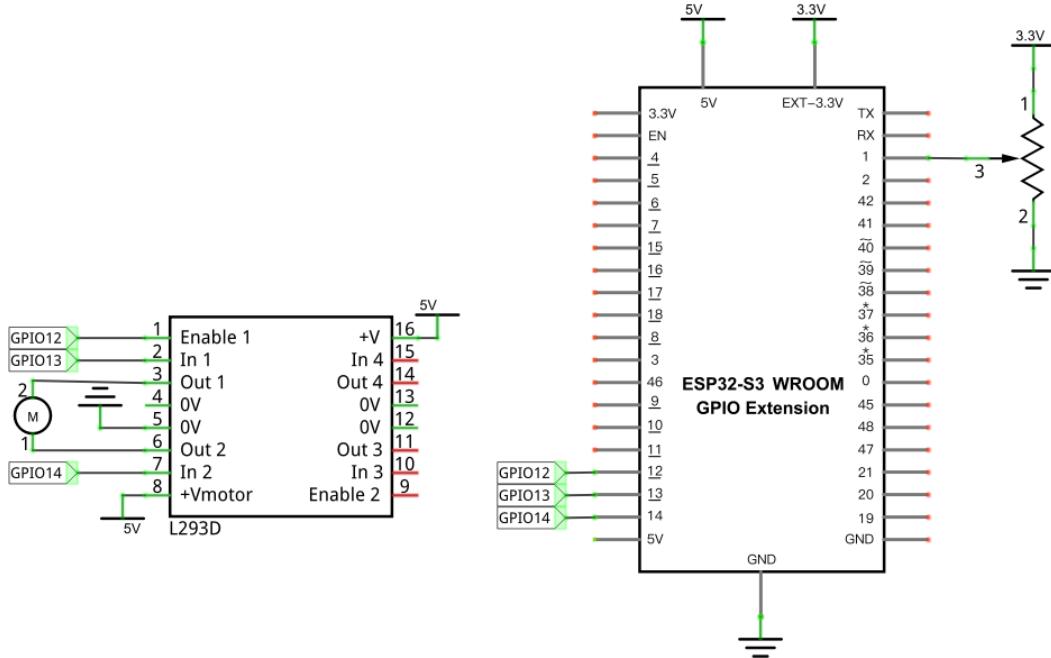


In practical use the motor is usually connected to channel 1 and 2 by outputting different levels to in1 and in2 to control the rotational direction of the motor, and output to the PWM wave to Enable1 port to control the motor's rotational speed. If the motor is connected to channel 3 and 4 by outputting 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.

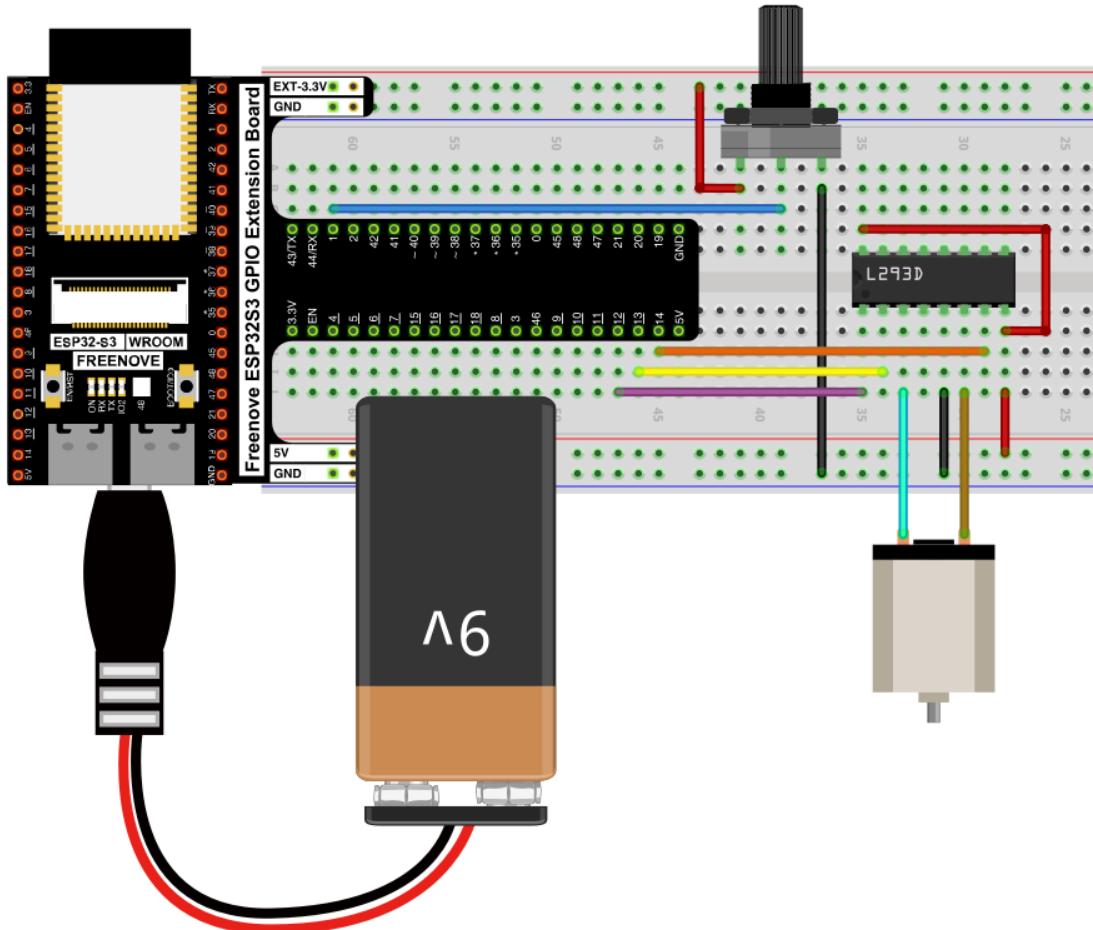
## Circuit

Use caution when connecting this circuit, because the DC motor is a high-power component, do not use the power provided by the ESP32-S3 to power the motor directly, which may cause permanent damage to your ESP32-S3! The logic circuit can be powered by the ESP32-S3 power or an external power supply, which should share a common ground with ESP32-S3.

Schematic diagram



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

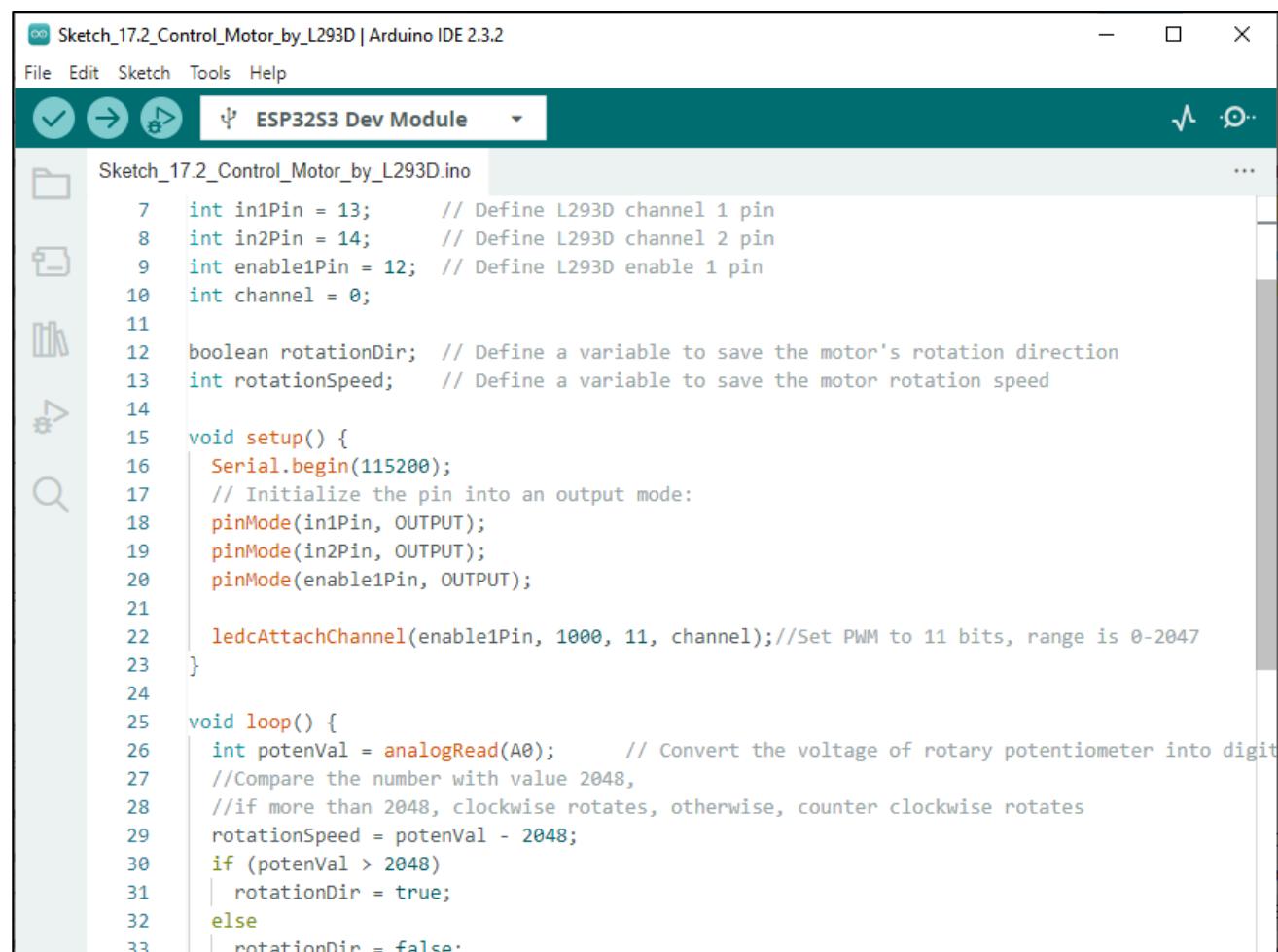


Note: the motor circuit uses a large current, about 0.2-0.3A without load. We recommend that you use a 9V battery to power the extension board.

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

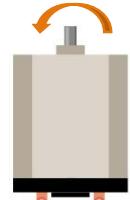
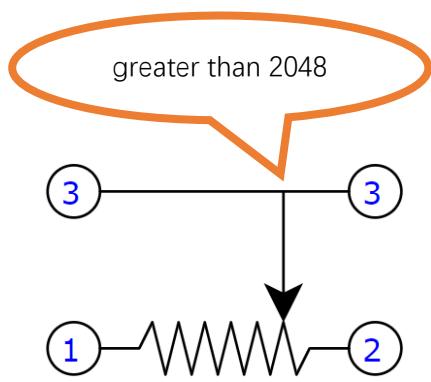
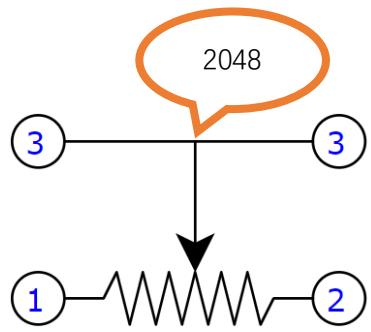
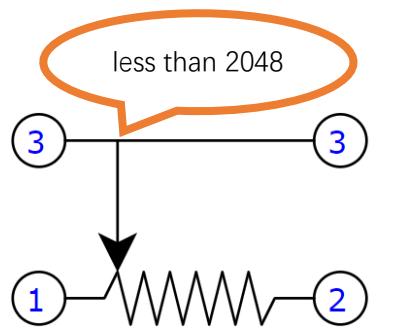
## Sketch

### Sketch\_17.2\_Control\_Motor\_by\_L293D



```
Sketch_17.2_Control_Motor_by_L293D | Arduino IDE 2.3.2
File Edit Sketch Tools Help
ESP32S3 Dev Module
Sketch_17.2_Control_Motor_by_L293D.ino
1
2
3
4
5
6
7 int in1Pin = 13;      // Define L293D channel 1 pin
8 int in2Pin = 14;      // Define L293D channel 2 pin
9 int enable1Pin = 12;  // Define L293D enable 1 pin
10 int channel = 0;
11
12 boolean rotationDir; // Define a variable to save the motor's rotation direction
13 int rotationSpeed;   // Define a variable to save the motor rotation speed
14
15 void setup() {
16     Serial.begin(115200);
17     // Initialize the pin into an output mode:
18     pinMode(in1Pin, OUTPUT);
19     pinMode(in2Pin, OUTPUT);
20     pinMode(enable1Pin, OUTPUT);
21
22     ledcAttachChannel(enable1Pin, 1000, 11, channel); //Set PWM to 11 bits, range is 0-2047
23 }
24
25 void loop() {
26     int potenVal = analogRead(A0);      // Convert the voltage of rotary potentiometer into digit
27     //Compare the number with value 2048,
28     //if more than 2048, clockwise rotates, otherwise, counter clockwise rotates
29     rotationSpeed = potenVal - 2048;
30     if (potenVal > 2048)
31         rotationDir = true;
32     else
33         rotationDir = false;
```

Download code to ESP32-S3 WROOM, rotate the potentiometer in one direction and the motor speeds up slowly in one direction. And then rotate the potentiometer in the other direction and the motor will slow down to stop. And then rotate it in an inverse direction to accelerate the motor.



The following is the sketch:

```
1 int in1Pin = 13;      // Define L293D channel 1 pin
2 int in2Pin = 14;      // Define L293D channel 2 pin
3 int enable1Pin = 12;  // Define L293D enable 1 pin
4 int channel = 0;
5
6 boolean rotationDir; // Define a variable to save the motor's rotation direction
7 int rotationSpeed;   // Define a variable to save the motor rotation speed
8
9 void setup() {
10    // Initialize the pin into an output mode:
11    pinMode(in1Pin, OUTPUT);
12    pinMode(in2Pin, OUTPUT);
13    pinMode(enable1Pin, OUTPUT);
14    ledcAttachChannel(enable1Pin, 1000, 11, channel); //Set PWM to 11 bits, range is 0-2047
15 }
16
17 void loop() {
18    int potenVal = analogRead(A0); // Convert the voltage of rotary potentiometer into digital
19    rotationSpeed = potenVal - 2048;
20    if (potenVal > 2048)
21        rotationDir = true;
22    else
23        rotationDir = false;
24    // Calculate the motor speed
25    rotationSpeed = abs(potenVal - 2048);
26    //Control the steering and speed of the motor
27    Serial.println(rotationSpeed);
28    delay(100);
29    driveMotor(rotationDir, constrain(rotationSpeed, 0, 2048));
30 }
31
32 void driveMotor(boolean dir, int spd) {
33    if (dir) { // Control motor rotation direction
34        digitalWrite(in1Pin, HIGH);
35        digitalWrite(in2Pin, LOW);
36    }
37    else {
38        digitalWrite(in1Pin, LOW);
39        digitalWrite(in2Pin, HIGH);
40    }
41    ledcWrite(enable1Pin, spd); // Control motor rotation speed
42 }
```



The ADC of ESP32-S3 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 use this result as the speed of the motor.

```

20 int potenVal = analogRead(A0); // Convert the voltage of rotary potentiometer into digital
21 rotationSpeed = potenVal - 2048;
22 if (potenVal > 2048)
23     rotationDir = true;
24 else
25     rotationDir = false;
26 // Calculate the motor speed
27 rotationSpeed = abs(potenVal - 2048);
28 //Control the steering and speed of the motor
29 driveMotor(rotationDir, constrain(rotationSpeed, 0, 2048));
30 }
```

Set the accuracy of the PWM to 11 bits and range from 0 to 2047 to control the rotation speed of the motor.

```
15 ledcSetup(channel, 1000, 11); //Set PWM to 11 bits, range is 0-2047
```

Function `driveMotor` is used to control the rotation direction and speed of the motor. The `dir` represents direction while `spd` refers to speed.

```

34 void driveMotor(boolean dir, int spd) {
35     // Control motor rotation direction
36     if (rotationDir) {
37         digitalWrite(in1Pin, HIGH);
38         digitalWrite(in2Pin, LOW);
39     }
40     else {
41         digitalWrite(in1Pin, LOW);
42         digitalWrite(in2Pin, HIGH);
43     }
44     // Control motor rotation speed
45     ledcWrite(enable1Pin, spd);
46 }
```

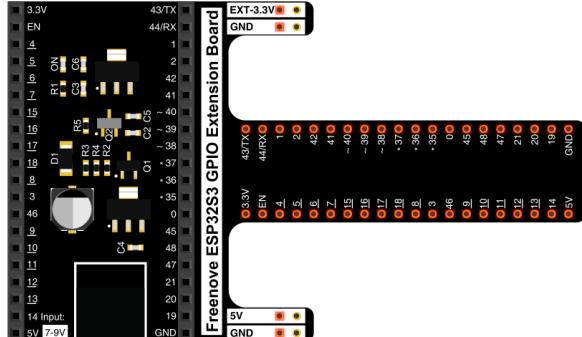
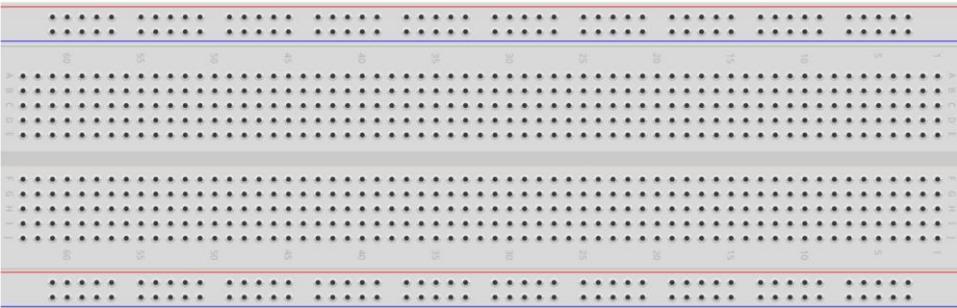
# Chapter 18 Servo

Previously, we learned how to control the speed and rotational direction of a motor. In this chapter, we will learn about servos which are a rotary actuator type motor that can be controlled to rotate to specific angles.

## Project 18.1 Servo Sweep

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

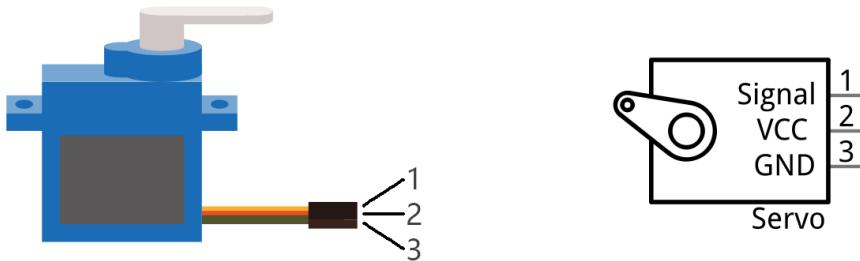
### Component List

ESP32-S3 WROOM 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 lasting time 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:

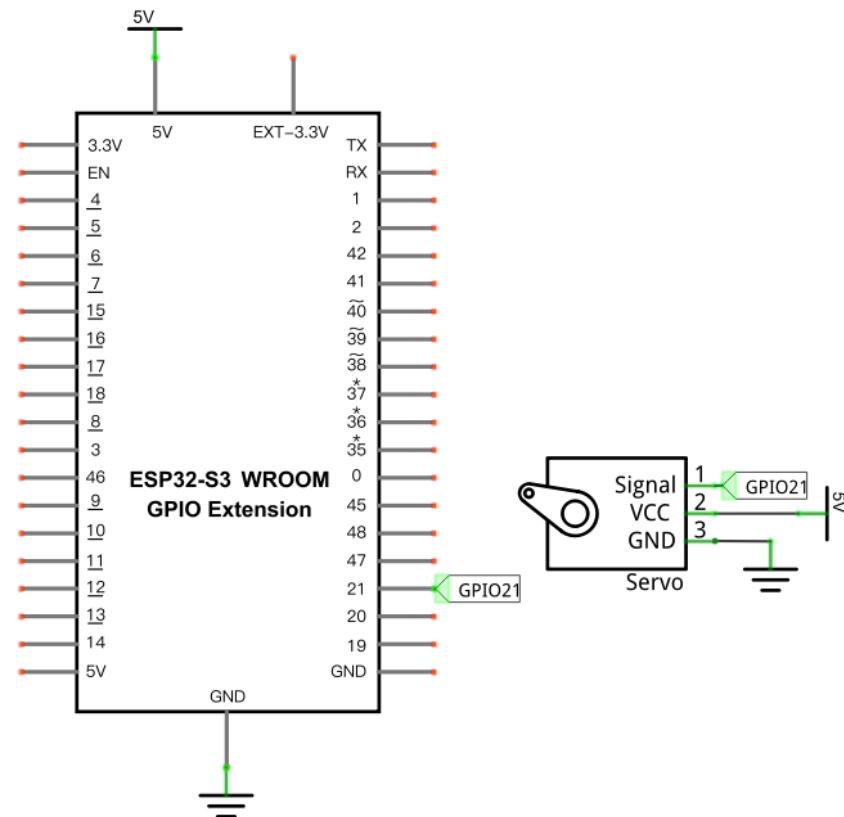
High level time	Servo angle
0.5ms	0 degree
1ms	45 degree
1.5ms	0 degree
2ms	45 degree
2.5ms	180 degree

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

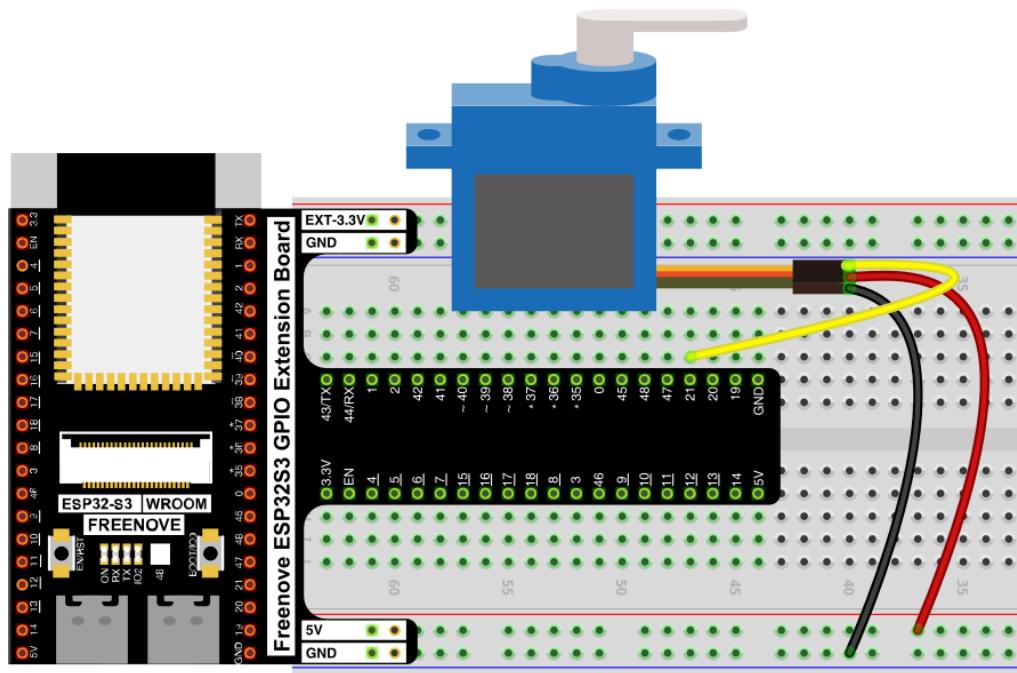
## Circuit

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



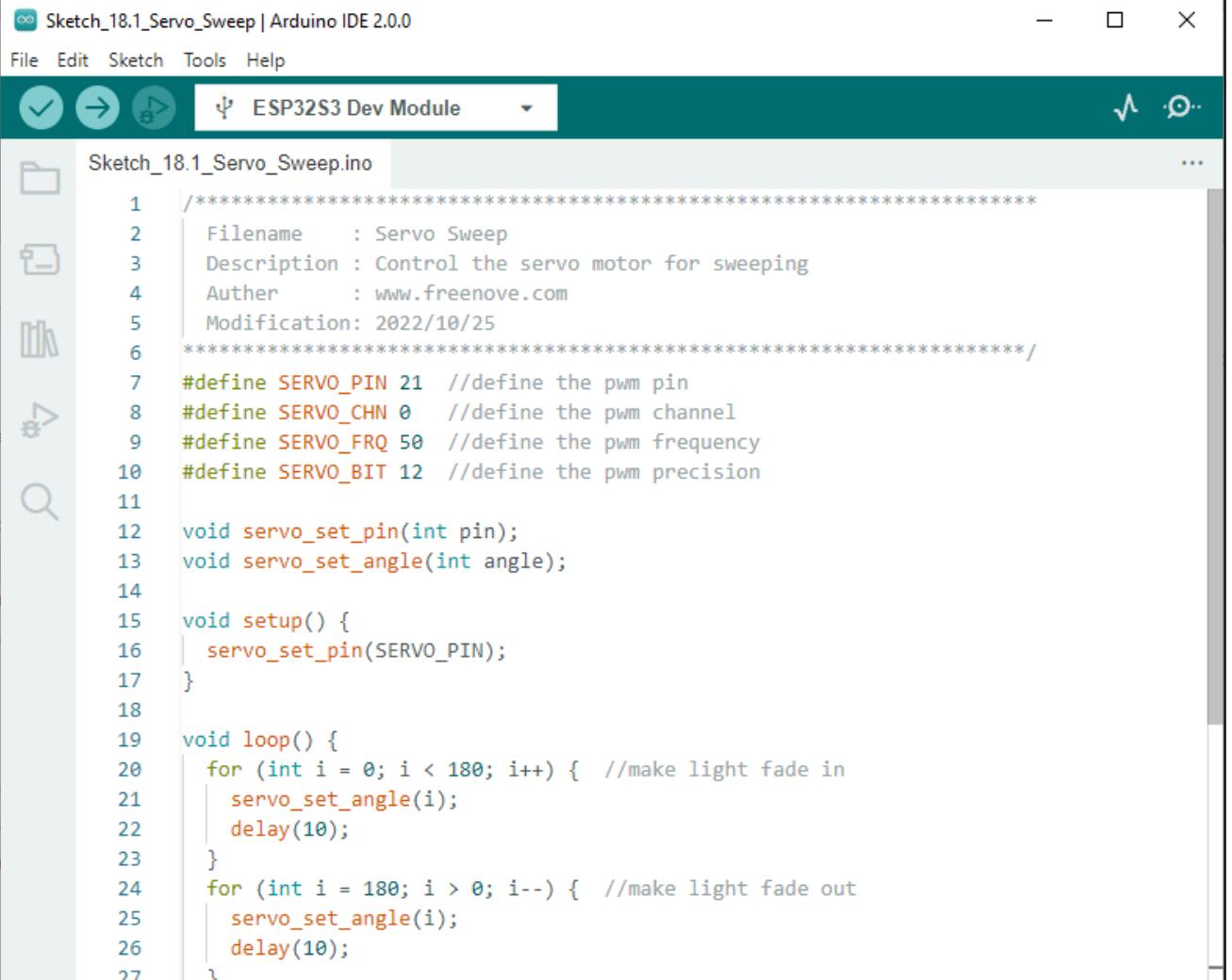
Hardware connection. If you need any support, please feel free to contact us via: [support@freenove.com](mailto:support@freenove.com)



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

## Sketch

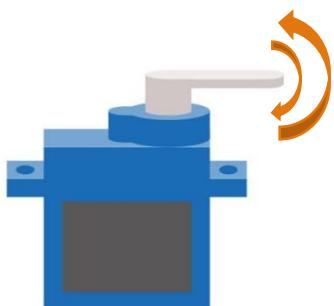
### Sketch\_18.1\_Servo\_Sweep



The screenshot shows the Arduino IDE interface with the title bar "Sketch\_18.1\_Servo\_Sweep | Arduino IDE 2.0.0". The menu bar includes File, Edit, Sketch, Tools, and Help. The toolbar has icons for save, upload, and refresh. The board selector dropdown shows "ESP32S3 Dev Module". The code editor contains the following sketch:

```
1 // ****
2 // Filename : Servo Sweep
3 // Description : Control the servo motor for sweeping
4 // Author : www.freenove.com
5 // Modification: 2022/10/25
6 // ****
7 #define SERVO_PIN 21 //define the pwm pin
8 #define SERVO_CHN 0 //define the pwm channel
9 #define SERVO_FRQ 50 //define the pwm frequency
10 #define SERVO_BIT 12 //define the pwm precision
11
12 void servo_set_pin(int pin);
13 void servo_set_angle(int angle);
14
15 void setup() {
16     servo_set_pin(SERVO_PIN);
17 }
18
19 void loop() {
20     for (int i = 0; i < 180; i++) { //make light fade in
21         servo_set_angle(i);
22         delay(10);
23     }
24     for (int i = 180; i > 0; i--) { //make light fade out
25         servo_set_angle(i);
26         delay(10);
27     }
}
```

Compile and upload the code to ESP32-S3 WROOM, 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 #define SERVO_PIN 21 //define the pwm pin
2 #define SERVO_CHN 0 //define the pwm channel
3 #define SERVO_FRQ 50 //define the pwm frequency
4 #define SERVO_BIT 12 //define the pwm precision
5 void servo_set_pin(int pin);
6 void servo_set_angle(int angle);
7
8 void setup() {
9     servo_set_pin(SERVO_PIN);
10 }
11
12 void loop() {
13     for (int i = 0; i < 180; i++) { //make light fade in
14         servo_set_angle(i);
15         delay(10);
16     }
17     for (int i = 180; i > 0; i--) { //make light fade out
18         servo_set_angle(i);
19         delay(10);
20     }
21 }
22
23 void servo_set_pin(int pin) {
24     ledcAttachChannel(pin, SERVO_FRQ, SERVO_BIT, SERVO_CHN);
25 }
26
27 void servo_set_angle(int angle) {
28     if (angle > 180 || angle < 0)
29         return;
30     long pwm_value = map(angle, 0, 180, 103, 512);
31     ledcWrite(SERVO_PIN, pwm_value);
32 }
```

Define the pins controlling Servo and the frequency and duty cycle of the signal.

```

1 #define SERVO_PIN 21 //define the pwm pin
2 #define SERVO_CHN 0 //define the pwm channel
3 #define SERVO_FRQ 50 //define the pwm frequency
4 #define SERVO_BIT 12 //define the pwm precision
```

Initialize Servo pin. Here, PWM control mode is used to control Servo motor.

```

23 void servo_set_pin(int pin) {
24     ledcAttachChannel(pin, SERVO_FRQ, SERVO_BIT, SERVO_CHN);
25 }
```



Write a function to control the rotation angle of Servo. The angle range is 0-180 degrees.

```
27 void servo_set_angle(int angle) {  
28     if (angle > 180 || angle < 0)  
29         return;  
30     long pwm_value = map(angle, 0, 180, 103, 512);  
31     ledcWrite(SERVO_PIN, pwm_value);  
32 }
```

Control the steering gear to rotate from 0 ° to 180 °, and then rotate from 180 ° to 0 °, and keep rotating circularly.

```
13 for (int i = 0; i < 180; i++) { //make light fade in  
14     servo_set_angle(i);  
15     delay(10);  
16 }  
17 for (int i = 180; i > 0; i--) { //make light fade out  
18     servo_set_angle(i);  
19     delay(10);  
20 }
```

## Project 18.2 Servo Knop

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

### Component List

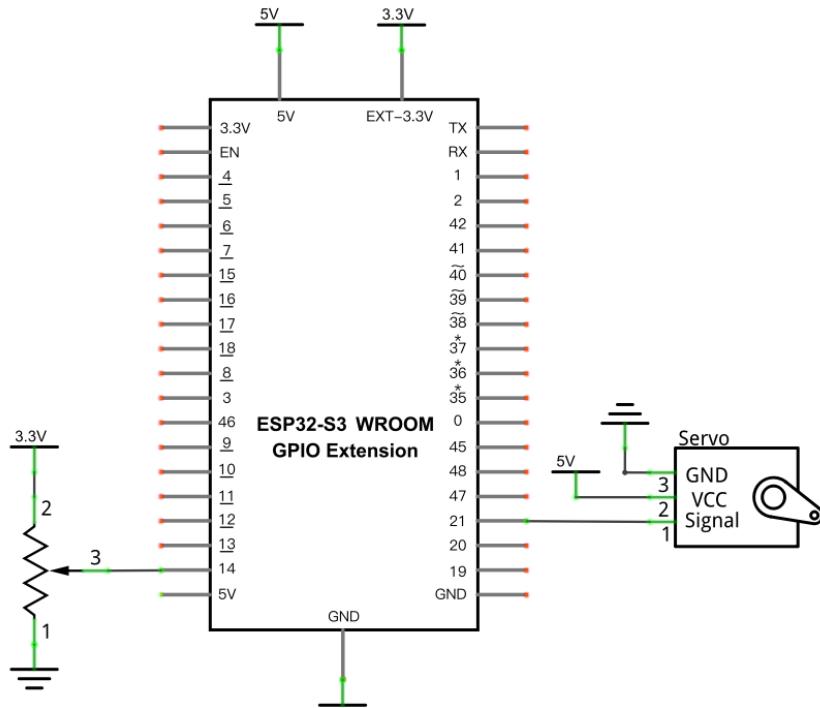
ESP32-S3 WROOM x1	GPIO Extension Board x1	
Breadboard x1		
Servo x1	Jumper M/M x6	Rotary potentiometer x1



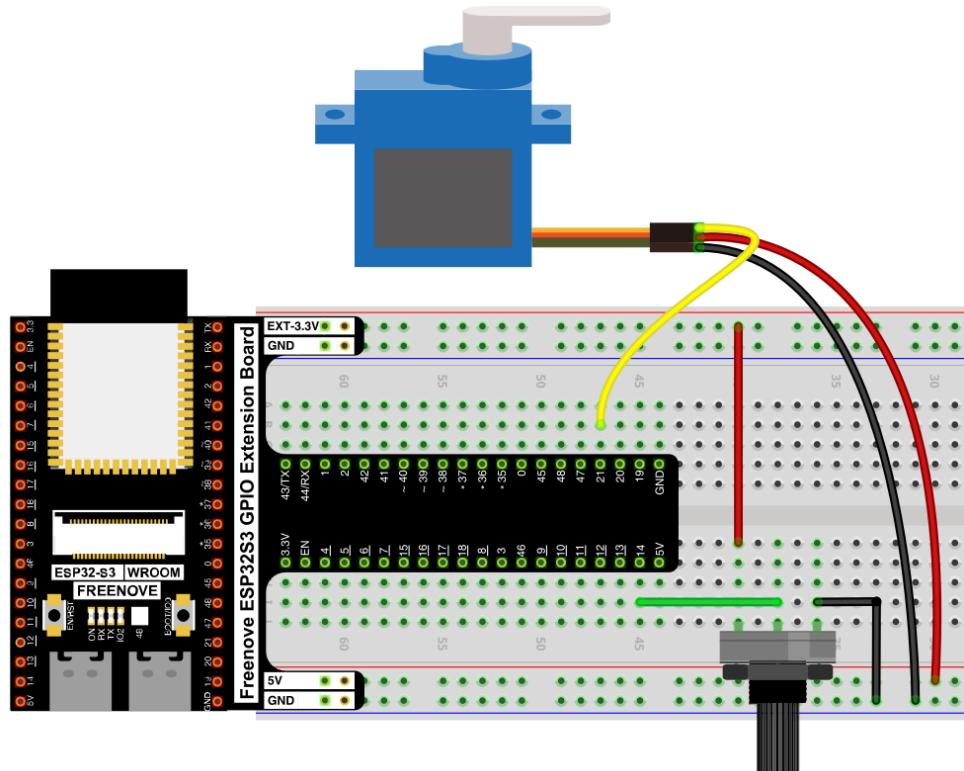
## Circuit

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



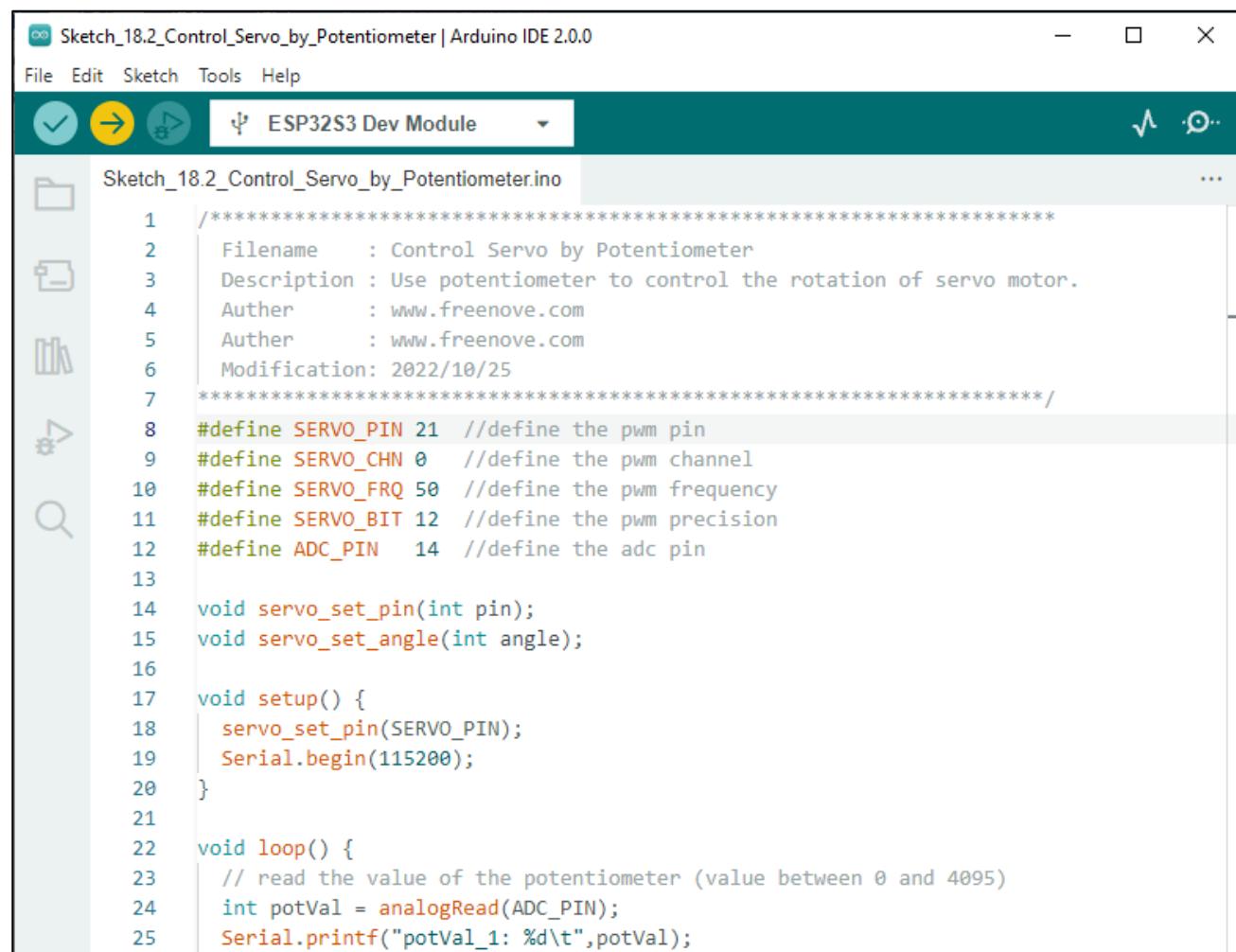
Hardware connection. If you need any support, please feel free to contact us via: [support@freenove.com](mailto:support@freenove.com)



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

## Sketch

### Sketch\_18.2\_Servo\_Sweep



```
Sketch_18.2_Control_Servo_by_Potentiometer.ino
1  ****
2  Filename      : Control Servo by Potentiometer
3  Description   : Use potentiometer to control the rotation of servo motor.
4  Author        : www.freenove.com
5  Author        : www.freenove.com
6  Modification: 2022/10/25
7  ****
8  #define SERVO_PIN 21 //define the pwm pin
9  #define SERVO_CHN 0 //define the pwm channel
10 #define SERVO_FRQ 50 //define the pwm frequency
11 #define SERVO_BIT 12 //define the pwm precision
12 #define ADC_PIN 14 //define the adc pin
13
14 void servo_set_pin(int pin);
15 void servo_set_angle(int angle);
16
17 void setup() {
18     servo_set_pin(SERVO_PIN);
19     Serial.begin(115200);
20 }
21
22 void loop() {
23     // read the value of the potentiometer (value between 0 and 4095)
24     int potVal = analogRead(ADC_PIN);
25     Serial.printf("potVal_1: %d\t",potVal);
```

Compile and upload the code to ESP32-S3 WROOM, twist the potentiometer back and forth, and the servo motor rotates accordingly.



The following is the program code:

```

1 #define SERVO_PIN 21 //define the pwm pin
2 #define SERVO_CHN 0 //define the pwm channel
3 #define SERVO_FRQ 50 //define the pwm frequency
4 #define SERVO_BIT 12 //define the pwm precision
5 #define ADC_PIN 14 //define the adc pin
6
7 void servo_set_pin(int pin);
8 void servo_set_angle(int angle);
9
10 void setup() {
11     servo_set_pin(SERVO_PIN);
12     Serial.begin(115200);
13 }
14
15 void loop() {
16     // read the value of the potentiometer (value between 0 and 4095)
17     int potVal = analogRead(ADC_PIN);
18     Serial.printf("potVal_1: %d\t", potVal);
19     // scale it to use it with the servo (value between 0 and 180)
20     potVal = map(potVal, 0, 4095, 0, 180);
21     // set the servo position according to the scaled value
22     servo_set_angle(potVal);
23     Serial.printf("potVal_2: %d\r\n", potVal);
24     delay(15); // wait for the servo to get there
25 }
26
27 void servo_set_pin(int pin) {
28     ledcAttachChannel(pin, SERVO_FRQ, SERVO_BIT, SERVO_CHN);
29 }
30
31 void servo_set_angle(int angle) {
32     if (angle > 180 || angle < 0)
33         return;
34     long pwm_value = map(angle, 0, 180, 103, 512);
35     ledcWrite(SERVO_PIN, pwm_value);
36 }
```

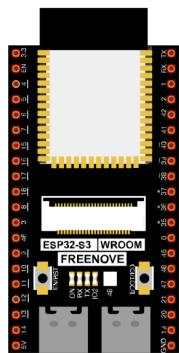
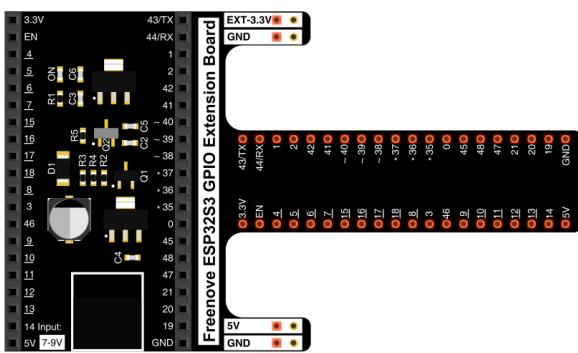
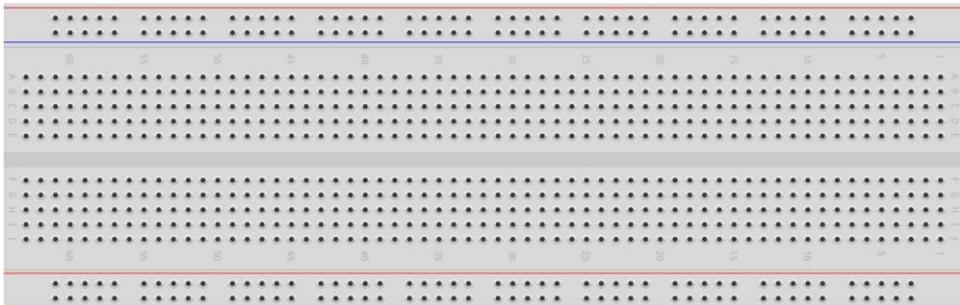
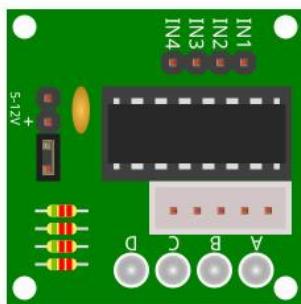
In this experiment, we obtain the ADC value of the potentiometer and store it in potVal. Use map function to convert it into corresponding angle value and we can control the motor to rotate to a specified angle, and print the value via serial.

# Chapter 19 Stepper Motor

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

## Project 19.1 Stepper Motor

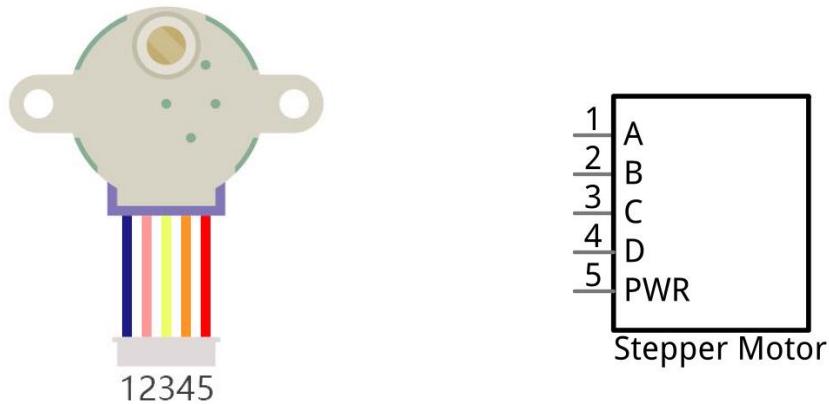
### Component List

ESP32-S3 WROOM x1	GPIO Extension Board x1
	
Breadboard x1	
Stepper Motor x1	ULN2003 Stepper Motor Driver x1
	
	Jumper F/M x6
	

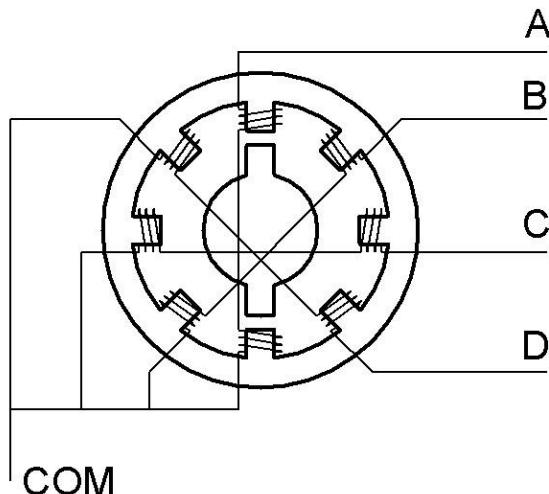
## Component knowledge

### Stepper Motor

Stepper motors are an open-loop control device, which converts an electronic pulse signal into angular displacement or linear displacement. In a non-overload condition, the speed of the motor and the location of the stops depends only on the pulse signal frequency and number of pulses and is not affected by changes in load as with a DC motor. A small four-phase deceleration stepper motor is shown here:

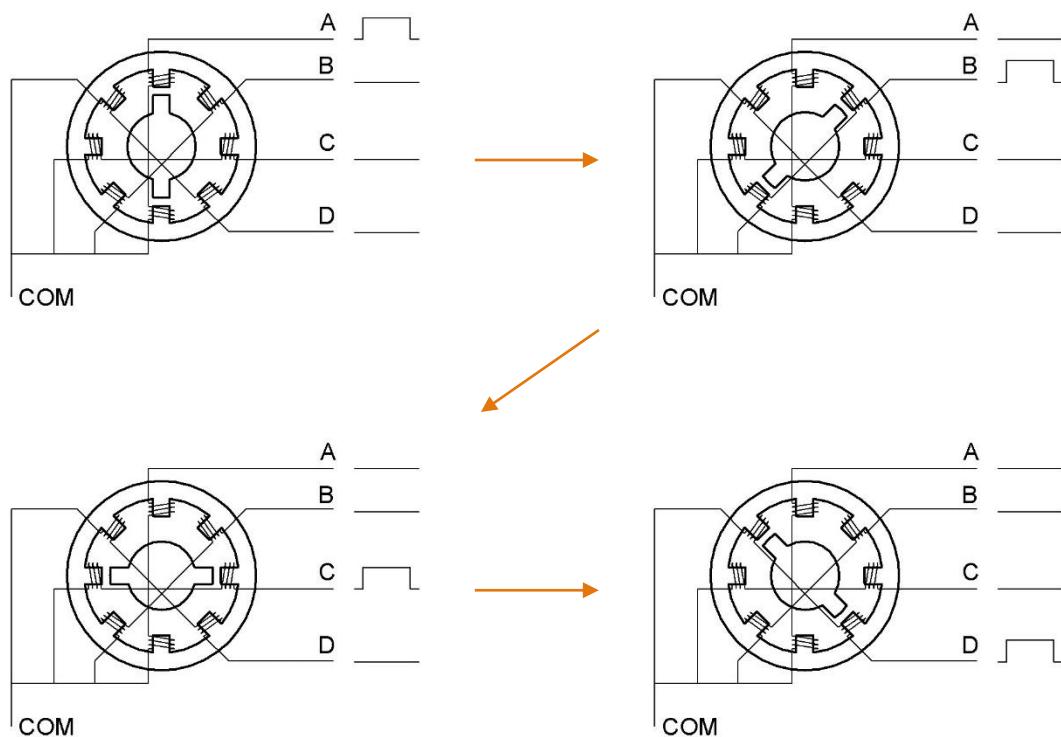


The electronic schematic diagram of a four-phase stepper motor is shown below:



The outside case or housing of the stepper motor is the stator and inside the stator is the rotor. There are a specific number of individual coils, usually an integer multiple of the number of phases the motor has, when the stator is powered ON, an electromagnetic field will be formed to attract a corresponding convex diagonal groove or indentation in the rotor's surface. The rotor is usually made of iron or a permanent magnet. Therefore, the stepper motor can be driven by powering the coils on the stator in an ordered sequence (producing a series of "steps" or stepped movements).

A common driving process is as follows:



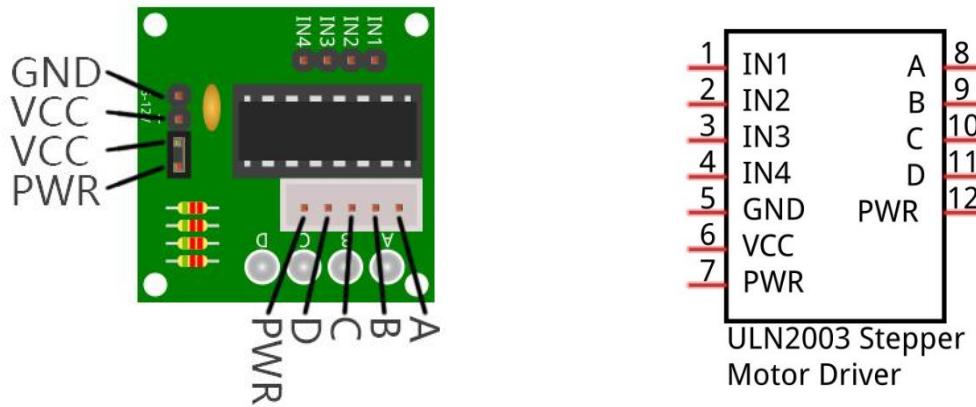
In the course above, the stepper motor rotates a certain angle once, which is called a step. By controlling the number of rotation steps, you can control the stepper motor rotation angle. By controlling the time between two steps, you can control the stepper motor rotation speed. When rotating clockwise,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

There are other methods to control stepper motors, such as: connect A phase, then connect A B phase, the stator will be located in the center of A B, which is called a half-step. This method can improve the stability of the stepper motor and reduces noise. The sequence of powering the coils looks like this: A→ AB→ B →BC→ C →CD→ D→ DA→ A→…… , the rotor will rotate in accordance to this sequence at a half-step at a time, called four-steps, eight-part. Conversely, if the coils are powered ON in the reverse order the stepper motor will rotate in the opposite direction.

The stator in the stepper motor we have supplied has 32 magnetic poles. Therefore, to complete one full revolution requires 32 full steps. The rotor (or output shaft) of the stepper motor is connected to a speed reduction set of gears and the reduction ratio is 1:64. Therefore, the final output shaft (exiting the stepper motor's housing) requires  $32 \times 64 = 2048$  steps to make one full revolution.

### ULN2003 Stepper motor driver

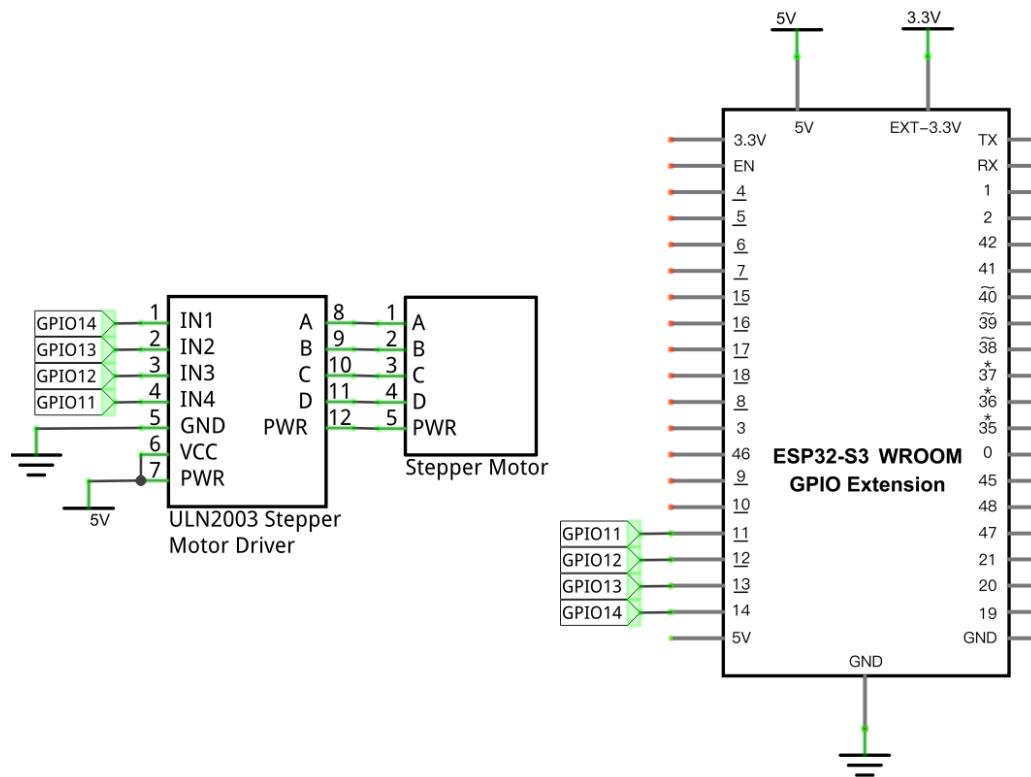
A ULN2003 stepper motor driver is used to convert weak signals into more powerful control signals in order to drive the stepper motor. In the illustration below, the input signal IN1-IN4 corresponds to the output signal A-D, and 4 LEDs are integrated into the board to indicate the state of these signals. The PWR interface can be used as a power supply for the stepper motor. By default, PWR and VCC are connected.



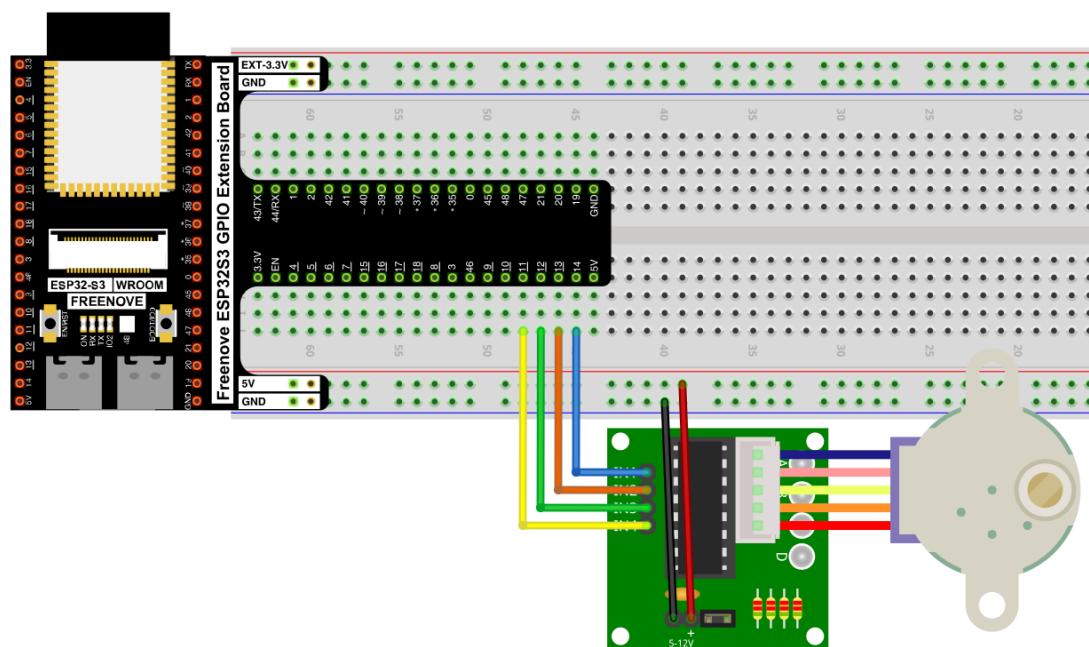
## Circuit

When building the circuit, note that rated voltage of the stepper motor is 5V, and we need to use the breadboard power supply independently. Additionally, the breadboard power supply needs to share Ground with ESP32-S3.

Schematic diagram



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





## Sketch

This code uses the four-step, four-part mode to drive the stepper motor in the clockwise and anticlockwise directions.

### Sketch\_19.1\_Drive\_Stepper\_Motor

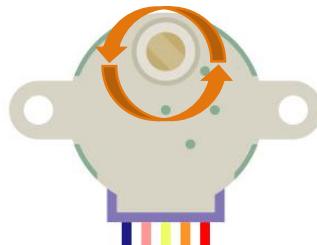
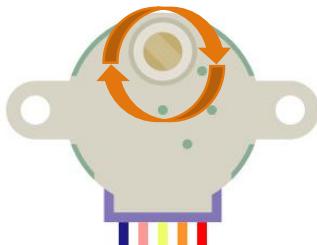
The screenshot shows the Arduino IDE interface with the following details:

- Title Bar:** Sketch\_19.1\_Drive\_Stepper\_Motor | Arduino IDE 2.0.0
- Menu Bar:** File Edit Sketch Tools Help
- Toolbar:** Includes icons for Save, Run, Stop, and a dropdown for ESP32S3 Dev Module.
- Code Editor:** Displays the `Sketch_19.1_Drive_Stepper_Motor.ino` file content. The code is a C++ program for driving a stepper motor using the ULN2003 driver. It sets up pins 14, 13, 12, and 11 as outputs and rotates the motor 3 full turns in both directions.
- Output Window:** Shows the terminal output for the upload process:

```
writing at 0x00027c11... (58 %)
Writing at 0x0002d277... (62 %)
Writing at 0x00034226... (75 %)
Writing at 0x0003dd21... (87 %)
Writing at 0x00043374... (100 %)
Wrote 228240 bytes (127129 compressed) at 0x00010000 in 3.2 seconds (effective 572.8 kbit/s)...
Hash of data verified.

Leaving...
Hard resetting via RTS pin...
```
- Status Bar:** Ln 56, Col 39 UTF-8 ESP32S3 Dev Module on COM3 3

Compile and upload the code to the ESP32-S3 WROOM, the stepper motor will rotate 360° clockwise and stop for 1s, and then rotate 360° anticlockwise and stop for 1s. And it will repeat this action in an endless loop.



The following is the program code:

```
1 // Connect the port of the stepper motor driver
2 int outPorts[] = {14, 13, 12, 11};
3
4 void setup() {
5     // set pins to output
6     for (int i = 0; i < 4; i++) {
7         pinMode(outPorts[i], OUTPUT);
8     }
9 }
10
11 void loop() {
12     // Rotate a full turn
13     moveSteps(true, 32 * 64, 3);
14     delay(1000);
15     // Rotate a full turn towards another direction
16     moveSteps(false, 32 * 64, 3);
17     delay(1000);
18 }
19
20 //Suggestion: the motor turns precisely when the ms range is between 3 and 20
21 void moveSteps(bool dir, int steps, byte ms) {
22     for (unsigned long i = 0; i < steps; i++) {
23         moveOneStep(dir); // Rotate a step
24         delay(constrain(ms, 3, 20)); // Control the speed
25     }
26 }
27
28 void moveOneStep(bool dir) {
29     // Define a variable, use four low bit to indicate the state of port
30     static byte out = 0x01;
31     // Decide the shift direction according to the rotation direction
32     if (dir) { // ring shift left
33         out != 0x08 ? out = out << 1 : out = 0x01;
34     }
```

```

35     else {      // ring shift right
36         out != 0x01 ? out = out >> 1 : out = 0x08;
37     }
38     // Output singal to each port
39     for (int i = 0; i < 4; i++) {
40         digitalWrite(outPorts[i], (out & (0x01 << i)) ? HIGH : LOW);
41     }
42 }
43
44 void moveAround(bool dir, int turns, byte ms){
45     for(int i=0;i<turns;i++)
46         moveSteps(dir, 32*64, ms);
47 }
48 void moveAngle(bool dir, int angle, byte ms){
49     moveSteps(dir, (angle*32*64/360), ms);
50 }
```

In this project, we define four pins to drive stepper motor.

```

1 // Connect the port of the stepper motor driver
2 int outPorts[] = {14, 13, 12, 11};
```

moveOneStep Function is used to drive the stepper motor to rotate clockwise or counterclockwise. The parameter "dir" indicates the direction of rotation. If "dir" returns true, the stepper motor rotates clockwise, otherwise the stepper motor rotates counterclockwise.

```

28 void moveOneStep(bool dir) {
...
42 }
```

Define a static byte variable, calculate the value of the variable according to the rotation direction of the motor, and use the keyword static to save the position status of the previous step of the stepper motor. Use the four low bits of the variable to control the output state of the four pins.

```

29 // Define a variable, use four low bit to indicate the state of port
30 static byte out = 0x01;
31 // Decide the shift direction according to the rotation direction
32 if(dir){ // ring shift left
33     out != 0x08 ? out = out << 1 : out = 0x01;
34 }
35 else {      // ring shift right
36     out != 0x01 ? out = out >> 1 : out = 0x08;
37 }
```

Make the pin to output corresponding level based on the value of the variable.

```

38 // Output singal to each port
39 for (int i = 0; i < 4; i++) {
40     digitalWrite(outPorts[i], (out & (0x01 << i)) ? HIGH : LOW);
41 }
```

The moveSteps function can control the direction of the stepper motor, the number of rotation steps, and the speed of rotation. According to the previous knowledge, the stepper motor needs 32\*64 steps for one revolution. The speed of rotation is determined by the parameter ms. The larger the ms is, the slower the rotation speed is. There is a range for the speed of the motor, which is determined by the motor itself and according to our test, the value of ms is limited to 3-20.

```

20 //Suggestion: the motor turns precisely when the ms range is between 3 and 20
21 void moveSteps(bool dir, int steps, byte ms) {
22     for (unsigned long i = 0; i < steps; i++) {
23         moveOneStep(dir); // Rotate a step
24         delay(constrain(ms, 3, 20)); // Control the speed
25     }
26 }
```

The function moveTurns() is a further package of moveSteps(), which is used to control the stepper motor to rotate a specified number of turns. The parameter "turns" represents the number of turns that need to be rotated.

```

44 void moveAround(bool dir, int turns, byte ms) {
45     for(int i=0;i<turns;i++)
46         moveSteps(dir, 32*64, ms);
47 }
```

The function moveAround () is a further package of moveSteps (), which is used to control the stepper motor to rotate by a specified angle, and the parameter "angle" represents the angle to be rotated.

```

48 void moveAngle(bool dir, int angle, byte ms) {
49     moveSteps(dir, (angle*32*64/360), ms);
50 }
```

In the loop function, call the moveSteps function to loop the stepper motor: rotate clockwise one turn and stop for 1s, then rotate counterclockwise one turn and stop for 1s.

```

11 void loop() {
12     // Rotate a full turn
13     moveSteps(true, 32 * 64, 3);
14     delay(1000);
15     // Rotate a full turn towards another direction
16     moveSteps(false, 32 * 64, 3);
17     delay(1000);
18 }
```

# Chapter 20 LCD1602

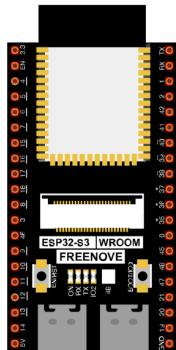
In this chapter, we will learn about the LCD1602 Display Screen

## Project 20.1 LCD1602

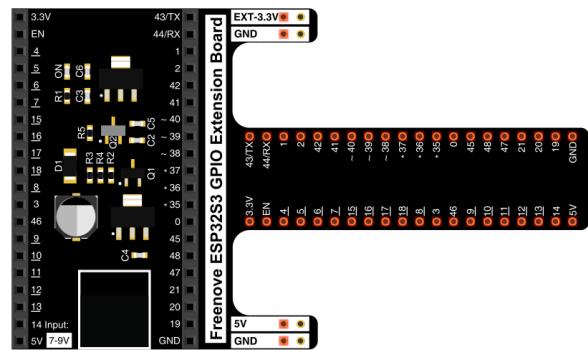
In this section we learn how to use LCD1602 to display something.

### Component List

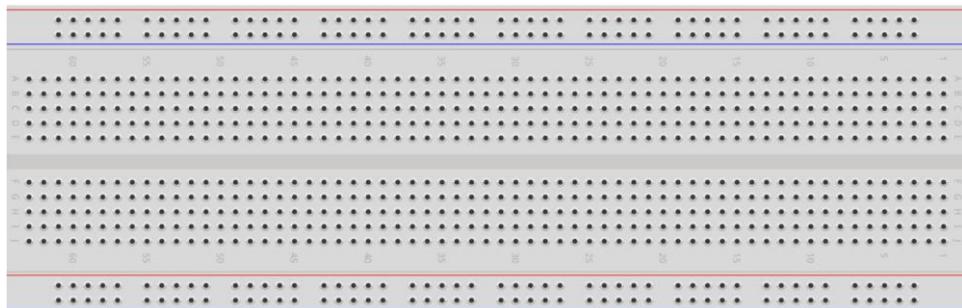
ESP32-S3 WROOM x1



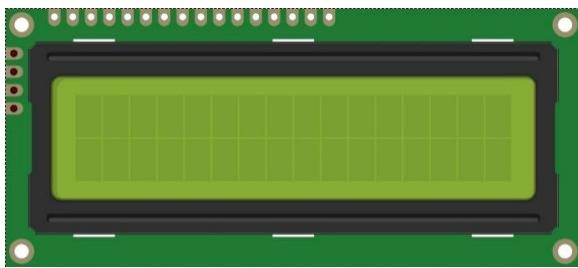
GPIO Extension Board x1



Breadboard x1



LCD1602 Module x1



Jumper F/M x4



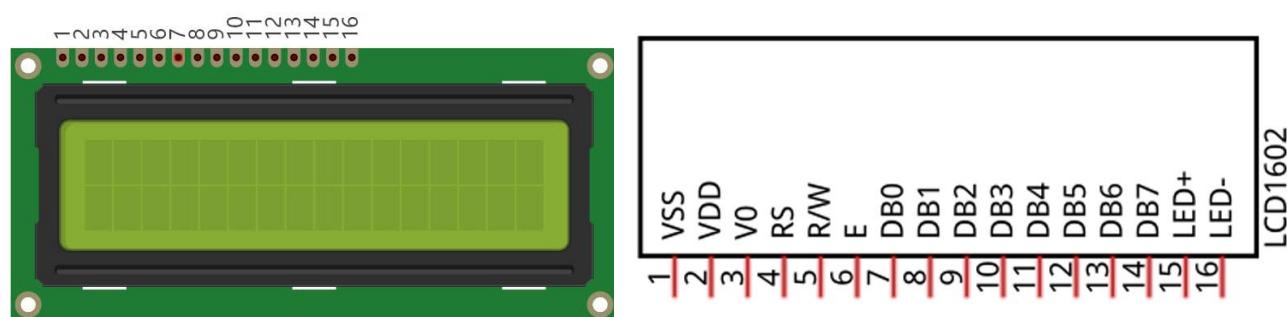
## Component knowledge

### I2C communication

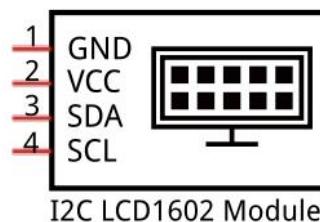
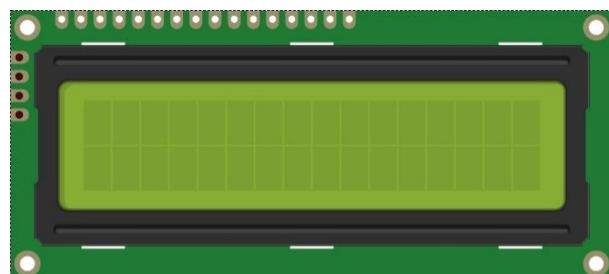
I2C (Inter-Integrated Circuit) is a two-wire serial communication mode, which can be used for the connection of micro controllers and their peripheral equipment. Devices using I2C communication must be connected to the serial data (SDA) line, and serial clock (SCL) line (called I2C bus). Each device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

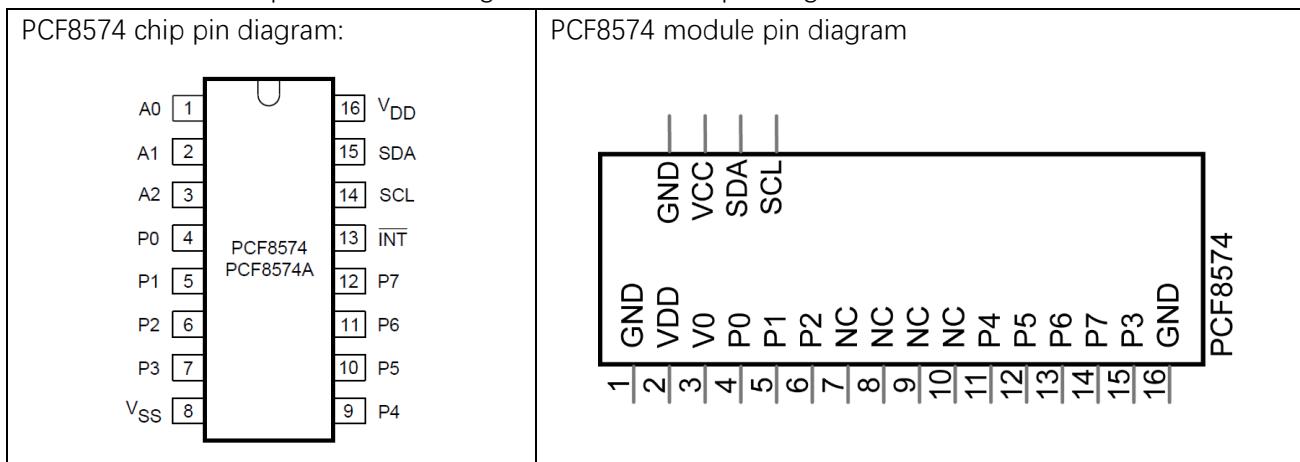


I2C LCD1602 display screen integrates a I2C interface, which connects the serial-input & parallel-output module to the LCD1602 display screen. This allows us to only use 4 lines to operate the LCD1602.

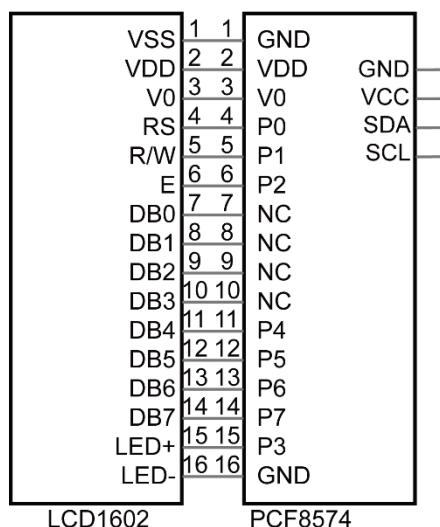


The serial-to-parallel IC chip used in this module is PCF8574T (PCF8574AT), and its default I2C address is 0x27(0x3F).

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



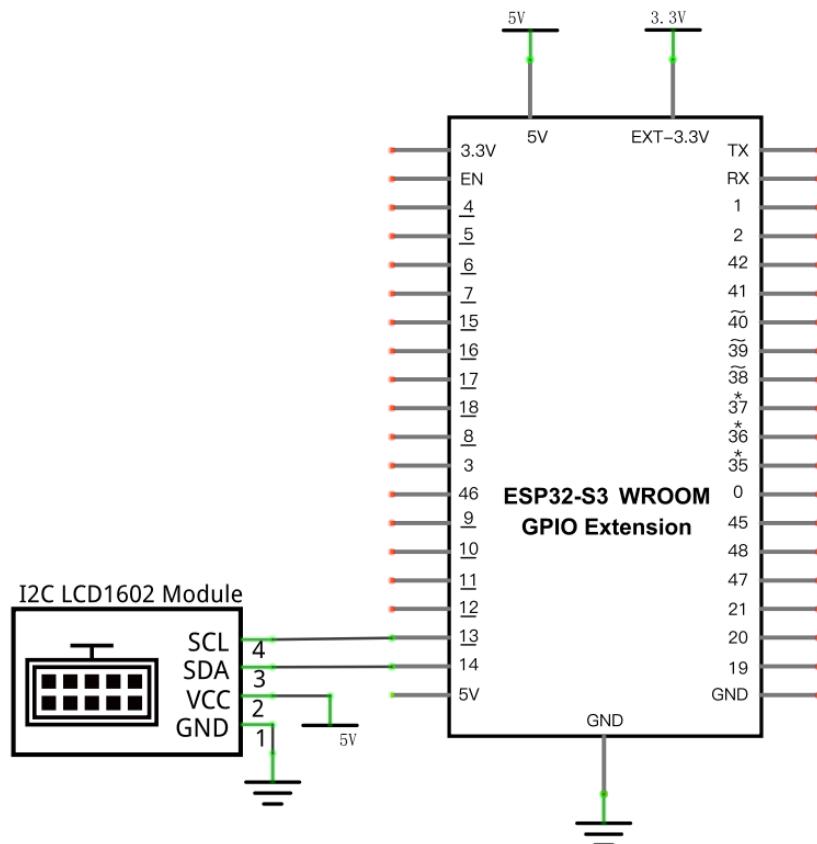
PCF8574 module pin and LCD1602 pin are corresponding to each other and connected with each other:



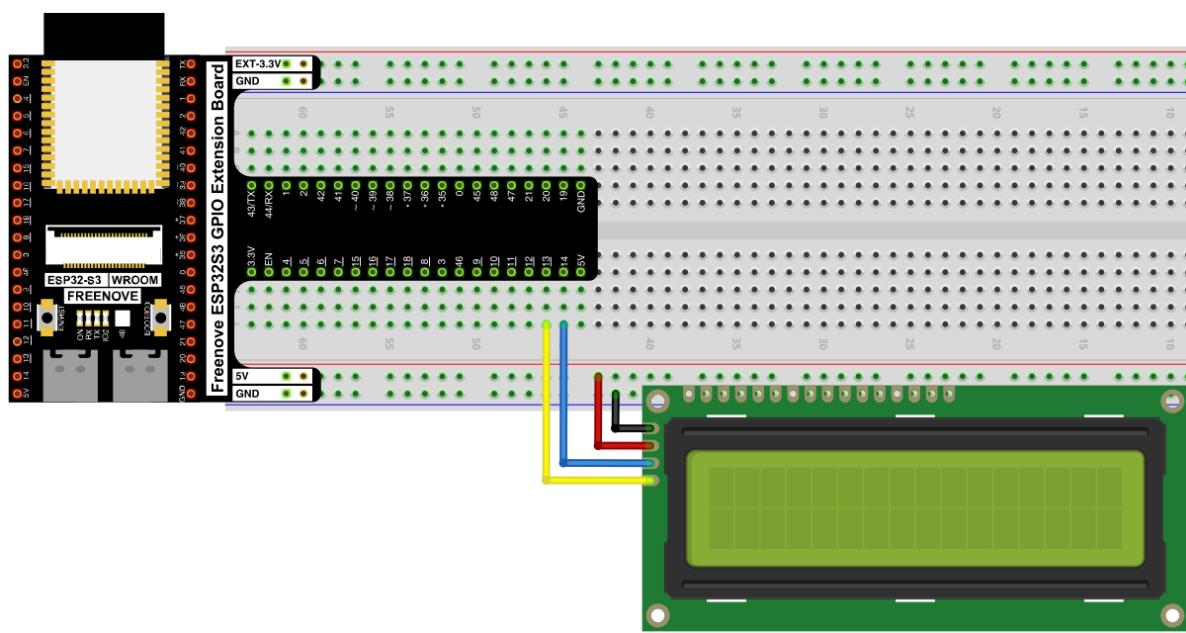
So we only need 4 pins to control the 16 pins of the LCD1602 display screen through the I<sub>2</sub>C interface. In this project, we will use the I<sub>2</sub>C LCD1602 to display some static characters and dynamic variables.

## Circuit

Schematic diagram



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



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

## Sketch

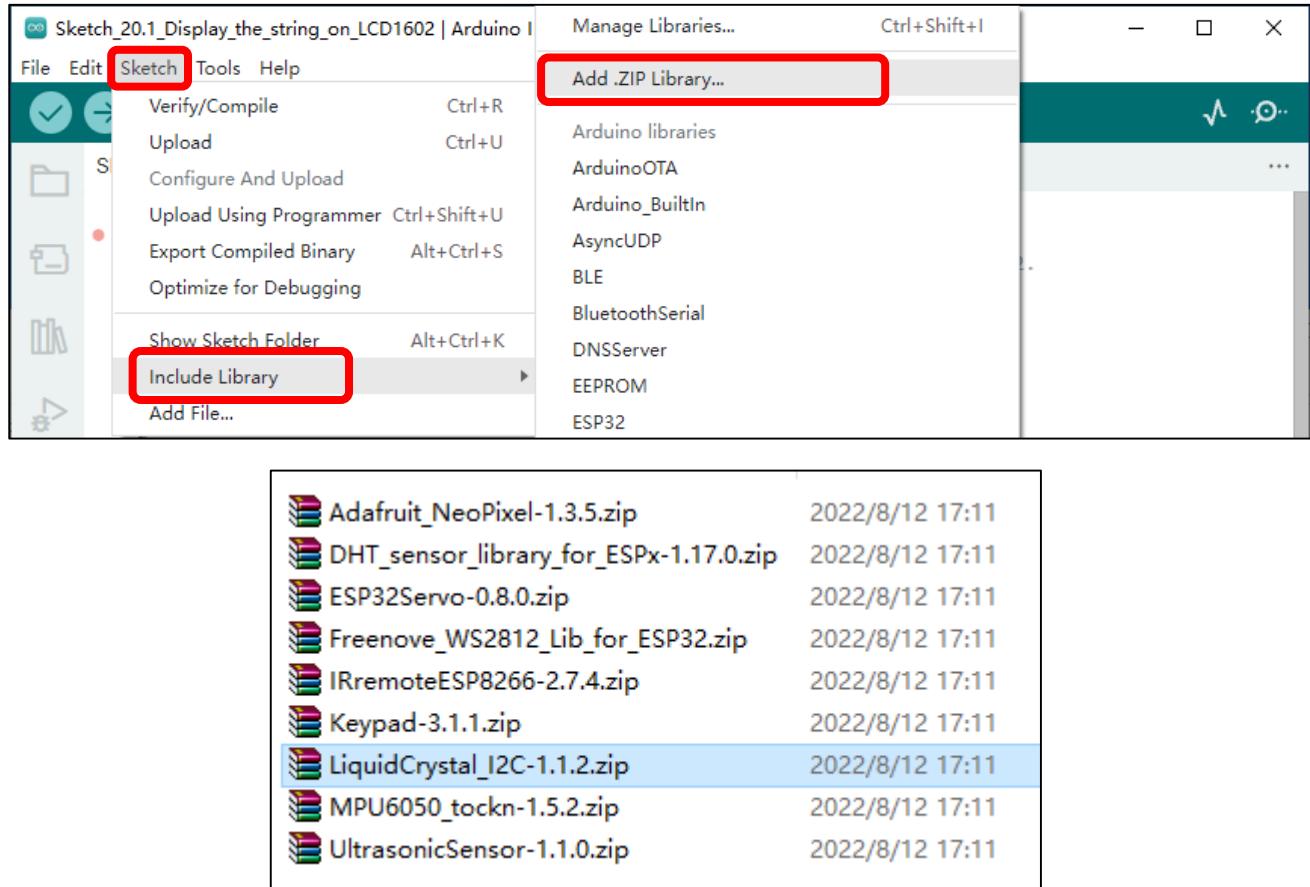
### How to install the library

We use the third party library LiquidCrystal I2C. If you haven't installed it yet, please do so before learning.

The steps to add third-party Libraries are as follows:

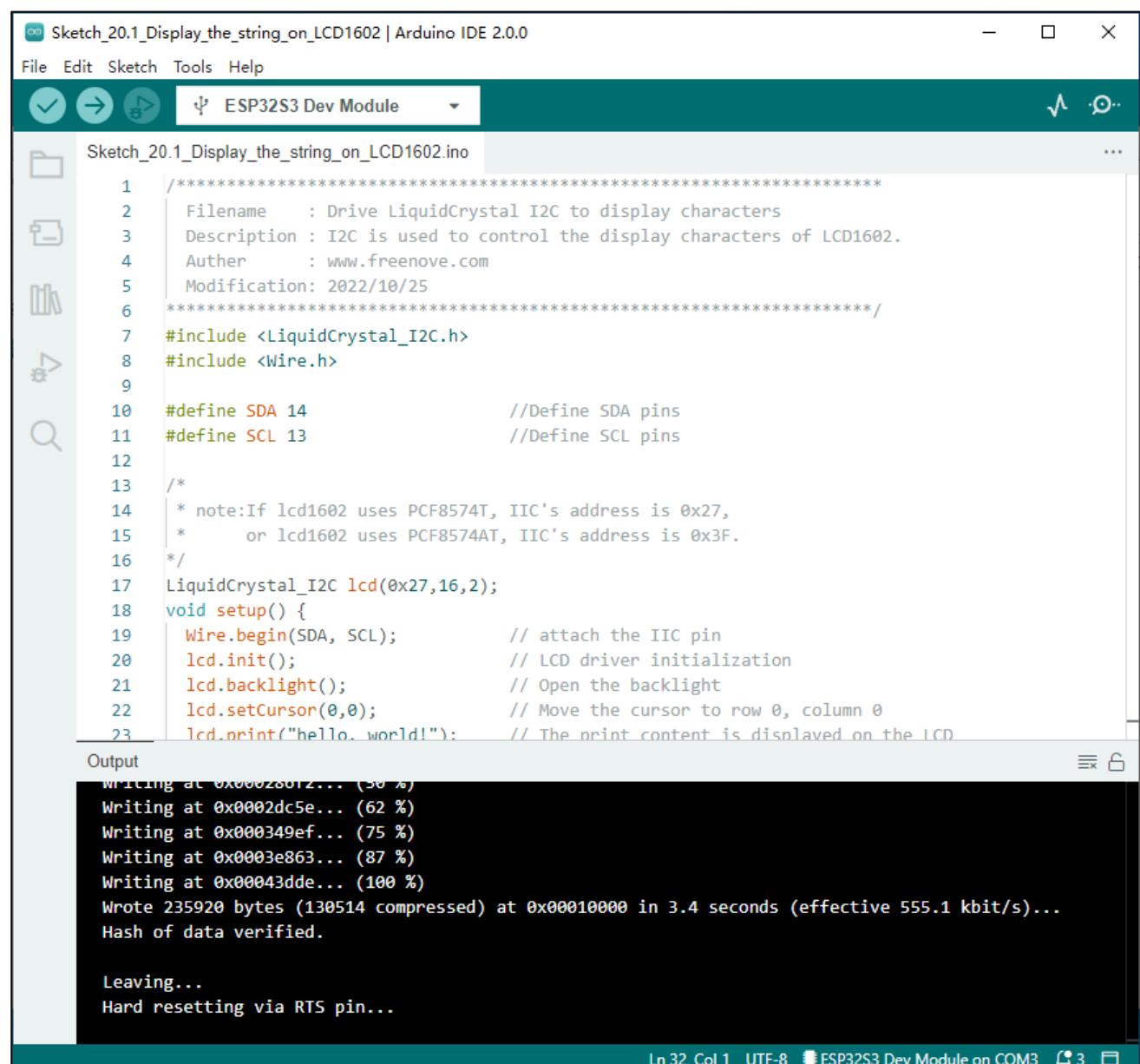
open arduino->Sketch->Include library-> Add .zip Library....

Select "Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32\_S3\CLibraries\LiquidCrystal\_I2C.zip" for installation.



Use I2C LCD 1602 to display characters and variables.

### Sketch\_20.1\_Display\_the\_string\_on\_LCD1602



The screenshot shows the Arduino IDE interface with the following details:

- Title Bar:** Sketch\_20.1\_Display\_the\_string\_on\_LCD1602 | Arduino IDE 2.0.0
- Toolbar:** File, Edit, Sketch, Tools, Help
- Sketch Selection:** ESP32S3 Dev Module
- Code Area:**

```

1 // ****
2 // Filename : Drive LiquidCrystal I2C to display characters
3 // Description : I2C is used to control the display characters of LCD1602.
4 // Author : www.freenove.com
5 // Modification: 2022/10/25
6 ****
7 #include <LiquidCrystal_I2C.h>
8 #include <Wire.h>
9
10 #define SDA 14           //Define SDA pins
11 #define SCL 13           //Define SCL pins
12
13 /*
14  * note:If lcd1602 uses PCF8574T, IIC's address is 0x27,
15  *       or lcd1602 uses PCF8574AT, IIC's address is 0x3F.
16 */
17 LiquidCrystal_I2C lcd(0x27,16,2);
18 void setup() {
19     Wire.begin(SDA, SCL);          // attach the IIC pin
20     lcd.init();                  // LCD driver initialization
21     lcd.backlight();             // Open the backlight
22     lcd.setCursor(0,0);          // Move the cursor to row 0, column 0
23     lcd.print("Hello, world!");   // The print content is displayed on the LCD

```
- Output Area:**

```

Writing at 0x00028012... (50 %)
Writing at 0x0002dc5e... (62 %)
Writing at 0x000349ef... (75 %)
Writing at 0x0003e863... (87 %)
Writing at 0x00043dde... (100 %)
Wrote 235920 bytes (130514 compressed) at 0x00010000 in 3.4 seconds (effective 555.1 kbit/s)...
Hash of data verified.

Leaving...
Hard resetting via RTS pin...

```
- Status Bar:** Ln 32, Col 1 UTF-8 ■ ESP32S3 Dev Module on COM3

Compile and upload the code to ESP32-S3 WROOM and the LCD1602 displays characters.



The following is the program code:

```

1 #include <LiquidCrystal_I2C.h>
2 #include <Wire.h>
3
4 #define SDA 14           //Define SDA pins
5 #define SCL 13           //Define SCL pins
6
7 /*
8  * note:If lcd1602 uses PCF8574T, IIC's address is 0x27,
9  *       or lcd1602 uses PCF8574AT, IIC's address is 0x3F.
10 */
11 LiquidCrystal_I2C lcd(0x27, 16, 2);
12 void setup() {
13     Wire.begin(SDA, SCL);           // attach the IIC pin
14     if (!i2CAddrTest(0x27)) {
15         lcd = LiquidCrystal_I2C(0x3F, 16, 2);
16     }
17     lcd.init();                   // LCD driver initialization
18     lcd.backlight();             // Open the backlight
19     lcd.setCursor(0, 0);          // Move the cursor to row 0, column 0
20     lcd.print("hello, world!");   // The print content is displayed on the LCD
21 }
22
23 void loop() {
24     lcd.setCursor(0, 1);          // Move the cursor to row 1, column 0
25     lcd.print("Counter:");        // The count is displayed every second
26     lcd.print(millis() / 1000);
27     delay(1000);
28 }
29
30 bool i2CAddrTest(uint8_t addr) {
31     Wire.beginTransmission(addr);
32     if (Wire.endTransmission() == 0) {
33         return true;
34     }
35     return false;
36 }
```

Include header file of Liquid Crystal Display (LCD)1602 and I2C.

```

1 #include <LiquidCrystal_I2C.h>
2 #include <Wire.h>
```

**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.**

```

13     Wire.begin(SDA, SCL);           // attach the IIC pin
14     if (!i2CAddrTest(0x27)) {
```

```

15     lcd = LiquidCrystal_I2C(0x3F, 16, 2);
16 }
```

Initialize LCD1602 and turn on the backlight of LCD.

```

17     lcd.init();           // LCD driver initialization
18     lcd.backlight();      // Turn on the backlight
```

Move the cursor to the first row, first column, and then display the character.

```

19     lcd.setCursor(0,0);    // Move the cursor to row 0, column 0
20     lcd.print("hello, world!"); // The print content is displayed on the LCD
```

Print the number on the second line of LCD1602.

```

23 void loop() {
24     lcd.setCursor(0,1);      // Move the cursor to row 1, column 0
25     lcd.print("Counter:");   // The count is displayed every second
26     lcd.print(millis() / 1000);
27     delay(1000);
28 }
```

Check whether the I2C address is responded by a device.

```

30 bool i2CAddrTest(uint8_t addr) {
31     Wire.beginTransmission(addr);
32     if (Wire.endTransmission() == 0) {
33         return true;
34     }
35     return false;
36 }
```

## Reference

### class LiquidCrystal

The LiquidCrystal class can manipulate common LCD screens. The first step is defining an object of LiquidCrystal, for example:

```
LiquidCrystal_I2C lcd(0x27, 16, 2);
```

Instantiate the Lcd1602 and set the I2C address to 0x27, with 16 columns per row and 2 rows per column.

```

init();
    Initializes the Lcd1602's device
backlight();
    Turn on Lcd1602's backlight.
setCursor(column, row);
    Sets the screen's column and row.
    column: The range is 0 to 15.
    row: The range is 0 to 1.
print(String);
    Print the character string on Lcd1602
```



# Chapter 21 Ultrasonic Ranging

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

## Project 21.1 Ultrasonic Ranging

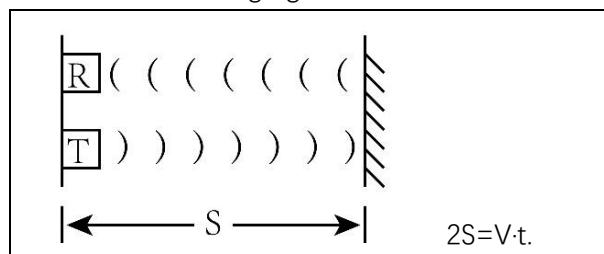
In this project, we use ultrasonic ranging module to measure distance, and print out the data in the terminal.

### Component List

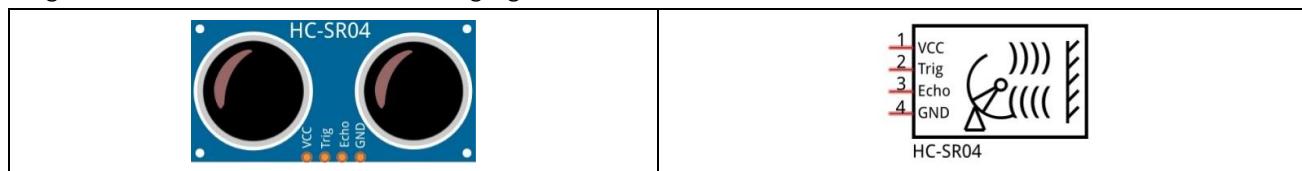
ESP32-S3 WROOM x1	GPIO Extension Board x1
Breadboard x1	
Jumper F/M x4	HC SR04 x1

## Component Knowledge

The ultrasonic ranging module uses the principle that ultrasonic waves will be sent back when encounter obstacles. We can measure the distance by counting the time interval between sending and receiving of the ultrasonic waves, and the time difference 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, 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:

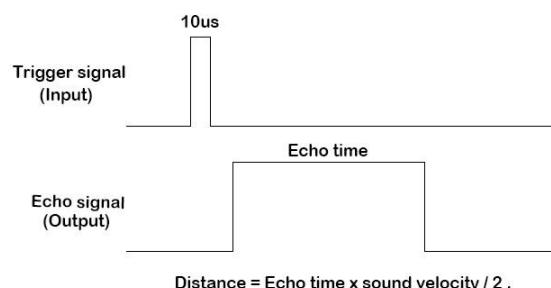
Working voltage: 5V

Working current: 12mA

Minimum measured distance: 2cm

Maximum measured distance: 200cm

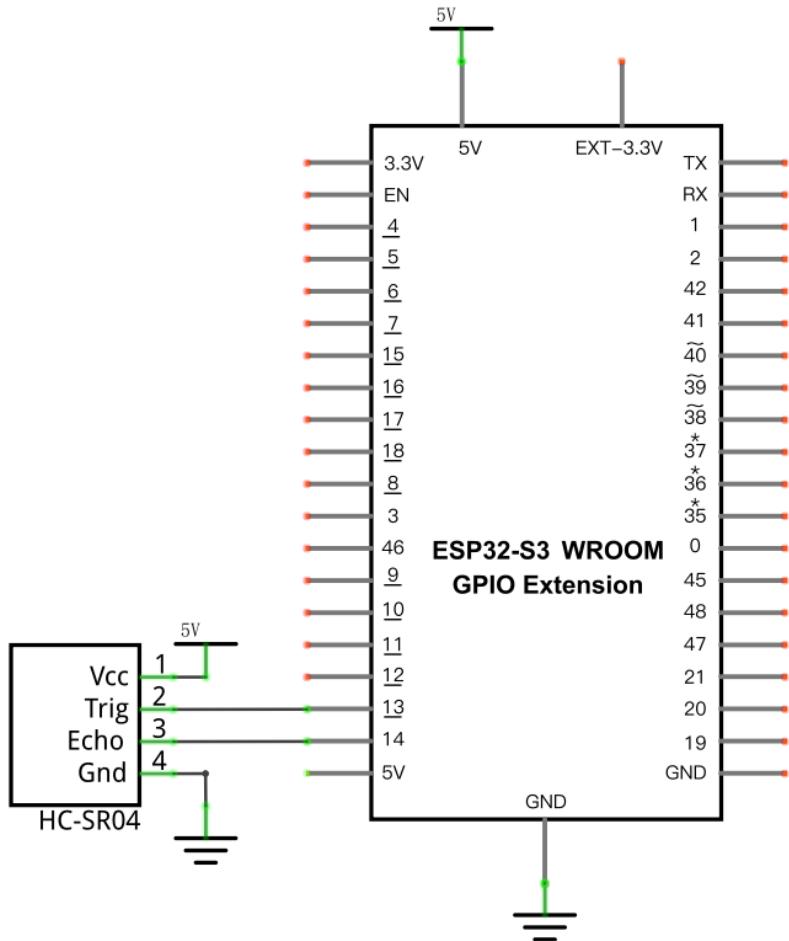
Instructions for use: output a high-level pulse in Trig pin lasting for least 10us, the module begins to transmit ultrasonic waves. At the same time, the Echo pin is pulled up. When the module receives the returned ultrasonic waves from encountering an obstacle, the Echo pin will be pulled down. The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



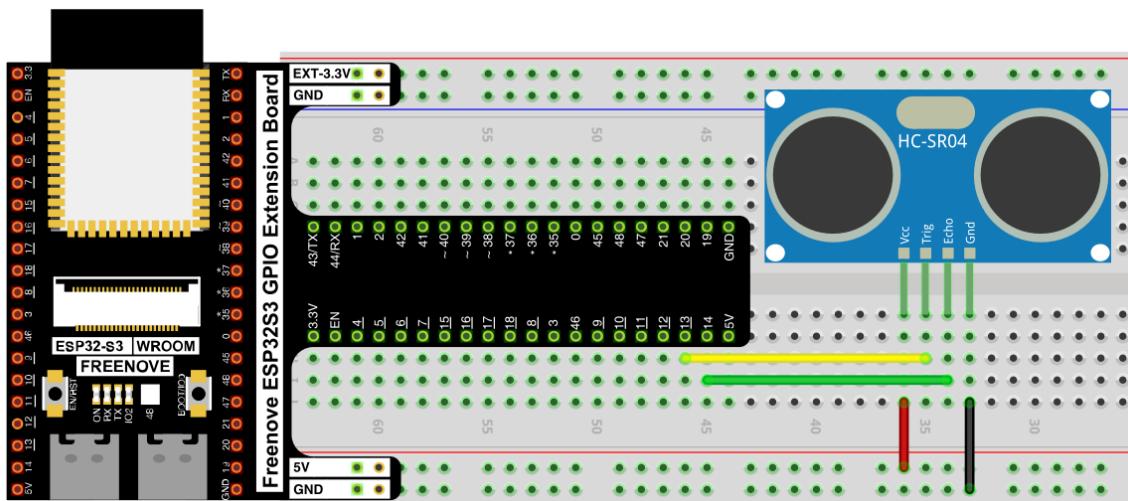
## Circuit

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)



## Sketch

### Sketch\_21.1\_Ultrasonic\_Ranging

The screenshot shows the Arduino IDE interface with the following details:

- Title Bar:** Sketch\_21.1\_Ultrasonic\_Ranging | Arduino IDE 2.0.0
- Menu Bar:** File Edit Sketch Tools Help
- Toolbar:** Includes icons for Save, Run, Stop, and a dropdown for the connected board (ESP32S3 Dev Module).
- Code Editor:** Displays the `Sketch_21.1_Ultrasonic_Ranging.ino` file content. The code is a simple ultrasonic ranging sketch using pins 13 and 14 on an ESP32S3 Dev Module.
- Output Window:** Shows the serial monitor output:

```
Writing at 0x00033a5c... (66 %)
Writing at 0x0003cdd5... (77 %)
Writing at 0x00044484... (88 %)
Writing at 0x00049ec7... (100 %)
Wrote 247712 bytes (138439 compressed) at 0x00010000 in 3.7 seconds (effective 532.1 kbit/s)...
Hash of data verified.

Leaving...
Hard resetting via RTS pin...
```
- Status Bar:** Indicators for Line 34, Column 57, UTF-8 encoding, and the connection to the ESP32S3 Dev Module on COM3.

Download the code to ESP32-S3 WROOM, open the serial port monitor, set the baud rate to 115200 and you can use it to measure the distance between the ultrasonic module and the object. As shown in the following figure:



The following is the program code:

```

1 #define trigPin 13 // define trigPin
2 #define echoPin 14 // define echoPin.
3 #define MAX_DISTANCE 700 // Maximum sensor distance is rated at 400–500cm.
4 //timeOut= 2*MAX_DISTANCE /100 /340 *1000000 = MAX_DISTANCE*58.8
5 float timeOut = MAX_DISTANCE * 60;
6 int soundVelocity = 340; // define sound speed=340m/s
7
8 void setup() {
9     pinMode(trigPin, OUTPUT); // set trigPin to output mode
10    pinMode(echoPin, INPUT); // set echoPin to input mode
11    Serial.begin(115200); // Open serial monitor at 115200 baud to see ping results.
12 }
13
14 void loop() {
15     delay(100); // Wait 100ms between pings (about 20 pings/sec).
16     Serial.printf("Distance: ");
17     Serial.print(getSonar()); // Send ping, get distance in cm and print result
18     Serial.println("cm");
19 }
20
21 float getSonar() {
22     unsigned long pingTime;
23     float distance;
24     // make trigPin output high level lasting for 10us to trigger HC_SR04
25     digitalWrite(trigPin, HIGH);
26     delayMicroseconds(10);
27     digitalWrite(trigPin, LOW);
28     // Wait HC-SR04 returning to the high level and measure out this waiting time
29     pingTime = pulseIn(echoPin, HIGH, timeOut);
30     // calculate the distance according to the time

```

```

31     distance = (float)pingTime * soundVelocity / 2 / 10000;
32     return distance; // return the distance value
33 }
```

First, define the pins and the maximum measurement distance.

```

1 #define trigPin 13 // define trigPin
2 #define echoPin 14 // define echoPin.
3 #define MAX_DISTANCE 700           //define the maximum measured distance
```

If the module does not return high level, we cannot wait for this forever, so we need to calculate the time period for the maximum distance, that is, time Out. timeOut=2\*MAX\_DISTANCE/100/340\*1000000. The result of the constant part in this formula is approximately 58.8.

```
5 float timeOut = MAX_DISTANCE * 60;
```

Subfunction getSonar () function is used to start the ultrasonic module to begin measuring, and return the measured distance in cm units. 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.

```

21 float getSonar() {
22     unsigned long pingTime;
23     float distance;
24     // make trigPin output high level lasting for 10µs to trigger HC_SR04?
25     digitalWrite(trigPin, HIGH);
26     delayMicroseconds(10);
27     digitalWrite(trigPin, LOW);
28     // Wait HC-SR04 returning to the high level and measure out this waiting time
29     pingTime = pulseIn(echoPin, HIGH, timeOut);
30     // calculate the distance according to the time
31     distance = (float)pingTime * soundVelocity / 2 / 10000;
32     return distance; // return the distance value
33 }
```

Lastly, in loop() function, get the measurement distance and display it continually.

```

14 void loop() {
15     delay(100); // Wait 100ms between pings (about 20 pings/sec).
16     Serial.printf("Distance: ");
17     Serial.print(getSonar()); // Send ping, get distance in cm and print result
18     Serial.println("cm");
19 }
```

About function **pulseIn()**:

**int pulseIn(int pin, int level, int timeout);**

**pin**: the number of the Arduino pin on which you want to read the pulse. Allowed data types: int.

**value**: type of pulse to read: either HIGH or LOW. Allowed data types: int.

**timeout** (optional): the number of microseconds to wait for the pulse to start; default is one second.



## Project 21.2 Ultrasonic Ranging

### Component List and Circuit

Component List and Circuit are the same as the previous section.

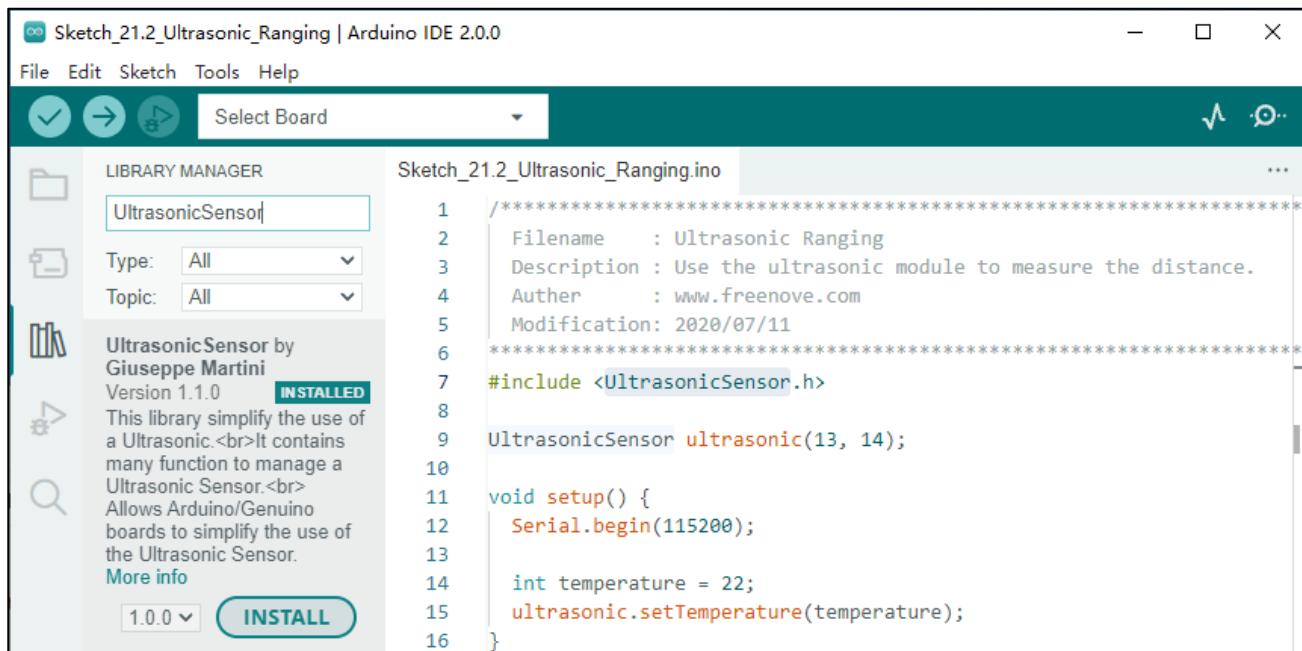
### Sketch

#### How to install the library

We use the third party library UltrasonicSensor. If you haven't installed it yet, please do so before learning. The steps to add third-party Libraries are as follows: open arduino->Sketch->Include library-> Manage libraries.

Enter "UltrasonicSensor" in the search bar and select "UltrasonicSensor" for installation.

Refer to the following operations:



The screenshot shows the Arduino IDE 2.0.0 Library Manager interface. In the search bar, 'UltrasonicSensor' is typed. A list item for 'UltrasonicSensor by Giuseppe Martini Version 1.1.0' is highlighted, with the status 'INSTALLED'. To the right, the code editor displays a sketch named 'Sketch\_21.2\_Ultrasonic\_Ranging.ino' containing the following C++ code:

```
1 //*****
2 // Filename : Ultrasonic Ranging
3 // Description : Use the ultrasonic module to measure the distance.
4 // Author : www.freenove.com
5 // Modification: 2020/07/11
6 ****
7 #include <UltrasonicSensor.h>
8
9 UltrasonicSensor ultrasonic(13, 14);
10
11 void setup() {
12     Serial.begin(115200);
13
14     int temperature = 22;
15     ultrasonic.setTemperature(temperature);
16 }
```

## Sketch\_21.2\_Ultrasonic\_Ranging

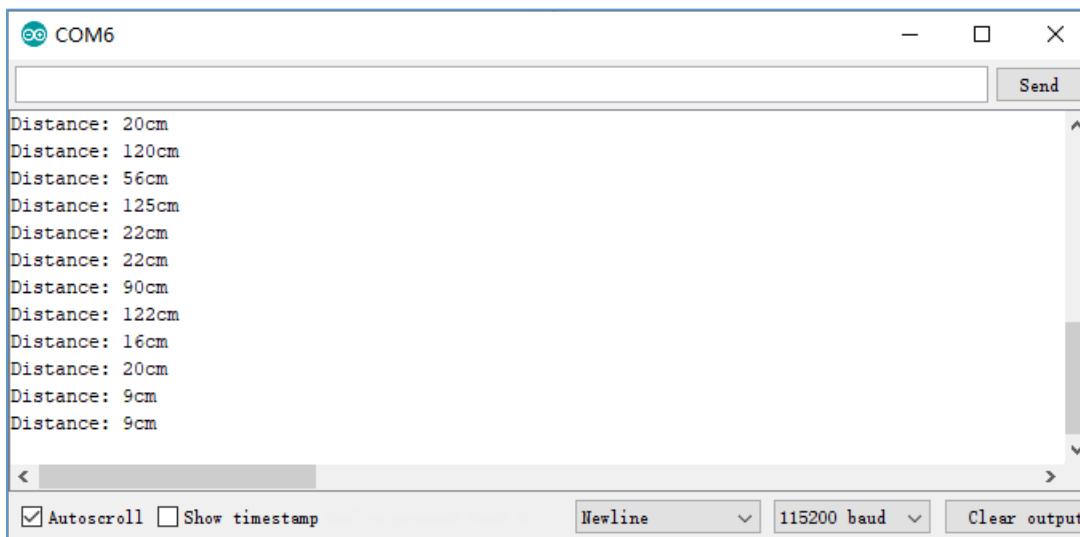
The screenshot shows the Arduino IDE interface with the following details:

- Title Bar:** Sketch\_21.2\_Ultrasonic\_Ranging | Arduino IDE 2.0.0
- Toolbar:** File, Edit, Sketch, Tools, Help
- Sketch Selection:** ESP32S3 Dev Module
- Code Area:** The code for `Sketch_21.2_Ultrasonic_Ranging.ino` is displayed. It includes comments about the file's purpose, author, and modification date, along with the necessary libraries and function definitions for an ultrasonic sensor.
- Output Window:** Shows the serial port monitor output:

```
Writing at 0x0002e400... (55 %)
Writing at 0x00033cb6... (66 %)
Writing at 0x0003d16e... (77 %)
Writing at 0x00044550... (88 %)
Writing at 0x00049f3d... (100 %)
Wrote 247328 bytes (137997 compressed) at 0x00010000 in 3.7 seconds (effective 531.5 kbit/s)...
Hash of data verified.

Leaving...
Hard resetting via RTS pin...
```
- Bottom Status Bar:** Building sketch, Ln 23, Col 1, UTF-8, ESP32S3 Dev Module on COM3, 3, and a refresh icon.

Download the code to ESP32-S3 WROOM, open the serial port monitor, set the baud rate to 115200. Use the ultrasonic module to measure distance. As shown in the following figure:



The following is the program code:

```

1 #include <UltrasonicSensor.h>
2 //Attach the trigger and echo pins to pins 13 and 14 of esp32
3 UltrasonicSensor ultrasonic(13, 14);
4
5 void setup() {
6     Serial.begin(115200);
7     //set the speed of sound propagation according to the temperature to reduce errors
8     int temperature = 22; //Setting ambient temperature
9     ultrasonic.setTemperature(temperature);
10 }
11
12 void loop() {
13     int distance = ultrasonic.distanceInCentimeters();
14     Serial.printf("Distance: %dcm\n", distance);
15     delay(300);
16 }
```

First, add UltrasonicSensor library.

```
1 #include <UltrasonicSensor.h>
```

Define an ultrasonic object and associate the pins.

```
3 UltrasonicSensor ultrasonic(13, 14);
```

Set the ambient temperature to make the module measure more accurately.

```
9 ultrasonic.setTemperature(temperature);
```

Use the `distanceInCentimeters` function to get the distance measured by the ultrasound and print it out through the serial port.

```

16 void loop() {
17     int distance = ultrasonic.distanceInCentimeters();
18     Serial.printf("Distance: %dcm\n", distance);
19     delay(300);
20 }
```

## Reference

### class UltrasonicSensor

**class UltrasonicSensor** must be instantiated when used, that is, define an object of Servo type, for example:

**UltrasonicSensor ultrasonic(13, 14);**

**setTemperature(value):** The speed of sound propagation is different at different temperatures. In order to get more accurate data, this function needs to be called. **value** is the temperature value of the current environment.

**distanceInCentimeters():** The ultrasonic distance acquisition function returns the value in centimeters.

**distanceInMillimeters():** The ultrasonic distance acquisition function returns the value in millimeter.



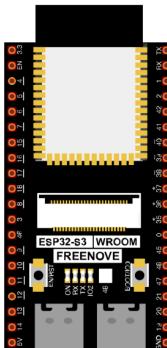
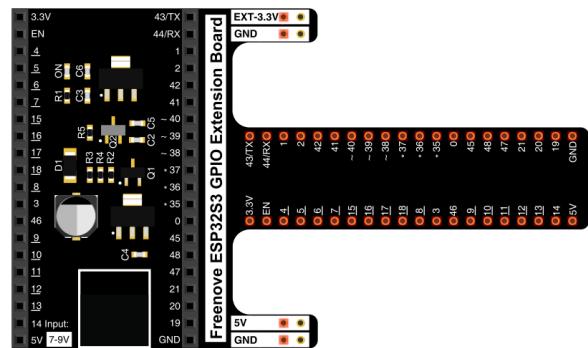
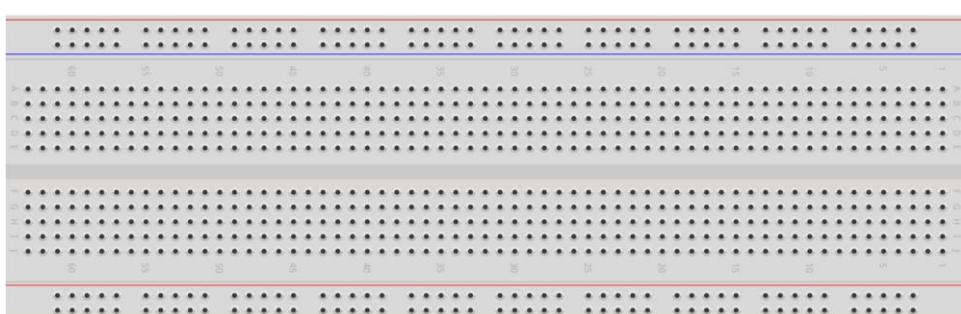
# Chapter 22 Matrix Keypad

Earlier we learned about a single push button switch. In this chapter, we will learn about matrix keyboards, which integrates a number of push button switches as keys for the purposes of input.

## Project 22.1 Matrix Keypad

In this project, we will attempt to get every key code on the matrix keypad to work.

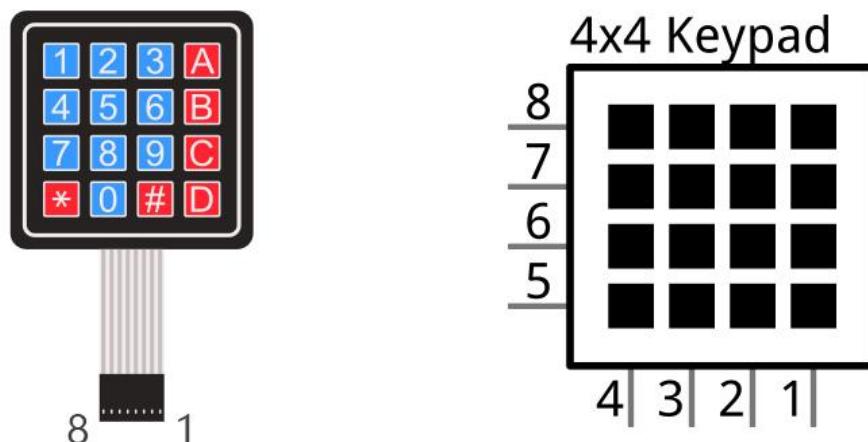
### Component List

ESP32-S3 WROOM x1	GPIO Extension Board x1
	
Breadboard x1	
Jumper M/M x8	4x4 Matrix Keypad x1
	

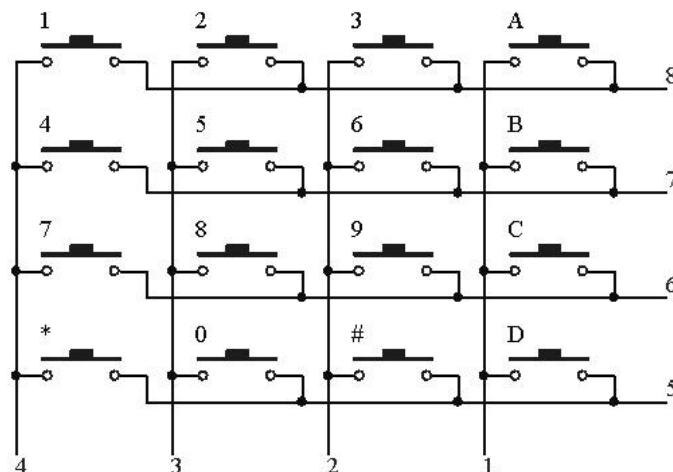
## Component knowledge

### 4x4 Matrix Keypad

A keypad matrix is a device that integrates a number of keys in one package. As is shown below, a 4x4 keypad matrix integrates 16 keys:



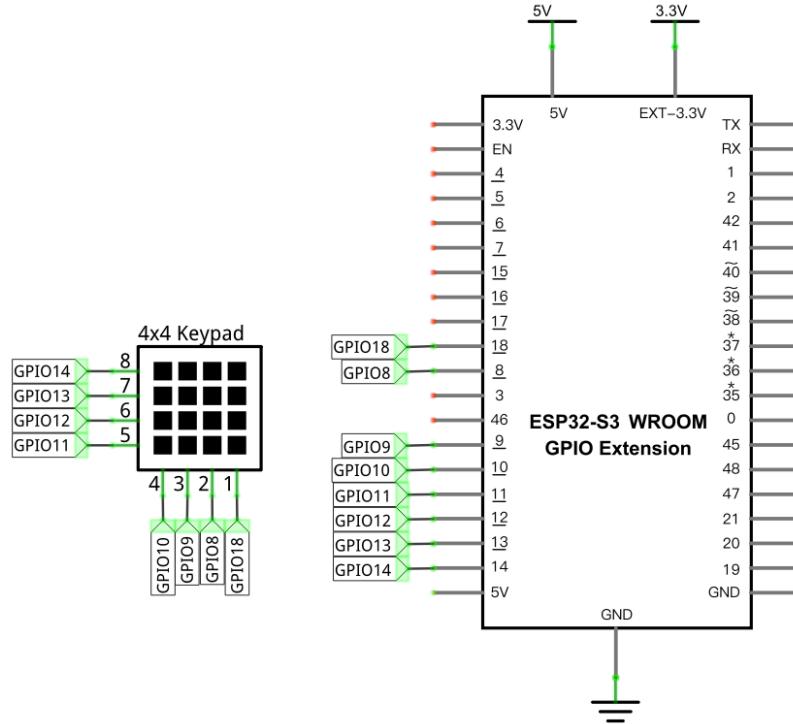
Similar to the integration of a LED matrix, the 4x4 keypad matrix has each row of keys connected with one pin and this is the same for the columns. Such efficient connections reduce the number of processor ports required. The internal circuit of the Keypad Matrix is shown below.



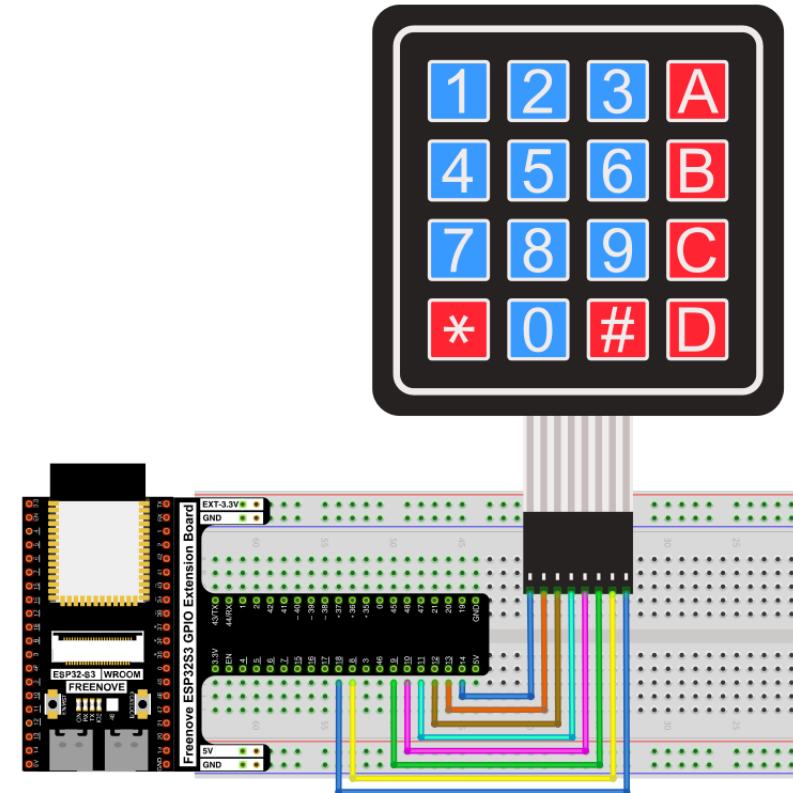
The usage is similar to the LED matrix, using a row or column scanning method to detect the state of each key's position by column and row. Take column scanning method as an example, send low level to the first 1 column (Pin1), detect level state of row 5, 6, 7, 8 to judge whether the key A, B, C, D are pressed. Then send low level to column 2, 3, 4 in turn to detect whether other keys are pressed. Therefore, you can get the state of all of the keys.

## Circuit

Schematic diagram



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



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

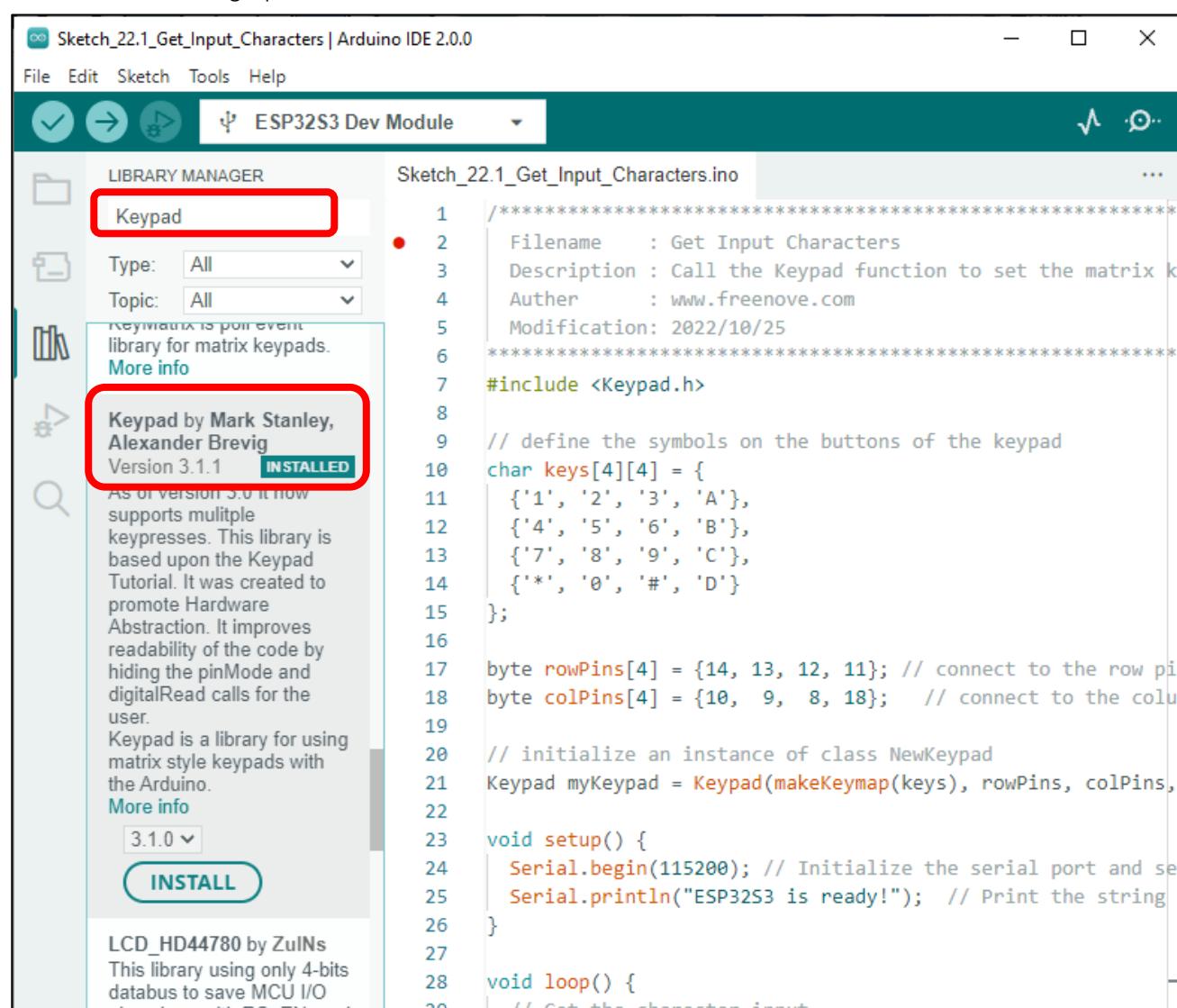
## Sketch

This code is used to obtain all key codes of the 4x4 matrix keypad, when one of the keys is pressed, the key code will be printed out via serial port.

### How to install the library

We use the third party library Keypad. If you haven't installed it yet, please do so before learning. The steps to add third-party Libraries are as follows: open arduino->Sketch->Include library-> Manage libraries. Enter " Keypad" in the search bar and select " Keypad " for installation.

Refer to the following operations:



### Sketch\_22.1\_Get\_Input\_Characters

The screenshot shows the Arduino IDE interface with the following details:

- Title Bar:** Sketch\_22.1\_Get\_Input\_Characters | Arduino IDE 2.0.0
- Menu Bar:** File Edit Sketch Tools Help
- Toolbar:** Includes icons for Save, Run, Stop, and a dropdown for the connected board (ESP32S3 Dev Module).
- Sketch Area:** Displays the code for `Sketch_22.1_Get_Input_Characters.ino`. The code is as follows:

```
1 // ****
2 // Filename : Get Input Characters
3 // Description : Call the Keypad function to set the matrix keyboard and get the value
4 // Author : www.freenove.com
5 // Modification: 2022/10/25
6 // ****
7 #include <Keypad.h>
8
9 // define the symbols on the buttons of the keypad
10 char keys[4][4] = {
11     {'1', '2', '3', 'A'},
12     {'4', '5', '6', 'B'},
13     {'7', '8', '9', 'C'},
14     {'*', '0', '#', 'D'}
15 };
16
17 byte rowPins[4] = {14, 13, 12, 11}; // connect to the row pinouts of the keypad
18 byte colPins[4] = {10, 9, 8, 18}; // connect to the column pinouts of the keypad
19
20 // initialize an instance of class NewKeypad
21 Keypad myKeypad = Keypad(makeKeymap(keys), rowPins, colPins, 4, 4);
22
23 void setup() {
24     Serial.begin(115200); // Initialize the serial port and set the baud rate to 115200
25     Serial.println("ESP32S3 is ready!"); // Print the string "UNO is ready!"
26 }
27
```

Download the code to ESP32-S3 WROOM, open the serial port monitor, set the baud rate to 115200, press the keyboard, the value of the pressed keys will be printed out via the serial port. As shown in the following figure:



The following is the program code:

```
1 #include <Keypad.h>
2 // define the symbols on the buttons of the keypad
3 char keys[4][4] = {
4     {'1', '2', '3', 'A'},
5     {'4', '5', '6', 'B'},
6     {'7', '8', '9', 'C'},
7     {'*', '0', '#', 'D'}
8 };
9 byte rowPins[4] = {14, 13, 12, 11}; // connect to the row pinouts of the keypad
10 byte colPins[4] = {10, 9, 8, 18}; // connect to the column pinouts of the keypad
11
12 // initialize an instance of class NewKeypad
13 Keypad myKeypad = Keypad(makeKeymap(keys), rowPins, colPins, 4, 4);
14
15 void setup() {
16     Serial.begin(115200); // Initialize the serial port and set the baud rate to 115200
17     Serial.println("ESP32S3 is ready!"); // Print the string "ESP32S3 is ready!"
18 }
19
20 void loop() {
21     // Get the character input
22     char keyPressed = myKeypad.getKey();
23     // If there is a character input, sent it to the serial port
24     if (keyPressed) {
25         Serial.println(keyPressed);
26     }
27 }
```

First, add header file, define 4\*4 matrix keyboard key value and the matrix keyboard pin.

```

1 #include <Keypad.h>
2 // define the symbols on the buttons of the keypad
3 char keys[4][4] = {
4     {'1', '2', '3', 'A'},
5     {'4', '5', '6', 'B'},
6     {'7', '8', '9', 'C'},
7     {'*', '0', '#', 'D'}
8 };
9 byte rowPins[4] = {14, 13, 12, 11}; // connect to the row pinouts of the keypad
10 byte colPins[4] = {10, 9, 8, 18}; // connect to the column pinouts of the keypad

```

Second, define a matrix keyboard object and associate the keys and pins with it.

```
13 Keypad myKeypad = Keypad(makeKeymap(keys), rowPins, colPins, 4, 4);
```

Finally, get the key value and print it out via the serial port.

```

20 void loop() {
21     // Get the character input
22     char keyPressed = myKeypad.getKey();
23     // If there is a character input, sent it to the serial port
24     if (keyPressed) {
25         Serial.println(keyPressed);
26     }
27 }
```

### Reference

**class Keypad** You need to add the library each time you use the Keypad.

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

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

**char getKey();**

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

**void setDebounceTime(uint);**

Set the debounce time with a default time of 10ms.

**void setHoldTime(uint);**

Set the duration for the key to keep stable state after pressed.

**bool isPressed(char keyChar);**

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

**char waitForKey();**

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

**KeyState getState();**

Get the state of the keys.

**bool keyStateChanged();**

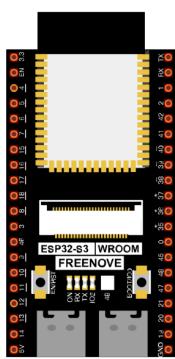
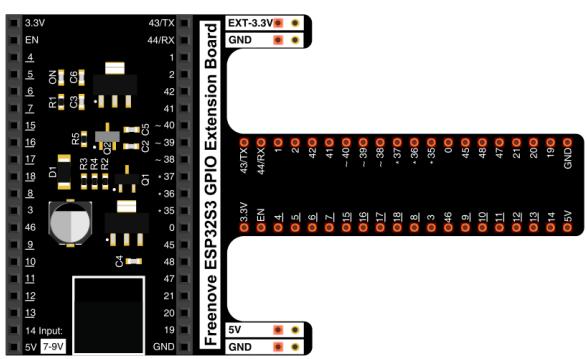
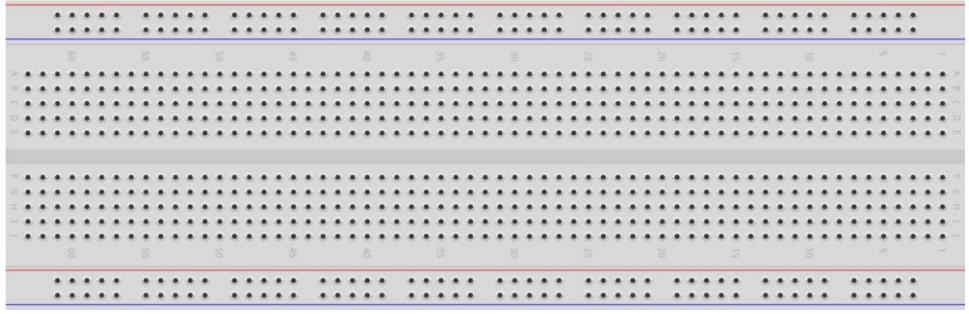
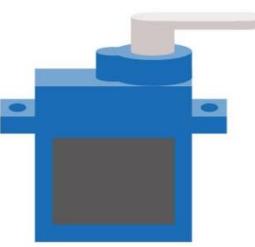
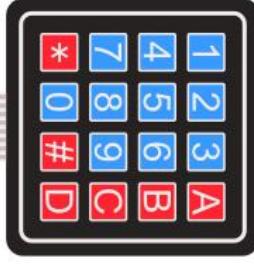
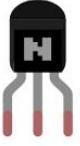
Judge whether there is a change of key state, then return True or False.

For More information about Keypad, please visit: <http://playground.arduino.cc/Code/Keypad>

## Project 22.2 Keypad Door

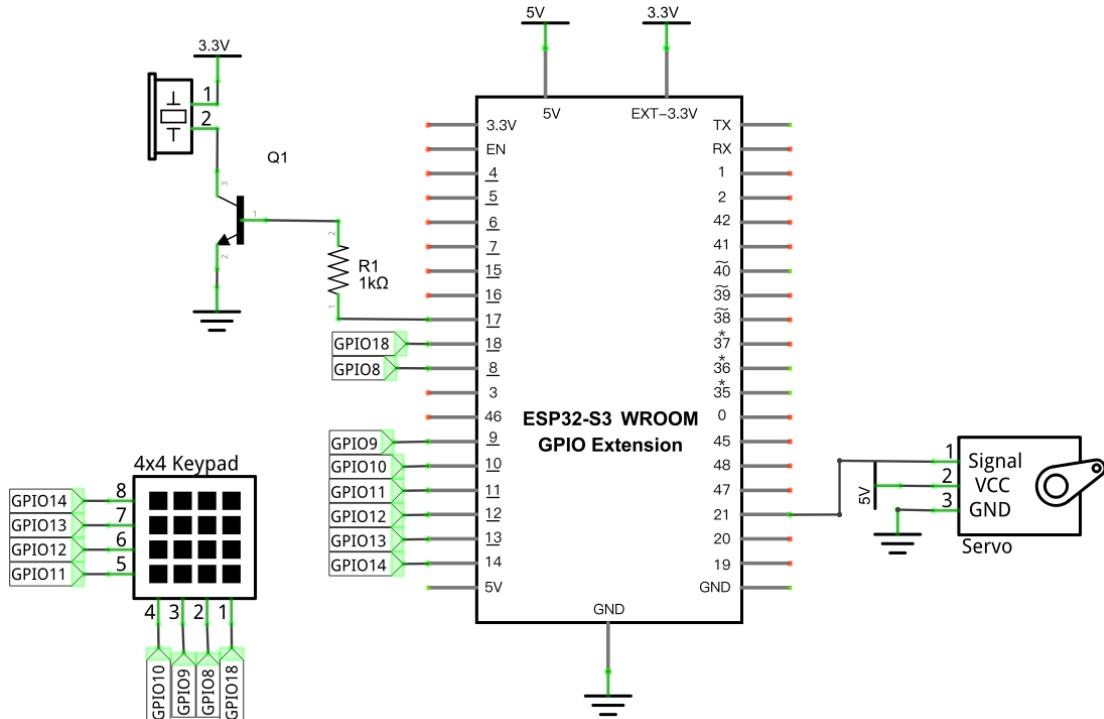
In this project, we use keypad as a keyboard to control the action of the servo motor.

### Component List

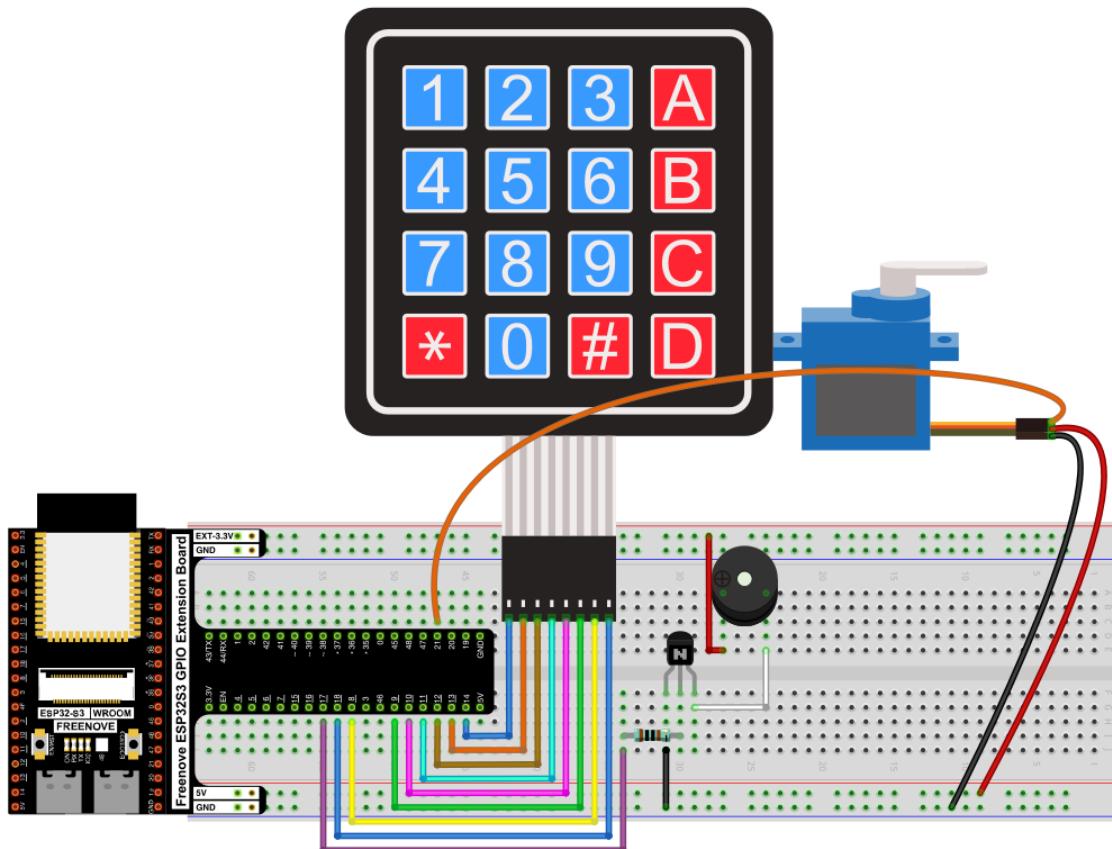
ESP32-S3 WROOM x1	GPIO Extension Board x1	
		
Breadboard x1		
Jumper M/M	Servo x1	4x4 Matrix Keypad x1
		
NPN transistor x1 (S8050)	Active buzzer x1	Resistor 1kΩ x1
		

## Circuit

Schematic diagram



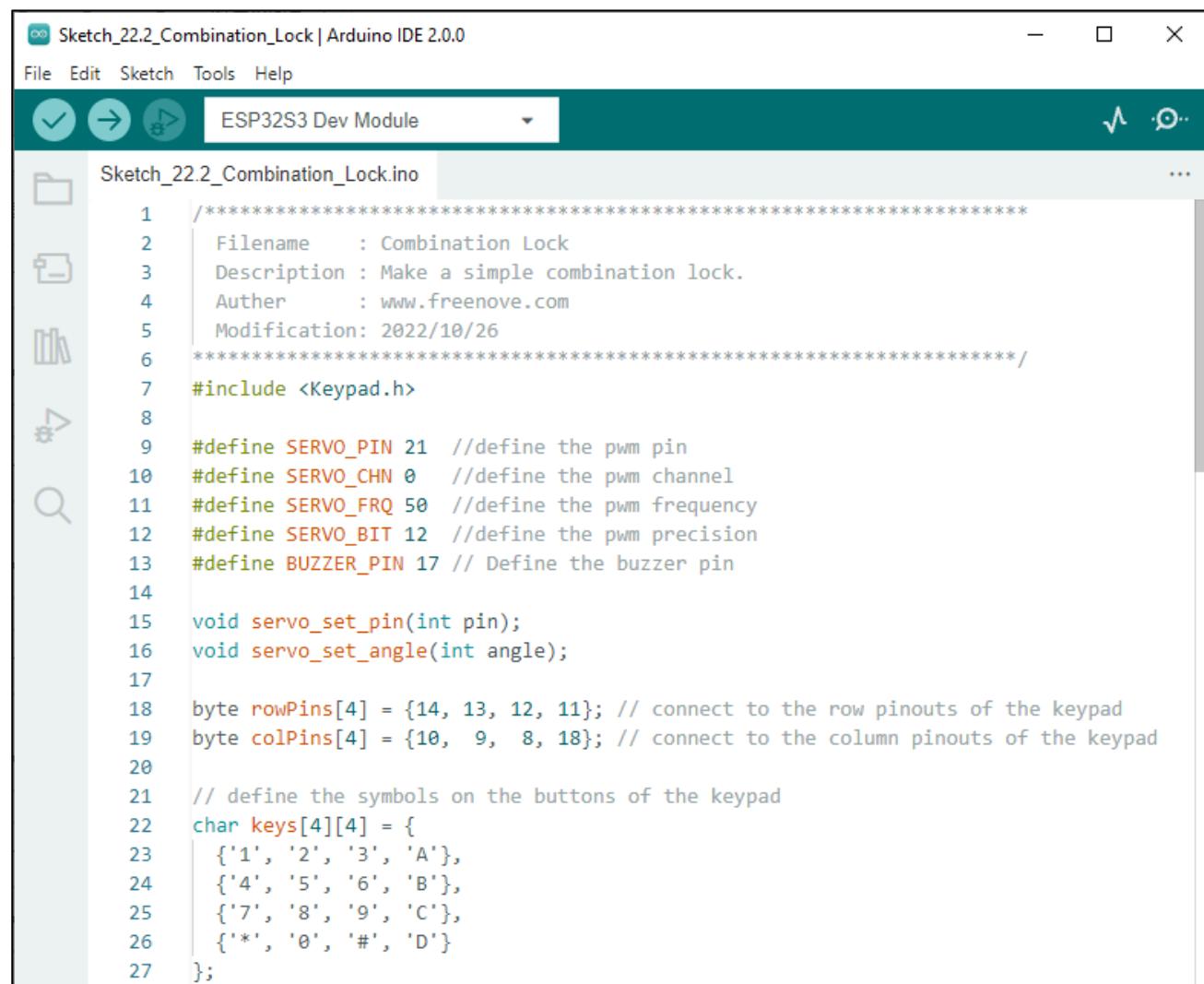
Hardware connection. If you need any support, please feel free to contact us via: [support@freenove.com](mailto:support@freenove.com)



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

## Sketch

### Sketch\_22.2\_Keypad\_Door



The screenshot shows the Arduino IDE interface with the following details:

- Title Bar:** Sketch\_22.2\_Combination\_Lock | Arduino IDE 2.0.0
- Menu Bar:** File Edit Sketch Tools Help
- Toolbar:** Includes icons for save, build, upload, and others.
- Sketch Selection:** ESP32S3 Dev Module
- Code Area:** Displays the `Sketch_22.2_Combination_Lock.ino` file content.

```
1  ****
2  Filename      : Combination Lock
3  Description   : Make a simple combination lock.
4  Author        : www.freenove.com
5  Modification: 2022/10/26
6  ****
7 #include <Keypad.h>
8
9 #define SERVO_PIN 21 //define the pwm pin
10 #define SERVO_CHN 0 //define the pwm channel
11 #define SERVO_FRQ 50 //define the pwm frequency
12 #define SERVO_BIT 12 //define the pwm precision
13 #define BUZZER_PIN 17 // Define the buzzer pin
14
15 void servo_set_pin(int pin);
16 void servo_set_angle(int angle);
17
18 byte rowPins[4] = {14, 13, 12, 11}; // connect to the row pinouts of the keypad
19 byte colPins[4] = {10, 9, 8, 18}; // connect to the column pinouts of the keypad
20
21 // define the symbols on the buttons of the keypad
22 char keys[4][4] = {
23     {'1', '2', '3', 'A'},
24     {'4', '5', '6', 'B'},
25     {'7', '8', '9', 'C'},
26     {'*', '0', '#', 'D'}
27 };
```

Verify and upload the code to the ESP32-S3 WROOM and press the keypad to input password with 4 characters. If the input is correct, the servo will move to a certain degree, then return to the original position. If the input is wrong, an input error alarm will be generated.

The following is the program code:

```

1 #include <Keypad.h>
2
3 #define SERVO_PIN 21 //define the pwm pin
4 #define SERVO_CHN 0 //define the pwm channel
5 #define SERVO_FRQ 50 //define the pwm frequency
6 #define SERVO_BIT 12 //define the pwm precision
7 #define BUZZER_PIN 17 //Define the buzzer pin
8
9 void servo_set_pin(int pin);
10 void servo_set_angle(int angle);
11
12 byte rowPins[4] = {14, 13, 12, 11}; //connect to the row pinouts of the keypad
13 byte colPins[4] = {10, 9, 8, 18}; //connect to the column pinouts of the keypad
14
15 //define the symbols on the buttons of the keypad
16 char keys[4][4] = {
17     {'1', '2', '3', 'A'},
18     {'4', '5', '6', 'B'},
19     {'7', '8', '9', 'C'},
20     {'*', '0', '#', 'D'}
21 };
22
23 //initialize an instance of class NewKeypad
24 Keypad myKeypad = Keypad(makeKeymap(keys), rowPins, colPins, 4, 4);
25
26 char passWord[] = {"1234"}; //Save the correct password
27
28 void setup() {
29     servo_set_pin(SERVO_PIN);
30     pinMode(BUZZER_PIN, OUTPUT);
31     Serial.begin(115200);
32 }
33
34 void loop() {
35     static char keyIn[4]; //Save the input character
36     static byte keyInNum = 0; //Save the the number of input characters
37     char keyPressed = myKeypad.getKey(); //Get the character input
38     //Handle the input characters
39     if (keyPressed) {
40         //Make a prompt tone each time press the key
41         digitalWrite(BUZZER_PIN, HIGH);
42         delay(100);
43         digitalWrite(BUZZER_PIN, LOW);

```

```

44 //Save the input characters
45 keyIn[keyInNum++] = keyPressed;
46 //Judge the correctness after input
47 if (keyInNum == 4) {
48     bool isRight = true;           //Save password is correct or not
49     for (int i = 0; i < 4; i++) { //Judge each character of the password is correct or not
50         if (keyIn[i] != passWord[i])
51             isRight = false;        //Mark wrong passageword if there is any wrong
52             character.
53     }
54     if (isRight) {                //If the input password is right
55         servo_set_angle(90);      //Open the switch
56         delay(2000);            //Delay a period of time
57         servo_set_angle(0);       //Close the switch
58         Serial.println("passWord right!");
59     }
60     else {                      //If the input password is wrong
61         digitalWrite(BUZZER_PIN, HIGH); //Make a wrong password prompt tone
62         delay(1000);
63         digitalWrite(BUZZER_PIN, LOW);
64         Serial.println("passWord error!");
65     }
66     keyInNum = 0; //Reset the number of the input characters to 0
67 }
68 }
69
70 void servo_set_pin(int pin) {
71     ledcAttachChannel(pin, SERVO_FRQ, SERVO_BIT, SERVO_CHN);
72 }
73
74 void servo_set_angle(int angle) {
75     if (angle > 180 || angle < 0)
76         return;
77     long pwm_value = map(angle, 0, 180, 103, 512);
78     ledcWrite(SERVO_PIN, pwm_value);
79 }
```

First, we need to set the value of the password.

26	char passWord[] = {"1234"}; // Save the correct password
----	--

Second, each time the key is pressed, the buzzer makes a short sound and stores the key value entered.

37	char keyPressed = myKeypad.getKey(); // Get the character input
38	// Handle the input characters
39	if (keyPressed) {
40	// Make a prompt tone each time press the key

```

41   digitalWrite(buzzerPin, HIGH);
42   delay(100);
43   digitalWrite(buzzerPin, LOW);
44   // Save the input characters
45   keyIn[keyInNum++] = keyPressed;

```

Third, if the button has been pressed for four times, ESP32-S3 begins to judge if the password is correct.

```

47   if (keyInNum == 4) {
48     bool isRight = true;           // Save password is correct or not
49     for (int i = 0; i < 4; i++) {  // Judge each character of the password is correct or
50       not
51       if (keyIn[i] != passWord[i])
52         isRight = false;          // Mark wrong password if there is any wrong character.
53     }

```

If the password is correct, control the servo motor to open the lock and wait for 2 seconds before closing the lock. If it is not correct, the buzzer makes a long sound and prints the error message through the serial port.

```

53   if (isRight) {                  // If the input password is right
54     myservo.write(90);           // Open the switch
55     delay(2000);                // Delay a period of time
56     myservo.write(0);            // Close the switch
57     Serial.println("passWord right! ");
58   }
59   else {                         // If the input password is wrong
60     digitalWrite(buzzerPin, HIGH); // Make a wrong password prompt tone
61     delay(1000);
62     digitalWrite(buzzerPin, LOW);
63     Serial.println("passWord error! ");
64   }

```

Finally, remember to empty the keyInNum every time.

```

65   keyInNum = 0; // Reset the number of the input characters to 0

```

For More information about Keypad, please visit: <http://playground.arduino.cc/Code/Keypad>.

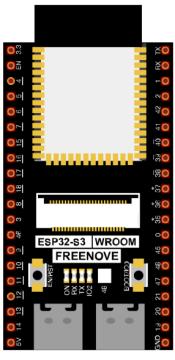
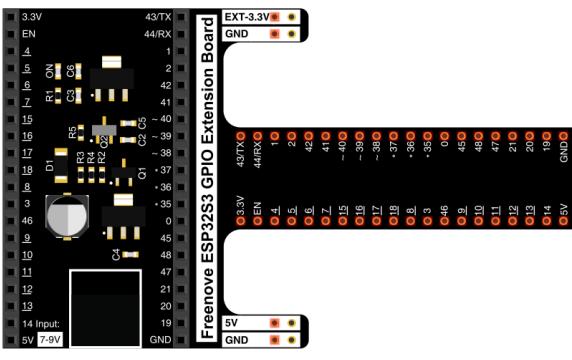
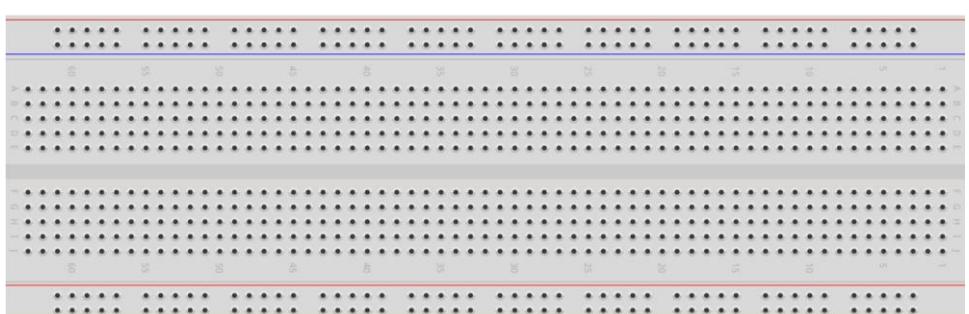
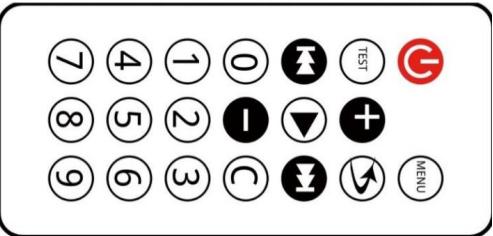
# Chapter 23 Infrared Remote

In this chapter, we'll learn how to use an infrared remote control, and control a LED.

## Project 23.1 Infrared Remote Control

First, we need to understand how infrared remote control works, then get the command sent from infrared remote control.

### Component List

ESP32-S3 WROOM x1	GPIO Extension Board x1
	
	
Breadboard x1	
	
Jumper M/M x4	Infrared Remote x1 (May need CR2025 battery x1, please check the holder)
	
Infrared Remote x1	Resistor 10kΩ x1



## Component knowledge

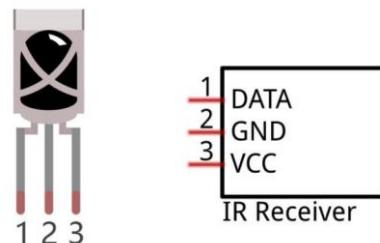
### Infrared Remote

An infrared(IR) remote control is a device with a certain number of buttons. Pressing down different buttons will make the infrared emission tube, which is located in the front of the remote control, send infrared ray with different command. Infrared remote control technology is widely used in electronic products such as TV, air conditioning, etc. Thus making it possible for you to switch TV programs and adjust the temperature of the air conditioning when away from them. The remote control we use is shown below:



### Infrared receiver

An infrared(IR) receiver is a component which can receive the infrared light, so we can use it to detect the signal emitted by the infrared remote control. DATA pin here outputs the received infrared signal.



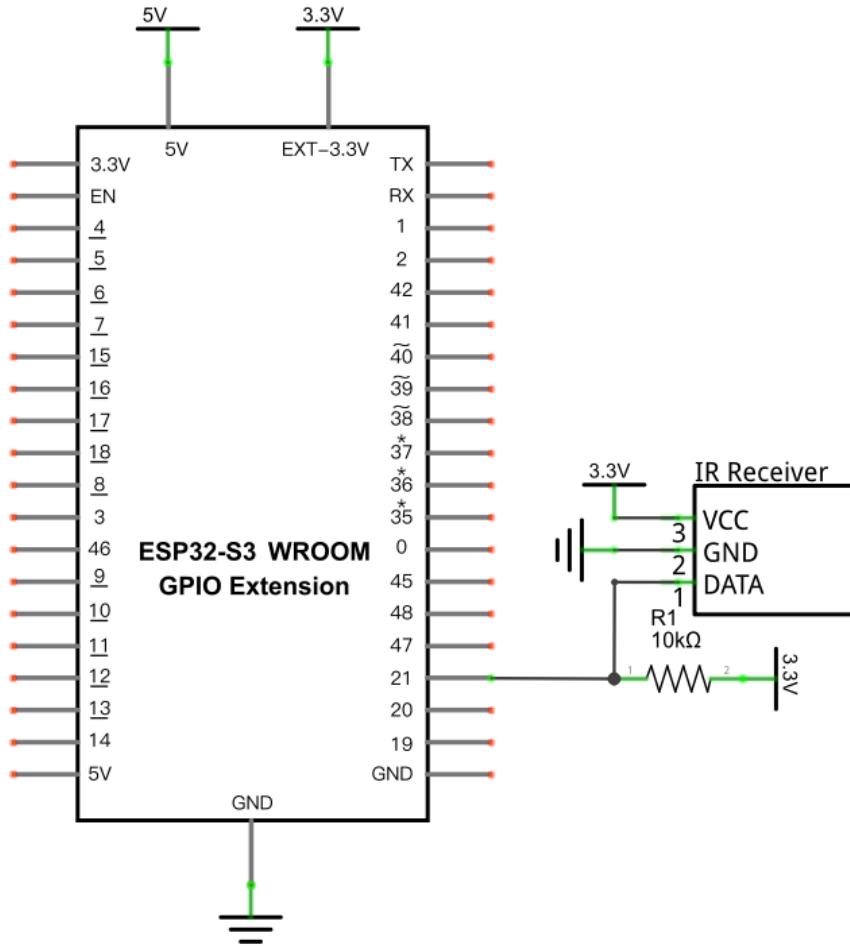
When you use the infrared remote control, the infrared remote control sends a key value to the receiving circuit according to the pressed keys. We can program the ESP32-S3 WROOM to do things like lighting, when a key value is received.

The following is the key value that the receiving circuit will receive when each key of the infrared remote control is pressed.

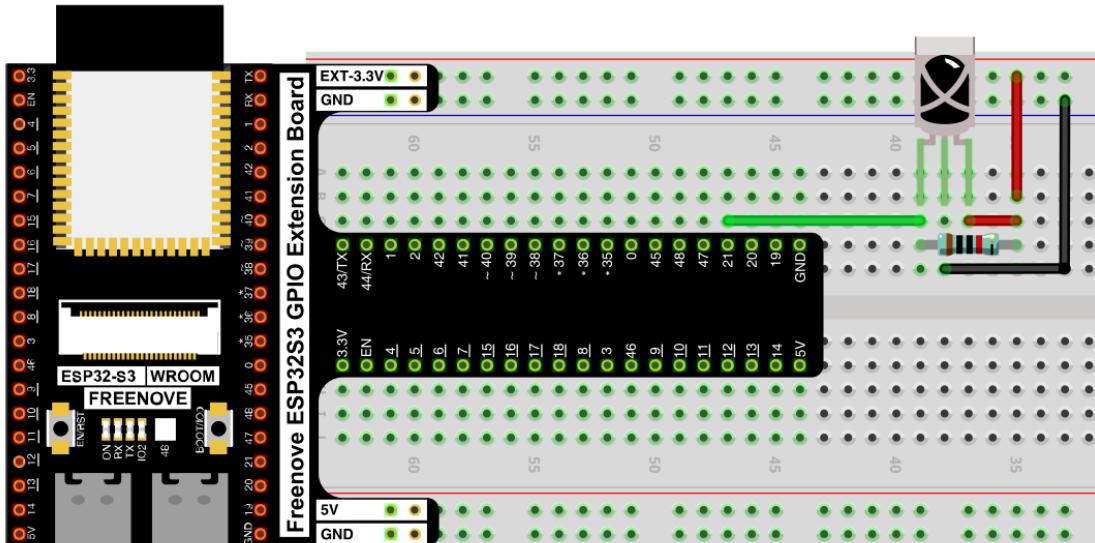
ICON	KEY Value	ICON	KEY Value
	FFA25D		FFB04F
	FFE21D		FF30CF
	FF22DD		FF18E7
	FF02FD		FF7A85
	FFC23D		FF10EF
	FFE01F		FF38C7
	FFA857		FF5AA5
	FF906F		FF42BD
	FF6897		FF4AB5
	FF9867		FF52AD

## Circuit

Schematic diagram



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



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

## Sketch

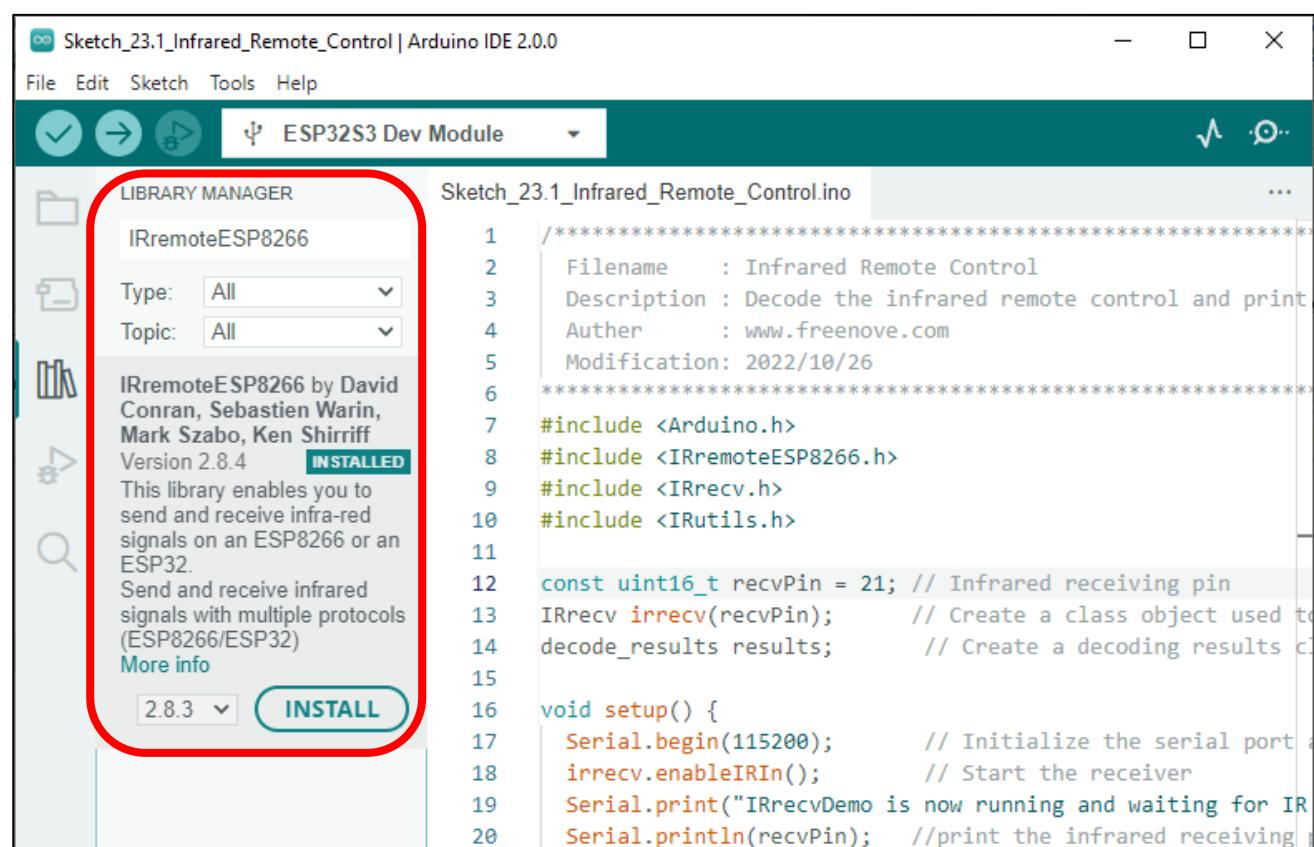
This sketch uses the infrared receiving tube to receive the value sent from the infrared remote control, and print it out via the serial port.

### How to install the library

We use the third party library IRremoteESP8266. If you haven't installed it yet, please do so first. The steps to add third-party Libraries are as follows: open arduino->Sketch->Include library-> Manage libraries.

Enter "IRremoteESP8266" in the search bar and select "IRremoteESP8266" for installation.

Refer to the following operations:





### Sketch\_23.1\_Infrared\_Remote\_Control

```

Sketch_23.1_Infrared_Remote_Control | Arduino IDE 2.3.2
File Edit Sketch Tools Help
ESP32S3 Dev Module
Sketch_23.1_Infrared_Remote_Control.ino
1 // ****
2 Filename : Infrared Remote Control
3 Description : Decode the infrared remote control and print it out through the serial port.
4 Author : www.freenove.com
5 Modification: 2024/07/01
6 ****
7 #include "Freenove_IR_Lib_for_ESP32.h"
8
9 const uint16_t recvPin = 21; // Infrared receiving pin
10 Freenove_ESP32_IR_Recv ir_recv(recvPin); // Create a class object used to receive class
11
12 void setup() {
13     Serial.begin(115200); // Initialize the serial port and set the baud rate to 115200
14     Serial.print("IRrecvDemo is now running and waiting for IR message on Pin ");
15     Serial.println(recvPin); //print the infrared receiving pin
16 }
17
18 void loop() {
19     ir_recv.task(); //Get IR receice data.
20     if(ir_recv.nec_available()){ //The data of the NEC protocol is checked
21         //Print IR data.
22         Serial.printf("IR Code: %#x\r\n", ir_recv.data());
23     }
24 }

```

Download the code to ESP32-S3 WROOM, open the serial port monitor, set the baud rate to 115200, press the IR remote control, the pressed keys value will be printed out through the serial port. As shown in the following figure: (Note that when the remote control button is pressed for a long time, the infrared receiving circuit receives a continuous high level, that is, it receives a hexadecimal "F")

Time	Message
14:45:03.857	-> IRrecvDemo is now running and waiting for IR message on Pin 21
14:48:57.153	-> IR Code: 0xfffa25d
14:48:57.199	-> IR Code: 0xffffffff
14:48:58.910	-> IR Code: 0xffff02fd
14:48:59.327	-> IR Code: 0xffff22dd
14:48:59.730	-> IR Code: 0xffff02fd
14:48:59.776	-> IR Code: 0xffffffff
14:49:00.143	-> IR Code: 0xffffc23d
14:49:00.548	-> IR Code: 0xfffe01f
14:49:00.636	-> IR Code: 0xffffffff
14:49:01.179	-> IR Code: 0xffff22dd

The following is the program code:

```

1 #include "Freenove_IR_Lib_for_ESP32.h"
2
3 const uint16_t recvPin = 21; // Infrared receiving pin
4 Freenove_ESP32_IR_Recv ir_recv(recvPin); // Create a class object used to receive class
5
6 void setup() {
7     Serial.begin(115200); // Initialize the serial port and set the baud rate to 115200
8     Serial.print("IRrecvDemo is now running and waiting for IR message on Pin ");

```

```

9   Serial.println(recvPin); //print the infrared receiving pin
10 }
11
12 void loop() {
13   ir_recv.task();           //Get IR receive data.
14   if(ir_recv.nec_available()){ //The data of the NEC protocol is checked
15     //Print IR data.
16   Serial.printf("IR Code: %#x\r\n", ir_recv.data());
17 }
18 }
```

First, include header file. Each time you use the infrared library, you need to include the header file at the beginning of the program.

```
1 #include "Freenove_IR_Lib_for_ESP32.h"
```

Second, define an infrared receive pin and associates it with the receive class.

```

3 const uint16_t recvPin = 21;           // Infrared receiving pin
4 Freenove_ESP32_IR_Recv ir_recv(recvPin); // Create a class object used to receive class
```

Third, call the infrared reception function, if you do not use this function, you won't receive the value from the infrared remote control.

```
13 ir_recv.task();           //get IR receive data.
```

Finally, determine whether the detection IR data has been obtained, and if so, print the data.

```

12 void loop() {
13   ir_recv.task();           //get IR receive data.
14   if(ir_recv.nec_available()){ //The data of the NEC protocol is checked
15     Serial.printf("IR Code: %#x\r\n", ir_recv.data()); //Print IR data.
16   }
17 }
```

### Reference

<b>class Freenove_ESP32_IR_Recv</b>	You need to add the library each time you use the Infrared Reception.
<b>Freenove_ESP32_IR_Recv irrecv(Pin):</b>	Create a class object used to receive class, and associated with <b>Pin</b> .
<b>task():</b>	You need to keep calling this function, so that IR can accurately get the data.
<b>nec_available():</b>	Check whether IR data is obtained from the buffer.
<b>data():</b>	Get IR data.



## Project 23.2 Control LED through Infrared Remote

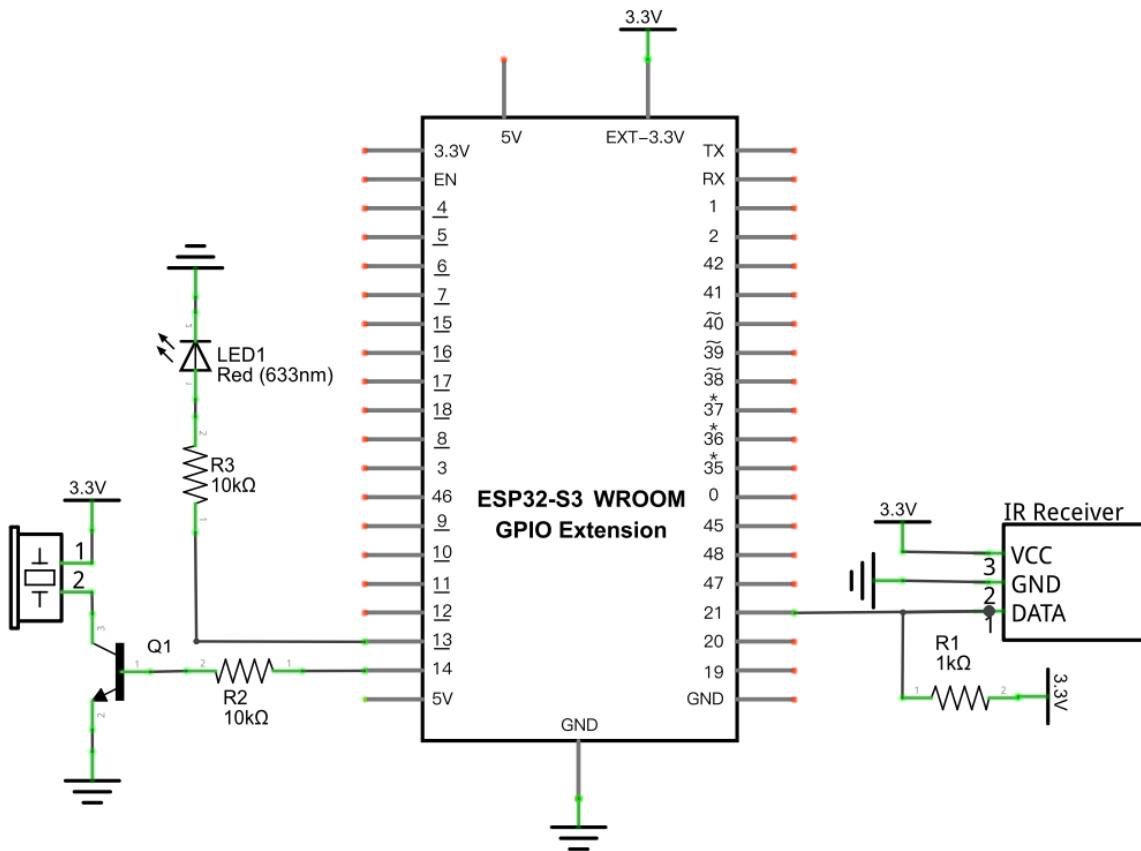
In this project, we will control the brightness of LED lights through an infrared remote control.

### Component List

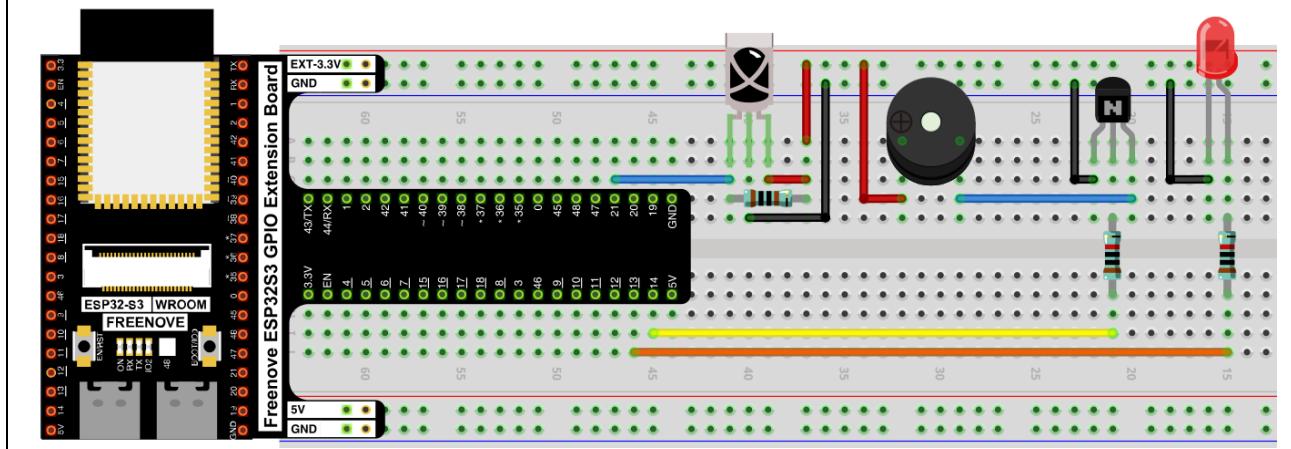
ESP32-S3 WROOM x1	GPIO Extension Board x1			
A black rectangular module with a central chip and various pins and pads for mounting.	A black rectangular board with a central ESP32 chip, several component pads, and a grid of numbered pins (1-48) for breadboarding or soldering.			
Breadboard x1				
A grey rectangular breadboard with a grid of holes for component placement and a red power rail across the top.				
Jumper M/M x10	Infrared Remote x1 (May need CR2025 battery x1, please check the holder)			
A simple black jumper wire with two flat metal ends.	A black remote control with a digital display showing numbers 0-9 and various function buttons like power, menu, test, and arrows.			
LED x1	Resistor 1kΩ x2	Resistor 10k Ω x1		
A small red light-emitting diode with two leads.	A resistor component with a brown band indicating 1k ohms.	A resistor component with a brown band indicating 10k ohms.		
Infrared receiver x1 (S8050)	NPN transistor x1 (S8050)	Active buzzer x1		
A small black module with a lens and internal components.	A black NPN transistor component with three leads.	A black circular component with a central button and two leads.		

# Circuit

## Schematic diagram



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



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## Sketch

The sketch controls the brightness of the LED by determining the key value of the infrared received.

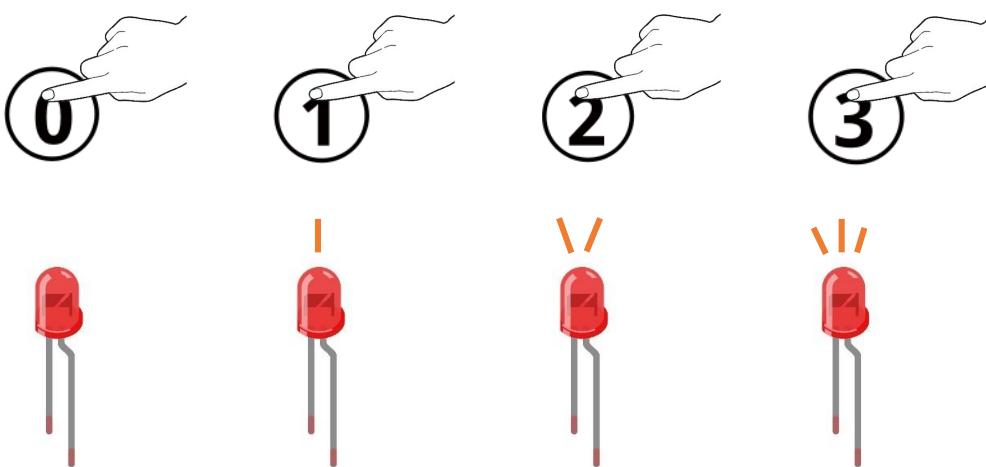
[Sketch\\_23.2\\_Control\\_LED\\_through\\_Infrared\\_Remote](#)

```

Sketch_23.2_Control_LED_through_Infrared_Remote | Arduino IDE 2.3.2
File Edit Sketch Tools Help
ESP32S3 Dev Module
Sketch_23.2_Control_LED_through_Infrared_Remote.ino ...
7 #include "Freenove_IR_Lib_for_ESP32.h"
8
9 const uint16_t recvPin = 21; // Infrared receiving pin
10 Freenove_ESP32_IR_Recv ir_recv(recvPin); // Create a class object used to receive class
11
12 int ledPin = 13; // the number of the LED pin
13 int buzzerPin = 14; // the number of the buzzer pin
14
15 void setup()
16 {
17     //Initialize the ledc configuration
18     ledcAttachChannel(ledPin, 1000, 8, 0); // set the frequency,solution_bits,channel to GPIO pin
19     pinMode(buzzerPin, OUTPUT); // set buzzer pin into output mode
20 }
21
22 void loop() {
23     ir_recv.task(); // Get IR receice data.
24     if(ir_recv.nec_available()){ // The data of the NEC protocol is checked
25         handleControl(ir_recv.data()); // Handle the commands from remote control
26     }
27 }
28
29 void handleControl(unsigned long value) {
30     // Make a sound when it rereives commands
31     digitalWrite(buzzerPin, HIGH);
32     delay(100);
33     digitalWrite(buzzerPin, LOW);
34     // Handle the commands
35     switch (value) {
36         case 0xff6897: // Receive the number '0'

```

Compile and upload the code to the ESP32-S3 WROOM. When pressing "0", "1", "2", "3" of the infrared remote control, the buzzer will sound once, and the brightness of the LED light will change correspondingly. rendering



The following is the program code:

```
1 #include "Freenove_IR_Lib_for_ESP32.h"
2
3 const uint16_t recvPin = 21; // Infrared receiving pin
4 Freenove_ESP32_IR_Recv ir_recv(recvPin); // Create a class object used to receive class
5
6 int ledPin = 13; // the number of the LED pin
7 int buzzerPin = 14; // the number of the buzzer pin
8
9 void setup()
10 {
11     //Initialize the ledc configuration
12     ledcAttachChannel(ledPin, 1000, 8, 0); // set the frequency, solution_bits, channel to GPIO pin
13     pinMode(buzzerPin, OUTPUT); // set buzzer pin into output mode
14 }
15
16 void loop() {
17     ir_recv.task(); // Get IR receive data.
18     if(ir_recv.nec_available()){ // The data of the NEC protocol is checked
19         handleControl(ir_recv.data()); // Handle the commands from remote control
20     }
21 }
22
23 void handleControl(unsigned long value) {
24     // Make a sound when it receives commands
25     digitalWrite(buzzerPin, HIGH);
26     delay(100);
27     digitalWrite(buzzerPin, LOW);
28     // Handle the commands
29     switch (value) {
30         case 0xff6897: // Receive the number '0'
31             ledcWrite(ledPin, 0); // Turn off LED
32             break;
33         case 0xff30CF: // Receive the number '1'
34             ledcWrite(ledPin, 7); // Dimmest brightness
35             break;
36         case 0xff18E7: // Receive the number '2'
37             ledcWrite(ledPin, 63); // Medium brightness
38             break;
39         case 0xff7A85: // Receive the number '3'
40             ledcWrite(ledPin, 255); // Strongest brightness
41             break;
42     }
43 }
```

Any concerns? ✉ support@freenove.com



The handleControl() function is used to execute events corresponding to infrared code values. Every time when the function is called, the buzzer sounds once and determine the brightness of the LED based on the infrared key value. If the key value is not "0", "1", "2", "3", the buzzer sounds once, but the brightness of LED will not change.

```

23 void handleControl(unsigned long value) {
24     // Make a sound when it receives commands
25     digitalWrite(buzzerPin, HIGH);
26     delay(100);
27     digitalWrite(buzzerPin, LOW);
28     // Handle the commands
29     switch (value) {
30         case 0xff6897:           // Receive the number '0'
31             ledcWrite(ledPin, 0); // Turn off LED
32             break;
33         case 0xff30CF:           // Receive the number '1'
34             ledcWrite(ledPin, 7); // Dimmest brightness
35             break;
36         case 0xff18E7:           // Receive the number '2'
37             ledcWrite(ledPin, 63); // Medium brightness
38             break;
39         case 0xff7A85:           // Receive the number '3'
40             ledcWrite(ledPin, 255); // Strongest brightness
41             break;
42     }
43 }
```

Each time when the command is received, the function above will be called in the loop() function.

```

16 void loop() {
17     ir_recv.task();           // Get IR receive data.
18     if(ir_recv.nec_available()){ // The data of the NEC protocol is checked
19         handleControl(ir_recv.data()); // Handle the commands from remote control
20     }
21 }
```

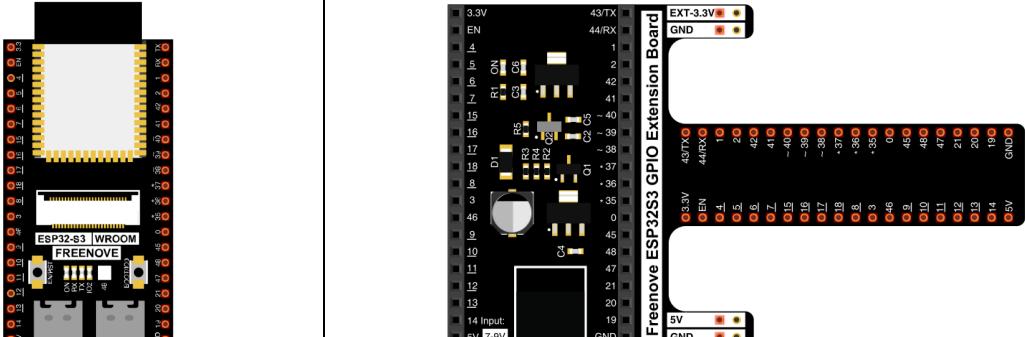
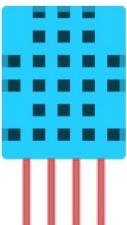
# Chapter 24 Hygrothermograph DHT11

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

## Project 24.1 Hygrothermograph

Hygrothermograph is an important tool in our lives to give us data on the temperature and humidity in our environment. In this project, we will use the ESP32-S3 to read temperature and humidity data of the DHT11 Module.

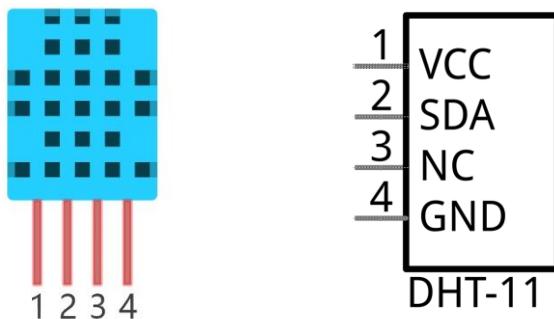
### Component List

ESP32-S3 WROOM x1	GPIO Extension Board x1
 <p>The image shows the Freenove ESP32S3 GPIO Extension Board. It is a black rectangular board with various pins, jumpers, and components. On the left side, there is a header labeled "Freenove ESP32S3 GPIO Extension Board". On the right side, there are two sets of pins: one set labeled "EXT-3.3V" and "GND" at the top, and another set labeled "5V" and "GND" at the bottom. The board has a central circular component and several other smaller components and resistors.</p>	
Breadboard x1	
Jumper M/M x4	DHT11 x1
	 <p>The image shows a blue DHT11 sensor module. It has a square blue PCB with a grid of pads and four red wires extending from the bottom. The wires are connected to the pins of the sensor chip.</p>
	Resistor 10kΩ x1



## Component knowledge

The temperature & humidity sensor DHT11 is a compound temperature & humidity sensor, and the output digital signal has been calibrated by its manufacturer.



DHT11 uses customized single-line communication protocol, so we can use the library to read data more conveniently.

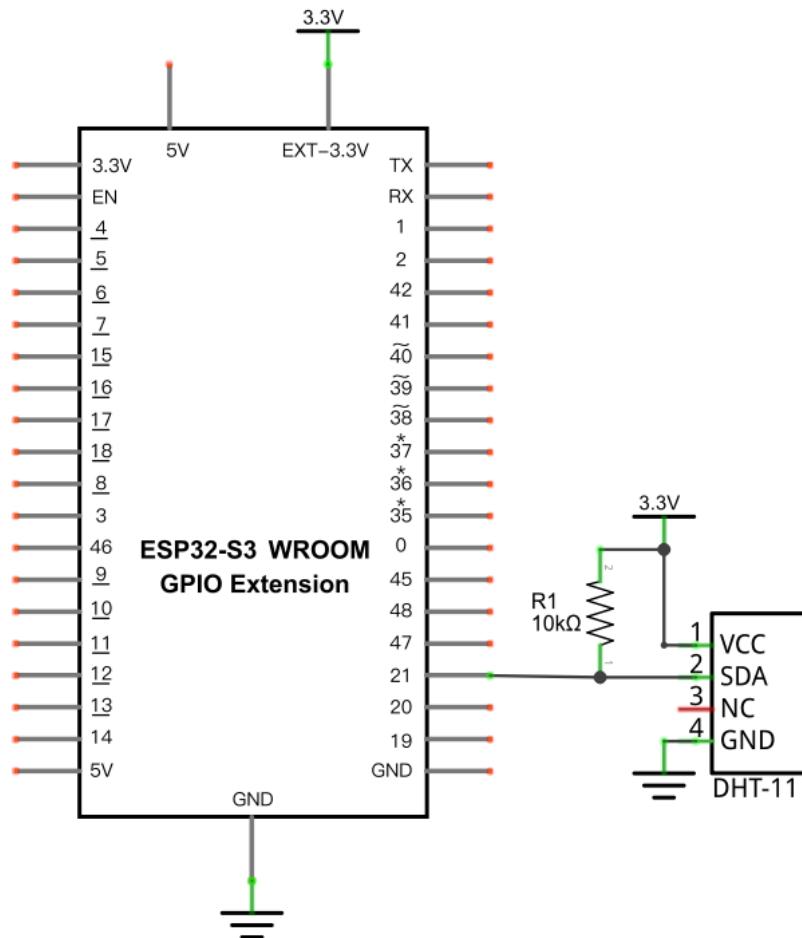
After being powered up, it will initialize in 1s. Its operating voltage is within the range of 3.3V-5.5V.

The SDA pin is a data pin, which is used to communicate with other devices.

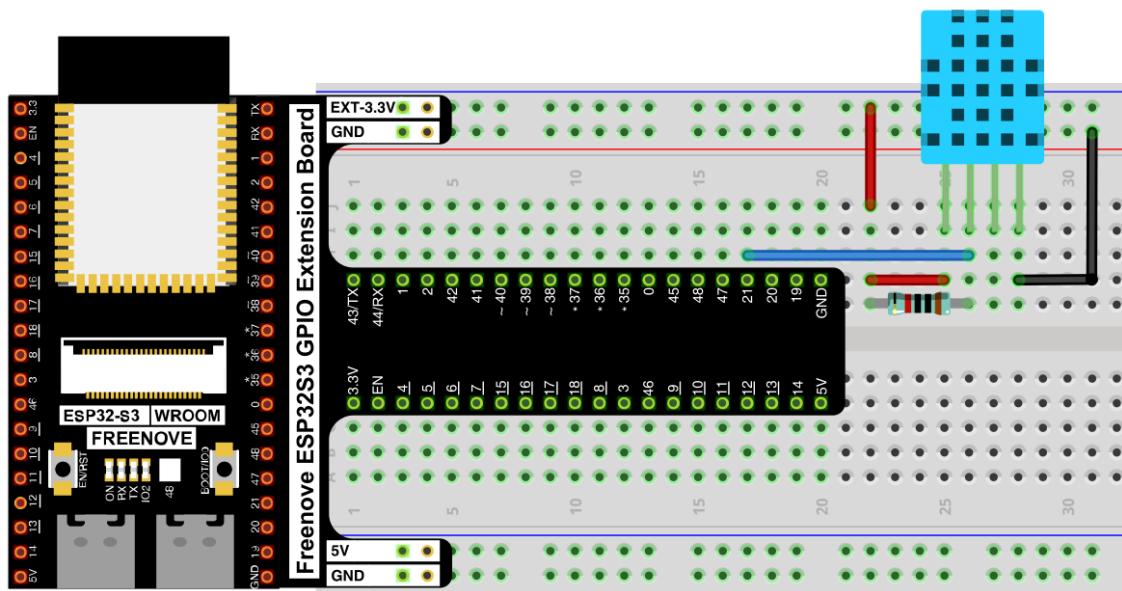
The NC pin (Not Connected Pin) is a type of pin found on various integrated circuit packages. Those pins have no functional purpose to the outside circuit (but may have an unknown functionality during manufacture and test). Those pins should not be connected to any of the circuit connections.

# Circuit

## Schematic diagram



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



Any concerns?  support@freenove.com



## Sketch

### How to install the library

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

We use the third party library DHTesp. If you haven't installed it yet, please do so now. The steps to add third-party libraries are as follows: open arduino->Sketch->Include library-> Manage libraries.

Enter " DHT " in the search bar and select "DHT sensor library for ESPx" for installation.

Refer to the following operations:

The screenshot shows the Arduino IDE 2.0.0 interface. On the left, the Library Manager is open under the 'Sketch' menu. It lists several DHT-related libraries, with one specifically for ESPx highlighted and circled in red. This library is 'DHT sensor library for ESPx by beegee\_tokyo, Version 1.18' and is marked as 'INSTALLED'. On the right, the main workspace displays a sketch titled 'Sketch\_24.1\_Temperature\_and\_Humidity\_Sensor.ino'. The code uses the DHTesp library to read data from a DHT11 sensor connected to pin 21 and prints the temperature and humidity to the serial monitor.

```
Sketch_24.1_Temperature_and_Humidity_Sensor.ino
1 // ****
2 |   Filename      : Temperature and Humidity Sensor
3 |   Description   : Use DHT11 to measure temperature and humidity
4 |   Author        : www.freenove.com
5 |   Modification  : 2022/10/26
6 ****
7 #include "DHTesp.h"
8
9 DHTesp dht;      //Define the DHT object
10 int dhtPin = 21; //Define the dht pin
11
12 void setup() {
13     dht.setup(dhtPin, DHTesp::DHT11); //Initialize the dht pin
14     Serial.begin(115200);           //Set the baud rate at 115200
15 }
16
17 void loop() {
18     flag(TempAndHumidity newValues = dht.getTempAndHumidity()
19     if (dht.getStatus() != 0) { //Judge if the correct value
20         goto flag;           //If there is an error, go back
21     }
22     Serial.println(" Temperature:" + String(newValues.temperature)
23     " Humidity:" + String(newValues.humidity));
24     delay(2000);
25 }
```

### Sketch\_24.1\_Temperature\_and\_Humidity\_Sensor

The screenshot shows the Arduino IDE interface with the following details:

- Title Bar:** Sketch\_24.1\_Temperature\_and\_Humidity\_Sensor | Arduino IDE 2.0.0
- Toolbar:** File, Edit, Sketch, Tools, Help
- Sketch Selection:** Sketch\_24.1\_Temperature\_and\_Humidity\_Sensor.ino
- Sketch Content:** The code is for a DHT11 sensor connected to pin 21. It initializes the serial port at 115200 baud and prints temperature and humidity values to the serial monitor every 2000ms.

```
1 // ****
2 // Filename : Temperature and Humidity Sensor
3 // Description : Use DHT11 to measure temperature and humidity. Print the result to the serial port
4 // Author : www.freenove.com
5 // Modification: 2022/10/26
6 ****
7 #include "DHTesp.h"
8
9 DHTesp dht;      //Define the DHT object
10 int dhtPin = 21; //Define the dht pin
11
12 void setup() {
13     dht.setup(dhtPin, DHTesp::DHT11); //Initialize the dht pin and dht object
14     Serial.begin(115200);           //Set the baud rate as 115200
15 }
16
17 void loop() {
18     flag:TempAndHumidity newValues = dht.getTempAndHumidity(); //Get the Temperature and humidity
19     if (dht.getStatus() != 0) { //Judge if the correct value is read
20         goto flag;           //If there is an error, go back to the flag and re-read the data
21     }
22     Serial.println(" Temperature:" + String(newValues.temperature) +
23     " Humidity:" + String(newValues.humidity));
24     delay(2000);
25 }
```

- Output Window:** Shows the serial communication log, indicating file upload progress and a hash verification message.

```
Writing at 0x00034571... (66 %)
Writing at 0x0003d5f6... (77 %)
Writing at 0x00044d4c... (88 %)
Writing at 0x0004a4a2... (100 %)
Wrote 257232 bytes (143345 compressed) at 0x00010000 in 2.9 seconds (effective 715.8 kbit/s)...
Hash of data verified.

Leaving...
Hard resetting via RTS pin...
```

Details from the bottom status bar: Ln 26, Col 1 UTF-8 ESP32S3 Dev Module on COM24 4



Compile and upload the code to the ESP32-S3 WROOM, turn on the serial monitor, and set the baud rate to 115200. Print out data of temperature and humidity sensor via the serial port.

The screenshot shows the Arduino Serial Monitor window. The title bar says "Output Serial Monitor". The message area contains the following text:

```

Message (Ctrl + Enter to send message to 'ESP32S3 Dev Module' on 'COM3')
rst:0x1 (POWERON), boot:0x8 (SPI_FLASH_BOOT)
SPIWP:0xee
mode:DIO, clock div:1
load:0x3fce3808, len:0x43c
load:0x403c9700, len:0xbec
load:0x403cc700, len:0xa3c
entry 0x403c98d8
Temperature:27.50 Humidity:56.00
Temperature:28.10 Humidity:56.00
Temperature:28.50 Humidity:48.00
Temperature:28.50 Humidity:53.00
Temperature:28.50 Humidity:57.00
Temperature:28.80 Humidity:63.00
Temperature:28.70 Humidity:61.00
Temperature:28.80 Humidity:59.00
Temperature:28.80 Humidity:57.00
Temperature:29.80 Humidity:80.00
Temperature:29.80 Humidity:83.00
Temperature:30.00 Humidity:83.00
Temperature:30.10 Humidity:84.00

```

The status bar at the bottom shows "Ln 17, Col 14 UTF-8" and "ESP32S3 Dev Module on COM3".

The following is the program code:

```

1 #include "DHTesp.h"
2
3 DHTesp dht; //Define the DHT object
4 int dhtPin = 21;//Define the dht pin
5
6 void setup() {
7     dht.setup(dhtPin, DHTesp::DHT11); //Initialize the dht pin and dht object
8     Serial.begin(115200); //Set the baud rate to 115200
9 }
10
11 void loop() {
12     flag:TempAndHumidity newValues = dht.getTempAndHumidity(); //Get the Temperature and humidity
13     if (dht.getStatus() != 0) { //Judge if the correct value is
14         read
15         goto flag; //If there is an error, go back to
16         the flag and re-read the data
17     }
18     Serial.println(" Temperature:" + String(newValues.temperature) +
19     " Humidity:" + String(newValues.humidity));
20     delay(2000);
21 }
```

In this project code, we use a third party library, DHTesp, and we need to define the objects for it first; Otherwise we could not use its functionality.

```
1 #include "DHTesp.h"
3 DHTesp dht; //Define the DHT object
```

Initialize the connection pin of DHT and select the type of temperature and humidity sensor as DHT11. If the temperature and humidity sensor is DHT12, we can also change it to DHT12.

```
7 dht.setup(dhtPin, DHTesp::DHT11); //Initialize the dht pin and dht object
```

Due to the use of the single-line protocol, data may be lost in the transmission process. So each time when getting the data of the temperature and humidity sensor, we need to call the getStatus function to determine whether the data is normal. If not, use goto to go back to line 12 and re-execute the program.

```
12 flag:TempAndHumidity newValues = dht.getTempAndHumidity(); //Get the Temperature and
13 humidity
14 if (dht.getStatus() != 0) { //Judge if the correct value is read
15     goto flag; //If there is an error, go back to the flag and re-read
16     the data
17 }
```

Get the temperature and humidity data and store it in a TempAndHumidity class called newValues.

```
12 TempAndHumidity newValues = dht.getTempAndHumidity(); //Get the Temperature and humidity
```

#### Reference

**class DHTesp**

Make sure that the library and header files are added before using the object every time.

**setup(Pin, DHTesp::DHTxx):** Select the type of DHTxx and associate Pin with the DHTesp class.

Parameter 1: the pin to be associated.

Parameter 2: select the type of sensor, DHT11 or DHT12.

**getTempAndHumidity():** Obtain temperature and humidity data. The received data must be stored in the 'TempAndHumidity' class.

**getStatus():** To judge whether the obtained data format is normal, the return value of 0 means the data is normal, and the return value of non-0 means the data is abnormal or the data fails to be obtained.



## Project 24.2 Hygrothermograph

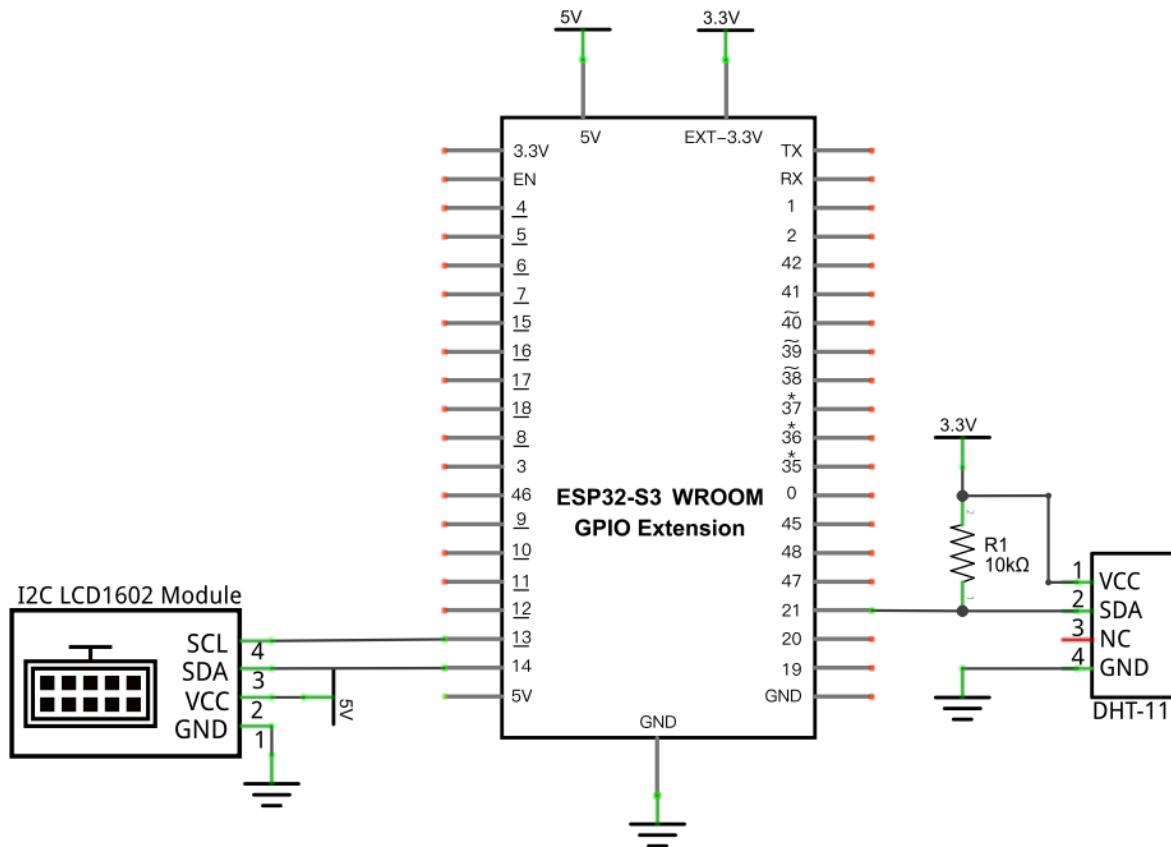
In this project, we use L2C-LCD1602 to display data collected by DHT11.

### Component List

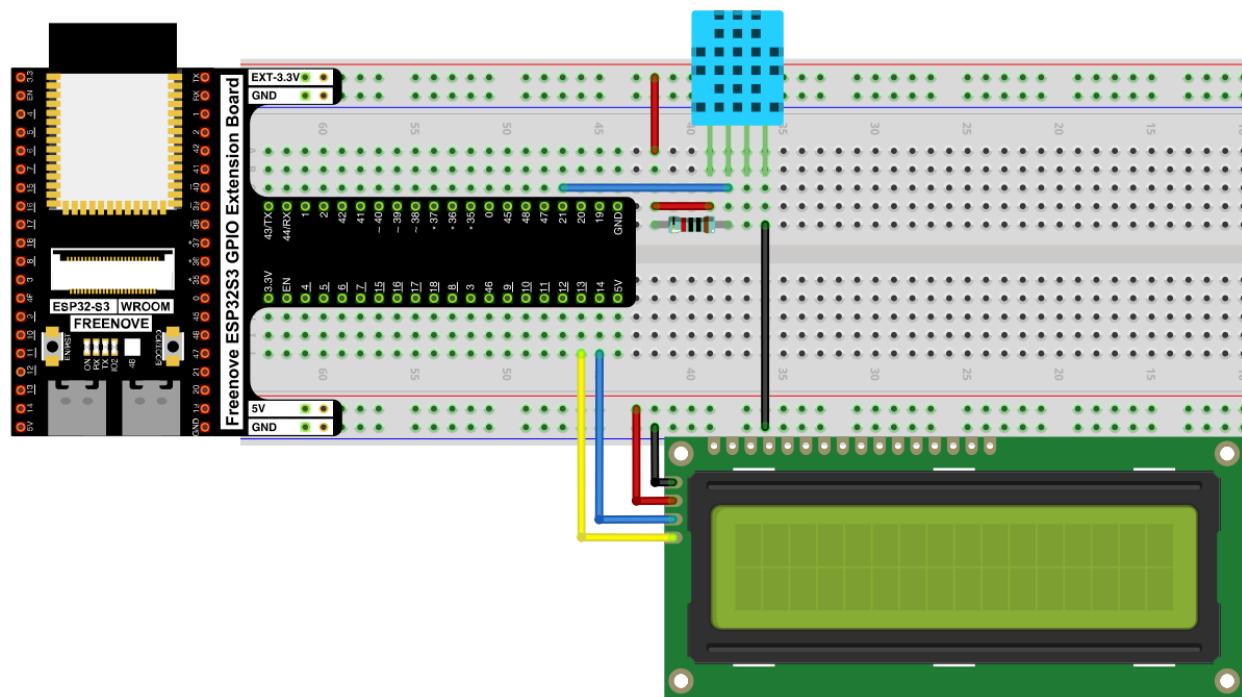
<b>ESP32-S3 WROOM x1</b> 	<b>GPIO Extension Board x1</b> 
<b>Breadboard x1</b> 	
<b>LCD1602 Module x1</b> 	<b>Resistor 10kΩ x1</b> 
<b>Jumper F/M x4</b> <b>Jumper M/M x4</b> 	<b>DHT11 x1</b> 

## 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)



## Sketch

This code uses the DHTesp and LiquidCrystal\_I2C libraries, so make sure the relevant library files are added before writing the program.

### Sketch\_24.2\_Temperature\_and\_Humidity\_Sensor

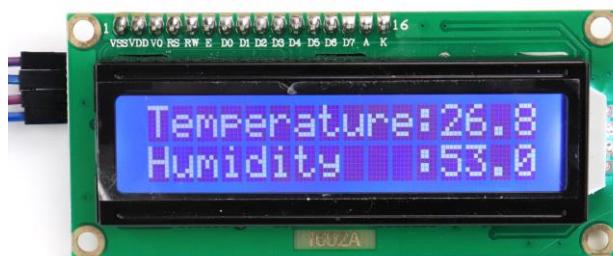
```

Sketch_24.2_Temperature_and_Humidity_Sensor | Arduino IDE 2.0.4
File Edit Sketch Tools Help
ESP32S3 Dev Module
Sketch_24.2_Temperature_and_Humidity_Sensor.ino ...
1 // ****
2 | Filename : Temperature and Humidity Sensor
3 | Description : Use DHT11 to measure temperature and humidity. Print the result to the LCD1602.
4 | Author : www.freenove.com
5 | Modification: 2022/10/26
6 ****
7 #include <Wire.h>
8 #include <LiquidCrystal_I2C.h>
9 #include "DHTesp.h"
10
11 #define SDA 14 //Define SDA pins
12 #define SCL 13 //Define SCL pins
13
14 DHTesp dht; // create dht object
15 LiquidCrystal_I2C lcd(0x27,16,2); //initialize the LCD
16 int dhtPin = 21; // the number of the DHT11 sensor pin
17
18 void setup() {
19     Wire.begin(SDA, SCL); // attach the IIC pin
20     if (!i2cAddrTest(0x27)) {
21         lcd = LiquidCrystal_I2C(0x3F, 16, 2);
22     }
23     lcd.init(); // LCD driver initialization
24     lcd.backlight(); // Open the backlight
25     dht.setup(dhtPin, DHTesp::DHT11); //attach the dht pin and initialize it
26 }
27
28 void loop() {
29     // read DHT11 data and save it
30     flag:TempAndHumidity DHT = dht.getTempAndHumidity();

```

Ln 50, Col 2 ESP32S3 Dev Module [not connected] 🔍

Download the code to ESP32-S3 WROOM. The first line of LCD1602 shows the temperature value, and the second line shows the humidity value. Try to “pinch” the thermistor (without touching the leads) with your index finger and thumb for a brief time to observe the change in the LCD display value.



The following is the program code:

```
1 #include <Wire.h>
2 #include <LiquidCrystal_I2C.h>
3 #include "DHTesp.h"
4
5 #define SDA 14           //Define SDA pins
6 #define SCL 13           //Define SCL pins
7 DHTesp dht;           // create dht object
8 LiquidCrystal_I2C lcd(0x27, 16, 2); //initialize the LCD
9 int dhtPin = 21;       // the number of the DHT11 sensor pin
10
11 void setup() {
12     Wire.begin(SDA, SCL);           // attach the IIC pin
13     if (!i2CAddrTest(0x27)) {
14         lcd = LiquidCrystal_I2C(0x3F, 16, 2);
15     }
16     lcd.init();                     // LCD driver initialization
17     lcd.backlight();               // Open the backlight
18     dht.setup(dhtPin, DHTesp::DHT11); //attach the dht pin and initialize it
19 }
20
21 void loop() {
22     // read DHT11 data and save it
23     flag:TempAndHumidity DHT = dht.getTempAndHumidity();
24     if (dht.getStatus() != 0) {      //Determine if the read is successful, and if it fails, go
back to flag and re-read the data
25         goto flag;
26     }
27     lcd.setCursor(0, 0);           //set the cursor to column 0, line 1
28     lcd.print("Temperature:");    //display the Humidity on the LCD1602
29     lcd.print(DHT.temperature);
30     lcd.setCursor(0, 1);           //set the cursor to column 0, line 0
31     lcd.print("Humidity :");      //display the Humidity on the LCD1602
32     lcd.print(DHT.humidity);
33     delay(2000);
34 }
35
36 bool i2CAddrTest(uint8_t addr) {
37     Wire.beginTransmission(addr);
38     if (Wire.endTransmission() == 0) {
39         return true;
40     }
41     return false;
42 }
```

First, add the library function header file.

```
1 #include <Wire.h>
2 #include <LiquidCrystal_I2C.h>
3 #include "DHTesp.h"
```

Second, initialize the pins associated with the DHT11 sensor and I2C-LCD1602.

```
8 DHTesp dht; // create dht object
9 LiquidCrystal_I2C lcd(0x27, 16, 2); //initialize the LCD
10 int dhtPin = 21; // the number of the DHT11 sensor pin
11
12 void setup() {
13     Wire.begin(SDA, SCL); // attach the IIC pin
14     if (!i2CAddrTest(0x27)) {
15         lcd = LiquidCrystal_I2C(0x3F, 16, 2);
16     }
17     lcd.init(); // LCD driver initialization
18     lcd.backlight(); // Open the backlight
19     dht.setup(dhtPin, DHTesp::DHT11); //attach the dht pin and initialize it
20 }
```

Finally, the data of temperature and humidity sensor are obtained and displayed on LCD1602. The first row shows the temperature and the second shows the humidity.

```
24 flag:TempAndHumidity DHT = dht.getTempAndHumidity();
25 if (dht.getStatus() != 0) { //Determine if the read is successful, and if it fails, go
back to flag and re-read the data
26     goto flag;
27 }
28 lcd.setCursor(0, 0); //set the cursor to column 0, line 1
29 lcd.print("Temperature:");
30 lcd.print(DHT.temperature);
31 lcd.setCursor(0, 1); //set the cursor to column 0, line 0
32 lcd.print("Humidity :");
33 lcd.print(DHT.humidity);
```

# Chapter 25 Infrared Motion Sensor

In this chapter, we will learn a widely used sensor, infrared motion sensor.

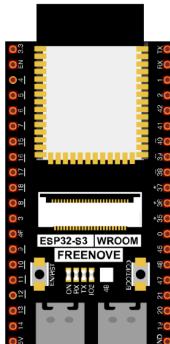
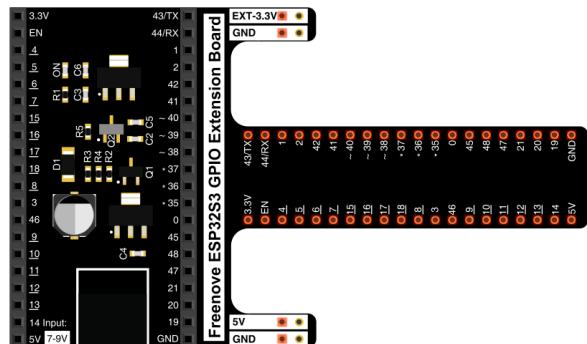
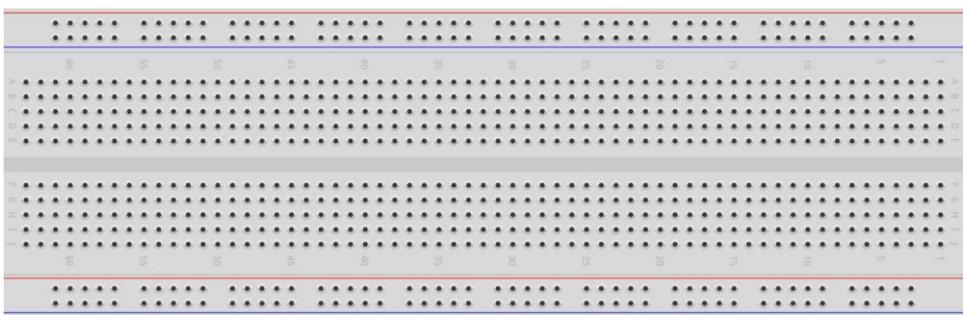
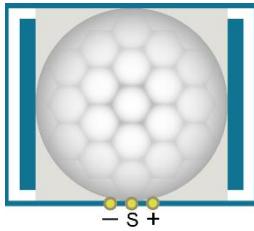
## Project 25.1 Infrared Motion Detector with LED Indicator

In this project, we will make a motion detector, with the human body infrared pyroelectric sensors.

When someone is in close proximity to the motion detector, it will automatically light up and when there is no one close by, it will be out.

This infrared motion sensor can detect the infrared spectrum (heat signatures) emitted by living humans and animals.

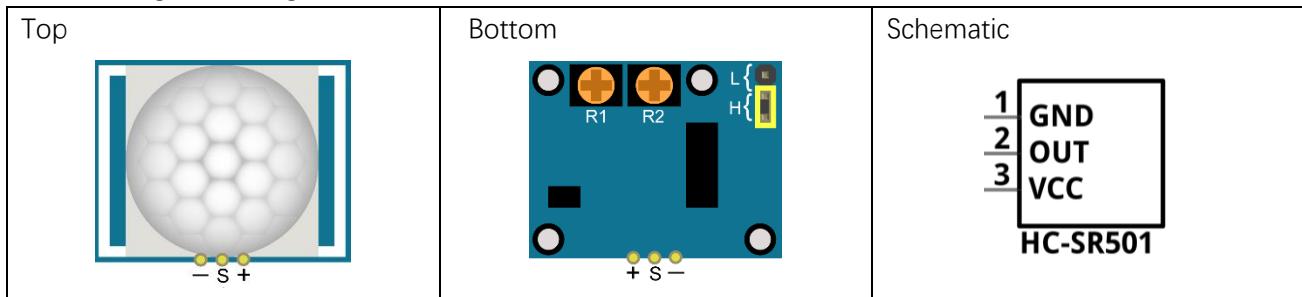
### Component List

ESP32-S3 WROOM x1	GPIO Extension Board x1				
					
Breadboard x1					
HC SR501 x1	LED x1	Resistor 220Ω x1	Jumper F/M x3	Jumper M/M x2	
					

Any concerns? ✉ support@freenove.com

## Component knowledge

The following is the diagram of the infrared Motion sensor (HC SR-501) :



Description:

Working voltage: 5v-20v(DC) Static current: 65uA.

Automatic Trigger. When a living body enters into the active area of sensor, the module will output high level (3.3V). When the body leaves the sensor's active detection area, it will output high level lasting for time period T, then output low level(0V). Delay time T can be adjusted by the potentiometer R1.

According to the position of jumper cap, you can choose non-repeatable trigger mode or repeatable mode.

L: non-repeatable trigger mode. The module output high level after sensing a body, then when the delay time is over, the module will output low level. During high level time, the sensor no longer actively senses bodies.

H: repeatable trigger mode. The distinction from the L mode is that it can sense a body until that body leaves during the period of high level output. After this, it starts to time and output low level after delaying T time.

Induction block time: the induction will stay in block condition and does not induce external signal at lesser time intervals (less than delay time) after outputting high level or low level

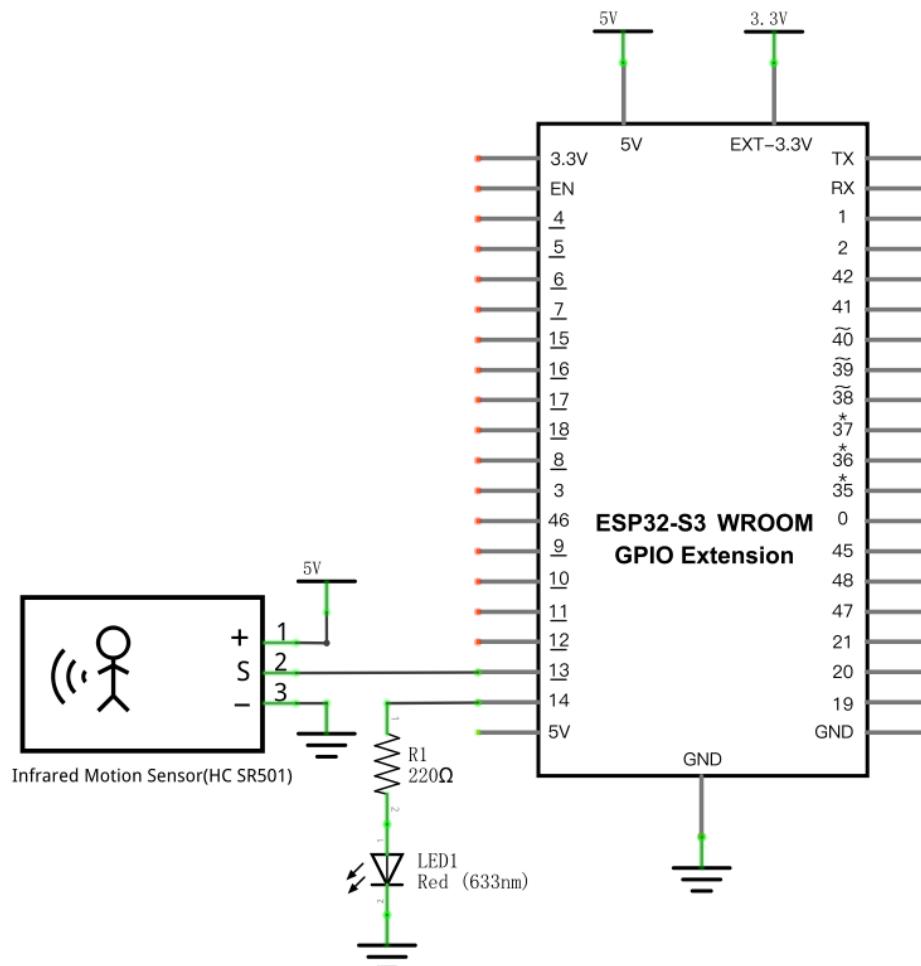
Initialization time: the module needs about 1 minute to initialize after being powered ON. During this period, it will alternately output high or low level.

One characteristic of this sensor is when a body moves close to or moves away from the sensor's dome edge, the sensor will work at high sensitivity. When a body moves close to or moves away from the sensor's dome in a vertical direction, the sensor cannot detect well (please take note of this deficiency). Note: The sensing range (distance before a body is detected) is adjusted by the potentiometer.

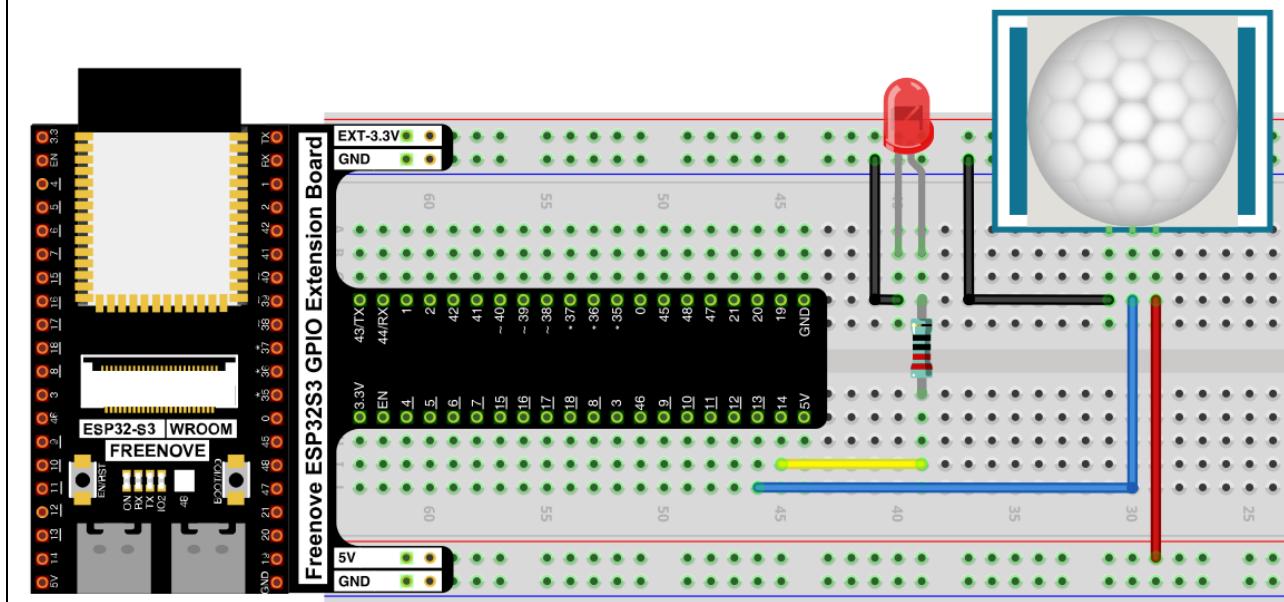
We can regard this sensor as a simple inductive switch when in use.

## Circuit

Schematic diagram



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



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

## Sketch

In this project, we will use the infrared motion sensor to trigger a LED, essentially making the infrared motion sensor act as a motion switch. Therefore, the code is very similar to the earlier project "push button switch and LED". The difference is that, when infrared motion sensor detects change, it will output high level; when button is pressed, it will output low level. When the sensor output high level, the LED turns ON, or it will turn OFF.

### Sketch\_25.1\_Infrared\_Motion\_Sensor

The screenshot shows the Arduino IDE interface with the following details:

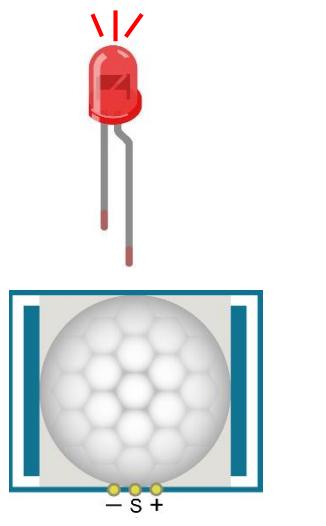
- Title Bar:** Sketch\_25.1\_Infrared\_Motion\_Sensor | Arduino IDE 2.0.0
- Toolbar:** File, Edit, Sketch, Tools, Help
- Sketch Selection:** ESP32S3 Dev Module
- Code Area:** The code is named Sketch\_25.1\_Infrared\_Motion\_Sensor.ino. It includes comments and defines two pins: sensorPin (13) and ledPin (14). The setup() function initializes the sensor pin as INPUT and the LED pin as OUTPUT. The loop() function reads the sensor's digital value and sets the LED accordingly, with a 1-second delay.
- Output Area:** Shows the upload process:
  - Writing at 0x0002d260... (62 %)
  - Writing at 0x00034233... (75 %)
  - Writing at 0x0003dd0d... (87 %)
  - Writing at 0x0004333a... (100 %)
  - Wrote 228080 bytes (127067 compressed) at 0x00010000 in 3.2 seconds (effective 571.2 kbit/s)...
  - Hash of data verified.
- Status Bar:** Ln 20, Col 1 UTF-8 ESP32S3 Dev Module on COM3

Verify and upload the code, and put the sensor on a stationary table and wait for about a minute. Then try to move away from or move closer to the infrared motion sensor and observe whether the LED turns ON or OFF automatically.

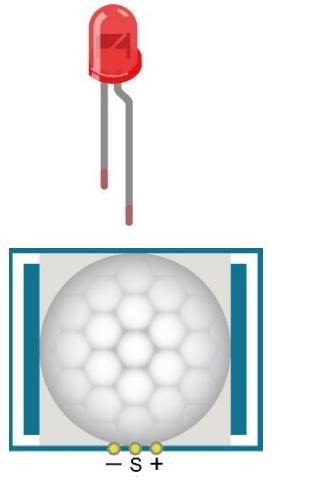
You can rotate the potentiometer on the sensor to adjust the detection effect, or use different modes by changing the jumper.

Apart from that, you can also use this sensor to control some other modules to implement different functions by reediting the code, such as the induction lamp, induction door.

Move to the Infrared Motion Sensor



Move away from the Infrared Motion Sensor





# Chapter 26 Attitude Sensor MPU6050

In this chapter, we will learn about a MPU6050 attitude sensor which integrates an accelerometer and gyroscope.

## Project 26.1 Read a MPU6050 Sensor Module

In this project, we will read acceleration and gyroscope data of the MPU6050 sensor

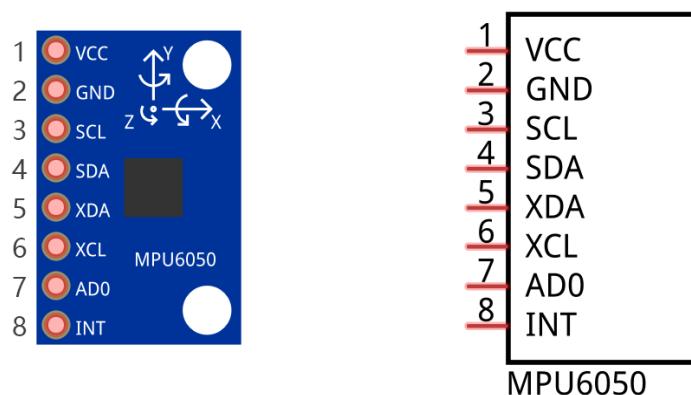
### Component List

ESP32-S3 WROOM x1	GPIO Extension Board x1
Breadboard x1	
Jumper F/M x4	
	MPU6050 x1

## Component knowledge

### MPU6050

MPU6050 sensor module is a complete 6-axis motion tracking device. It combines a 3-axis gyroscope, a 3-axis accelerometer and a DMP (Digital Motion Processor) all in a small package. The settings of the accelerometer and gyroscope of MPU6050 can be changed. A precision wide range digital temperature sensor is also integrated to compensate data readings for changes in temperature, and temperature values can also be read. The MPU6050 Module follows the I2C communication protocol and the default address is 0x68. MPU6050 is widely used to assist with balancing vehicles, robots and aircraft, mobile phones and other products which require stability to control stability and attitude or which need to sense same.



The port description of the MPU6050 module is as follows:

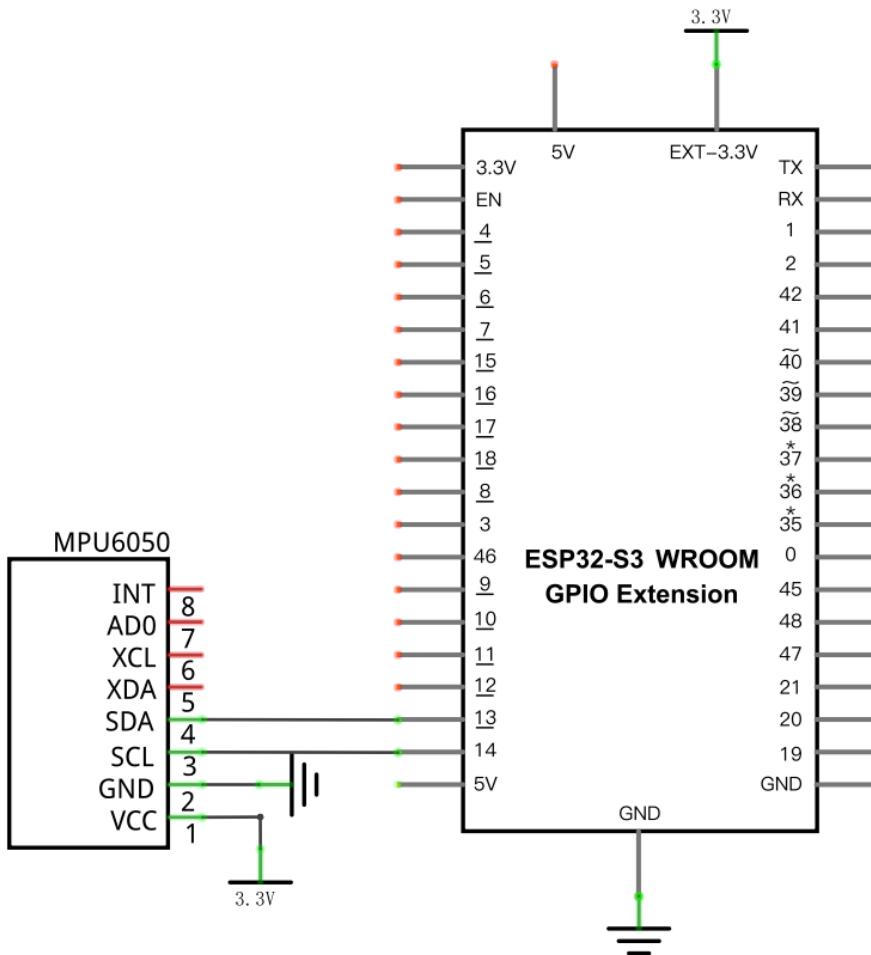
Pin name	Pin number	Description
<b>VCC</b>	1	Positive pole of power supply with voltage 5V
<b>GND</b>	2	Negative pole of power supply
<b>SCL</b>	3	I2C communication clock pin
<b>SDA</b>	4	I2C communication clock pin
<b>XDA</b>	5	I2C host data pin which can be connected to other devices.
<b>XCL</b>	6	I2C host clock pin which can be connected to other devices.
<b>AD0</b>	7	I2C address bit control pin. Low level: the device address is 0x68 High level: the device address is 0x69
<b>INT</b>	8	Output interrupt pin

For more detail, please refer to datasheet.

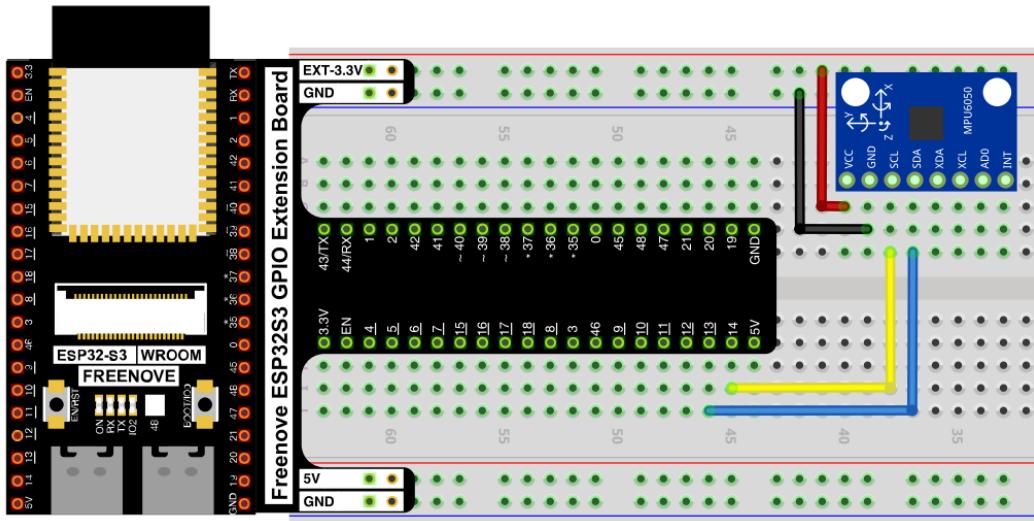
## Circuit

Note that the power supply voltage for MPU6050 module is 5V in the circuit.

## Schematic diagram



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



Any concerns?  support@freenove.com

## Sketch

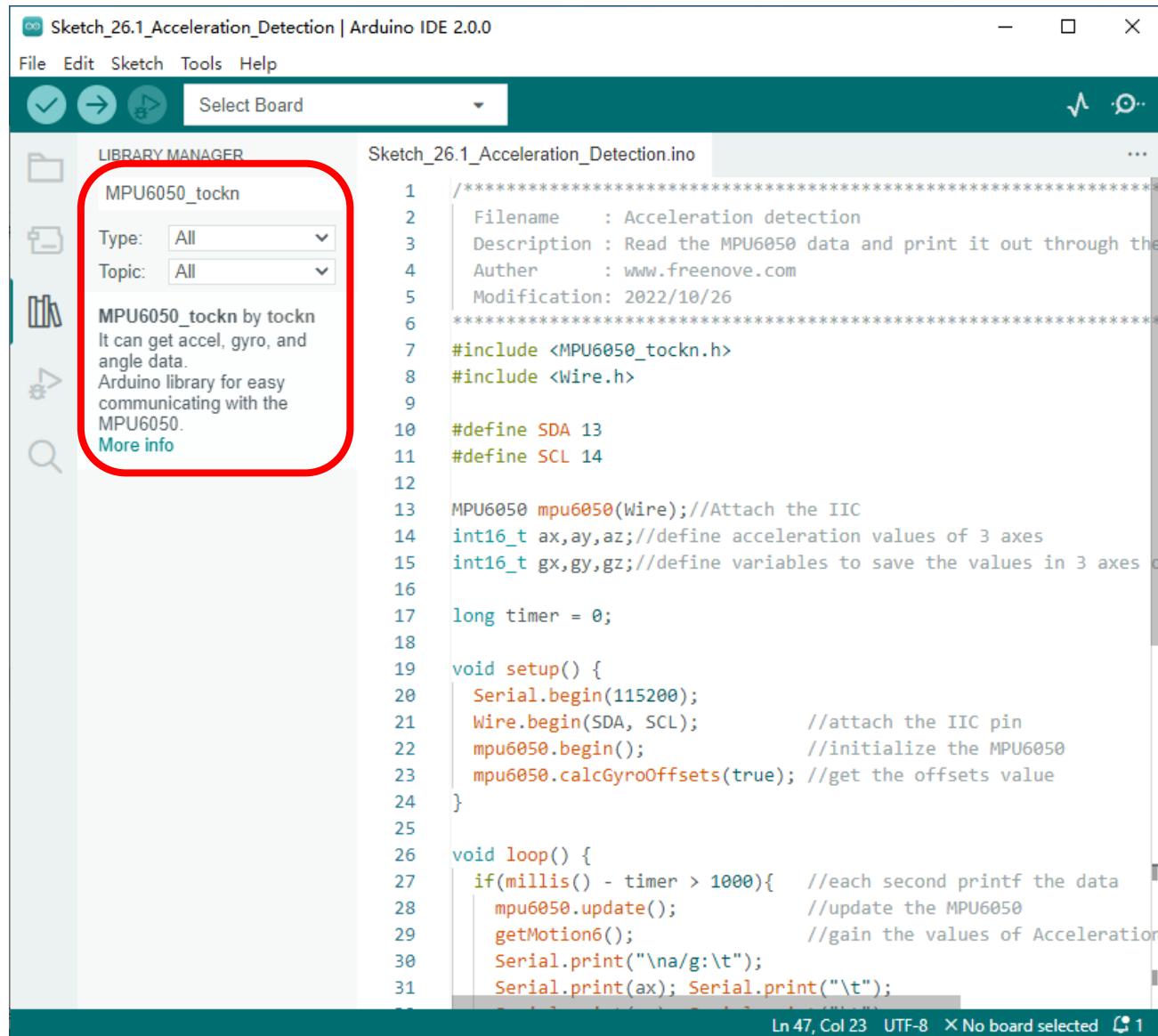
### How to install the library

In this project, we will read the acceleration data and gyroscope data of MPU6050, and print them out.

We use the third party library MPU6050\_tockn. If you haven't installed it yet, please do so now. The steps to add third-party Libraries are as follows: open arduino->Sketch->Include library-> Manage libraries.

Enter "MPU6050\_tockn" in the search bar and select "MPU6050\_tockn" for installation.

Refer to the following operations:





### Sketch\_26.1\_Acceleration\_Detection

The screenshot shows the Arduino IDE 2.0.0 interface with the following details:

- Title Bar:** Sketch\_26.1\_Acceleration\_Detection | Arduino IDE 2.0.0
- Menu Bar:** File Edit Sketch Tools Help
- Toolbar:** Includes icons for Save, Run, Stop, and Select Board (ESP32S3 Dev Module).
- Sketch Area:** Displays the C++ code for the sketch.
- Code Content:**

```
1 // ****
2 // Filename : Acceleration detection
3 // Description : Read the MPU6050 data and print it out through the serial port
4 // Author : www.freenove.com
5 // Modification: 2022/10/26
6 // ****
7 #include <MPU6050_tockn.h>
8 #include <Wire.h>
9
10 #define SDA 13
11 #define SCL 14
12
13 MPU6050 mpu6050(Wire); //Attach the IIC
14 int16_t ax,ay,az; //define acceleration values of 3 axes
15 int16_t gx,gy,gz; //define variables to save the values in 3 axes of gyroscope
16
17 long timer = 0;
18
19 void setup() {
20     Serial.begin(115200);
21     Wire.begin(SDA, SCL); //attach the IIC pin
```
- Output Tab:** Shows the serial monitor output.
- Serial Monitor Output:**

```
Writing at 0x00033da7... (66 %)
Writing at 0x0003c3b1... (77 %)
Writing at 0x0004470f... (88 %)
Writing at 0x00049df5... (100 %)
Wrote 254016 bytes (142353 compressed) at 0x00010000 in 3.9 seconds (effective 519.7 kbit/s)...
Hash of data verified.

Leaving...
Hard resetting via RTS pin...
```
- Status Bar:** Ln 46, Col 2 UTF-8 ESP32S3 Dev Module on COM3 4 2

Download the code to ESP32-S3 WROOM, open the serial port monitor, set the baud rate to 115200 and you can use it to measure the distance between the ultrasonic module and the object. As shown in the following figure:

```

Output  Serial Monitor ×
Message (Ctrl + Enter to send message to 'ESP32S3 Dev Module' on 'COM3')  New Line  115200 baud
-----
Calculating gyro offsets
DO NOT MOVE MPU6050...
Done!
X : -6.56
Y : -0.32
Z : 0.83
Program will start after 3 seconds
=====
a/g: 2040    -4     16312   -427      -427      -427
a/g: 0.12g   -0.00g  1.00g   -3.26d/s  -3.26d/s  -3.26d/s

a/g: 1924    -8     16312   -440      -440      -440
a/g: 0.12g   -0.00g  1.00g   -3.36d/s  -3.36d/s  -3.36d/s

a/g: 1984    -40    16456   -427      -427      -427
a/g: 0.12g   -0.00g  1.00g   -3.26d/s  -3.26d/s  -3.26d/s

a/g: 2044    48     16208   -430      -430      -430
a/g: 0.12g   0.00g   0.99g   -3.28d/s  -3.28d/s  -3.28d/s

a/g: 1992    12     16420   -422      -422      -422
a/g: 0.12g   0.00g   1.00g   -3.22d/s  -3.22d/s  -3.22d/s

```

The following is the program code:

```

1 #include <MPU6050_tockn.h>
2 #include <Wire.h>
3
4 #define SDA 13
5 #define SCL 14
6
7 MPU6050 mpu6050(Wire); //Attach the IIC
8 int16_t ax,ay,az;//define acceleration values of 3 axes
9 int16_t gx,gy,gz;//define variables to save the values in 3 axes of gyroscope
10
11 long timer = 0;
12
13 void setup() {
14     Serial.begin(115200);
15     Wire.begin(SDA, SCL);           //attach the IIC pin
16     mpu6050.begin();               //initialize the MPU6050
17     mpu6050.calcGyroOffsets(true); //get the offsets value
18 }
19
20 void loop() {
21     if(millis() - timer > 1000){ //each second print the data

```

```

22     mpu6050.update();           //update the MPU6050
23     getMotion6();             //gain the values of Acceleration and Gyroscope value
24     Serial.print("\n/a/g:\t");
25     Serial.print(ax); Serial.print("\t");
26     Serial.print(ay); Serial.print("\t");
27     Serial.print(az); Serial.print("\t");
28     Serial.print(gx); Serial.print("\t\t");
29     Serial.print(gy); Serial.print("\t\t");
30     Serial.println(gz);
31     Serial.print("a/g:\t");
32     Serial.print((float)ax / 16384); Serial.print("g\t");
33     Serial.print((float)ay / 16384); Serial.print("g\t");
34     Serial.print((float)az / 16384); Serial.print("g\t");
35     Serial.print((float)gx / 131); Serial.print("d/s \t");
36     Serial.print((float)gy / 131); Serial.print("d/s \t");
37     Serial.print((float)gz / 131); Serial.print("d/s \n");
38     timer = millis();
39   }
40 }
41 void getMotion6(void) {
42   ax=mpu6050.getRawAccX(); //gain the values of X axis acceleration raw data
43   ay=mpu6050.getRawAccY(); //gain the values of Y axis acceleration raw data
44   az=mpu6050.getRawAccZ(); //gain the values of Z axis acceleration raw data
45   gx=mpu6050.getRawGyroX(); //gain the values of X axis Gyroscope raw data
46   gy=mpu6050.getRawGyroY(); //gain the values of Y axis Gyroscope raw data
47   gz=mpu6050.getRawGyroZ(); //gain the values of Z axis Gyroscope raw data
48 }
```

Two library files "MPU6050\_tockn.h" and "Wire.h" are used in the code and will be compiled with others.

Class MPU6050 is used to operate the MPU6050. When using it, please instantiate an object first.

7	MPU6050 mpu6050(Wire); //Attach the IIC
---	---

In the setup function, IIC and MPU6050 are initialized and the offset difference of MPU6050 is obtained.

13	void setup() {
14	Serial.begin(115200);
15	Wire.begin(SDA, SCL); //attach the IIC pin
16	mpu6050.begin(); //initialize the MPU6050
17	mpu6050.calcGyroOffsets(true); //get the offsets value
18	}

The getMotion6 function is used to obtain the x, y, z axis acceleration raw data and the Gyroscope raw data.

41	void getMotion6(void){
42	ax=mpu6050.getRawAccX(); //gain the values of X axis acceleration raw data
43	ay=mpu6050.getRawAccY(); //gain the values of Y axis acceleration raw data
44	az=mpu6050.getRawAccZ(); //gain the values of Z axis acceleration raw data
45	gx=mpu6050.getRawGyroX(); //gain the values of X axis Gyroscope raw data
46	gy=mpu6050.getRawGyroY(); //gain the values of Y axis Gyroscope raw data

```

47     gz=mpu6050.getRawGyroX(); //gain the values of Z axis Gyroscope raw data
48 }
```

Finally, the original data of the gyroscope is updated and acquired every second, and the original data, the processed acceleration and angular velocity data are printed out through the serial port.

```

20 void loop() {
21     if(millis() - timer > 1000){      //each second print the data
22         mpu6050.update();           //update the MPU6050
23         getMotion6();             //gain the values of Acceleration and Gyroscope value
24         Serial.print("\n\na/g:\t");
25         Serial.print(ax); Serial.print("\t");
26         Serial.print(ay); Serial.print("\t");cc
27         Serial.print(az); Serial.print("\t");
28         Serial.print(gx); Serial.print("\t\t");
29         Serial.print(gy); Serial.print("\t\t");
30         Serial.println(gz);
31         Serial.print("a/g:\t");
32         Serial.print((float)ax / 16384); Serial.print("g\t");
33         Serial.print((float)ay / 16384); Serial.print("g\t");
34         Serial.print((float)az / 16384); Serial.print("g\t");
35         Serial.print((float)gx / 131); Serial.print("d/s \t");
36         Serial.print((float)gy / 131); Serial.print("d/s \t");
37         Serial.print((float)gz / 131); Serial.print("d/s \n");
38         timer = millis();
39     }
40 }
```

## Reference

### Class MPU6050

This is a class library used to operate MPU6050, which can directly read and set MPU6050. Here are some member functions:

**MPU6050 mpu6050(Wire):** Associate MPU6050 with IIC.

**begin():** Initialize the MPU6050.

**calcGyroOffsets(true):** If the parameter is true, get the gyro offset and automatically correct the offset. If the parameter is false, the offset value is not obtained and the offset is not corrected.

**getRawAccX():** Gain the values of X axis acceleration raw data.

**getRawAccY():** Gain the values of Y axis acceleration raw data.

**getRawAccZ():** Gain the values of Z axis acceleration raw data.

**getRawGyroX():** Gain the values of X axis Gyroscope raw data.

**getRawGyroY():** Gain the values of Y axis Gyroscope raw data.

**getRawGyroZ():** gain the values of Z axis Gyroscope raw data.

**getTemp():** Gain the values of MPU6050's temperature data.

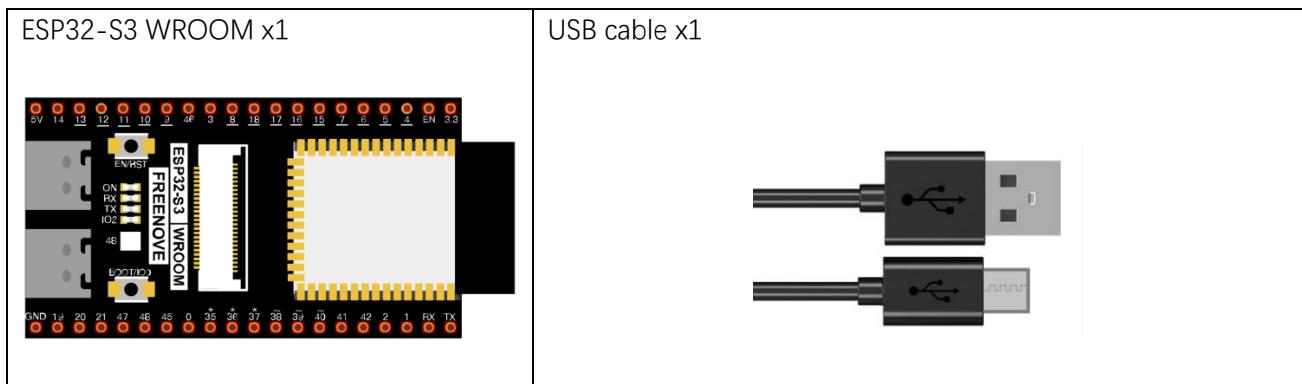
**update():** Update the MPU6050. If the updated function is not used, the IIC will not be able to retrieve the new data.

# Chapter 27 Bluetooth

This chapter mainly introduces how to make simple data transmission through Bluetooth of ESP32-S3 WROOM and mobile phones.

## Project 27.1 Bluetooth Low Energy Data Passthrough

### Component List



### Component knowledge

ESP32-S3's integrated Bluetooth function Bluetooth is a short-distance communication system, which can be divided into two types, namely Bluetooth Low Energy(BLE) and Classic Bluetooth. There are two modes for simple data transmission: master mode and slave mode.

#### Master mode

In this mode, works are done in the master device and it can connect with a slave device. And we can search and select slave devices nearby to connect with. When a device initiates connection request in master mode, it requires information of the other Bluetooth devices including their address and pairing passkey. After finishing pairing, it can connect with them directly.

#### Slave mode

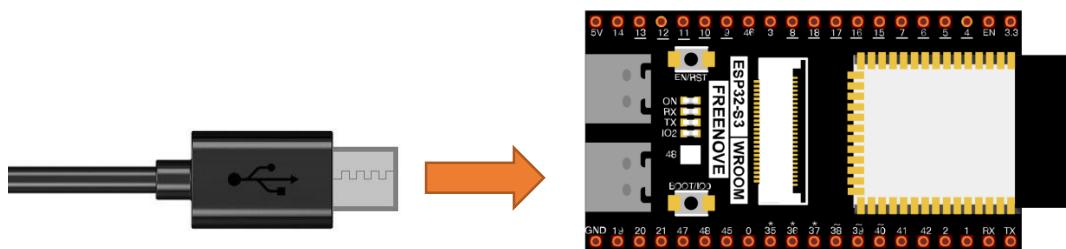
The Bluetooth module in slave mode can only accept connection request from a host computer, but cannot initiate a connection request. After connecting with a host device, it can send data to or receive from the host device.

Bluetooth devices can make data interaction with each other, as one is in master mode and the other in slave mode. When they are making data interaction, the Bluetooth device in master mode searches and selects devices nearby to connect to. When establishing connection, they can exchange data. When mobile phones exchange data with ESP32-S3, they are usually in master mode and ESP32-S3 in slave mode.



## Circuit

Connect Freenove ESP32-S3 to the computer using the USB cable.



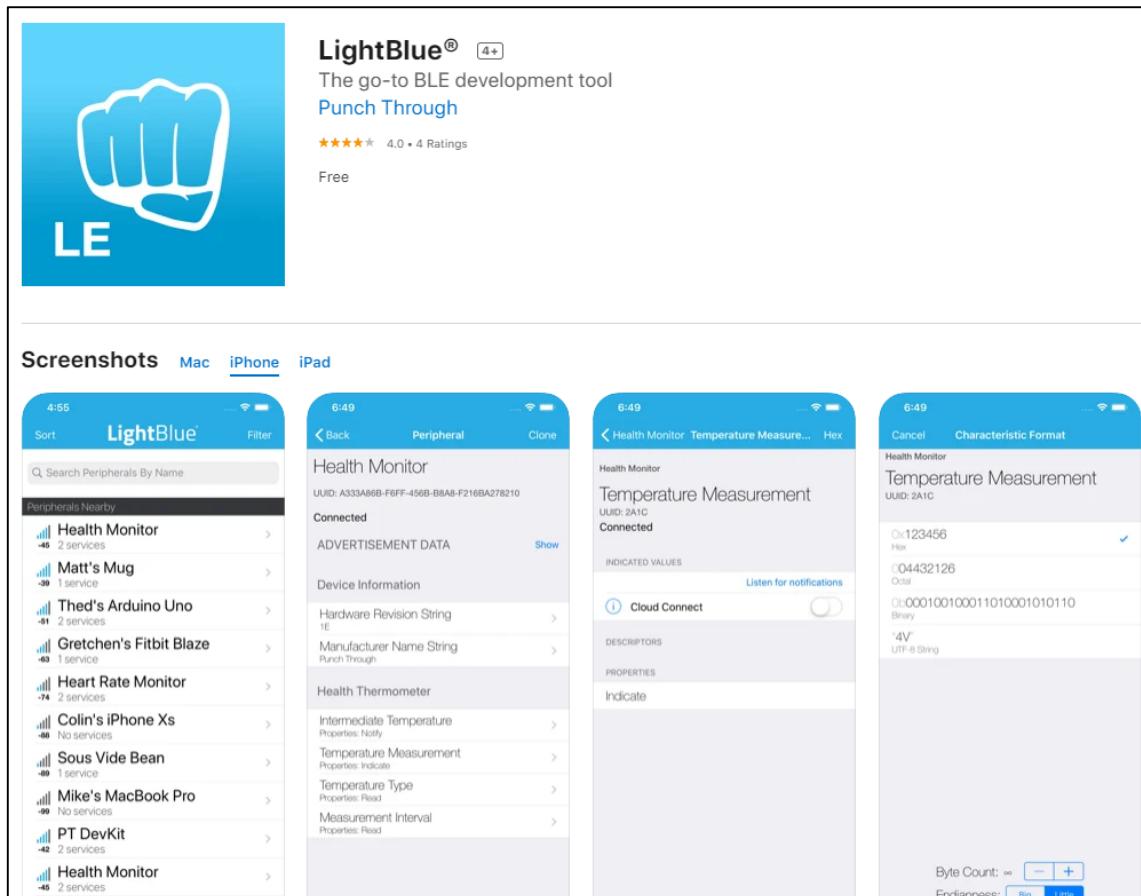


## Sketch

### Lightblue

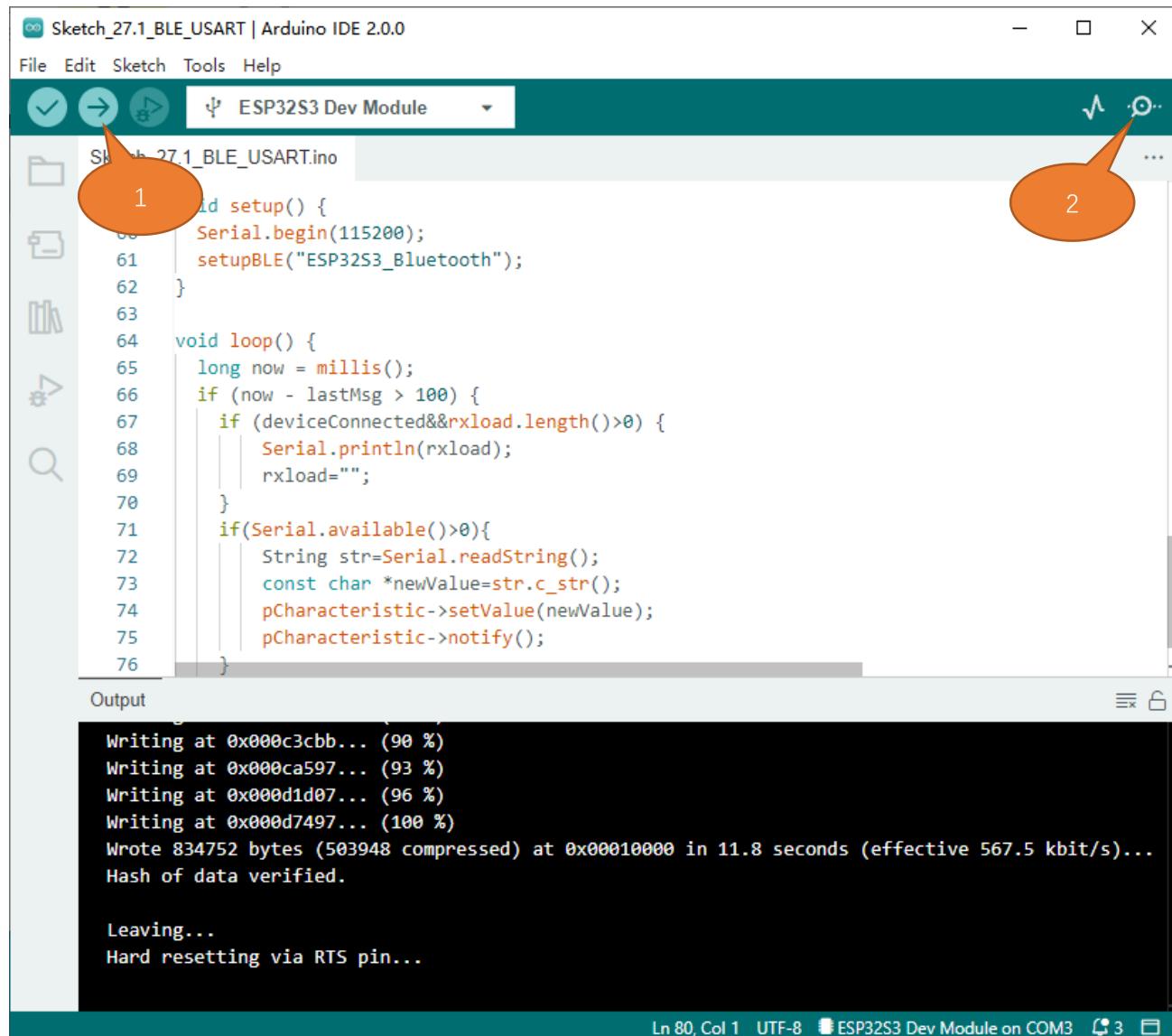
If you can't install Serial Bluetooth on your phone, try LightBlue. If you do not have this software installed on your phone, you can refer to this link:

<https://apps.apple.com/us/app/lightblue/id557428110#?platform=iphone.>



Step1. Upload the code of Project 27.1 to ESP32-S3.

Step2. Click on serial monitor.



```

Sketch_27.1_BLE_USART | Arduino IDE 2.0.0
File Edit Sketch Tools Help
ESP32S3 Dev Module
Sketch_27.1_BLE_USART.ino
1
2
1 void setup() {
2   Serial.begin(115200);
3   setupBLE("ESP32S3_Bluetooth");
4
5 void loop() {
6   long now = millis();
7   if (now - lastMsg > 100) {
8     if (deviceConnected&&rxload.length()>0) {
9       Serial.println(rxload);
10      rxload="";
11    }
12    if(Serial.available()>0){
13      String str=Serial.readString();
14      const char *newValue=str.c_str();
15      pCharacteristic->setValue(newValue);
16      pCharacteristic->notify();
17    }
18  }
19}

```

Output

```

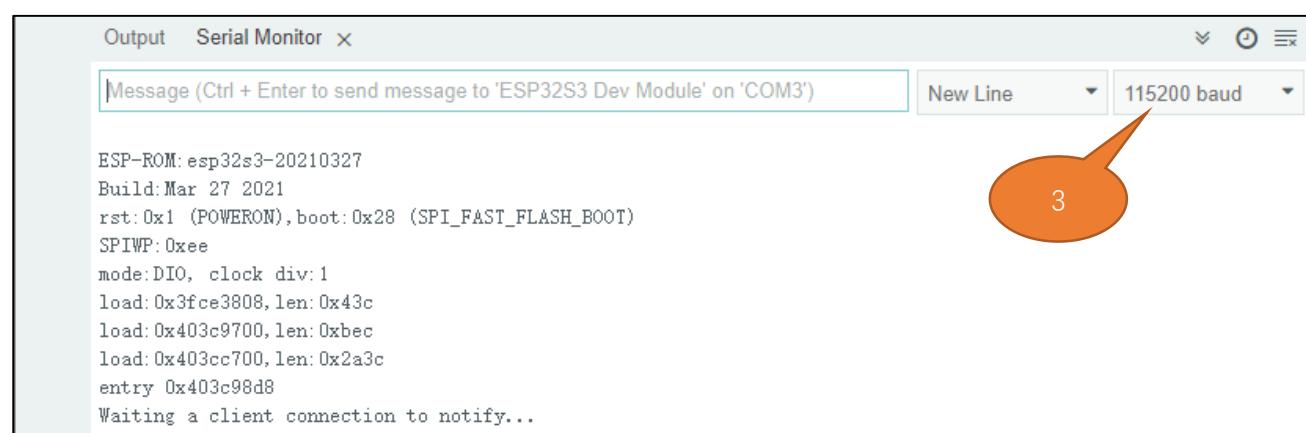
Writing at 0x000c3cbb... (90 %)
Writing at 0x000ca597... (93 %)
Writing at 0x000d1d07... (96 %)
Writing at 0x000d7497... (100 %)
Wrote 834752 bytes (503948 compressed) at 0x00010000 in 11.8 seconds (effective 567.5 kbit/s)...
Hash of data verified.

Leaving...
Hard resetting via RTS pin...

```

Ln 80, Col 1 UTF-8 ESP32S3 Dev Module on COM3 3

Step3. Set baud rate to 115200.



Output Serial Monitor

Message (Ctrl + Enter to send message to 'ESP32S3 Dev Module' on 'COM3')

New Line 115200 baud

```

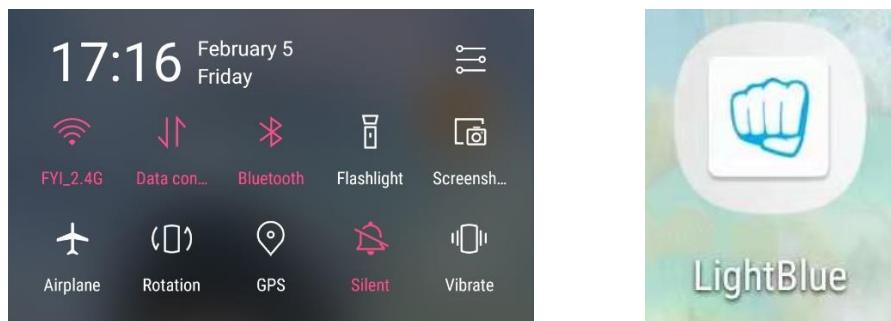
ESP-ROM: esp32s3-20210327
Build: Mar 27 2021
rst:0x1 (POWERON), boot:0x28 (SPI_FAST_FLASH_BOOT)
SPIWP:0xee
mode:DIO, clock div:1
load:0x3fce3808, len:0x43c
load:0x403c9700, len:0xbec
load:0x403cc700, len:0x2a3c
entry 0x403c98d8
Waiting a client connection to notify...

```

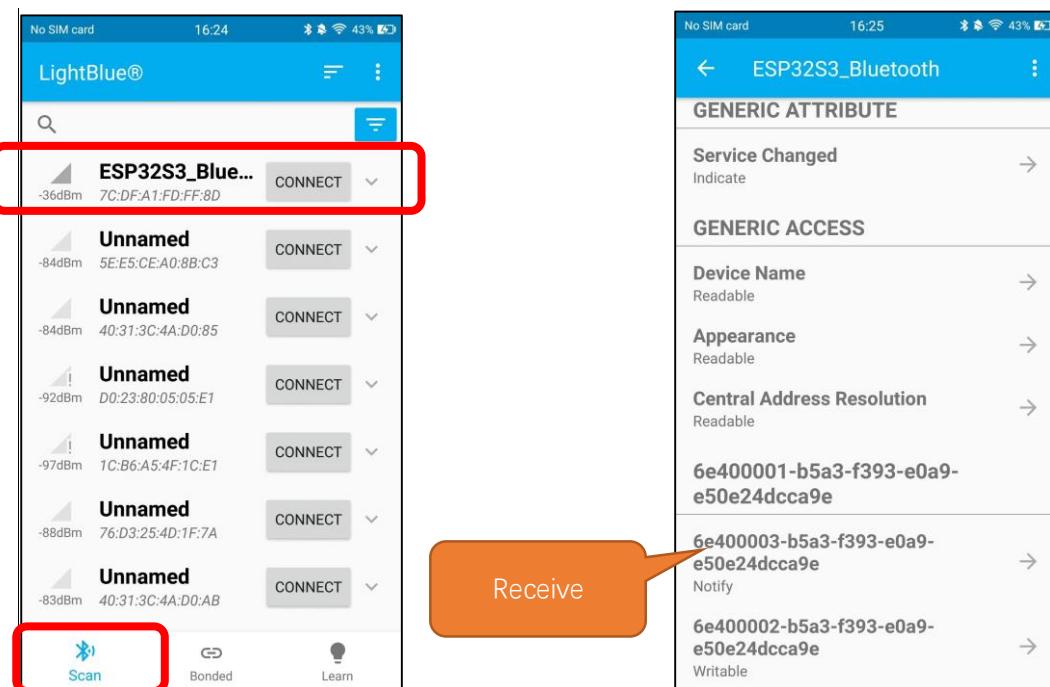
3



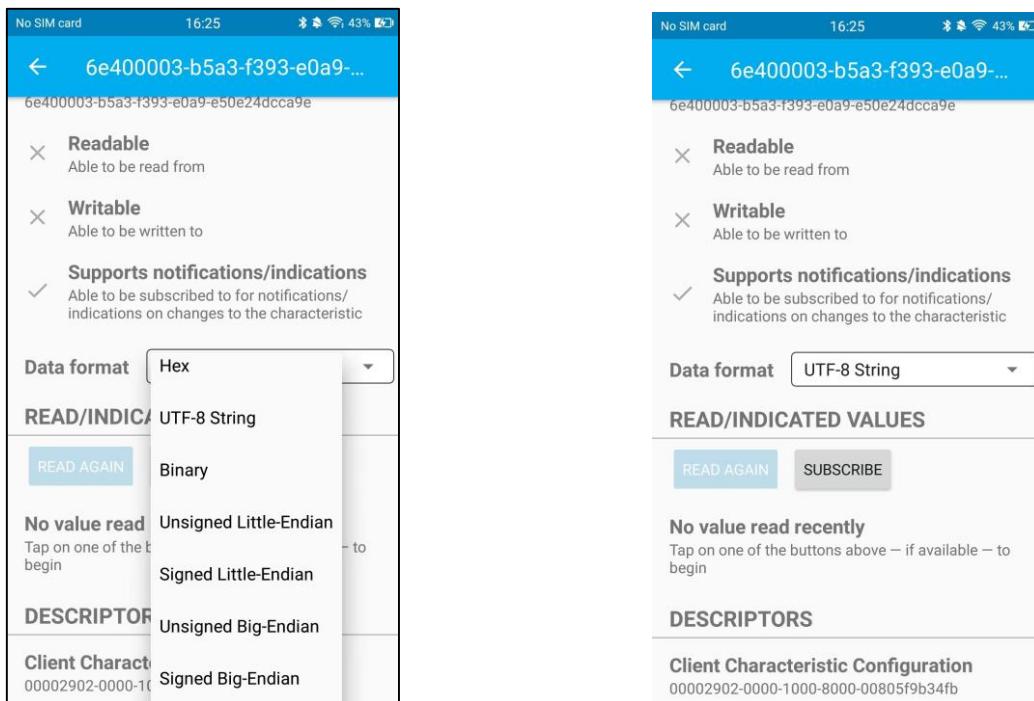
Turn ON Bluetooth on your phone, and open the Lightblue APP.



In the Scan page, swipe down to refresh the name of Bluetooth that the phone searches for. Click ESP32S3\_Bluetooth.



Click “Receive”. Select the appropriate Data format in the box to the right of Data Format. For example, HEX for hexadecimal, utf-string for character, Binary for Binary, etc. Then click SUBSCRIBE.



Back to the serial monitor on your computer. You can type anything in the left border of Send, and then click Send.

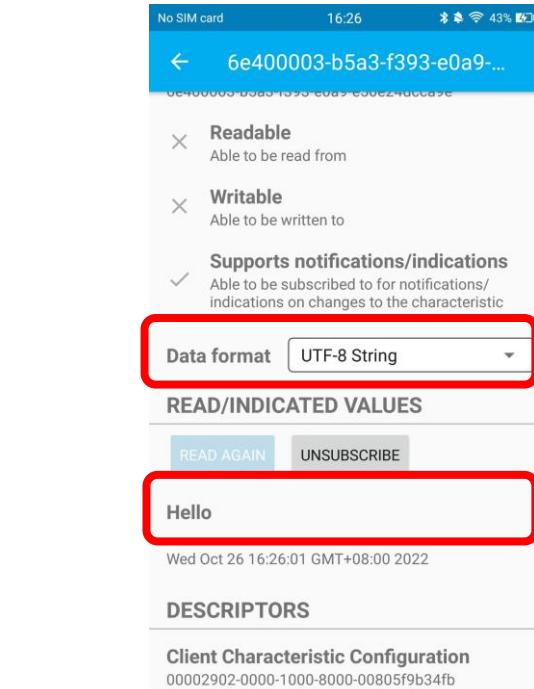
```

Output  Serial Monitor X
Hello
New Line  115200 baud

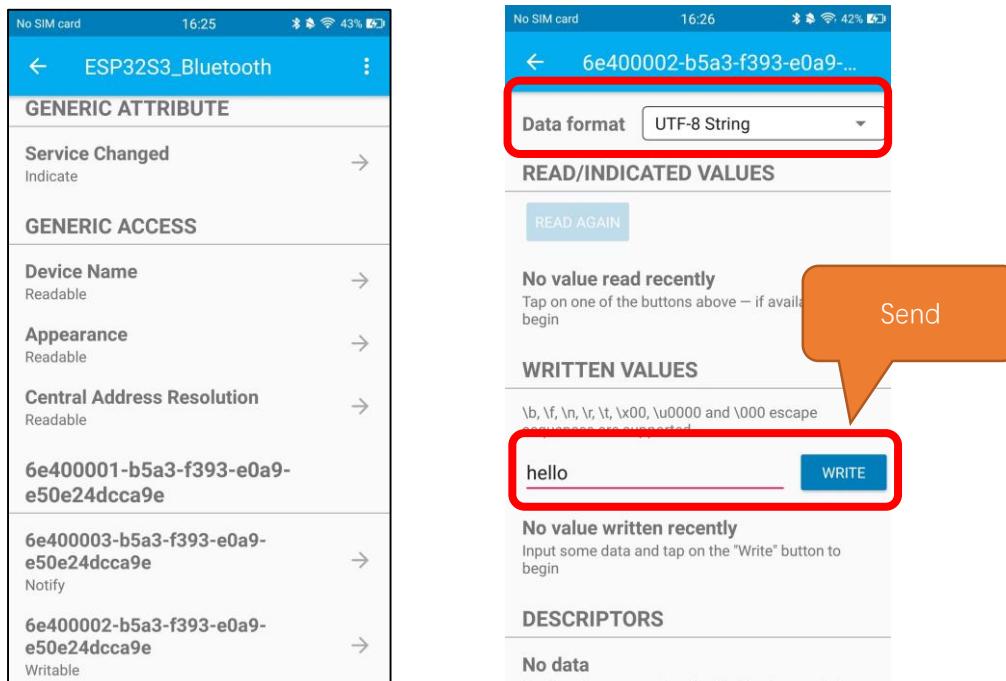
ESP-ROM: esp32s3-20210327
Build: Mar 27 2021
rst:0x1 (POWERON), boot:0x28 (SPI_FAST_FLASH_BOOT)
SPIWP:0xee
mode:DIO, clock div:1
load:0x3fce3808, len:0x43c
load:0x403c9700, len:0xbec
load:0x403cc700, len:0x2a3c
entry 0x403c98d8
Waiting a client connection to notify...
Test

```

And then you can see the mobile Bluetooth has received the message.



Similarly, you can select “Send” on your phone. Set Data format, and then enter anything in the sending box and click Write to send.



And the computer will receive the message from the mobile Bluetooth.

The screenshot shows a Serial Monitor window with the following details:

- Output** tab is selected.
- Serial Monitor** tab is visible.
- Message** input field: "Message (Ctrl + Enter to send message to 'ESP32S3 Dev Module' on 'COM3')".
- Baud Rate**: 115200 baud.
- Text Output:**

```
ESP-ROM: esp32s3-20210327
Build: Mar 27 2021
rst:0x1 (POWERON),boot:0x28 (SPI_FAST_FLASH_BOOT)
SPIWP:0xee
mode:DIO, clock div:1
load:0x3fce3808, len:0x43c
load:0x403c9700, len:0xbec
load:0x403cc700, len:0x2a3c
entry 0x403c98d8
Waiting a client connection to notify...
Test

hello
```
- Status Bar:** Ln 80, Col 1 | UTF-8 | ESP32S3 Dev Module on COM3 | 3 messages | icon.

And now data can be transferred between your mobile phone and computer via ESP32-S3 WROOM.

The following is the program code:

```

1 #include <BLEDevice.h>
2 #include <BLEServer.h>
3 #include <BLEUtils.h>
4 #include <BLE2902.h>
5
6 BLECharacteristic *pCharacteristic;
7 bool deviceConnected = false;
8 uint8_t txValue = 0;
9 long lastMsg = 0;
10 String rxload="Test\n";
11
12 #define SERVICE_UUID "6E400001-B5A3-F393-E0A9-E50E24DCCA9E"
13 #define CHARACTERISTIC_UUID_RX "6E400002-B5A3-F393-E0A9-E50E24DCCA9E"
14 #define CHARACTERISTIC_UUID_TX "6E400003-B5A3-F393-E0A9-E50E24DCCA9E"
15
16 class MyServerCallbacks: public BLEServerCallbacks {
17     void onConnect(BLEServer* pServer) {
18         deviceConnected = true;
19     };
20     void onDisconnect(BLEServer* pServer) {
21         deviceConnected = false;
22     }
23 };
24
25 class MyCallbacks: public BLECharacteristicCallbacks {
26     void onWrite(BLECharacteristic *pCharacteristic) {
27         String rxValue = pCharacteristic->getValue();
28         if (rxValue.length() > 0) {
29             rxload="";
30             for (int i = 0; i < rxValue.length(); i++) {
31                 rxload +=(char)rxValue[i];
32             }
33         }
34     }
35 };
36
37 void setupBLE(String BLEName) {
38     const char *ble_name=BLEName.c_str();
39     BLEDevice::init(ble_name);
40     BLEServer *pServer = BLEDevice::createServer();
41     pServer->setCallbacks(new MyServerCallbacks());
42     BLEService *pService = pServer->createService(SERVICE_UUID);

```

```
43     pCharacteristic=
44     pService->createCharacteristic(CHARACTERISTIC_UUID_TX,BLECharacteristic::PROPERTY_NOTIFY);
45     pCharacteristic->addDescriptor(new BLE2902());
46     BLECharacteristic *pCharacteristic =
47     pService->createCharacteristic(CHARACTERISTIC_UUID_RX,BLECharacteristic::PROPERTY_WRITE);
48     pCharacteristic->setCallbacks(new MyCallbacks());
49     pService->start();
50     pServer->getAdvertising()->start();
51     Serial.println("Waiting a client connection to notify...");
52 }
53
54 void setup() {
55     Serial.begin(115200);
56     setupBLE("ESP32S3_Bluetooth");
57 }
58
59 void loop() {
60     long now = millis();
61     if (now - lastMsg > 1000) {
62         if (deviceConnected&&rxload.length()>0) {
63             Serial.println(rxload);
64             rxload="";
65         }
66         if(Serial.available()>0) {
67             String str=Serial.readString();
68             const char *newValue=str.c_str();
69             pCharacteristic->setValue(newValue);
70             pCharacteristic->notify();
71         }
72     }
73 }
```

Define the specified UUID number for BLE vendor.

```
12 #define SERVICE_UUID          "6E400001-B5A3-F393-E0A9-E50E24DCCA9E"
13 #define CHARACTERISTIC_UUID_RX "6E400002-B5A3-F393-E0A9-E50E24DCCA9E"
14 #define CHARACTERISTIC_UUID_TX "6E400003-B5A3-F393-E0A9-E50E24DCCA9E"
```



Write a Callback function for BLE server to manage connection of BLE.

```

16 class MyServerCallbacks: public BLEServerCallbacks {
17     void onConnect(BLEServer* pServer) {
18         deviceConnected = true;
19     };
20     void onDisconnect(BLEServer* pServer) {
21         deviceConnected = false;
22     }
23 };

```

Write Callback function with BLE features. When it is called, as the mobile terminal send data to ESP32-S3, it will store them into reload.

```

25 class MyCallbacks: public BLECharacteristicCallbacks {
26     void onWrite(BLECharacteristic *pCharacteristic) {
27         String rxValue = pCharacteristic->getValue();
28         if (rxValue.length() > 0) {
29             rxload="";
30             for (int i = 0; i < rxValue.length(); i++) {
31                 rxload +=(char)rxValue[i];
32             }
33         }
34     }
35 };

```

Initialize the BLE function and name it.

```
54 setupBLE("ESP32S3_Bluetooth");
```

When the mobile phone send data to ESP32-S3 via BLE Bluetooth, it will print them out with serial port;

When the serial port of ESP32-S3 receive data, it will send them to mobile via BLE Bluetooth.

```

58 long now = millis();
59 if (now - lastMsg > 1000) {
60     if (deviceConnected&&rxload.length()>0) {
61         Serial.println(rxload);
62         rxload="";
63     }
64     if(Serial.available()>0) {
65         String str=Serial.readString();
66         const char *newValue=str.c_str();
67         pCharacteristic->setValue(newValue);
68         pCharacteristic->notify();
69     }
70     lastMsg = now;
71 }

```

The design for creating the BLE server is:

1. Create a BLE Server
2. Create a BLE Service
3. Create a BLE Characteristic on the Service
4. Create a BLE Descriptor on the characteristic
5. Start the service.
6. Start advertising.

```
37 void setupBLE(String BLEName) {  
38     const char *ble_name=BLEName.c_str();  
39     BLEDevice::init(ble_name);  
40     BLEServer *pServer = BLEDevice::createServer();  
41     pServer->setCallbacks(new MyServerCallbacks());  
42     BLEService *pService = pServer->createService(SERVICE_UUID);  
43     pCharacteristic=  
44         pService->createCharacteristic(CHARACTERISTIC_UUID_TX,BLECharacteristic::PROPERTY_NOTIFY);  
45     pCharacteristic->addDescriptor(new BLE2902());  
46     BLECharacteristic *pCharacteristic =  
47         pService->createCharacteristic(CHARACTERISTIC_UUID_RX,BLECharacteristic::PROPERTY_WRITE);  
48     pCharacteristic->setCallbacks(new MyCallbacks());  
49     pService->start();  
50     pServer->getAdvertising()->start();  
51     Serial.println("Waiting a client connection to notify...");  
52 }
```

## Project 27.2 Bluetooth Control LED

In this section, we will control the LED with Bluetooth.

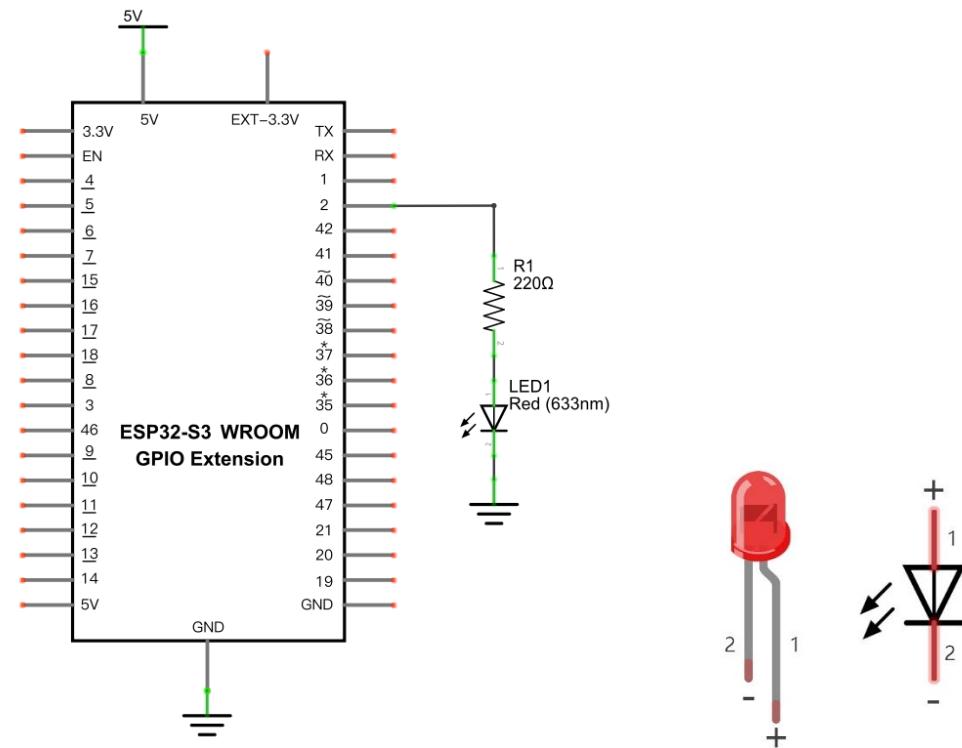
### Component List

ESP32-S3 WROOM x1	GPIO Extension Board x1		
Micro USB Wire x1	LED x1	Resistor 220Ω x1	Jumper M/M x2
Breadboard x1			

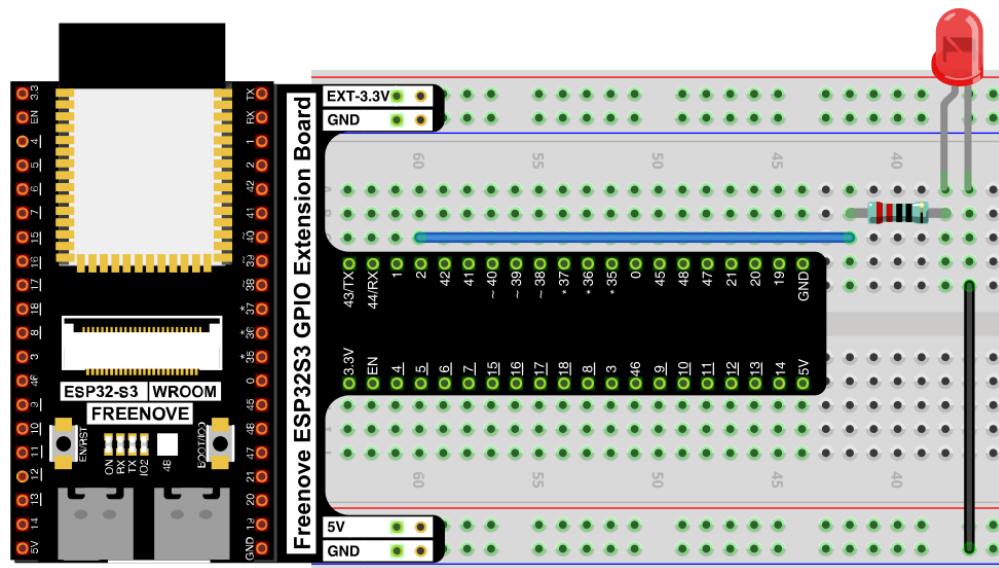
# Circuit

Connect Freenove ESP32-S3 to the computer using a USB cable.

## Schematic diagram



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



Any concerns? ✉ support@freenove.com



## Sketch

### Sketch\_27.2\_Bluetooth\_Control\_LED

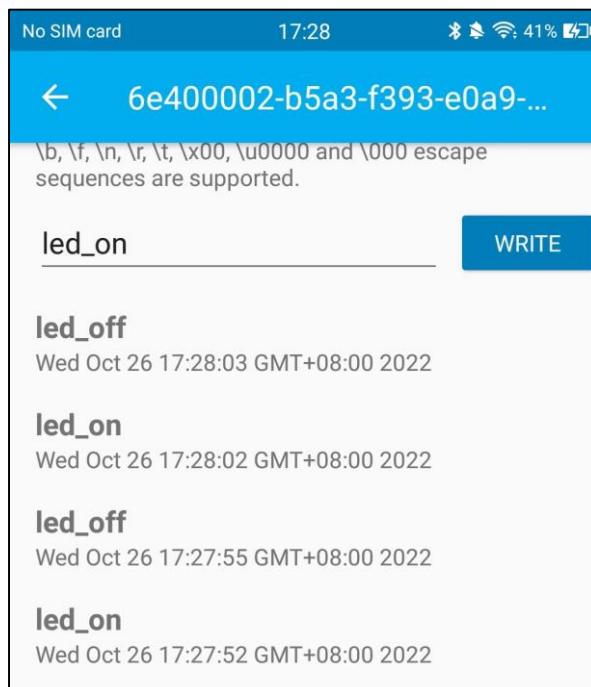
```

Sketch_27.2_BluetoothToLed | Arduino IDE 2.0.0
File Edit Sketch Tools Help
ESP32S3 Dev Module
Sketch_27.2_BluetoothToLed.ino ...
1 //*****
2   Filename : BLE_USART
3   Description : Esp32 communicates with the phone by BLE and sends incoming data via a serial port
4   Author : www.freenove.com
5   Modification: 2022/10/26
6 *****/
7 #include "BLEDevice.h"
8 #include "BLEServer.h"
9 #include "BLEUtils.h"
10 #include "BLE2902.h"
11 #include "String.h"
12
13 BLECharacteristic *pCharacteristic;
14 bool deviceConnected = false;
15 uint8_t txValue = 0;
16 long lastMsg = 0;
17 char rxload[20];
18
19 #define SERVICE_UUID "6E400001-B5A3-F393-E0A9-E50E24DCCA9E"
20 #define CHARACTERISTIC_UUID_RX "6E400002-B5A3-F393-E0A9-E50E24DCCA9E"
21 #define CHARACTERISTIC_UUID_TX "6E400003-B5A3-F393-E0A9-E50E24DCCA9E"
22 #define LED 2
23
24 class MyServerCallbacks : public BLEServerCallbacks {
25   void onConnect(BLEServer *pServer) {
Output
Using previously compiled file: C:\Users\DESKTOP-LIN\AppData\Local\Temp\arduino-sketch-00210B5DD19E5DAADA0F3D5CFF1DE6
Compiling core...
Using precompiled core: C:\Users\DESKTOP-LIN\AppData\Local\Temp\arduino-core-cache\core_8cd763890f2ad07cf718ef8a4f8ae
Linking everything together...
"C:\Users\DESKTOP-LIN\AppData\Local\Arduino15\Compiling sketch...
Ln 56, Col 52  UTF-8  ESP32S3 Dev Module on COM3  21

```

Compile and upload code to **ESP32S3\_Bluetooth**. The operation of the APP is the same as 27.1, you only need to change the sending content to "led\_on" and "led\_off" to operate LEDs on the ESP32-S3 WROOM.

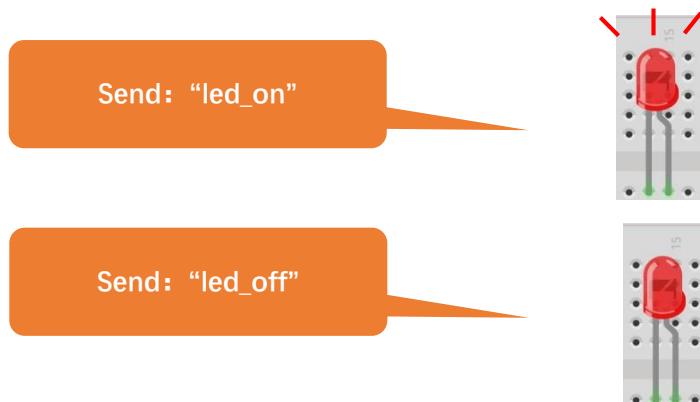
Data sent from mobile APP:



Display on the serial port of the computer:

```
The device started, now you can pair it with Bluetooth!
led_on
led_off
led_on
led_off
led_on
led_off
```

The phenomenon of LED



Attention: If the sending content isn't "led-on" or "led-off", then the state of LED will not change. If the LED is on, when receiving irrelevant content, it keeps on; Correspondingly, if the LED is off, when receiving irrelevant content, it keeps off.

The following is the program code:

```

1 #include "BLEDevice.h"
2 #include "BLEServer.h"
3 #include "BLEUtils.h"
4 #include "BLE2902.h"
5 #include "String.h"
6
7 BLECharacteristic *pCharacteristic;
8 bool deviceConnected = false;
9 uint8_t txValue = 0;
10 long lastMsg = 0;
11 char rxload[20];
12
13 #define SERVICE_UUID "6E400001-B5A3-F393-E0A9-E50E24DCCA9E"
14 #define CHARACTERISTIC_UUID_RX "6E400002-B5A3-F393-E0A9-E50E24DCCA9E"
15 #define CHARACTERISTIC_UUID_TX "6E400003-B5A3-F393-E0A9-E50E24DCCA9E"
16 #define LED 2
17
18 class MyServerCallbacks : public BLEServerCallbacks {
19     void onConnect(BLEServer *pServer) {
20         deviceConnected = true;
21     };
22     void onDisconnect(BLEServer *pServer) {
23         deviceConnected = false;
24     }
25 };
26
27 class MyCallbacks : public BLECharacteristicCallbacks {
28     void onWrite(BLECharacteristic *pCharacteristic) {
29         String rxValue = pCharacteristic->getValue();
30         if (rxValue.length() > 0) {
31             for (int i = 0; i < 20; i++) {
32                 rxload[i] = 0;
33             }
34             for (int i = 0; i < rxValue.length(); i++) {
35                 rxload[i] = (char)rxValue[i];
36             }
37         }
38     }
39 };
40
41 void setupBLE(String BLEName) {
42     const char *ble_name = BLEName.c_str();
43     BLEDevice::init(ble_name);

```

```
44 BLEServer *pServer = BLEDevice::createServer();
45 pServer->setCallbacks(new MyServerCallbacks());
46 BLEService *pService = pServer->createService(SERVICE_UUID);
47 pCharacteristic = pService->createCharacteristic(CHARACTERISTIC_UUID_TX,
48 BLECharacteristic::PROPERTY_NOTIFY);
49 pCharacteristic->addDescriptor(new BLE2902());
50 BLECharacteristic *pCharacteristic = pService->createCharacteristic(CHARACTERISTIC_UUID_RX,
51 BLECharacteristic::PROPERTY_WRITE);
52 pCharacteristic->setCallbacks(new MyCallbacks());
53 pService->start();
54 pServer->getAdvertising()->start();
55 Serial.println("Waiting a client connection to notify...");
```

```
56 }
57
58 void setup() {
59   pinMode(LED, OUTPUT);
60   setupBLE("ESP32S3_Bluetooth");
61   Serial.begin(115200);
62   Serial.println("\nThe device started, now you can pair it with Bluetooth!");
63 }
64
65 void loop() {
66   long now = millis();
67   if (now - lastMsg > 100) {
68     if (deviceConnected && strlen(rxload) > 0) {
69       if (strncmp(rxload, "led_on", 6) == 0) {
70         digitalWrite(LED, HIGH);
71       }
72       if (strncmp(rxload, "led_off", 7) == 0) {
73         digitalWrite(LED, LOW);
74       }
75       Serial.println(rxload);
76       memset(rxload, 0, sizeof(rxload));
77     }
78     lastMsg = now;
79   }
```

Use character string to handle function header file.

```
5 #include "string.h"
```

Define a character array to save data from Bluetooth.

```
11 char rxload[20];
```

Initialize the BLE Bluetooth and name it as "ESP32-S3"

```
58 setupBLE("ESP32S3_Bluetooth");
```

Write a Callback function for BLE server to manage connection of BLE.

```
18 class MyServerCallbacks: public BLEServerCallbacks {
19     void onConnect(BLEServer* pServer) {
20         deviceConnected = true;
21     };
22     void onDisconnect(BLEServer* pServer) {
23         deviceConnected = false;
24     }
25 };
```

Write Callback function with BLE features. When it is called, as the mobile terminal send data to ESP32-S3, it will store them into reload.

```
29     String rxValue = pCharacteristic->getValue();
30     if (rxValue.length() > 0) {
31         rxload="";
32         for (int i = 0; i < rxValue.length(); i++) {
33             rxload +=(char)rxValue[i];
34         }
35     }
```

Compare the content in buffer array with "led\_on" and "led\_off" to see whether they are the same. If yes, execute the corresponding operation.

```
66     if (deviceConnected && strlen(rxload) > 0) {
67         if (strcmp(rxload, "led_on", 6) == 0) {
68             digitalWrite(LED, HIGH);
69         }
70         if (strcmp(rxload, "led_off", 7) == 0) {
71             digitalWrite(LED, LOW);
72         }
73         Serial.println(rxload);
74     }
```

After comparing the content of array, to ensure successful transmission next time, please empty the array.

```
73     Serial.println(rxload);
74     memset(rxload, 0, sizeof(rxload));
```

## Reference

strcmp() functions are often used for string comparisons, which are accurate and stable.

```
int strcmp(const char *str1, const char *str2, size_t n)
```

str1: the first string to be compared

str2: the second string to be compared

n: the biggest string to be compared

Return value: if str1>str2, then return value>0.

If return value is 0, then the contents of str1 and str2 are the same.

If str1< str2, then return value<0.

Function memset is mainly used to clean and initialize the memory of array

```
void memset(void *s, int c, unsigned long n)
```

Function memset() is to set the content of a certain internal storage as specified value.

\*s: the initial address of the content to clear out.

c: to be replaced as specified value

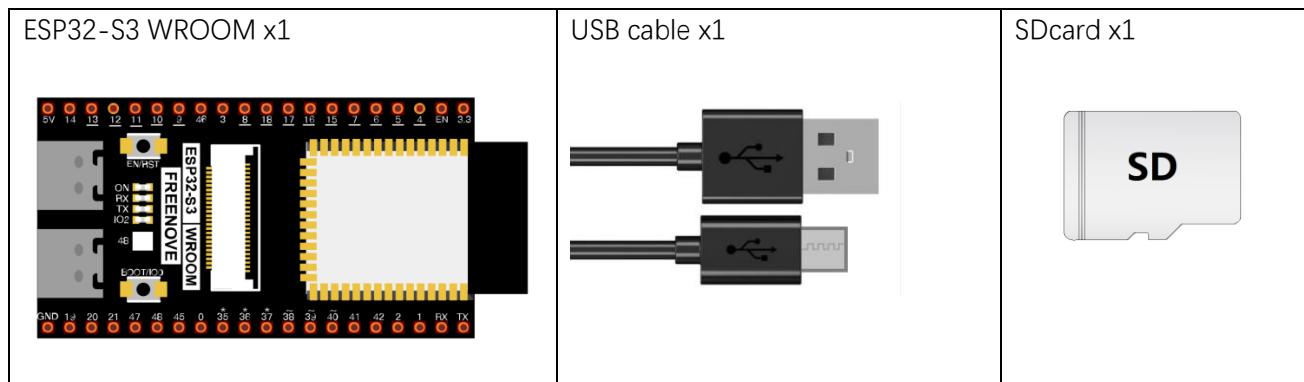
n: the number of byte to be replaced

# Chapter 28 Read and Write the SDcard

An SDcard slot is integrated on the back of the ESP32-S3 WROOM. In this chapter we learn how to use ESP32-S3 to read and write SDcard.

## Project 28.1 SDMMC Test

### Component List



### Component knowledge

#### SD card read and write method

ESP32-S3 has two ways to use SD card, one is to use the SPI interface to access the SD card, and the other is to use the SDMMC interface to access the SD card. SPI mode uses 4 IOs to access SD card. The SDMMC has one-bit bus mode and four-bit bus mode. In one-bit bus mode, SDMMC use 3 IOs to access SD card. In four-bit bus mode, SDMMC uses 6 IOs to access the SD card.

The above three methods can all be used to access the SD card, the difference is that the access speed is different.

In the four-bit bus mode of SDMMC, the reading and writing speed of accessing the SD card is the fastest. In the one-bit bus mode of SDMMC, the access speed is about 80% of the four-bit bus mode. The access speed of SPI is the slowest, which is about 50% of the four-bit bus mode of SDMMC.

Usually, we recommend using the one-bit bus mode to access the SD card, because in this mode, we only need to use the least pin IO to access the SD card with good performance and speed.

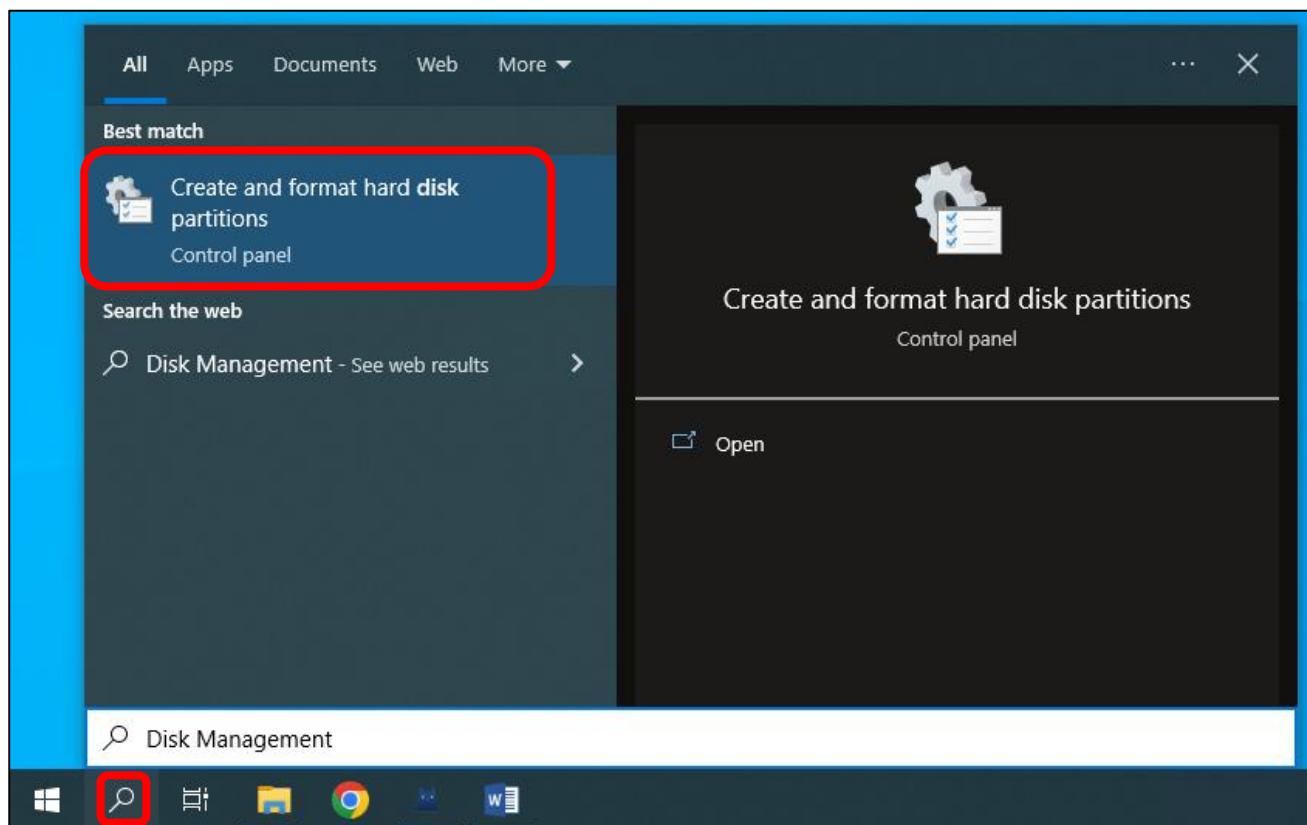
## Format SD card

Before starting the tutorial, we need to create a drive letter for the blank SD card and format it. This step requires a card reader and SD card. Please prepare them in advance. Below we will guide you to do it on different computer systems. You can choose the guide that matches your computer.

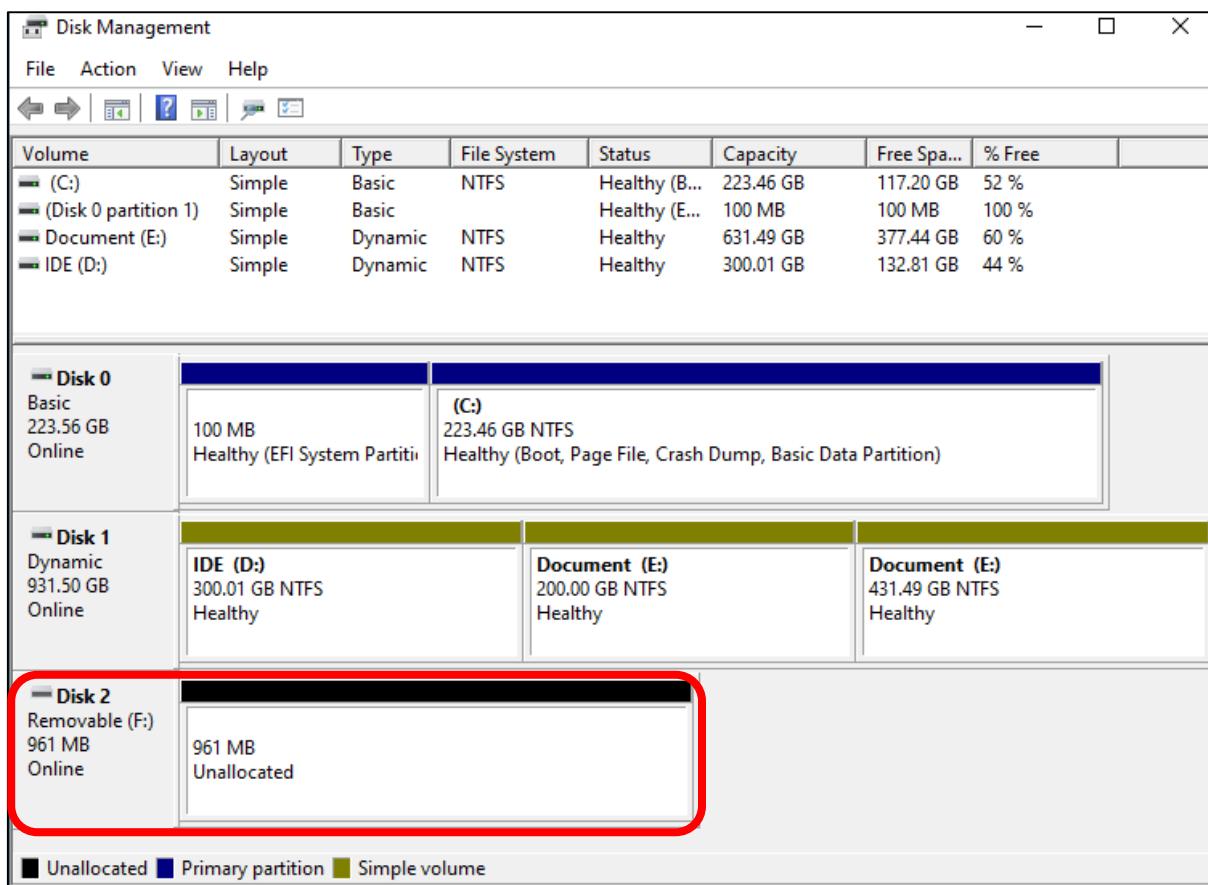
### Windows

Insert the SD card into the card reader, then insert the card reader into the computer.

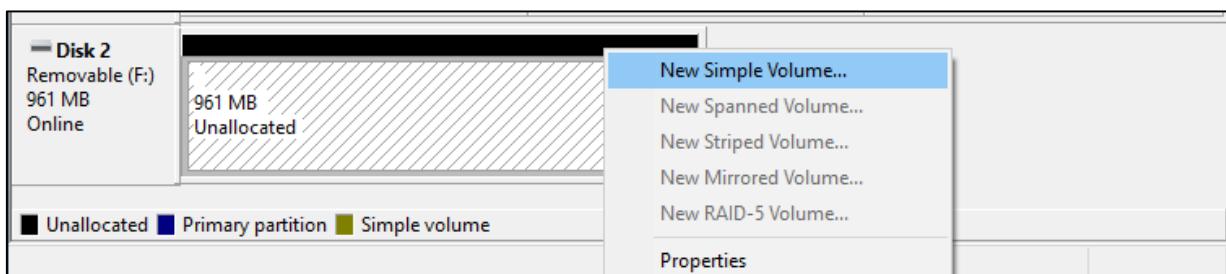
In the Windows search box, enter "Disk Management" and select "Create and format hard disk partitions".



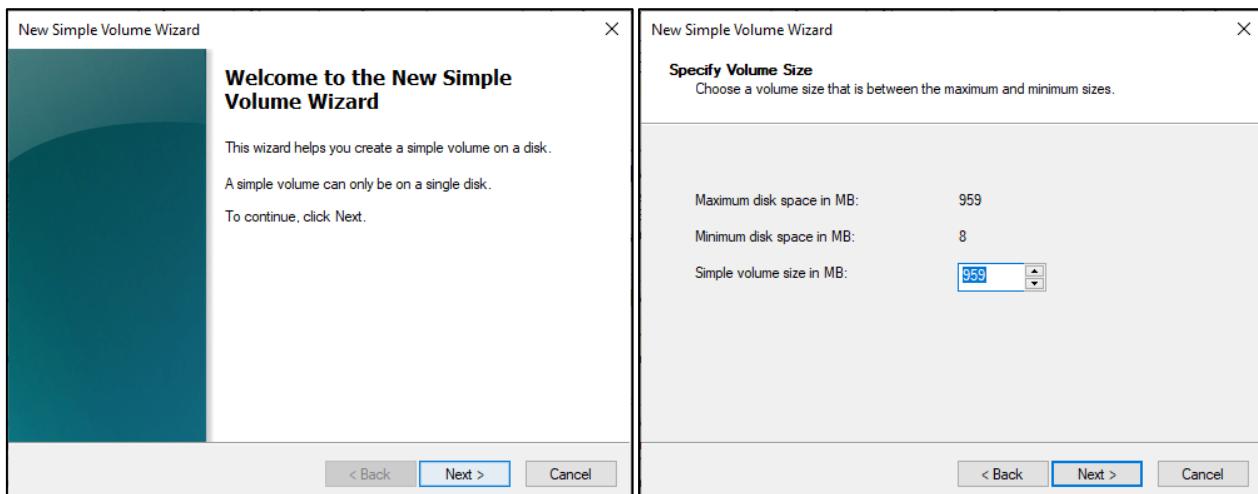
In the new pop-up window, find an unallocated volume close to 1G in size.



Click to select the volume, right-click and select "New Simple Volume".

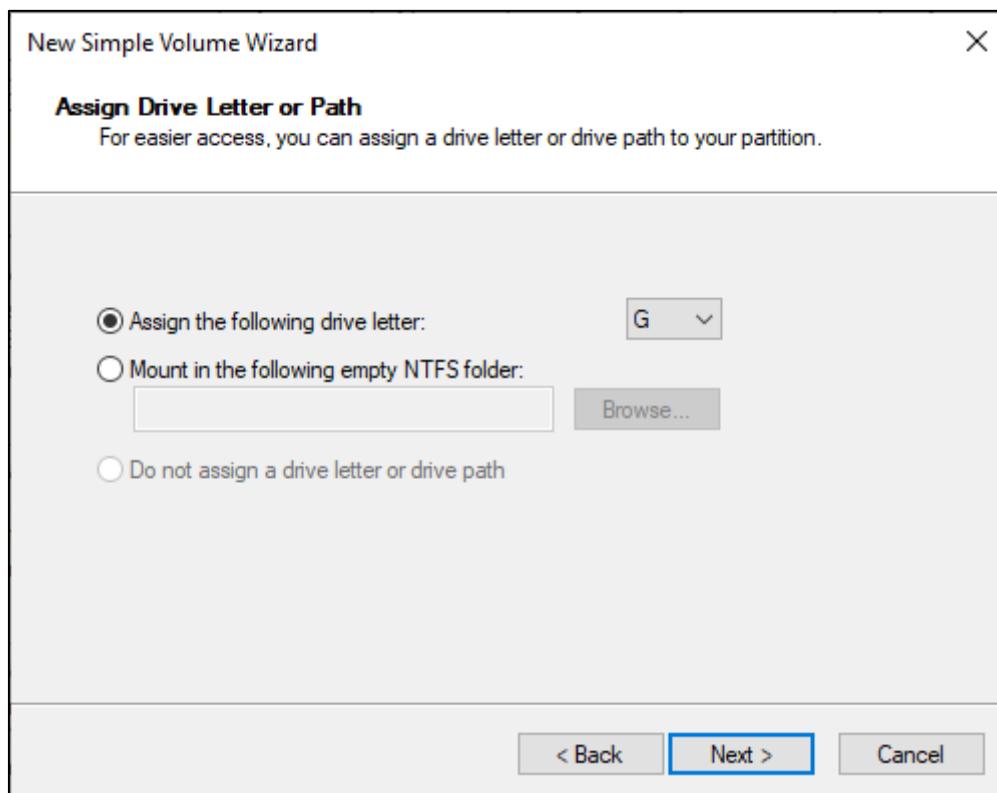


Click Next.

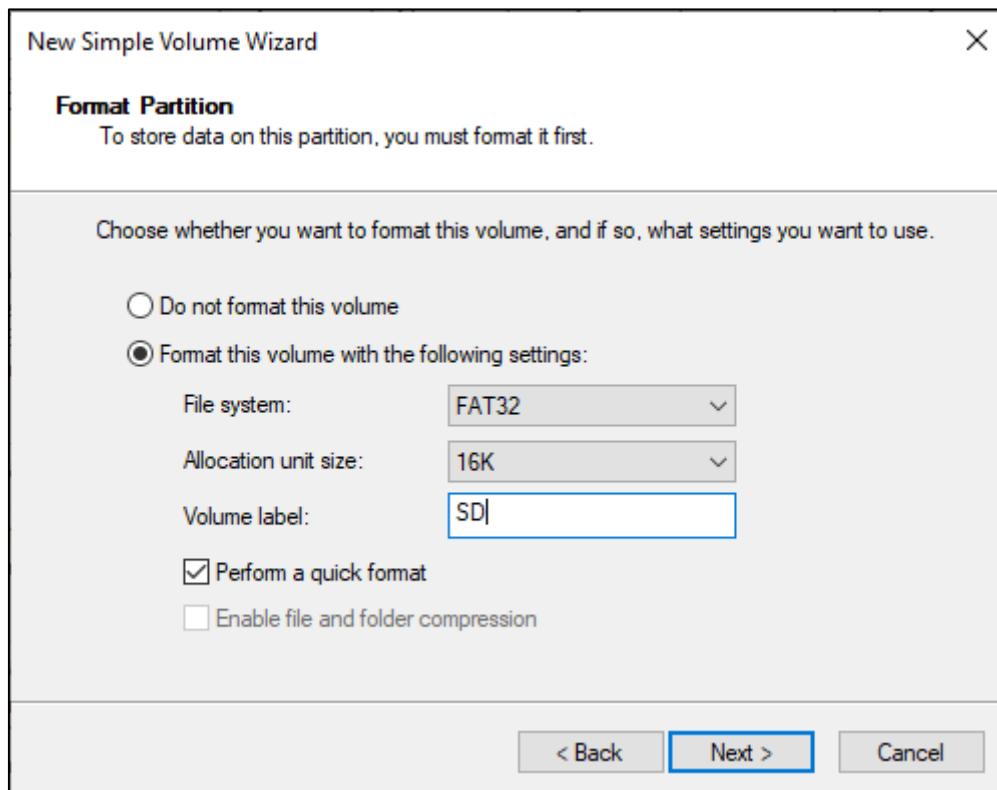


Any concerns? [✉ support@freenove.com](mailto:support@freenove.com)

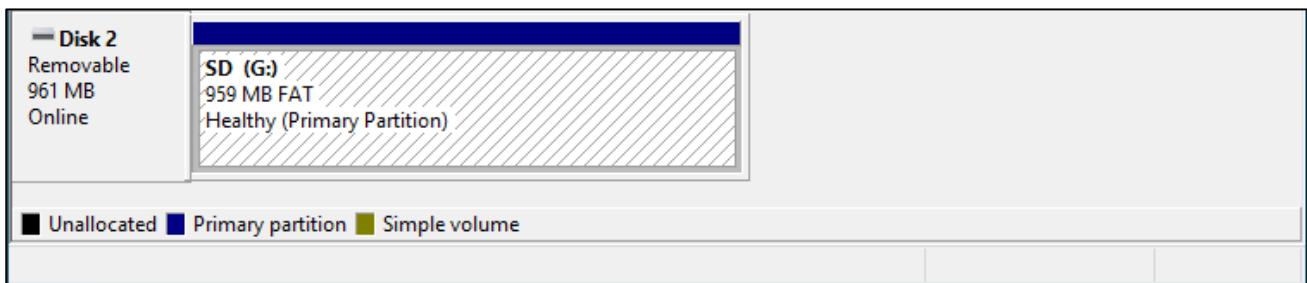
You can choose the drive letter on the right, or you can choose the default. By default, just click Next.



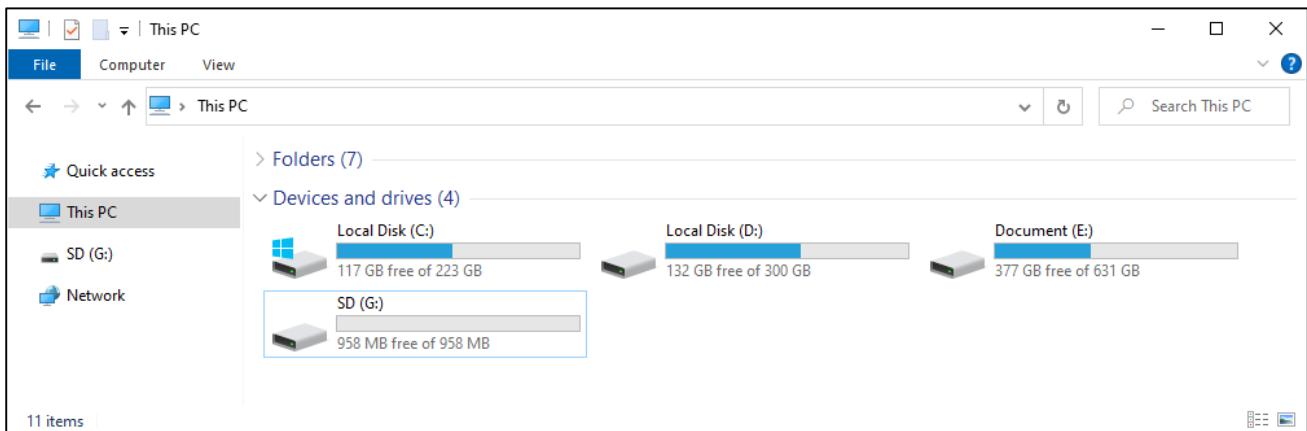
File system is FAT(or FAT32). The Allocation unit size is 16K, and the Volume label can be set to any name. After setting, click Next.



Click Finish. Wait for the SD card initialization to complete.

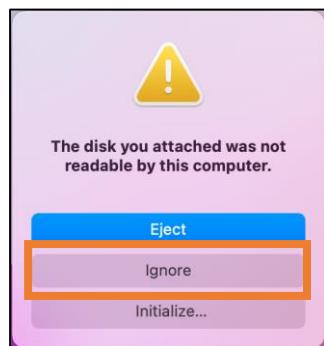


At this point, you can see the SD card in This PC.

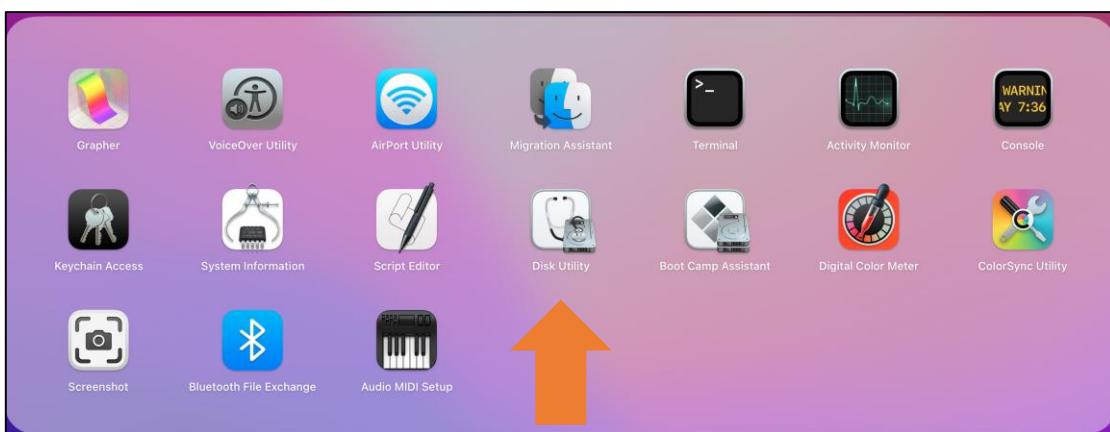


## MAC

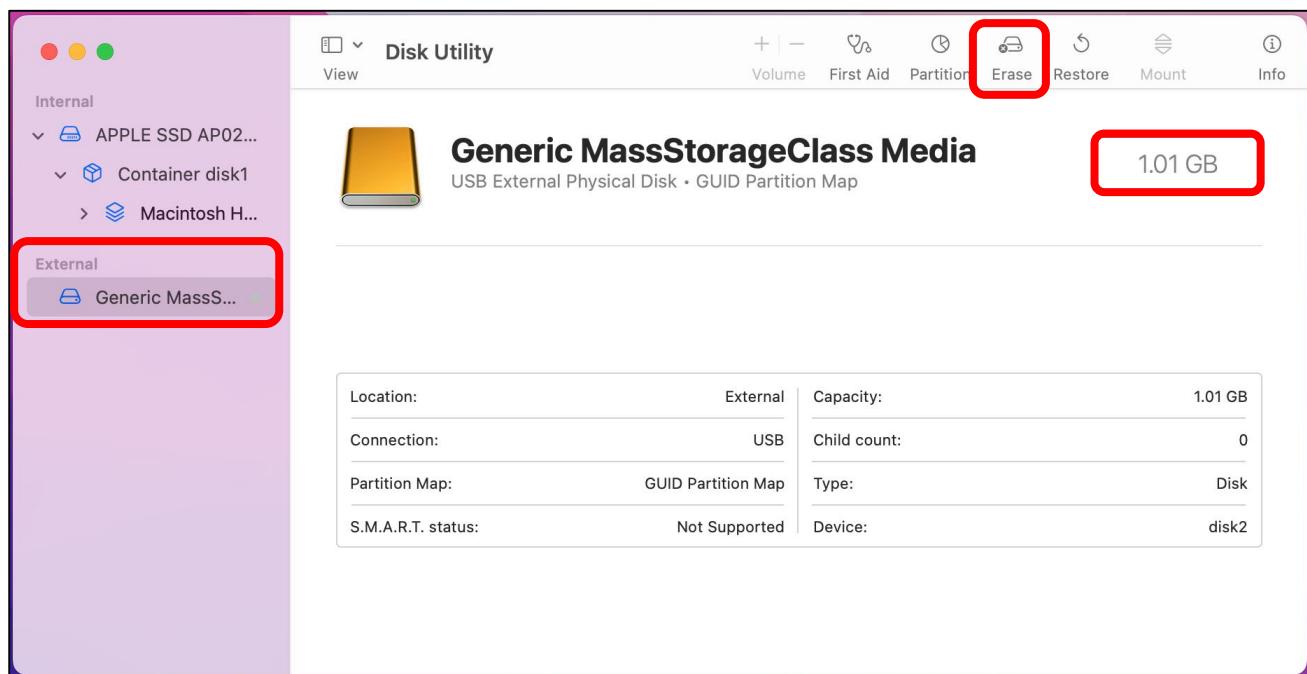
Insert the SD card into the card reader, then insert the card reader into the computer. Some computers will prompt the following information, please click to ignore it.



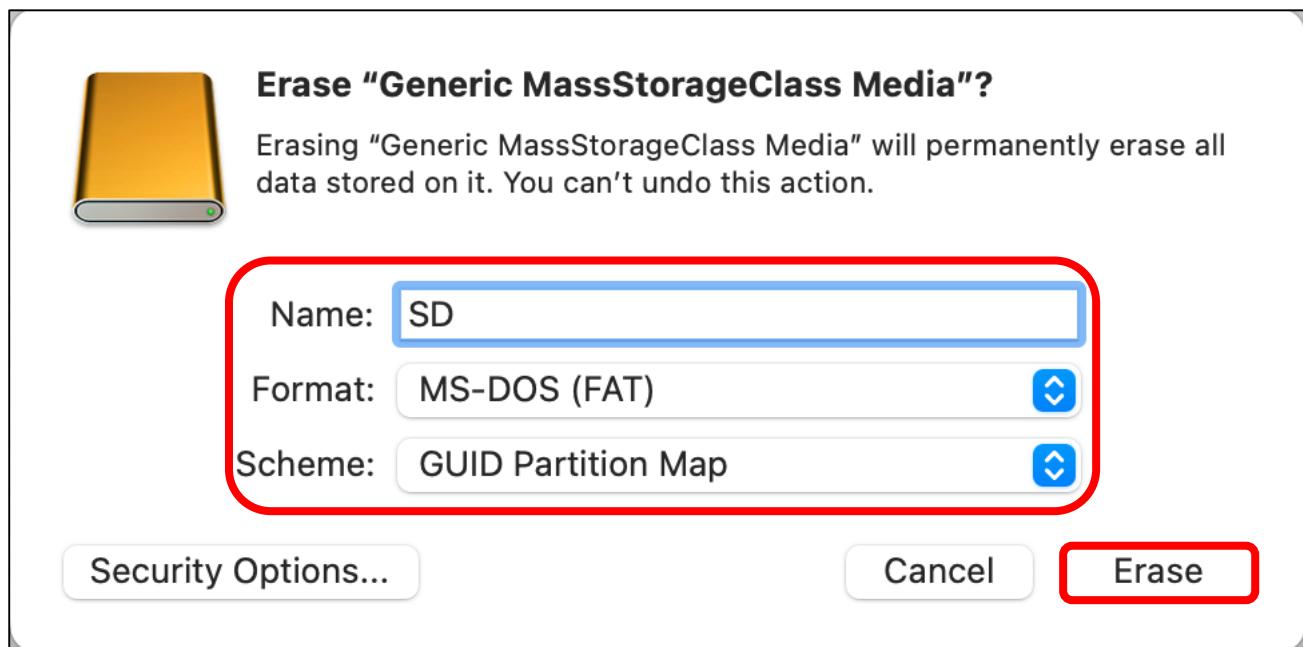
Find "Disk Utility" in the MAC system and click to open it.



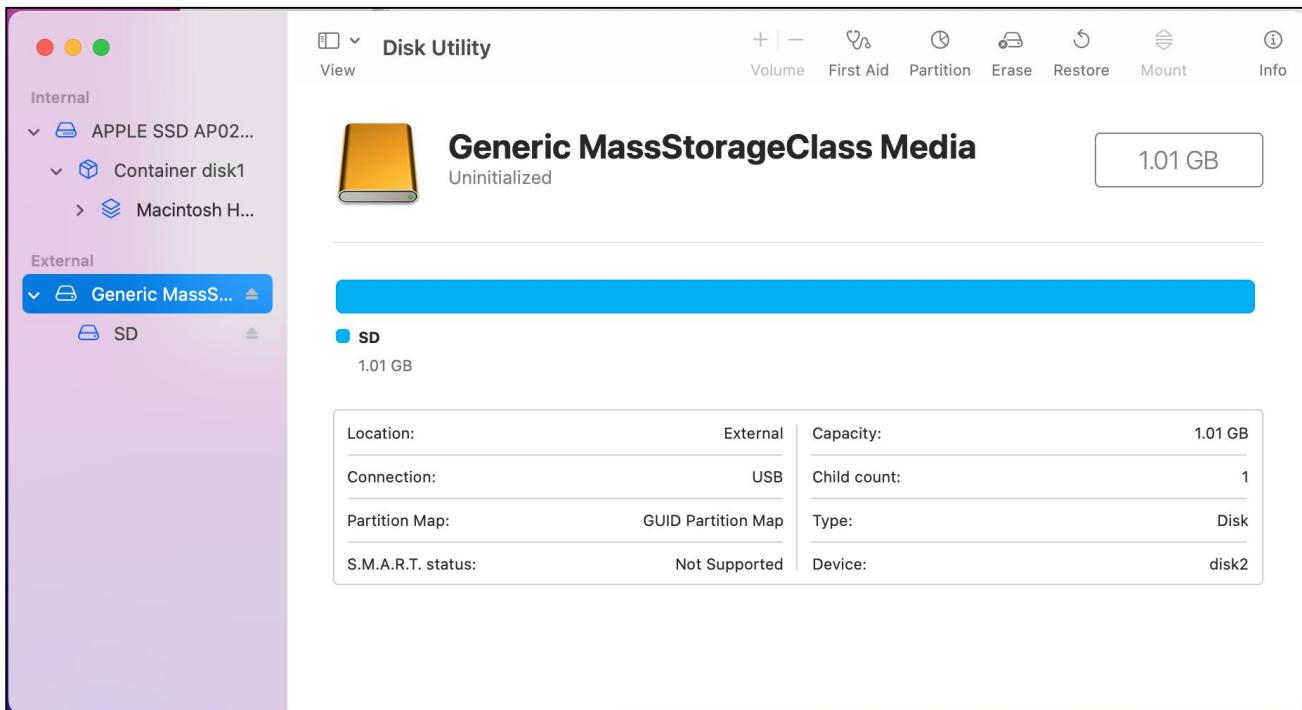
Select "Generic MassStorageClass Media", note that its size is about 1G. Please do not choose wrong item. Click "Erase".



Select the configuration as shown in the figure below, and then click "Erase".

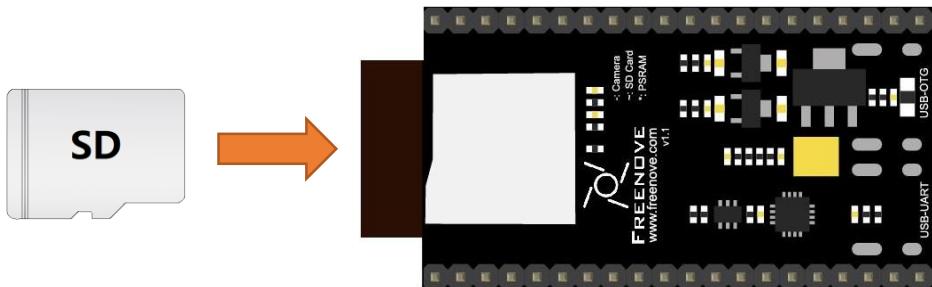


Wait for the formatting to complete. When finished, it will look like the picture below. At this point, you can see a new disk on the desktop named "SD".

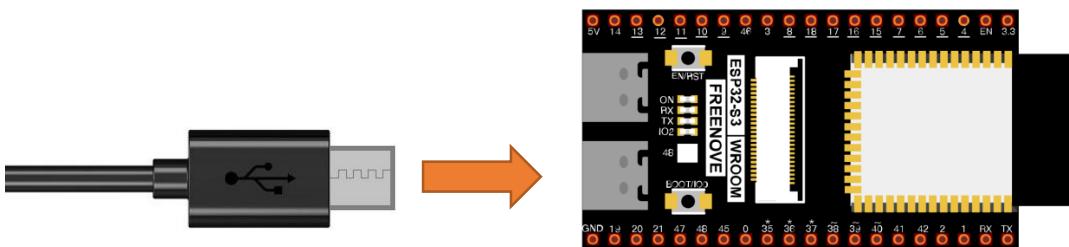


## Circuit

Before connecting the USB cable, insert the SD card into the SD card slot on the back of the ESP32-S3.

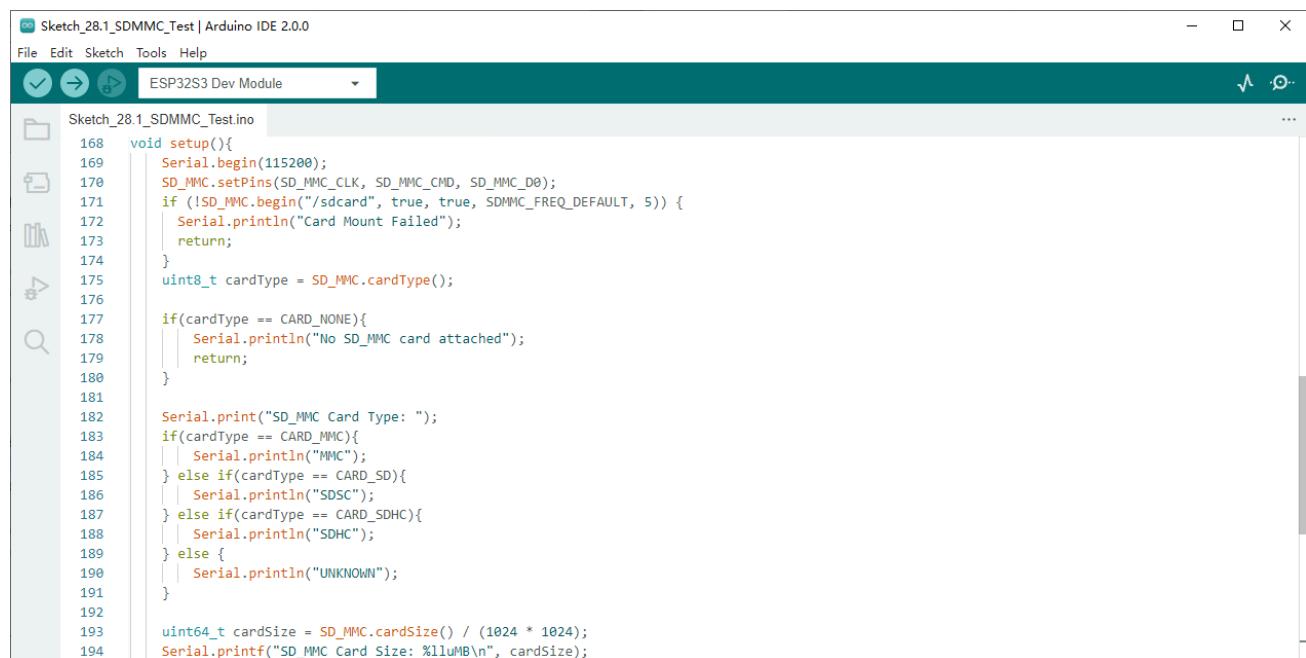


Connect Freenove ESP32-S3 to the computer using the USB cable.



## Sketch

### Sketch\_28.1\_SDMMC\_Test



The screenshot shows the Arduino IDE interface with the following details:

- Title Bar:** Sketch\_28.1\_SDMMC\_Test | Arduino IDE 2.0.0
- Menu Bar:** File Edit Sketch Tools Help
- Toolbar:** Includes icons for Save, Run, Stop, and others.
- Board Selector:** Set to ESP32S3 Dev Module
- Code Editor:** Displays the `Sketch_28.1_SDMMC_Test.ino` file content. The code is as follows:

```
Sketch_28.1_SDMMC_Test.ino
168 void setup(){
169     Serial.begin(115200);
170     SD_MMC.setPins(SD_MMC_CLK, SD_MMC_CMD, SD_MMC_D0);
171     if (!SD_MMC.begin("/sdcard", true, true, SDMMC_FREQ_DEFAULT, 5)) {
172         Serial.println("Card Mount Failed");
173         return;
174     }
175     uint8_t cardType = SD_MMC.cardType();
176
177     if(cardType == CARD_NONE){
178         Serial.println("No SD_MMC card attached");
179         return;
180     }
181
182     Serial.print("SD_MMC Card Type: ");
183     if(cardType == CARD_MMC){
184         Serial.println("MMC");
185     } else if(cardType == CARD_SD){
186         Serial.println("SDSC");
187     } else if(cardType == CARD_SDHC){
188         Serial.println("SDHC");
189     } else {
190         Serial.println("UNKNOWN");
191     }
192
193     uint64_t cardSize = SD_MMC.cardSize() / (1024 * 1024);
194     Serial.printf("SD_MMC Card Size: %lluMB\n", cardSize);
```

Compile and upload the code to ESP32-S3-WROOM, open the serial monitor, and press the RST button on the board.



You can see the printout as shown below.

The screenshot shows the Serial Monitor window with the following output:

```
Message (Ctrl + Enter to send message to 'ESP32S3 Dev Module' on 'COM24')
New Line 115200 baud

Listing directory: /
DIR : System Volume Information
Listing directory: /System Volume Information
FILE: IndexerVolumeGuid SIZE: 76
FILE: WPSettings.dat SIZE: 12
FILE: test.txt SIZE: 1048576
FILE: foo.txt SIZE: 13
FILE: 1.py SIZE: 22
Writing file: /hello.txt
File written
Appending to file: /hello.txt
Message appended
Reading file: /hello.txt
Read from file: Hello World!
Deleting file: /foo.txt
File deleted
Renaming file /hello.txt to /foo.txt
File renamed
Reading file: /foo.txt
Read from file: Hello World!
1048576 bytes read for 549 ms
1048576 bytes written for 809 ms
Total space: 960MB
Used space: 1MB
```

Ln 41, Col 12 UTF-8 ESP32S3 Dev Module on COM24 2

The following is the program code:

```
1 #include "sd_read_write.h"
2 #include "SD_MMC.h"
3
4 #define SD_MMC_CMD 38 //Please do not modify it.
5 #define SD_MMC_CLK 39 //Please do not modify it.
6 #define SD_MMC_DO 40 //Please do not modify it.
7
8 void setup() {
9     Serial.begin(115200);
10    SD_MMC.setPins(SD_MMC_CLK, SD_MMC_CMD, SD_MMC_DO);
11    if (!SD_MMC.begin("/sdcard", true, true, SDMMC_FREQ_DEFAULT, 5)) {
12        Serial.println("Card Mount Failed");
13        return;
14    }
15    uint8_t cardType = SD_MMC.cardType();
16    if(cardType == CARD_NONE) {
17        Serial.println("No SD_MMC card attached");
18        return;
19    }
20    Serial.print("SD_MMC Card Type: ");
21    if(cardType == CARD_MMC) {
22        Serial.println("MMC");
23    } else if(cardType == CARD_SD) {
24        Serial.println("SDSC");
25    } else if(cardType == CARD_SDHC) {
26        Serial.println("SDHC");
27    } else {
28        Serial.println("UNKNOWN");
29    }
30
31    uint64_t cardSize = SD_MMC.cardSize() / (1024 * 1024);
32    Serial.printf("SD_MMC Card Size: %lluMB\n", cardSize);
33
34    listDir(SD_MMC, "/", 0);
35
36    createDir(SD_MMC, "/mydir");
37    listDir(SD_MMC, "/", 0);
38
39    removeDir(SD_MMC, "/mydir");
40    listDir(SD_MMC, "/", 2);
41
42    writeFile(SD_MMC, "/hello.txt", "Hello ");
43    appendFile(SD_MMC, "/hello.txt", "World!\n");
```

```

44     readFile(SD_MMC, "/hello.txt");
45
46     deleteFile(SD_MMC, "/foo.txt");
47     renameFile(SD_MMC, "/hello.txt", "/foo.txt");
48     readFile(SD_MMC, "/foo.txt");
49
50     testFileIO(SD_MMC, "/test.txt");
51
52     Serial.printf("Total space: %luMB\r\n", SD_MMC.totalBytes() / (1024 * 1024));
53     Serial.printf("Used space: %luMB\r\n", SD_MMC.usedBytes() / (1024 * 1024));
54 }
55
56 void loop() {
57     delay(10000);
58 }
```

Add the SD card drive header file.

```

1 #include "sd_read_write.h"
2 #include "SD_MMC.h"
```

Defines the drive pins of the SD card. Please do not modify it. Because these pins are fixed.

```

4 #define SD_MMC_CMD 38 //Please do not modify it.
5 #define SD_MMC_CLK 39 //Please do not modify it.
6 #define SD_MMC_DO 40 //Please do not modify it.
```

Initialize the serial port function. Sets the drive pin for SDMMC one-bit bus mode.

```

9     Serial.begin(115200);
10    SD_MMC.setPins(SD_MMC_CLK, SD_MMC_CMD, SD_MMC_DO);
```

Set the mount point of the SD card, set SDMMC to one-bit bus mode, and set the read and write speed to 20MHz.

```

11    if (!SD_MMC.begin("/sdcard", true, true, SDMMC_FREQ_DEFAULT, 5)) {
12        Serial.println("Card Mount Failed");
13        return;
14    }
```

Get the type of SD card and print it out through the serial port.

```

15    uint8_t cardType = SD_MMC.cardType();
16    if(cardType == CARD_NONE) {
17        Serial.println("No SD_MMC card attached");
18        return;
19    }
20    Serial.print("SD_MMC Card Type: ");
21    if(cardType == CARD_MMC) {
22        Serial.println("MMC");
23    } else if(cardType == CARD_SD) {
24        Serial.println("SDSC");
25    } else if(cardType == CARD_SDHC) {
26        Serial.println("SDHC");
```

```
27     } else {
28         Serial.println("UNKNOWN");
29     }
```

Call the listDir() function to read the folder and file names in the SD card, and print them out through the serial port. This function can be found in "sd\_read\_write.cpp".

```
34     listDir(SD_MMC, "/", 0);
```

Call createDir() to create a folder, and call removeDir() to delete a folder.

```
36     createDir(SD_MMC, "/mydir");
39     removeDir(SD_MMC, "/mydir");
```

Call writeFile() to write any content to the txt file. If there is no such file, create this file first.

Call appendFile() to append any content to txt.

Call readFile() to read the content in txt and print it via the serial port.

```
42     writeFile(SD_MMC, "/hello.txt", "Hello ");
43     appendFile(SD_MMC, "/hello.txt", "World!\n");
44     readFile(SD_MMC, "/hello.txt");
```

Call deleteFile() to delete a specified file.

Call renameFile() to copy a file and rename it.

```
46     deleteFile(SD_MMC, "/foo.txt");
47     renameFile(SD_MMC, "/hello.txt", "/foo.txt");
```

Call the testFileIO() function to test the time it takes to read 512 bytes and the time it takes to write 2048\*512 bytes of data.

```
50     testFileIO(SD_MMC, "/test.txt");
```

Print the total size and used size of the SD card via the serial port.

```
52     Serial.printf("Total space: %lluMB\r\n", SD_MMC.totalBytes() / (1024 * 1024));
53     Serial.printf("Used space: %lluMB\r\n", SD_MMC.usedBytes() / (1024 * 1024));
```



# Chapter 29 Play SD card music

In the previous study, we have learned how to use the SD card, and then we will learn to play the music in the SD card.

## Project 29.1 SDMMC Music

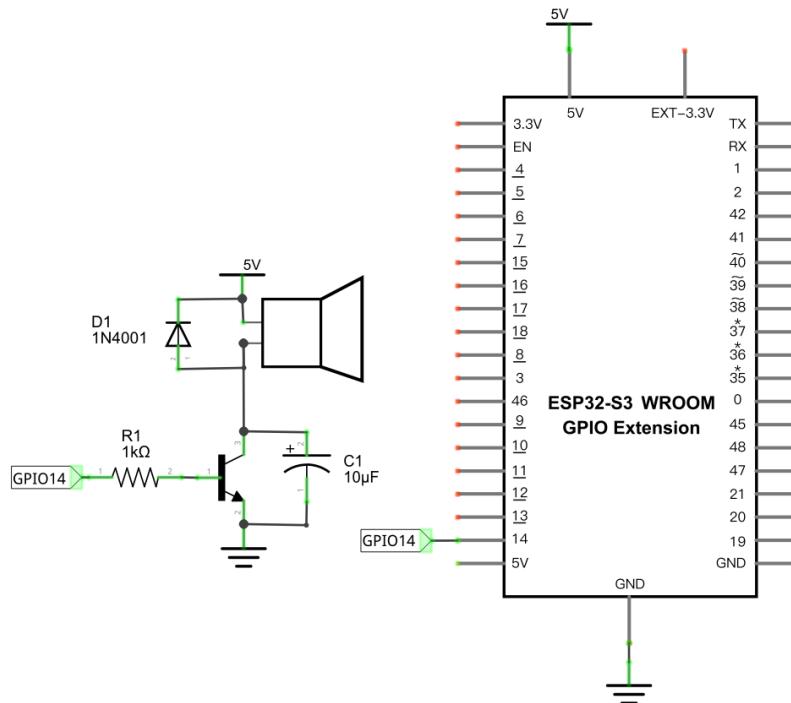
In this project, we will read an mp3 file from an SD card, decode it through ESP32-S3, and use a speaker to play it.

### Component List

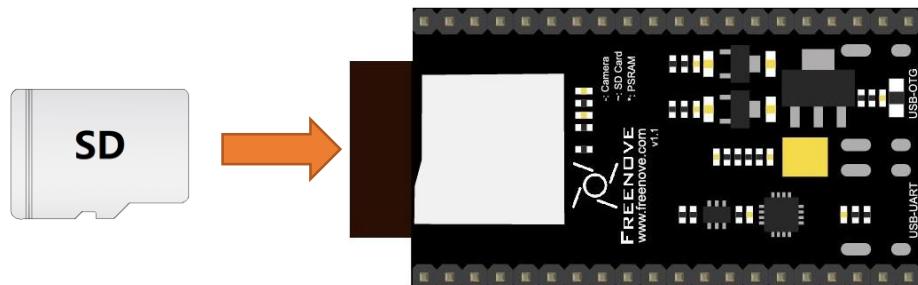
ESP32-S3 WROOM x1	USB cable x1	SDcard x1
Micro USB Wire x1	NPN transistor x1 (S8050)	Speaker
Diode x1	Resistor 1kΩ x1	Capacitor 10uF x1
Jumper F/M x4 Jumper F/F x2		
	Card reader x1 (random color)	

# Circuit

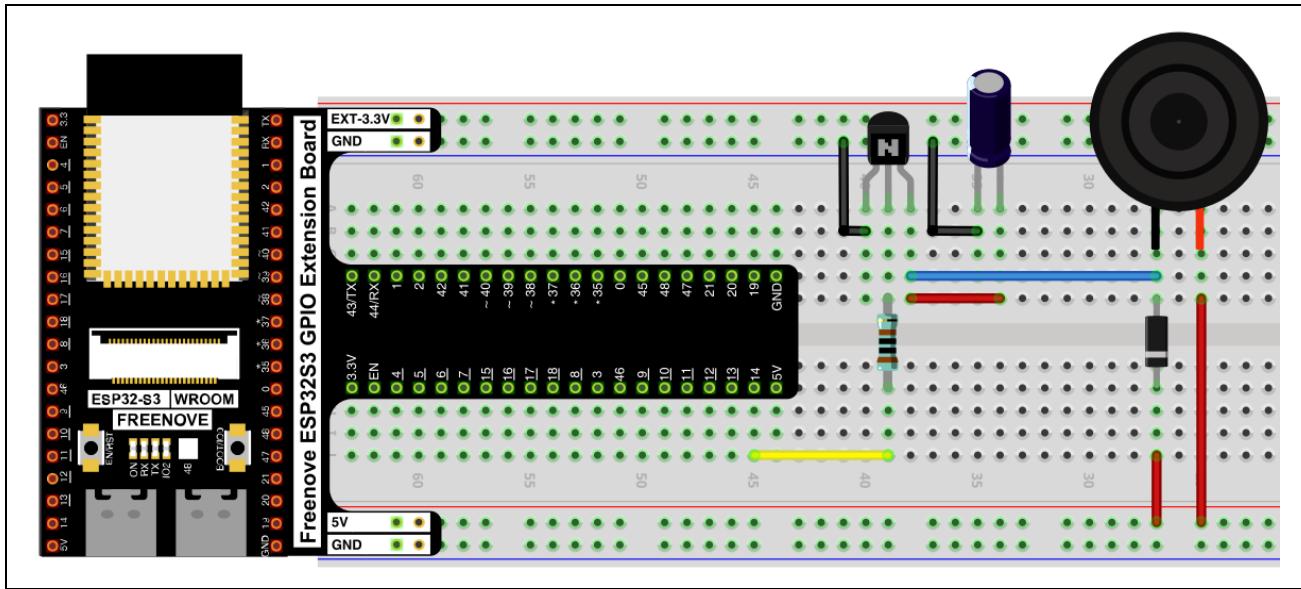
## Schematic diagram



Please note that before connecting the USB cable, please put the music into the SD card and insert the SD card into the card slot on the back of the ESP32-S3.



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

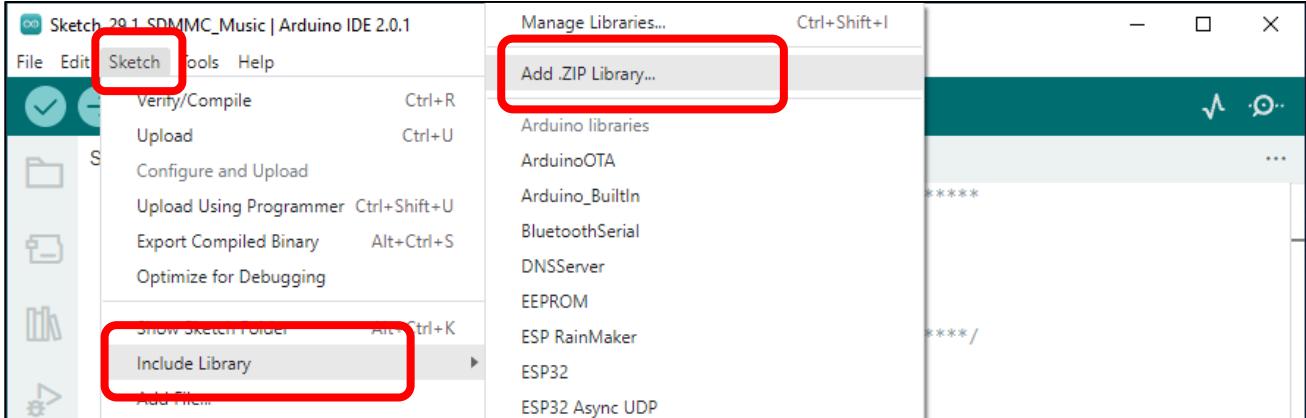


## Sketch

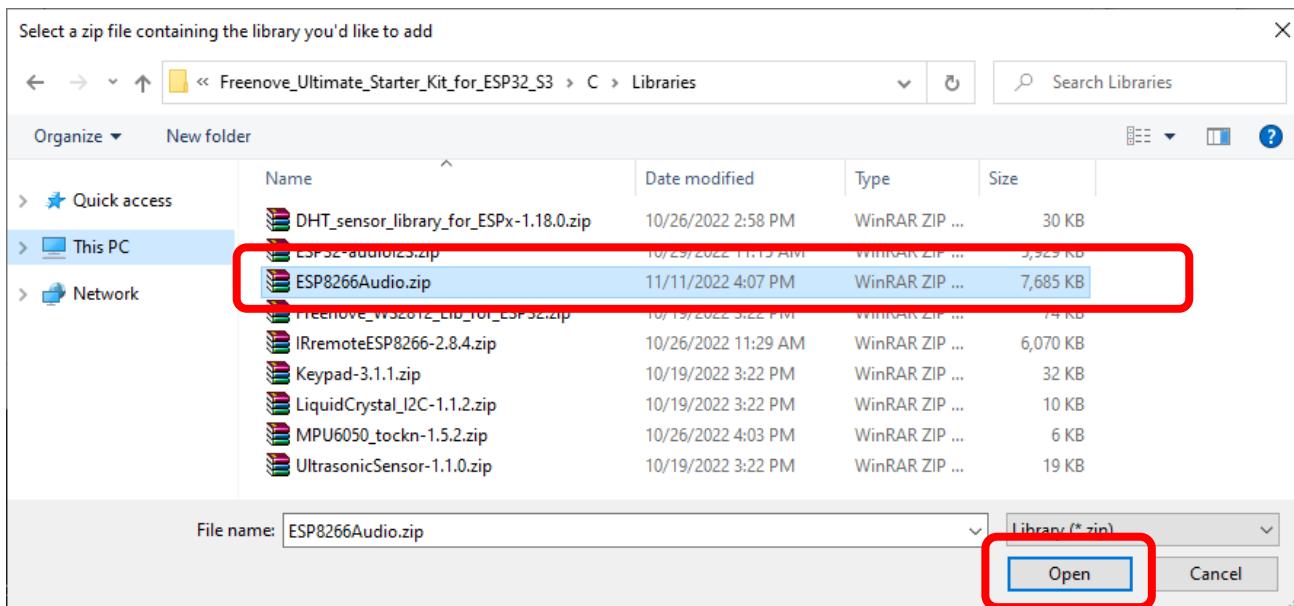
### How to install the library

In this project, we will use the `ESP8266Audio.zip` library to decode the audio files in the SD card, and then output the audio signal through GPIO. If you have not installed this library, please follow the steps below to install it.

Open arduino->Sketch->Include library-> Add .ZIP Library.



In the new pop-up window, select "`Freenove_Ultimate_Starter_Kit_for_ESP32_S3\Library\ESP8266Audio.zip`". Then click "Open".

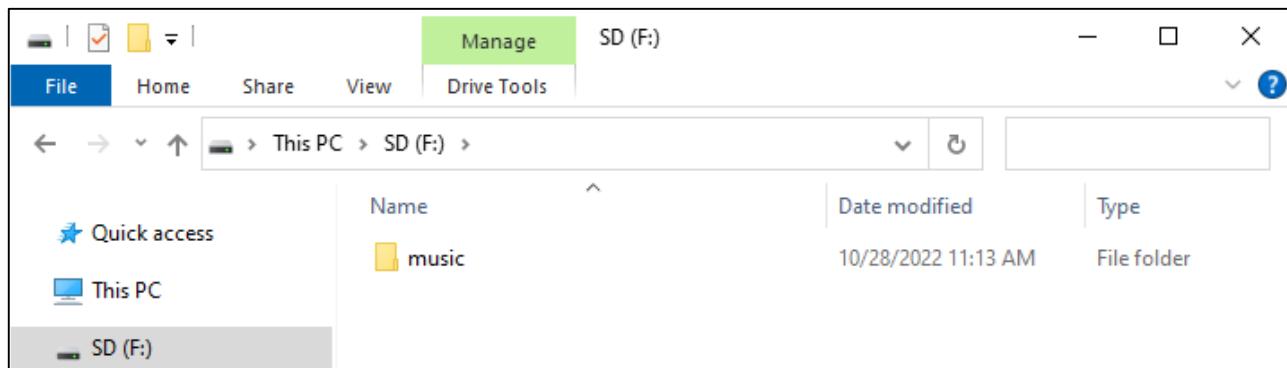


### Sketch\_29.1\_PlayMP3FromSD

We placed a folder called "music" in:

**Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32\_S3\Sketches\Sketch\_29.1\_PlayMP3FromSD**

User needs to copy this folder to SD card.



Click upload.



Compile and upload the code to the ESP32-S3 WROOM and open the serial monitor. ESP32-S3 takes a few seconds to initialize the program. When you see the message below, it means that ESP32-S3 has started parsing the mp3 in sd and started playing music through Pin.

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

```
Message (Ctrl + Enter to send message to 'ESP32S3 Dev Module'

SPIWP:0xee
mode:DIO, clock div:1
load:0x3fce3808,len:0x43c
load:0x403c9700,len:0xbec
load:0x403cc700,len:0x2a3c
entry 0x403c98d8
Sample MP3 playback begins...
+0 0x3fce2c34
ID3 callback for: Year = ''
ID3 callback for: eof = 'id3'
```

The following is the program code:

```

1 #include <Arduino.h>
2 #include <WiFi.h>
3 #include "FS.h"
4 #include "SD_MMC.h"
5 #include "AudioFileSourceSD_MMC.h"
6 #include "AudioFileSourceID3.h"
7 #include "AudioGeneratorMP3.h"
8 #include "AudioOutputI2SNoDAC.h"
9
10 #define SD_MMC_CMD 38 //Please do not modify it.
11 #define SD_MMC_CLK 39 //Please do not modify it.
12 #define SD_MMC_DO 40 //Please do not modify it.
13
14 AudioGeneratorMP3 *mp3;
15 AudioFileSourceID3 *id3;
16 AudioOutputI2SNoDAC *out;
17 AudioFileSourceSD_MMC *file = NULL;
18
19 // Called when a metadata event occurs (i.e. an ID3 tag, an ICY block, etc.
20 void MDCallback(void *cbData, const char *type, bool isUnicode, const char *string)
21 {
22     (void)cbData;
23     Serial.printf("ID3 callback for: %s = '", type);
24
25     if (isUnicode) {
26         string += 2;
27     }
28
29     while (*string) {
30         char a = *(string++);
31         if (isUnicode) {
32             string++;
33         }
34         Serial.printf("%c", a);
```

```
35 }
36 Serial.printf("\n");
37 Serial.flush();
38 }
39
40 void setup()
41 {
42 WiFi.mode(WIFI_OFF);
43 Serial.begin(115200);
44 delay(1000);
45 SD_MMC.setPins(SD_MMC_CLK, SD_MMC_CMD, SD_MMC_DO);
46 if (!SD_MMC.begin("/sdcard", true, true, SDMMC_FREQ_DEFAULT, 5)) {
47     Serial.println("Card Mount Failed");
48     return;
49 }
50 Serial.printf("Sample MP3 playback begins...\n");
51
52 audioLogger = &Serial;
53 file = new AudioFileSourceSD_MMC("/music/01.mp3");
54 id3 = new AudioFileSourceID3(file);
55 id3->RegisterMetadataCB(MDCallback, (void*)"ID3TAG");
56 out = new AudioOutputI2SNoDAC();
57 out->SetPinout(12,13,14); //Set the audio output pin, Only 14 were used
58 out->SetGain(0.3); //Setting the Volume
59 mp3 = new AudioGeneratorMP3();
60 mp3->begin(id3, out);
61 }
62
63 void loop()
64 {
65 if (mp3->isRunning()) {
66     if (!mp3->loop()) mp3->stop();
67 } else {
68     Serial.printf("MP3 done\n");
69     delay(1000);
70 }
71 }
```



Add music decoding header files and SD card drive files.

```

1 #include <Arduino.h>
2 #include <WiFi.h>
3 #include "FS.h"
4 #include "SD_MMC.h"
5 #include "AudioFileSourceSD_MMC.h"
6 #include "AudioFileSourceID3.h"
7 #include "AudioGeneratorMP3.h"
8 #include "AudioOutputI2SNoDAC.h"

```

Define the drive pins for SD card. Note that the SD card driver pins cannot be modified.

```

10 #define SD_MMC_CMD 38 //Please do not modify it.
11 #define SD_MMC_CLK 39 //Please do not modify it.
12 #define SD_MMC_DO 40 //Please do not modify it.

```

Apply for audio decoding class object.

```

14 AudioGeneratorMP3 *mp3;
15 AudioFileSourceID3 *id3;
16 AudioOutputI2SNoDAC *out;
17 AudioFileSourceSD_MMC *file = NULL;

```

Set the audio file source and associate it with the decoder. Initialize the audio output pin and set the volume to 2.

```

52 audioLogger = &Serial;
53 file = new AudioFileSourceSD_MMC("/music/01.mp3");
54 id3 = new AudioFileSourceID3(file);
55 id3->RegisterMetadataCB(MDCallback, (void*)"ID3TAG");
56 out = new AudioOutputI2SNoDAC();
57 out->SetPinout(12,13,14); //Set the audio output pin, Only 14 were used
58 out->SetGain(2); //Setting the Volume(0~3.9)
59 mp3 = new AudioGeneratorMP3();
60 mp3->begin(id3, out);

```

Determine whether the mp3 player is finished. If it is playing, continue playing. If it is finished, print a message.

```

65 if (mp3->isRunning()) {
66     if (!mp3->loop()) mp3->stop();
67 } else {
68     Serial.printf("MP3 done\n");
69     delay(1000);
70 }

```

## Project 29.2 SDMMC Music

In this project, we will read mp3 files from SD card, decode them through ESP32-S3, and use Audio Converter & Amplifier module to transcode into stereo output.

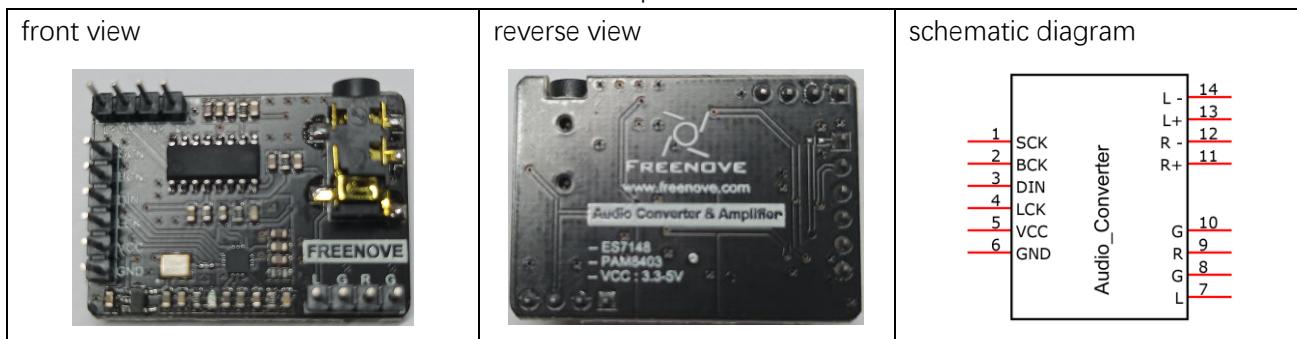
### Component List

ESP32-S3 WROOM x1	USB cable x1	SDcard x1
Micro USB Wire x1	Audio Converter & Amplifier	Speaker
Jumper F/M x4 Jumper F/F x2	Card reader x1 (random color)	



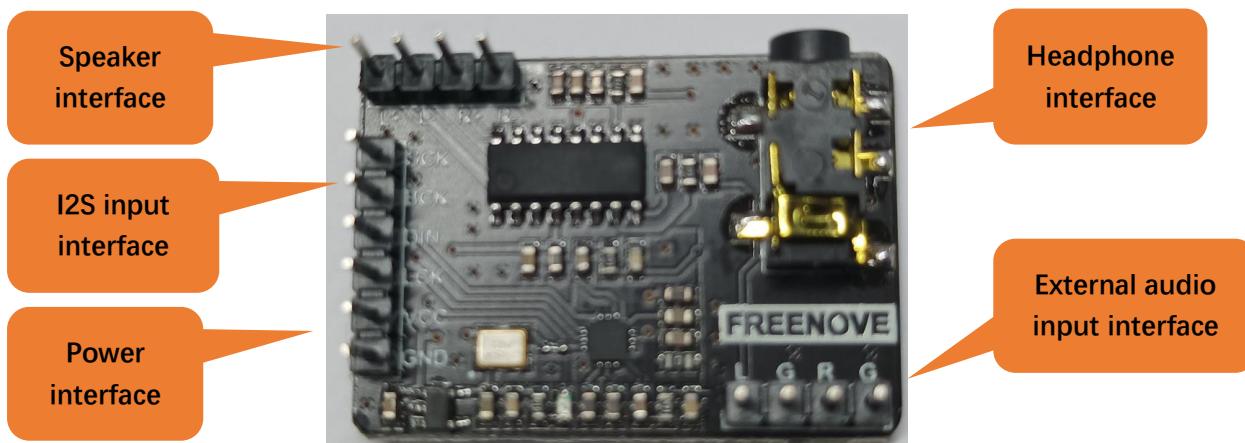
## Component knowledge

The front and reverse view of Audio Converter & Amplifier module.



Interface description for Audio Converter & Amplifier module

Pin	Name	Introductions
1	SCK	System clock input
2	BCK	Audio data bit clock input
3	DIN	Audio data input
4	LCK	Audio data word clock input
5	VCC	Power input, 3.3V~5.0V
6	GND	Power Ground
7	L	External audio left channel input
8	G	Power Ground
9	R	External audio right channel input
10	G	Power Ground
11	R+	Positive pole of right channel horn
12	R-	Negative pole of right channel horn
13	L+	Positive pole of left channel horn
14	L-	Negative pole of left channel horn



Speaker interface: Connect left channel speaker and right channel speaker. Group L: L+ & L-; Group R: R+ & R-. The two interfaces of the speaker can be connected to the interfaces of group L or group R. But when one interface is connected to group L, the other cannot be connected to group R. Doing so may cause the module to malfunction.

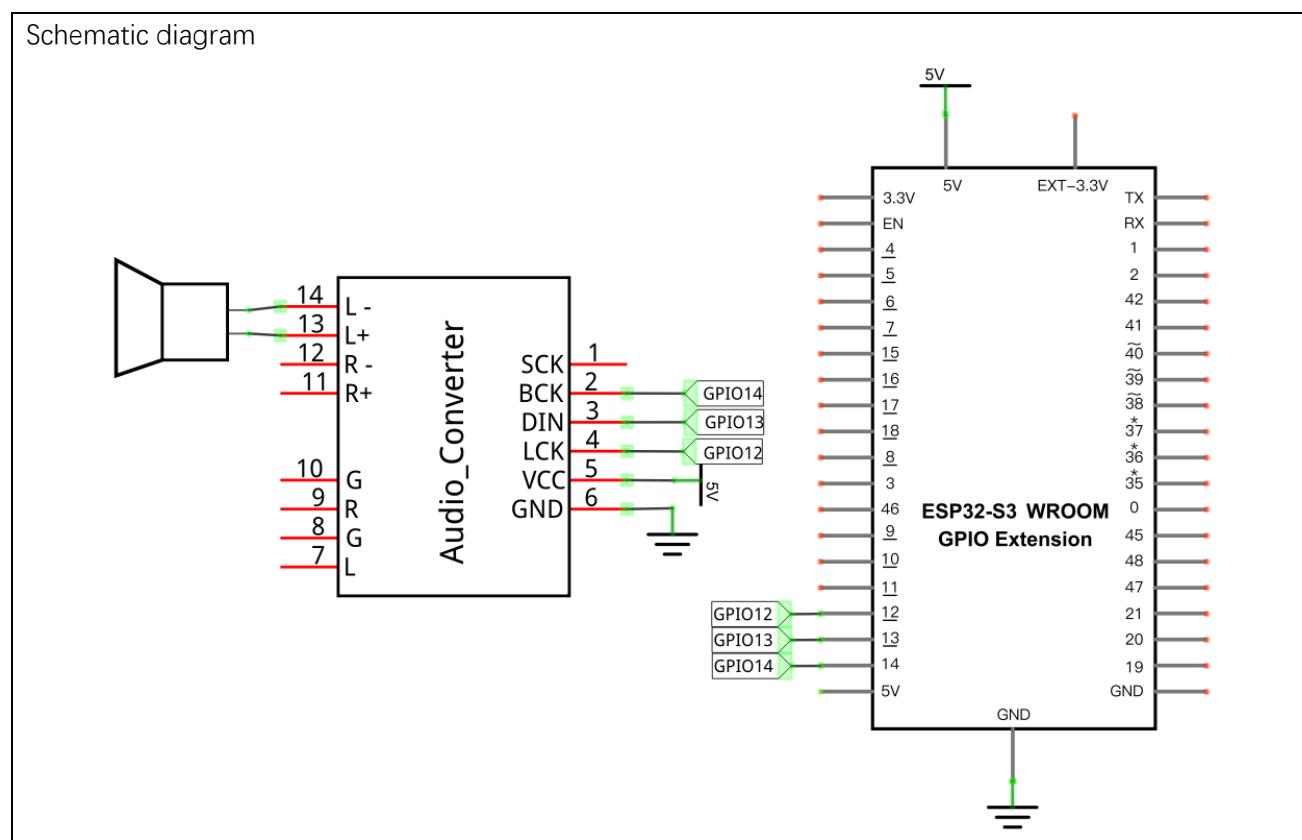
Headphone interface: the interface to connect the headphones.

I2S input interface: connect to the device with I2S. Used to transcode audio data into DAC audio signals.

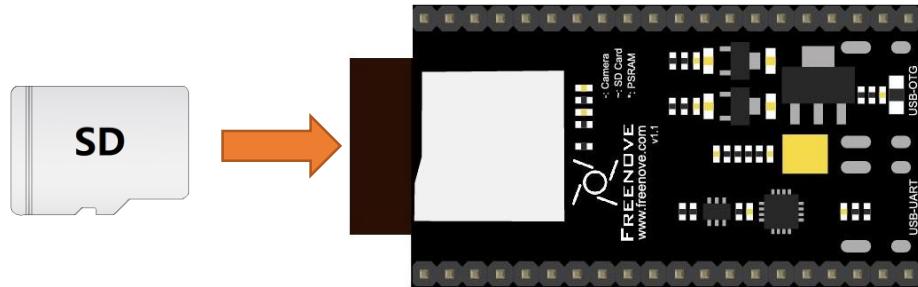
External audio input interface: connect to external audio equipment. Used to amplify externally input audio signals.

Power interface: connect to external power supply. External power supply selection range: 3.3V-5.0V.

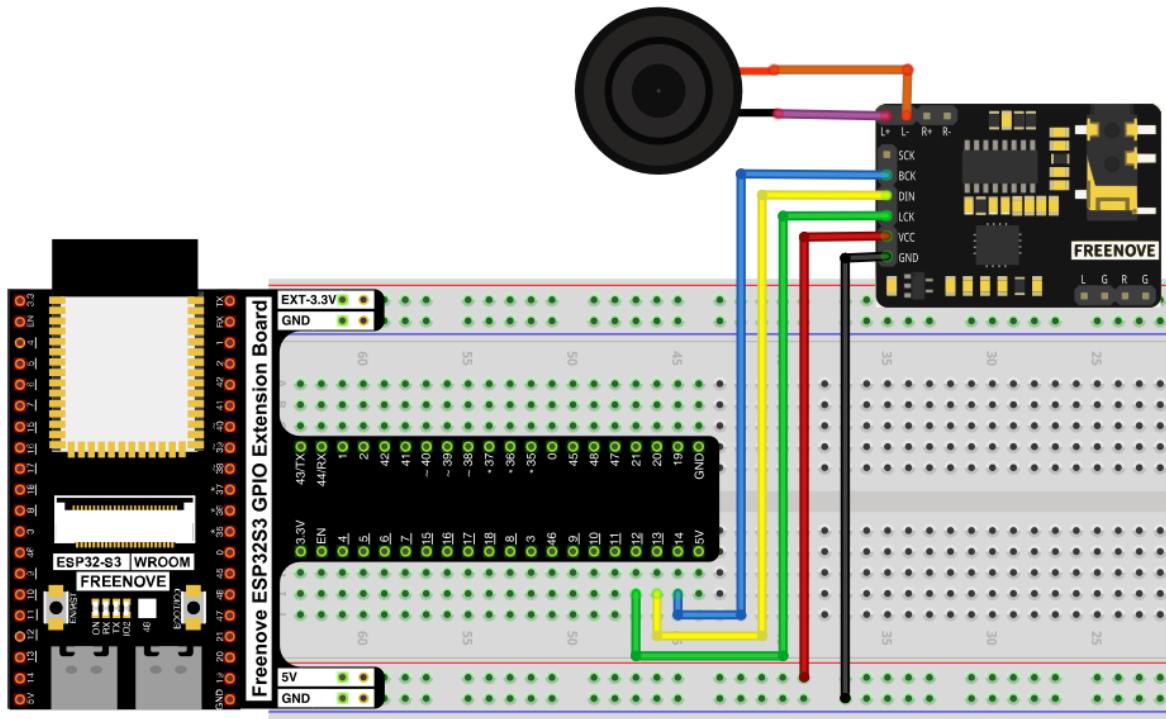
## Circuit



Please note that before connecting the USB cable, please put the music into the SD card and insert the SD card into the card slot on the back of the ESP32-S3.



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

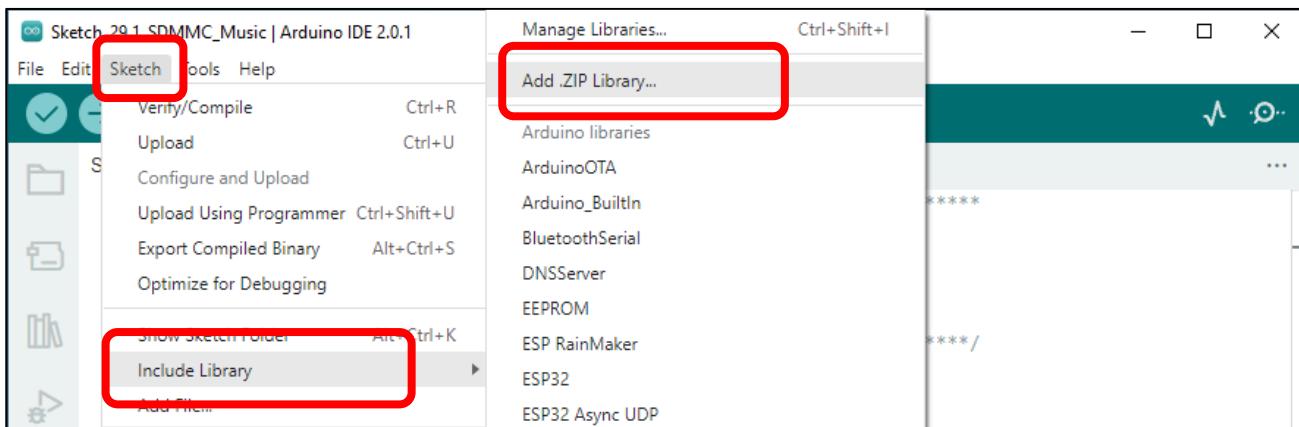


## Sketch

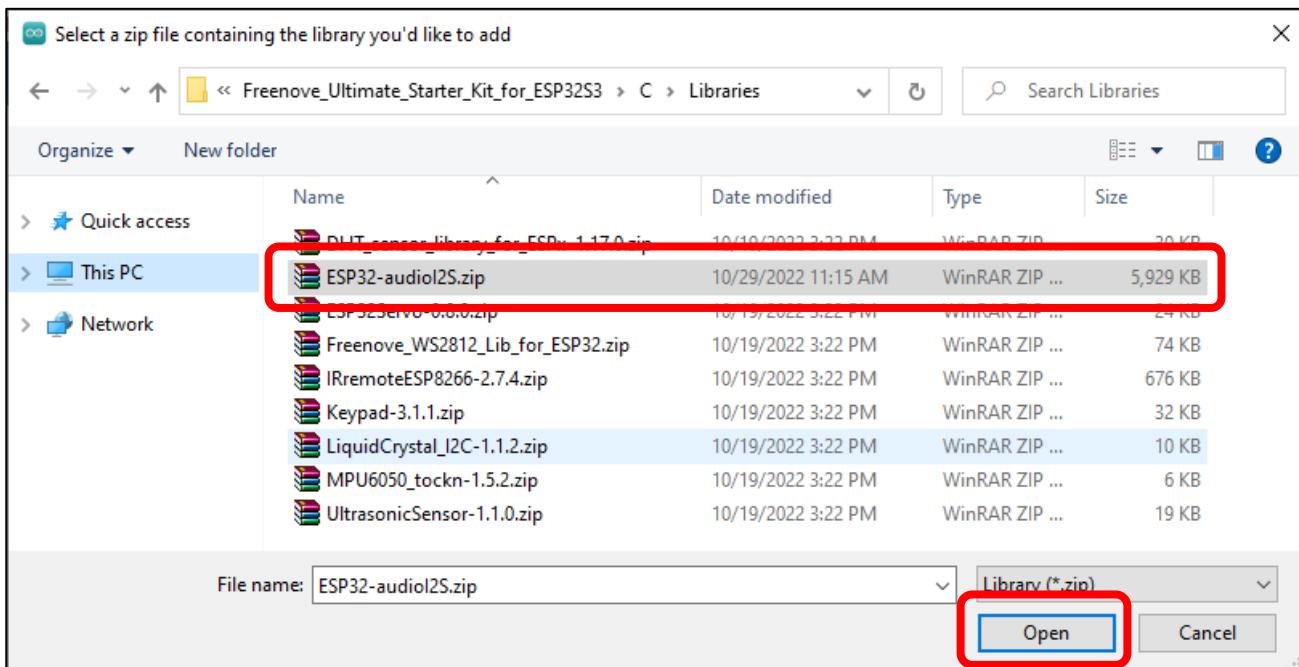
### How to install the library

In this project, we will use the ESP32-audioI2S.zip library to decode the audio files in the SD card, and then output the audio signal through IIS. If you have not installed this library, please follow the steps below to install it.

Open arduino->Sketch->Include library-> Add .ZIP Library.



In the new pop-up window, select "Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32\_S3\C\Libraries\ESP32-audioI2S.zip". Then click "Open".

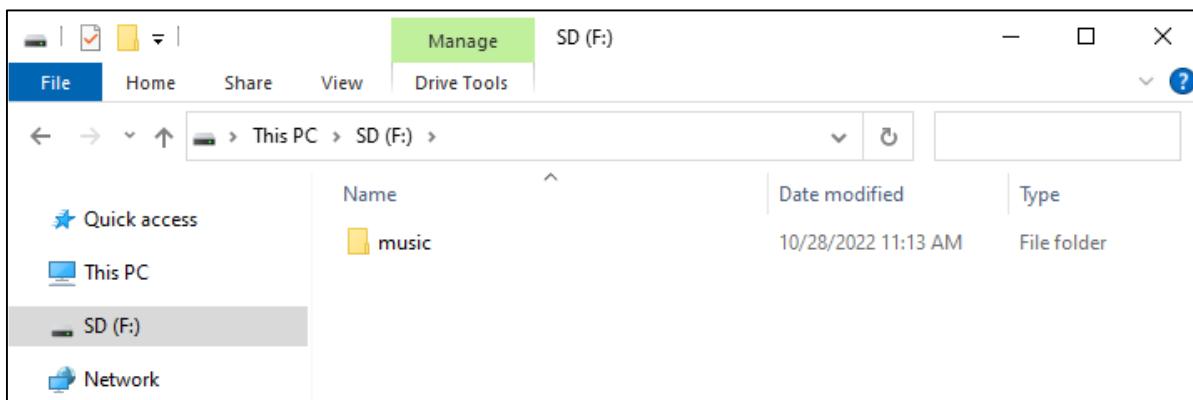


Sketch\_29.1\_SDMMC\_Music

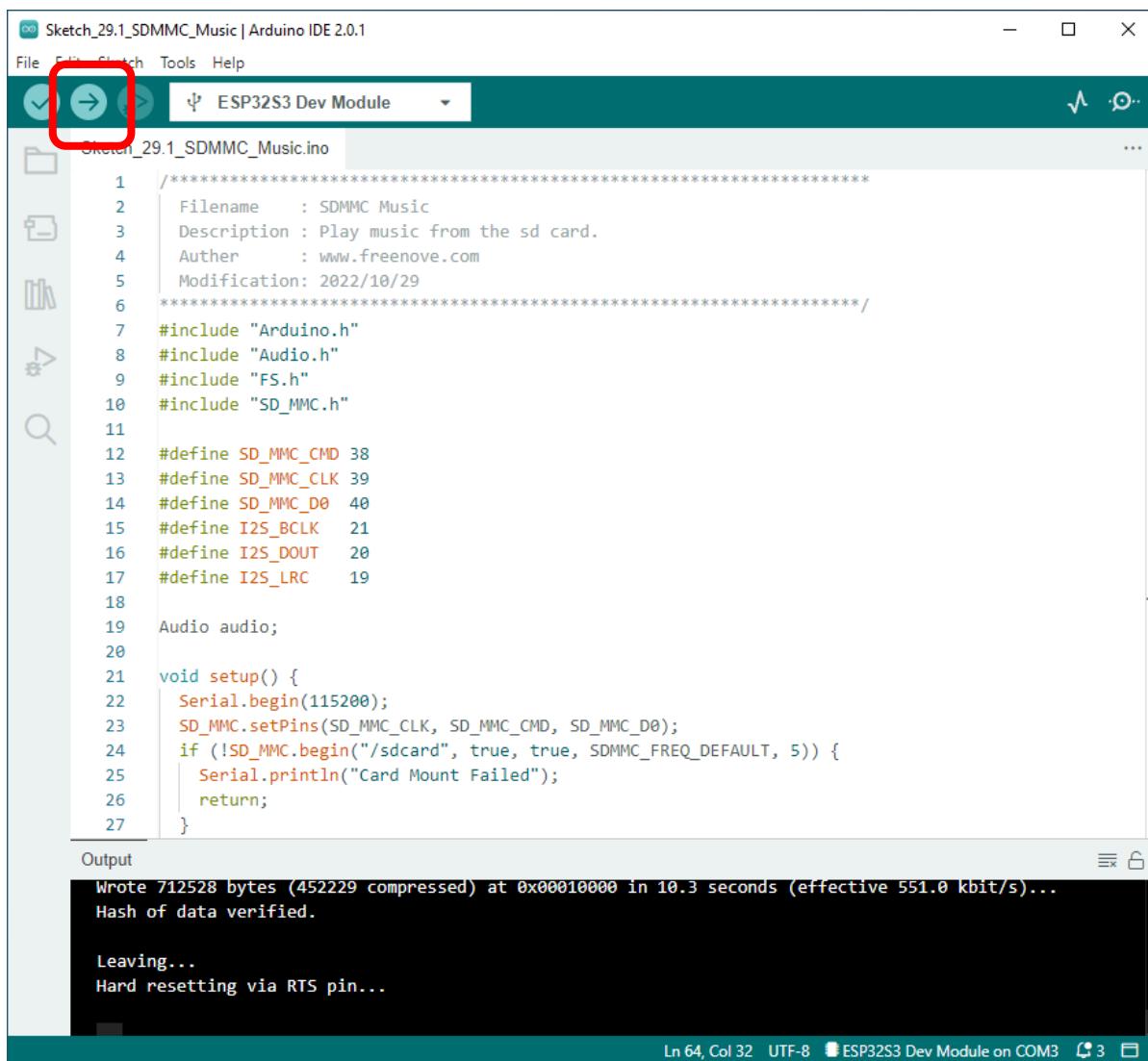
We placed a folder called "music" in:

**Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32\_S3\Sketches\Sketch\_29.2\_SDMMC\_Music.**

User needs to copy this folder to SD card.



Click upload.



Compile and upload the code to the ESP32-S3 WROOM and open the serial monitor. ESP32-S3 takes a few seconds to initialize the program. When you see the message below, it means that ESP32-S3 has started parsing the mp3 in sd and started playing music through iis.

```
SDHC
SD_MMC Card Size: 15193MB
info      PSRAM not found, inputBufferSize: 6399 bytes
info      buffers freed, free Heap: 258860 bytes
info      Reading file: "/music/Jingle Bells.mp3"
info      MP3Decoder has been initialized, free Heap: 231020 bytes
info      Content-Length: 8004409
info      ID3 framesSize: 1409
info      ID3 version: 2.3
info      ID3 normal frames
id3data  UserDefinedText: EXTENDXTEND
id3data  UserDefinedText: KGHASHGHASH
id3data  Year:
info      Audio-Length: 8003000
info      stream ready
info      syncword found at pos 0
info      Channels: 2
info      SampleRate: 44100
info      BitsPerSample: 16
info      BitRate: 320000
```

The following is the program code:

```
1 #include "Arduino.h"
2 #include "Audio.h"
3 #include "FS.h"
4 #include "SD_MMC.h"
5
6 #define SD_MMC_CMD 38
7 #define SD_MMC_CLK 39
8 #define SD_MMC_DO 40
9 #define I2S_BCLK 14
10 #define I2S_DOUT 13
11 #define I2S_LRC 12
12
13 Audio audio;
14
15 void setup() {
16     Serial.begin(115200);
17     SD_MMC.setPins(SD_MMC_CLK, SD_MMC_CMD, SD_MMC_DO);
18     if (!SD_MMC.begin("/sdcard", true, true, SDMMC_FREQ_DEFAULT, 5)) {
19         Serial.println("Card Mount Failed");
20         return;
21     }
22     uint8_t cardType = SD_MMC.cardType();
23     if (cardType == CARD_NONE) {
24         Serial.println("No SD_MMC card attached");
25         return;
26     }
```

```
27     if (cardType == CARD_MMC) {
28         Serial.println("MMC");
29     } else if (cardType == CARD_SD) {
30         Serial.println("SDSC");
31     } else if (cardType == CARD_SDHC) {
32         Serial.println("SDHC");
33     } else {
34         Serial.println("UNKNOWN");
35     }
36     uint64_t cardSize = SD_MMC.cardSize() / (1024 * 1024);
37     Serial.printf("SD_MMC Card Size: %lluMB\n", cardSize);
38
39     audio.setPinout(I2S_BCLK, I2S_LRC, I2S_DOUT);
40     audio.setVolume(12); // 0...21
41     audio.connecttoFS(SD_MMC, "/music/Jingle Bells.mp3");
42 }
43
44 void loop() {
45     audio.loop();
46     if (Serial.available()) { // put streamURL in serial monitor
47         audio.stopSong();
48         String r = Serial.readString();
49         r.trim();
50         if (r.length() > 5) audio.connecttoFS(SD_MMC, r.c_str());
51         log_i("free heap=%i", ESP.getFreeHeap());
52     }
53 }
54
55 // optional
56 void audio_info(const char *info) {
57     Serial.print("info      ");
58     Serial.println(info);
59 }
60 void audio_id3data(const char *info) { //id3 metadata
61     Serial.print("id3data      ");
62     Serial.println(info);
63 }
64 void audio_eof_mp3(const char *info) { //end of file
65     Serial.print("eof_mp3      ");
66     Serial.println(info);
67 }
68 void audio_showstation(const char *info) {
69     Serial.print("station      ");
70     Serial.println(info);
```

```

71 }
72 void audio_showstreamtitle(const char *info) {
73   Serial.print("streamtitle ");
74   Serial.println(info);
75 }
76 void audio_bitrate(const char *info) {
77   Serial.print("bitrate      ");
78   Serial.println(info);
79 }
80 void audio_commercial(const char *info) { //duration in sec
81   Serial.print("commercial   ");
82   Serial.println(info);
83 }
84 void audio_icyurl(const char *info) { //homepage
85   Serial.print("icyurl      ");
86   Serial.println(info);
87 }
88 void audio_lasthost(const char *info) { //stream URL played
89   Serial.print("lasthost     ");
90   Serial.println(info);
91 }
```

Add music decoding header files and SD card drive files.

```

1 #include "Arduino.h"
2 #include "Audio.h"
3 #include "FS.h"
4 #include "SD_MMC.h"
```

Define the drive pins for SD card and IIS. Note that the SD card driver pins cannot be modified, but the IIS drive pins can be modified.

```

6 #define SD_MMC_CMD 38
7 #define SD_MMC_CLK 39
8 #define SD_MMC_DO 40
9 #define I2S_BCLK 14
10 #define I2S_DOUT 13
11 #define I2S_LRC 12
```

Declare an audio decoding object, associate it with the pin, set the volume, and set the decoding object.

```

13 Audio audio;
...
39   audio.setPinout(I2S_BCLK, I2S_LRC, I2S_DOUT);
40   audio.setVolume(12); // 0...21
41   audio.connecttoFS(SD_MMC, "/music/Jingle Bells.mp3");
```

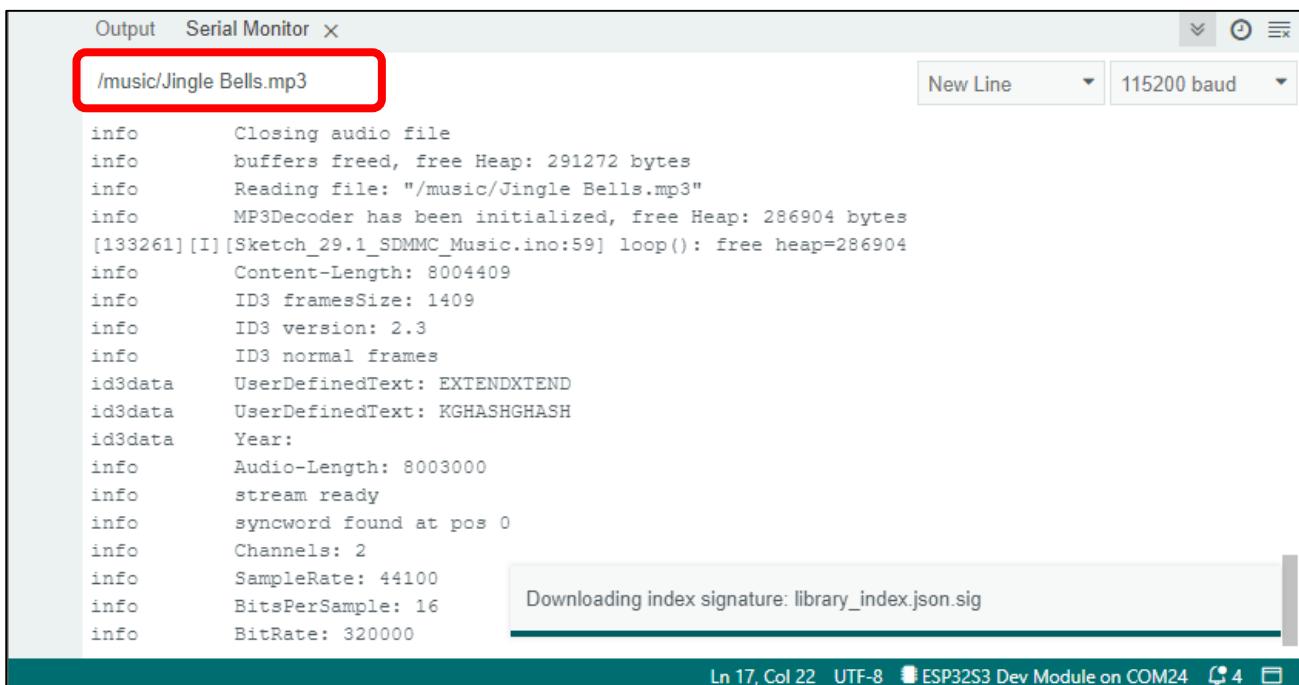


Play music until one piece of music finishes playing. If the serial port receives data, it will call the audio object to decode it after removing the spaces at the head and tail of the data.

```

45   audio.loop();
46   if (Serial.available()) { // put streamURL in serial monitor
47     audio.stopSong();
48     String r = Serial.readString();
49     r.trim();
50     if (r.length() > 5) audio.connecttoFS(SD_MMC, r.c_str());
51     log_i("free heap=%i", ESP.getFreeHeap());
52 }
```

In other words, if you want to switch the music in the SD card, you can directly input the song through the serial port.



The following functions are used to print the audio decoding information. If you do not want to see the decoding information in the serial port, you can directly comment out these functions.

```

67 void audio_info(const char *info);
71 void audio_id3data(const char *info);
75 void audio_eof_mp3(const char *info);
79 void audio_showstation(const char *info);
83 void audio_showstreamtitle(const char *info);
87 void audio_bitrate(const char *info);
91 void audio_commercial(const char *info);
95 void audio_icyurl(const char *info);
99 void audio_lasthost(const char *info);
```

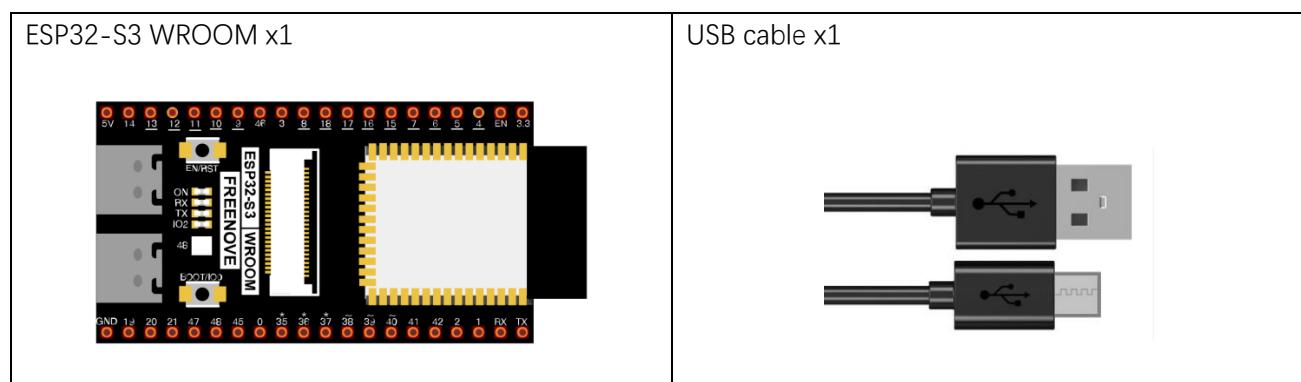
# Chapter 30 WiFi Working Modes

In this chapter, we'll focus on the WiFi infrastructure for ESP32-S3 WROOM.

ESP32-S3 WROOM 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 30.1 Station mode

### Component List



### Component knowledge

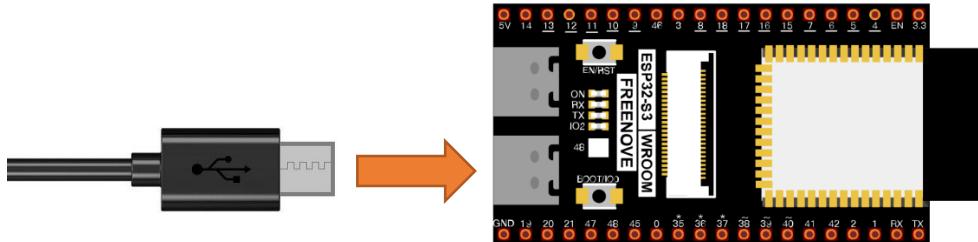
#### Station mode

When ESP32-S3 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-S3 wants to communicate with the PC, it needs to be connected to the router.



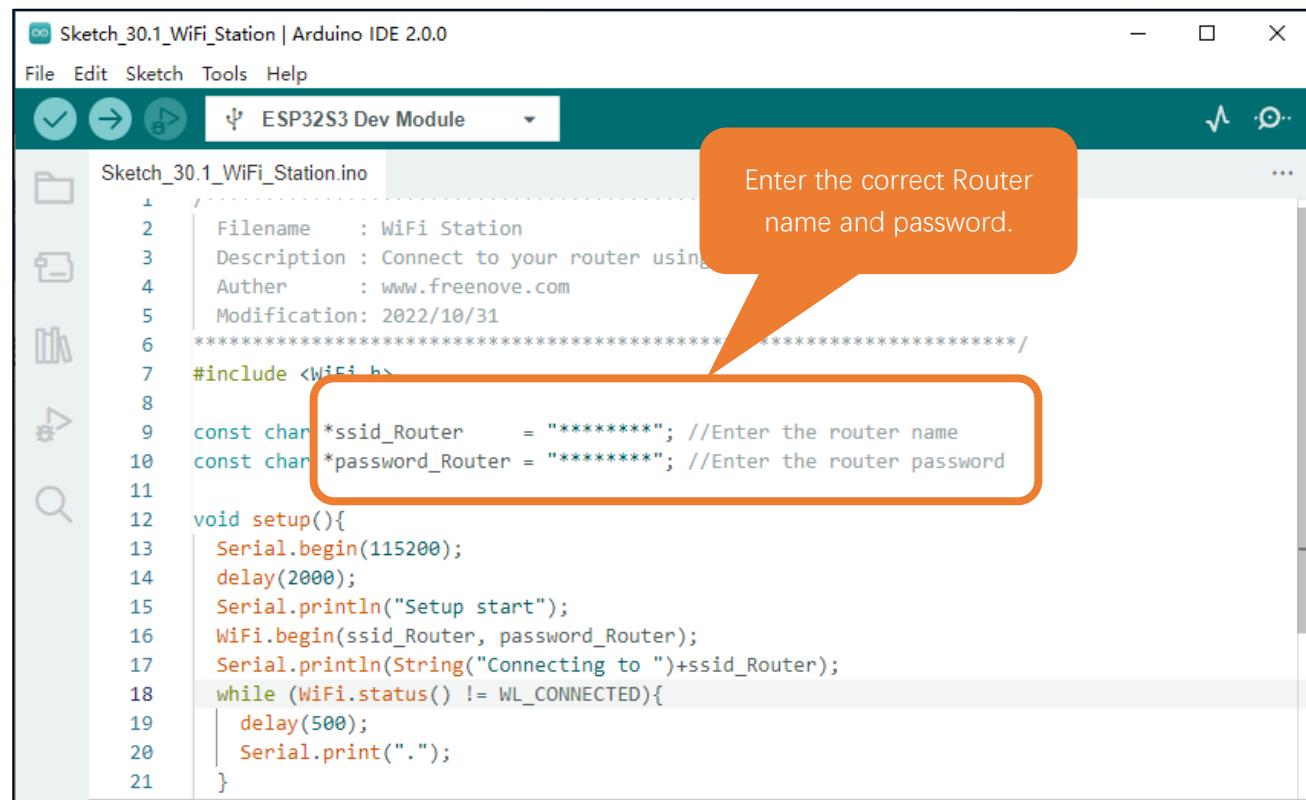
## Circuit

Connect Freenove ESP32-S3 to the computer using the USB cable.



## Sketch

### Sketch\_30.1\_Station\_mode



The screenshot shows the Arduino IDE interface with the file `Sketch_30.1_WiFi_Station.ino` open. The code is as follows:

```

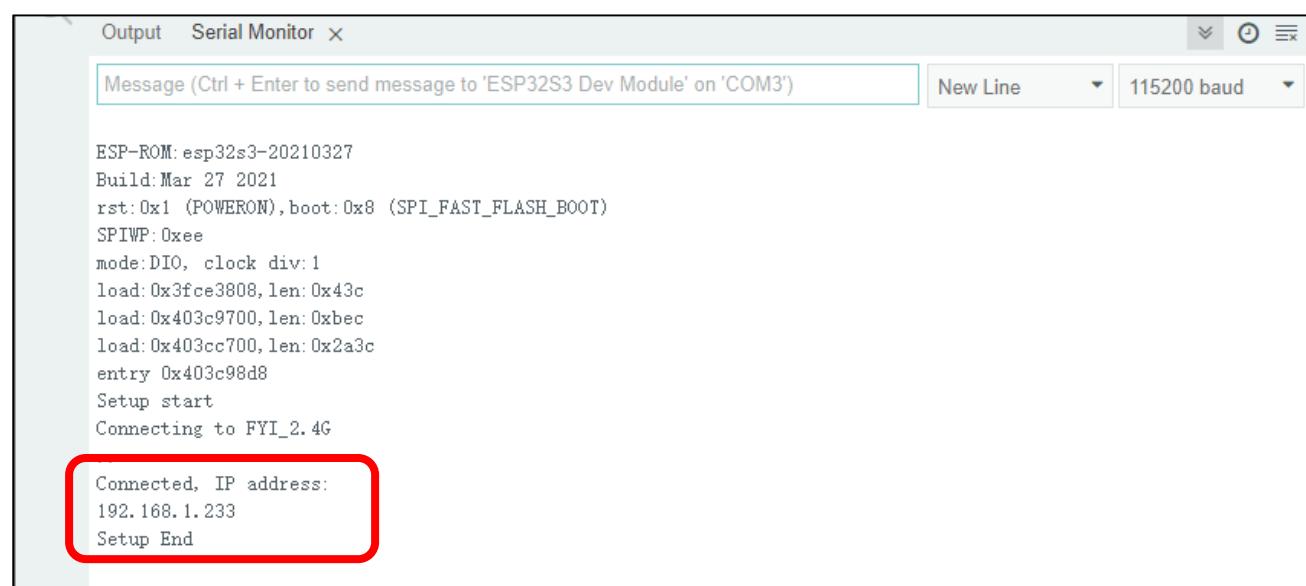
1 // Filename      : WiFi Station
2 Description   : Connect to your router using WiFi
3 Author        : www.freenove.com
4 Modification  : 2022/10/31
5 ****
6
7 #include <WiFi.h>
8
9 const char *ssid_Router      = "*****"; //Enter the router name
10 const char *password_Router = "*****"; //Enter the router password
11
12 void setup(){
13     Serial.begin(115200);
14     delay(2000);
15     Serial.println("Setup start");
16     WiFi.begin(ssid_Router, password_Router);
17     Serial.println(String("Connecting to ") +ssid_Router);
18     while (WiFi.status() != WL_CONNECTED){
19         delay(500);
20         Serial.print(".");
21     }

```

A callout bubble with the text "Enter the correct Router name and password." points to the two lines of code that define the router's SSID and password.

Because the names and passwords of routers in various places are different, before the Sketch 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-S3 WROOM, open serial monitor and set baud rate to 115200. And then it will display as follows:



The screenshot shows the Serial Monitor window with the following output:

```

ESP-ROM: esp32s3-20210327
Build: Mar 27 2021
rst:0x1 (POWERON), boot:0x8 (SPI_FAST_FLASH_BOOT)
SPIWP:0xee
mode:DIO, clock div:1
load:0x3fce3808, len:0x43c
load:0x403c9700, len:0xbec
load:0x403cc700, len:0x2a3c
entry 0x403c98d8
Setup start
Connecting to FYI_2.4G

Connected, IP address:
192.168.1.233
Setup End

```

A red box highlights the line "Connected, IP address: 192.168.1.233".

When ESP32-S3 WROOM successfully connects to "ssid\_Router", serial monitor will print out the IP address assigned to ESP32-S3 WROOM by the router.

The following is the program code:

```

1 #include <WiFi.h>

2

3 const char *ssid_Router      = "*****"; //Enter the router name
4 const char *password_Router = "*****"; //Enter the router password

5

6 void setup() {
7     Serial.begin(115200);
8     delay(2000);
9     Serial.println("Setup start");
10    WiFi.begin(ssid_Router, password_Router);
11    Serial.println(String("Connecting to ") + ssid_Router);
12    while (WiFi.status() != WL_CONNECTED) {
13        delay(500);
14        Serial.print(".");
15    }
16    Serial.println("\nConnected, IP address: ");
17    Serial.println(WiFi.localIP());
18    Serial.println("Setup End");
19 }
20
21 void loop() {
22 }
```

Include the WiFi Library header file of ESP32-S3.

```
1 #include <WiFi.h>
```

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-S3 in Station mode and connect it to your router.

```
10 WiFi.begin(ssid_Router, password_Router);
```

Check whether ESP32-S3 has connected to router successfully every 0.5s.

```

12 while (WiFi.status() != WL_CONNECTED) {
13     delay(500);
14     Serial.print(".");
15 }
```

Serial monitor prints out the IP address assigned to ESP32-S3 WROOM

```
17 Serial.println(WiFi.localIP());
```

Reference

### Class Station

Every time when using WiFi, you need to include header file "WiFi.h".

**begin(ssid, password,channel, bssid, connect)**: ESP32-S3 is used as Station to connect hotspot.

**ssid**: WiFi hotspot name

**password:** WiFi hotspot password

**channel:** WiFi hotspot channel number; communicating through specified channel; optional parameter

**bssid:** mac address of WiFi hotspot, optional parameter

**connect:** boolean optional parameter, defaulting to true. If set as false, then ESP32-S3 won't connect WiFi.

**config(local\_ip, gateway, subnet, dns1, dns2):** set static local IP address.

**local\_ip:** station fixed IP address.

**subnet:** subnet mask

**dns1,dns2:** optional parameter. define IP address of domain name server

**status:** obtain the connection status of WiFi

**local IP():** obtain IP address in Station mode

**disconnect():** disconnect wifi

**setAutoConnect(boolean):** set automatic connection Every time ESP32-S3 is power on, it will connect WiFi automatically.

**setAutoReconnect(boolean):** set automatic reconnection Every time ESP32-S3 disconnects WiFi, it will reconnect to WiFi automatically.

## Project 30.2 AP mode

# Component List & Circuit

Component List & Circuit are the same as in Project 30.1.

# Component knowledge

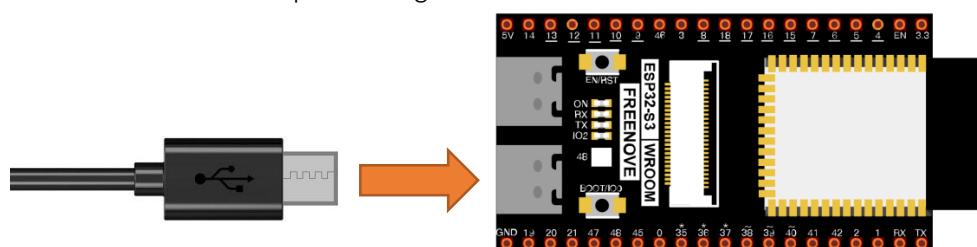
## AP mode

When ESP32-S3 selects AP mode, it creates a hotspot network that is separate from the Internet and waits for other WiFi devices to connect. As shown in the figure below, ESP32-S3 is used as a hotspot. If a mobile phone or PC wants to communicate with ESP32-S3, it must be connected to the hotspot of ESP32-S3. Only after a connection is established with ESP32-S3 can they communicate.



# Circuit

Connect Freenove ESP32-S3 to the computer using the USB cable.



Any concerns?  support@freenove.com

## Sketch

The screenshot shows the Arduino IDE interface with the following details:

- Title Bar:** Sketch\_30.2\_WiFi\_AP | Arduino IDE 2.0.0
- Menu Bar:** File Edit Sketch Tools Help
- Toolbar:** Includes icons for Save, Run, Stop, and others.
- Sketch Area:** Displays the code for `Sketch_30.2_WiFi_AP.ino`. The code configures an ESP32 to act as a WiFi Access Point (AP). A callout bubble highlights the following lines:

```
9 const char *ssid_AP      = "WiFi_Name"; //Enter the router name
10 const char *password_AP = "12345678"; //Enter the router password
```
- Output Area:** Shows the serial monitor output during the upload process:

```
Writing at 0x00086bd3... (84 %)
Writing at 0x0008c22f... (88 %)
Writing at 0x00094986... (92 %)
Writing at 0x0009cb02... (96 %)
Writing at 0x000a1dc0... (100 %)
Wrote 618112 bytes (407091 compressed) at 0x00010000 in 9.1 seconds (effective 543.9 kbit/s)...
Hash of data verified.

Leaving...
Hard resetting via RTS pin...
```
- Status Bar:** Ln 35, Col 14 UTF-8 ESP32S3 Dev Module on COM3 2

Before the Sketch runs, you can make any changes to the AP name and password for ESP32-S3 in the box as shown in the illustration above. Of course, you can leave it alone by default.

Compile and upload codes to ESP32-S3 WROOM, open the serial monitor and set the baud rate to 115200. And then it will display as follows.

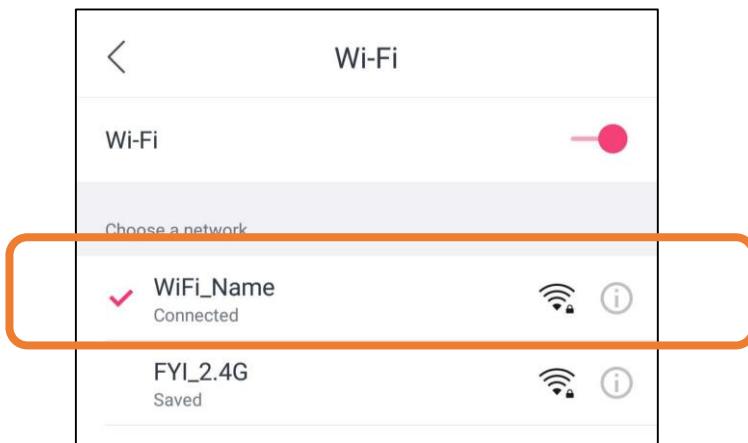


The screenshot shows the Arduino Serial Monitor window titled "Serial Monitor". The message area displays the following text:

```
Message (Ctrl + Enter to send message to 'ESP32S3 Dev Module' on 'COM3')
load: 0x403cc700, len: 0x2a3c
entry 0x403c98d8
Setting soft-AP configuration ...
Ready
Setting soft-AP ...
Ready
Soft-AP IP address = 192.168.1.100
MAC address = 7E:DF:A1:FD:FF:8C
Setup End
```

The status bar at the bottom shows "Ln 35, Col 14" and "ESP32S3 Dev Module on COM3".

When observing the print information of the serial monitor, turn on the WiFi scanning function of your phone, and you can see the ssid\_AP on ESP32-S3, which is called "WiFi\_Name" in this Sketch. You can enter the password "12345678" to connect it or change its AP name and password by modifying Sketch.



### Sketch\_30\_2\_AP\_mode

The following is the program code:

```

1 #include <WiFi.h>
2
3 const char *ssid_AP      = "WiFi_Name"; //Enter the router name
4 const char *password_AP = "12345678"; //Enter the router password
5
6 IPAddress local_IP(192, 168, 1, 100); //Set the IP address of ESP32-S3 itself
7 IPAddress gateway(192, 168, 1, 10); //Set the gateway of ESP32-S3 itself
8 IPAddress subnet(255, 255, 255, 0); //Set the subnet mask for ESP32-S3 itself
9
10 void setup() {
11     Serial.begin(115200);
12     delay(2000);
13     Serial.println("Setting soft-AP configuration ... ");
14     WiFi.disconnect();
15     WiFi.mode(WIFI_AP);
16     Serial.println(WiFi.softAPConfig(local_IP, gateway, subnet) ? "Ready" : "Failed!");
17     Serial.println("Setting soft-AP ... ");
18     boolean result = WiFi.softAP(ssid_AP, password_AP);
19     if(result){
20         Serial.println("Ready");
21         Serial.println(String("Soft-AP IP address = ") + WiFi.softAPIP().toString());
22         Serial.println(String("MAC address = ") + WiFi.softAPmacAddress().c_str());
23     }else{
24         Serial.println("Failed!");
25     }
26     Serial.println("Setup End");
27 }
28
29 void loop() {
30 }
```

Include WiFi Library header file of ESP32-S3.

```
1 #include <WiFi.h>
```

Enter correct AP name and password.

```
3 const char *ssid_AP      = "WiFi_Name"; //Enter the router name
4 const char *password_AP = "12345678"; //Enter the router password
```

Set ESP32-S3 in AP mode.

```
15 WiFi.mode(WIFI_AP);
```

Configure IP address, gateway and subnet mask for ESP32-S3.

```
16 WiFi.softAPConfig(local_IP, gateway, subnet)
```

Turn on an AP in ESP32-S3, whose name is set by ssid\_AP and password is set by password\_AP.

```
18 WiFi.softAP(ssid_AP, password_AP);
```

Check whether the AP is turned on successfully. If yes, print out IP and MAC address of AP established by ESP32-S3. If no, print out the failure prompt.

```
19 if(result){  
20     Serial.println("Ready");  
21     Serial.println(String("Soft-AP IP address = ") + WiFi.softAPIP().toString());  
22     Serial.println(String("MAC address = ") + WiFi.softAPmacAddress().c_str());  
23 }else{  
24     Serial.println("Failed!");  
25 }  
26 Serial.println("Setup End");
```

#### Reference

##### Class AP

Every time when using WiFi, you need to include header file "WiFi.h".

**softAP(ssid, password, channel, ssid\_hidden, max\_connection):**

**ssid:** WiFi hotspot name

**password:** WiFi hotspot password

**channel:** Number of WiFi connection channels, range 1-13. The default is 1.

**ssid\_hidden:** Whether to hide WiFi name from scanning by other devices. The default is not hide.

**max\_connection:** Maximum number of WiFi connected devices. The range is 1-4. The default is 4.

**softAPConfig(local\_ip, gateway, subnet):** set static local IP address.

**local\_ip:** station fixed IP address.

**Gateway:** gateway IP address

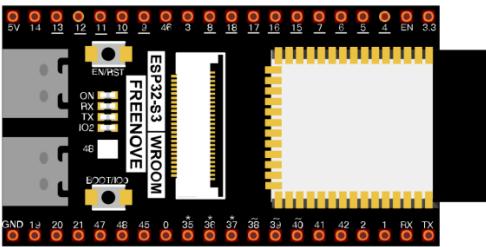
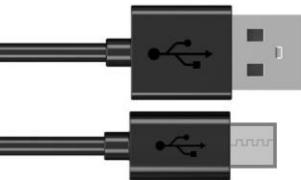
**subnet:** subnet mask

**softAP():** obtain IP address in AP mode

**softAPdisconnect ():** disconnect AP mode.

## Project 30.3 AP+Station mode

### Component List

ESP32-S3 WROOM x1	USB cable x1
 A detailed pinout diagram of the ESP32-S3 WROOM module. It shows a 40-pin DIP package with various pins labeled. Key pins include 5V, GND, EN/HST, RX, TX, IO2, 4B, and several digital pins numbered 1 through 40. A yellow ribbon cable is attached to the right side of the module.	 A diagram showing two USB cables. One is a standard A-to-A cable, and the other is a shorter cable with a standard A connector on one end and a smaller micro-B or similar connector on the other.

### Component knowledge

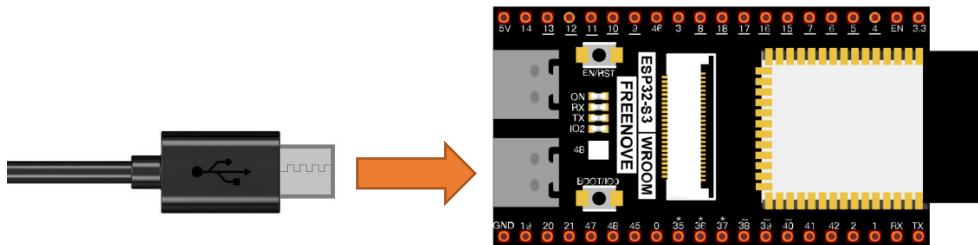
#### AP+Station mode

In addition to AP mode and station mode, ESP32-S3 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-S3'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-S3.



## Circuit

Connect Freenove ESP32-S3 to the computer using the USB cable.



## Sketch

### Sketch\_30.3\_AP\_Station\_mode

```

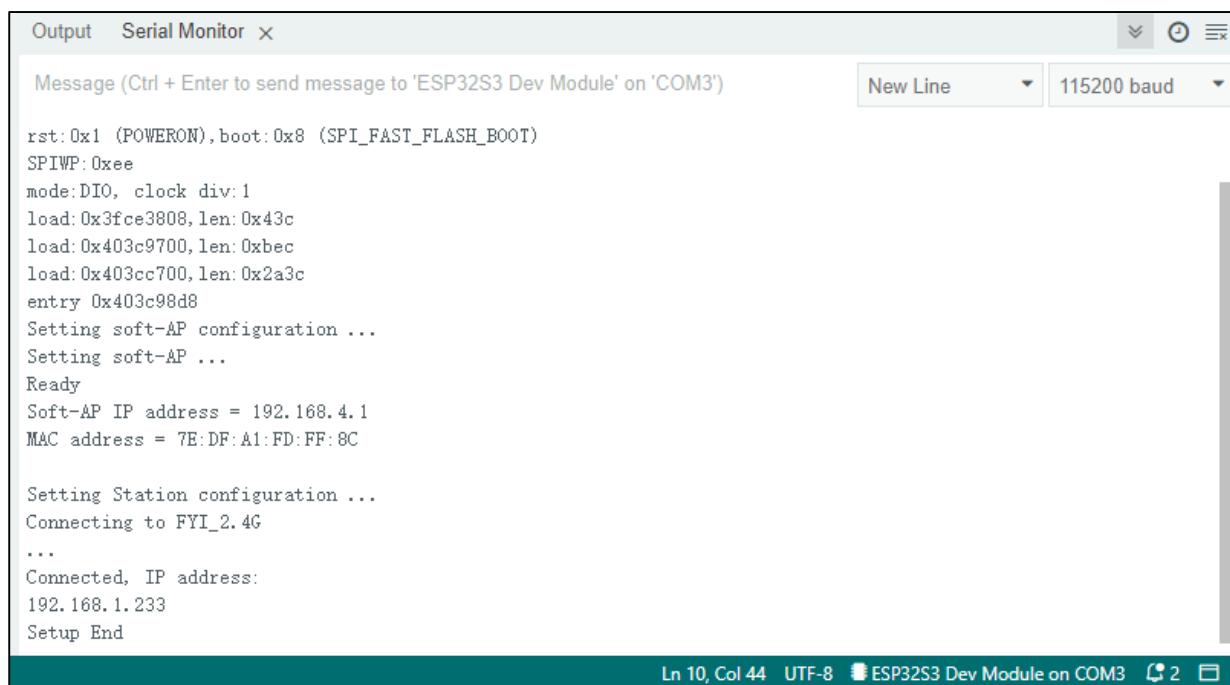
Sketch_30.3_AP_Station | Arduino IDE 2.0.0
File Edit Sketch Tools Help
Select Board
Sketch_30.3_AP_Station.ino ...
1 //*****
2   Filename    : WiFi AP+Station
3   Description : ESP32 connects to the u
4   Author     : www.freenove.com
5   Modification: 2022/10/31
6 ****
7 #include <WiFi.h>
8
9 const char *ssid_Router      = "*****"; //Enter the router name
10 const char *password_Router = "*****"; //Enter the router password
11 const char *ssid_AP          = "WiFi_Name"; //Enter the router name
12 const char *password_AP      = "12345678"; //Enter the router password
13
14 void setup(){
15   Serial.begin(115200);
16   Serial.println("Setting soft-AP configuration ... ");
17   WiFi.disconnect();
18   WiFi.mode(WIFI_AP);
19   Serial.println("Setting soft-AP ... ");
20   boolean result = WiFi.softAP(ssid_AP, password_AP);
21   if(result){
22     Serial.println("Ready");
23     Serial.println(String("Soft-AP IP address = ") + WiFi.softAPIP().toString());
24     Serial.println(String("MAC address = ") + WiFi.softAPmacAddress().c_str());
25   }else{
26     Serial.println("Failed!");
27 }

```

Please enter the correct names and passwords of Router and AP.

It is analogous to project 30.1 and project 30.2. Before running the Sketch, you need to modify ssid\_Router, password\_Router, ssid\_AP and password\_AP shown in the box of the illustration above.

After making sure that Sketch is modified correctly, compile and upload codes to ESP32-S3 WROOM, open serial monitor and set baud rate to 115200. And then it will display as follows:



```

Output  Serial Monitor X

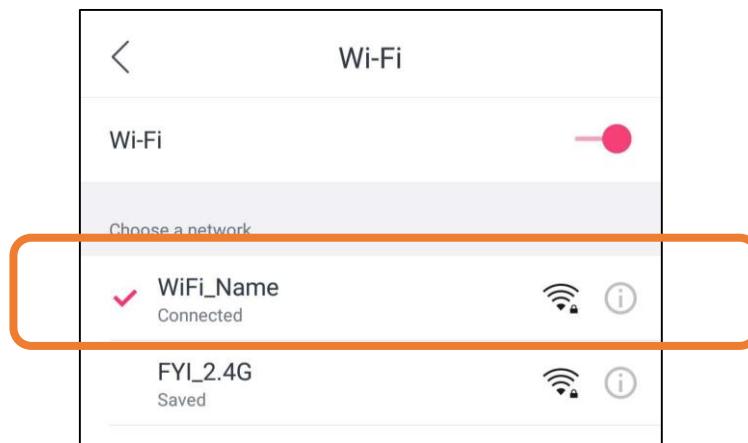
Message (Ctrl + Enter to send message to 'ESP32S3 Dev Module' on 'COM3')
rst:0x1 (POWERON), boot:0x8 (SPI_FAST_FLASH_BOOT)
SPIWP:0xee
mode:DIO, clock div:1
load:0x3fce3808,len:0x43c
load:0x403c9700,len:0xbec
load:0x403cc700,len:0x2a3c
entry 0x403c98d8
Setting soft-AP configuration ...
Setting soft-AP ...
Ready
Soft-AP IP address = 192.168.4.1
MAC address = 7E:DF:A1:FD:FF:8C

Setting Station configuration ...
Connecting to FYI_2.4G
...
Connected, IP address:
192.168.1.233
Setup End

Ln 10, Col 44  UTF-8  ■ ESP32S3 Dev Module on COM3  ↻ 2  □

```

When observing the print information of the serial monitor, turn on the WiFi scanning function of your phone, and you can see the ssid\_AP on ESP32-S3.



The following is the program code:

```

1 #include <WiFi.h>
2
3 const char *ssid_Router      = "*****"; //Enter the router name
4 const char *password_Router = "*****"; //Enter the router password
5 const char *ssid_AP         = "WiFi_Name"; //Enter the AP name
6 const char *password_AP     = "12345678"; //Enter the AP password
7
8 void setup() {
9     Serial.begin(115200);
10    Serial.println("Setting soft-AP configuration ... ");

```

```
11 WiFi.disconnect();
12 WiFi.mode(WIFI_AP);
13 Serial.println("Setting soft-AP ... ");
14 boolean result = WiFi.softAP(ssid_AP, password_AP);
15 if(result){
16     Serial.println("Ready");
17     Serial.println(String("Soft-AP IP address = ") + WiFi.softAPIP().toString());
18     Serial.println(String("MAC address = ") + WiFi.softAPmacAddress().c_str());
19 }else{
20     Serial.println("Failed!");
21 }
22
23 Serial.println("\nSetting Station configuration ... ");
24 WiFi.begin(ssid_Router, password_Router);
25 Serial.println(String("Connecting to ") + ssid_Router);
26 while (WiFi.status() != WL_CONNECTED) {
27     delay(500);
28     Serial.print(".");
29 }
30 Serial.println("\nConnected, IP address: ");
31 Serial.println(WiFi.localIP());
32 Serial.println("Setup End");
33 }
34
35 void loop() {
36 }
```

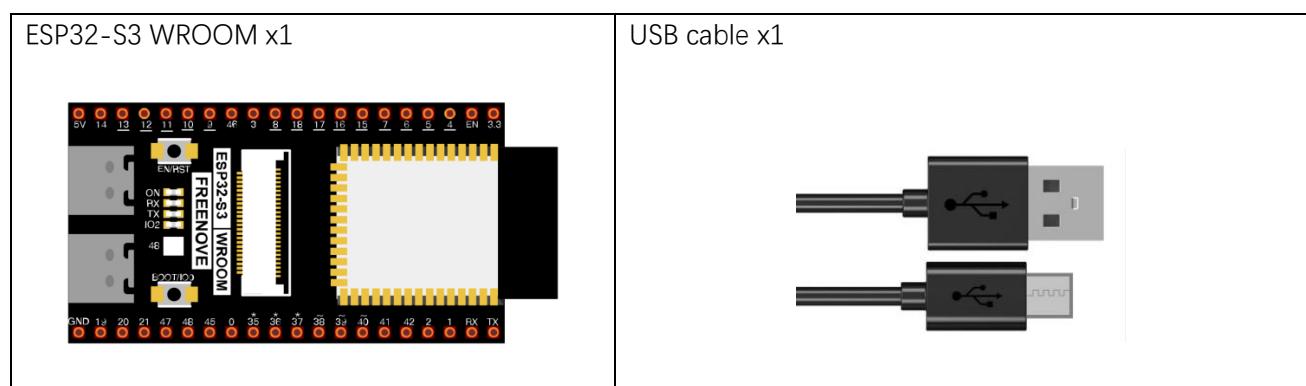
# Chapter 31 TCP/IP

In this chapter, we will introduce how ESP32-S3 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 31.1 As Client

In this section, ESP32-S3 is used as Client to connect Server on the same LAN and communicate with it.

### Component List



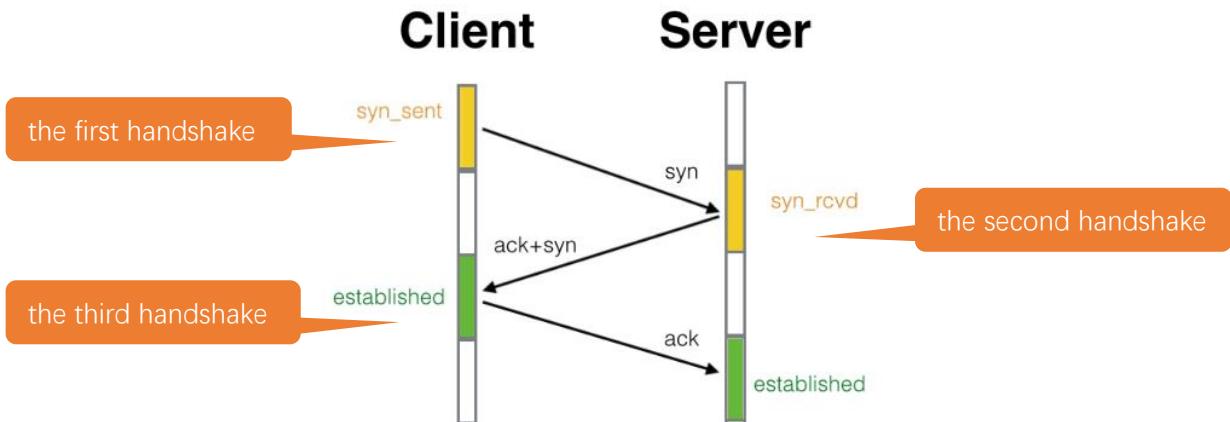
### Component knowledge

#### TCP connection

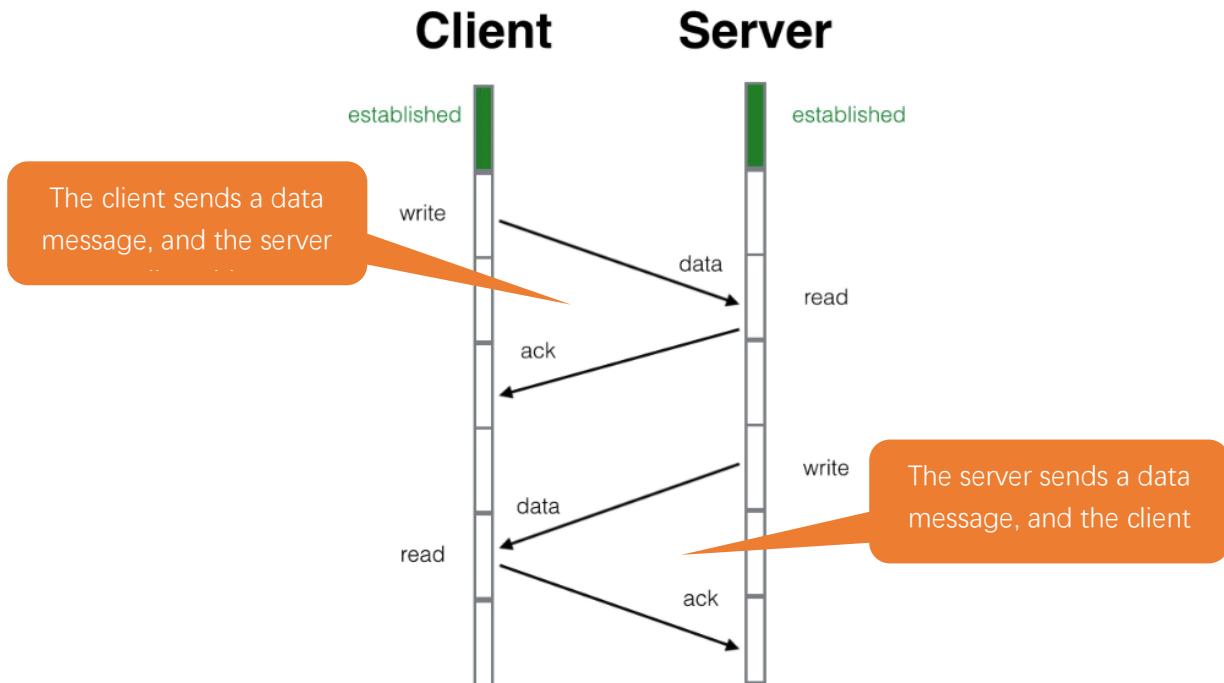
Before transmitting data, TCP needs to establish a logical connection between the sending end and the receiving end. It provides reliable and error-free data transmission between the two computers. In the TCP connection, the client and the server must be clarified. The client sends a connection request 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.

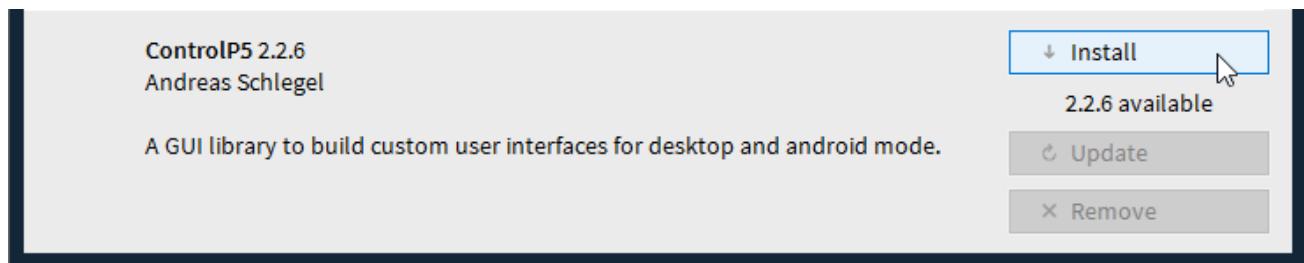
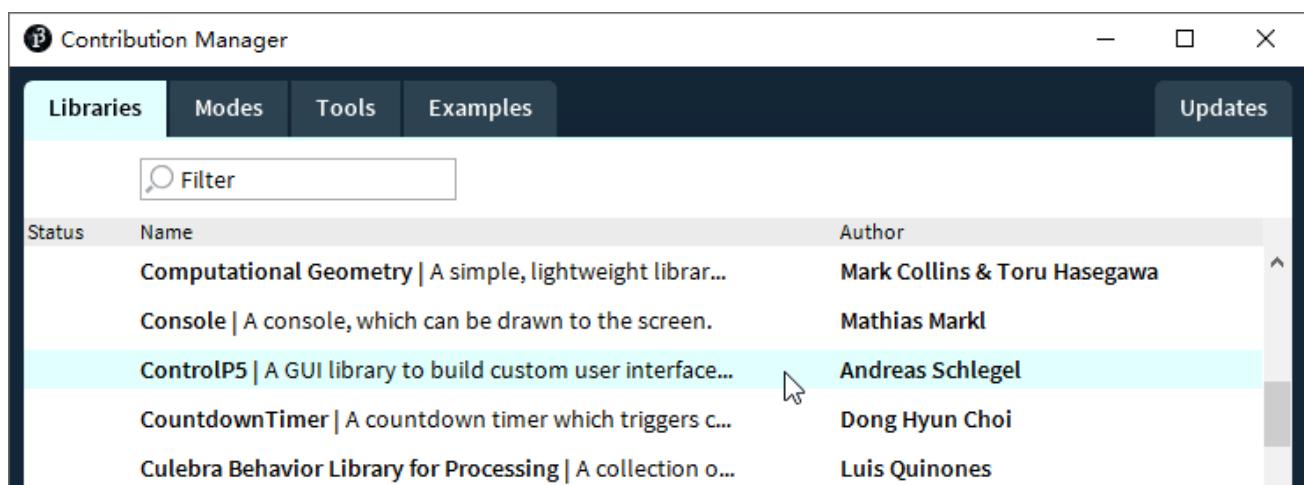
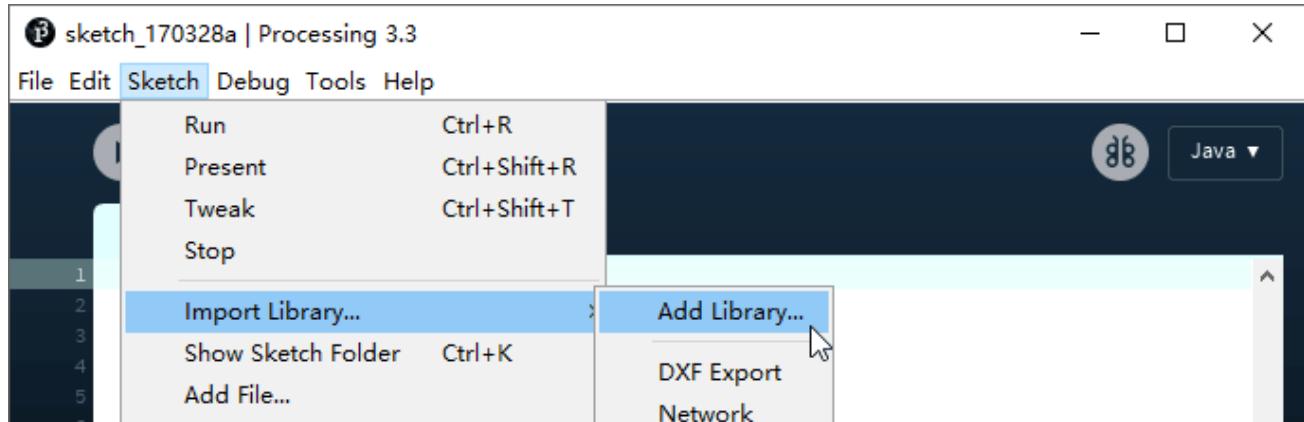
The screenshot shows the official Processing website. At the top, there's a navigation bar with links for 'Processing', 'p5.js', 'Processing.py', 'Processing for Android', 'Processing for Pi', and 'Processing Foundation'. Below the navigation bar is a large banner with the word 'Processing' and a geometric background. To the right of the banner is a search bar. On the left side of the main content area, there's a sidebar with links for '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.' It shows a large 'P' logo with a geometric pattern. Below the logo, it says '3.5.4 (17 January 2020)' and provides download links for 'Windows 64-bit', 'Windows 32-bit', 'Linux 64-bit', and 'Mac OS X'. Under the 'Tutorials' section, there are links to '» Github', '» Report Bugs', '» Wiki', '» Supported Platforms', and a note about changes in 3.0.

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

	<b>core</b>	2020/1/17 12:16
	<b>java</b>	2020/1/17 12:17
	<b>lib</b>	2020/1/17 12:16
	<b>modes</b>	2020/1/17 12:16
	<b>tools</b>	2020/1/17 12:16
	<b>processing.exe</b>	2020/1/17 12:16
	<b>processing-java.exe</b>	2020/1/17 12:16
	<b>revisions.txt</b>	2020/1/17 12:16

Use Server mode for communication

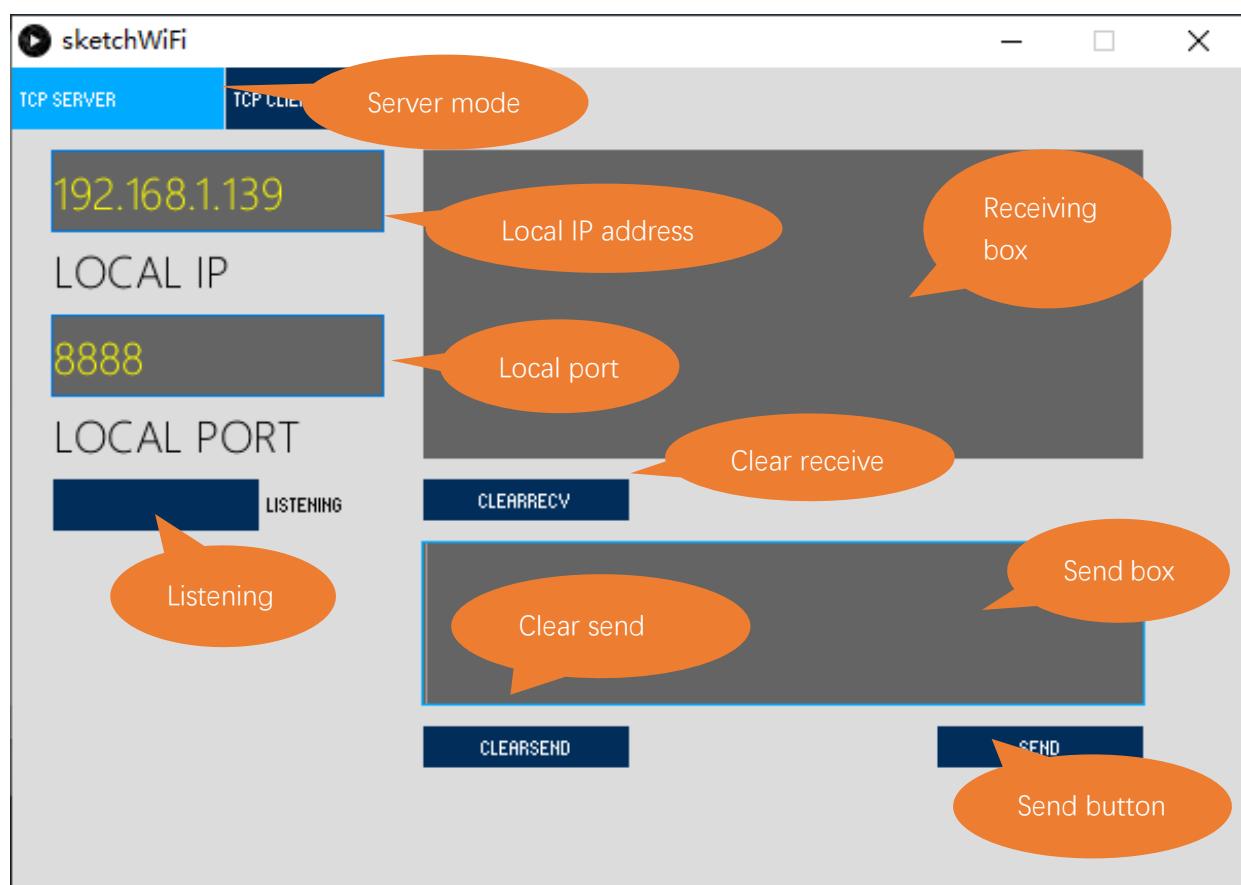
Install ControlP5.



Open the “**Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32\_S3\Sketches\Sketches\Sketch\_31.1\_WiFiClient\sketchWiFi\sketchWiFi.pde**”, and click “Run”.

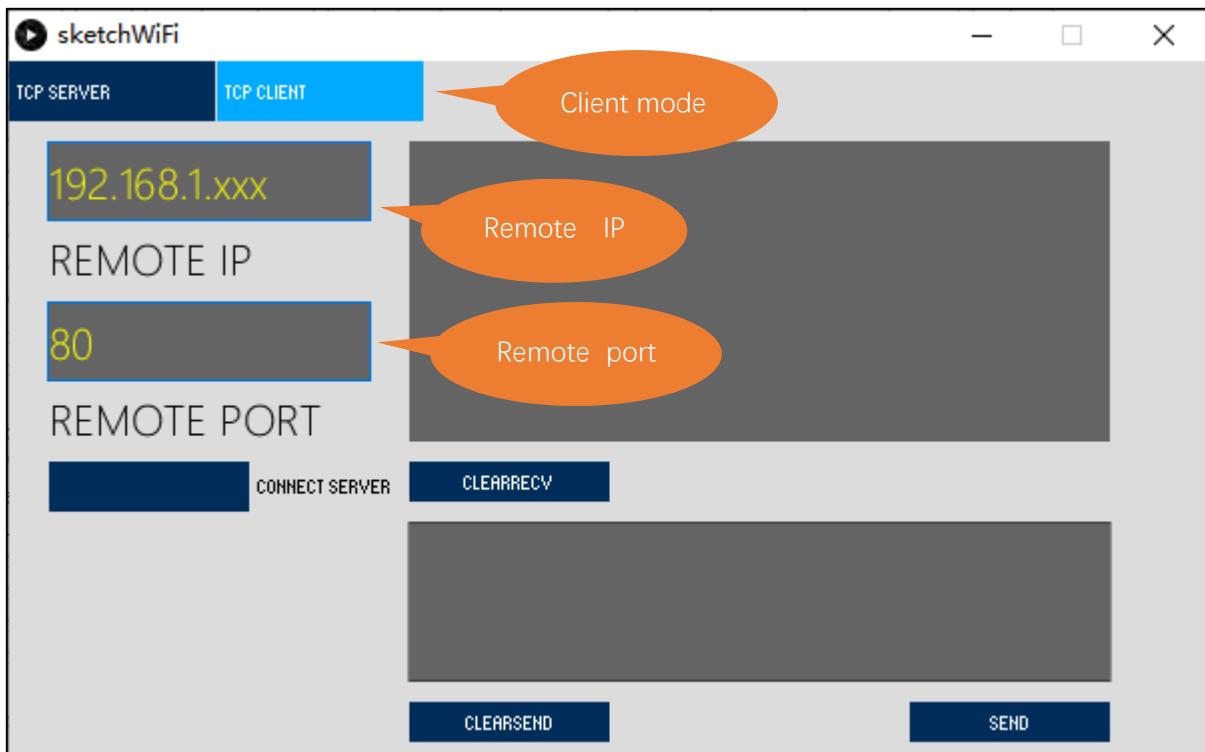


The new pop-up interface is as follows. If ESP32-S3 is used as client, select TCP SERVER mode for sketchWiFi.



When sketchWiFi selects TCP SERVER mode, ESP32-S3 Sketch needs to be changed according to sketchWiFi's displaying of LOCAL IP or LOCAL PORT.

If ESP32-S3 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, 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.

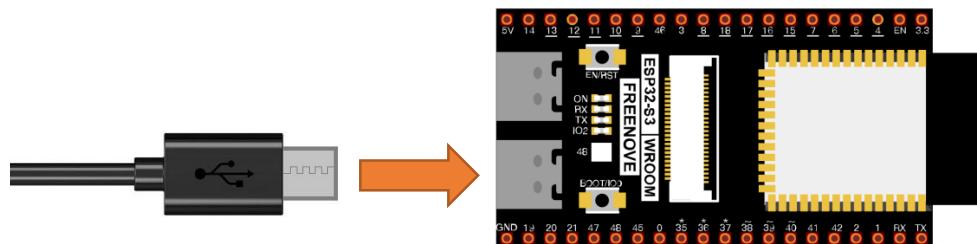
**clear receive:** clear out the content in the receiving text box

**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.

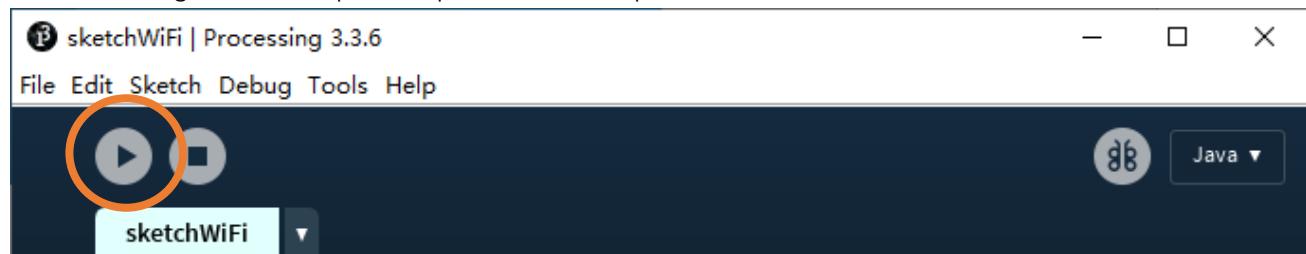
## Circuit

Connect Freenove ESP32-S3 to the computer using the USB cable.

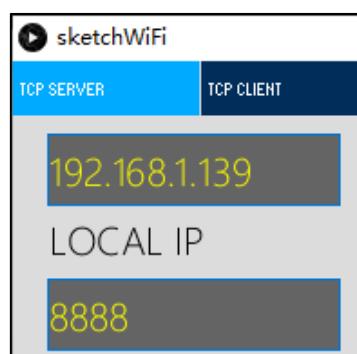


## Sketch

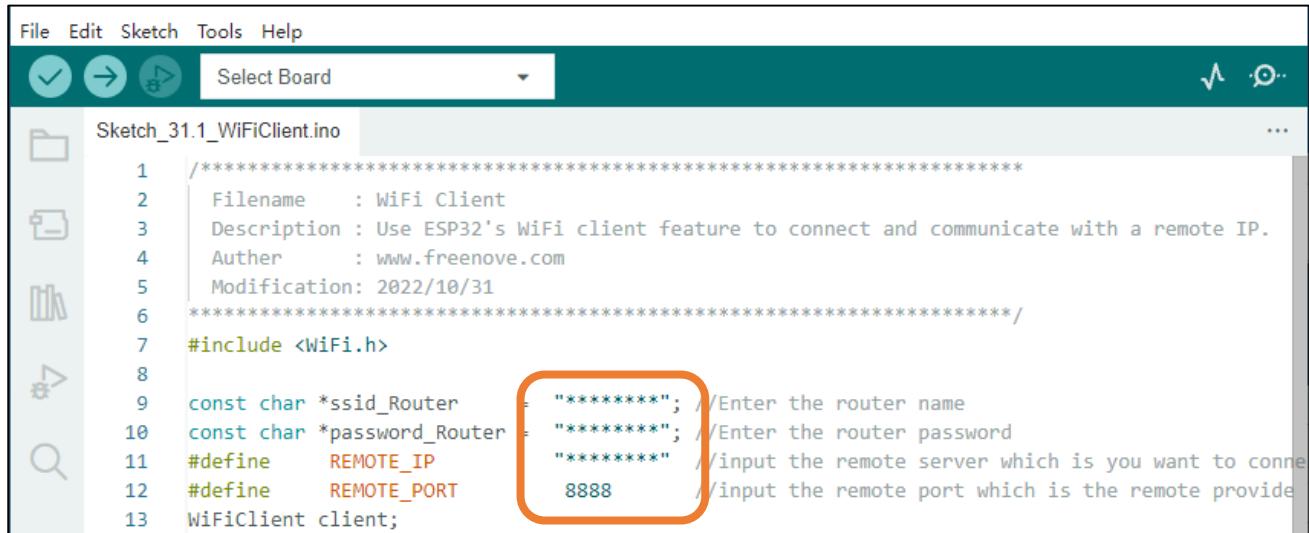
Before running the Sketch, please open “sketchWiFi.pde.” first, and click “Run”.



The newly pop up window will use the computer's IP address by default and open a data monitor port.



Next, open Sketch\_31.1\_WiFiClient.ino. Before running it, please change the following information based on "LOCAL IP" and "LOCAL PORT" in the figure above.



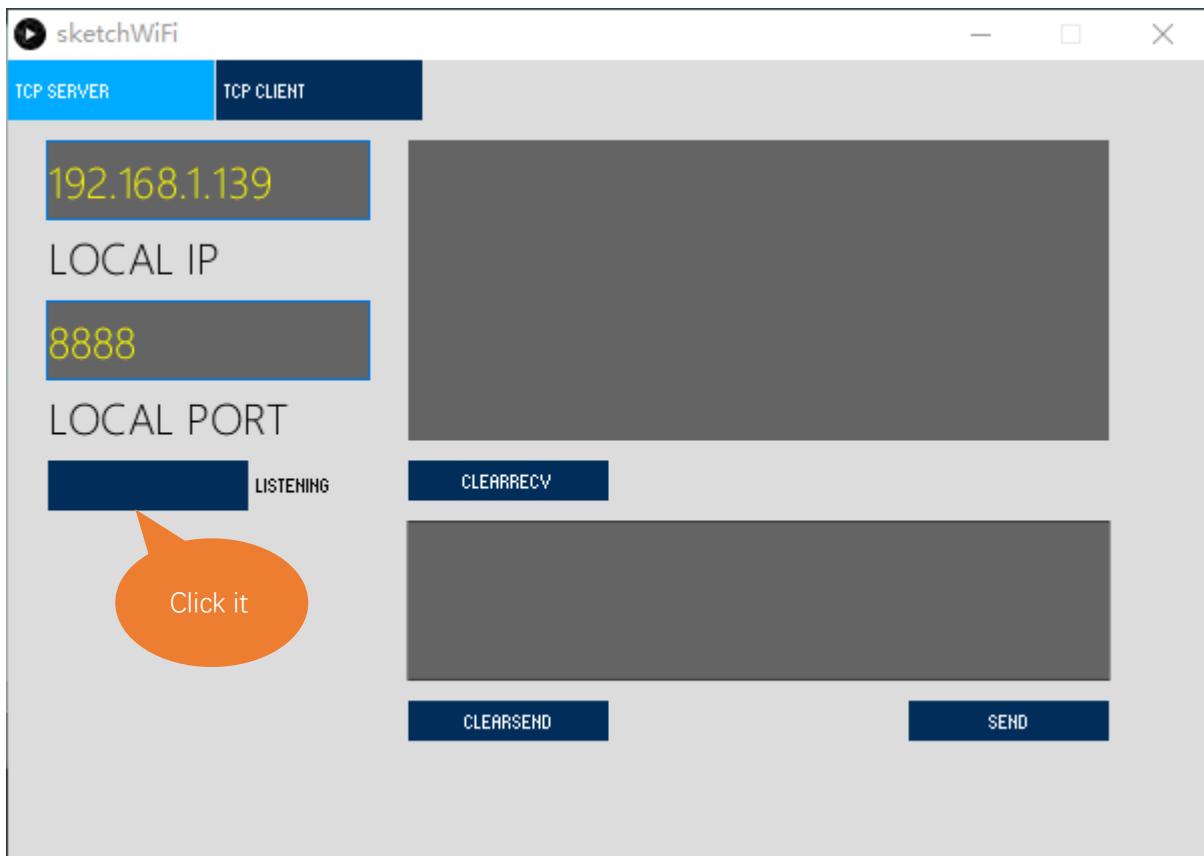
```

File Edit Sketch Tools Help
Select Board ...
Sketch_31.1_WiFiClient.ino ...
1 //*****
2   Filename    : WiFi Client
3   Description : Use ESP32's WiFi client feature to connect and communicate with a remote IP.
4   Author     : www.freenove.com
5   Modification: 2022/10/31
6 *****/
7 #include <WiFi.h>
8
9 const char *ssid_Router = "*****"; //Enter the router name
10 const char *password_Router = "*****"; //Enter the router password
11 #define REMOTE_IP "*****" //input the remote server which is you want to connect
12 #define REMOTE_PORT 8888 //input the remote port which is the remote provider
13 WiFiClient client;

```

REMOTE\_IP needs to be filled in according to the interface of sketchWiFi.pde. Taking this tutorial as an example, its REMOTE\_IP is “192.168.1.133”. Generally, by default, the ports do not need to change its value.

Click LISTENING, turn on TCP SERVER's data listening function and wait for ESP32-S3 to connect.

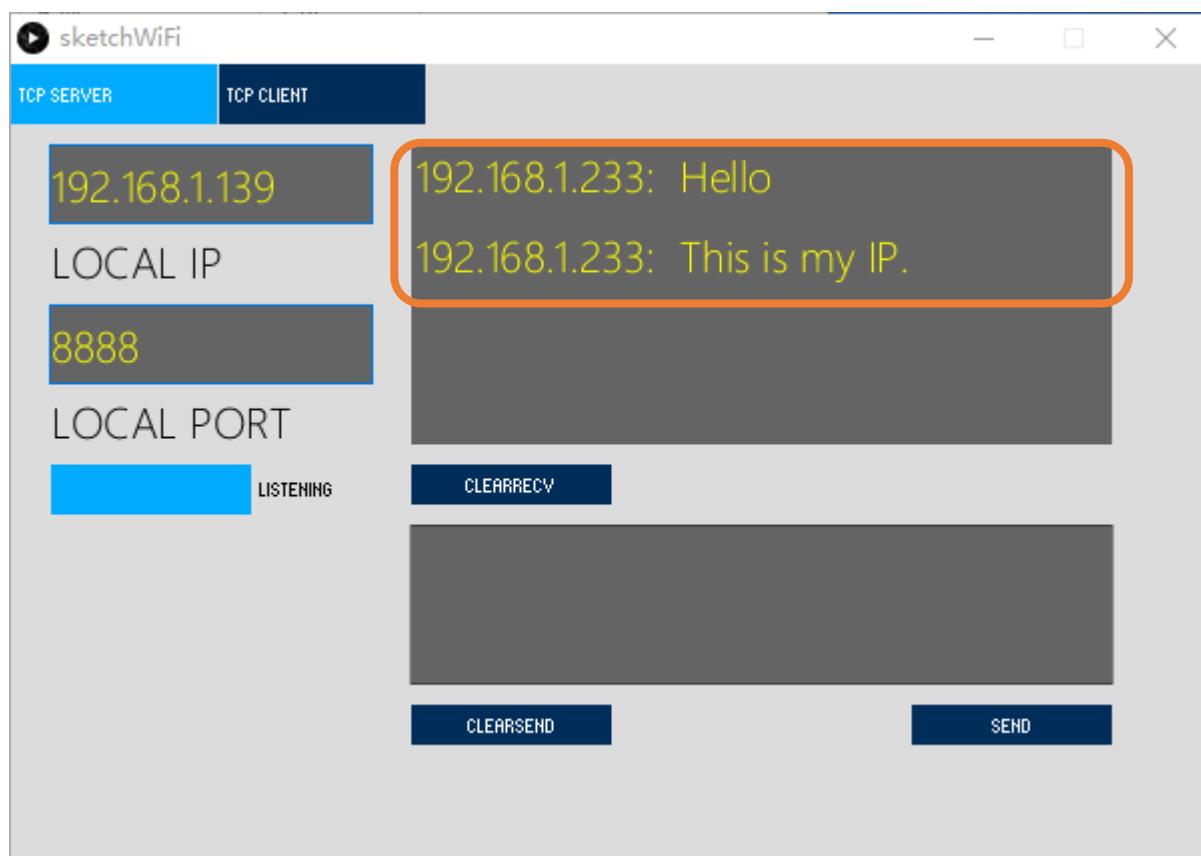


Compile and upload code to ESP32-S3 WROOM, open the serial monitor and set the baud rate to 115200. ESP32-S3 connects router, obtains IP address and sends access request to server IP address on the same LAN till the connection is successful. When connect successfully, ESP32-S3 can send messages to server.

```
Output Serial Monitor X
Message (Ctrl + Enter to send message to 'ESP32S3 Dev Module' on 'COM3') New Line 115200 baud
192.168.1.233
Connecting to 192.168.1.139
Connected
ESP-ROM: esp32s3-20210327
Build: Mar 27 2021
rst:0x1 (POWERON), boot:0x8 (SPI_FAST_FLASH_BOOT)
SPIWP:0xee
mode:DIO, clock div:1
load:0x3fce3808, len:0x43c
load:0x403c9700, len:0xbec
load:0x403cc700, len:0x2a3c
entry 0x403c98d8

Waiting for WiFi... ...
WiFi connected
IP address:
192.168.1.233
Connecting to 192.168.1.139
Connected
Ln 11, Col 46 UTF-8 ESP32S3 Dev Module on COM3 3
```

ESP32-S3 connects with TCP SERVER, and TCP SERVER receives messages from ESP32-S3, as shown in the figure below.



### Sketch\_31.1\_As Client

The following is the program code:

```
1 #include <WiFi.h>
2
3 const char *ssid_Router      = "*****"; //Enter the router name
4 const char *password_Router = "*****"; //Enter the router password
5 #define    REMOTE_IP        "*****" //input the remote server which is you want to connect
6 #define    REMOTE_PORT       8888     //input the remote port which is the remote provide
7 WiFiClient client;
8
9 void setup() {
10   Serial.begin(115200);
11   delay(10);
12
13   WiFi.begin(ssid_Router, password_Router);
14   Serial.print("\nWaiting for WiFi... ");
15   while (WiFi.status() != WL_CONNECTED) {
16     Serial.print(".");
17     delay(500);
18   }
19   Serial.println("");
20   Serial.println("WiFi connected");
21   Serial.println("IP address: ");
22   Serial.println(WiFi.localIP());
23   delay(500);
24
25   Serial.print("Connecting to ");
26   Serial.println(REMOTE_IP);
27
28   while (!client.connect(REMOTE_IP, REMOTE_PORT)) {
29     Serial.println("Connection failed.");
30     Serial.println("Waiting a moment before retrying... ");
31   }
32   Serial.println("Connected");
33   client.print("Hello\n");
34   client.print("This is my IP.\n");
35
36 void loop() {
37   if (client.available() > 0) {
38     delay(20);
39     //read back one line from the server
40     String line = client.readString();
41     Serial.println(REMOTE_IP + String(":") + line);
```

```

42 }
43 if (Serial.available() > 0) {
44     delay(20);
45     String line = Serial.readString();
46     client.print(line);
47 }
48 if (client.connected () == 0) {
49     client.stop();
50     WiFi.disconnect();
51 }
52 }
```

Add WiFi function header file.

```
1 #include <WiFi.h>
```

Enter the actual router name, password, remote server IP address, and port number.

```

3 const char *ssid_Router      = "*****"; //Enter the router name
4 const char *password_Router = "*****"; //Enter the router password
5 #define    REMOTE_IP        "*****"   //input the remote server which is you want to connect
6 #define    REMOTE_PORT       8888      //input the remote port which is the remote provide
```

Apply for the method class of WiFiClient.

```
7 WiFiClient client;
```

Connect specified WiFi until it is successful. If the name and password of WiFi are correct but it still fails to connect, please push the reset key.

```

13 WiFi.begin(ssid_Router, password_Router);
14 Serial.print("\nWaiting for WiFi... ");
15 while (WiFi.status() != WL_CONNECTED) {
16     Serial.print(".");
17     delay(500);
18 }
```

Send connection request to remote server until connect successfully. When connect successfully, print out the connecting prompt on the serial monitor and send messages to remote server.

```

28 while (!client.connect(REMOTE_IP, REMOTE_PORT)) { //Connect to Server
29     Serial.println("Connection failed.");
30     Serial.println("Waiting a moment before retrying... ");
31 }
32 Serial.println("Connected");
33 client.print("Hello\n");
```

When ESP32-S3 receive messages from servers, it will print them out via serial port; Users can also send messages to servers from serial port.

```

37 if (client.available() > 0) {
38     delay(20);
39     //read back one line from the server
40     String line = client.readString();
41     Serial.println(REMOTE_IP + String(":") + line);
42 }
```

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

```
43  if (Serial.available() > 0) {  
44      delay(20);  
45      String line = Serial.readString();  
46      client.print(line);  
47  }
```

If the server is disconnected, turn off WiFi of ESP32-S3.

```
48  if (client.connected () == false) {  
49      client.stop();  
50      WiFi.disconnect();  
51  }
```

#### Reference

##### Class Client

Every time when using Client, you need to include header file "WiFi.h."

**connect(ip, port, timeout)/connect(\*host, port, timeout)**: establish a TCP connection.

**ip, \*host**: ip address of target server

**port**: port number of target server

**timeout**: connection timeout

**connected()**: judge whether client is connecting. If return value is 1, then connect successfully; If return value is 0, then fail to connect.

**stop()**: stop tcp connection

**print()**: send data to server connecting to client

**available()**: return to the number of bytes readable in receive buffer, if no, return to 0 or -1.

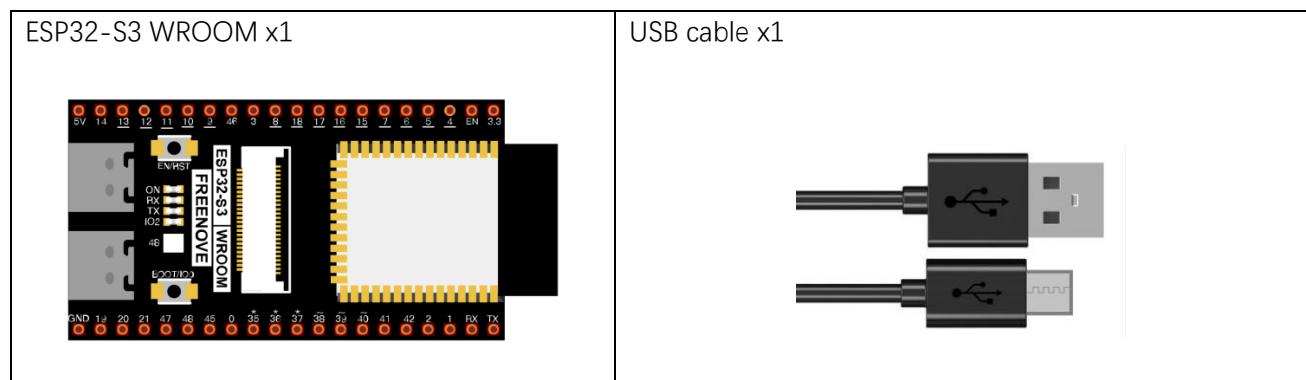
**read()**: read one byte of data in receive buffer

**readString()**: read string in receive buffer

## Project 31.2 As Server

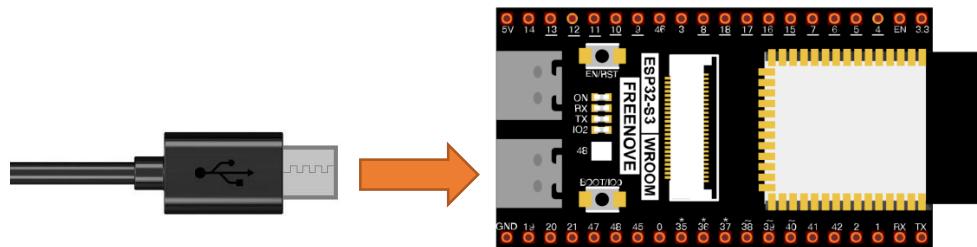
In this section, ESP32-S3 is used as a server to wait for the connection and communication of client on the same LAN.

### Component List



### Circuit

Connect Freenove ESP32-S3 to the computer using a USB cable.





## Sketch

Before running Sketch, please modify the contents of the box below first.

[Sketch\\_31.2\\_As\\_Server](#)

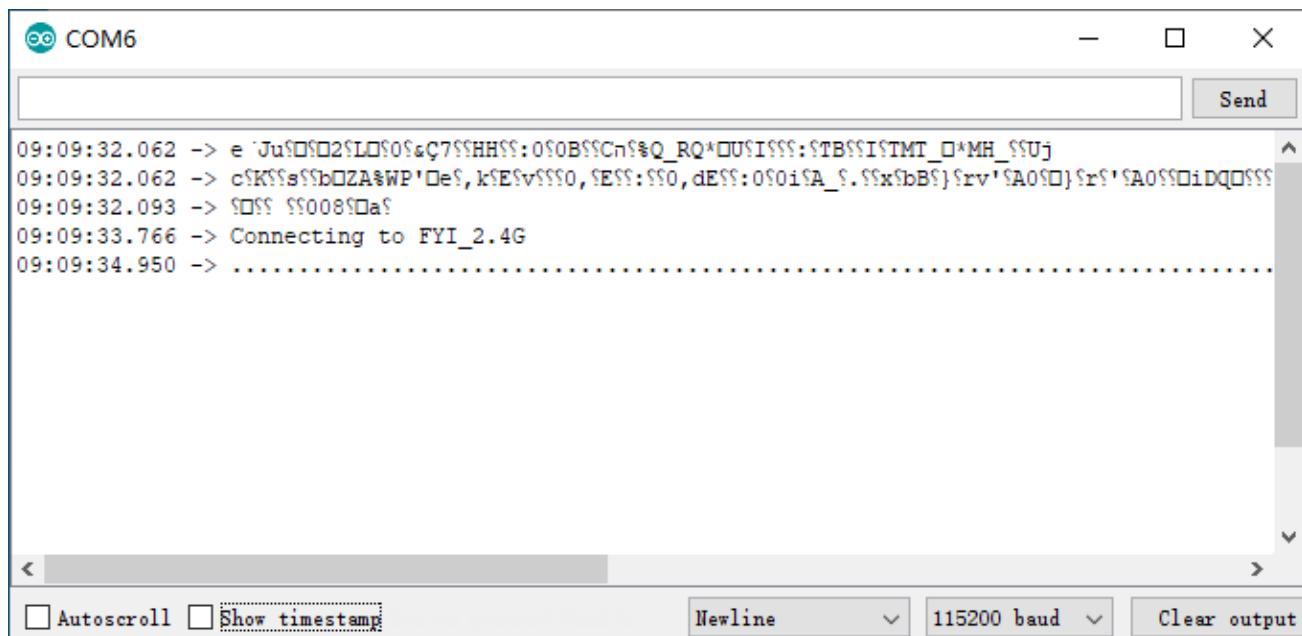
```

8 #include <WiFi.h>
9
10 #define port 80
11 const char *ssid_Router
12 const char *password_Router
13 WiFiServer server(port);
14
15 void setup()
16 {
17     Serial.begin(115200);
18     Serial.printf("\nConnecting to ");
19     Serial.println(ssid_Router);
20     WiFi.disconnect();
21     WiFi.begin(ssid_Router, password_Router);

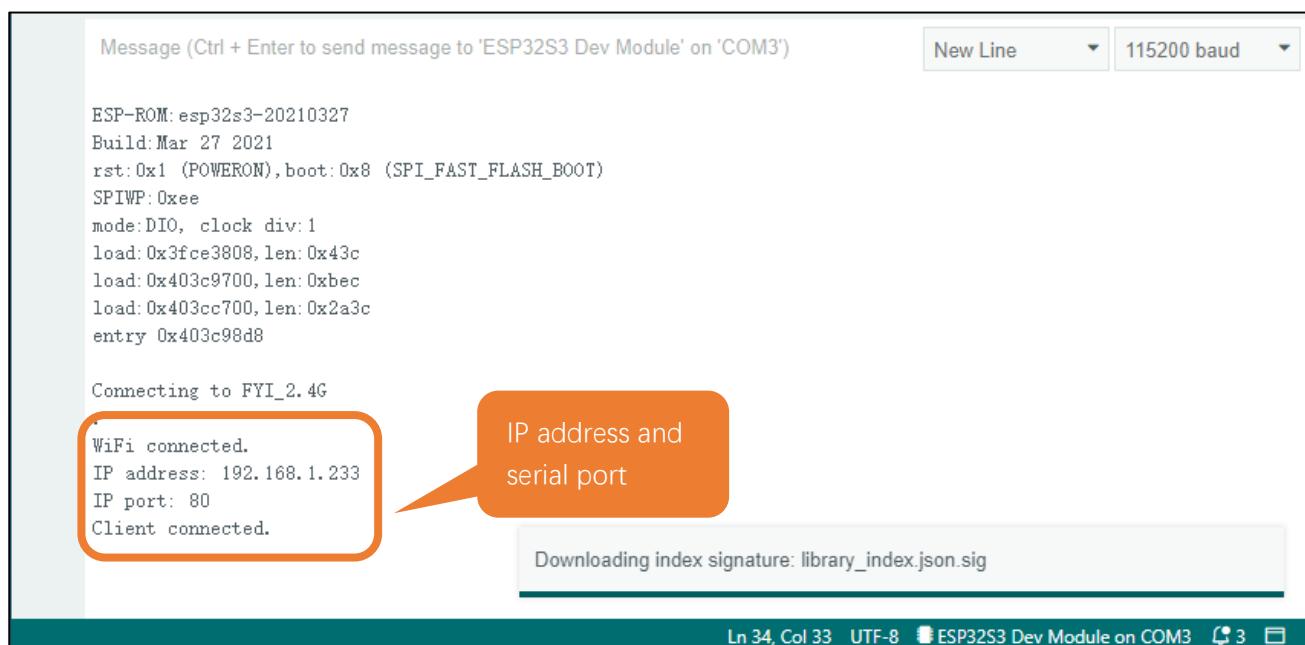
```

Compile and upload code to ESP32-S3 WROOM board, open the serial monitor and set the baud rate to 115200. Turn on server mode for ESP32-S3, waiting for the connection of other devices on the same LAN. Once a device connects to server successfully, they can send messages to each other.

If the ESP32-S3 fails to connect to router, press the reset button as shown below and wait for ESP32-S3 to run again.



## Serial Monitor



The screenshot shows the Serial Monitor interface. At the top, it says "Message (Ctrl + Enter to send message to 'ESP32S3 Dev Module' on 'COM3')". Below that, the ESP32 boot logs are displayed:

```
ESP-ROM: esp32s3-20210327
Build: Mar 27 2021
rst:0x1 (POWERON), boot:0x8 (SPI_FAST_FLASH_BOOT)
SPIWP:0xee
mode:DIO, clock div:1
load:0x3fce3808, len:0x43c
load:0x403c9700, len:0xbec
load:0x403cc700, len:0x2a3c
entry 0x403c98d8

Connecting to FYI_2.4G
```

Below the logs, a message box contains the following text:

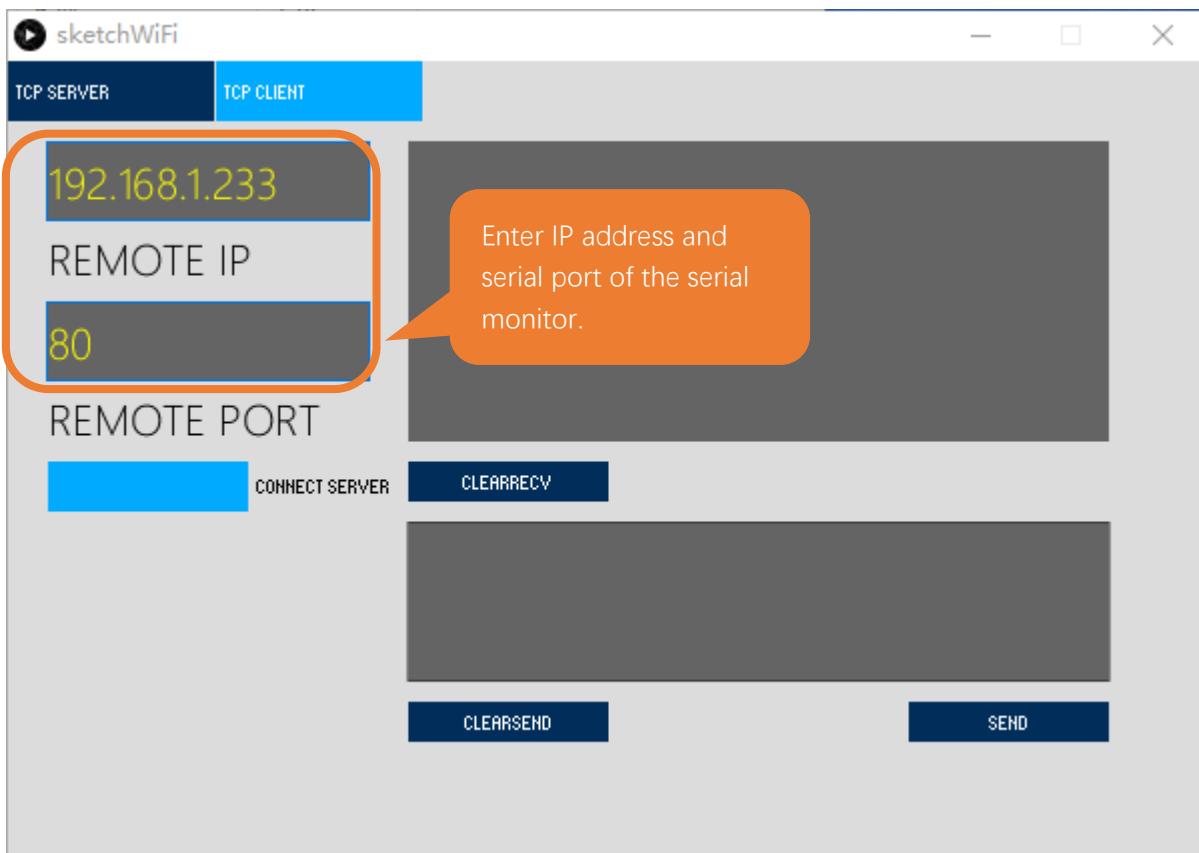
```
WiFi connected.
IP address: 192.168.1.233
IP port: 80
Client connected.
```

An orange callout bubble points from this message box to the text "IP address and serial port". To the right of the message box, another callout bubble points to the text "Downloading index signature: library\_index.json.sig". At the bottom of the monitor, the status bar shows "Ln 34, Col 33 UTF-8" and "ESP32S3 Dev Module on COM3".

Processing:

Open the “[Freenove\\_Ultimate\\_Starter\\_Kit\\_for\\_ESP32\\_S3\Sketches\Sketches\Sketch\\_31.2\\_WiFiServer\sketchWiFi\sketchWiFi.pde](#)”.

Based on the messages printed by the serial monitor, enter correct IP address and serial port in Processing to establish connection and make communication.



The following is the program code:

```
1 #include <WiFi.h>
2
3 #define port 80
4 const char *ssid_Router      = "*****"; //input your wifi name
5 const char *password_Router  = "*****"; //input your wifi passwords
6 WiFiServer server(port);
7
8 void setup()
9 {
10     Serial.begin(115200);
11     Serial.printf("\nConnecting to ");
12     Serial.println(ssid_Router);
13     WiFi.disconnect();
14     WiFi.begin(ssid_Router, password_Router);
15     delay(1000);
16     while (WiFi.status() != WL_CONNECTED) {
17         delay(500);
18         Serial.print(".");
19     }
20     Serial.println("");
21     Serial.println("WiFi connected.");
22     Serial.print("IP address: ");
23     Serial.println(WiFi.localIP());
24     Serial.printf("IP port: %d\n", port);
25     server.begin(port);
26     WiFi.setAutoReconnect(true);
27 }
28
29 void loop() {
30     WiFiClient client = server.accept();           // listen for incoming clients
31     if (client) {                                // if you get a client
32         Serial.println("Client connected.");
33         while (client.connected()) {              // loop while the client's connected
34             if (client.available()) {            // if there's bytes to read from the
35                 Serial.println(client.readStringUntil('\n'));// print it out the serial monitor
36                 while (client.read() > 0);          // clear the wifi receive area cache
37             }
38             if (Serial.available()) {            // if there's bytes to read from the
39                 client.print(Serial.readStringUntil('\n'));// print it out the client.
40                 while (Serial.read() > 0);          // clear the wifi receive area cache
41             }
42 }
```

```

42     }
43     client.stop();           // stop the client connecting.
44     Serial.println("Client Disconnected.");
45   }
46 }
```

Apply for method class of WiFiServer.

```
6 WiFiServer server(port);      //Apply for a Server object whose port number is 80
```

Connect specified WiFi until it is successful. If the name and password of WiFi are correct but it still fails to connect, please push the reset key.

```

13 WiFi.disconnect();
14 WiFi.begin(ssid_Router, password_Router);
15 delay(1000);
16 while (WiFi.status() != WL_CONNECTED) {
17     delay(500);
18     Serial.print(".");
19 }
20 Serial.println("");
21 Serial.println("WiFi connected.");
```

Print out the IP address and port number of ESP32-S3.

```
22 Serial.print("IP address: ");
23 Serial.println(WiFi.localIP());          //print out IP address of ESP32-S3
24 Serial.printf("IP port: %d\n",port);    //Print out ESP32-S3's port number
```

Turn on server mode of ESP32-S3, turn on automatic reconnection.

```
25 server.begin();                  //Turn ON ESP32-S3 as Server mode
26 WiFi.setAutoReconnect(true);
```

When ESP32-S3 receive messages from servers, it will print them out via serial port; Users can also send messages to servers from serial port.

```

34 if (client.available()) {           // if there's bytes to read from the
client
35   Serial.println(client.readStringUntil('\n')); // print it out the serial monitor
36   while(client.read()>0);                   // clear the wifi receive area cache
37 }
38 if(Serial.available()){            // if there's bytes to read from the
serial monitor
39   client.print(Serial.readStringUntil('\n')); // print it out the client.
40   while(Serial.read()>0);                  // clear the wifi receive area cache
41 }
```



## Reference

## Class Server

Every time use Server functionality, we need to include header file "WiFi.h".

**WiFiServer(uint16\_t port=80, uint8\_t max\_clients=4)**: create a TCP Server.

**port**: ports of Server; range from 0 to 65535 with the default number as 80.

**max\_clients**: maximum number of clients with default number as 4.

**begin(port)**: start the TCP Server.

**port**: ports of Server; range from 0 to 65535 with the default number as 0.

**setNoDelay(bool nodelay)**: whether to turn off the delay sending functionality.

**nodelay**: true stands for forbidden Nagle algorithm.

**close()**: close tcp connection.

**stop()**: stop tcp connection.

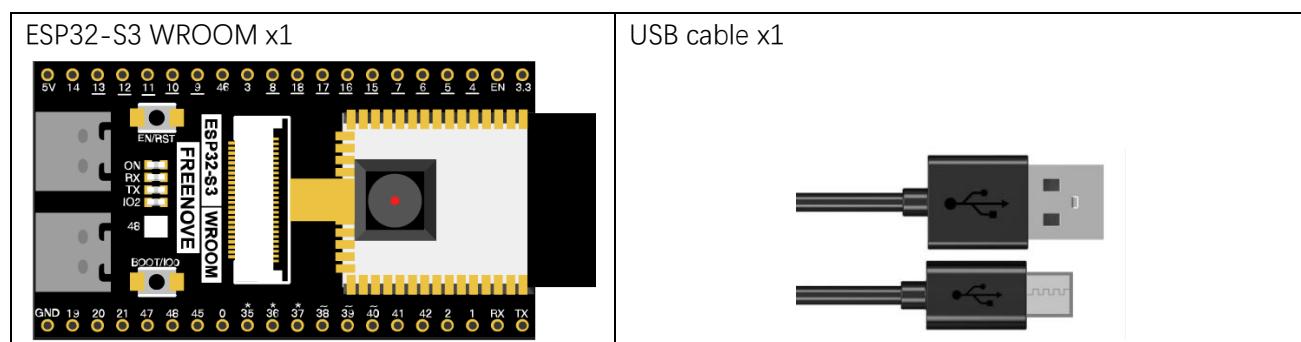
# Chapter 32 Camera Web Server

In this section, we'll use ESP32-S3's video function as an example to study.

## Project 32.1 Camera Web Server

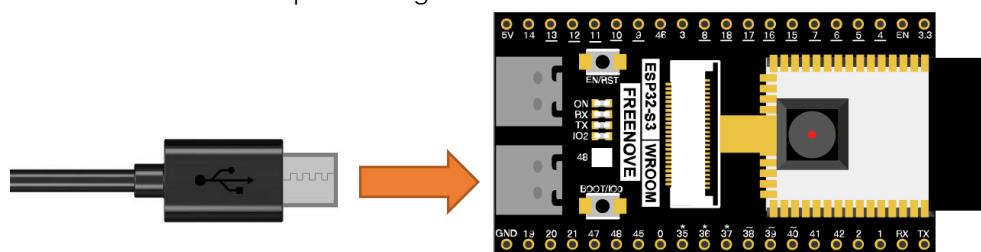
Connect ESP32-S3 using USB and check its IP address through serial monitor. Use web page to access IP address to obtain video and image data.

### Component List



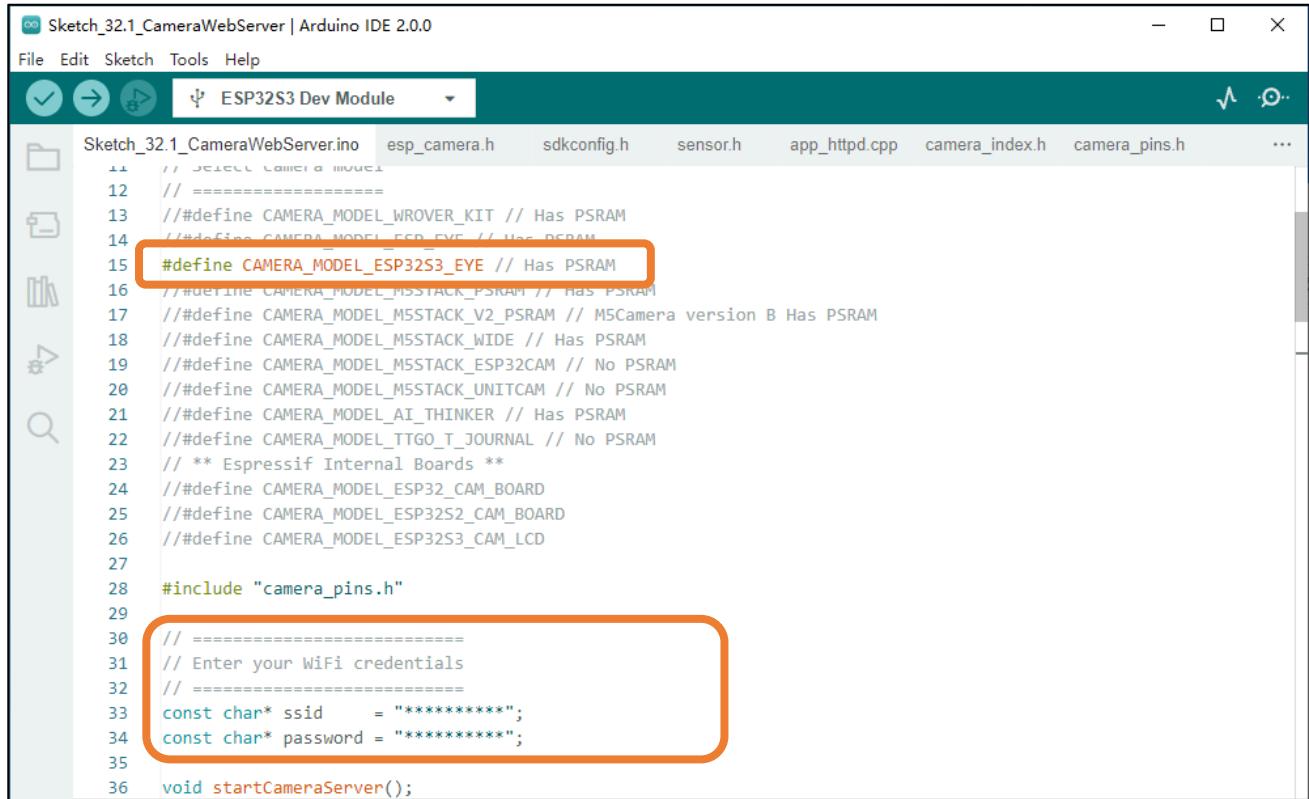
### Circuit

Connect Freenove ESP32-S3 to the computer using the USB cable.



## Sketch

### Sketch\_32.1\_As\_CameraWebServer



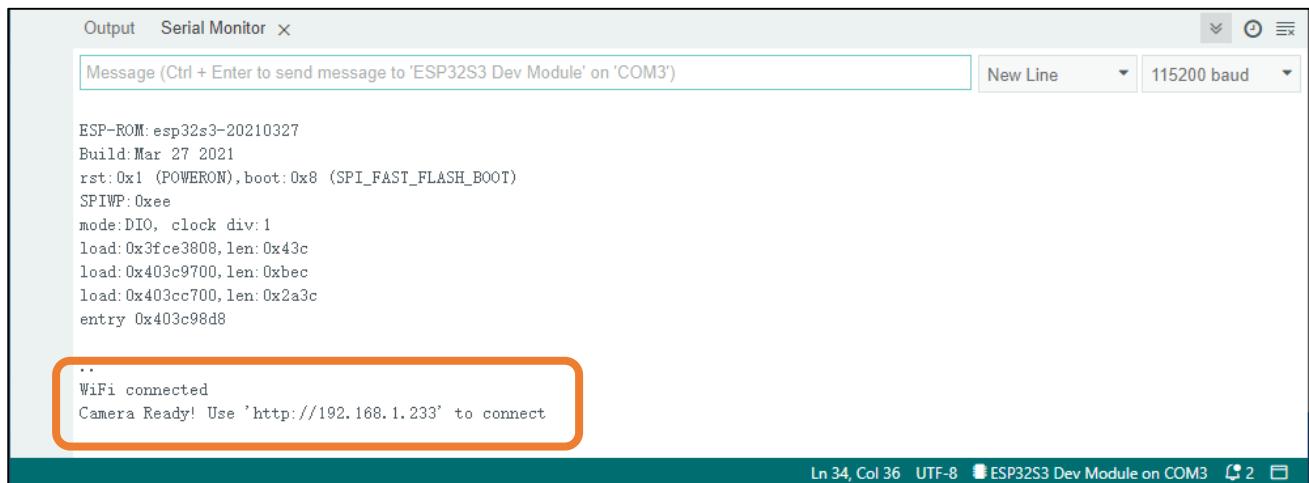
```

Sketch_32.1_CameraWebServer | Arduino IDE 2.0.0
File Edit Sketch Tools Help
ESP32S3 Dev Module
Sketch_32.1_CameraWebServer.ino esp_camera.h sdkconfig.h sensor.h app_httpd.cpp camera_index.h camera_pins.h ...
1 // =====
2 // =====
3 //define CAMERA_MODEL_WROVER_KIT // Has PSRAM
4 //define CAMERA_MODEL_ESP_EYE // Has PSRAM
5 #define CAMERA_MODEL_ESP32S3_EYE // Has PSRAM
6 //define CAMERA_MODEL_M5STACK_PSRAM // Has PSRAM
7 //define CAMERA_MODEL_M5STACK_V2_PSRAM // M5Camera version B Has PSRAM
8 //define CAMERA_MODEL_M5STACK_WIDE // Has PSRAM
9 //define CAMERA_MODEL_M5STACK_ESP32CAM // No PSRAM
10 //define CAMERA_MODEL_M5STACK_UNITCAM // No PSRAM
11 //define CAMERA_MODEL_AI_THINKER // Has PSRAM
12 //define CAMERA_MODEL_TTGO_T_JOURNAL // No PSRAM
13 // ** Espressif Internal Boards **
14 //define CAMERA_MODEL_ESP32_CAM_BOARD
15 //define CAMERA_MODEL_ESP32S2_CAM_BOARD
16 //define CAMERA_MODEL_ESP32S3_CAM_LCD
17
18 #include "camera_pins.h"
19
20 // =====
21 // Enter your WiFi credentials
22 // =====
23 const char* ssid      = "*****";
24 const char* password = "*****";
25
26 void startCameraServer();
27
28
29
30
31
32
33
34
35
36

```

Before running the program, please modify your router's name and password in the box shown in the illustration above to make sure that your Sketch can compile and work successfully.

Compile and upload codes to ESP32-S3, open the serial monitor and set the baud rate to 115200, and the serial monitor will print out a network link address.



```

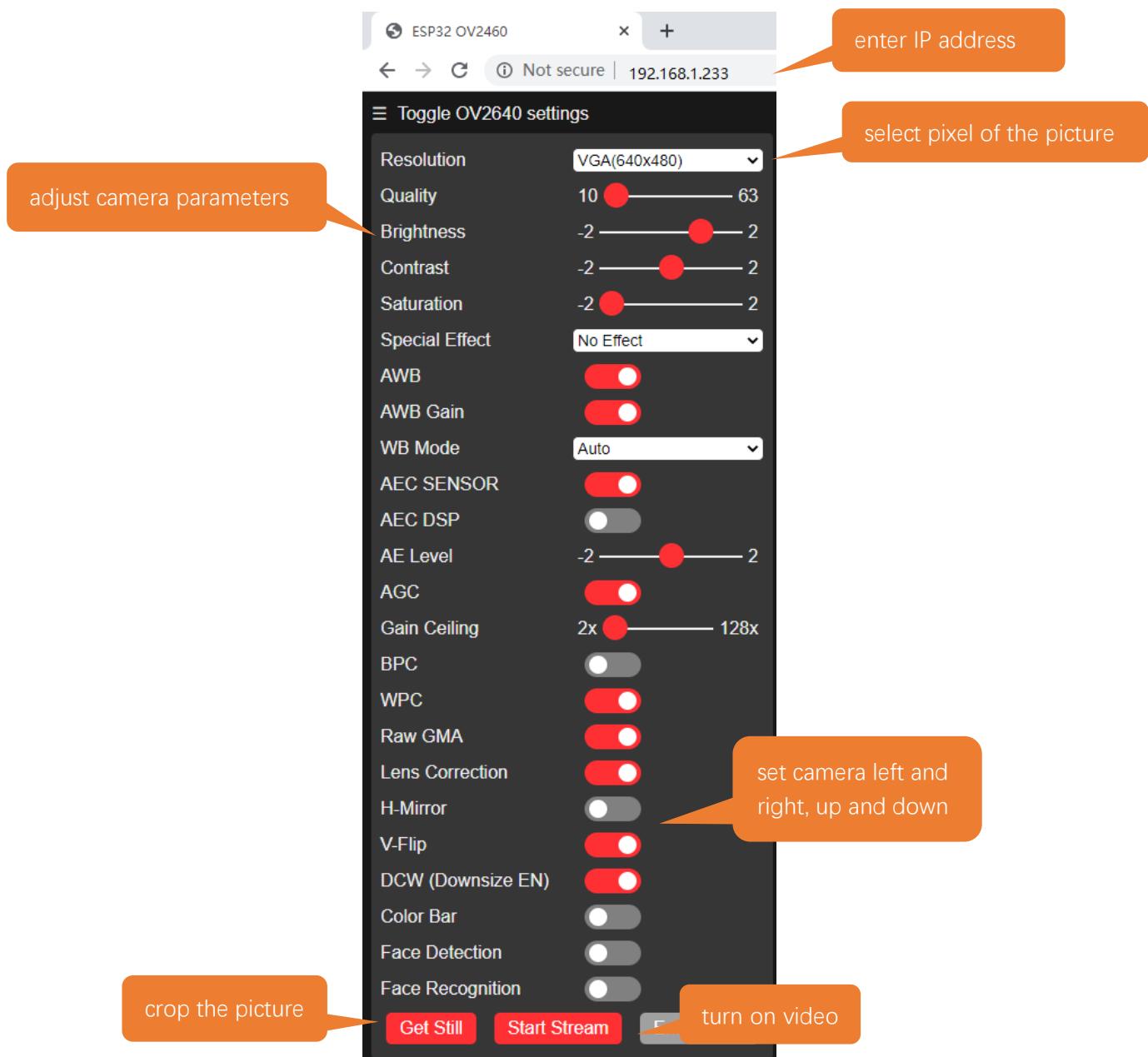
Output Serial Monitor ×
Message (Ctrl + Enter to send message to 'ESP32S3 Dev Module' on 'COM3') New Line 115200 baud
ESP-ROM: esp32s3-20210327
Build: Mar 27 2021
rst: 0x1 (POWERON), boot: 0x8 (SPI_FAST_FLASH_BOOT)
SPIWP: 0xee
mode:DIO, clock div: 1
load: 0x3fce3808, len: 0x43c
load: 0x403c9700, len: 0xbec
load: 0x403cc700, len: 0x2a3c
entry 0x403c98d8

..
WiFi connected
Camera Ready! Use 'http://192.168.1.233' to connect

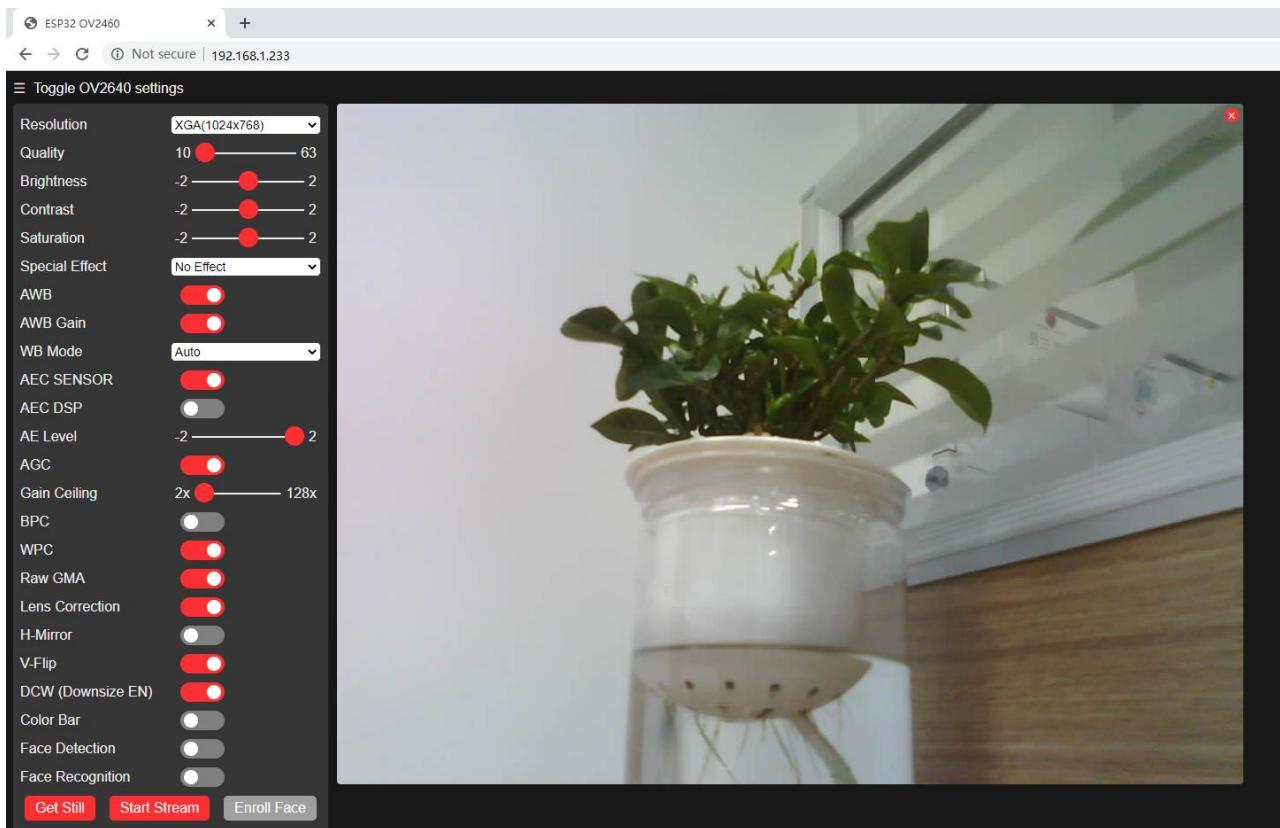
```

If your ESP32-S3 has been in the process of connecting to router, but the information above has not been printed out, please re-check whether the router name and password have been entered correctly and press the reset key on ESP32-S3 WROOM to wait for a successful connection prompt.

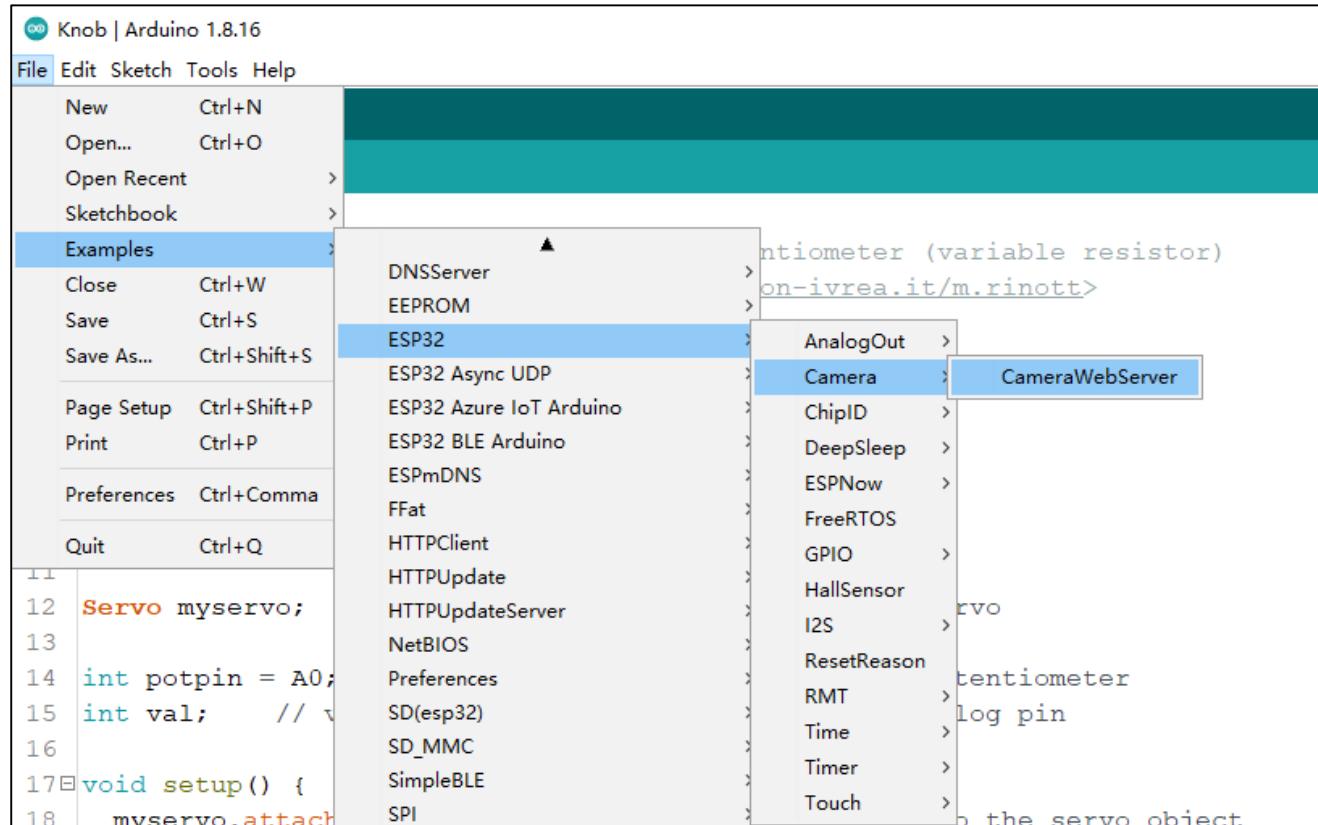
Open a web browser, enter the IP address printed by the serial monitor in the address bar, and access it. Taking the Google browser as an example, here's what the browser prints out after successful access to ESP32-S3's IP.



Click on Start Stream. The effect is shown in the image below.



Note: If sketch compilation fails due to ESP32-S3 support package, follow the steps of the image to open the CameraWebServer. This sketch is the same as described in the tutorial above.



The following is the main program code. You need include other code files in the same folder when write your own code.

```
1 #include "esp_camera.h"
2 #include <WiFi.h>
3
4 // =====
5 // Select camera model
6 // =====
7 //#define CAMERA_MODEL_WROVER_KIT // Has PSRAM
8 //#define CAMERA_MODEL_ESP_EYE // Has PSRAM
9 #define CAMERA_MODEL_ESP32S3_EYE // Has PSRAM
10 //#define CAMERA_MODEL_M5STACK_PSRAM // Has PSRAM
11 //#define CAMERA_MODEL_M5STACK_V2_PSRAM // M5Camera version B Has PSRAM
12 //#define CAMERA_MODEL_M5STACK_WIDE // Has PSRAM
13 //#define CAMERA_MODEL_M5STACK_ESP32CAM // No PSRAM
14 //#define CAMERA_MODEL_M5STACK_UNITCAM // No PSRAM
15 //#define CAMERA_MODEL_AI_THINKER // Has PSRAM
16 //#define CAMERA_MODEL_TTGO_T_JOURNAL // No PSRAM
17 // ** Espressif Internal Boards **
18 //#define CAMERA_MODEL_ESP32_CAM_BOARD
19 //#define CAMERA_MODEL_ESP32S2_CAM_BOARD
20 //#define CAMERA_MODEL_ESP32S3_CAM_LCD
21
22 #include "camera_pins.h"
23
24 // =====
25 // Enter your WiFi credentials
26 // =====
27 const char* ssid      = "*****";
28 const char* password = "*****";
29
30 void startCameraServer();
31
32 void setup() {
33     Serial.begin(115200);
34     Serial.setDebugOutput(true);
35     Serial.println();
36
37     camera_config_t config;
38     config.ledc_channel = LEDC_CHANNEL_0;
39     config.ledc_timer = LEDC_TIMER_0;
40     config.pin_d0 = Y2_GPIO_NUM;
41     config.pin_d1 = Y3_GPIO_NUM;
42     config.pin_d2 = Y4_GPIO_NUM;
```



```

43 config.pin_d3 = Y5_GPIO_NUM;
44 config.pin_d4 = Y6_GPIO_NUM;
45 config.pin_d5 = Y7_GPIO_NUM;
46 config.pin_d6 = Y8_GPIO_NUM;
47 config.pin_d7 = Y9_GPIO_NUM;
48 config.pin_xclk = XCLK_GPIO_NUM;
49 config.pin_pclk = PCLK_GPIO_NUM;
50 config.pin_vsync = VSYNC_GPIO_NUM;
51 config.pin_href = HREF_GPIO_NUM;
52 config.pin_sccb_sda = SIOD_GPIO_NUM;
53 config.pin_sccb_scl = SIOC_GPIO_NUM;
54 config.pin_pwdn = PWDN_GPIO_NUM;
55 config.pin_reset = RESET_GPIO_NUM;
56 config.xclk_freq_hz = 2000000;
57 config.frame_size = FRAMESIZE_UXGA;
58 config.pixel_format = PIXFORMAT_JPEG; // for streaming
59 config.grab_mode = CAMERA_GRAB_WHEN_EMPTY;
60 config.fb_location = CAMERA_FB_IN_PSRAM;
61 config.jpeg_quality = 12;
62 config.fb_count = 1;
63
64 // if PSRAM IC present, init with UXGA resolution and higher JPEG quality
65 // for larger pre-allocated frame buffer.
66 if(psramFound()){
67     config.jpeg_quality = 10;
68     config.fb_count = 2;
69     config.grab_mode = CAMERA_GRAB_LATEST;
70 } else {
71     // Limit the frame size when PSRAM is not available
72     config.frame_size = FRAMESIZE_SVGA;
73     config.fb_location = CAMERA_FB_IN_DRAM;
74 }
75
76 // camera init
77 esp_err_t err = esp_camera_init(&config);
78 if (err != ESP_OK) {
79     Serial.printf("Camera init failed with error 0x%x", err);
80     return;
81 }
82
83 sensor_t * s = esp_camera_sensor_get();
84 // initial sensors are flipped vertically and colors are a bit saturated
85 s->set_vflip(s, 1); // flip it back
86 s->set_brightness(s, 1); // up the brightness just a bit

```

```

87     s->set_saturation(s, -1); // lower the saturation
88
89     WiFi.begin(ssid, password);
90     WiFi.setSleep(false);
91
92     while (WiFi.status() != WL_CONNECTED) {
93         delay(500);
94         Serial.print(".");
95     }
96     while (WiFi.STA.hasIP() != true) {
97         delay(500);
98         Serial.print(".");
99     }
100
101    Serial.println("");
102    Serial.println("WiFi connected");
103
104    startCameraServer();
105
106    Serial.print("Camera Ready! Use 'http://");
107    Serial.print(WiFi.localIP());
108    Serial.println(" to connect");
109 }
110
111 void loop() {
112     // Do nothing. Everything is done in another task by the web server
113     delay(10000);
114 }
```

Add procedure files and API interface files related to ESP32-S3 camera.

```

1 #include "esp_camera.h"
2 #include <WiFi.h>
...
9 #define CAMERA_MODEL_ESP32S3_EYE // Has PSRAM
...
11 #include "camera_pins.h"
```

Enter the name and password of the router

```

13 const char *ssid      = "*****"; //input your wifi name
14 const char *password = "*****"; //input your wifi passwords
```

Initialize serial port, set baud rate to 115200; open the debug and output function of the serial.

```

21 Serial.begin(115200);
22 Serial.setDebugOutput(true);
23 Serial.println();
```



Configure parameters including interface pins of the camera. Note: It is generally not recommended to change them.

```

37  camera_config_t config;
38  config.ledc_channel = LEDC_CHANNEL_0;
39  config.ledc_timer = LEDC_TIMER_0;
40  config.pin_d0 = Y2_GPIO_NUM;
41  config.pin_d1 = Y3_GPIO_NUM;
42  config.pin_d2 = Y4_GPIO_NUM;
43  config.pin_d3 = Y5_GPIO_NUM;
44  config.pin_d4 = Y6_GPIO_NUM;
45  config.pin_d5 = Y7_GPIO_NUM;
46  config.pin_d6 = Y8_GPIO_NUM;
47  config.pin_d7 = Y9_GPIO_NUM;
48  config.pin_xclk = XCLK_GPIO_NUM;
49  config.pin_pclk = PCLK_GPIO_NUM;
50  config.pin_vsync = VSYNC_GPIO_NUM;
51  config.pin_href = HREF_GPIO_NUM;
52  config.pin_sccb_sda = SIOD_GPIO_NUM;
53  config.pin_sccb_scl = SIOC_GPIO_NUM;
54  config.pin_pwdn = PWDN_GPIO_NUM;
55  config.pin_reset = RESET_GPIO_NUM;
56  config.xclk_freq_hz = 20000000;
57  config.frame_size = FRAMESIZE_UXGA;
58  config.pixel_format = PIXFORMAT_JPEG; // for streaming
59  config.grab_mode = CAMERA_GRAB_WHEN_EMPTY;
60  config.fb_location = CAMERA_FB_IN_PSRAM;
61  config.jpeg_quality = 12;
62  config.fb_count = 1;

```

ESP32-S3 connects to the router and prints a successful connection prompt. If it has not been successfully connected, press the reset key on the ESP32-S3 WROOM.

```

89  WiFi.begin(ssid, password);
90  WiFi.setSleep(false);

91

92  while (WiFi.status() != WL_CONNECTED) {
93      delay(500);
94      Serial.print(".");
95  }
96  while (WiFi.STA.hasIP() != true) {
97      delay(500);
98      Serial.print(".");
99  }

100  Serial.println("");
101  Serial.println("WiFi connected");
102

```

Open the video streams server function of the camera and print its IP address via serial port.

```

99  startCameraServer();
100
101  Serial.print("Camera Ready! Use 'http://");
102  Serial.print(WiFi.localIP());
103  Serial.println("' to connect");

```

Configure the display image information of the camera.

The set\_vflip() function sets whether the image is flipped 180°, with 0 for no flip and 1 for flip 180°.

The set\_brightness() function sets the brightness of the image, with values ranging from -2 to 2.

The set\_saturation() function sets the color saturation of the image, with values ranging from -2 to 2.

```

36  sensor_t * s = esp_camera_sensor_get();
37  s->set_vflip(s, 1);           //flip it back
38  s->set_brightness(s, 1);     //up the brightness just a bit
39  s->set_saturation(s, -1);   //lower the saturation

```

Modify the resolution and sharpness of the images captured by the camera. The sharpness ranges from 10 to 63, and the smaller the number, the sharper the picture. The larger the number, the blurrier the picture. Please refer to the table below.

```

26  config.frame_size = FRAMESIZE_VGA;
27  config.jpeg_quality = 10;

```

#### Reference

Image resolution	Sharpness	Image resolution	Sharpness
FRAMESIZE_96x96	96x96	FRAMESIZE_HVGA	480x320
FRAMESIZE_QQVGA	160x120	FRAMESIZE_VGA	640x480
FRAMESIZE_QCIF	176x144	FRAMESIZE_SVGA	800x600
FRAMESIZE_HQVGA	240x176	FRAMESIZE_XGA	1024x768
FRAMESIZE_240x240	240x240	FRAMESIZE_HD	1280x720
FRAMESIZE_QVGA	320x240	FRAMESIZE_SXGA	1280x1024
FRAMESIZE_CIF	400x296	FRAMESIZE_UXGA	1600x1200

We recommend that the resolution not exceed VGA(640x480).



## Project 32.2 Video Web Server

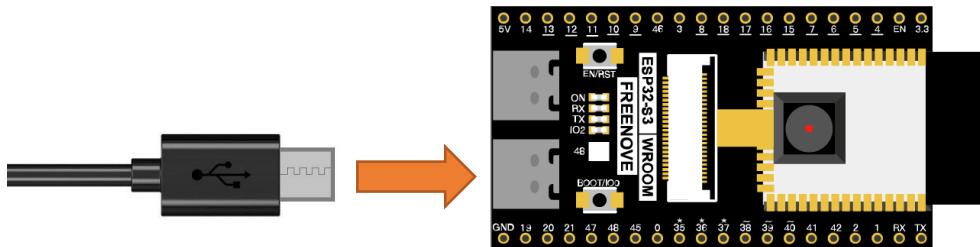
Connect to ESP32-S3 using USB and view its IP address through a serial monitor. Access IP addresses through web pages to obtain real-time video data.

### Component List

ESP32-S3 WROOM x1	USB cable x1	SDcard x1

### Circuit

Connect Freenove ESP32-S3 to the computer using the USB cable.



## Sketch

### Sketch\_32.2\_As\_VideoWebServer

```

Sketch_32.2_As_VideoWebServer | Arduino IDE 2.0.0
File Edit Sketch Tools Help
ESP32S3 Dev Module
Sketch_32.2_As_VideoWebServer.ino app_httpd.cpp camera_pins.h ...
1 //*****
2 Filename : Video Web Server
3 Description : The camera images captured by the ESP32S3 are displayed on the web page.
4 Author : www.freenove.com
5 Modification: 2022/11/01
6 *****/
7 #include "esp_camera.h"
8 #include <WiFi.h>
9
10 // Select camera model
11 #define CAMERA_MODEL_ESP32S3_EYE // Has PSRAM
12
13 #include "camera_pins.h"
14
15 const char* ssid      = "*****";    //input your wifi name
16 const char* password = "*****";    //input your wifi passwords
17
18 void startCameraServer();
19
20 void setup() {
21   Serial.begin(115200);
22   Serial.setDebugOutput(true);
23   Serial.println();
24
25   camera_config_t config;
26   config. ....

```

Before running the program, please modify your router's name and password in the box shown in the illustration above to make sure that your Sketch can compile and work successfully.

Compile and upload codes to ESP32-S3, open the serial monitor and set the baud rate to 115200, and the serial monitor will print out a network link address.

```

SD_MMC Card Type: SDSC
SD_MMC Card Size: 961MB
Total space: 958MB
Used space: 15MB
Removing Dir: /video
rmdir failed
Creating Dir: /video
Dir created

WiFi connected
[ 1543][I][app_httpd.cpp:305] startCameraServer(): [] Starting web server on port: '80'
[ 1545][I][app_httpd.cpp:315] startCameraServer(): [] Starting stream server on port: '81'
Camera Ready! Use 'http://192.168.1.233' to connect

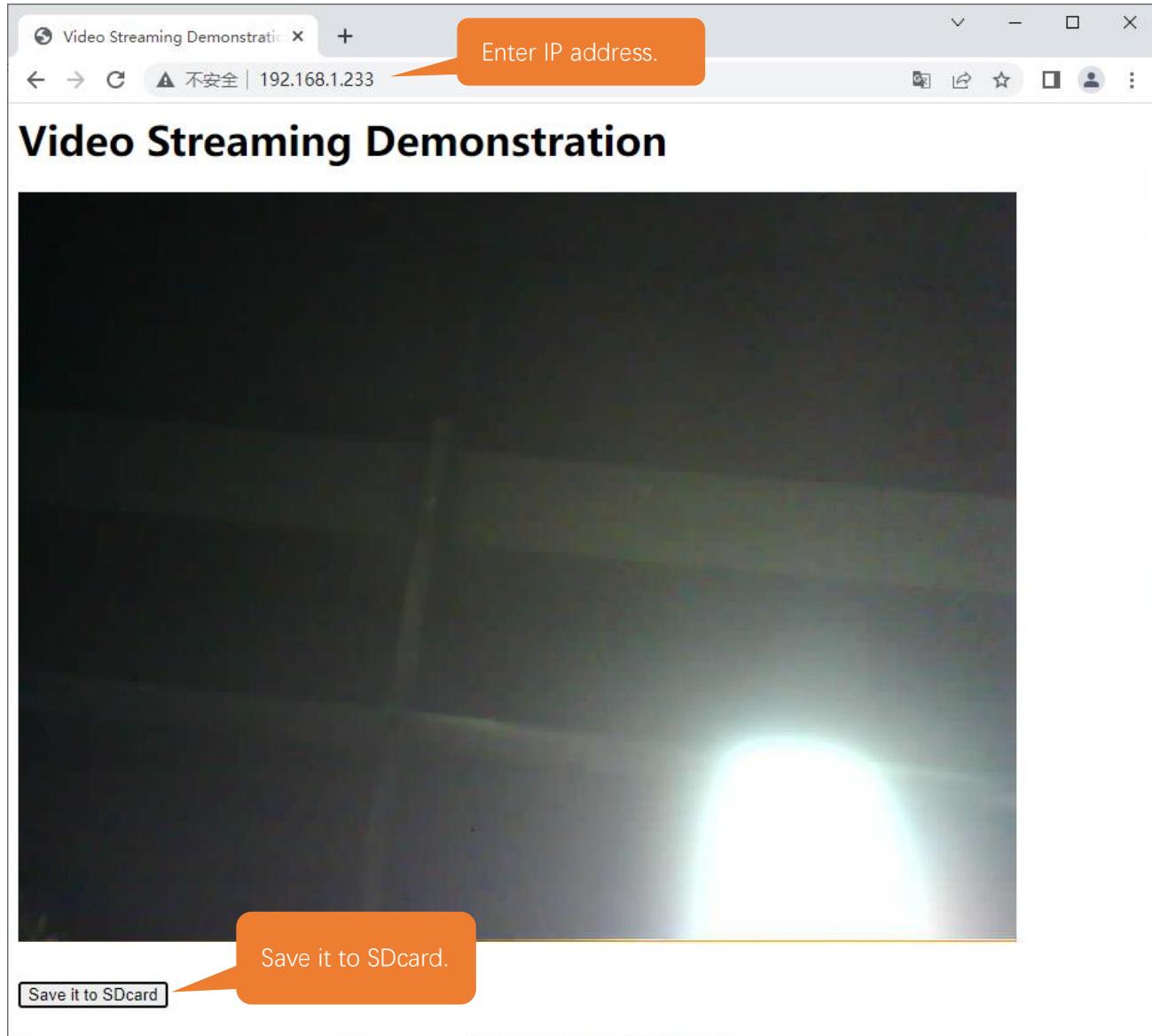
```

Ln 14, Col 25 UTF-8 ESP32S3 Dev Module on COM3

If your ESP32-S3 has been in the process of connecting to router, but the information above has not been printed out, please re-check whether the router name and password have been entered correctly and press the reset key on ESP32-S3 WROOM to wait for a successful connection prompt.

Open a web browser, enter the IP address printed by the serial monitor in the address bar, and access it. Taking the Google browser as an example, here's what the browser prints out after successful access to ESP32-S3's IP.

The effect is shown in the image below.



The following is the main program code. You need include other code files in the same folder when write your own code.

```
1 #include "esp_camera.h"
2 #include <WiFi.h>
3
4 // Select camera model
5 #define CAMERA_MODEL_ESP32S3_EYE // Has PSRAM
6 #include "camera_pins.h"
7
```

```
8 const char* ssid      = "*****";    //input your wifi name
9 const char* password = "*****";    //input your wifi passwords
10 void startCameraServer();
11
12 void setup() {
13     Serial.begin(115200);
14     Serial.setDebugOutput(true);
15     Serial.println();
16
17     camera_config_t config;
18     config.ledc_channel = LEDC_CHANNEL_0;
19     config.ledc_timer = LEDC_TIMER_0;
20     config.pin_d0 = Y2_GPIO_NUM;
21     config.pin_d1 = Y3_GPIO_NUM;
22     config.pin_d2 = Y4_GPIO_NUM;
23     config.pin_d3 = Y5_GPIO_NUM;
24     config.pin_d4 = Y6_GPIO_NUM;
25     config.pin_d5 = Y7_GPIO_NUM;
26     config.pin_d6 = Y8_GPIO_NUM;
27     config.pin_d7 = Y9_GPIO_NUM;
28     config.pin_xclk = XCLK_GPIO_NUM;
29     config.pin_pclk = PCLK_GPIO_NUM;
30     config.pin_vsync = VSYNC_GPIO_NUM;
31     config.pin_href = HREF_GPIO_NUM;
32     config.pin_sccb_sda = SIOD_GPIO_NUM;
33     config.pin_sccb_scl = SIOC_GPIO_NUM;
34     config.pin_pwdn = PWDN_GPIO_NUM;
35     config.pin_reset = RESET_GPIO_NUM;
36     config.xclk_freq_hz = 20000000;
37     config.frame_size = FRAMESIZE_UXGA;
38     config.pixel_format = PIXFORMAT_JPEG; // for streaming
39     config.grab_mode = CAMERA_GRAB_WHEN_EMPTY;
40     config.fb_location = CAMERA_FB_IN_PSRAM;
41     config.jpeg_quality = 12;
42     config.fb_count = 1;
43
44     // if PSRAM IC present, init with UXGA resolution and higher JPEG quality
45     // for larger pre-allocated frame buffer.
46     if(psramFound()){
47         config.jpeg_quality = 10;
48         config.fb_count = 2;
49         config.grab_mode = CAMERA_GRAB_LATEST;
50     } else {
51         // Limit the frame size when PSRAM is not available
```



```
52     config.frame_size = FRAMESIZE_SVGA;
53     config.fb_location = CAMERA_FB_IN_DRAM;
54 }
55
56 // camera init
57 esp_err_t err = esp_camera_init(&config);
58 if (err != ESP_OK) {
59     Serial.printf("Camera init failed with error 0x%x", err);
60     return;
61 }
62
63 sensor_t * s = esp_camera_sensor_get();
64 // initial sensors are flipped vertically and colors are a bit saturated
65 s->set_vflip(s, 1); // flip it back
66 s->set_brightness(s, 1); // up the brightness just a bit
67 s->set_saturation(s, 0); // lower the saturation
68
69 WiFi.begin(ssid, password);
70
71 while (WiFi.status() != WL_CONNECTED) {
72     delay(500);
73     Serial.print(".");
74 }
75 Serial.println("");
76 Serial.println("WiFi connected");
77
78 startCameraServer();
79
80 Serial.print("Camera Ready! Use 'http://");
81 Serial.print(WiFi.localIP());
82 Serial.println(" to connect");
83 }
84
85 void loop() {
86     // put your main code here, to run repeatedly:
87     delay(10000);
88 }
```

Configure parameters including interface pins of the camera. Note: It is generally not recommended to change them.

```

17  camera_config_t config;
18  config.ledc_channel = LEDC_CHANNEL_0;
19  config.ledc_timer = LEDC_TIMER_0;
20  config.pin_d0 = Y2_GPIO_NUM;
21  config.pin_d1 = Y3_GPIO_NUM;
22  config.pin_d2 = Y4_GPIO_NUM;
23  config.pin_d3 = Y5_GPIO_NUM;
24  config.pin_d4 = Y6_GPIO_NUM;
25  config.pin_d5 = Y7_GPIO_NUM;
26  config.pin_d6 = Y8_GPIO_NUM;
27  config.pin_d7 = Y9_GPIO_NUM;
28  config.pin_xclk = XCLK_GPIO_NUM;
29  config.pin_pclk = PCLK_GPIO_NUM;
30  config.pin_vsync = VSYNC_GPIO_NUM;
31  config.pin_href = HREF_GPIO_NUM;
32  config.pin_sccb_sda = SIOD_GPIO_NUM;
33  config.pin_sccb_scl = SIOC_GPIO_NUM;
34  config.pin_pwdn = PWDN_GPIO_NUM;
35  config.pin_reset = RESET_GPIO_NUM;
36  config.xclk_freq_hz = 20000000;
37  config.frame_size = FRAMESIZE_UXGA;
38  config.pixel_format = PIXFORMAT_JPEG; // for streaming
39  config.grab_mode = CAMERA_GRAB_WHEN_EMPTY;
40  config.fb_location = CAMERA_FB_IN_PSRAM;
41  config.jpeg_quality = 12;
42  config.fb_count = 1;

```

ESP32-S3 connects to the router and prints a successful connection prompt. If it has not been successfully connected, press the reset key on the ESP32-S3 WROOM.

```

69  WiFi.begin(ssid, password);
70
71  while (WiFi.status() != WL_CONNECTED) {
72      delay(500);
73      Serial.print(".");
74  }
75  Serial.println("");
76  Serial.println("WiFi connected");

```

Open the video streams server function of the camera and print its IP address via serial port.

```

82  startCameraServer();
83
84  Serial.print("Camera Ready! Use 'http://");
85  Serial.print(WiFi.localIP());
86  Serial.println(" to connect");

```



## Project 32.3 Camera and SDcard

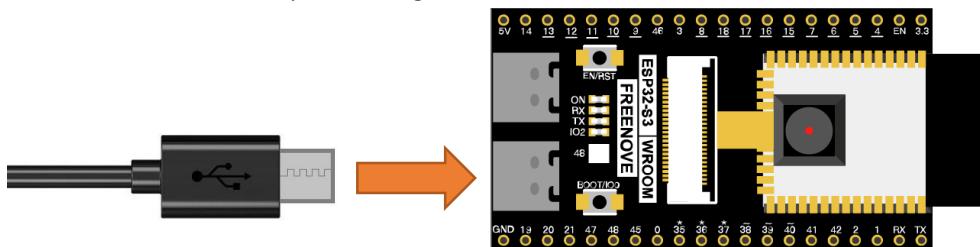
In this chapter, we continue to use the camera and SD card. We will use the onboard button as the shutter. When the button is pressed, the ESP32-S3 takes a photo and stores the photo in the SD folder.

### Component List

ESP32-S3 WROOM x1	USB cable x1	SDcard x1
A photograph of the Freenove ESP32-S3 WROOM module. It features a built-in camera at the top left, a microSD card slot at the top right, and various pins labeled on the bottom edge. The module is labeled "ESP32-S3 WROOM" and "FREENOVE".	A photograph showing two standard USB-A to USB-B cables, one black and one grey, used for connecting the ESP32 module to a computer.	A simple graphic of an SD memory card with the letters "SD" printed on it.

### Circuit

Connect Freenove ESP32-S3 to the computer using the USB cable.



## Sketch

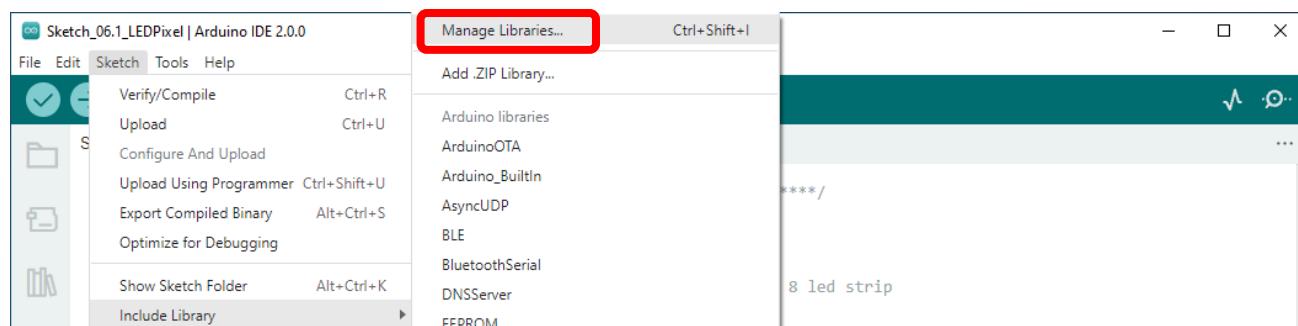
This code uses a library named "Freenove\_WS2812\_Lib\_for\_ESP32", if you have not installed it, please do so first.

Library is an important feature of the open source world, and we know that Arduino is an open source platform that everyone can contribute to. Libraries are generally licensed under the LGPL, which means you can use them for free to apply to your creations.

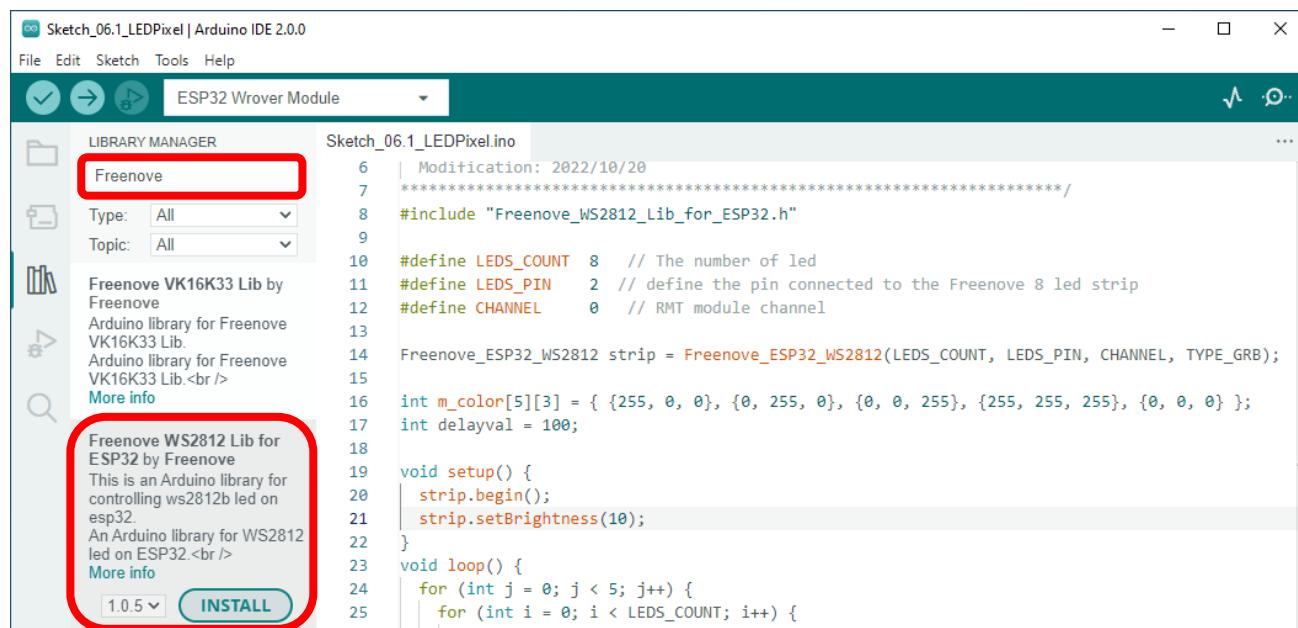
### How to install the library

There are two ways to add libraries.

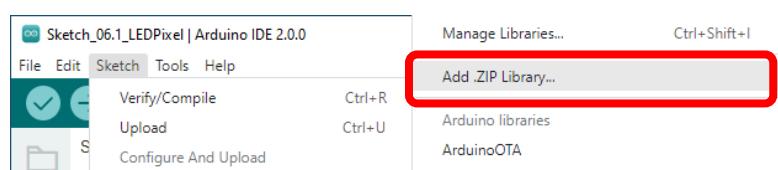
The first way, open the Arduino IDE, click Sketch → Include Library → Manager Libraries.



In the pop-up window, Library Manager, search for the name of the Library, "Freenove WS2812 Lib for ESP32". Then click Install.



The second way, open Arduino IDE, click Sketch→Include Library→Add .ZIP Library, In the pop-up window, find the file named "./Libraries/Freenove\_WS2812\_Lib\_for\_ESP32.Zip" which locates in this directory, and click OPEN.





### Sketch\_32.3\_Camera\_SDcard

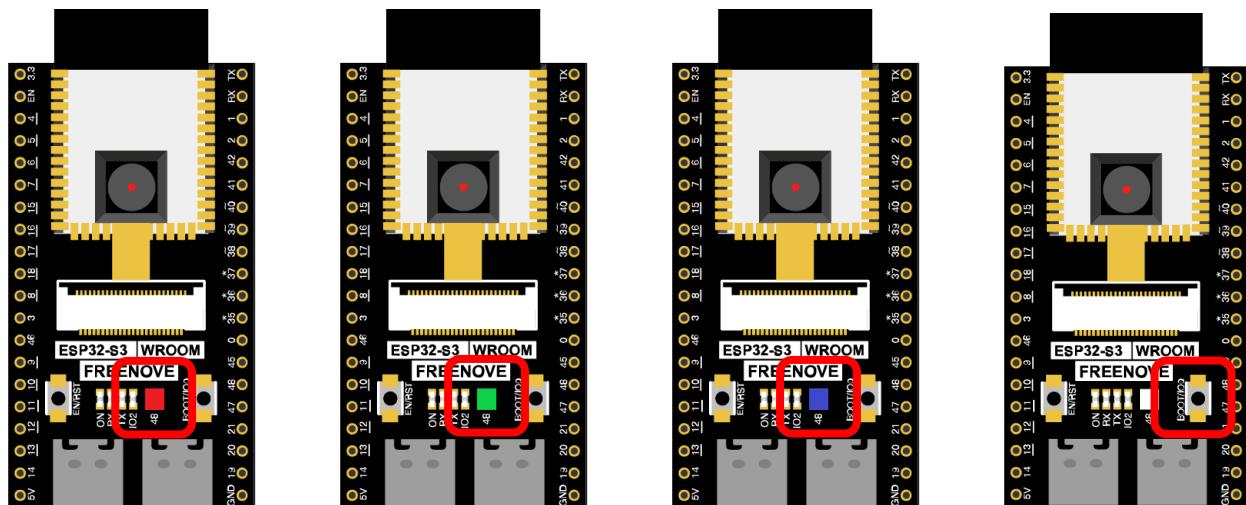
```

Sketch_32.3_Camera_SDcard | Arduino IDE 2.0.0
File Edit Sketch Tools Help
ESP32S3 Dev Module
Sketch_32.3_Camera_SDcard.ino camera_pins.h sd_read_write.cpp sd_read_write.h ws2812.cpp ws2812.h ...
1 // ****
2 Filename : Camera and SDcard
3 Description : Use the onboard buttons to take photo and save them to an SD card.
4 Author : www.freenove.com
5 Modification: 2022/11/02
6 ****
7 #include "esp_camera.h"
8 #define CAMERA_MODEL_ESP32S3_EYE
9 #include "camera_pins.h"
10 #include "ws2812.h"
11 #include "sd_read_write.h"
12
13 #define BUTTON_PIN 0
14
15 void setup() {
16     Serial.begin(115200);
17     Serial.setDebugOutput(false);
18     Serial.println();
19     pinMode(BUTTON_PIN, INPUT_PULLUP);
20     ws2812Init();
21     sdmmcInit();
22     //removeDir(SD_MMC, "/camera");
23     createDir(SD_MMC, "/camera");
24     listDir(SD_MMC, "/camera");

```

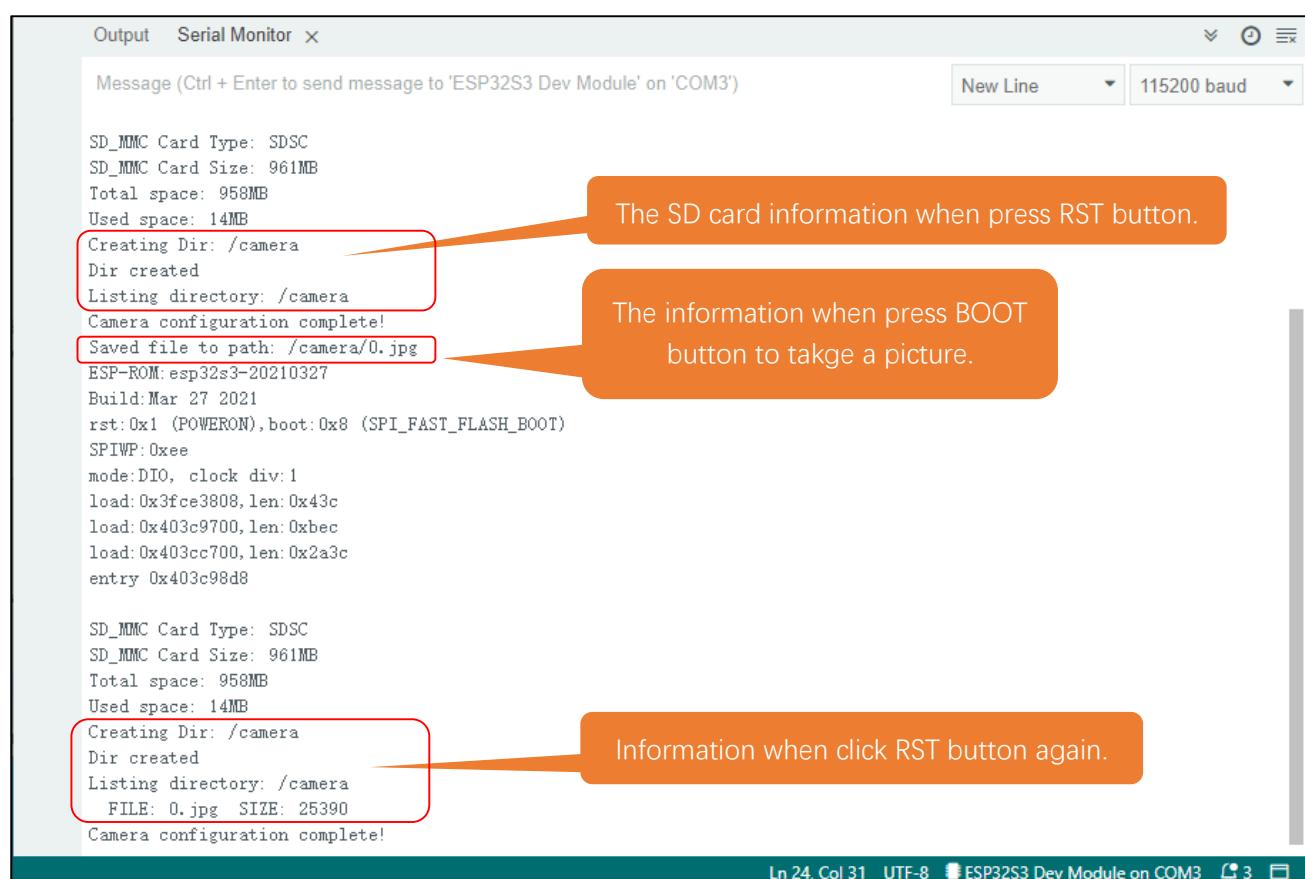
Compile and upload the code to the ESP32-S3.

If your camera is not installed properly, causing the camera to fail to initialize, or you have not inserted the SD card into the ESP32-S3 in advance, the on-board colored lights will turn on red as a reminder. If all is well, the onboard colored light will light up green. When the onboard BOOT button is pressed, the ESP32-S3 will capture the current camera image and save it in the "Camera" folder of the SD card. At the same time, the onboard LED lights up blue, and returns to green after taking a photo.



As shown in the image below, after uploading the code to the ESP32-S3, the ESP32-S3 will automatically create a folder named "camera" in the SD card. Every time the BOOT button is pressed, the on-board colored light turns on blue, and ESP32-S3 collects a photo information and stores it in the "camera" folder. Press the button once to take a photo.

When we press the RST button to reset the ESP32-S3, we can see that there are some photo files in the SD card folder. These photos you can read directly through the card reader.



```
Output Serial Monitor ×
Message (Ctrl + Enter to send message to 'ESP32S3 Dev Module' on 'COM3')
New Line 115200 baud
SD_MMC Card Type: SDSC
SD_MMC Card Size: 961MB
Total space: 958MB
Used space: 14MB
Creating Dir: /camera
Dir created
Listing directory: /camera
Camera configuration complete!
Saved file to path: /camera/0.jpg
ESP-ROM: esp32s3-20210327
Build: Mar 27 2021
rst:0x1 (POWERON), boot:0x8 (SPI_FAST_FLASH_BOOT)
SPIWP:0xee
mode:DIO, clock div:1
load:0x3fce3808, len:0x43c
load:0x403c9700, len:0xbec
load:0x403cc700, len:0x2a3c
entry 0x403c98d8

SD_MMC Card Type: SDSC
SD_MMC Card Size: 961MB
Total space: 958MB
Used space: 14MB
Creating Dir: /camera
Dir created
Listing directory: /camera
FILE: 0.jpg SIZE: 25390
Camera configuration complete!
```

The SD card information when press RST button.

The information when press BOOT button to take a picture.

Information when click RST button again.



The following is the main program code. You need include other code files in the same folder when write your own code.

```
1 #include "esp_camera.h"
2 #define CAMERA_MODEL_ESP32S3_EYE
3 #include "camera_pins.h"
4 #include "ws2812.h"
5 #include "sd_read_write.h"
6
7 #define BUTTON_PIN 0
8
9 void setup() {
10     Serial.begin(115200);
11     Serial.setDebugOutput(false);
12     Serial.println();
13     pinMode(BUTTON_PIN, INPUT_PULLUP);
14     ws2812Init();
15     sdmmcInit();
16     //removeDir(SD_MMC, "/camera");
17     createDir(SD_MMC, "/camera");
18     listDir(SD_MMC, "/camera", 0);
19     if(cameraSetup()==1) {
20         ws2812SetColor(2);
21     }
22     else{
23         ws2812SetColor(1);
24         return;
25     }
26 }
27
28 void loop() {
29     if(digitalRead(BUTTON_PIN)==LOW) {
30         delay(20);
31         if(digitalRead(BUTTON_PIN)==LOW) {
32             ws2812SetColor(3);
33             while(digitalRead(BUTTON_PIN)==LOW);
34             camera_fb_t * fb = NULL;
35             fb = esp_camera_fb_get();
36             if (fb != NULL) {
37                 int photo_index = readFileNum(SD_MMC, "/camera");
38                 if(photo_index!=-1)
39                 {
40                     String path = "/camera/" + String(photo_index) + ".jpg";
41                     writeJpg(SD_MMC, path.c_str(), fb->buf, fb->len);
42                 }
43             }
44         }
45     }
46 }
```

```
43         esp_camera_fb_return(fb);
44     }
45     else {
46         Serial.println("Camera capture failed.");
47     }
48     ws2812SetColor(2);
49 }
50 }
51 }
52
53 int cameraSetup(void) {
54     camera_config_t config;
55     config.ledc_channel = LEDC_CHANNEL_0;
56     config.ledc_timer = LEDC_TIMER_0;
57     config.pin_d0 = Y2_GPIO_NUM;
58     config.pin_d1 = Y3_GPIO_NUM;
59     config.pin_d2 = Y4_GPIO_NUM;
60     config.pin_d3 = Y5_GPIO_NUM;
61     config.pin_d4 = Y6_GPIO_NUM;
62     config.pin_d5 = Y7_GPIO_NUM;
63     config.pin_d6 = Y8_GPIO_NUM;
64     config.pin_d7 = Y9_GPIO_NUM;
65     config.pin_xclk = XCLK_GPIO_NUM;
66     config.pin_pclk = PCLK_GPIO_NUM;
67     config.pin_vsync = VSYNC_GPIO_NUM;
68     config.pin_href = HREF_GPIO_NUM;
69     config.pin_sccb_sda = SIOD_GPIO_NUM;
70     config.pin_sccb_scl = SIOC_GPIO_NUM;
71     config.pin_pwdn = PWDN_GPIO_NUM;
72     config.pin_reset = RESET_GPIO_NUM;
73     config.xclk_freq_hz = 20000000;
74     config.frame_size = FRAMESIZE_UXGA;
75     config.pixel_format = PIXFORMAT_JPEG; // for streaming
76     config.grab_mode = CAMERA_GRAB_WHEN_EMPTY;
77     config.fb_location = CAMERA_FB_IN_PSRAM;
78     config.jpeg_quality = 12;
79     config.fb_count = 1;
80
81 // if PSRAM IC present, init with UXGA resolution and higher JPEG quality
82 // for larger pre-allocated frame buffer.
83 if(psramFound()){
84     config.jpeg_quality = 10;
85     config.fb_count = 2;
86     config.grab_mode = CAMERA_GRAB_LATEST;
```

```

87 } else {
88     // Limit the frame size when PSRAM is not available
89     config.frame_size = FRAMESIZE_SVGA;
90     config.fb_location = CAMERA_FB_IN_DRAM;
91 }
92
93 // camera init
94 esp_err_t err = esp_camera_init(&config);
95 if (err != ESP_OK) {
96     Serial.printf("Camera init failed with error 0x%x", err);
97     return 0;
98 }
99
100 sensor_t * s = esp_camera_sensor_get();
101 // initial sensors are flipped vertically and colors are a bit saturated
102 s->set_vflip(s, 1); // flip it back
103 s->set_brightness(s, 1); // up the brightness just a bit
104 s->set_saturation(s, 0); // lower the saturation
105
106 Serial.println("Camera configuration complete!");
107 return 1;
108 }
```

Configure camera parameters, including camera interface pins and other information. Altering them is generally not recommended. Returns 1 if the camera is initialized successfully, and returns 0 if it fails.

```

53 int cameraSetup(void) {
54     camera_config_t config;
55     config.ledc_channel = LEDC_CHANNEL_0;
56     config.ledc_timer = LEDC_TIMER_0;
57     config.pin_d0 = Y2_GPIO_NUM;
58     config.pin_d1 = Y3_GPIO_NUM;
59     config.pin_d2 = Y4_GPIO_NUM;
60     config.pin_d3 = Y5_GPIO_NUM;
61     config.pin_d4 = Y6_GPIO_NUM;
62     config.pin_d5 = Y7_GPIO_NUM;
63     config.pin_d6 = Y8_GPIO_NUM;
64     config.pin_d7 = Y9_GPIO_NUM;
65     config.pin_xclk = XCLK_GPIO_NUM;
66     config.pin_pclk = PCLK_GPIO_NUM;
67     config.pin_vsync = VSYNC_GPIO_NUM;
68     config.pin_href = HREF_GPIO_NUM;
69     config.pin_sccb_sda = SIOD_GPIO_NUM;
70     config.pin_sccb_scl = SIOC_GPIO_NUM;
71     config.pin_pwdn = PWDN_GPIO_NUM;
72     config.pin_reset = RESET_GPIO_NUM;
```

```
73 config.xclk_freq_hz = 20000000;
74 config.frame_size = FRAMESIZE_UXGA;
75 config.pixel_format = PIXFORMAT_JPEG; // for streaming
76 config.grab_mode = CAMERA_GRAB_WHEN_EMPTY;
77 config.fb_location = CAMERA_FB_IN_PSRAM;
78 config.jpeg_quality = 12;
79 config.fb_count = 1;
80
81 // if PSRAM IC present, init with UXGA resolution and higher JPEG quality
82 // for larger pre-allocated frame buffer.
83 if(psramFound()){
84     config.jpeg_quality = 10;
85     config.fb_count = 2;
86     config.grab_mode = CAMERA_GRAB_LATEST;
87 } else {
88     // Limit the frame size when PSRAM is not available
89     config.frame_size = FRAMESIZE_SVGA;
90     config.fb_location = CAMERA_FB_IN_DRAM;
91 }
92
93 // camera init
94 esp_err_t err = esp_camera_init(&config);
95 if (err != ESP_OK) {
96     Serial.printf("Camera init failed with error 0x%x", err);
97     return 0;
98 }
99
100 sensor_t * s = esp_camera_sensor_get();
101 // initial sensors are flipped vertically and colors are a bit saturated
102 s->set_vflip(s, 1); // flip it back
103 s->set_brightness(s, 1); // up the brightness just a bit
104 s->set_saturation(s, 0); // lower the saturation
105
106 Serial.println("Camera configuration complete!");
107 return 1;
108 }
```

Initialize the serial port, buttons, lights and SD card.

```

10   Serial.begin(115200);
11   Serial.setDebugOutput(false);
12   Serial.println();
13   pinMode(BUTTON_PIN, INPUT_PULLUP);
14   ws2812Init();
15   sdmmcInit();

```

Call ws2812SetColor() to set the color of the LED. When the parameter is 0, the LED is turned off, when the parameter is 1, the red light is displayed, when the parameter is 2, the green light is displayed, and when the parameter is 3, the blue light is displayed.

```
20   ws2812SetColor(2);
```

Get the camera data once, then read the file number in the camera folder of the SD card, and create a new file based on this, write the camera data into it, and finally return the camera structure pointer. If the camera data cannot be obtained, the prompt information will be printed directly.

```

34   camera_fb_t * fb = NULL;
35   fb = esp_camera_fb_get();
36   if (fb != NULL) {
37       int photo_index = readFileNum(SD_MMC, "/camera");
38       if(photo_index!=-1)
39       {
40           String path = "/camera/" + String(photo_index) + ".jpg";
41           writejpg(SD_MMC, path.c_str(), fb->buf, fb->len);
42       }
43       esp_camera_fb_return(fb);
44   }
45   else {
46       Serial.println("Camera capture failed.");
47   }

```

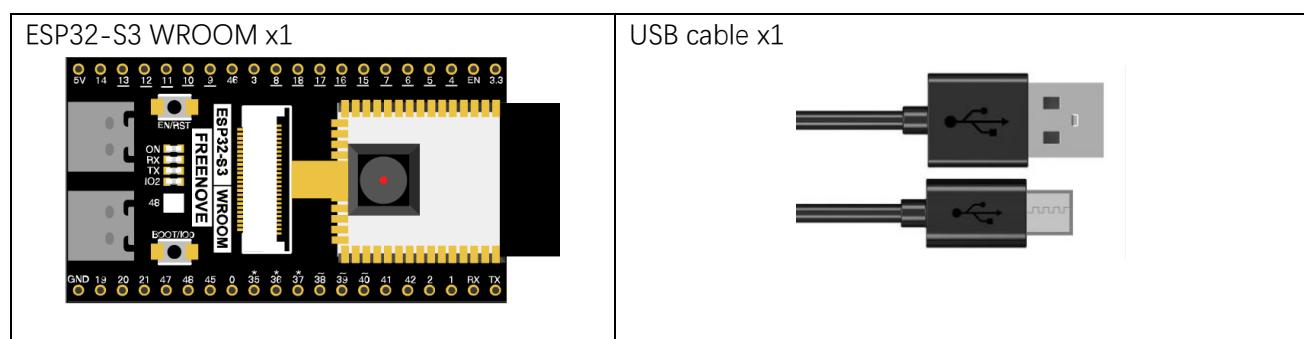
# Chapter 33 Camera Tcp Server

In the previous section, we used web page to display the video data captured by ESP32-S3, and in this section, we will use a mobile phone to display it.

## Project 33.1 Camera Tcp Server

Connect ESP32-S3 using USB and check its IP address through serial monitor. Use a mobile phone to obtain video and image data.

### Component List

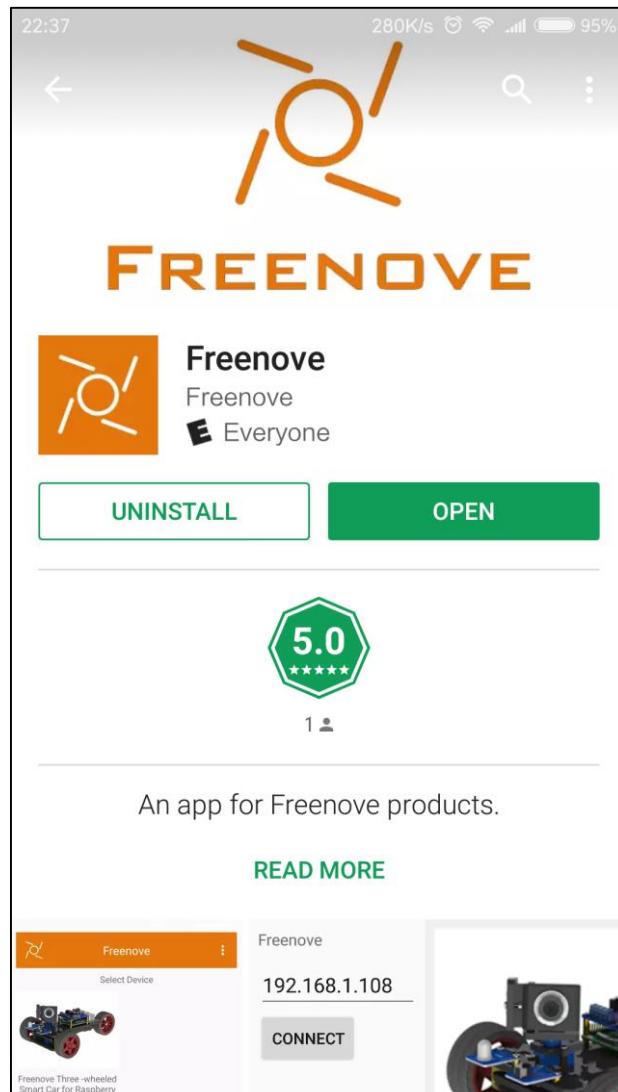


### Install Freenove app

There are three ways to install app, you can choose any one.

#### Method 1

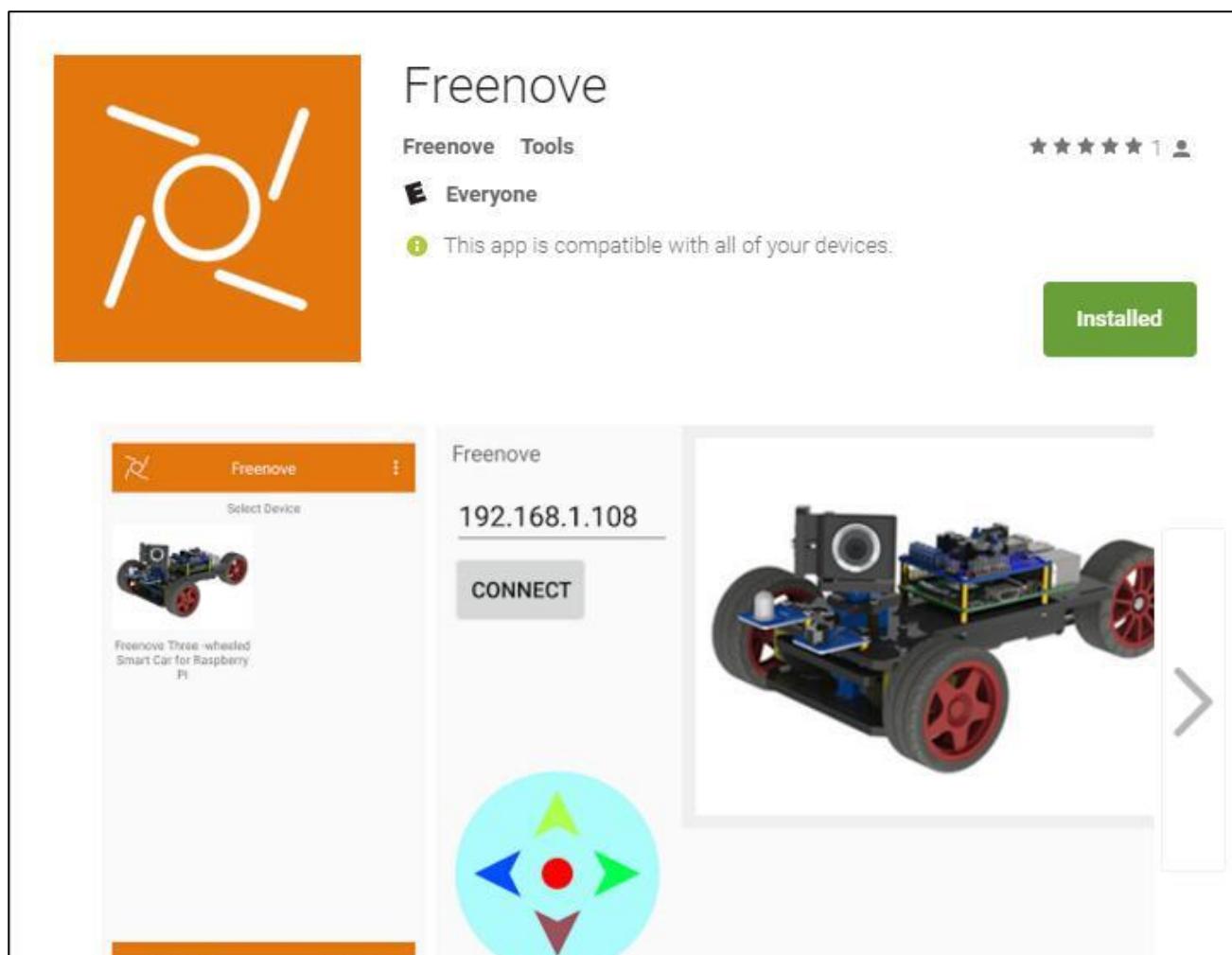
Use Google play to search “Freenove”, download and install.



Any concerns? ✉ support@freenove.com

## Method 2

Visit <https://play.google.com/store/apps/details?id=com.freenove.suhayl.Freenove>, and click install.





### Method 3

Visit [https://github.com/Freenove/Freenove\\_app\\_for\\_Android](https://github.com/Freenove/Freenove_app_for_Android), download the files in this library, and install freenove.apk to your Android phone manually.

The screenshot shows the GitHub repository page for 'Freenove / Freenove\_app\_for\_Android'. The repository has 1 commit, 1 branch, 0 releases, and 1 contributor. A callout box points to the 'Clone or download' button.

Apply to Freenove products.

1 commit 1 branch 0 releases 1 contributor

Branch: master New pull request

SuhaylZhao First Publish. ...

Readme.txt First Publish. 3 minutes ago

freenove.apk First Publish. 3 minutes ago

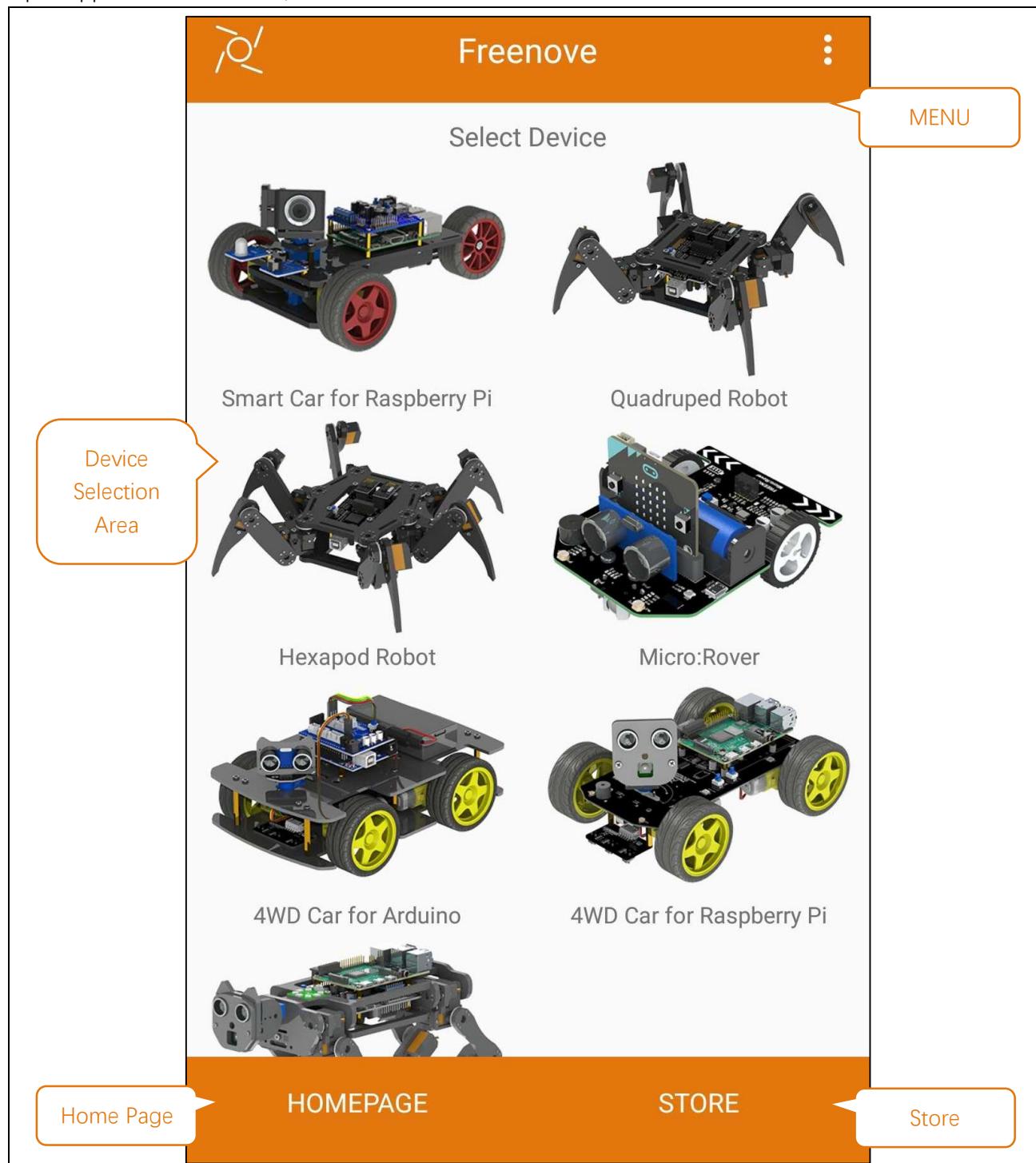
Clone or download

Latest commit 0523fc5 3 minutes ago

Click here to download.

## Menu

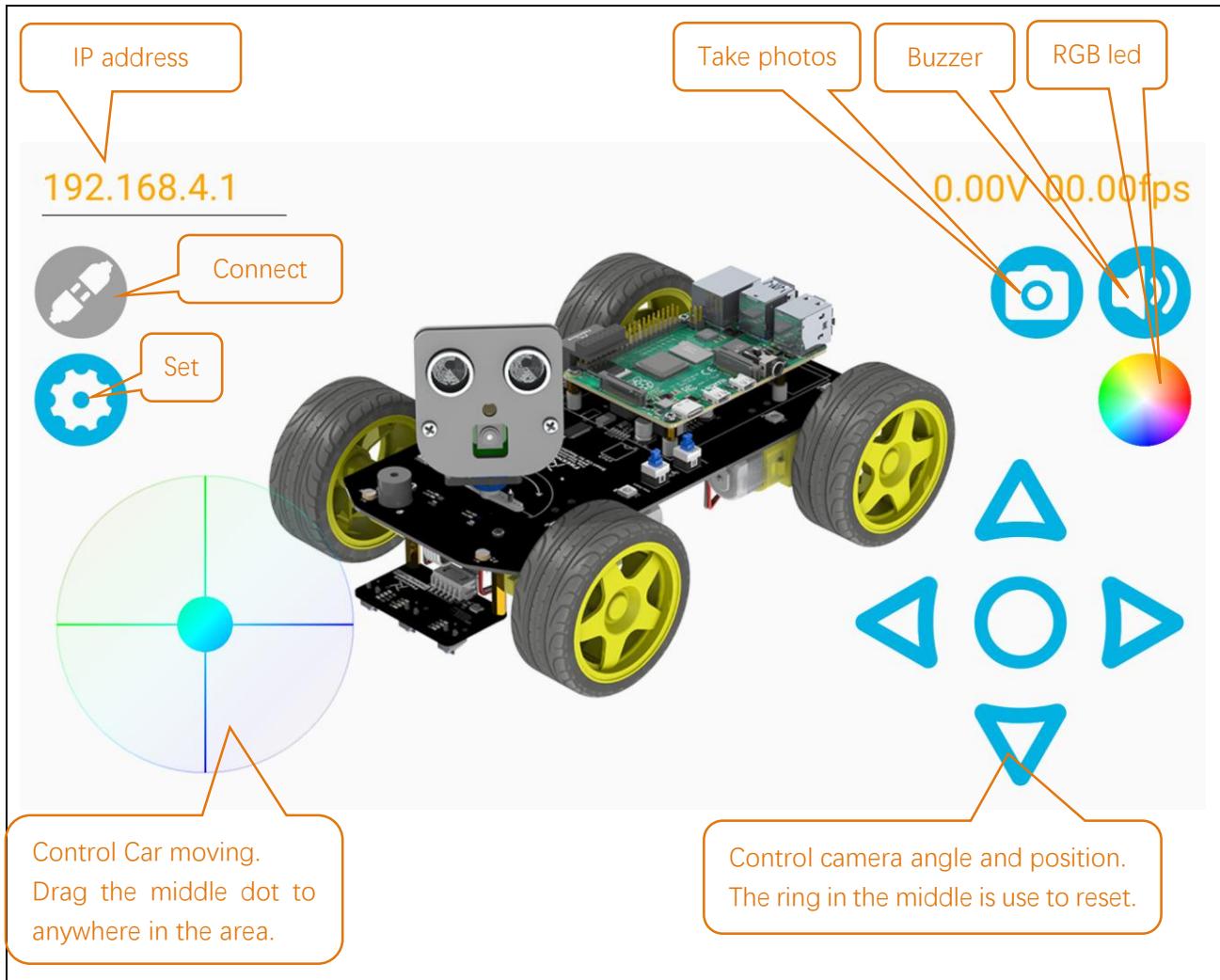
Open application “Freenove”, as shown below:





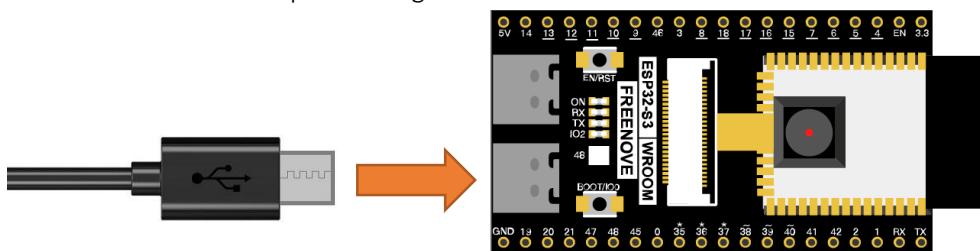
### Freenove 4WD Car for Raspberry Pi

In this chapter, we use Freenove 4WD Car for Raspberry Pi, so it is necessary to understand the interface of this mode.



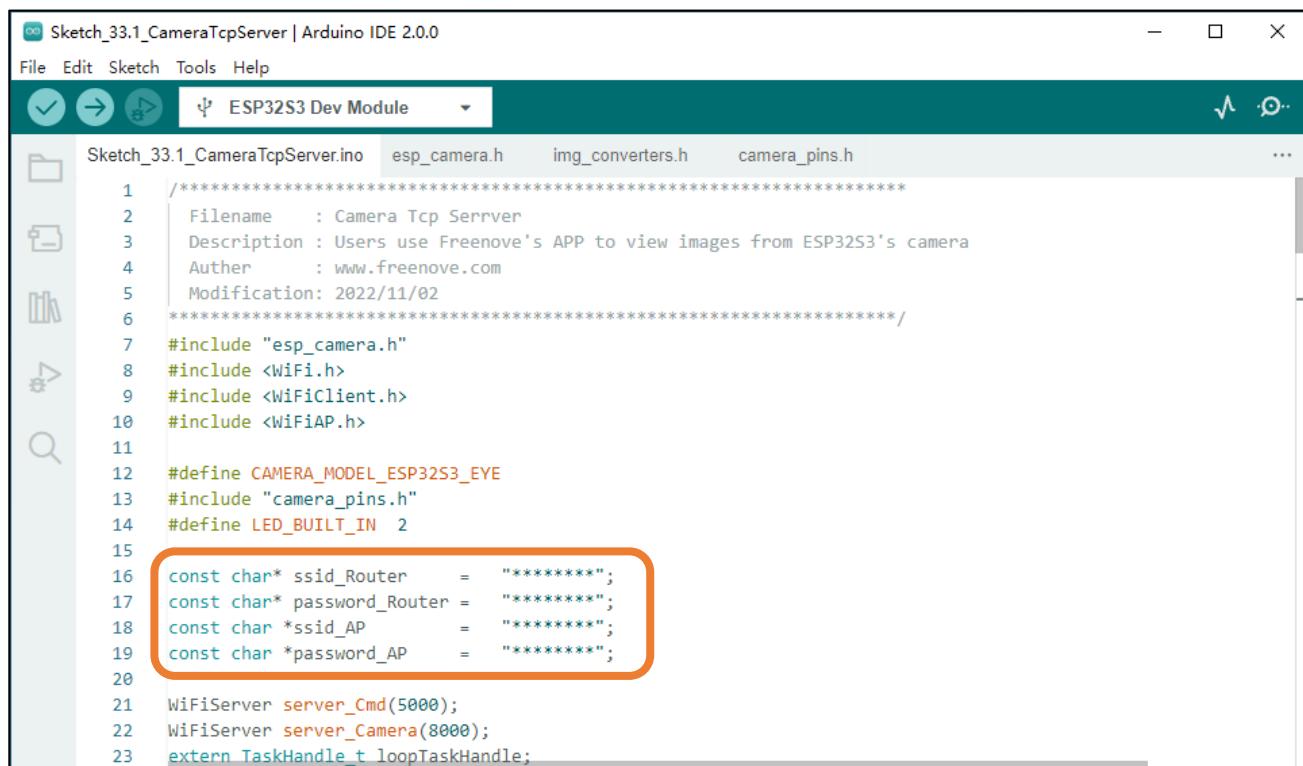
## Circuit

Connect Freenove ESP32-S3 to the computer using the USB cable.



## Sketch

After making sure the Tools is configured correctly, don't run Sketch. Due to WiFi, we need to modify Sketch a little bit based on physical situation.

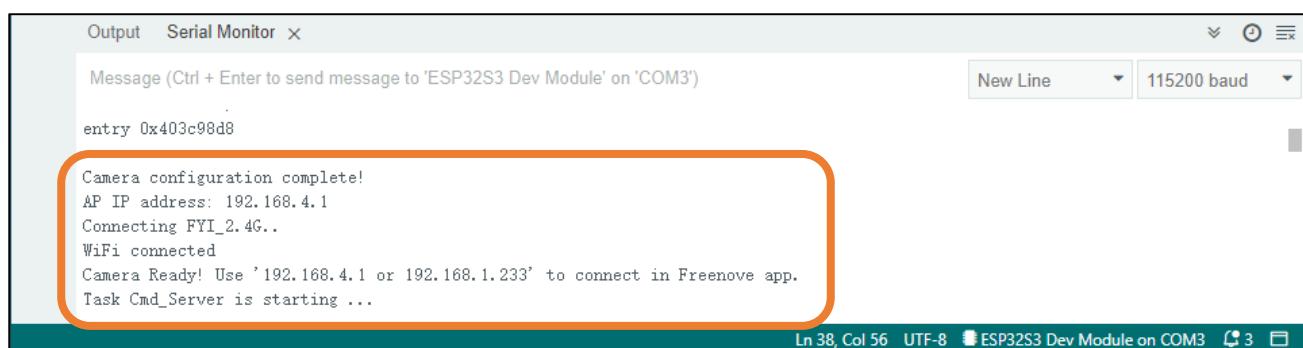


```

Sketch_33.1_CameraTcpServer | Arduino IDE 2.0.0
File Edit Sketch Tools Help
ESP32S3 Dev Module
Sketch_33.1_CameraTcpServer.ino esp_camera.h img_converters.h camera_pins.h ...
1 //*****
2   Filename : Camera Tcp Serrver
3   Description : Users use Freenove's APP to view images from ESP32S3's camera
4   Author : www.freenove.com
5   Modification: 2022/11/02
6 *****/
7 #include "esp_camera.h"
8 #include <WiFi.h>
9 #include <WiFiClient.h>
10 #include <WiFiAP.h>
11
12 #define CAMERA_MODEL_ESP32S3_EYE
13 #include "camera_pins.h"
14 #define LED_BUILT_IN 2
15
16 const char* ssid_Router      = "*****";
17 const char* password_Router = "*****";
18 const char *ssid_AP          = "*****";
19 const char *password_AP      = "*****";
20
21 WiFiServer server_Cmd(5000);
22 WiFiServer server_Camera(8000);
23 extern TaskHandle_t loopTaskHandle;

```

In the box in the figure above, ssid\_Router and password\_Router are the user's Router name and password, which need to be modified according to the actual name and password. ssid\_AP and password\_AP are name and password of a AP created by ESP32-S3, and they are freely set by the user. When all settings are correct, compile and upload the code to ESP32-S3, turn on the serial port monitor, and set the baud rate to 115200. The serial monitor will print out two IP addresses.



```

Output Serial Monitor X
Message (Ctrl + Enter to send message to 'ESP32S3 Dev Module' on 'COM3')
entry 0x403c98d8

Camera configuration complete!
AP IP address: 192.168.4.1
Connecting FYI_2.4G..
WiFi connected
Camera Ready! Use '192.168.4.1 or 192.168.1.233' to connect in Freenove app.
Task Cmd_Server is starting ...

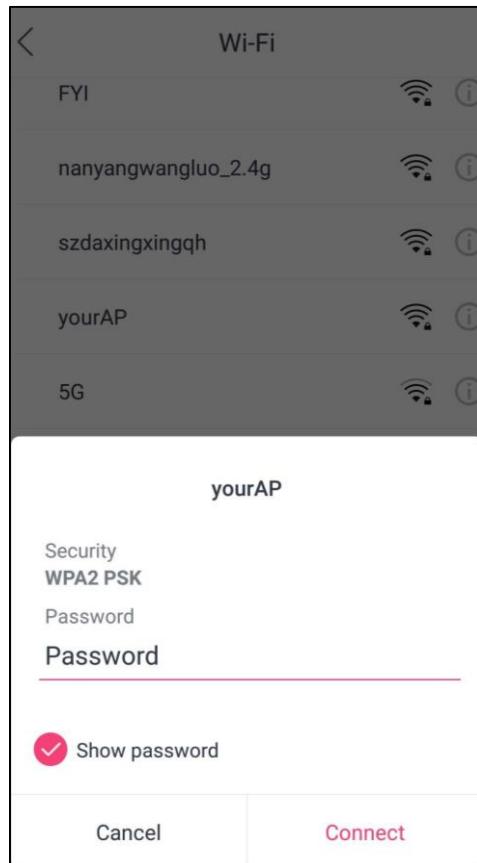
```



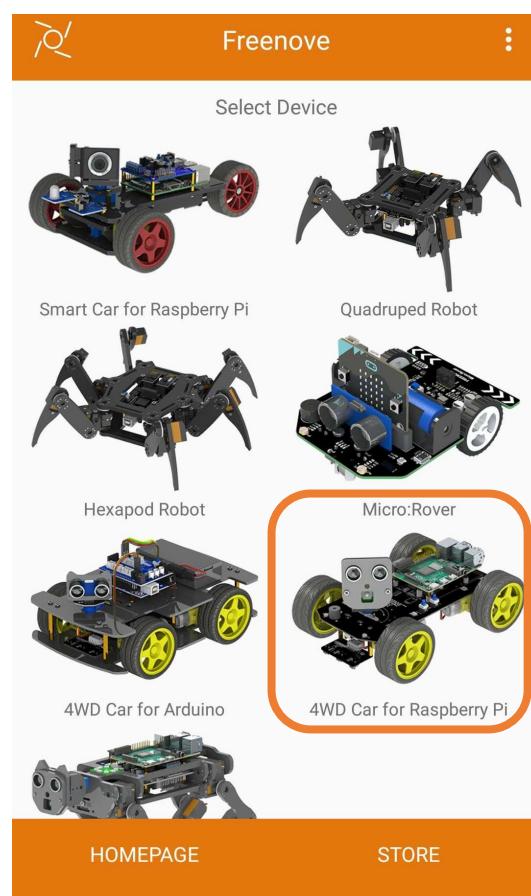
There are two methods for you to check camera data of ESP32-S3 via mobile phone APP.

#### Method 1:

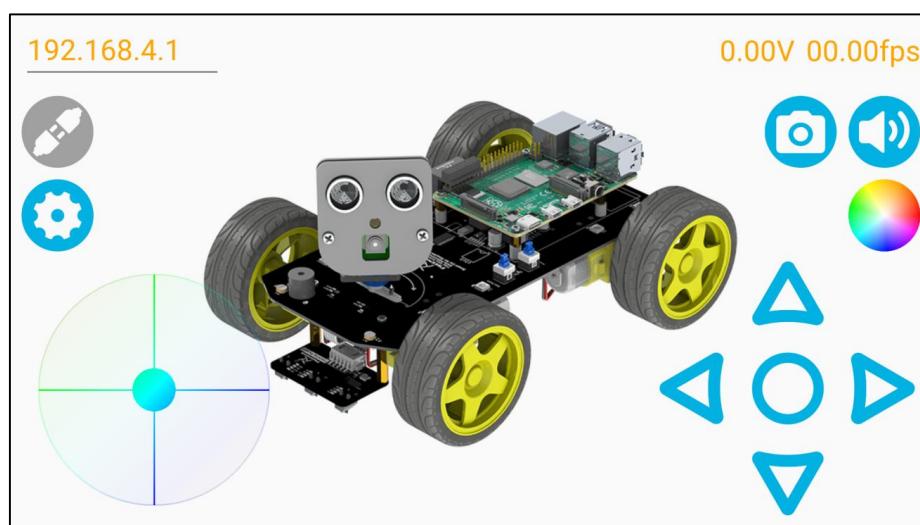
Using your phone's WiFi function, select the WiFi name represented by ssid\_AP in Sketch and enter the password "password\_AP" to connect.



Next, open Freenove app and select 4WD Car for Raspberry Pi mode.

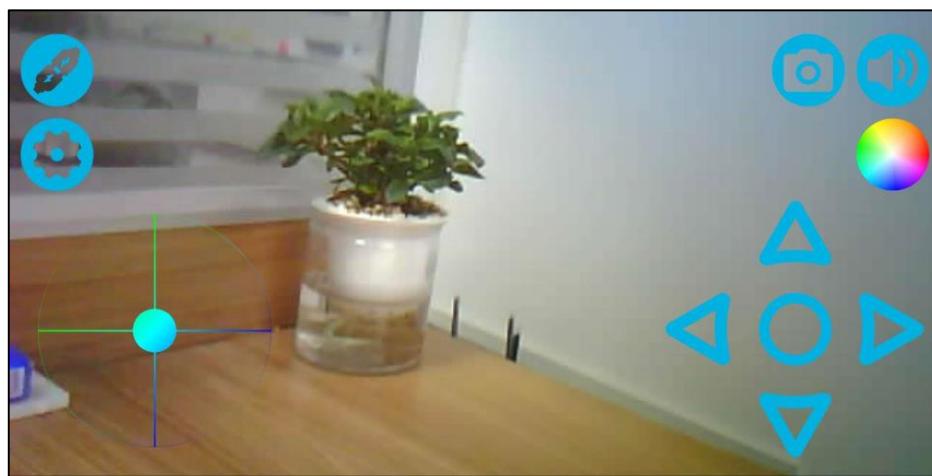


Enter the IP address printed by serial port in the new interface, which generally is "192.168.4.1"



Any concerns? ✉ support@freenove.com

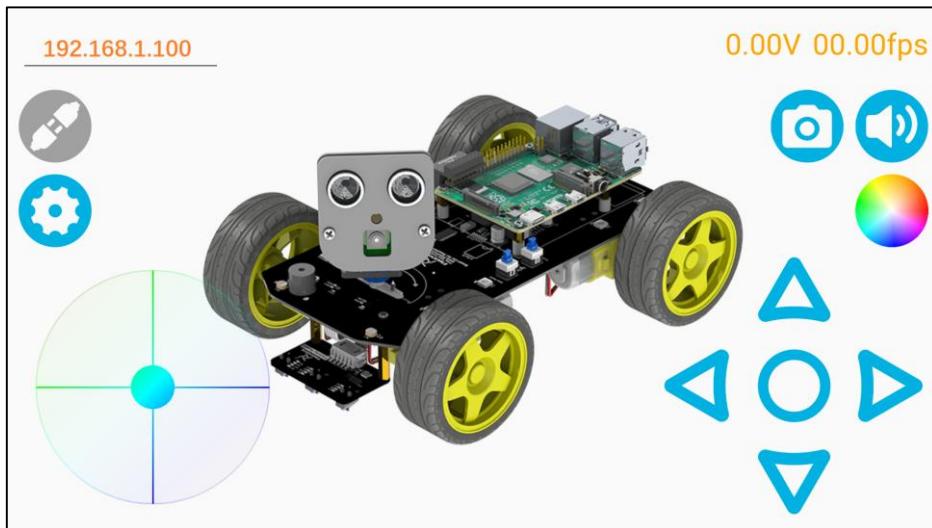
Click “Connect”.



### Method 2:

Using your phone's WiFi function, select the router named ssid\_Router and enter the password "ssid\_password" to connect. And then open Freenove app and select 4WD Car for Raspberry Pi mode. The operation is similar to Method 1.

Enter the IP address printed by serial port in the new interface, which generally is not "192.168.4.1" but another one. The IP address in this example is "192.168.1.100". After entering the IP address, click "Connect".



The following is the main program code. You need include other code files in the same folder when write your own code.

#### Sketch\_33.1\_Camera\_Tcp\_Server

```

1 #include "esp_camera.h"
2 #include <WiFi.h>
3 #include <WiFiClient.h>
4 #include <WiFiAP.h>
5
6 #define CAMERA_MODEL_ESP32S3_EYE

```

```
7 #include "camera_pins.h"
8 #define LED_BUILT_IN 2
9
10 const char *ssid_Router      = "*****";
11 const char *password_Router = "*****";
12 const char *ssid_AP         = "*****";
13 const char *password_AP     = "*****";
14
15 WiFiServer server_Cmd(5000);
16 WiFiServer server_Camera(8000);
17 extern TaskHandle_t loopTaskHandle;
18
19 void setup() {
20   Serial.begin(115200);
21   Serial.setDebugOutput(false);
22   Serial.println();
23   pinMode(LED_BUILT_IN, OUTPUT);
24   cameraSetup();
25
26   WiFi.softAP(ssid_AP, password_AP);
27   IPAddress myIP = WiFi.softAPIP();
28   Serial.print("AP IP address: ");
29   Serial.println(myIP);
30   server_Camera.begin(8000);
31   server_Cmd.begin(5000);
32   /////////////////////////////////
33   WiFi.begin(ssid_Router, password_Router);
34   Serial.print("Connecting ");
35   Serial.print(ssid_Router);
36   while (WiFi.isConnected() != true) {
37     delay(500);
38     Serial.print(".");
39   }
40   while (WiFi.STA.hasIP() != true) {
41     Serial.print(".");
42     delay(500);
43   }
44   Serial.println("");
45   Serial.println("WiFi connected");
46   /////////////////////////////////
47   Serial.print("Camera Ready! Use '");
48   Serial.print(WiFi.softAPIP());
49   Serial.print(" or ");
50   Serial.print(WiFi.localIP());
```

```

51   Serial.println(" to connect in Freenove app.");
52
53   disableCore0WDT();
54   xTaskCreateUniversal(loopTask_Cmd, "loopTask_Cmd", 8192, NULL, 1, &loopTaskHandle,
55   0); //loopTask_Cmd uses core 0.
56   xTaskCreateUniversal(loopTask_Blink, "loopTask_Blink", 8192, NULL, 1, &loopTaskHandle,
57   0); //loopTask_Blink uses core 0.
58 }
59 //task loop uses core 1.
60 void loop() {
61   WiFiClient client = server_Camera.available();           // listen for incoming clients
62   if (client) {                                            // if you get a client,
63     Serial.println("Camera Server connected to a client."); // print a message out the serial
64   port
65   String currentLine = ""; // make a String to hold incoming data from the client
66   while (client.connected()) { // loop while the client's connected
67     camera_fb_t * fb = NULL;
68     while (client.connected()) {
69       fb = esp_camera_fb_get();
70       if (fb != NULL) {
71         uint8_t slen[4];
72         slen[0] = fb->len >> 0;
73         slen[1] = fb->len >> 8;
74         slen[2] = fb->len >> 16;
75         slen[3] = fb->len >> 24;
76         client.write(slen, 4);
77         client.write(fb->buf, fb->len);
78         esp_camera_fb_return(fb);
79       }
80     }
81   }
82   // close the connection:
83   client.stop();
84   Serial.println("Camera Client Disconnected.");
85 }
86
87
88 void loopTask_Cmd(void *pvParameters) {
89   Serial.println("Task Cmd_Server is starting ... ");
90   while (1) {
91     WiFiClient client = server_Cmd.available(); // listen for incoming clients

```

```
92     if (client) {                                // if you get a client,
93         Serial.println("Command Server connected to a client."); // print a message out the
94         serial port
95         String currentLine = "";                  // make a String to hold incoming data from the client
96         while (client.connected()) {               // loop while the client's connected
97             if (client.available()) {              // if there's bytes to read from the client,
98                 char c = client.read();           // read a byte, then
99                 client.write(c);
100                Serial.write(c);                // print it out the serial monitor
101                if (c == '\n') {                  // if the byte is a newline character
102                    currentLine = "";
103                }
104                else {
105                    currentLine += c;            // add it to the end of the currentLine
106                }
107            }
108            // close the connection:
109            client.stop();
110            Serial.println("Command Client Disconnected.");
111        }
112    }
113 }
114 void loopTask_Blink(void *pvParameters) {
115     Serial.println("Task Blink is starting ... ");
116     while (1) {
117         digitalWrite(LED_BUILT_IN, !digitalRead(LED_BUILT_IN));
118         delay(1000);
119     }
120 }
121
122 void cameraSetup() {
123     camera_config_t config;
124     config.ledc_channel = LEDC_CHANNEL_0;
125     config.ledc_timer = LEDC_TIMER_0;
126     config.pin_d0 = Y2_GPIO_NUM;
127     config.pin_d1 = Y3_GPIO_NUM;
128     config.pin_d2 = Y4_GPIO_NUM;
129     config.pin_d3 = Y5_GPIO_NUM;
130     config.pin_d4 = Y6_GPIO_NUM;
131     config.pin_d5 = Y7_GPIO_NUM;
132     config.pin_d6 = Y8_GPIO_NUM;
133     config.pin_d7 = Y9_GPIO_NUM;
134     config.pin_xclk = XCLK_GPIO_NUM;
```



```

135 config.pin_pclk = PCLK_GPIO_NUM;
136 config.pin_vsync = VSYNC_GPIO_NUM;
137 config.pin_href = HREF_GPIO_NUM;
138 config.pin_sccb_sda = SIOD_GPIO_NUM;
139 config.pin_sccb_scl = SIOC_GPIO_NUM;
140 config.pin_pwdn = PWDN_GPIO_NUM;
141 config.pin_reset = RESET_GPIO_NUM;
142 config.xclk_freq_hz = 20000000;
143 config.frame_size = FRAMESIZE_UXGA;
144 config.pixel_format = PIXFORMAT_JPEG; // for streaming
145 config.grab_mode = CAMERA_GRAB_WHEN_EMPTY;
146 config.fb_location = CAMERA_FB_IN_PSRAM;
147 config.jpeg_quality = 12;
148 config.fb_count = 1;
149
150 // if PSRAM IC present, init with UXGA resolution and higher JPEG quality
151 // for larger pre-allocated frame buffer.
152 if(psramFound()){
153     config.jpeg_quality = 10;
154     config.fb_count = 2;
155     config.grab_mode = CAMERA_GRAB_LATEST;
156 } else {
157     // Limit the frame size when PSRAM is not available
158     config.frame_size = FRAMESIZE_SVGA;
159     config.fb_location = CAMERA_FB_IN_DRAM;
160 }
161
162 // camera init
163 esp_err_t err = esp_camera_init(&config);
164 if (err != ESP_OK) {
165     Serial.printf("Camera init failed with error 0x%x", err);
166     return;
167 }
168
169 sensor_t * s = esp_camera_sensor_get();
170 // initial sensors are flipped vertically and colors are a bit saturated
171 s->set_vflip(s, 1); // flip it back
172 s->set_brightness(s, 1); // up the brightness just a bit
173 s->set_saturation(s, 0); // lower the saturation
174
175 Serial.println("Camera configuration complete!");
176 }
```

Include header files that drive camera and WiFi.

```

1 #include "esp_camera.h"
2 #include <WiFi.h>
3 #include <WiFiClient.h>
4 #include <WiFiAP.h>
5
6 #define CAMERA_MODEL_ESP32S3_EYE
7 #include "camera_pins.h"
```

Set name and password for router that ESP32-S3 needs to connect to. And set ESP32-S3 to open two servers, whose port are 8000 and 5000 respectively.

```

10 const char *ssid_Router      = "*****";
11 const char *password_Router = "*****";
12 const char *ssid_AP         = "*****";
13 const char *password_AP    = "*****";
```

Enable ESP32-S3's server function and set two monitor ports as 5000 and 8000. In general, the two port numbers do not require modifications.

```

15 WiFiServer server_Cmd(5000);
16 WiFiServer server_Camera(8000);
17 extern TaskHandle_t loopTaskHandle;
```

Initialize serial port, set baud rate to 115200; open the debug and output function of the serial.

```

20 Serial.begin(115200);
21 Serial.setDebugOutput(true);
22 Serial.println();
```

Define a variable for camera interface and initialize it.

```

119 void cameraSetup() {
120     camera_config_t config;
121     config.ledc_channel = LEDC_CHANNEL_0;
122     config.ledc_timer = LEDC_TIMER_0;
123     config.pin_d0 = Y2_GPIO_NUM;
124     config.pin_d1 = Y3_GPIO_NUM;
125     config.pin_d2 = Y4_GPIO_NUM;
126     config.pin_d3 = Y5_GPIO_NUM;
127     config.pin_d4 = Y6_GPIO_NUM;
128     config.pin_d5 = Y7_GPIO_NUM;
129     config.pin_d6 = Y8_GPIO_NUM;
130     config.pin_d7 = Y9_GPIO_NUM;
131     config.pin_xclk = XCLK_GPIO_NUM;
132     config.pin_pclk = PCLK_GPIO_NUM;
133     config.pin_vsync = VSYNC_GPIO_NUM;
134     config.pin_href = HREF_GPIO_NUM;
135     config.pin_sccb_sda = SIOD_GPIO_NUM;
136     config.pin_sccb_scl = SIOC_GPIO_NUM;
137     config.pin_pwdn = PWDN_GPIO_NUM;
138     config.pin_reset = RESET_GPIO_NUM;
```

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```

139 config.xclk_freq_hz = 20000000;
140 config.frame_size = FRAMESIZE_UXGA;
141 config.pixel_format = PIXFORMAT_JPEG; // for streaming
142 config.grab_mode = CAMERA_GRAB_WHEN_EMPTY;
143 config.fb_location = CAMERA_FB_IN_PSRAM;
144 config.jpeg_quality = 12;
145 config.fb_count = 1;
146
147 // if PSRAM IC present, init with UXGA resolution and higher JPEG quality
148 // for larger pre-allocated frame buffer.
149 if(psramFound()) {
150     config.jpeg_quality = 10;
151     config.fb_count = 2;
152     config.grab_mode = CAMERA_GRAB_LATEST;
153 } else {
154     // Limit the frame size when PSRAM is not available
155     config.frame_size = FRAMESIZE_SVGA;
156     config.fb_location = CAMERA_FB_IN_DRAM;
157 }
158
159 // camera init
160 esp_err_t err = esp_camera_init(&config);
161 if (err != ESP_OK) {
162     Serial.printf("Camera init failed with error 0x%x", err);
163     return;
164 }
165
166 sensor_t * s = esp_camera_sensor_get();
167 // initial sensors are flipped vertically and colors are a bit saturated
168 s->set_vflip(s, 1); // flip it back
169 s->set_brightness(s, 1); // up the brightness just a bit
170 s->set_saturation(s, 0); // lower the saturation
171
172 Serial.println("Camera configuration complete!");
173 }
```

Loop function will constantly send camera data obtained to mobile phone APP.

```

60     while (client.connected()) {
61         fb = esp_camera_fb_get();
62         if (fb != NULL) {
63             uint8_t slen[4];
64             slen[0] = fb->len >> 0;
65             slen[1] = fb->len >> 8;
66             slen[2] = fb->len >> 16;
```

```
67     slen[3] = fb->len >> 24;
68     client.write(slen, 4);
69     client.write(fb->buf, fb->len);
70     esp_camera_fb_return(fb);
71 }
72 else {
73     Serial.println("Camera Error");
74 }
75 }
```

The loopTask\_Cmd() function sends the received instruction back to the phone app and prints it out through a serial port.

```
85 void loopTask_Cmd(void *pvParameters) {
86     Serial.println("Task Cmd_Server is starting ... ");
87     while (1) {
88         WiFiClient client = server_Cmd.available(); // listen for incoming clients
89         if (client) { // if you get a client,
90             Serial.println("Command Server connected to a client."); // print a message out the
91             // serial port
92             String currentLine = ""; // make a String to hold incoming data from the client
93             while (client.connected()) { // loop while the client's connected
94                 if (client.available()) { // if there's bytes to read from the client,
95                     char c = client.read(); // read a byte, then
96                     client.write(c); // print it out the serial monitor
97                     if (c == '\n') { // if the byte is a newline character
98                         currentLine = "";
99                     }
100                 else {
101                     currentLine += c; // add it to the end of the currentLine
102                 }
103             }
104         }
105         // close the connection:
106         client.stop();
107         Serial.println("Command Client Disconnected.");
108     }
109 }
110 }
```



loopTask\_Blink()function will control the blinking of LED. When you see LED blinking, it indicates that ESP32-S3 has been configured and starts working.

```
112 void loopTask_Blink(void *pvParameters) {  
113     Serial.println("Task Blink is starting ... ");  
114     while (1) {  
115         digitalWrite(LED_BUILT_IN, !digitalRead(LED_BUILT_IN));  
116         delay(1000);  
117     }  
118 }
```

If you do not have a router near you, or if you are outdoors, you can annotate the following code, and then compile and upload it to ESP32-S3. And you can display the video images on your phone by Method 1.

```
32 //////////////////////////////////////////////////////////////////  
33 WiFi.begin(ssid_Router, password_Router);  
34 Serial.print("Connecting ");  
35 Serial.print(ssid_Router);  
36 while (WiFi.isConnected() != true) {  
37     delay(500);  
38     Serial.print(".");  
39 }  
40 while (WiFi.STA.hasIP() != true) {  
41     Serial.print(".");  
42     delay(500);  
43 }  
44 Serial.println("");  
45 Serial.println("WiFi connected");  
46 //////////////////////////////////////////////////////////////////
```

# Chapter 34 Soldering Circuit Board

## Project 34.1 Soldering a Buzzer

We have tried to use a buzzer in a previous chapter, and now we will solder a circuit that when the button is pressed, the buzzer sounds.

This circuit does not need programming and can work when it is powered on. And when the button is not pressed, there is no power consumption.

You can install it on your bike, bedroom door or any other places where it is needed.

### Component List

Pin header x2	LED x1	Resistor 220Ω x1	Active buzzer x1	Push button x1
				

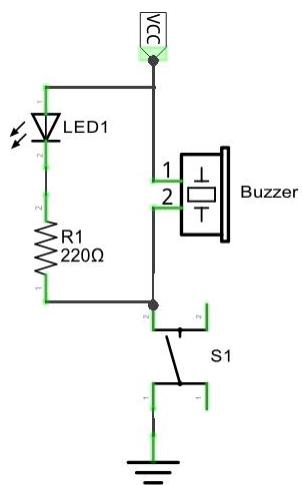
  

AA Battery Holder x1


## Circuit

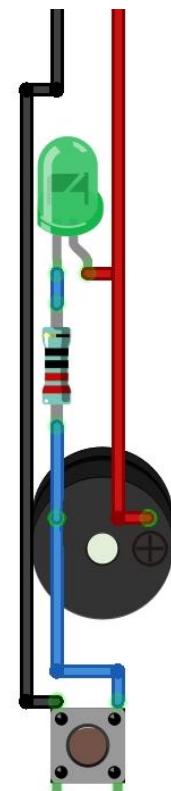
We will solder the following circuit on the main board.

Schematic diagram



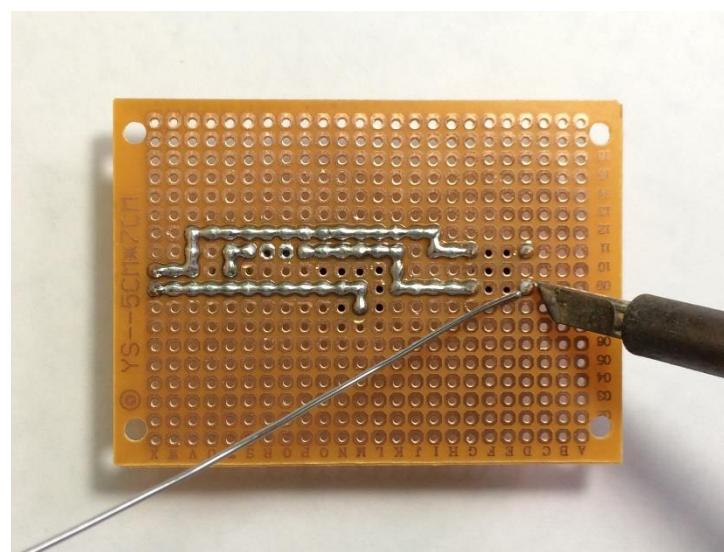
Hardware connection.

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

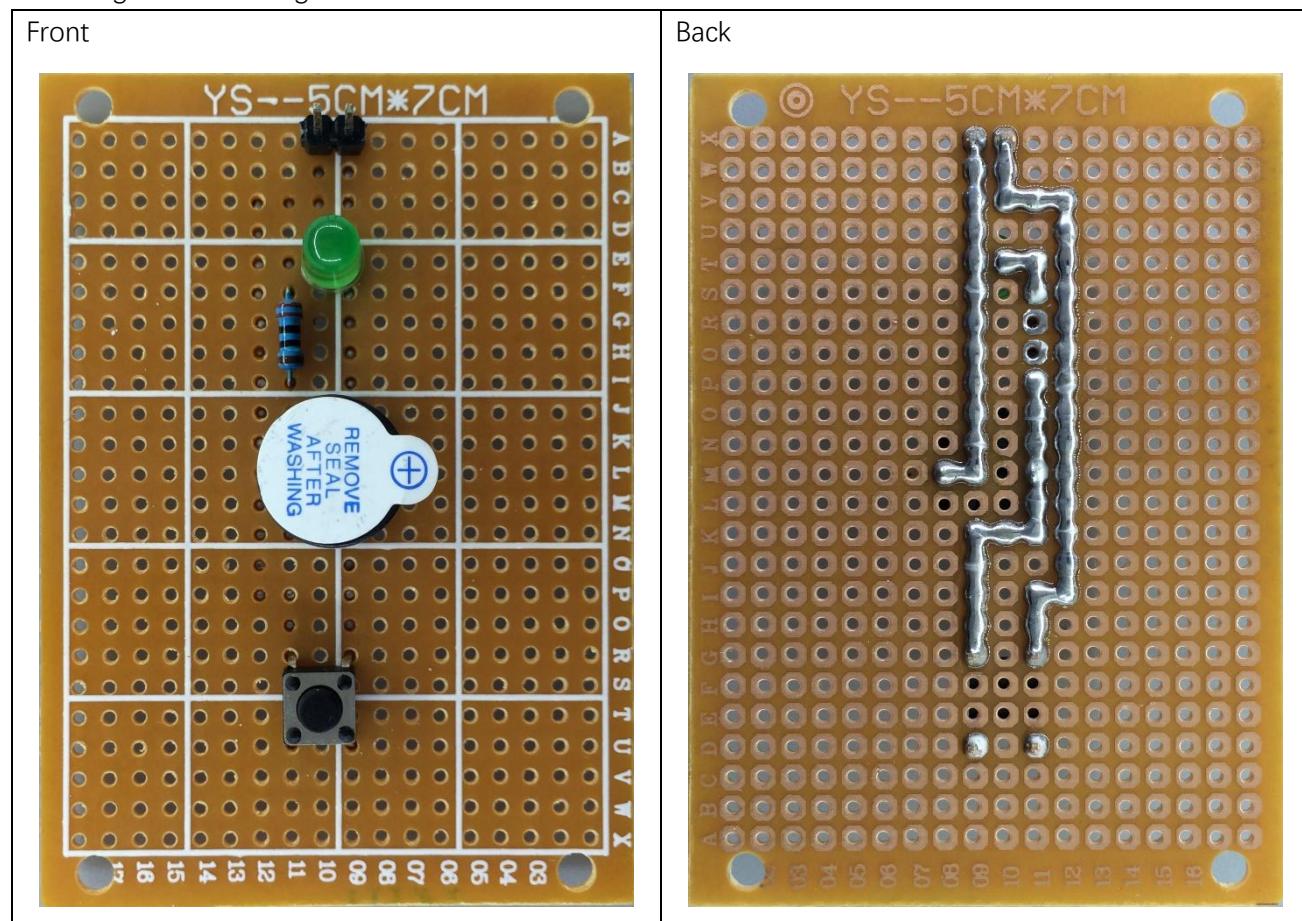


## Soldering the Circuit

Insert the components on the main board and solder the circuit on its back.

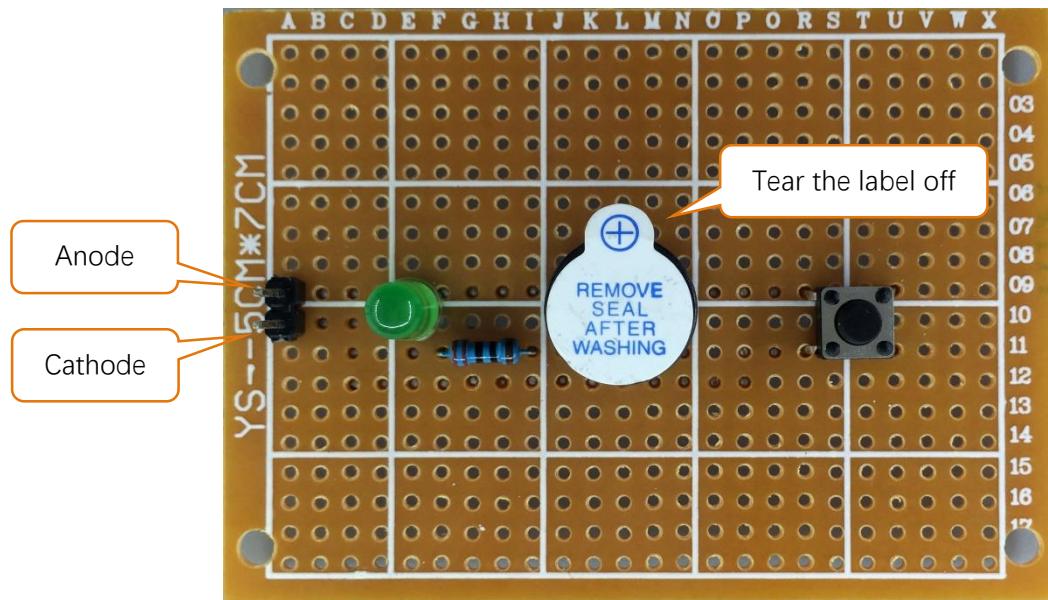


rendering after soldering:



## Testing circuit

Connect the circuit board to power supply (3~5V). You can use ESP32-S3 board or battery box as the power supply.



Press the push button after connecting the power, and then the buzzer will make a sound.

## Project 34.2 Soldering a Flowing Water Light

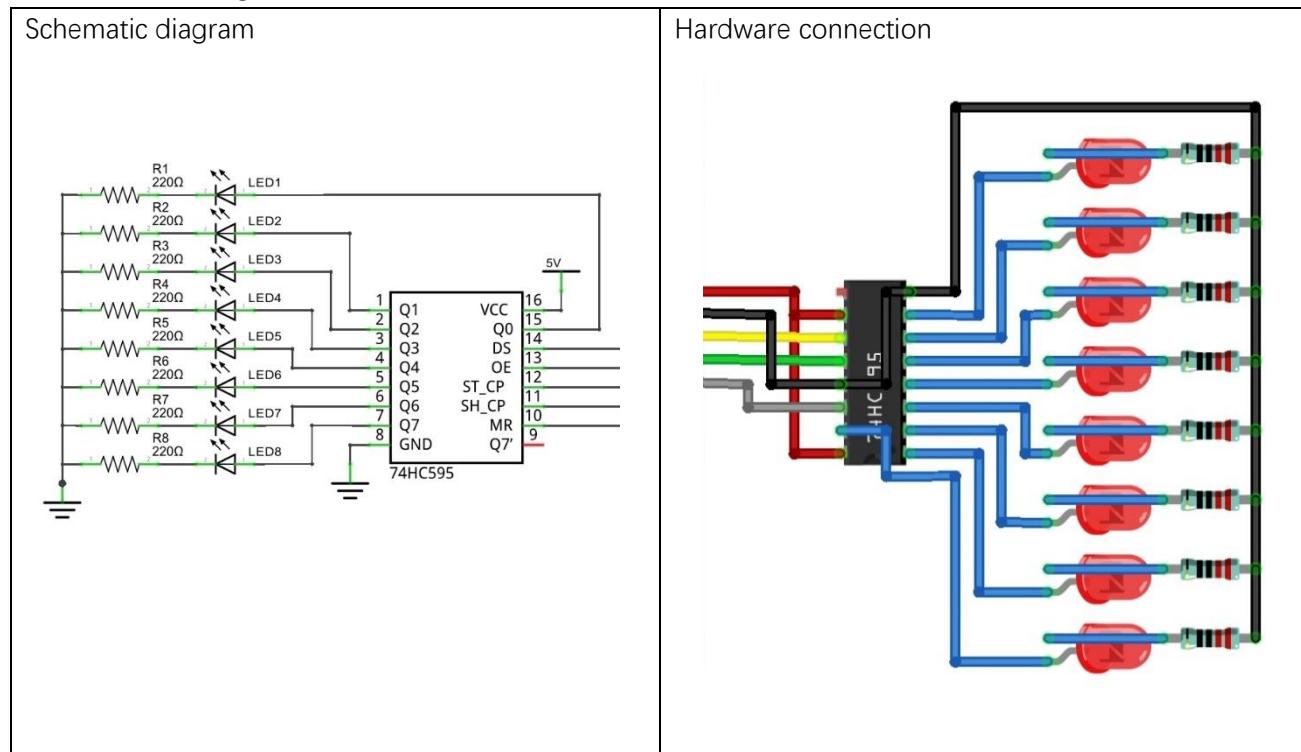
From previous chapter, we have learned to make a flowing water light with LED. Now, we will solder a circuit board, and use the improved code to make a more interesting flowing water light.

### Component List

Pin header x5	Resistor 220Ω x8	LED x1	74HC595 x1

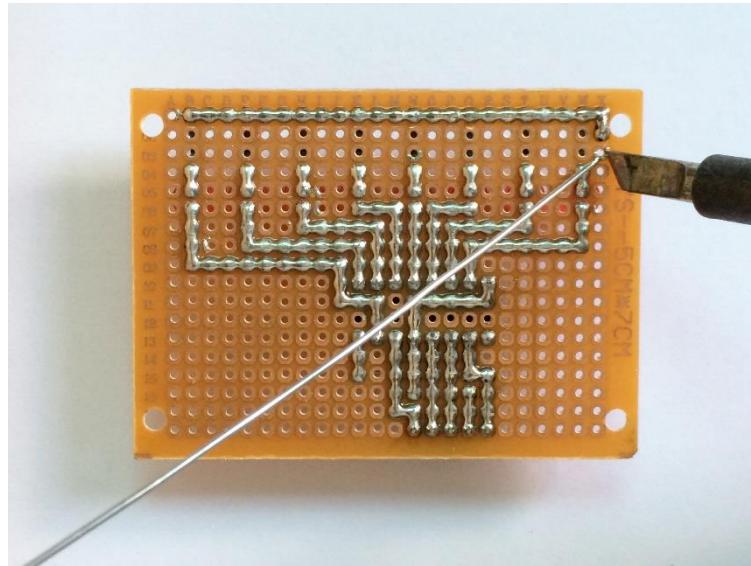
### Circuit

Solder the following circuit on the main board.

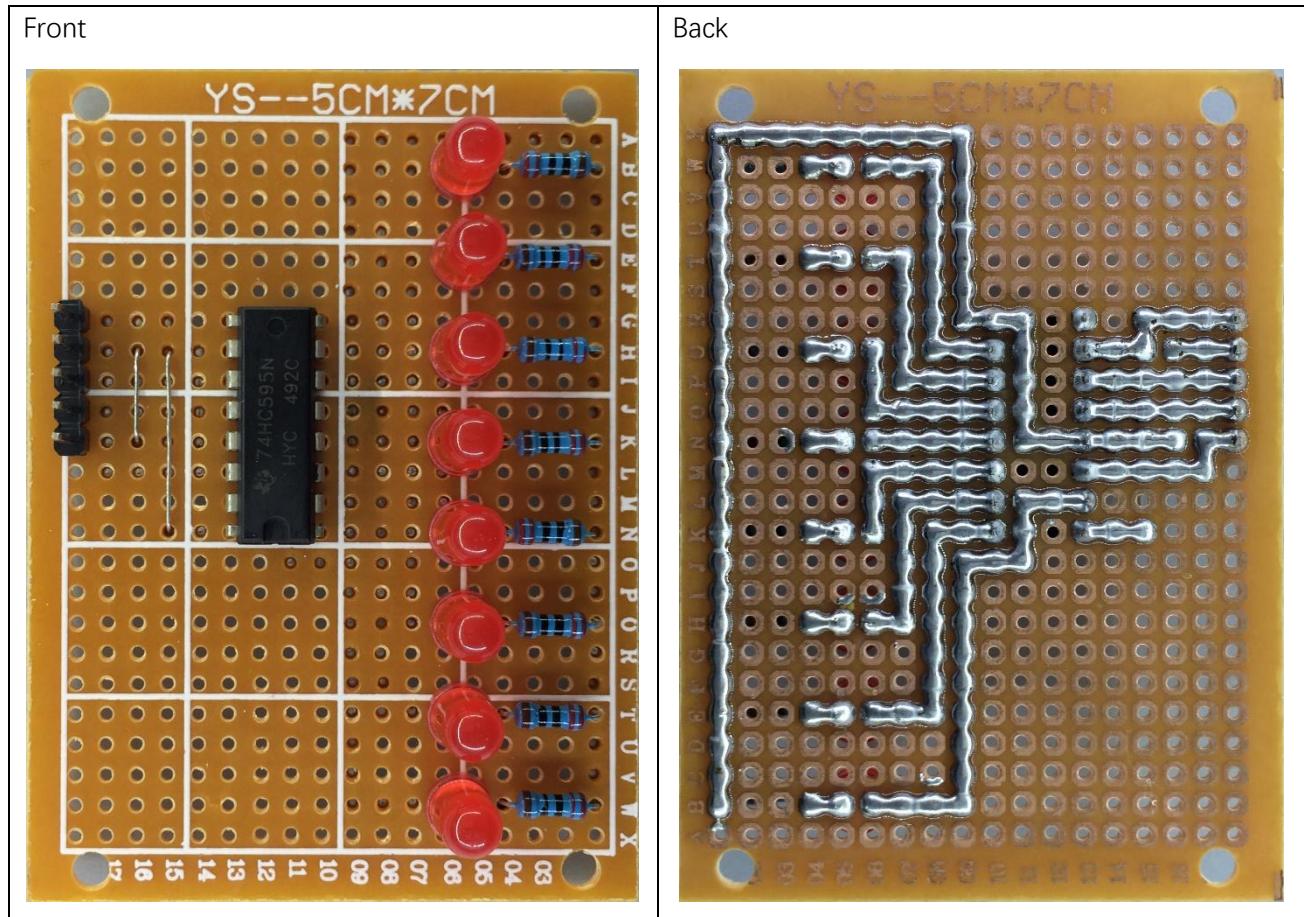


## Soldering the Circuit

Insert the components on the main board and solder the circuit on its back.

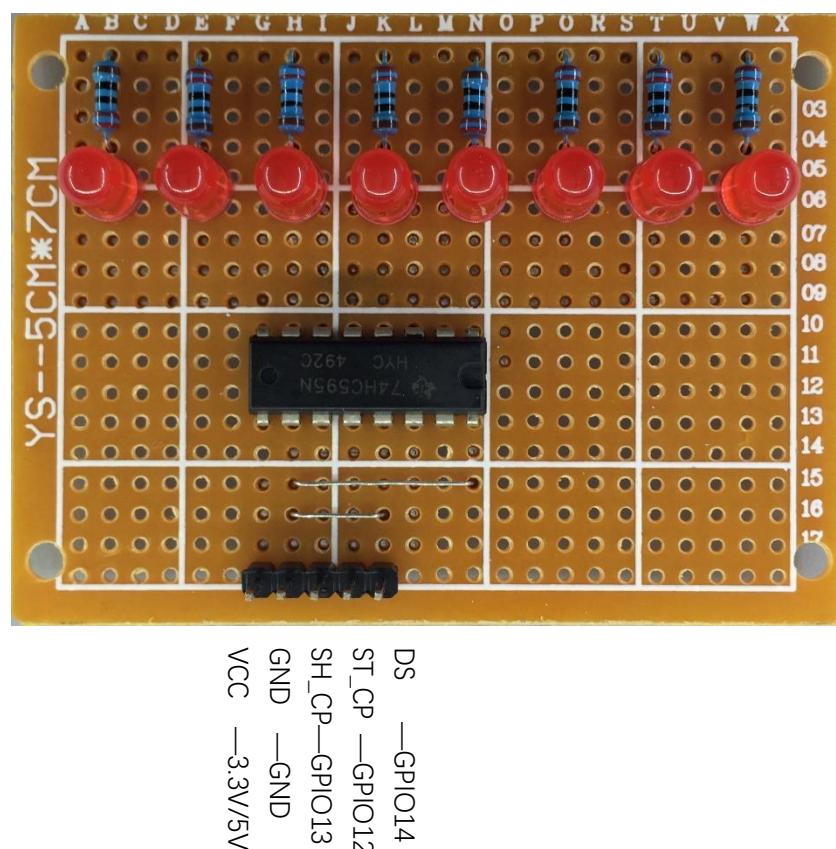


Rendering after soldering:



## Connecting the Circuit

Connect the board to ESP32-S3 with jumper wire in the following way.



## Sketch

The following is the program code:

```
1 int latchPin = 13          // Pin connected to ST_CP of 74HC595(Pin12)
2 int clockPin = 14          // Pin connected to SH_CP of 74HC595(Pin13)
3 int dataPin = 12           // Pin connected to DS of 74HC595(Pin14)
4
5 void setup() {
6     // set pins to output
7     pinMode(latchPin, OUTPUT);
8     pinMode(clockPin, OUTPUT);
9     pinMode(dataPin, OUTPUT);
10 }
11
12 void loop() {
13     // Define a one-byte variable to use the 8 bits to represent the state of 8 LEDs of LED bar
```

```
graph.  
15 // This variable is assigned to 0x01, that is, binary 00000001, which indicates only one LED light  
16 on.  
17 byte x = 0x01;      // 0b 0000 0001  
18 for (int j = 0; j < 8; j++) { // Let LED light up from right to left  
19     writeTo595(LSBFIRST, x);  
20     x <<= 1; // make the variable move one bit to left once, then the bright LED move one step  
21 to the left once.  
22     delay(50);  
23 }  
24 delay(100);  
25 x = 0x80;          //0b 1000 0000  
26 for (int j = 0; j < 8; j++) { // Let LED light up from left to right  
27     writeTo595(LSBFIRST, x);  
28     x >>= 1;  
29     delay(50);  
30 }  
31 delay(100);  
32 }  
33 void writeTo595(int order, byte _data) {  
34     // Output low level to latchPin  
35     digitalWrite(latchPin, LOW);  
36     // Send serial data to 74HC595  
37     shiftOut(dataPin, clockPin, order, _data);  
38     // Output high level to latchPin, and 74HC595 will update the data to the parallel output  
39     port.  
40     digitalWrite(latchPin, HIGH);  
41 }
```

In fact, this code is copied from chapter 15. If you have any questions for the code, please click "[Chapter 15 74HC595 & LED Bar Graph](#)" to return to Chapter 15 to study again.

## 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 are interesting in processing, you can learn the Processing.pdf in:

**Freenove\_Ultimate\_Starter\_Kit\_for\_ESP32\_S3\C\Processing.pdf**

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## End of the Tutorial

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