

Important Information

Thank you for choosing Freenove products!

Getting Started

First, please read the **Read Me First.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.

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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:

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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.**
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- 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



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>

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Preface

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

ESP32 can be developed using the Arduino platform, which will definitely make it easier for people who have learned Arduino to master. Moreover, the code of ESP32 is completely open-source, so beginners can quickly learn how to develop and design IOT smart household products including smart curtains, fans, lamps and clocks.

Generally, ESP32 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

ESP32-WROVER

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

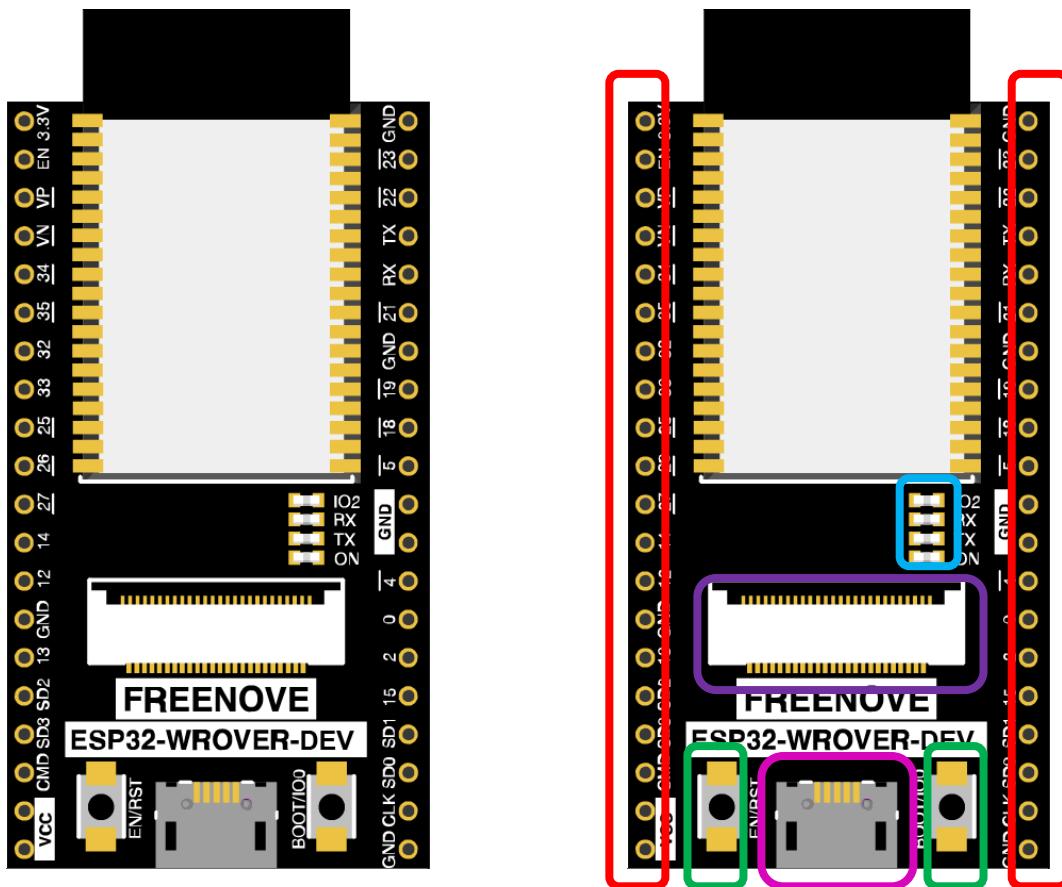


In this tutorial, the ESP32-WROVER is designed based on the PCB on-board antenna-packaged ESP32-WROVER module.

ESP32-WROVER



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



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

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

Name	No.	Type	Function
GND	1	P	Ground
3V3	2	P	Power supply
EN	3	I	Module-enable signal. Active high.
SENSOR_VP	4	I	GPIO36, ADC1_CH0, RTC_GPIO0
SENSOR_VN	5	I	GPIO39, ADC1_CH3, RTC_GPIO3
IO34	6	I	GPIO34, ADC1_CH6, RTC_GPIO4
IO35	7	I	GPIO35, ADC1_CH7, RTC_GPIO5
IO32	8	I/O	GPIO32, XTAL_32K_P (32.768 kHz crystal oscillator input), ADC1_CH4, TOUCH9, RTC_GPIO9
IO33	9	I/O	GPIO33, XTAL_32K_N (32.768 kHz crystal oscillator output), ADC1_CH5, TOUCH8, RTC_GPIO8
IO25	10	I/O	GPIO25, DAC_1, ADC2_CH8, RTC_GPIO6, EMAC_RXD0
IO26	11	I/O	GPIO26, DAC_2, ADC2_CH9, RTC_GPIO7, EMAC_RXD1
IO27	12	I/O	GPIO27, ADC2_CH7, TOUCH7, RTC_GPIO17, EMAC_RX_DV
IO14	13	I/O	GPIO14, ADC2_CH6, TOUCH6, RTC_GPIO16, MTMS, HSPICLK, HS2_CLK, SD_CLK, EMAC_TXD2
IO12 ¹	14	I/O	GPIO12, ADC2_CH5, TOUCH5, RTC_GPIO15, MTDI, HSPIQ, HS2_DATA2, SD_DATA2, EMAC_TXD3
GND	15	P	Ground
IO13	16	I/O	GPIO13, ADC2_CH4, TOUCH4, RTC_GPIO14, MTCK, HSPID, HS2_DATA3, SD_DATA3, EMAC_RX_ER
SHD/SD2 ²	17	I/O	GPIO9, SD_DATA2, SPIHD, HS1_DATA2, U1RXD
SWP/SD3 ²	18	I/O	GPIO10, SD_DATA3, SPIWP, HS1_DATA3, U1TXD
SCS/CMD ²	19	I/O	GPIO11, SD_CMD, SPICS0, HS1_CMD, U1RTS
SCK/CLK ²	20	I/O	GPIO6, SD_CLK, SPICLK, HS1_CLK, U1CTS
SDO/SD0 ²	21	I/O	GPIO7, SD_DATA0, SPIQ, HS1_DATA0, U2RTS
SDI/SD1 ²	22	I/O	GPIO8, SD_DATA1, SPID, HS1_DATA1, U2CTS
IO15	23	I/O	GPIO15, ADC2_CH3, TOUCH3, MTDO, HSPICS0, RTC_GPIO13, HS2_CMD, SD_CMD, EMAC_RXD3
IO2	24	I/O	GPIO2, ADC2_CH2, TOUCH2, RTC_GPIO12, HSPIWP, HS2_DATA0, SD_DATA0
IO0	25	I/O	GPIO0, ADC2_CH1, TOUCH1, RTC_GPIO11, CLK_OUT1, EMAC_TX_CLK
IO4	26	I/O	GPIO4, ADC2_CH0, TOUCH0, RTC_GPIO10, HSPIHD, HS2_DATA1, SD_DATA1, EMAC_TX_ER
NC1	27	-	-
NC2	28	-	-
IO5	29	I/O	GPIO5, VSPICS0, HS1_DATA6, EMAC_RX_CLK
IO18	30	I/O	GPIO18, VSPICLK, HS1_DATA7
IO19	31	I/O	GPIO19, VSPIQ, U0CTS, EMAC_TXD0
NC	32	-	-
IO21	33	I/O	GPIO21, VSPIHD, EMAC_TX_EN
RXD0	34	I/O	GPIO3, U0RXD, CLK_OUT2
TXD0	35	I/O	GPIO1, U0TXD, CLK_OUT3, EMAC_RXD2
IO22	36	I/O	GPIO22, VSPIWP, U0RTS, EMAC_TXD1
IO23	37	I/O	GPIO23, VSPID, HS1_STROBE
GND	38	P	Ground

Notice:

1. GPIO12 is internally pulled high in the module and is not recommended for use as a touch pin.
2. Pins SCK/CLK, SDO/SD0, SDI/SD1, SHD/SD2, SWP/SD3 and SCS/CMD, namely, GPIO6 to GPIO11 are connected to the SPI flash integrated on the module and are not recommended for other uses.

For more information, please visit: https://www.espressif.com/sites/default/files/documentation/esp32-wrover_datasheet_en.pdf

Any concerns? ✉ support@freenove.com

Extension board of the ESP32-WROVER

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

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



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

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

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

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

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

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

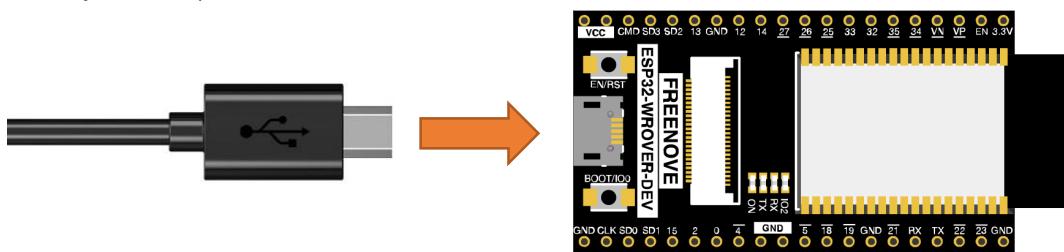
CH340 (Importance)

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

Windows

Check whether CH340 has been installed

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



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



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



Installing CH340

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

index / search / search CH340

All (14)

Downloads (7)

Products (4)

Application (2)

Video (1)

News (0)

keyword CH340

Downloads(7)

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

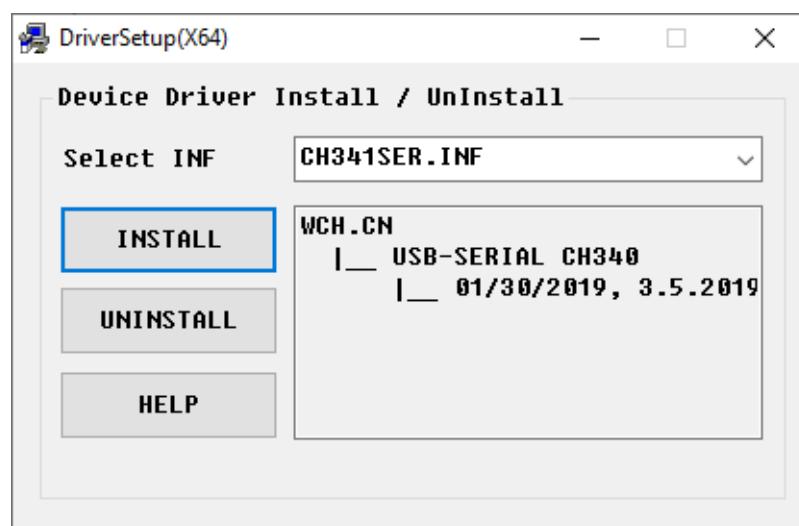
If you would not like to download the installation package, you can open “[Freenove_Ultimate_Starter_Kit_for_ESP32/CH340](#)”, we have prepared the installation package.

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

2. Open the folder “**Freenove_Ultimate_Starter_Kit_for_ESP32/CH340/Windows/**”



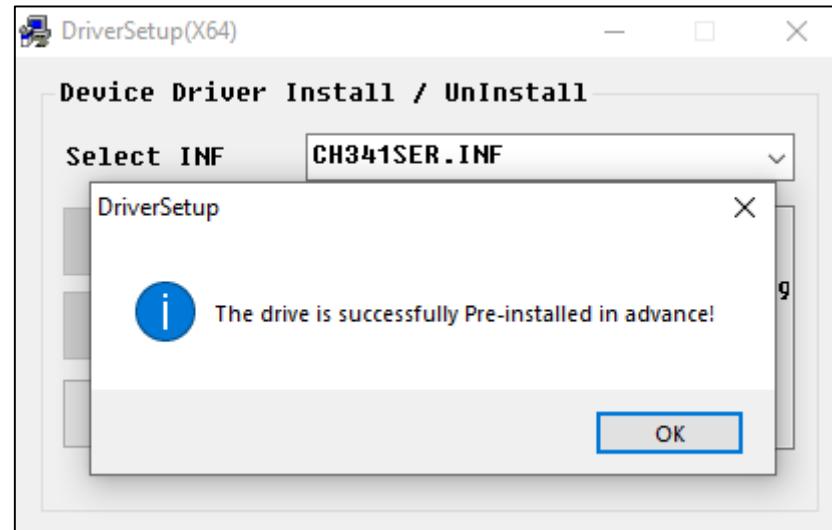
3. Double click “**CH341SER.EXE**”.



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



5. Install successfully. Close all interfaces.



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



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

MAC

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

The screenshot shows a search results page for 'ch340' on the WCH website. The left sidebar has categories: All (14), Downloads (7), Products (4), Application (2), Video (1), and News (0). The main area shows a table of search results with columns: file category, file content, version, and upload time. The results are categorized by file content: Windows, Linux, and MAC. An orange callout points to the Windows row, another to the Linux row, and a third to the MAC row.

file category	file content	version	upload time
Driver&Tools	CH341SER.EXE CH340/CH341 USB to serial port Windows driver, supports 32/64-bit Windows 10/8.1/8/7/VISTA/XP, Server 2016/2012/2008/2003, 2000/ME/98	3.5	2019-03-18
	CH341SER.ZIP CH340/CH341 USB to serial port Windows driver, includes DLL dynamic library and non-standard baud rate settings and other instructions. Supports 32/64-bit Windows 10/8.1/8/7/VISTA/XP, Server 2016/2012/2008/2003, 2000/ME/98	3.5	2019-03-05
	CH341SER_ANDROID... CH340/CH341 USB to serial port Android free drive application library, for Android OS 3.1 and above version which supports USB Host mode already, no need to load Android kernel driver, no root privileges. Contains apk, lib library file (Java Driver), App Demo Examples, and FTDI Demo SDK.	1.6	2019-04-19
	CH341SER_LINUX... CH340/CH341 USB to serial port LINUX driver	1.5	2018-03-18
	CH341SER_MAC.ZI... CH340/CH341 USB to serial port MAC OS driver	1.5	2018-07-05
	Others		

If you would not like to download the installation package, you can open "Freenove_Ultimate_Starter_Kit_for_ESP32/CH340", we have prepared the installation package. Second, open the folder "Freenove_Ultimate_Starter_Kit_for_ESP32/CH340/MAC/"

The screenshot shows a Mac Finder window with a sidebar containing Favorites (AirDrop, Recents, Applications, Desktop, Documents, Downloads), iCloud (iCloud Drive), Tags, Locations, and Network. The main pane is titled 'MAC' and contains two files: 'CH34x_Install_V1.5.pkg' (Installer package, 26 KB) and 'ReadMe.pdf' (Adobe...document, 146 KB). An orange callout points to the 'Run it.' button in the toolbar.

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

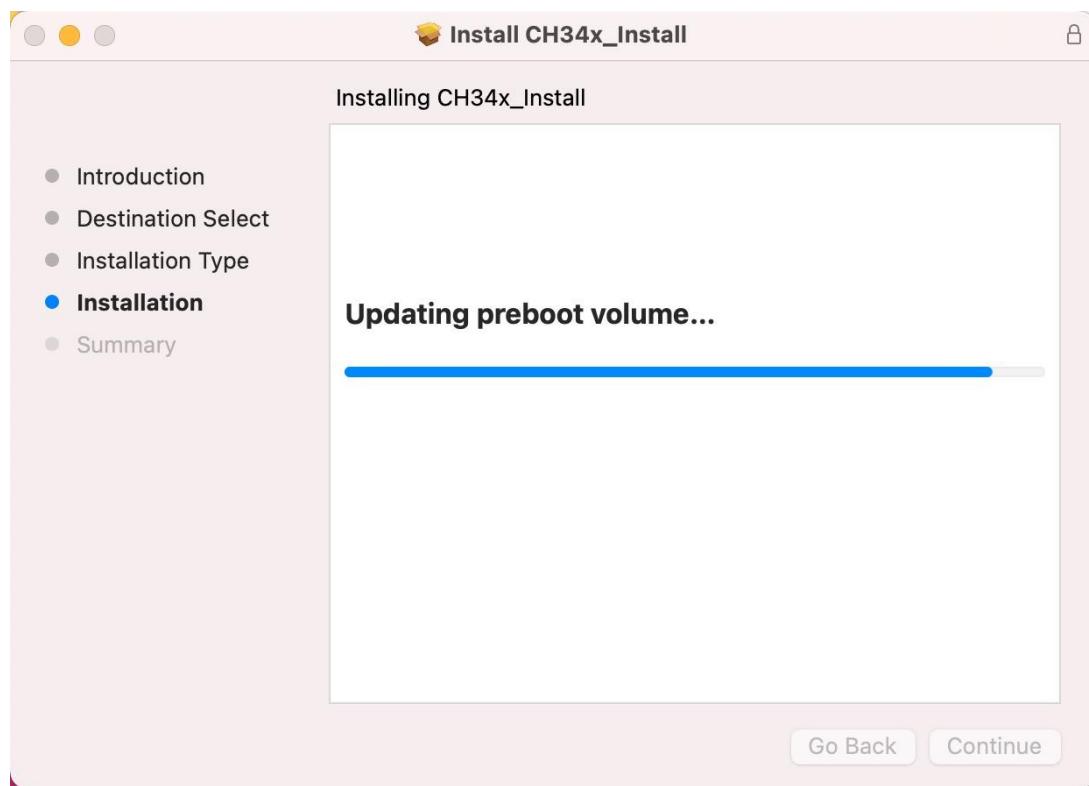
Third, click Continue.



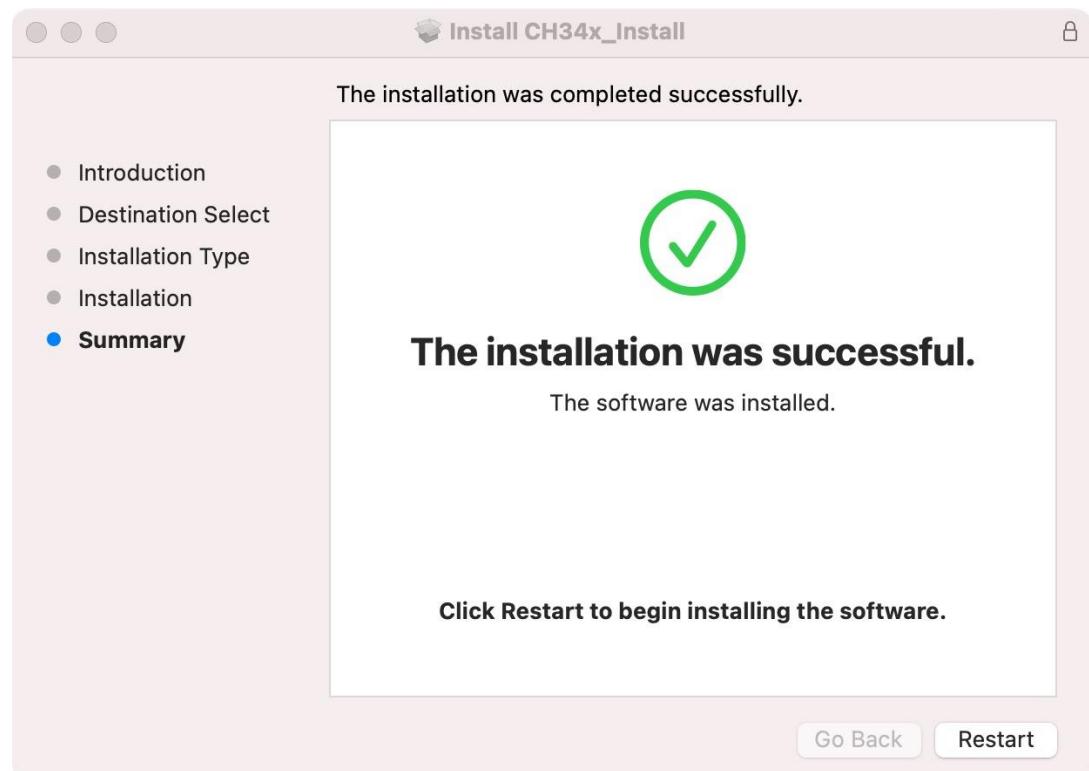
Fourth, click Install.



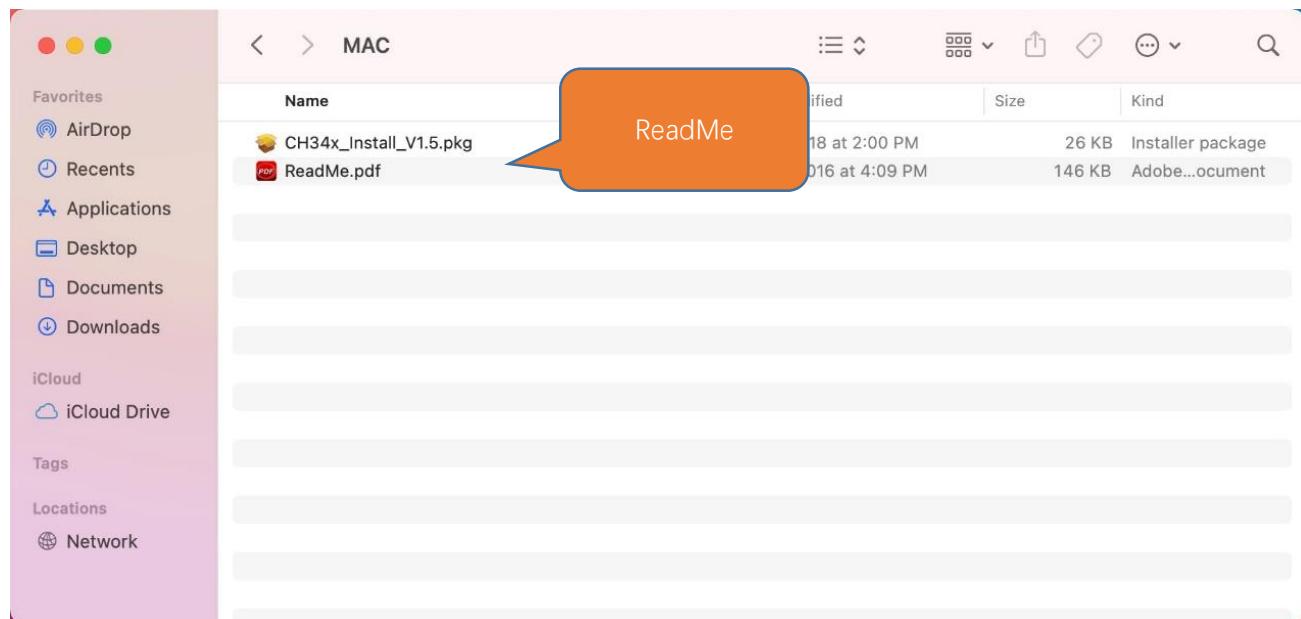
Then, waiting Finsh.



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.

Download the Arduino IDE

ARDUINO 1.8.12

The open-source Arduino Software (IDE) makes it easy to write code and upload it to the board. It runs on Windows, Mac OS X, and Linux. The environment is written in Java and based on Processing and other open-source software.

This software can be used with any Arduino board. Refer to the [Getting Started](#) page for installation instructions.

Windows **Installer**, for Windows XP and up
Windows **ZIP file** for non admin install

Windows **app** Requires Win 8.1 or 10
[Get](#)

Mac OS X 10.8 Mountain Lion or newer

Linux 32 bits
Linux 64 bits
Linux ARM 32 bits
Linux ARM 64 bits

[Release Notes](#)
[Source Code](#)
[Checksums \(sha512\)](#)

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.



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.



New

Create a new sketch.



Open

Present a menu of all the sketches in your sketchbook. Clicking one will open it within the current window and overwrite its content.



Save

Save your sketch.



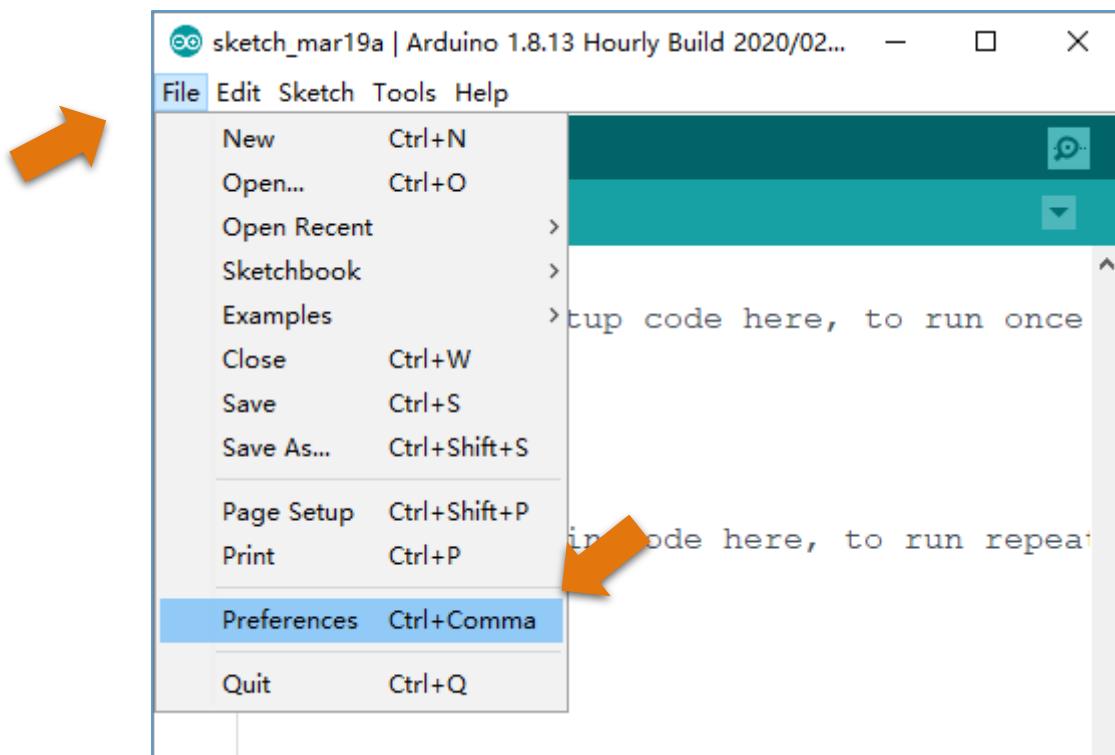
Serial Monitor

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 in the new window, click OK, and click OK on the Preferences window again.



Fourth, click Tools in Menus, select Board:"ArduinoUno", and then select "Boards Manager".



Fifth, input "esp32" in the window below, and press Enter. click "Install" to install.



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



Notes for GPIO

Strapping Pin

There are five Strapping pins for ESP32: MTDI、GPIO0、GPIO2、MTDO、GPIO5.

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'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 five strapping pins at power-on and their functions under the corresponding configuration.

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

Note:

- Firmware can configure register bits to change the settings of "Voltage of Internal LDO (VDD_SDIO)" and "Timing of SDIO Slave" after booting.
- The MTDI is internally pulled high in the module, as the flash and SRAM in ESP32-WROVER only support a power voltage of 1.8 V (output by VDD_SDIO).

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

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

or check: https://www.espressif.com/sites/default/files/documentation/esp32-wrover_datasheet_en.pdf

Any concerns? ✉ support@freenove.com



Flash Pin

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

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

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

For more relevant information, please check:

https://www.espressif.com/sites/default/files/documentation/esp32-wrover_datasheet_en.pdf.

Cam Pin

When using the camera of our ESP32-WROVER, 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
I2C_SDA	GPIO26
I2C_SCL	GPIO27
CSI_VSYNC	GPIO25
CSI_HREF	GPIO23
CSI_Y9	GPIO35
XCLK	GPIO21
CSI_Y8	GPIO34
CSI_Y7	GPIO39
CSI_PCLK	GPIO22
CSI_Y6	GPIO36
CSI_Y2	GPIO4
CSI_Y5	GPIO19
CSI_Y3	GPIO5
CSI_Y4	GPIO18

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

or check: https://www.espressif.com/sites/default/files/documentation/esp32-wrover_datasheet_en.pdf.

Chapter 0 LED

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

Project 0.1 Blink

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

Component List



Power

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



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

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

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

Sketch

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

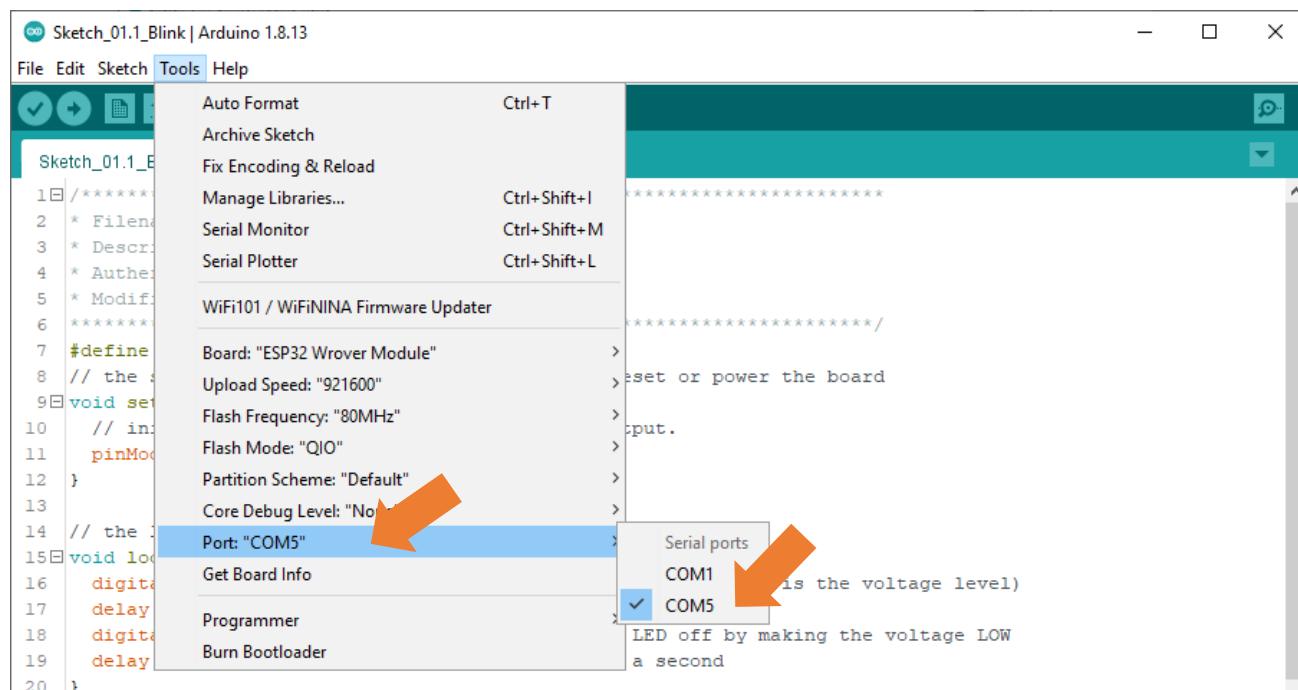
Upload the following Sketch:

Freenove_Ultimate_Starter_Kit_for_ESP32\Sketches\Sketch_01.1_Blink.

Before uploading the code, click "Tools", "Board" and select "ESP32 Wrover Module".



Select the serial port.



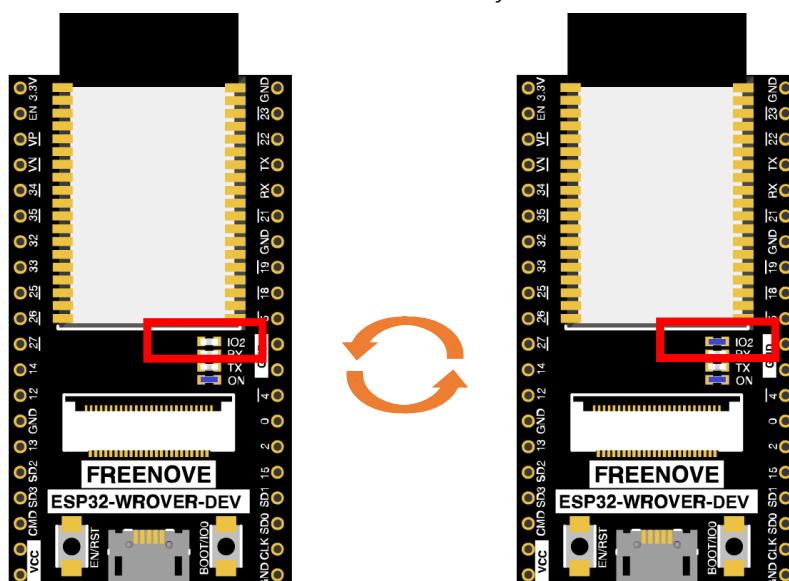
Note: For macOS users, if the uploading fails, please set the baud rate to 115200 before clicking “Upload Using Programmer”.



Sketch_01.1_Blink



Click “Upload”, Download the code to ESP32-WROVER and your LED in the circuit starts Blink.



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Any concerns? ✉ support@freenove.com

The following is the program code:

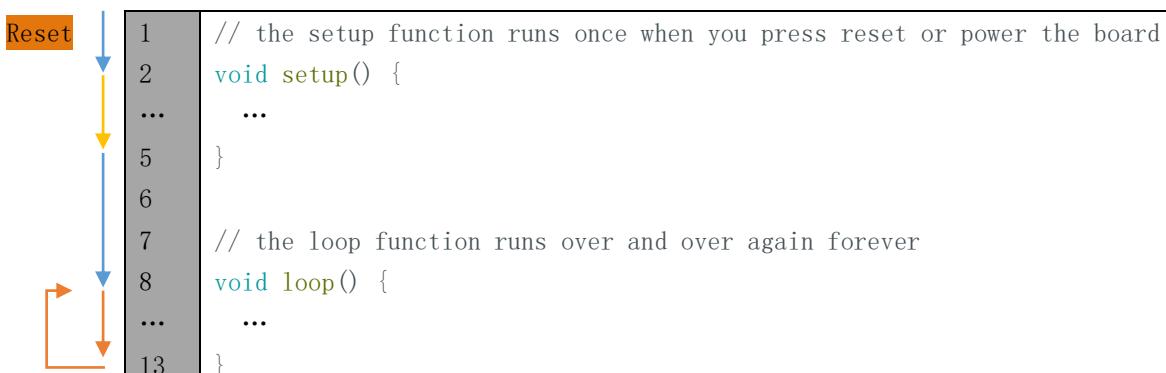
```

1 #define PIN_LED 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(PIN_LED, OUTPUT);
6 }
7
8 // the loop function runs over and over again forever
9 void loop() {
10    digitalWrite(PIN_LED, HIGH); // turn the LED on (HIGH is the voltage level)
11    delay(1000); // wait for a second
12    digitalWrite(PIN_LED, 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

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-WROVER's GPIO2 is connected to the LED, so the LED pin is defined as 2.

```
1 #define PIN_LED 2
```

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

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

```

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

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

```
10 digitalWrite(PIN_LED, 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 PIN_LED to output low level, and LED light off. One second later, the execution of loop () function will be completed.

```
12     digitalWrite(PIN_LED, 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/>

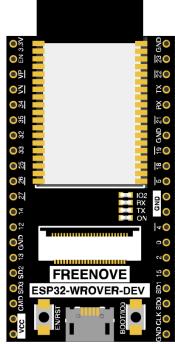
Chapter 1 LED

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

Project 1.1 Blink

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

Component List

ESP32-WROVER 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 (Ω) as the unit of measurement of their resistance (R). $1M\Omega=1000k\Omega$, $1k\Omega=1000\Omega$.

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



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

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

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

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

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

Breadboard

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



Power

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



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

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

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

Circuit

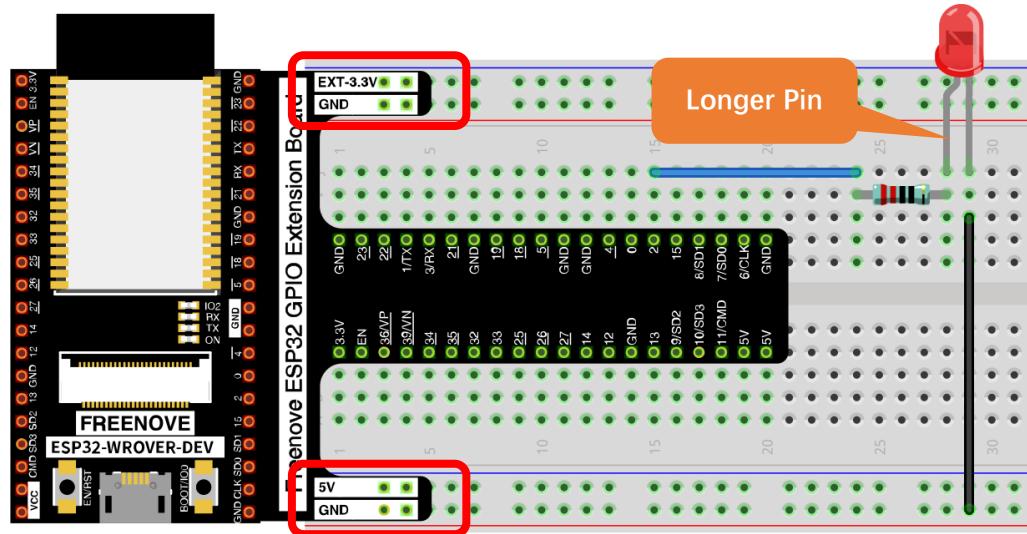
First, disconnect all power from the ESP32-WROVER. Then build the circuit according to the circuit and hardware diagrams. After the circuit is built and verified correct, connect the PC to ESP32-WROVER.

CAUTION: Avoid any possible short circuits (especially connecting 5V or GND, 3.3V and GND)! **WARNING:** A short circuit can cause high current in your circuit, 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**



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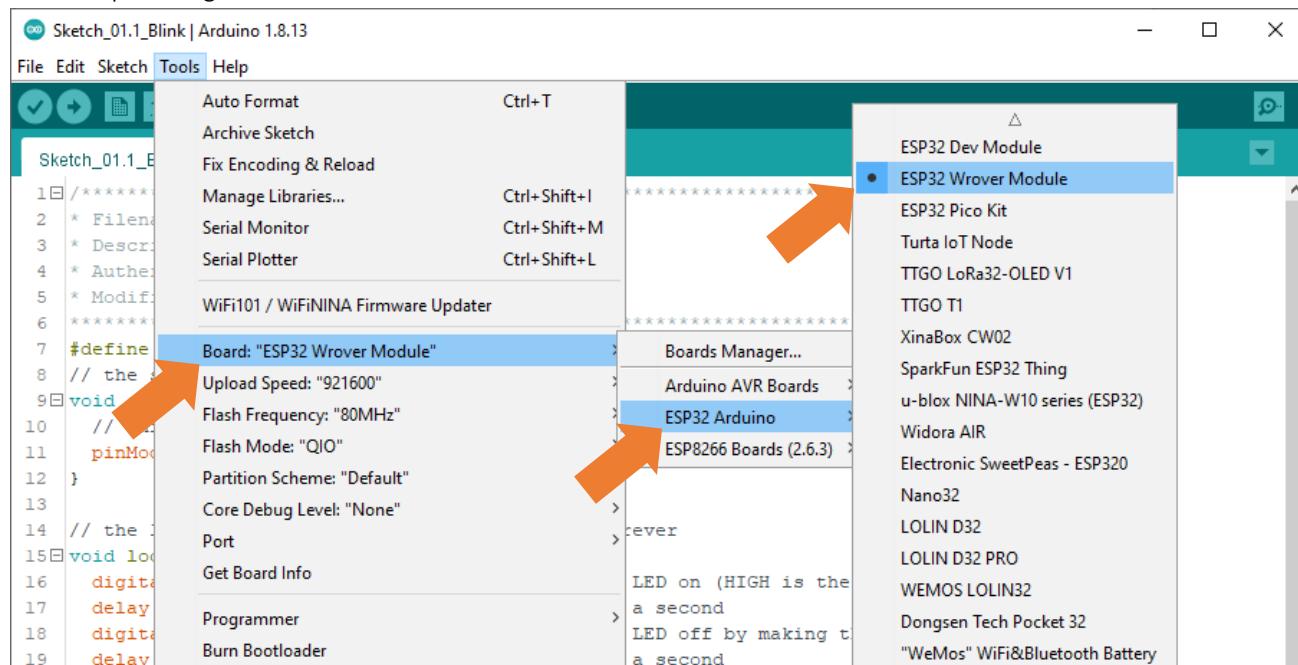
Sketch

According to the circuit, when the GPIO2 of ESP32-WROVER output level is high, the LED turns ON. Conversely, when the GPIO2 ESP32-WROVER 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\Sketches\Sketch_01.1_Blink.

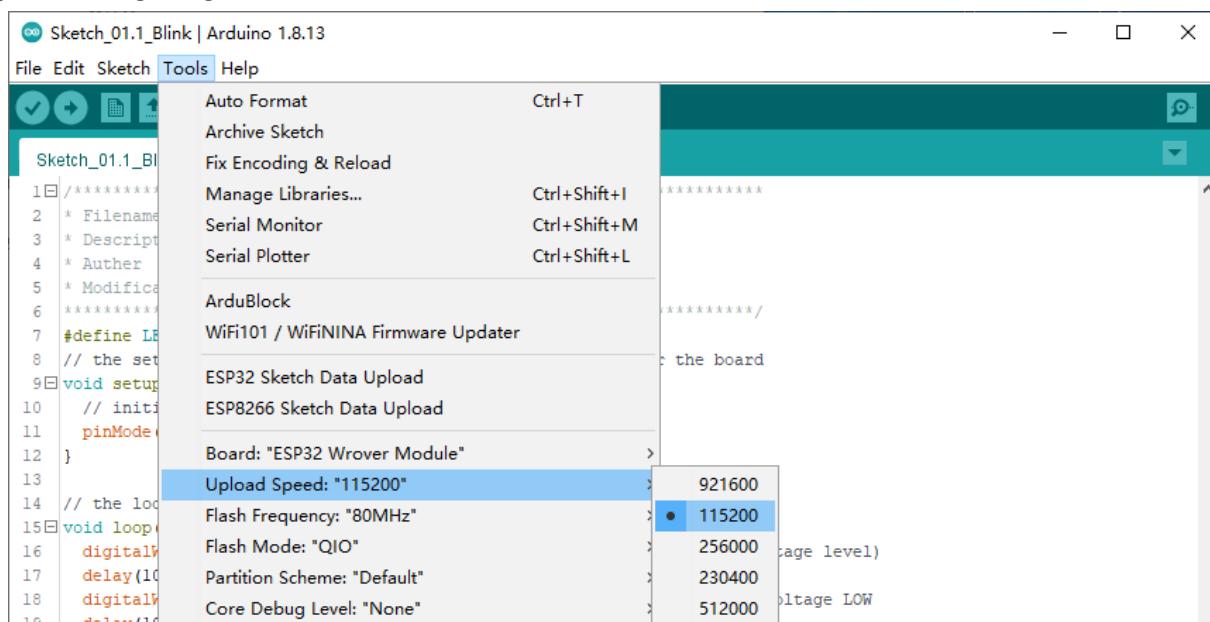
Before uploading the code, click "Tools", "Board" and select "ESP32 Wrover Module".



Select the serial port.



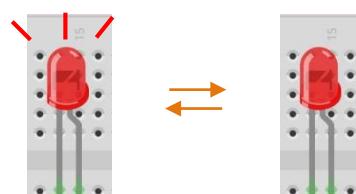
Note: For macOS users, if the uploading fails, please set the baud rate to 115200 before clicking “Upload Using Programmer”.



Sketch_01.1_Blink



Click “Upload”, Download the code to ESP32-WROVER and your LED in the circuit starts Blink.

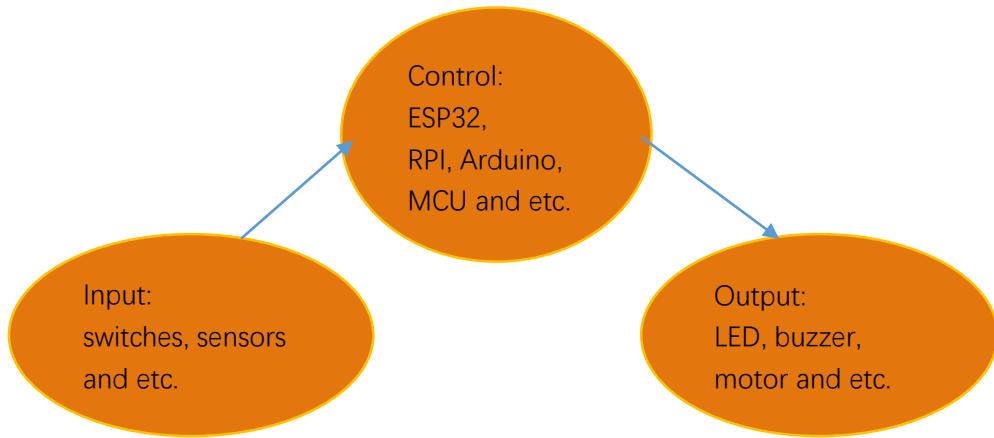


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Chapter 2 Button & LED

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

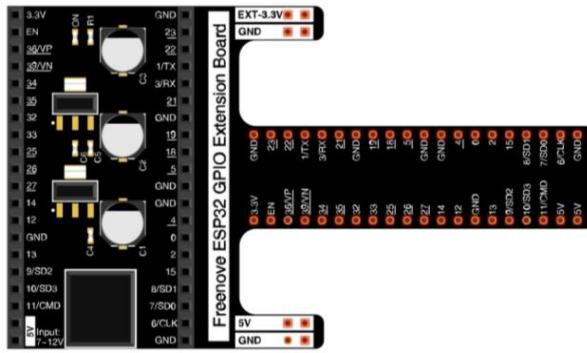


Next, we will build a simple control system to control a LED through a push button switch.

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



Component knowledge

Push button

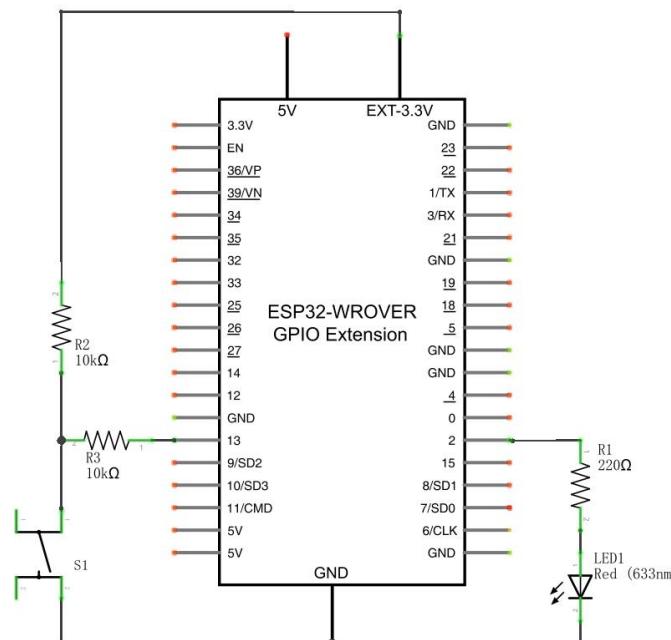
This type of push button switch has 4 pins (2 Pole Switch). Two pins on the left are connected, and both left and right sides are the same per the illustration:



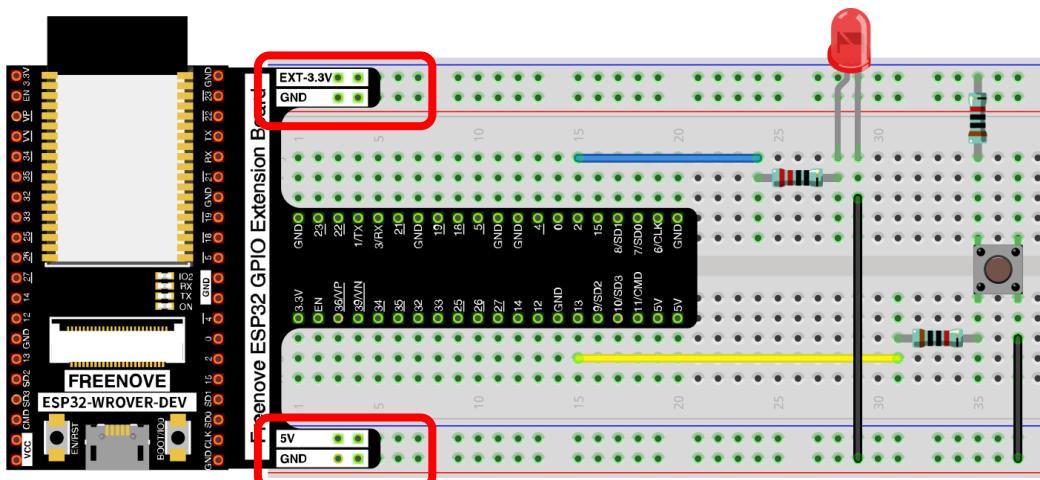
When the button on the switch is pressed, the circuit is completed (your project is powered ON).

Circuit

Schematic diagram



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



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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\Sketches\Sketch_02.1_ButtonAndLed.

Sketch_02.1_ButtonAndLed



```

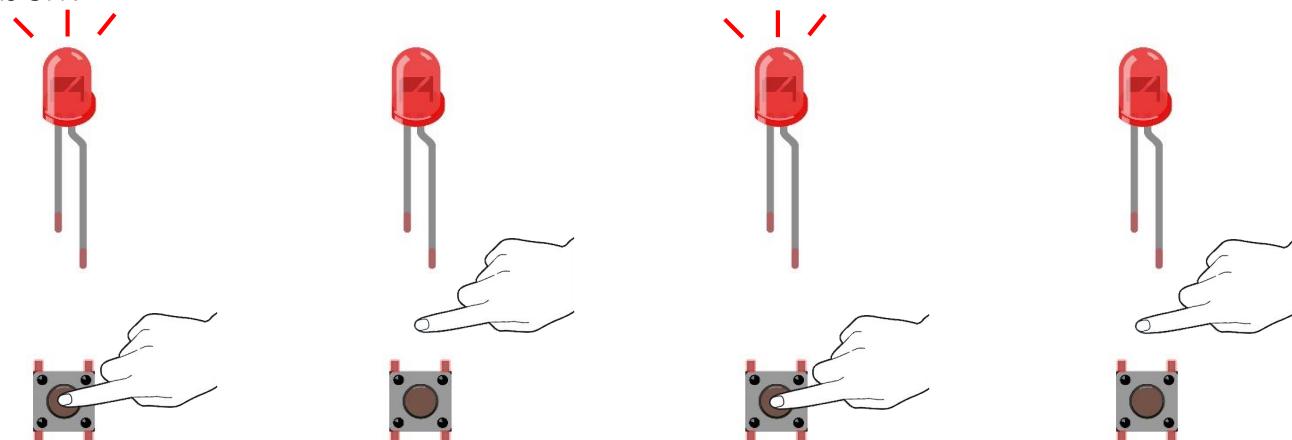
Sketch_02.1_ButtonAndLed | Arduino 1.8.10
File Edit Sketch Tools Help
Sketch_02.1_ButtonAndLed
1 //***** Buttons and LEDs *****
2 Filename : ButtonAndLed.c
3 Description : Control led by button.
4 Author : www.freenove.com
5 Modification: 2019-12-31
6 XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX/
7 #define 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 }

Done Saving.
Writing at 0x00028000... (87 %)
Writing at 0x0002c000... (100 %)
Wrote 253456 bytes (118231 compressed) at 0x00010000 in 3.0 seconds (effective 684.8 kbit/s)...
Hash of data verified.
Compressed 3072 bytes to 128...

Writing at 0x00008000... (100 %)
Wrote 3072 bytes (128 compressed) at 0x00008000 in 0.0 seconds (effective 4915.3 kbit/s)...
21
ESP32 Wrover Module on COM9

```

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



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Any concerns? ✉ 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 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

```
Sketch_02.2_TableLamp | Arduino 1.8.10
File Edit Sketch Tools Help
Sketch_02.2_TableLamp
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 }

Done uploading.

Writing at 0x00008000... (100 %)
Wrote 3072 bytes (128 compressed) at 0x00008000 in 0.0 seconds (effective 6143.7 kbit/s)...
Hash of data verified.

Leaving...
Hard resetting via RTS pin...
< >
7
ESP32 Wrover Module on COM9
```

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

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

Any concerns? ✉ 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

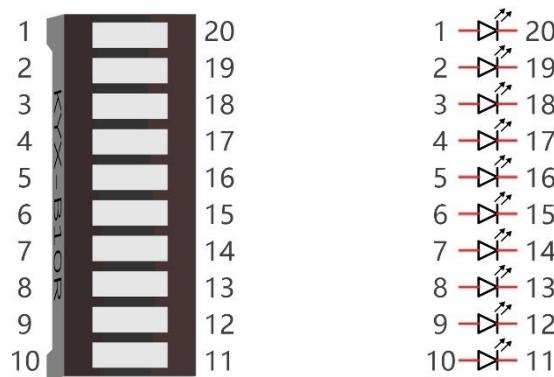
ESP32-WROVER x1	GPIO Extension Board x1	
Breadboard x1		
Jumper M/M x10	LED bar graph x1	Resistor 220Ω x10

Component knowledge

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

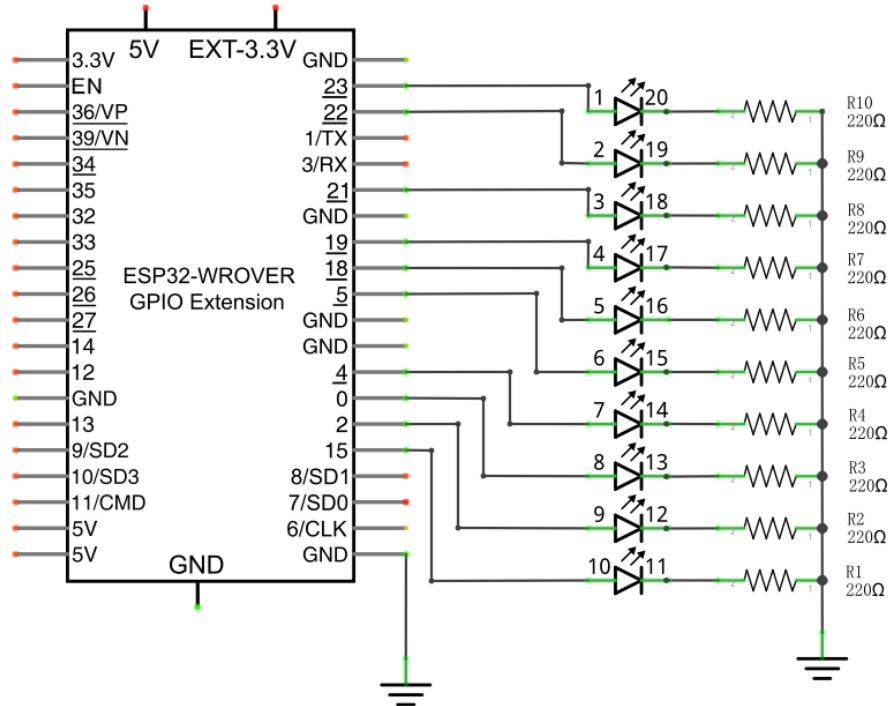
LED bar

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.

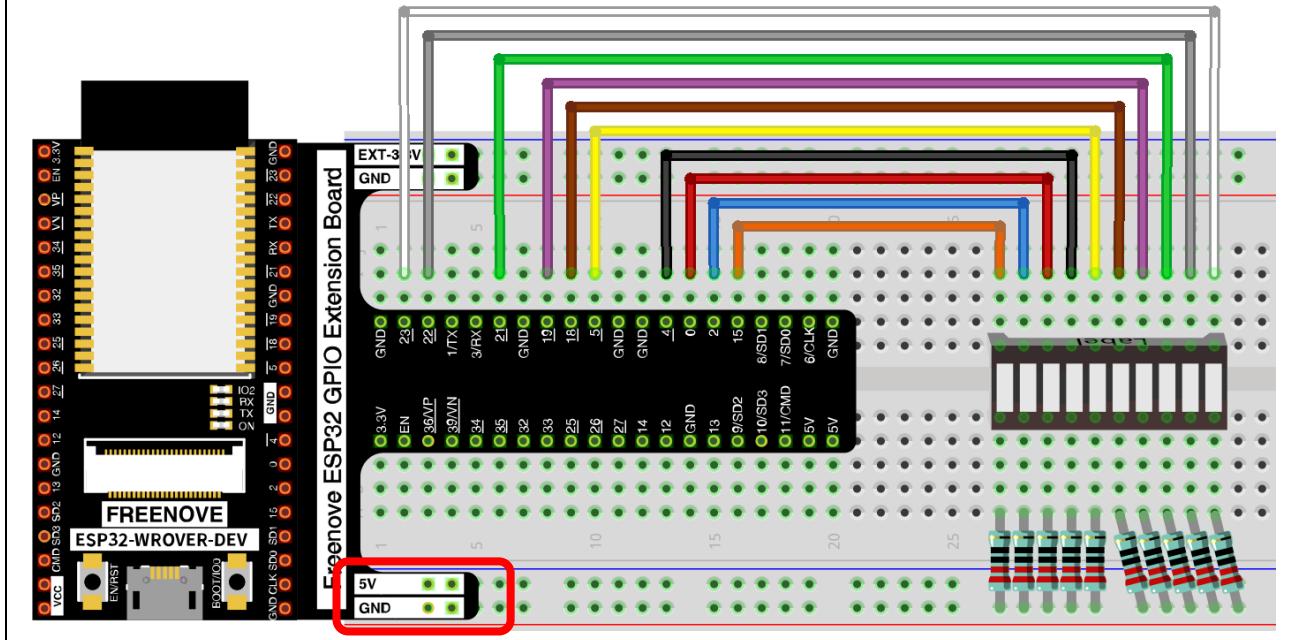


Circuit

Schematic diagram



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



If LED bar does not work, try to rotate it for 180°. The label is random.

Any concerns? ✉ support@freenove.com

Sketch

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

Upload following sketch:

Freenove_Ultimate_Starter_Kit_for_ESP32\Sketches\Sketch_03.1_FlowingLight.

Sketch_03.1_FlowingLight

The screenshot shows the Arduino IDE interface. The top menu bar includes File, Edit, Sketch, Tools, and Help. The main window displays the code for "Sketch_03.1_FlowingLight". The code initializes an array of pins (ledPins) and sets up pin modes for them. The loop function alternates between turning on and off each pin in sequence from left to right and back to left. Below the code, a message says "Done Saving." followed by the serial monitor output: "Writing at 0x00008000... (100 %)" and "Wrote 3072 bytes (128 compressed) at 0x00008000 in 0.0 seconds (effective 6144.1 kbit/s)... Hash of data verified." The bottom status bar indicates "ESP32 Wrover Module on COM9".

```
Sketch_03.1_FlowingLight | Arduino 1.8.10
File Edit Sketch Tools Help
Sketch_03.1_FlowingLight
6 ****
7 byte ledPins[] = {15, 2, 0, 4, 5, 18, 19, 21, 22, 23};
8 int ledCounts;
9 |
10 void setup() {
11   ledCounts = sizeof(ledPins);
12   for (int i = 0; i < ledCounts; i++) {
13     pinMode(ledPins[i], OUTPUT);
14   }
15 }
16
17 void loop() {
18   for (int i = 0; i < ledCounts; i++) {
19     digitalWrite(ledPins[i], HIGH);
20     delay(100);
21     digitalWrite(ledPins[i], LOW);
22   }
23   for (int i = ledCounts - 1; i > -1; i--) {
24     digitalWrite(ledPins[i], HIGH);
25     delay(100);
26     digitalWrite(ledPins[i], LOW);
27   }
28 }

Done Saving.

Writing at 0x00008000... (100 %)
Wrote 3072 bytes (128 compressed) at 0x00008000 in 0.0 seconds (effective 6144.1 kbit/s)...
Hash of data verified.

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

< >
9
ESP32 Wrover Module on COM9
```

Download the code to ESP32-WROVER 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

Any concerns? ✉ support@freenove.com



The following is the program code:

```

1 byte ledPins[] = {15, 2, 0, 4, 5, 18, 19, 21, 22, 23};
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[] = {15, 2, 0, 4, 5, 18, 19, 21, 22, 23};
```

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

Related knowledge

Analog & Digital

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



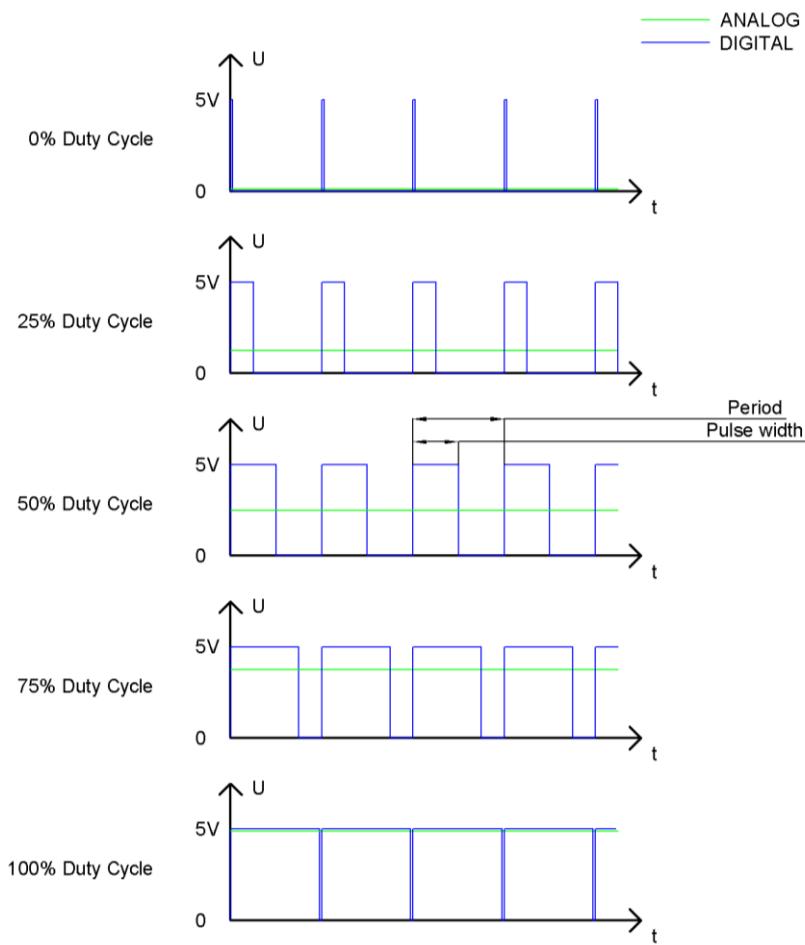
In practical application, we often use binary as the digital signal, that is a series of 0's and 1's. Since a binary signal only has two values (0 or 1), it has great stability and reliability. Lastly, both analog and digital signals can be converted into the other.

PWM

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

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

The longer the 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 and PWM

On ESP32, the LEDC(PWM) controller has 16 separate channels, each of which can independently control frequency, duty cycle, and even accuracy. Unlike traditional PWM pins, the PWM output pins of ESP32 are configurable, 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



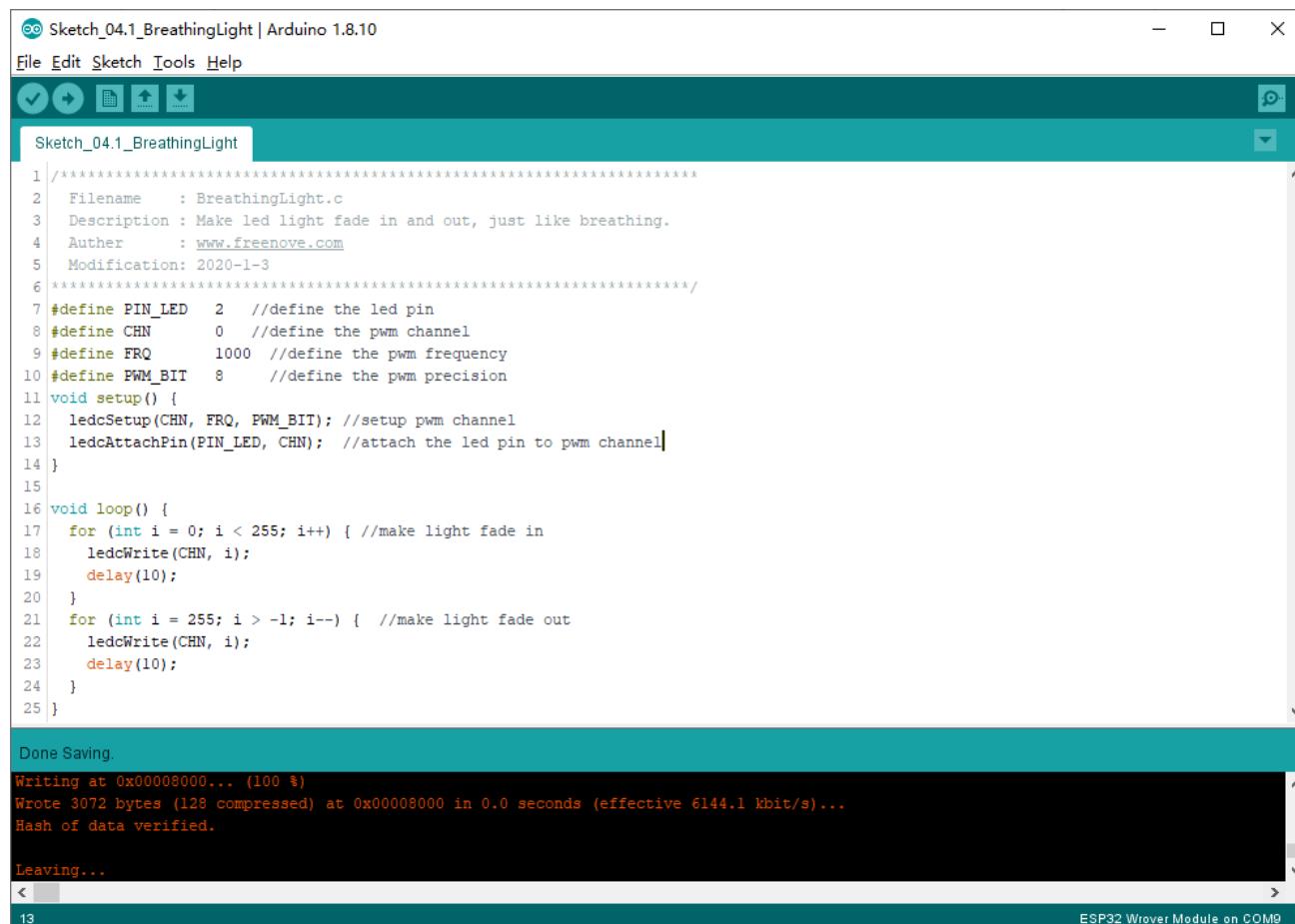
Hardware connection. **If you need any support, please contact us via: support@freenove.com**



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



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

- Title Bar:** Sketch_04.1_BreathingLight | Arduino 1.8.10
- Menu Bar:** File Edit Sketch Tools Help
- Toolbar:** Standard toolbar icons for Open, Save, Print, etc.
- Code Editor:** The main area contains the C++ code for the breathing light sketch. The code defines a LED on pin 2, uses channel 0 for PWM at 1000Hz, and sets the PWM bit to 8. It sets up the PWM channel and attaches the LED pin to it. The loop function fades the LED in and out over 255 steps, with a 10ms delay between steps.
- Status Bar:** Shows "Done Saving.", "Writing at 0x00008000... (100 %)", "Wrote 3072 bytes (128 compressed) at 0x00008000 in 0.0 seconds (effective 6144.1 kbit/s)...", "Hash of data verified.", "Leaving...", and "ESP32 Wrover Module on COM9".

Download the code to ESP32-WROVER, 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     ledcSetup(CHN, FRQ, PWM_BIT); //setup pwm channel
7     ledcAttachPin(PIN_LED, CHN); //attach the led pin to pwm channel
8 }
9
10 void loop() {
11     for (int i = 0; i < 255; i++) { //make light fade in
12         ledcWrite(CHN, i);
13         delay(10);
14     }
15     for (int i = 255; i > -1; i--) { //make light fade out
16         ledcWrite(CHN, i);
17         delay(10);
18     }
19 }
```

The PWM pin output mode of ESP32 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.

6	<code>ledcSetup(CHN, FRQ, PWM_BIT); //setup pwm channel</code>
---	--

Then the GPIO is associated with the PWM channel.

7	<code>ledcAttachPin(PIN_LED, CHN); //attach the led pin to pwm channel</code>
---	---

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(CHN, i);
13     delay(10);
14 }
15 for (int i = 255; i > -1; i--) { //make light fade out
16     ledcWrite(CHN, 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.

```
double ledcSetup(uint8_t chan, double freq, uint8_t bit_num)
```

Set the frequency and accuracy of a PWM channel.

Parameters

chan: channel index. Value range :0-15

freq: frequency, it could be a decimal.

bit_num: precision of values.

```
void ledcAttachPin(uint8_t pin, uint8_t channel);
```

```
void ledcDetachPin(uint8_t pin);
```

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.

Sketch

Meteor flowing light will be implemented with PWM.

Sketch_04.2_FlowingLight2



```

Sketch_04.2_FlowingLight2 | Arduino 1.8.10
File Edit Sketch Tools Help
Sketch_04.2_FlowingLight2
Sketch_04.2_FlowingLight2.c
1 //*****Filename : Flowinglight.c
2 //*****Description : More cool flowing light.
3 //*****Author : www.freenove.com
4 //*****Modification: 2020-1-3
5 //*****
6 const byte ledPins[] = {15, 2, 0, 4, 5, 18, 19, 21, 22, 23}; //define led pins
7 const byte chns[] = {0, 1, 2, 3, 4, 5, 6, 7, 8, 9}; //define the pwm channels
8 const int dutys[] = {0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
9 1023, 512, 256, 128, 64, 32, 16, 8, 4, 2,
11 0, 0, 0, 0, 0, 0, 0, 0, 0, 0
12 }; //define the pwm dutys
13 int ledCounts; //
14 int delayTimes = 50; //flowing speed ,the smaller, the faster
15 void setup() {
16 ledCounts = sizeof(ledPins); //get the led counts
17 for (int i = 0; i < ledCounts; i++) { //setup the pwm channels
18 ledcSetup(chns[i], 1000, 10);
19 ledcAttachPin(ledPins[i], chns[i]);
20 }
21 }
22
23 void loop() {
24 for (int i = 0; i < 20; i++) { //flowing one side to other side
25 for (int j = 0; j < ledCounts; j++) {
26 ledcWrite(chns[j], dutys[i + j]);
27 }
28 delay(delayTimes);
}
Done Saving.
Hash of data verified.
Leaving...
Hard resetting via RTS pin...
< >
2 ESP32 Wrover Module on COM9

```

Download the code to ESP32-WROVER, 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	<code>const byte ledPins[] = {15, 2, 0, 4, 5, 18, 19, 21, 22, 23}; //define led pins</code>
2	<code>const byte chns[] = {0, 1, 2, 3, 4, 5, 6, 7, 8, 9}; //define the pwm channels</code>
3	<code>const int dutys[] = {0, 0, 0, 0, 0, 0, 0, 0, 0, 0,</code>
4	<code>1023, 512, 256, 128, 64, 32, 16, 8, 4, 2,</code>
5	<code>0, 0, 0, 0, 0, 0, 0, 0, 0, 0</code>
6	<code>; //define the pwm dutys</code>
7	<code>int ledCounts; //led counts</code>
8	<code>int delayTimes = 50; //flowing speed ,the smaller, the faster</code>
9	<code>void setup() {</code>
10	<code>ledCounts = sizeof(ledPins); //get the led counts</code>
11	<code>for (int i = 0; i < ledCounts; i++) { //setup the pwm channels</code>

```

12     ledcSetup(chns[i], 1000, 10);
13     ledcAttachPin(ledPins[i], chns[i]);
14 }
15 }
16
17 void loop() {
18     for (int i = 0; i < 20; i++) {          //flowing one side to other side
19         for (int j = 0; j < ledCounts; j++) {
20             ledcWrite(chns[j], dutys[i + j]);
21         }
22         delay(delayTimes);
23     }
24     for (int i = 0; i < 20; i++) {          //flowing one side to other side
25         for (int j = ledCounts - 1; j > -1; j--) {
26             ledcWrite(chns[j], dutys[i + (ledCounts - 1 - j)]);
27         }
28         delay(delayTimes);
29     }
30 }
```

First we defined 10 GPIO, 10 PWM channels, and 30 pulse width values.

```

const byte ledPins[] = {15, 2, 0, 4, 5, 18, 19, 21, 22, 23};      //define led pins
const byte chns[] = {0, 1, 2, 3, 4, 5, 6, 7, 8, 9};           //define the pwm channels
const int dutys[] = {0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
                    1023, 512, 256, 128, 64, 32, 16, 8, 4, 2,
                    0, 0, 0, 0, 0, 0, 0, 0, 0, 0
};                                //define the pwm dutys
```

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

```

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



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 10 green squares in each row below represent the 10 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	11	1	1	1	1	1	1	1	2	2	2	2	2	2	3	2	3	0	
d	0	0	0	0	0	0	0	0	0	10	5	2	1	6	3	1	8	4	2	0	0	0	0	0	0	0	0	0
i										23	1	5	2	4	2	6												
0																												
1																												
2																												
3																												
...																												
1																												
8																												
1																												
9																												
2																												
0																												

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

```

for (int i = 0; i < 20; i++) {           //flowing one side to other side
    for (int j = 0; j < ledCounts; j++) {
        ledcWrite(chns[j], dutys[i + j]);
    }
    delay(delayTimes);
}

for (int i = 0; i < 20; i++) {           //flowing from one side to the other
    for (int j = ledCounts - 1; j > -1; j--) {
        ledcWrite(chns[j], dutys[i + (ledCounts - 1 - j)]);
    }
    delay(delayTimes);
}

```

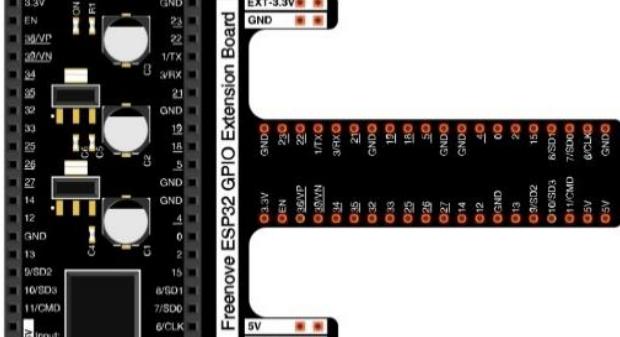
Chapter 5 RGB LED

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-WROVER 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,



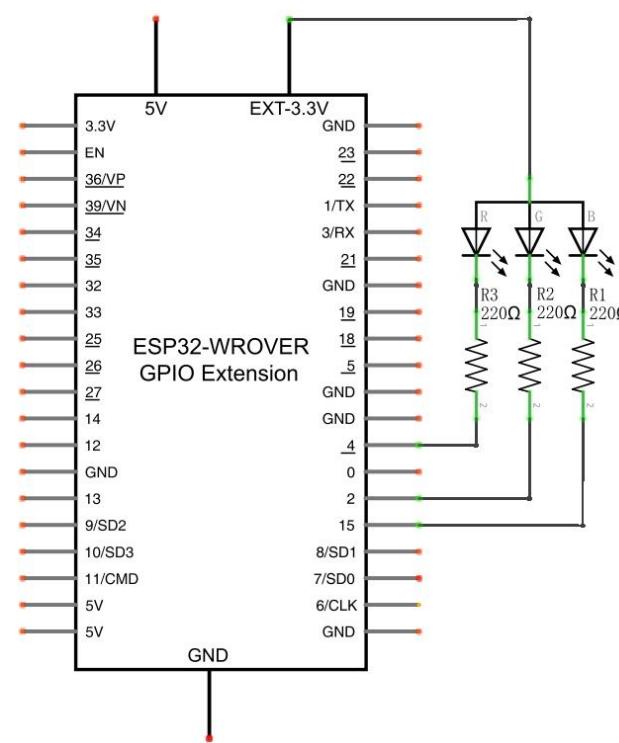
Red, green, and blue are known as three primary colors. When you combine these three primary-color lights with different brightness, it can produce almost all kinds of visible lights. Computer screens, single pixel of cell phone screen, neon, and etc. are working under this principle.



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





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_ColorfulLight | Arduino 1.8.10
File Edit Sketch Tools Help
Sketch_05.1_ColorfulLight
2 | Filename : ColorfulLight.c
3 | Description : Use RGBLED to show random color.
4 | Author : www.freenove.com
5 | Modification: 2020-1-3
6 | ****
7 | const byte ledPins[] = {15, 2, 4}; //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 |     ledcSetup(chns[i], 1000, 8);
13 |     ledcAttachPin(ledPins[i], chns[i]);
14 |   }
15 | }
16 |
17 | void loop() {
18 |   red = random(0, 256);
19 |   green = random(0, 256);
20 |   blue = random(0, 256);
21 |   setColor(red, green, blue);
22 |   delay(200);
23 | }
24 |
25 | void setColor(byte r, byte g, byte b) {
26 |   ledcWrite(ledPins[0], 255 - r); //Common anode LED, low level to turn on the led.
27 |   ledcWrite(ledPins[1], 255 - g);
28 |   ledcWrite(ledPins[2], 255 - b);
29 | }

Done uploading.
Leaving...
Hard resetting via RTS pin...

< 13 >
ESP32 Wrover Module on COM9
```

With the code downloaded to ESP32-WROVER, RGB LED begins to display random colors.

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

The following is the program code:

```

1 const byte ledPins[] = {15, 2, 4};      //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         ledcSetup(chns[i], 1000, 8);
7         ledcAttachPin(ledPins[i], chns[i]);
8     }
9 }
10
11 void loop() {
12     red = random(0, 256);
13     green = random(0, 256);
14     blue = random(0, 256);
15     setColor(red, green, blue);
16     delay(200);
17 }
18
19 void setColor(byte r, byte g, byte b) {
20     ledcWrite(chns[0], 255 - r); //Common anode LED, low level to turn on the led.
21     ledcWrite(chns[1], 255 - g);
22     ledcWrite(chns[2], 255 - b);
23 }
```

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[] = {15, 2, 4};      //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         ledcSetup(chns[i], 1000, 8);
7         ledcAttachPin(ledPins[i], chns[i]);
8     }
9 }
```

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.

```

19 void setColor(byte r, byte g, byte b) {
20     ledcWrite(chns[0], 255 - r); //Common anode LED, low level to turn on the led.
21     ledcWrite(chns[1], 255 - g);
22     ledcWrite(chns[2], 255 - b);
23 }
```



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

```

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

```

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

long random(min, max);

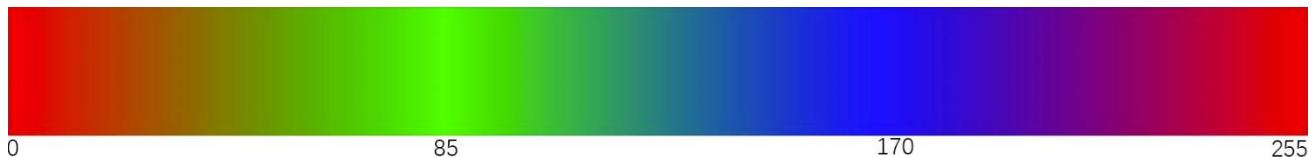
This function will return a random number(min --- max-1).

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_SoftColorfullLight

The following is the program code:

```

1 const byte ledPins[] = {15, 2, 4};      //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         ledcSetup(chns[i], 1000, 8);
7         ledcAttachPin(ledPins[i], chns[i]);
8     }
9 }
10
11 void loop() {
12     for (int i = 0; i < 256; i++) {
13         setColor(wheel(i));
14         delay(20);
15     }
}

```

```
16 }  
17  
18 void setColor(long rgb) {  
19     ledcWrite(chns[0], 255 - (rgb >> 16) & 0xFF);  
20     ledcWrite(chns[1], 255 - (rgb >> 8) & 0xFF);  
21     ledcWrite(chns[2], 255 - (rgb >> 0) & 0xFF);  
22 }  
23  
24 long wheel(int pos) {  
25     long WheelPos = pos % 0xff;  
26     if (WheelPos < 85) {  
27         return ((255 - WheelPos * 3) << 16) | ((WheelPos * 3) << 8);  
28     } else if (WheelPos < 170) {  
29         WheelPos -= 85;  
30         return (((255 - WheelPos * 3) << 8) | (WheelPos * 3));  
31     } else {  
32         WheelPos -= 170;  
33         return ((WheelPos * 3) << 16 | (255 - WheelPos * 3));  
34     }  
35 }
```

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(chns[0], 255 - (rgb >> 16) & 0xFF);  
20     ledcWrite(chns[1], 255 - (rgb >> 8) & 0xFF);  
21     ledcWrite(chns[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.

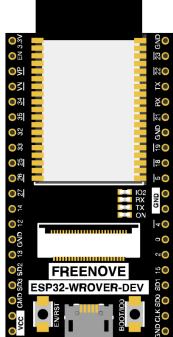
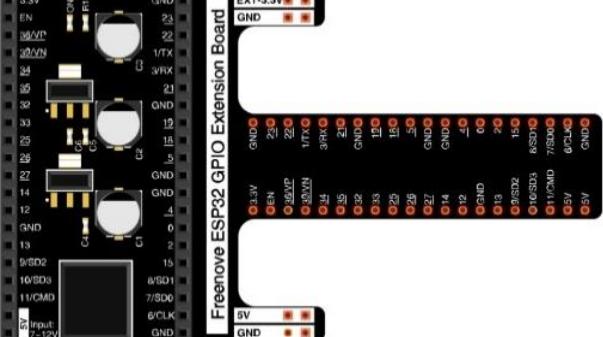
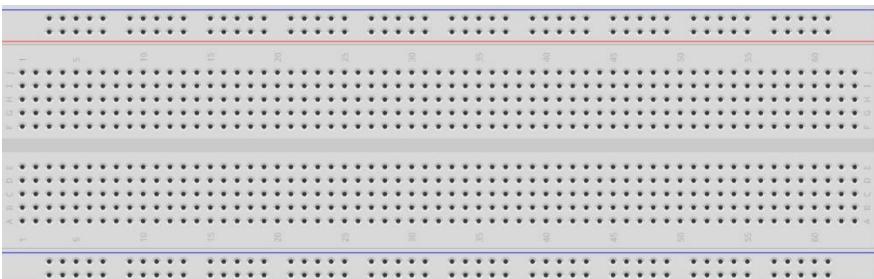
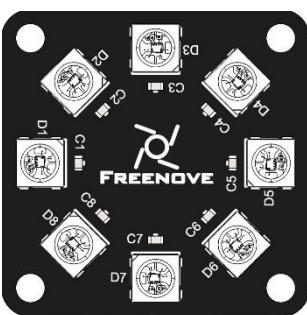
Chapter 6 LEDPixel

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

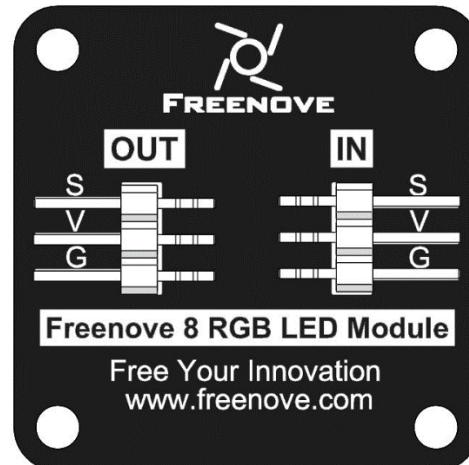
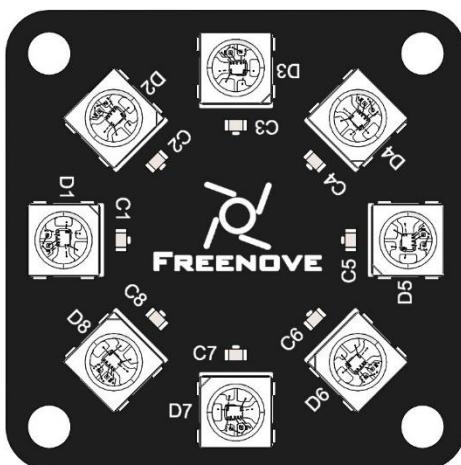
Related knowledge

Freenove 8 RGB LED Module

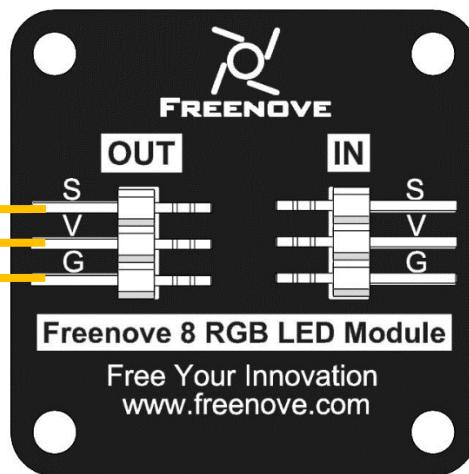
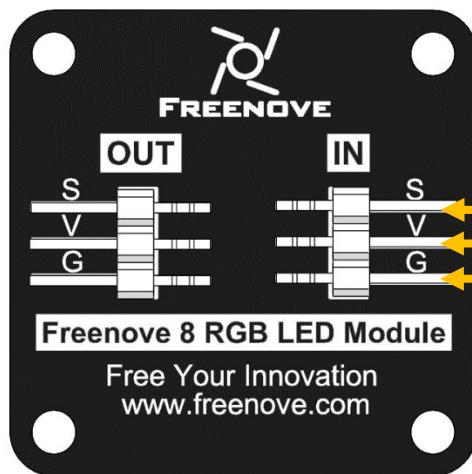
The Freenove 8 RGB LED Module is as below.

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.



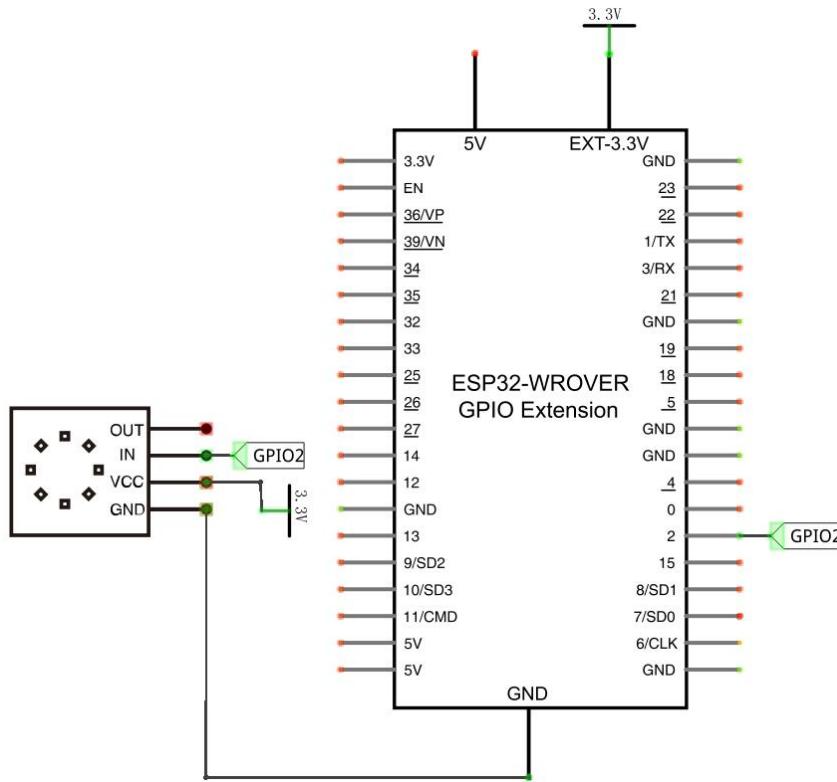
Pin description:

(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

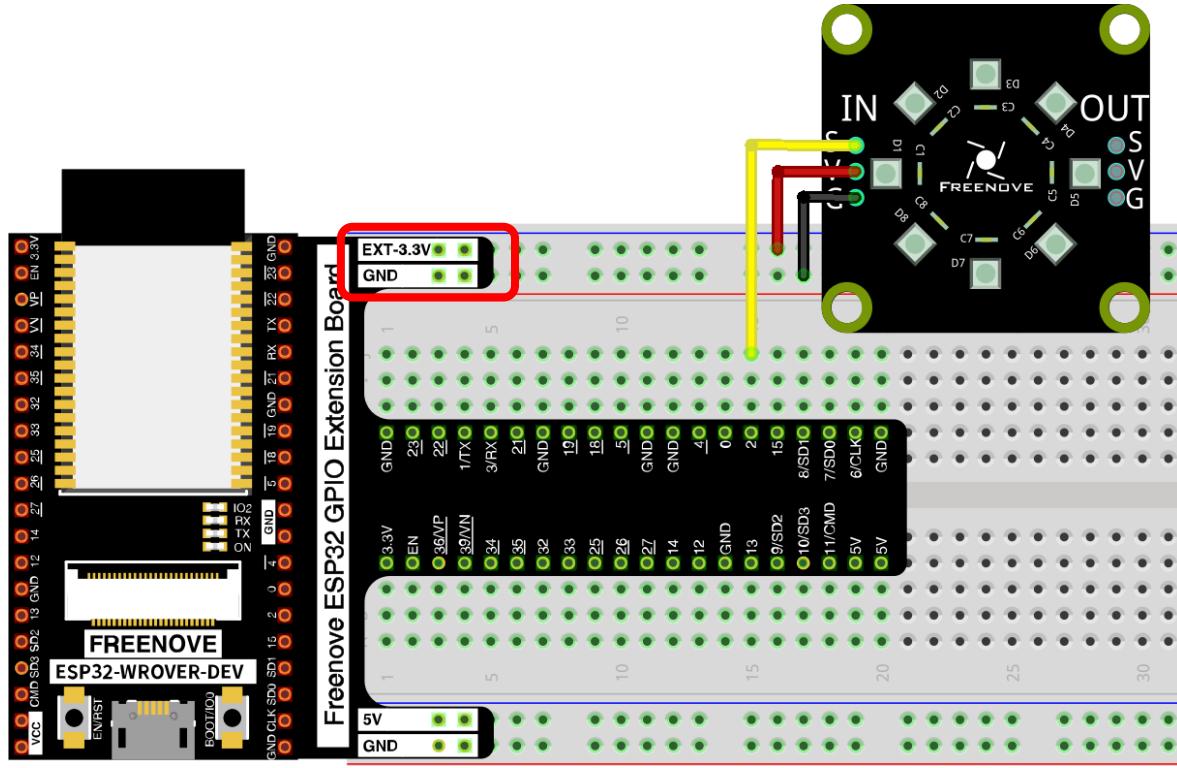
Any concerns? [✉ support@freenove.com](mailto:support@freenove.com)

Circuit

Schematic diagram



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



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

Sketch

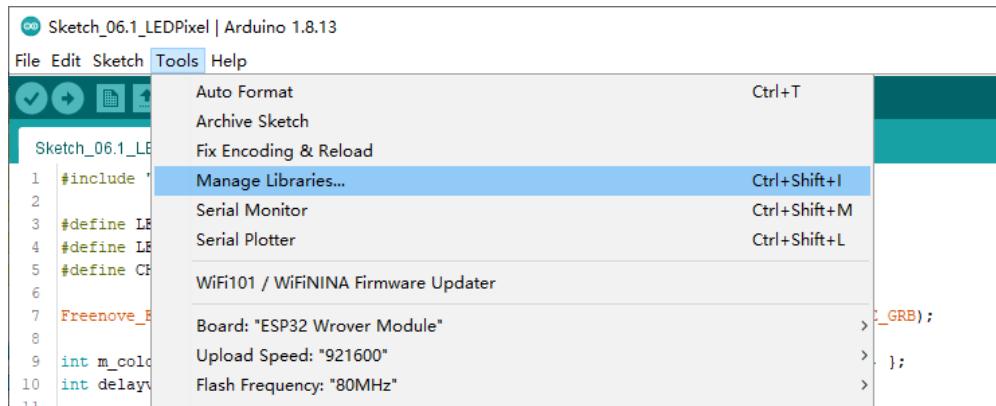
This code uses a library named "Freenove_WS2812_Lib_for_ESP32", if you have not installed it, please do so first.

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.

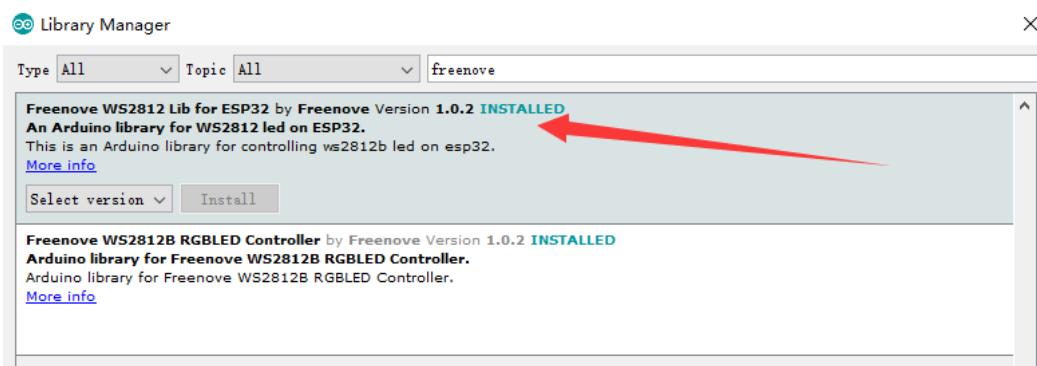
How to install the library

There are two ways to add libraries.

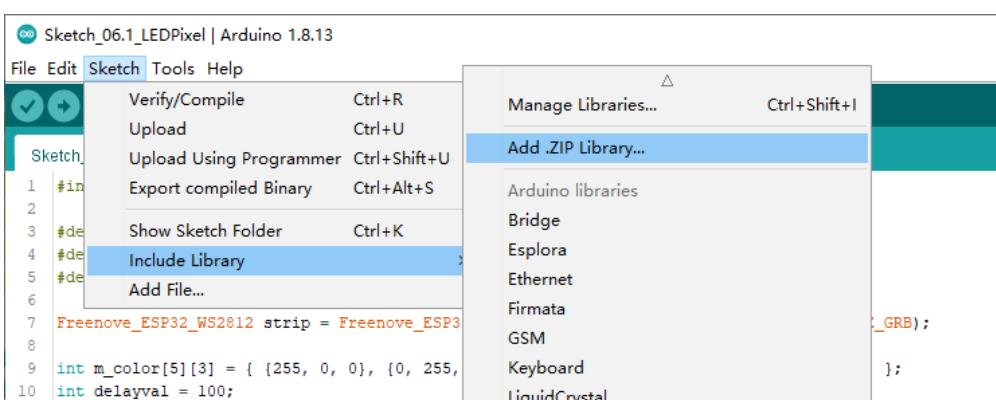
The first way, open the Arduino IDE, click Tools → Manager Libraries.



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.



Any concerns? ✉ support@freenove.com

Sketch_06.1_LEDPixel



```

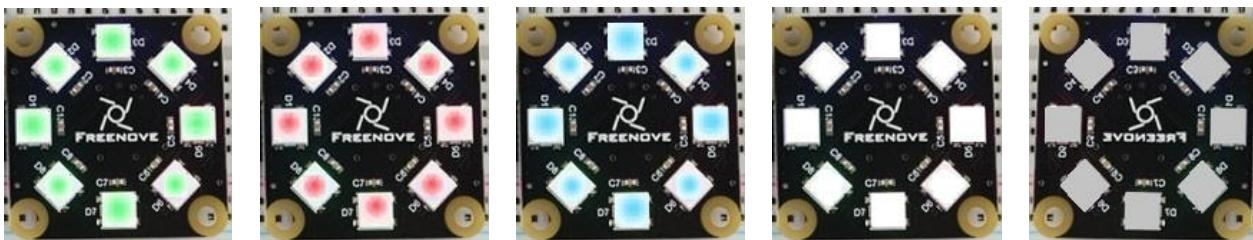
Sketch_06.1_LEDPixel | Arduino 1.8.13
File Edit Sketch Tools Help
Sketch_06.1_LEDPixel
1 #include "Freenove_WS2812_Lib_for_ESP32.h"
2
3 #define LEDS_COUNT 8 // The number of led
4 #define LEDS_PIN 2 // define the pin connected to the Freenove 8 led strip
5 #define CHANNEL 0 // RMT module channel
6
7 Freenove_ESP32_WS2812 strip = Freenove_ESP32_WS2812(LEDS_COUNT, LEDS_PIN, CHANNEL, TYPE_GRB);
8
9 int 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]); // Set color data.
20             strip.show(); // Send color data to LED, and display.
21             delay(delayval); // Interval time of each LED.
}

```

Done uploading.

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

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



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 2 // 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() {
    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    2 // 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

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

```
#include "Freenove_WS2812_Lib_for_ESP32.h"
#define LEDS_COUNT 8
#define LEDS_PIN 2
#define CHANNEL 0
Freenove_ESP32_WS2812 strip = Freenove_ESP32_WS2812(LEDS_COUNT, LEDS_PIN, CHANNEL, TYPE_GRB);
void setup() {
    strip.begin();
}
void loop() {
    for (int j = 0; j < 255; j += 2) {
        for (int i = 0; i < LEDS_COUNT; i++) {
            strip.setLedColorData(i, strip.Wheel((i * 256 / LEDS_COUNT + j) & 255));
        }
        strip.show();
        delay(5);
    }
}
```

Done uploading.
Leaving...
Hard resetting via RTS pin...

Download the code to ESP32-WROVER, 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 2 // 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 }
12
13 void loop() {
14     for (int j = 0; j < 255; j += 1) {
15         for (int i = 0; i < LEDS_COUNT; i++) {
16             strip.setLedColorData(i, strip.Wheel((i * 256 / LEDS_COUNT + j) & 255));
17         }
18         strip.show(); // Send color data to LED, and display.
19         delay(5);
20     }
21 }
```

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. `Wheel($i * 256 / LEDS_COUNT + j$) & 255)` will take color from the color model at equal intervals starting from i.

```

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

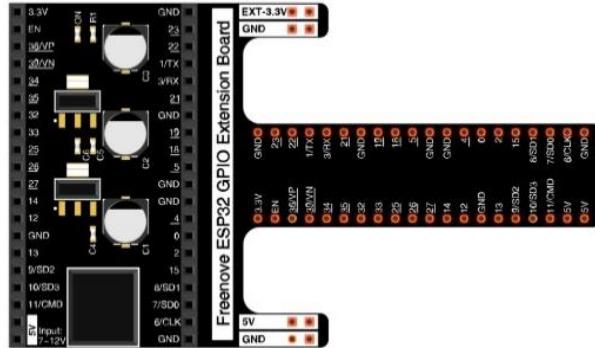
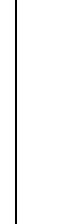
Chapter 7 Buzzer

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

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

Component knowledge

Buzzer

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



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

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

How to identify active and passive buzzer?

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

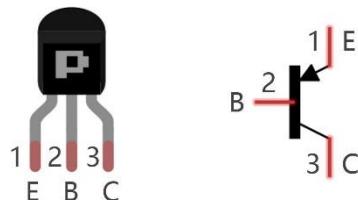


Transistor

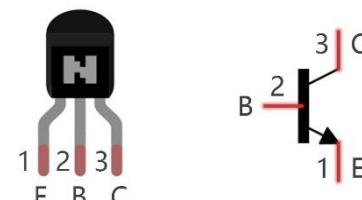
Because the buzzer requires such large current that GPIO of ESP32 output capability cannot meet the requirement, a transistor of NPN type is needed here to amplify the current.

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

PNP transistor



NPN transistor

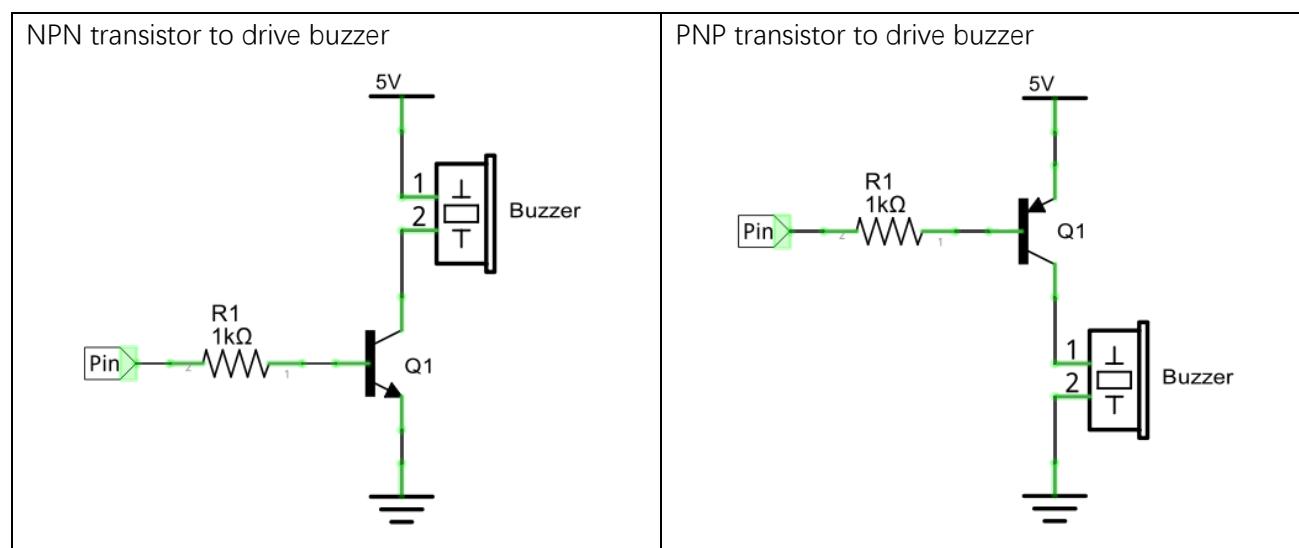


In our kit, the PNP transistor is marked with 8550, and the NPN transistor is marked with 8050.

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

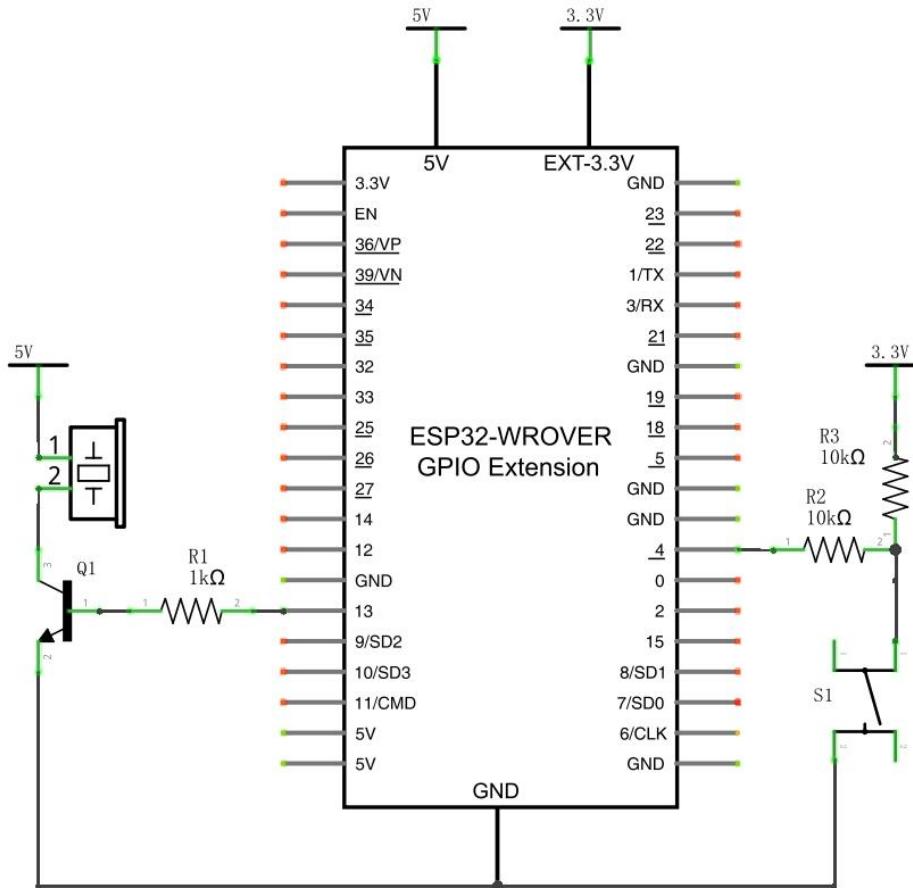
When use NPN transistor to drive buzzer, we often adopt the following method. If GPIO outputs high level, current will flow through R1, the transistor will get conducted, and the buzzer will sound. If GPIO outputs low level, no current flows through R1, the transistor will not be conducted, and buzzer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

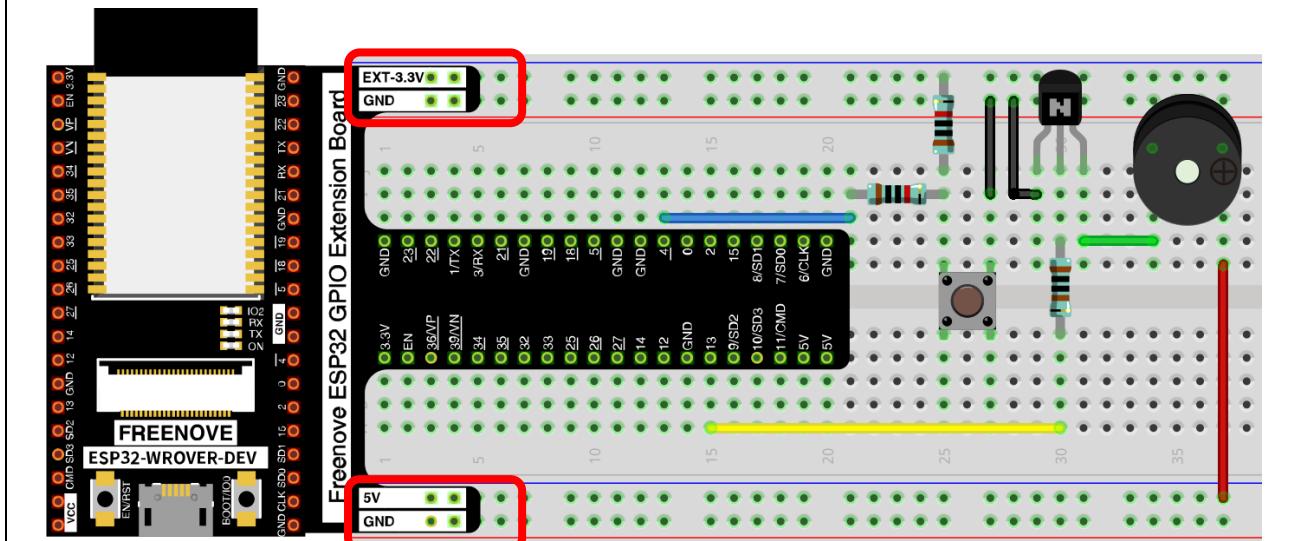


Circuit

Schematic diagram



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

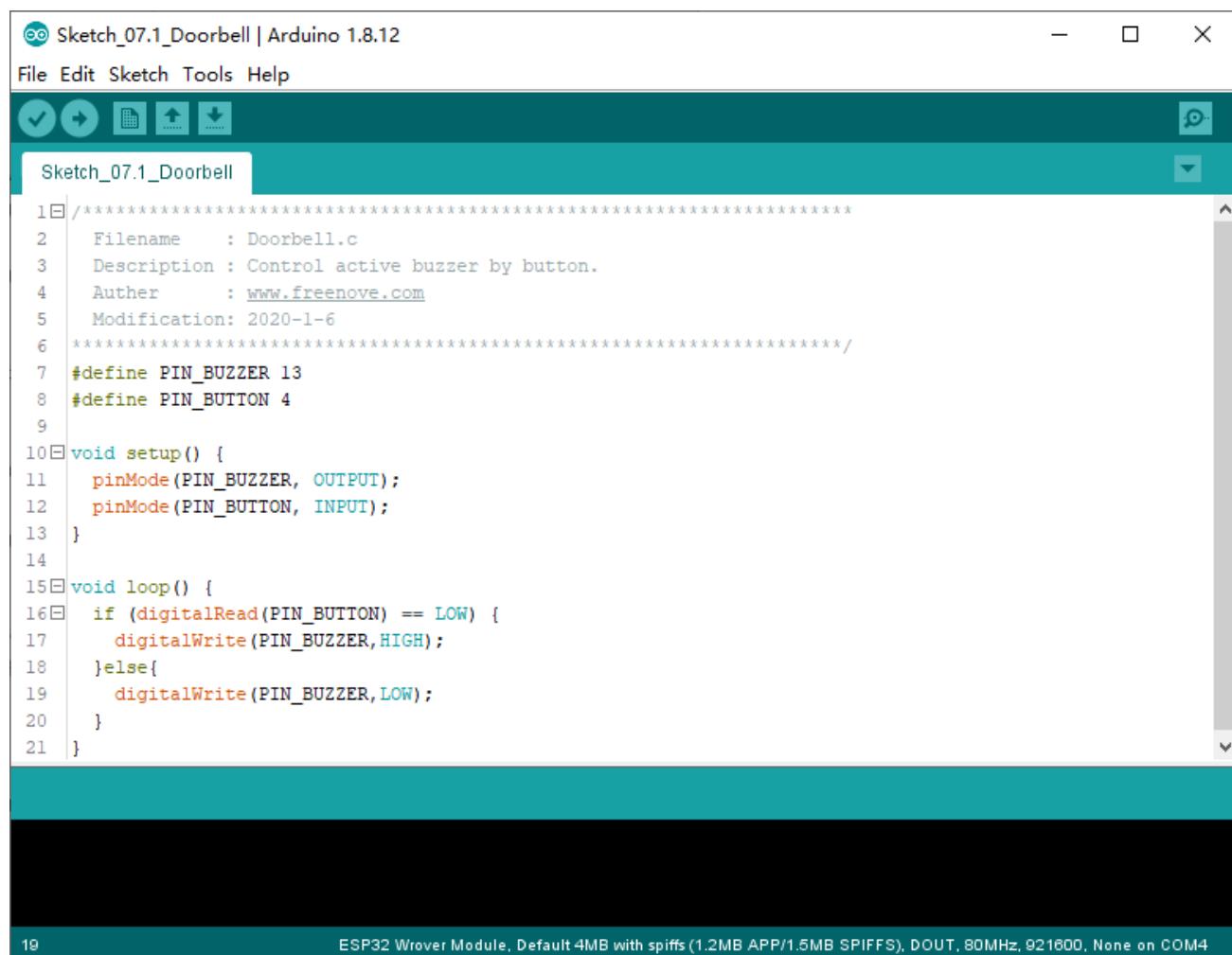


Note: in this circuit, the power supply for buzzer is 5V, and pull-up resistor of the button connected to the power 3.3V. The buzzer can work when connected to power 3.3V, but it will reduce the loudness.

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



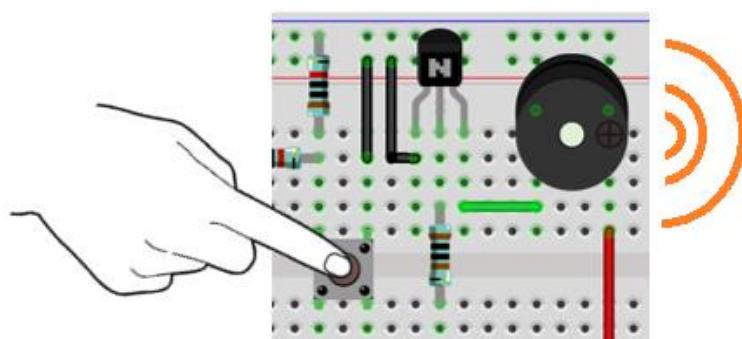
The screenshot shows the Arduino IDE interface with the following details:

- Title Bar:** Sketch_07.1_Doorbell | Arduino 1.8.12
- Menu Bar:** File Edit Sketch Tools Help
- Toolbar:** Includes icons for Open, Save, Print, and Upload.
- Code Editor:** Displays the C++ code for the sketch. The code defines pins for a buzzer and a button, sets up the button as an input and the buzzer as an output, and then loops to read the button state and set the buzzer state accordingly.

```
1 // ****
2 Filename      : Doorbell.c
3 Description   : Control active buzzer by button.
4 Author        : www.freenove.com
5 Modification  : 2020-1-6
6 ****
7 #define PIN_BUZZER 13
8 #define PIN_BUTTON 4
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 }
```

- Status Bar:** Shows the board as ESP32 Wrover Module, Default 4MB with spiffs (1.2MB APP/1.5MB SPIFFS), DOUT, 80MHz, 921600, None on COM4.

Download the code to ESP32-WROVER, 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 13
2 #define PIN_BUTTON 4
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

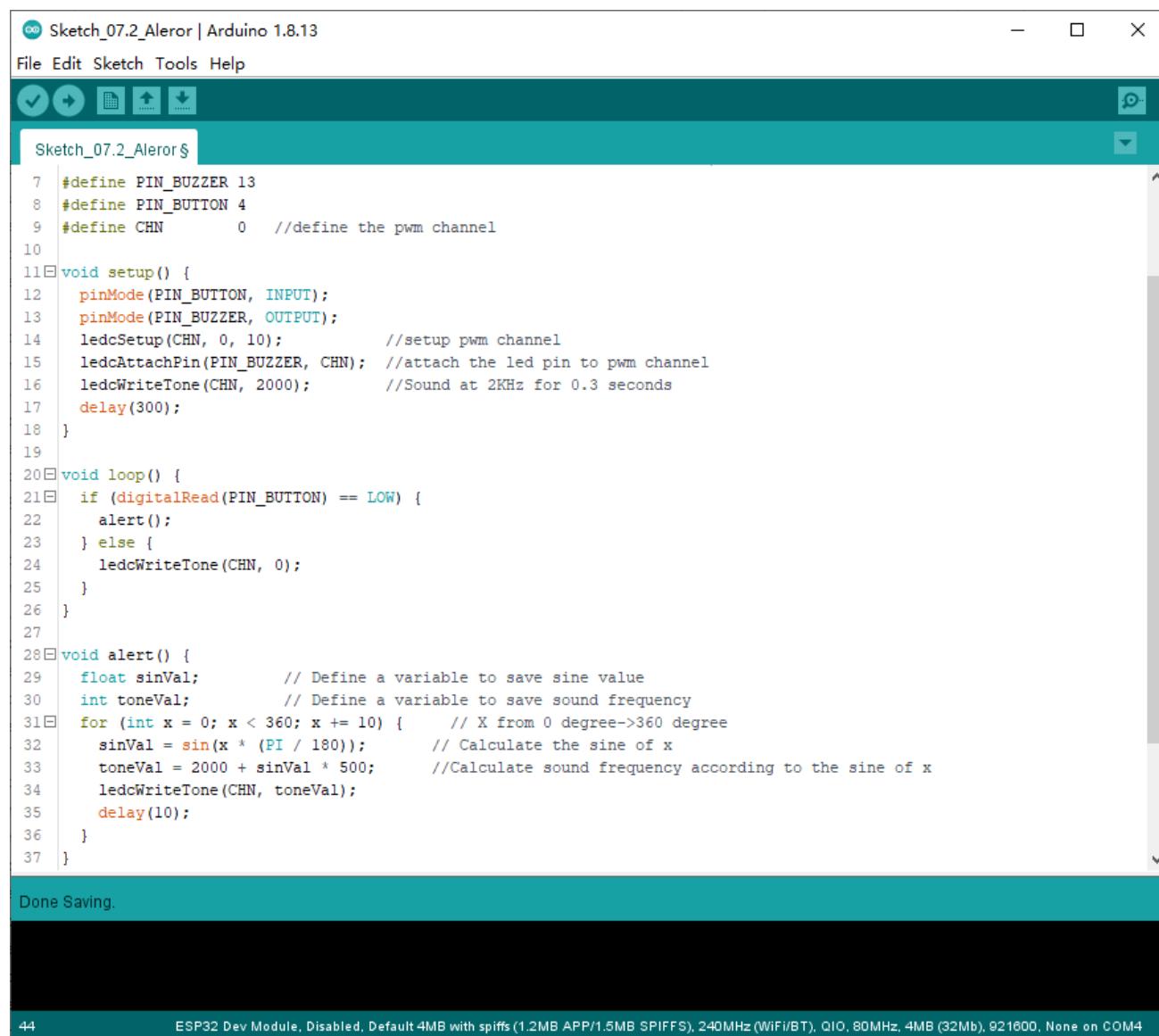
Next, we will use a passive buzzer to make an alarm.

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_Alertor



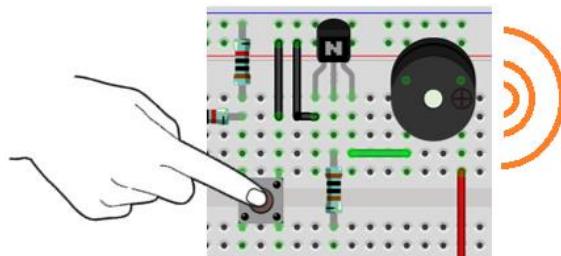
The screenshot shows the Arduino IDE interface with the following details:

- Title Bar:** Sketch_07.2_Aleror | Arduino 1.8.13
- Menu Bar:** File Edit Sketch Tools Help
- Toolbar:** Includes icons for Save, Run, Upload, and others.
- Code Editor:** Displays the C++ code for the sketch. The code defines pins for a button and a buzzer, sets up a PWM channel, and implements a sine wave alert function.

```
Sketch_07.2_Aleror
7 #define PIN_BUZZER 13
8 #define PIN_BUTTON 4
9 #define CHN      0 //define the pwm channel
10
11 void setup() {
12   pinMode(PIN_BUTTON, INPUT);
13   pinMode(PIN_BUZZER, OUTPUT);
14   ledcSetup(CHN, 0, 10);           //setup pwm channel
15   ledcAttachPin(PIN_BUZZER, CHN); //attach the led pin to pwm channel
16   ledcWriteTone(CHN, 2000);       //Sound at 2KHz for 0.3 seconds
17   delay(300);
18 }
19
20 void loop() {
21   if (digitalRead(PIN_BUTTON) == LOW) {
22     alert();
23   } else {
24     ledcWriteTone(CHN, 0);
25   }
26 }
27
28 void alert() {
29   float sinVal;           // Define a variable to save sine value
30   int toneVal;            // Define a variable to save sound frequency
31   for (int x = 0; x < 360; x += 10) { // X from 0 degree->360 degree
32     sinVal = sin(x * (PI / 180)); // Calculate the sine of x
33     toneVal = 2000 + sinVal * 500; //Calculate sound frequency according to the sine of x
34     ledcWriteTone(CHN, toneVal);
35     delay(10);
36   }
37 }
```

- Status Bar:** Done Saving.
- Bottom Status:** ESP32 Dev Module, Disabled, Default 4MB with spiffs (1.2MB APP/1.5MB SPIFFS), 240MHz (WiFi/BT), QIO, 80MHz, 4MB (32Mb), 921600, None on COM4

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



The following is the program code:

```

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

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 ledcSetup(). 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  ledcSetup(CHN, 0, 10);           //setup pwm channel
9  ledcAttachPin(PIN_BUZZER, CHN); //attach the led pin to pwm channel
10 ledcWriteTone(CHN, 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.

```
22 void alert() {
23     float sinVal;           // Define a variable to save sine value
24     int toneVal;            // Define a variable to save sound frequency
25     for (int x = 0; x < 360; x += 10) {      // X from 0 degree->360 degree
26         sinVal = sin(x * (PI / 180));        // Calculate the sine of x
27         toneVal = 2000 + sinVal * 500;        //Calculate sound frequency according to the sine of x
28         ledcWriteTone(CHN, toneVal);
29         delay(10);
30     }
31 }
```

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

```
18 ledcWriteTone(CHN, 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.

Project 7.3 Alertor (use timer)

Due to some bugs in the function ledcWriteTone(), this project uses timer to generate software PWM to control the buzzer. The circuit is exactly the same as the last project.

Sketch

The core of the code of this project is to create a timer to change the GPIO state to generate 50% pulse width PWM, and change the PWM frequency by changing the timing time of the timer.

Sketch_07.3_Alertor

The screenshot shows the Arduino IDE interface. The top menu bar includes File, Edit, Sketch, Tools, and Help. The main window displays the code for 'Sketch_07.3_Alertor'. The code defines pins for a buzzer and a button, initializes a timer, and sets up an interrupt for the button. It then configures the timer to trigger an alarm every 1000ms and starts it. In the loop, it checks if the button is pressed; if so, it sets the alerting state to true and triggers the alarm. The serial monitor at the bottom shows the message 'Leaving... Hard resetting via RTS pin...' followed by a series of '0' characters.

```

Sketch_07.3_Alertor | Arduino 1.8.10
File Edit Sketch Tools Help
Sketch_07.3_Alertor
7 #define BUZZER_PIN      13
8 #define PIN_BUTTON      4
9 hw_timer_t * timer = NULL;
10
11 bool isAlerting = false;
12
13 void IRAM_ATTR onTimer() {
14     digitalWrite(BUZZER_PIN, !digitalRead(BUZZER_PIN));
15 }
16
17 void setup() {
18     pinMode(PIN_BUTTON, INPUT);
19     pinMode(BUZZER_PIN, OUTPUT);
20     // Use 1st timer of 4 (counted from zero).
21     // Set 80 divider for prescaler (see ESP32 Technical Reference Manual for more info).
22     timer = timerBegin(0, 80, true);
23     // Attach onTimer function to our timer.
24     timerAttachInterrupt(timer, onTimer, true);
25 }
26 void loop() {
27     if (digitalRead(PIN_BUTTON) == LOW) {
28         if (!isAlerting) {
29             isAlerting = true;
30             // Set alarm, lms, repeat
31             timerAlarmWrite(timer, 1000, true);
32             // Start an alarm
33             timerAlarmEnable(timer);
34         }
35     }
36     alert();
37 }
Done uploading.

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

```

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

The following is the program code:

```
1 #define BUZZER_PIN      13
2 #define PIN_BUTTON      4
3 hw_timer_t * timer = NULL;
4
5 bool isAlerting = false;
6
7 void IRAM_ATTR onTimer() {
8     digitalWrite(BUZZER_PIN, ! digitalRead(BUZZER_PIN));
9 }
10
11 void setup() {
12     pinMode(PIN_BUTTON, INPUT);
13     pinMode(BUZZER_PIN, OUTPUT);
14     // Use 1st timer of 4 (counted from zero).
15     // Set 80 divider for prescaler (see ESP32 Technical Reference Manual for more info).
16     timer = timerBegin(0, 80, true);
17     // Attach onTimer function to our timer.
18     timerAttachInterrupt(timer, &onTimer, true);
19 }
20
21 void loop() {
22     if (digitalRead(PIN_BUTTON) == LOW) {
23         if (! isAlerting) {
24             isAlerting = true;
25             // Set alarm, 1ms, repeat
26             timerAlarmWrite(timer, 1000, true);
27             // Start an alarm
28             timerAlarmEnable(timer);
29         }
30         alert();
31     } else {
32         if (isAlerting) {
33             isAlerting = false;
34             timerAlarmDisable(timer);
35             digitalWrite(BUZZER_PIN, LOW);
36         }
37     }
38 }
39
40 void alert() {
41     float sinVal;
42     int toneVal;
43     for (int x = 0; x < 360; x += 1) {
44         sinVal = sin(x * (PI / 180));
```

```

44     toneVal = 2000 + sinVal * 500;
45     timerAlarmWrite(timer, 500000 / toneVal, true);
46     delay(1);
47 }
48 }
```

In the code, first define a timer variable, timer, and then create the timer in setup(), setting the function onTimer() that the timer will execute.

```

3     hw_timer_t * timer = NULL;
4
5     // Set 80 divider for prescaler (see ESP32 Technical Reference Manual for more info).
6     timer = timerBegin(0, 80, true);
7     // Attach onTimer function to our timer.
8     timerAttachInterrupt(timer, &onTimer, true);
```

In the loop(), use the timerAlarmWrite() to set the timer time and use timerAlarmEnable() to start the timer. Using the flag bit isAlerting, the code to set and start the timer is executed only when the key is pressed.

```

22    if (!isAlerting) {
23        isAlerting = true;
24        // Set alarm, 1ms, repeat
25        timerAlarmWrite(timer, 1000, true);
26        // Start an alarm
27        timerAlarmEnable(timer);
28    }
```

After the key is released, stop the timer and make the buzzer's GPIO output low.

```

31    if (isAlerting) {
32        isAlerting = false;
33        timerAlarmDisable(timer);
34        digitalWrite(BUZZER_PIN, LOW);
35    }
```

Reference

```
typedef struct hw_timer_s hw_timer_t;
```

Timer type, used to define a timer variable.

```
hw_timer_t * timerBegin(uint8_t timer, uint16_t divider, bool countUp);
```

Initialize the timer.

parameters

timer: The timer to initialize

divider: The frequency divider coefficient of the timer, the value range is 2-65535. The default clock frequency is 80MHz.

countUp: true means counter up technique and false means counter down.

```
void timerAttachInterrupt(hw_timer_t *timer, void (*fn)(void), bool edge);
```

Bind the function to execute when the interrupt is generated for the timer.

```
void timerAlarmWrite(hw_timer_t *timer, uint64_t interruptAt, bool autoreload);
```

Set the timer time.

```
void timerAlarmEnable(hw_timer_t *timer);
```

```
void timerAlarmDisable(hw_timer_t *timer);
```

Start/stop the timer.



Project 7.4 Alertor (use idf)

Although using software “timer” to generate PWM is to achieve our purpose, but frequent interruption will reduce the execution efficiency of the main program code, and when the project is too large, this problem will be more serious. Obviously, software PWM is not the optimal choice.

This project uses the function in esp-idf-sdk code base to make the hardware PWM with adjustable frequency, and then control the buzzer.

Because the code of this project applies the functions in the esp-idf-sdk code base, which is beyond the scope of “Arduino”, and there are many unfamiliar functions, it will be more complex.

The circuit is exactly the same as the previous project.

Sketch

Sketch_07.4_Alertor

```

Sketch_07.4_Alertor | Arduino 1.8.10
File Edit Sketch Tools Help
Sketch_07.4_Alertor
1 //*****
2 Filename : Alertor.ino
3 Description : Using IDF-SDK function to generate PWM control buzzer.
4 Author : www.freenove.com
5 Modification: 2020-1-17
6 *****/
7
8 #include "driver/ledc.h"
9
10 #define BUZZER_PIN 13
11 #define PIN_BUTTON 4
12
13 #define LEDC_HS_TIMER LEDC_TIMER_0
14 #define LEDC_LS_TIMER LEDC_TIMER_1
15
16 #define LEDC_HS_MODE LEDC_HIGH_SPEED_MODE
17 #define LEDC_LS_MODE LEDC_LOW_SPEED_MODE
18
19 #define LEDC_HS_CH0_GPIO (BUZZER_PIN)
20 #define LEDC_HS_CH0_CHANNEL LEDC_CHANNEL_0
21
22 bool isAlerting = false;

```

ESP32 Dev Module, Disabled, Default 4MB with spiffs (1.2MB APP/1.5MB SPIFFS), 240MHz (WiFi/BT), QIO, 80MHz, 4MB (32Mb), 921600, None on COM9

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

The following is the program code:

```
1 #include "driver/ledc.h"
2
3 #define BUZZER_PIN      13
4 #define PIN_BUTTON      4
5
6 #define LEDC_HS_TIMER    LEDC_TIMER_0
7 #define LEDC_LS_TIMER    LEDC_TIMER_1
8
9 #define LEDC_HS_MODE     LEDC_HIGH_SPEED_MODE
10 #define LEDC_LS_MODE     LEDC_LOW_SPEED_MODE
11
12 #define LEDC_HS_CH0_GPIO (BUZZER_PIN)
13 #define LEDC_HS_CH0_CHANNEL LEDC_CHANNEL_0
14
15 bool isAlerting = false;
16
17 void setup() {
18     pinMode(PIN_BUTTON, INPUT);
19     ledc_channel_config_t ledc_channel = {
20         LEDC_HS_CH0_GPIO,
21         LEDC_HIGH_SPEED_MODE,
22         LEDC_CHANNEL_0,
23         LEDC_INTR_DISABLE,
24         LEDC_HS_TIMER,
25         0,
26         0
27     };
28     ledc_timer_config_t ledc_timer = {
29         LEDC_HIGH_SPEED_MODE,
30         LEDC_TIMER_10_BIT,
31         LEDC_HS_TIMER,
32         5000
33     };
34     // Set configuration of timer0 for high speed channels
35     ledc_timer_config(&ledc_timer);
36     // Set LED Controller with previously prepared configuration
37     ledc_channel_config(&ledc_channel);
38     ledc_fade_func_install(0);
39 }
40 void loop() {
41     if (digitalRead(PIN_BUTTON) == LOW) {
42         if (!isAlerting) {
43             isAlerting = true;
```

```

44         ledc_set_duty_and_update(LEDC_HS_MODE, LEDC_CHANNEL_0, 0, 0);
45     }
46     alert();
47 }
48 else {
49     if (isAlerting) {
50         isAlerting = false;
51         ledc_set_duty_and_update(LEDC_HS_MODE, LEDC_CHANNEL_0, 0, 0);
52     }
53 }
54 }
55
56 void alert() {
57     float sinVal;
58     int toneVal;
59     for (int x = 0; x < 360; x += 1) {
60         sinVal = sin(x * (PI / 180));
61         toneVal = 2000 + sinVal * 500;
62         ledc_set_freq(LEDC_HS_MODE, LEDC_TIMER_0, toneVal);
63         ledc_set_duty_and_update(LEDC_HS_MODE, LEDC_CHANNEL_0, 512, 0);
64         delay(1);
65     }
66 }
```

The project code uses a lot of new functions, which are standard functions from the idf-sdk library. The code logic of the project is the same, but the method of generating PWM is different.

Functionality Overview

Getting LED to work on a specific channel in either high or low speed mode requires three steps:

1. Configure Timer by specifying the PWM signal's frequency and duty cycle resolution.
2. Configure Channel by associating it with the timer and GPIO to output the PWM signal.
3. Change PWM Signal that drives the output in order to change LED's intensity. This can be done under the full control of software or with hardware's fading functions.

For more information, please visit:

<https://docs.espressif.com/projects/esp-idf/en/latest/api-reference/peripherals/ledc.html>

Chapter 8 Serial Communication

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

Project 8.1 Serial Print

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

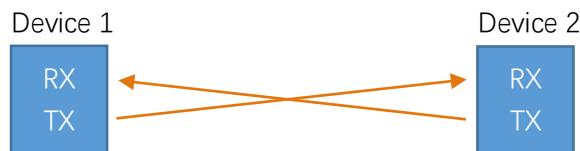
Component List

ESP32-WROVER x1	GPIO Extension Board x1
	

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

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

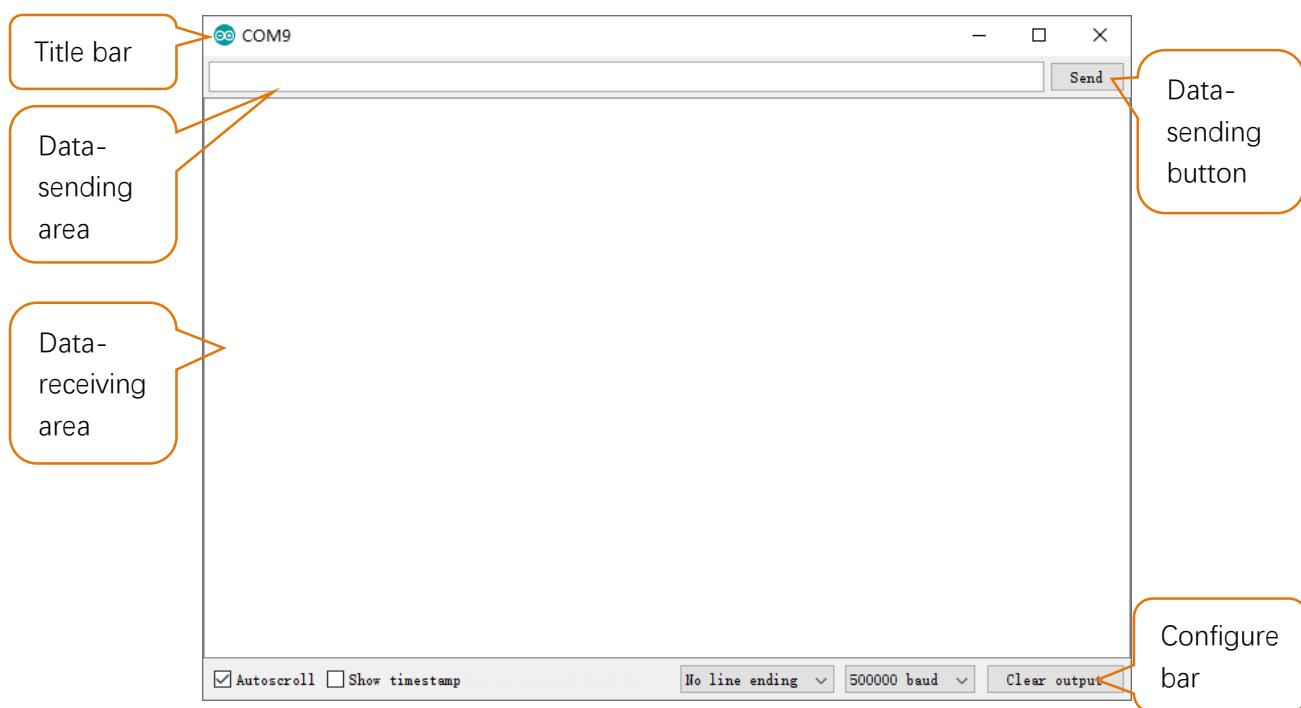


Arduino Software also uploads code to Freenove ESP32 through the serial connection.

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, connect Freenove ESP32 to computer through the USB cable, choose the correct device, and then click the Serial Monitor icon to open the Serial Monitor window.

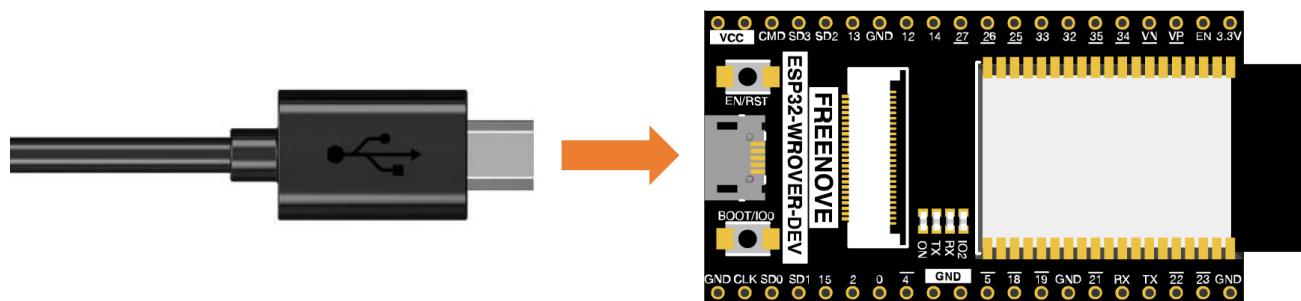


Interface of serial monitor window is as follows. If you can't open it, make sure Freenove ESP32 has been connected to the computer, and choose the right serial port in the menu bar "Tools".



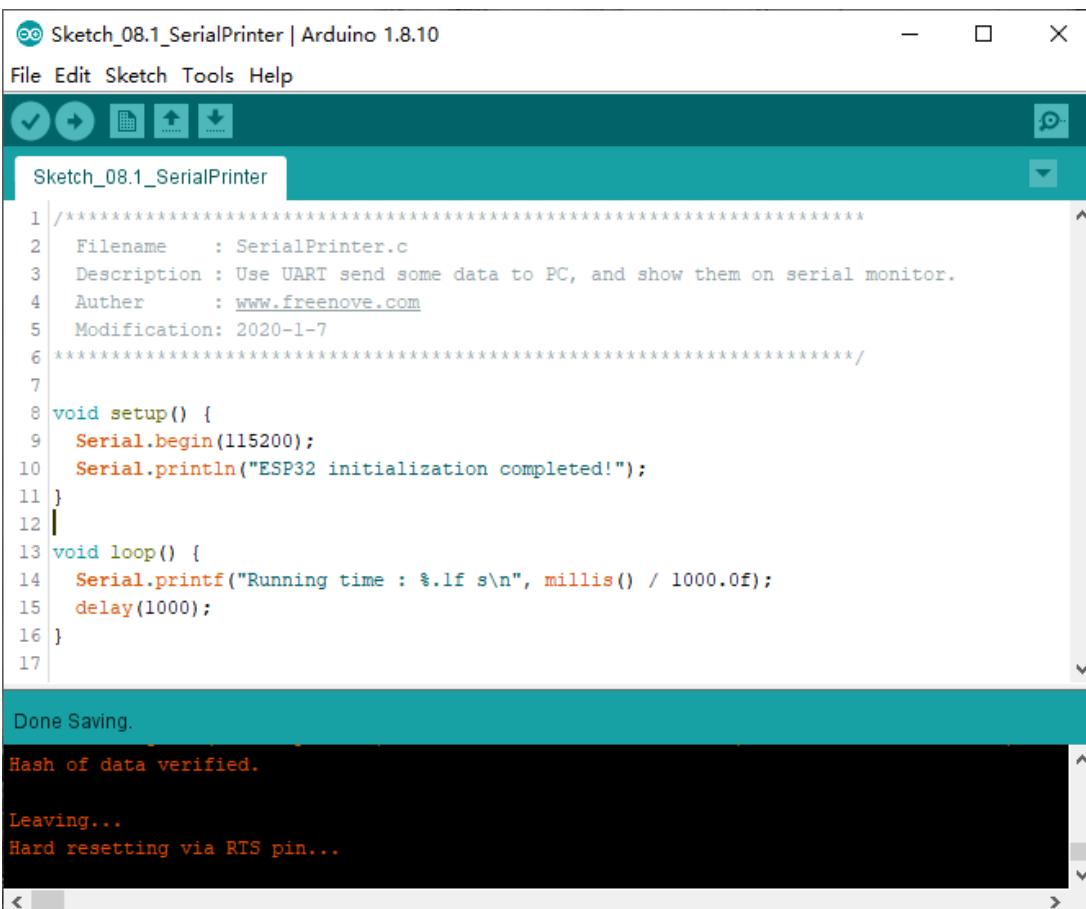
Circuit

Connect Freenove ESP32 to the computer with USB cable



Sketch

Sketch_08.1_SerialPrinter



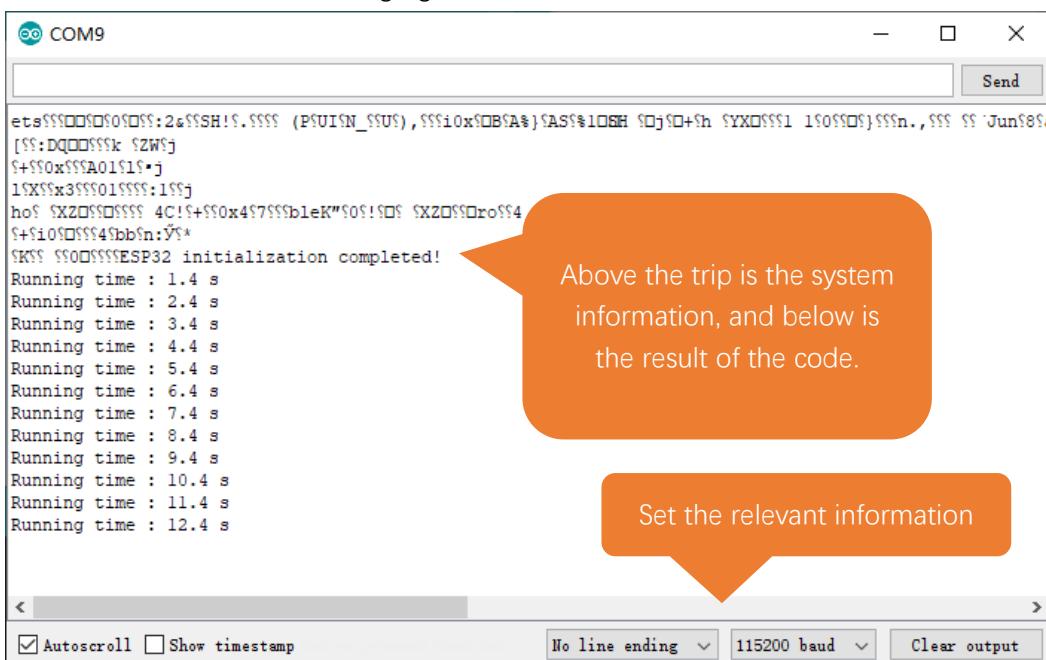
```
Sketch_08.1_SerialPrinter | Arduino 1.8.10
File Edit Sketch Tools Help
Sketch_08.1_SerialPrinter
1 //*****
2 Filename : SerialPrinter.c
3 Description : Use UART send some data to PC, and show them on serial monitor.
4 Author : www.freenove.com
5 Modification: 2020-1-7
6 *****/
7
8 void setup() {
9   Serial.begin(115200);
10  Serial.println("ESP32 initialization completed!");
11 }
12
13 void loop() {
14   Serial.printf("Running time : %.1f s\n", millis() / 1000.0f);
15   delay(1000);
16 }
17

Done Saving.

Hash of data verified.

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

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



ets!!!000000:2&!!SH!\$..!!!! (P\$UI\$N_!!\$),!!!i0x!!DB\$A\$)!AS%10EH \$Oj\$O+h 'YXD!!!!1 1\$0\$!!}!!!n.,!!! SS 'Jun\$8\$!
[!!:DQ\$0\$!!\$k f2W\$j
\$+!!0x\$!!\$A01\$1\$*j
1\$X\$!!x3\$!!\$01\$!!\$!!:1\$!!j
hof !XZDS\$0\$!!\$ 4C!\$+!!0x4\$7\$!!\$bleK"!\$0\$!\$0\$!XZ\$0\$!!\$ro\$!!4
\$+!i0\$!!\$!!\$4\$bb\$!!:\$!!\$*
\$K\$!! \$!!0\$!!\$!!\$ESP32 initialization completed!

Running time : 1.4 s
Running time : 2.4 s
Running time : 3.4 s
Running time : 4.4 s
Running time : 5.4 s
Running time : 6.4 s
Running time : 7.4 s
Running time : 8.4 s
Running time : 9.4 s
Running time : 10.4 s
Running time : 11.4 s
Running time : 12.4 s

Above the trip is the system information, and below is the result of the code.

Set the relevant information

<input checked="" type="checkbox"/> Autoscroll	<input type="checkbox"/> Show timestamp	No line ending	115200 baud	Clear output
--	---	----------------	-------------	--------------

As shown in the image above, "ESP32 initialization completed! " The previous is the printing message when the system is started, it uses the baud rate of 120,000, which is incorrect, so the garbled code is displayed. The user program is then printed at a baud rate of 115200.

How do I disable messages printed at system startup?

Use a jumper wire and connect one of its ends to GPIO5 of development board and the other to GND, so that we can disable the system to print out startup messages.

For more information, click [here](#).

The following is the program code:

```
1 void setup() {  
2     Serial.begin(115200);  
3     Serial.println("ESP32 initialization completed!");  
4 }  
5  
6 void loop() {  
7     Serial.printf("Running time : %.1f s\n", millis() / 1000.0f);  
8     delay(1000);  
9 }
```

Reference

```
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);
```

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

```
size_t println( arg );
```

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

```
size_t printf(const char * format, ...) __attribute__ ((format (printf, 2, 3)));
```

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

```
unsigned long millis();
```

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 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

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

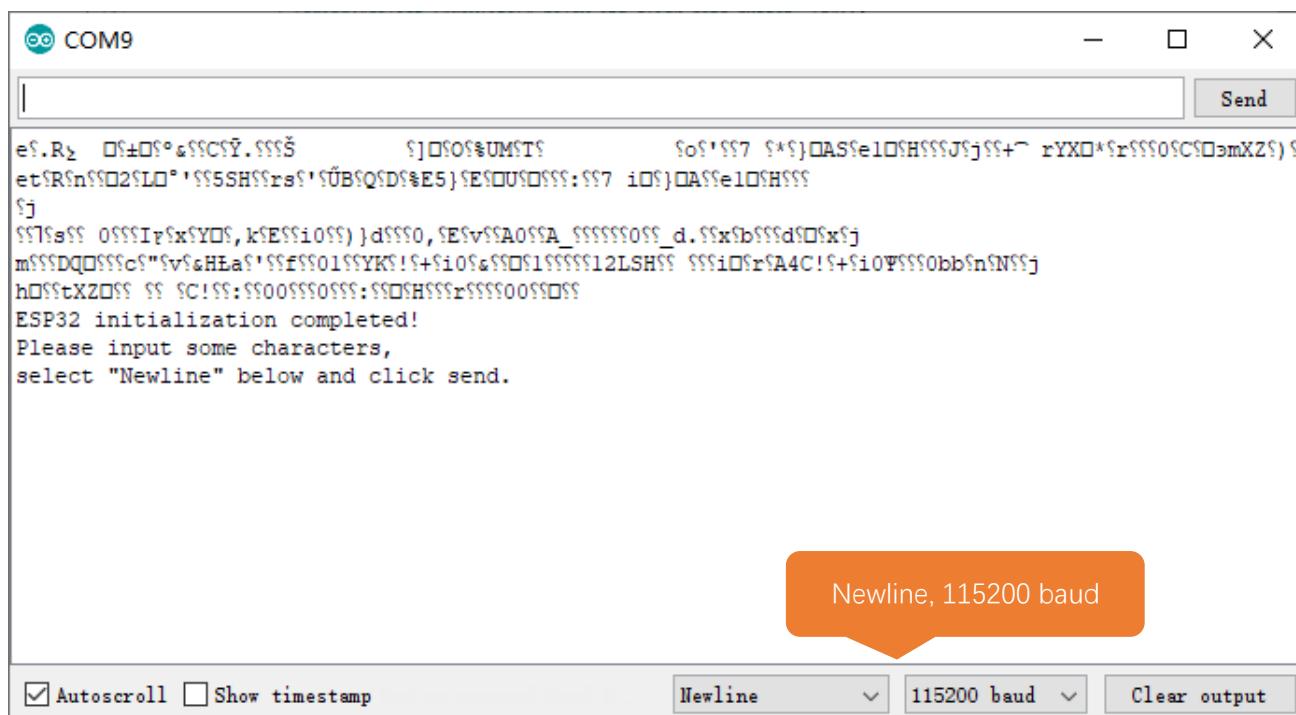
- Title Bar:** Sketch_08.2_SerialRW | Arduino 1.8.10
- Menu Bar:** File Edit Sketch Tools Help
- Toolbar:** Includes icons for Save, Upload, and others.
- Code Editor:** Displays the C++ code for the sketch. The code initializes the serial port at 115200 baud, prints a welcome message, and enters a loop to read incoming characters and build a string until a newline is received. It then prints the received string and resets the variables.

```
String inputString = ""; //a String to hold incoming data
bool stringComplete = false; // whether the string is complete

void setup() {
    Serial.begin(115200);
    Serial.println("\nESP32 initialization completed!\n");
    + String("Please input some characters,\n")
    + String("select \"Newline\" below and click send button. \n"));
}

void loop() {
    if (Serial.available()) { // judge whether data has been received
        char inChar = Serial.read(); // read one character
        inputString += inChar;
        if (inChar == '\n') {
            stringComplete = true;
        }
    }
    if (stringComplete) {
        Serial.printf("inputString: %s \n", inputString);
        inputString = "";
        stringComplete = false;
    }
}
```
- Status Bar:** Shows "Done uploading.", "Hash of data verified.", "Leaving...", "Hard resetting via RTS pin...", and "ESP32 Wrover Module on COM9".

Download the code to ESP32-WROVER, open the serial monitor, and set the bottom to Newline, 115200. As shown in the following figure:



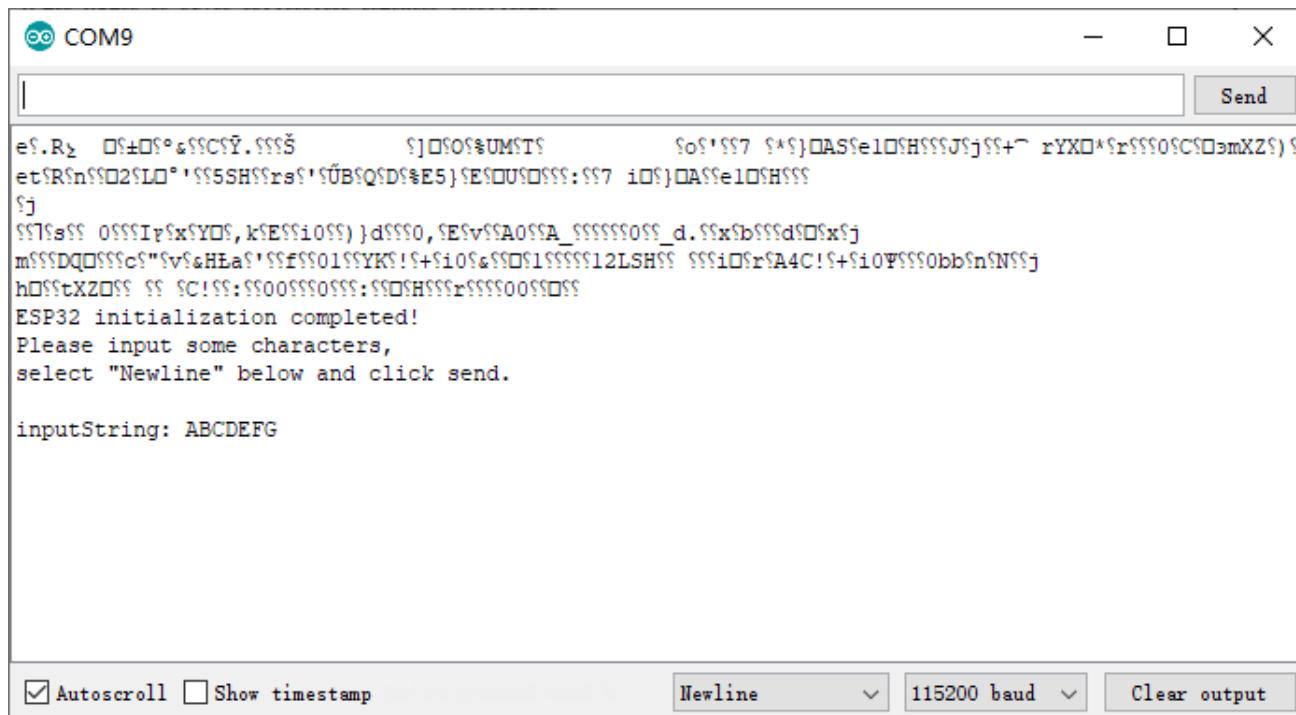
```

eF.Rz  09±0°&9C9Y.999S      $]090%UMST$      9o9'997 9*9}0ASfe109H999J9j99+^ rYX0*xr99909C909mXZ9)99
et9Rfn99929L0°'995SH99rs9'9UB9Q9D9%E5}9E90U90999:997 i99}0A9fe109H999
9j
99999999 0999I9x9Y99, k9E99i099) j9d9990, 9E9v99A099A_99999999_d.99x9b999d99x9j
m999D9Q999c9"9v9&H9a9'99f990199Y99!9+9i09&999919999912LSH99 999i9r9A4C!9+9i099990bb9n9N9j
h999tXZ999 99 9C!99:990999099:999H999r99999009999
ESP32 initialization completed!
Please input some characters,
select "Newline" below and click send.

Newline, 115200 baud
  
```

Autoscroll Show timestamp Newline 115200 baud Clear output

Then type characters like 'ABCDEF' into the data sent at the top and click the Send button to print out the data ESP32 receives.



```

eF.Rz  09±0°&9C9Y.999S      $]090%UMST$      9o9'997 9*9}0ASfe109H999J9j99+^ rYX0*xr99909C909mXZ9)99
et9Rfn99929L0°'995SH99rs9'9UB9Q9D9%E5}9E90U90999:997 i99}0A9fe109H999
9j
99999999 0999I9x9Y99, k9E99i099) j9d9990, 9E9v99A099A_99999999_d.99x9b999d99x9j
m999D9Q999c9"9v9&H9a9'99f990199Y99!9+9i09&999919999912LSH99 999i9r9A4C!9+9i099990bb9n9N9j
h999tXZ999 99 9C!99:990999099:999H999r99999009999
ESP32 initialization completed!
Please input some characters,
select "Newline" below and click send.

inputString: ABCDEFG

  
```

Autoscroll Show timestamp Newline 115200 baud Clear output

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("\nESP32 initialization completed! \n")
7                      + String("Please input some characters, \n")
8                      + String("select \"Newline\" below and click send button. \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 \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.

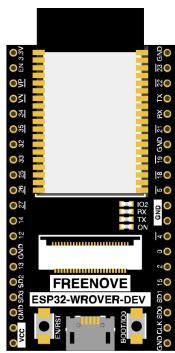
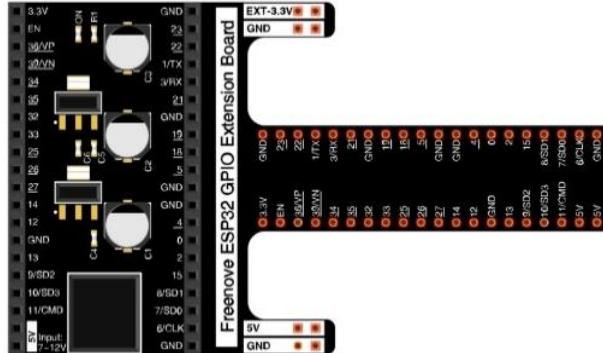
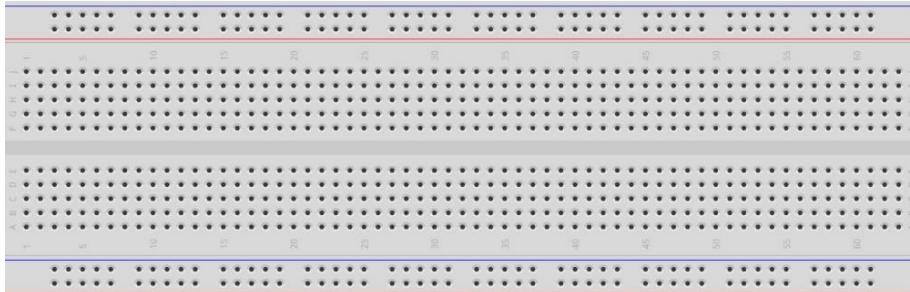
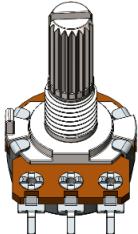
Chapter 9 AD/DA Converter

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

Project 9.1 Read the Voltage of Potentiometer

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

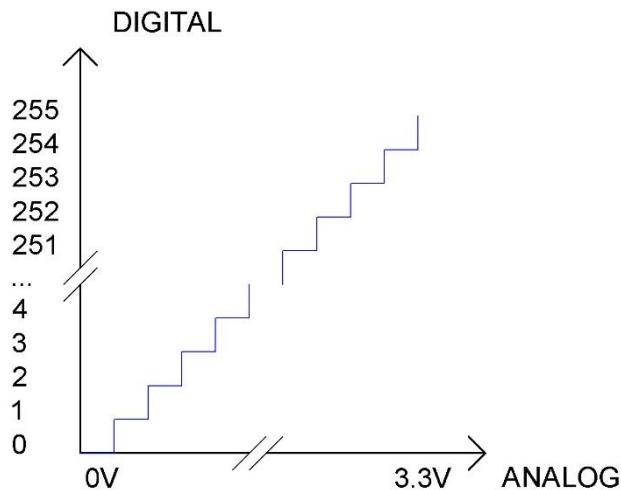
Component List

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

Related knowledge

ADC

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



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

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

...

The following analog will be divided accordingly.

The conversion formula is as follows:

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

DAC

The reversing of this process requires a DAC, Digital-to-Analog Converter. The digital I/O port can output high level and low level (0 or 1), but cannot output an intermediate voltage value. This is where a DAC is useful. ESP32 has two DAC output pins with 8-bit accuracy, GPIO25 and GPIO26, which can divide VDD (here is 3.3V) into $2^8=256$ parts. For example, when the digital quantity is 1, the output voltage value is $3.3/256 * 1$ V, and when the digital quantity is 128, the output voltage value is $3.3/256 * 128=1.65$ V, the higher the accuracy of DAC, the higher the accuracy of output voltage value will be.

The conversion formula is as follows:

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

ADC on ESP32

ESP32 has two digital analog converters with successive approximations of 12-bit accuracy, and a total of 16 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 36	ADC1_CH0
A3	GPIO 39	ADC1_CH3
A4	GPIO 32	ADC1_CH4
A5	GPIO 33	ADC1_CH5
A6	GPIO 34	ADC1_CH6
A7	GPIO 35	ADC1_CH7
A10	GPIO 4	ADC2_CH0
A11	GPIO 0	ADC2_CH1
A12	GPIO 2	ADC2_CH2
A13	GPIO 15	ADC2_CH3
A14	GPIO 13	ADC2_CH4
A15	GPIO 12	ADC2_CH5
A16	GPIO 14	ADC2_CH6
A17	GPIO 27	ADC2_CH7
A18	GPIO 25	ADC2_CH8
A19	GPIO 26	ADC2_CH9

The analog pin number is also defined in ESP32's code base. For example, you can replace GPIO36 with A0 in the code.

Note: ADC2 is disabled when ESP32's WiFi function is enabled.

DAC on ESP32

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

Simulate pin number	GPIO number
DAC1	25
DAC2	26

The DAC pin number is already defined in ESP32's code base; for example, you can replace GPIO25 with DAC1 in the code.

Note: In this ESP32, GPIO26 is used as the camera's IIC-SDA pin, which is connected to 3.3V through a resistor. Therefore, DAC2 cannot be used.

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.



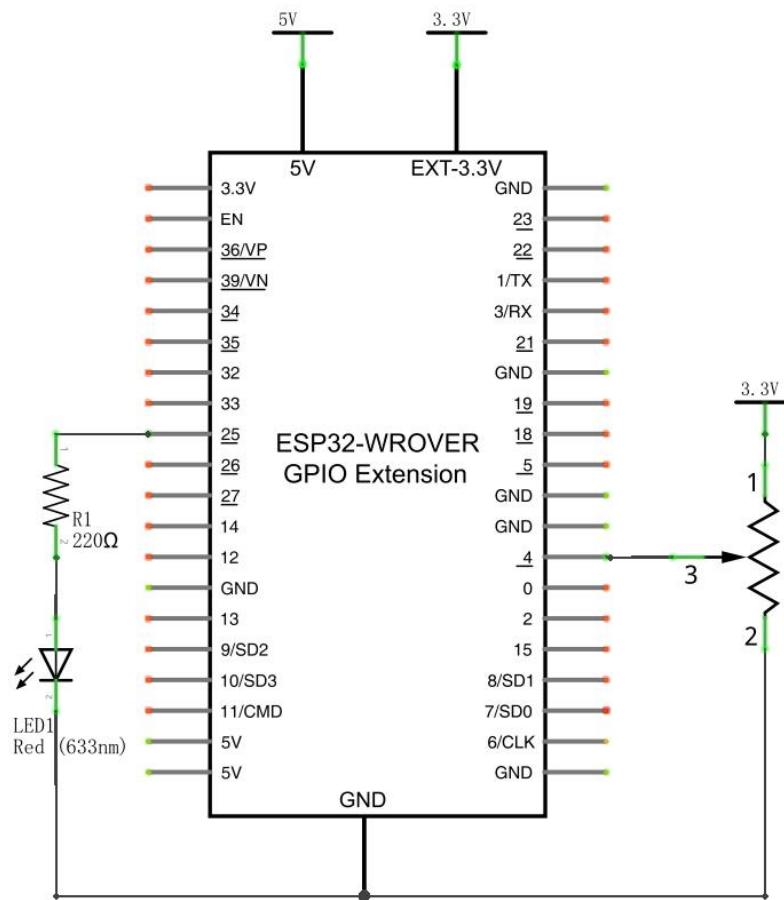
Rotary potentiometer

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



Any concerns? ✉ support@freenove.com



Sketch

Sketch_09.1_ADC_DAC

```

Sketch_09.1_ADC_DAC | Arduino 1.8.10
File Edit Sketch Tools Help
Sketch_09.1_ADC_DAC
1 // *****
2 Filename : ADC_DAC.ino
3 Description : Basic usage of ADC and DAC for esp32.
4 Author : www.freenove.com
5 Modification: 2020-1-9
6 *****
7 #define PIN_ANALOG_IN 4
8
9 void setup() {
10   Serial.begin(115200);
11 }
12
13 void loop() {
14   int adcVal = analogRead(PIN_ANALOG_IN);
15   int dacVal = map(adcVal, 0, 4095, 0, 255);
16   double voltage = adcVal / 4095.0 * 3.3;
17   dacWrite(DAC1, dacVal);
18   Serial.printf("ADC Val: %d, \t DAC Val: %d, \t Voltage: %.2f \n", adcVal, dacVal, voltage);
19   delay(200);
20 }

```

Done Saving.

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

ESP32 Dev Module on COM9

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

ADC Val	DAC Val	Voltage
1344	83	1.08V
1345	83	1.08V
1328	82	1.07V
1344	83	1.08V
1344	83	1.08V
1344	83	1.08V
1345	83	1.08V
1344	83	1.08V
1321	82	1.06V

Autoscroll Show timestamp No line ending 115200 baud Clear output

The serial monitor prints ADC values, DAC values, and the output voltage of the potentiometer. In the code, we made the voltage output from the DAC pin equal to the voltage input from the ADC pin. Rotate the handle of the potentiometer and the print will change. When the voltage is greater than 1.6V (voltage needed to turn on red LED), LED starts emitting light. If you continue to increase the output voltage, the LED will become more and more brighter. When the voltage is less than 1.6v, the LED will not light up, because it does not reach the voltage to turn on LED, which indirectly proves the difference between DAC and PWM. (if you have an oscilloscope, you can check the waveform of the DAC output through it.)

The following is the code:

```

1 #define PIN_ANALOG_IN 4
2
3 void setup() {
4     Serial.begin(115200);
5 }
6
7 void loop() {
8     int adcVal = analogRead(PIN_ANALOG_IN);
9     int dacVal = map(adcVal, 0, 4095, 0, 255);
10    double voltage = adcVal / 4095.0 * 3.3;
11    dacWrite(DAC1, dacVal);
12    Serial.printf("ADC Val: %d, \t DAC Val: %d, \t Voltage: %.2fV\n", adcVal, dacVal, voltage);
13    delay(200);
14 }
```

In loop(), the analogRead() function is used to obtain the ADC value, and then the map() function is used to convert the value into an 8-bit precision DAC value. The function dacWrite() is used to output the value. The input and output voltage are calculated according to the previous formula, and the information is finally printed out.

```

8 int adcVal = analogRead(PIN_ANALOG_IN);
9 int dacVal = map(adcVal, 0, 4095, 0, 255);
10 double voltage = adcVal / 4095.0 * 3.3;
11 dacWrite(DAC1, dacVal);
12 Serial.printf("ADC Val: %d, \t DAC Val: %d, \t Voltage: %.2fV\n", adcVal, dacVal, 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).

`void dacWrite(uint8_t pin, uint8_t value);`

This writes the given value to the supplied analog pin.

`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.



Project 9.2 Get Voltage (use idf)

If you have a voltmeter, in the previous project, you may discover there is a slight error between the voltage values for ESP32 and the voltmeter values.

ESP32 provides ADC calibration, but the Arduino code base doesn't use it. The functions in the IDF-SDK library help to obtain more accurate ADC and voltage values.

Related Knowledge

Minimizing Noise

The ESP32 ADC's sensitive to noise will lead to large discrepancies in ADC readings. To minimize noise, users may connect a 0.1uF capacitor to the ADC input pad in use. Multisampling may also be used to further mitigate the effects of noise.



Graph illustrating noise mitigation using capacitor and multisampling of 64 samples.

ADC Calibration

The [esp_adc_cal/include/esp_adc_cal.h](#) API provides functions to correct for differences in measured voltages caused by variation of ADC reference voltages (Vref) between chips. The designed ADC reference voltage is 1100mV, however the true reference voltage can range from 1000mV to 1200mV amongst different ESP32s.



Graph illustrating the effect of differing reference voltages on the ADC voltage curve.

Correcting ADC readings using this API involves characterizing one of the ADCs at a given attenuation to obtain a characteristics curve (ADC-Voltage curve) that takes into account the difference in ADC reference voltage. The characteristics curve is in the form of $y = \text{coeff_a} * x + \text{coeff_b}$ and is used to convert ADC readings to voltages in mV. Calculation of the characteristics curve is based on calibration values, which can be stored in eFuse or provided by the user.

For more details, please visit:

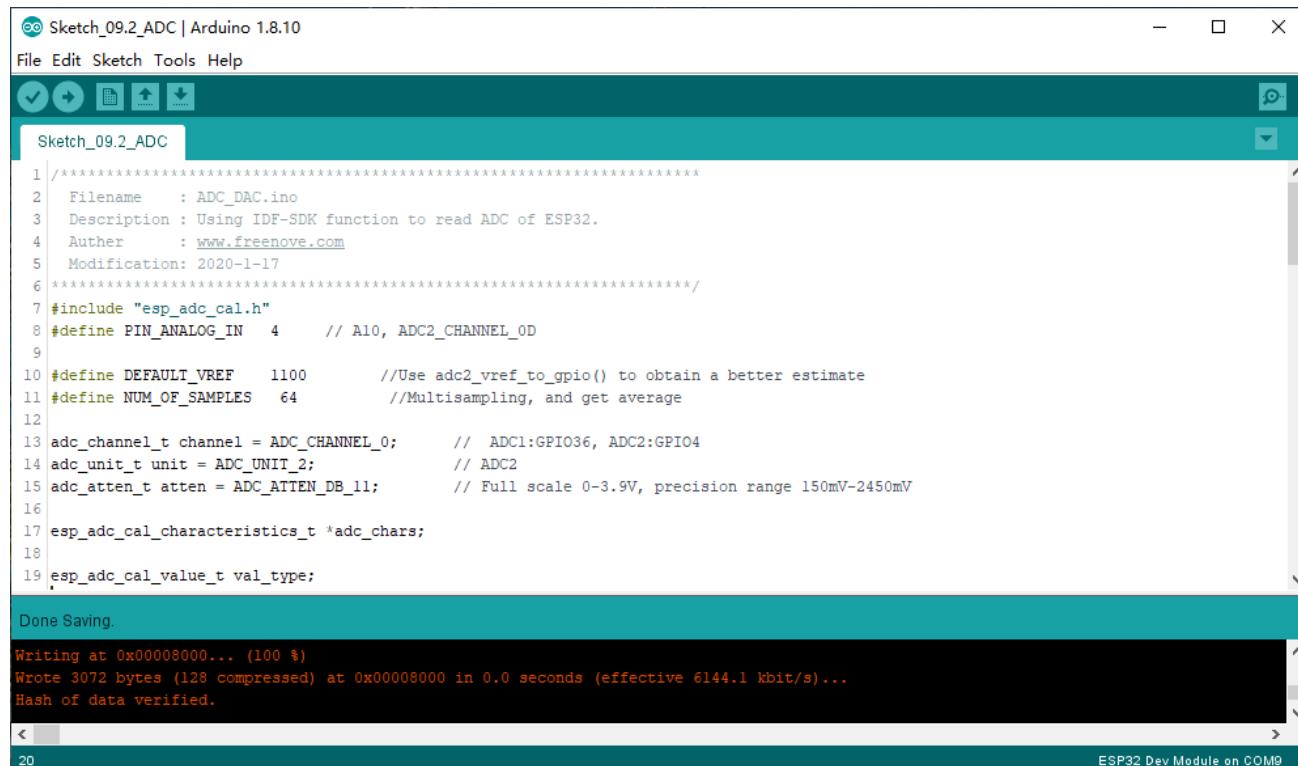
<https://docs.espressif.com/projects/esp-idf/en/latest/api-reference/peripherals/adc.html>

PIN Numbering

ADC serial number	pin number of Arduino	pin number of IDF-SDK	GPIO number
ADC1	A0	ADC1_CHANNEL_0	GPIO 36
	A1	ADC1_CHANNEL_1	GPIO 37
	A2	ADC1_CHANNEL_2	GPIO 38
	A3	ADC1_CHANNEL_3	GPIO 39
	A4	ADC1_CHANNEL_4	GPIO 32
	A5	ADC1_CHANNEL_5	GPIO 33
	A6	ADC1_CHANNEL_6	GPIO 34
	A7	ADC1_CHANNEL_7	GPIO 35
ADC2	A10	ADC2_CHANNEL_0	GPIO 4
	A11	ADC2_CHANNEL_1	GPIO 0
	A12	ADC2_CHANNEL_2	GPIO 2
	A13	ADC2_CHANNEL_3	GPIO 15
	A14	ADC2_CHANNEL_4	GPIO 13
	A15	ADC2_CHANNEL_5	GPIO 12
	A16	ADC2_CHANNEL_6	GPIO 14
	A17	ADC2_CHANNEL_7	GPIO 27
	A18	ADC2_CHANNEL_8	GPIO 25
	A19	ADC2_CHANNEL_9	GPIO 26

Sketch

Sketch_09.2_ADC



```

Sketch_09.2_ADC | Arduino 1.8.10
File Edit Sketch Tools Help
Sketch_09.2_ADC
1 // *****
2 Filename : ADC_DAC.ino
3 Description : Using IDF-SDK function to read ADC of ESP32.
4 Author : www.freenove.com
5 Modification: 2020-1-17
6 *****
7 #include "esp_adc_cal.h"
8 #define PIN_ANALOG_IN 4 // A10, ADC2_CHANNEL_0D
9
10 #define DEFAULT_VREF 1100 //Use adc2_vref_to_gpio() to obtain a better estimate
11 #define NUM_OF_SAMPLES 64 //Multisampling, and get average
12
13 adc_channel_t channel = ADC_CHANNEL_0; // ADC1:GPIO36, ADC2:GPIO4
14 adc_unit_t unit = ADC_UNIT_2; // ADC2
15 adc_atten_t atten = ADC_ATTEN_DB_11; // Full scale 0-3.9V, precision range 150mV-2450mV
16
17 esp_adc_cal_characteristics_t *adc_chars;
18
19 esp_adc_cal_value_t val_type;

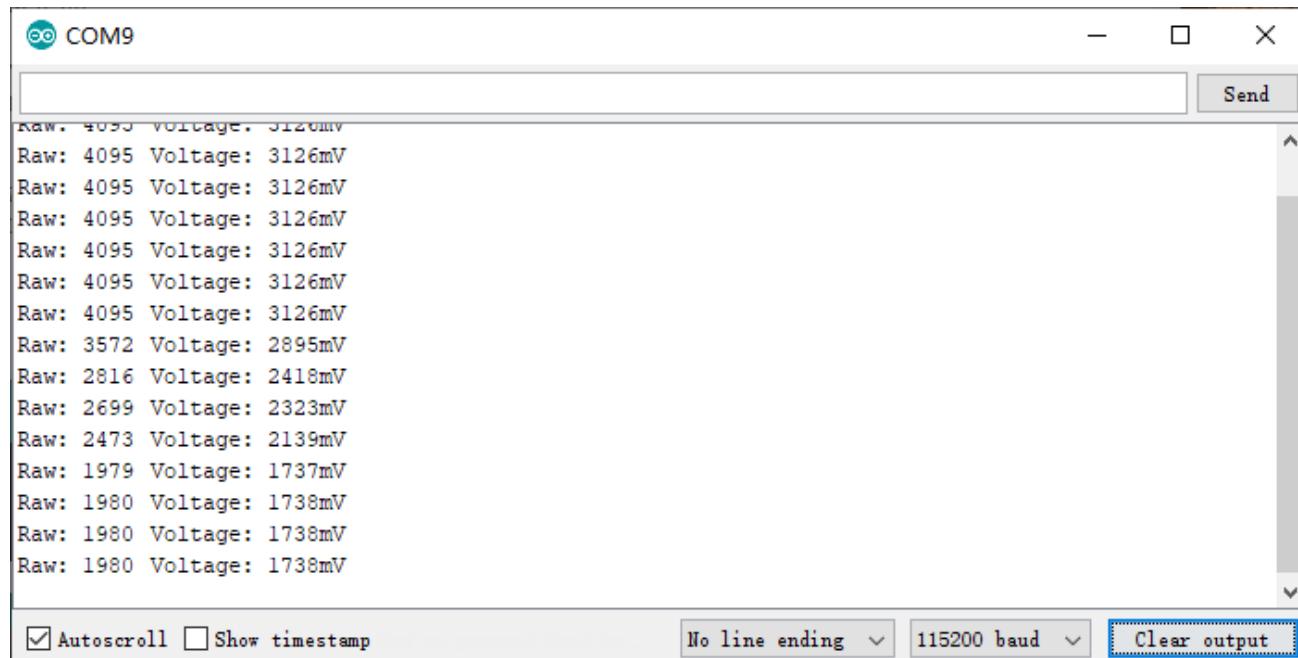
Done Saving.

Writing at 0x00008000... (100 %)
Wrote 3072 bytes (128 compressed) at 0x00008000 in 0.0 seconds (effective 6144.1 kbit/s)...
Hash of data verified.

< 20
ESP32 Dev Module on COM9

```

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



```

Raw: #033 Voltage: 3126mV
Raw: 4095 Voltage: 3126mV
Raw: 3572 Voltage: 2895mV
Raw: 2816 Voltage: 2418mV
Raw: 2699 Voltage: 2323mV
Raw: 2473 Voltage: 2139mV
Raw: 1979 Voltage: 1737mV
Raw: 1980 Voltage: 1738mV
Raw: 1980 Voltage: 1738mV
Raw: 1980 Voltage: 1738mV

Autoscroll  Show timestamp  No line ending  115200 baud  Clear output

```

By rotating the handle of the potentiometer, the voltage value printed by the serial monitor will change. If you have a voltmeter, you can verify that this value is more accurate than the value using analogRead(), but there are some limits to the range.

Any concerns? ✉ support@freenove.com

The following is the program code:

```

1 #include "esp_adc_cal.h"
2 #define PIN_ANALOG_IN 4           // A10, ADC2_CHANNEL_0D
3
4 #define DEFAULT_VREF 1100        //Use adc2_vref_to_gpio() to obtain a better estimate
5 #define NUM_OF_SAMPLES 64         //Multisampling, and get average
6
7 adc_channel_t channel = ADC_CHANNEL_0;      // ADC1:GPIO36, ADC2:GPIO4
8 adc_unit_t unit = ADC_UNIT_2;                 // ADC2
9 adc_atten_t atten = ADC_ATTEN_DB_11;          // Full scale 0-3.9V, precision range 150mV-2450mV
10
11 esp_adc_cal_characteristics_t *adc_chars;
12
13 esp_adc_cal_value_t val_type;
14
15
16 void setup() {
17   Serial.begin(115200);
18   //Check if Two Point or Vref are burned into eFuse
19   check_efuse();
20   //Configure ADC
21   if (unit == ADC_UNIT_1) {                  // ADC1 and ADC2 are initialized differently
22     adc1_config_width(ADC_WIDTH_BIT_12);
23     adc1_config_channel_atten((adc1_channel_t)channel, atten);
24   }
25   else {
26     adc2_config_channel_atten((adc2_channel_t)channel, atten);
27   }
28   //Characterize ADC
29   adc_chars = (esp_adc_cal_characteristics_t*)calloc(1,
30 sizeof(esp_adc_cal_characteristics_t));
31   esp_adc_cal_value_t val_type = esp_adc_cal_characterize(unit, atten, ADC_WIDTH_BIT_12,
32 DEFAULT_VREF, adc_chars);
33   print_char_val_type(val_type);
34 }
35
36 void loop() {
37   uint32_t adc_reading = 0;
38   for (int i = 0; i < NUM_OF_SAMPLES; i++) {    // Multisampling
39     if (unit == ADC_UNIT_1) {
40       adc_reading += adc1_get_raw((adc1_channel_t)channel);
41     }
42     else {
43       int raw;

```

```
44         adc2_get_raw((adc2_channel_t)channel, ADC_WIDTH_BIT_12, &raw);
45         adc_reading += raw;
46     }
47 }
48 adc_reading /= NUM_OF_SAMPLES;
49 //Convert adc_reading to voltage in mV
50 uint32_t voltage = esp_adc_cal_raw_to_voltage(adc_reading, adc_chars);
51 printf("Raw: %d\tVoltage: %dmV\n", adc_reading, voltage);
52 delay(1000);
53 }
54
55 void check_efuse()
56 {
57     //Check TP is burned into eFuse
58     if (esp_adc_cal_check_efuse(ESP_ADC_CAL_VAL_EFUSE_TP) == ESP_OK) {
59         printf("eFuse Two Point: Supported\n");
60     }
61     else {
62         printf("eFuse Two Point: NOT supported\n");
63     }
64
65     //Check Vref is burned into eFuse
66     if (esp_adc_cal_check_efuse(ESP_ADC_CAL_VAL_EFUSE_VREF) == ESP_OK) {
67         printf("eFuse Vref: Supported\n");
68     }
69     else {
70         printf("eFuse Vref: NOT supported\n");
71     }
72 }
73
74 void print_char_val_type(esp_adc_cal_value_t val_type)
75 {
76     if (val_type == ESP_ADC_CAL_VAL_EFUSE_TP) {
77         printf("Characterized using Two Point Value\n");
78     }
79     else if (val_type == ESP_ADC_CAL_VAL_EFUSE_VREF) {
80         printf("Characterized using eFuse Vref\n");
81     }
82     else {
83         printf("Characterized using Default Vref\n");
84     }
85 }
```



For most ADC related applications, `analogRead()` is sufficient. This method can be used in applications where ADC conversion accuracy is required.

About the project used in the IDF API, here is a detailed description:

<https://docs.espressif.com/projects/esp-idf/en/latest/api-reference/peripherals/adc.html>

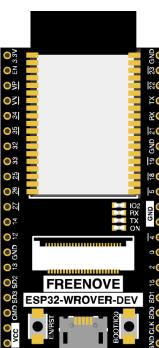
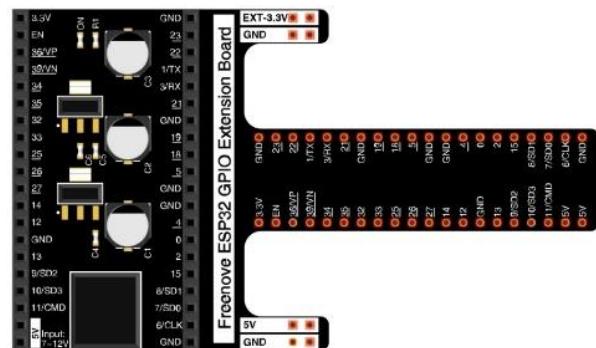
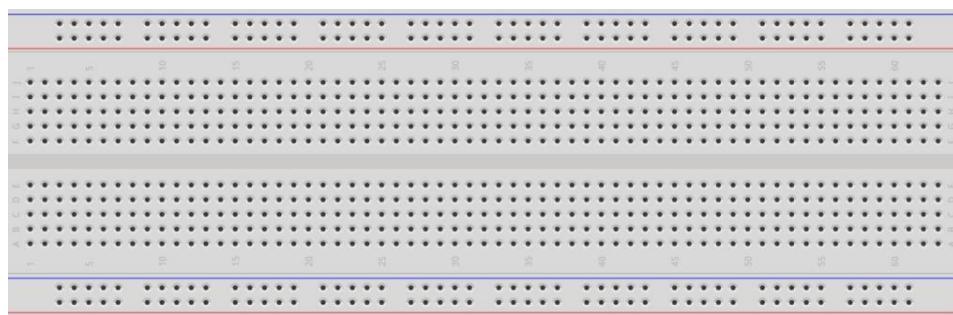
Chapter 10 Touch Sensor

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

Project 10.1 Read Touch Sensor

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

Component List

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

Related knowledge

Touch sensor

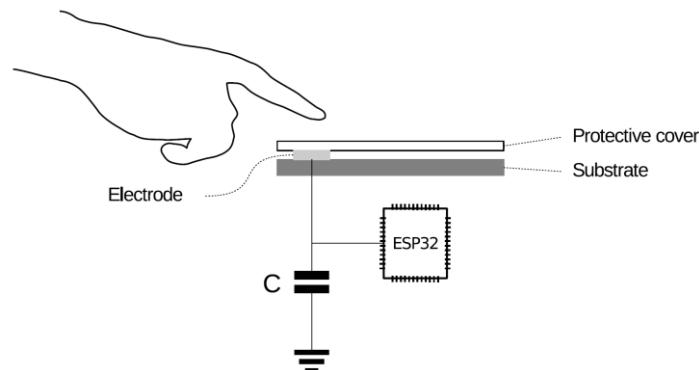
ESP32's touch sensor supports up to 10 GPIO channels as capacitive touch pins. Each pin can be used separately as an independent touch switch or be combined to produce multiple touch points. The following table is a list of available touch pins on ESP32.

Name of touch sensing signal	Functions of pins	GPIO number
T0	GPIO4	GPIO4
T1	GPIO0	GPIO0
T2	GPIO2	GPIO2
T3	MTDO	GPIO15
T4	MTCK	GPIO13
T5	MTDI	GPIO12
T6	MTMS	GPIO14
T7	GPIO27	GPIO27
T8	32K_XN	GPIO33
T9	32K_XP	GPIO32

The touch pin number is already defined in ESP32's code base. For example, in the code, you can use T0 to represent GPIO4.

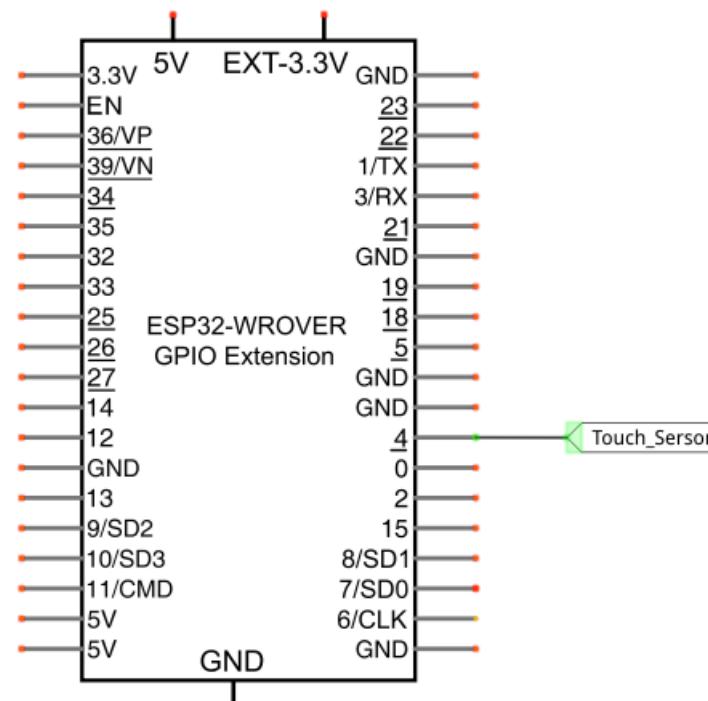
The electrical signals generated by touch are analog data, which are converted by an internal ADC converter. You may have noticed that all touch pins have ADC functionality.

The hardware connection method is shown in the following figure.



Circuit

Schematic diagram



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





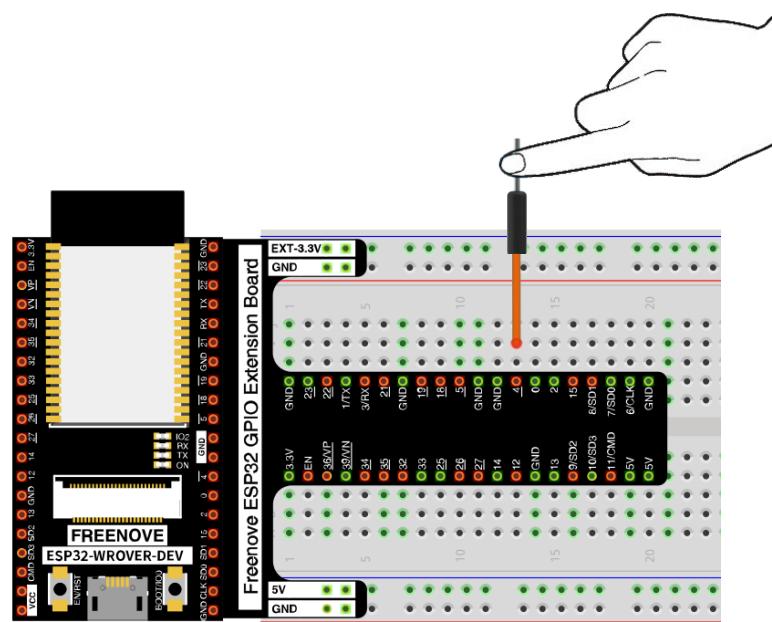
Sketch

Sketch_10.1_TouchRead

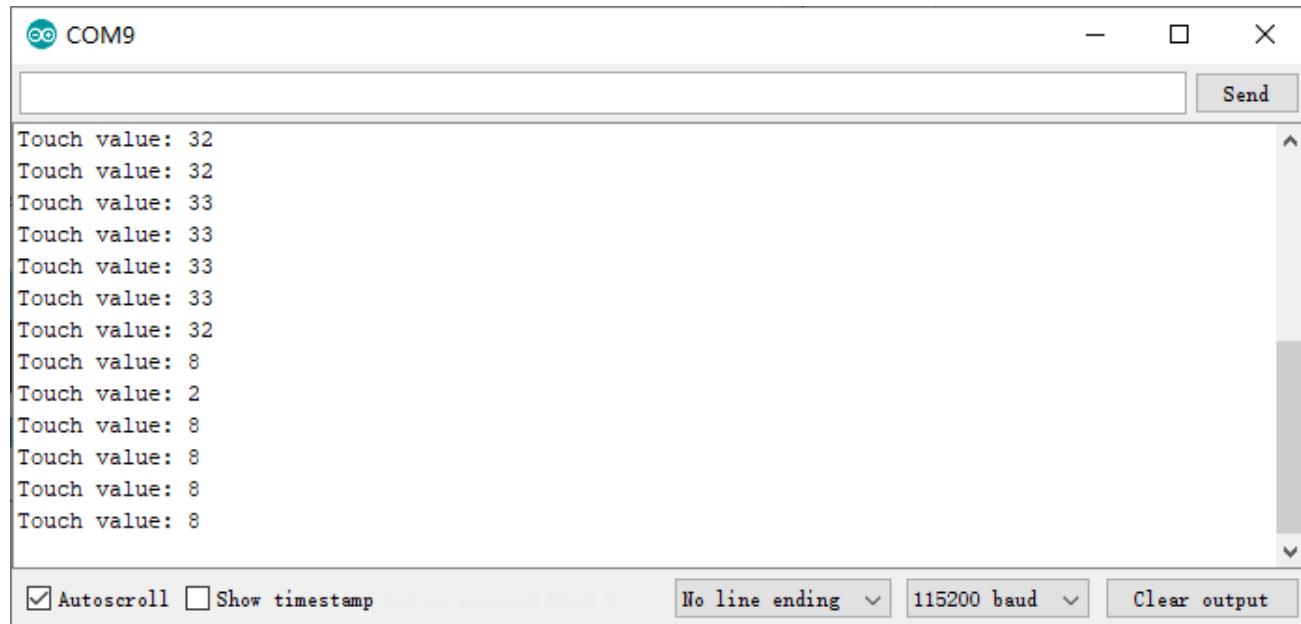
The screenshot shows the Arduino IDE interface. The top bar displays "Sketch_10.1_TouchRead | Arduino 1.8.12". The menu bar includes File, Edit, Sketch, Tools, Help. Below the menu is a toolbar with icons for save, upload, and others. The main code editor window contains the following code:

```
1 // ****
2   Filename    : TouchRead
3   Description : Read touch sensor value.
4   Author     : www.freenove.com
5   Modification: 2020/03/11
6 ****
7
8 void setup()
9 {
10   Serial.begin(115200);
11 }
12
13 void loop()
14 {
15   Serial.printf("Touch value: %d \n", touchRead(T0)); // get value using T0 (GPIO4)
16   delay(1000);
17 }
```

The status bar at the bottom indicates "Done Saving." and "ESP32 Wrover Module on COM5". The serial monitor window shows the message "Leaving... Hard resetting via RTS pin...".



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



Touched by hands, the value of the touch sensor will change. The closer the value is to zero, the more obviously the touch action will be detected. The value detected by the sensor may be different in different environments or when different people touch it. The code is very simple, just look at Reference.

Reference

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

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



Project 10.2 Touch Lamp

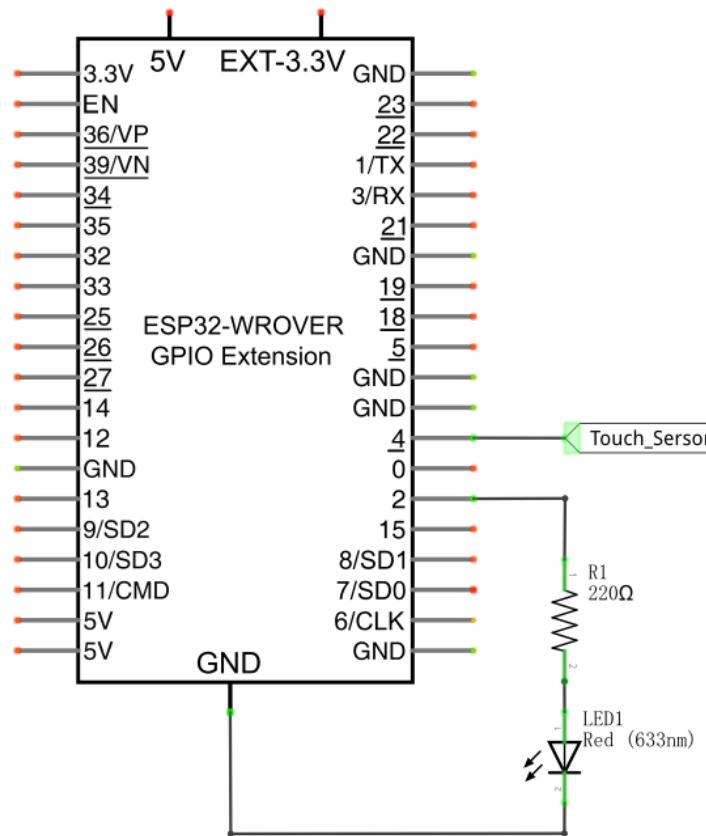
In this project, we will use ESP32's touch sensor to create a touch switch lamp.

Component List

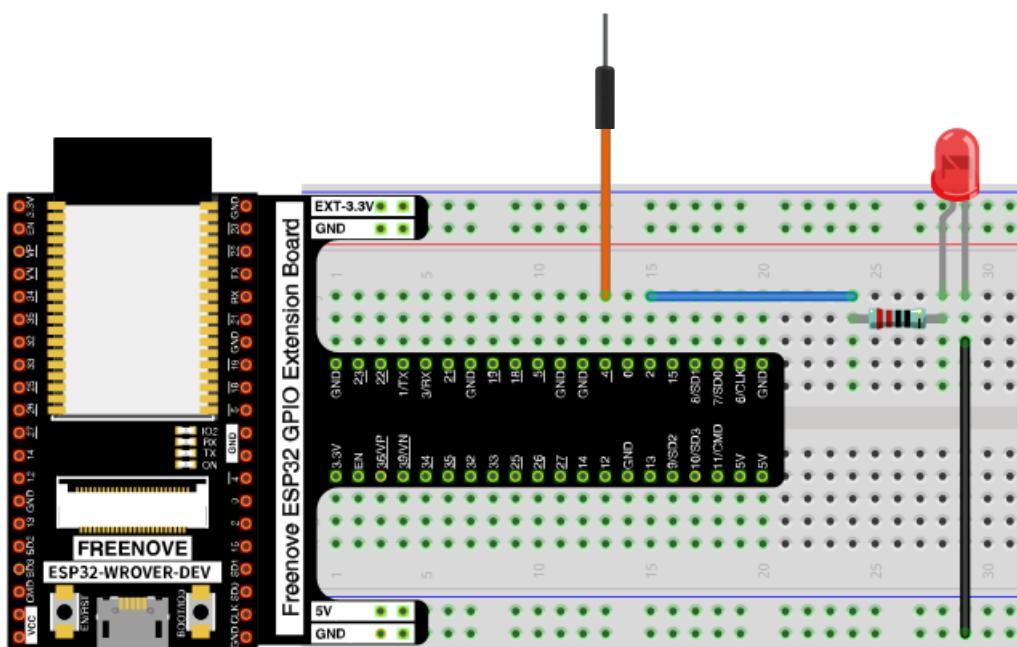
ESP32-WROVER x1	GPIO Extension Board x1	
Breadboard x1		
Jumper M/M x3	LED x1	Resistor 220Ω x1

Circuit

Schematic diagram



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



Any concerns? ✉ support@freenove.com

Sketch

Sketch_10.2_TouchLamp

The screenshot shows the Arduino IDE interface. The title bar reads "Sketch_10.2_TouchLamp | Arduino 1.8.12". The menu bar includes File, Edit, Sketch, Tools, and Help. Below the menu is a toolbar with icons for save, upload, and refresh. The main code editor window contains the following code:

```
1 // ****
2   Filename    : TouchLamp
3   Description : Control led by touch button.
4   Author     : www.freenove.com
5   Modification: 2020/03/11
6 ****
7 #define PIN_LED  2
8 #define PRESS_VAL 14 //Set a threshold to judge touch
9 #define RELEASE_VAL 25 //Set a threshold to judge release
10
11 bool isProcessed = false;
12 void setup() {
13   Serial.begin(115200);
14   pinMode(PIN_LED, OUTPUT);
15 }
16 void loop() {
17   if (touchRead(T0) < PRESS_VAL) {
18     if (!isProcessed) {
19       isProcessed = true;
20       Serial.println("Touch detected! ");
21       reverseGPIO(PIN_LED);
22     }
23   }
24 }
```

The status bar at the bottom indicates "Done uploading." and "Hash of data verified." followed by "Leaving..." and "Hard resetting via RTS pin...". The bottom right corner shows "ESP32 Wrover Module on COM5".

Download the code to ESP32-WROVER, open the serial monitor, and set the baud rate to 115200. 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 2
2 #define PRESS_VAL 14 //Set a threshold to judge touch
3 #define RELEASE_VAL 25//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(T0) < PRESS_VAL) {
12         if (! isProcessed) {
13             isProcessed = true;
14             Serial.println("Touch detected! ");
15             reverseGPIO(PIN_LED);
16         }
17     }
18
19     if (touchRead(T0) > 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 }
```

The closer the return value of the function touchRead() is to 0, the more obviously the touch is detected. This is not a fixed value, so you need to define a threshold that is considered valid (when the value of the sensor is less than this threshold). Similarly, a threshold value is to be defined in the release state, and a value in between is considered an invalid disturbance value.

```

2 #define PRESS_VAL 14 //Set a threshold to judge touch
3 #define RELEASE_VAL 25//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(T0) < 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(T0) > RELEASE_VAL) {
20     if (isProcessed) {
21         isProcessed = false;
22         Serial.println("Released! ");
23     }
24 }
```

Chapter 11 Potentiometer & LED

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

Project 11.1 Soft Light

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

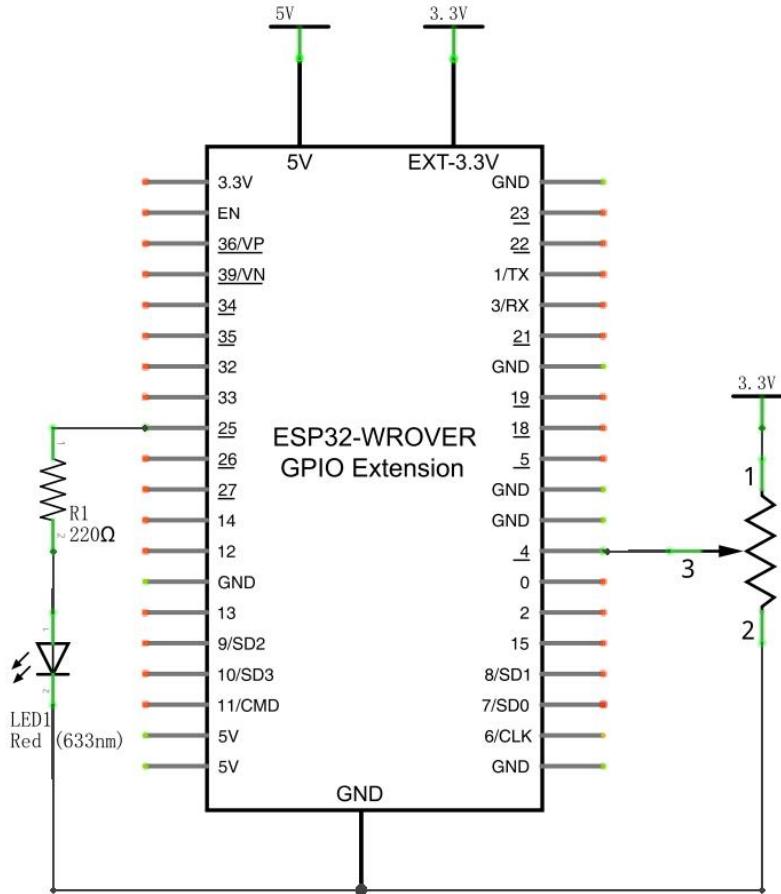
Component List

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

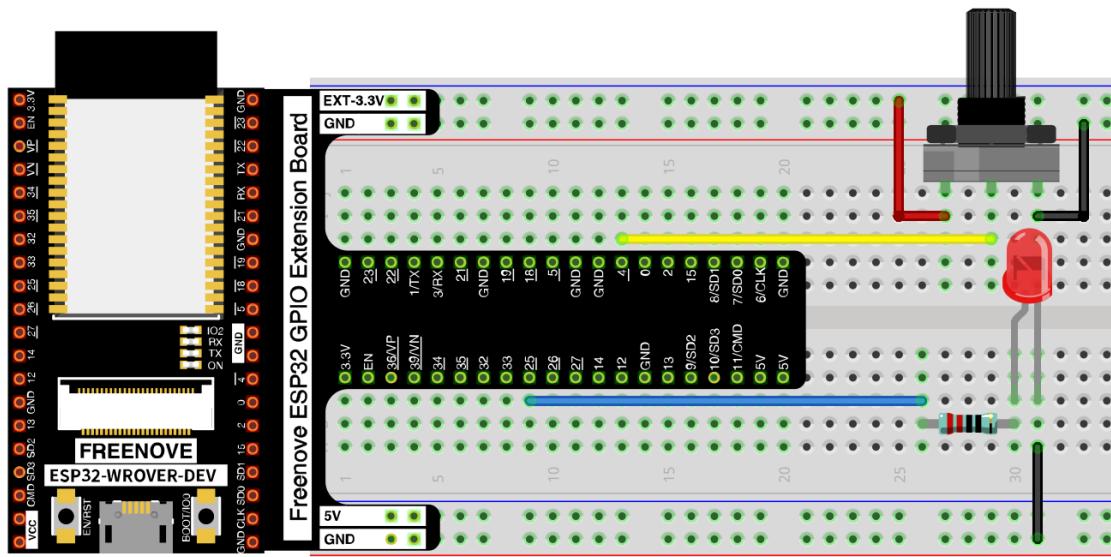
Any concerns? [✉ support@freenove.com](mailto:support@freenove.com)

Circuit

Schematic diagram



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



Sketch

Sketch_11.1_Softlight

```

Sketch_11.1_SoftLight | Arduino 1.8.10
File Edit Sketch Tools Help
Sketch_11.1_SoftLight
1 // www.freenove.com
2 Filename : SoftLight.ino
3 Description : Controlling the brightness of LED by potentiometer.
4 Author : www.freenove.com
5 Modification: 2020-1-10
6 ****
7 #define PIN_ANALOG_IN 4
8 #define PIN_LED 25
9 #define CHAN 0
10 void setup() {
11   ledcSetup(CHAN, 1000, 12);
12   ledcAttachPin(PIN_LED, CHAN);
13 }
14
15 void loop() {
16   int adcVal = analogRead(PIN_ANALOG_IN); //read adc
17   int pwmVal = adcVal; // adcVal re-map to pwmVal
18   ledcWrite(CHAN, pwmVal); // set the pulse width.
19   delay(10);
20 }

Done Saving.
Leaving...
Hard resetting via RTS pin...

```

ESP32 Dev Module on COM9

Download the code to ESP32-WROVER, by turning the adjustable resistor to change the input voltage of GPIO25, ESP32 changes the output voltage of GPIO4 according to this voltage value, thus changing the brightness of the LED.

The following is the code:

```

1 #define PIN_ANALOG_IN 4
2 #define PIN_LED 25
3 #define CHAN 0
4 void setup() {
5   ledcSetup(CHAN, 1000, 12);
6   ledcAttachPin(PIN_LED, CHAN);
7 }
8
9 void loop() {
10   int adcVal = analogRead(PIN_ANALOG_IN); //read adc
11   int pwmVal = adcVal; // adcVal re-map to pwmVal
12   ledcWrite(CHAN, pwmVal); // set the pulse width.
13   delay(10);
14 }

```

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



Project 11.2 Soft Colorful Light

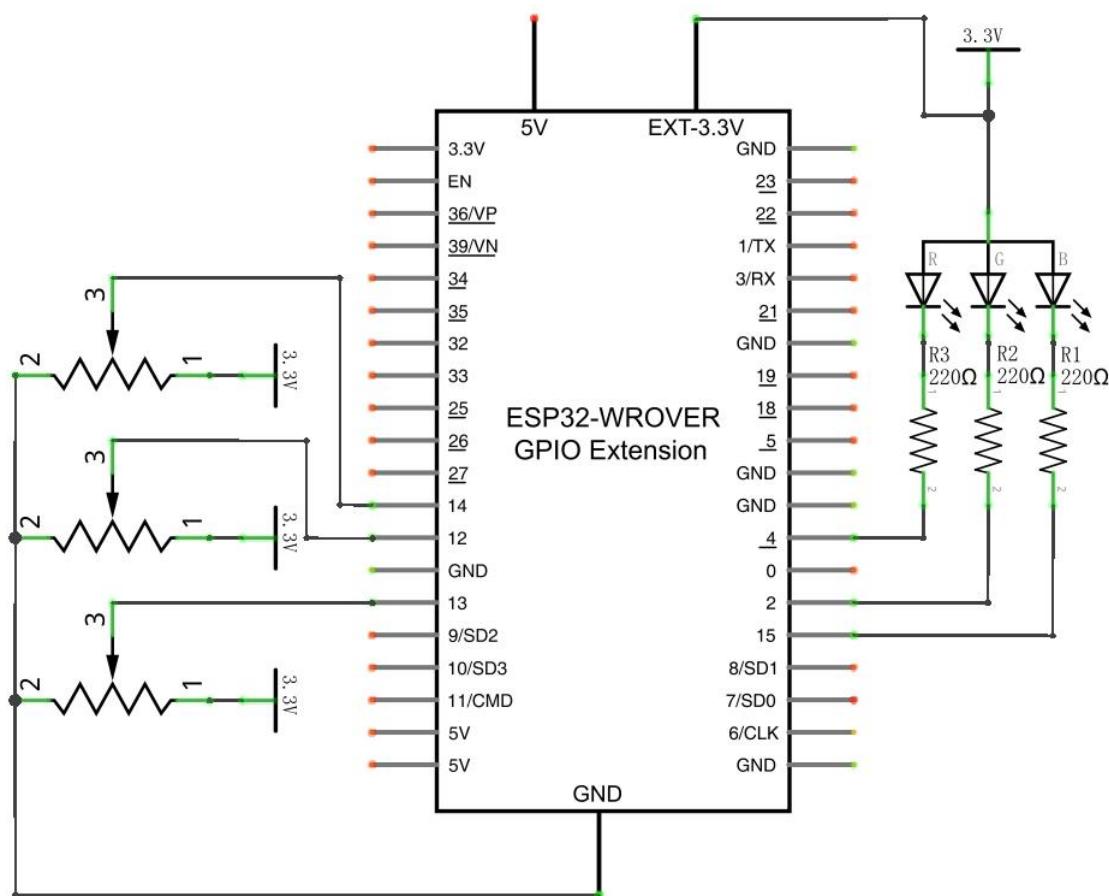
In this project, 3 potentiometers are used to control the RGB LED and in principle it is the same as the Soft Light project. Namely, read the voltage value of the potentiometer and then convert it to PWM used to control LED brightness. Difference is that the original project only controlled one LED,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

Component List

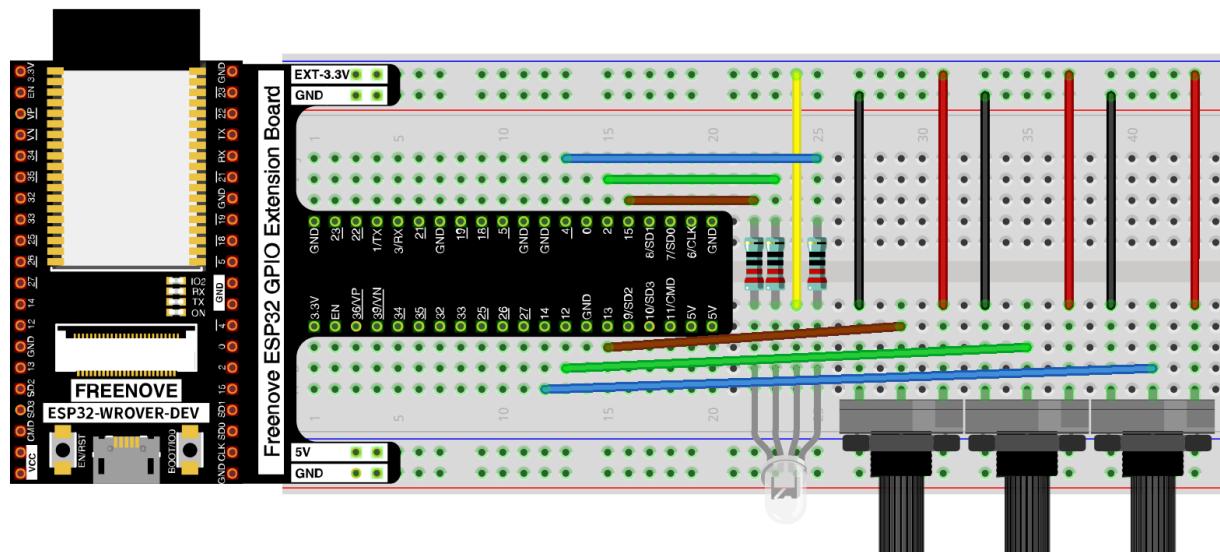
ESP32-WROVER x1	GPIO Extension Board x1			
Breadboard x1				
Rotary potentiometer x3	Resistor 220Ω x3	RGBLED x1	Jumper M/M x13	

Circuit

Schematic diagram



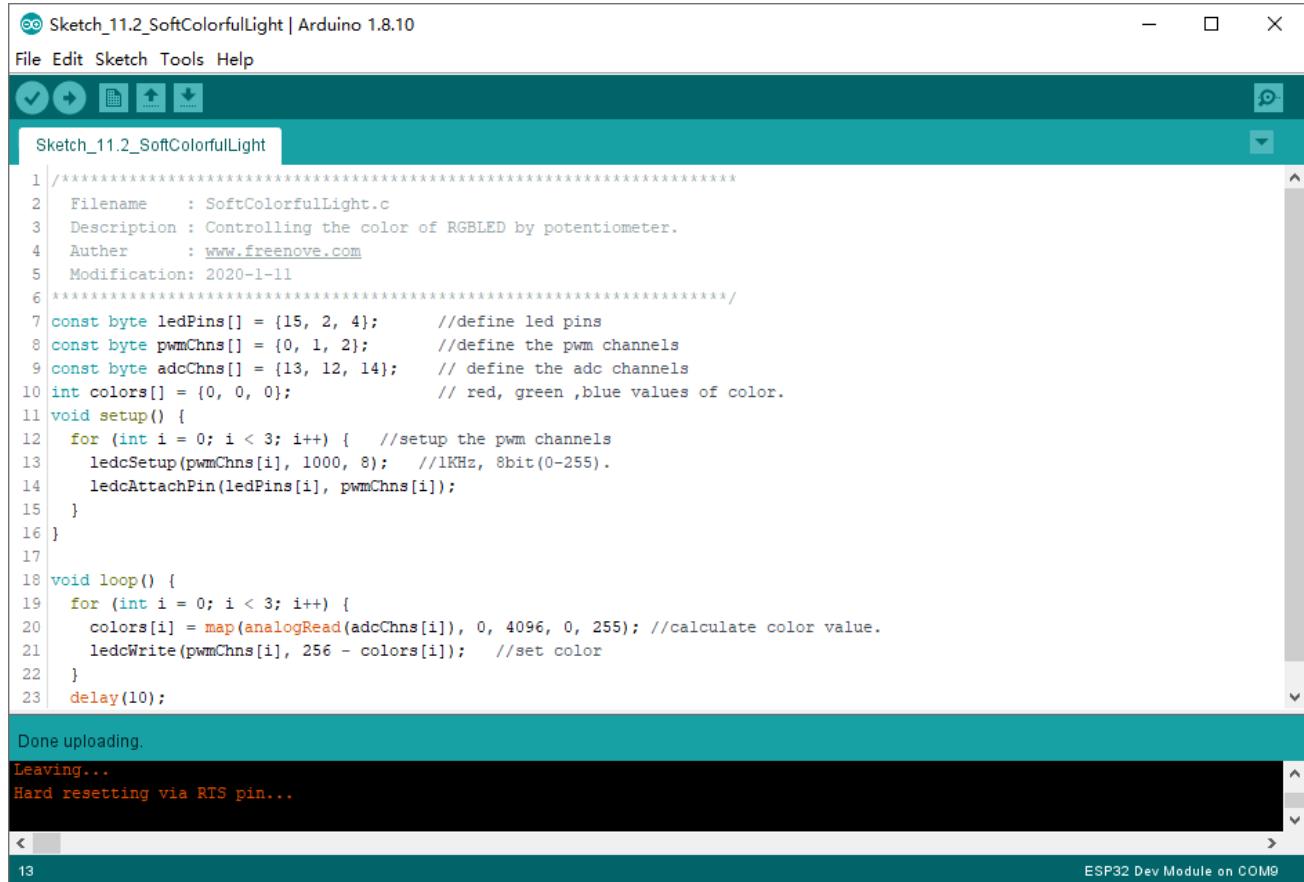
Hardware connection. If you need any support, please feel free to contact us via: support@freenove.com



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Sketch

Sketch_11.2_SoftColorfullLight



```
Sketch_11.2_SoftColorfullLight | Arduino 1.8.10
File Edit Sketch Tools Help
Sketch_11.2_SoftColorfullLight
1 //*****
2 Filename : SoftColorfullLight.c
3 Description : Controlling the color of RGBLED by potentiometer.
4 Author : www.freenove.com
5 Modification: 2020-1-11
6 ****
7 const byte ledPins[] = {15, 2, 4};      //define led pins
8 const byte pwmChns[] = {0, 1, 2};      //define the pwm channels
9 const byte adcChns[] = {13, 12, 14};    // define the adc channels
10 int colors[] = {0, 0, 0};            // red, green ,blue values of color.
11 void setup() {
12     for (int i = 0; i < 3; i++) {    //setup the pwm channels
13         ledcSetup(pwmChns[i], 1000, 8); //1KHz, 8bit(0-255).
14         ledcAttachPin(ledPins[i], pwmChns[i]);
15     }
16 }
17
18 void loop() {
19     for (int i = 0; i < 3; i++) {
20         colors[i] = map(analogRead(adcChns[i]), 0, 4096, 0, 255); //calculate color value.
21         ledcWrite(pwmChns[i], 256 - colors[i]); //set color
22     }
23     delay(10);
}
Done uploading.
Leaving...
Hard resetting via RTS pin...
< 13 >
ESP32 Dev Module on COM9
```

Download the code to ESP32-WROVER, 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 ledPins[] = {15, 2, 4};      //define led pins
2 const byte chns[] = {0, 1, 2};          //define the pwm channels
3 const byte adcChns[] = {13, 12, 14};    // define the adc 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         ledcSetup(pwmChns[i], 1000, 8); //1KHz, 8bit(0-255).
8         ledcAttachPin(ledPins[i], chns[i]);
9     }
10 }
11
12 void loop() {
13     for (int i = 0; i < 3; i++) {
14         colors[i] = map(analogReadadcChns[i]), 0, 4096, 0, 255); //calculate color
15         value.
16         ledcWrite(pwmChns[i], 256 - colors[i]); //set color
17     }
18 }
```

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

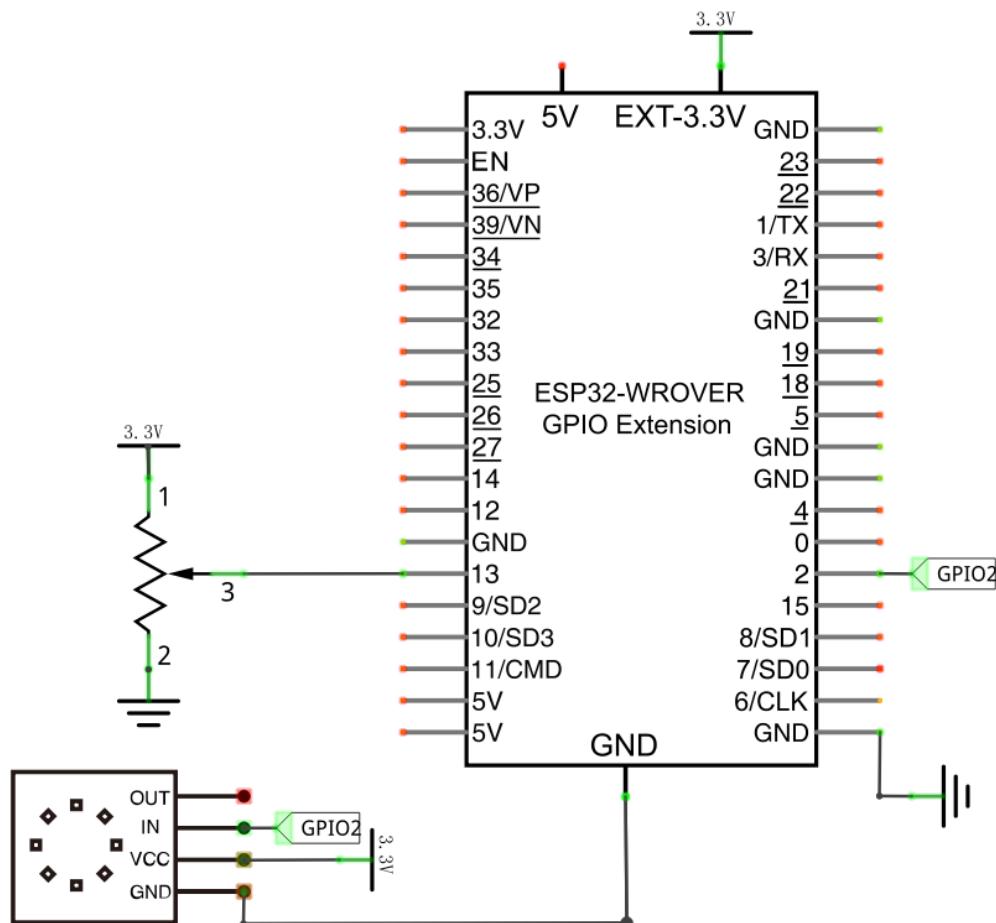
In this project, we use potentiometer to control Freenove 8 RGB LED Module.

Component List

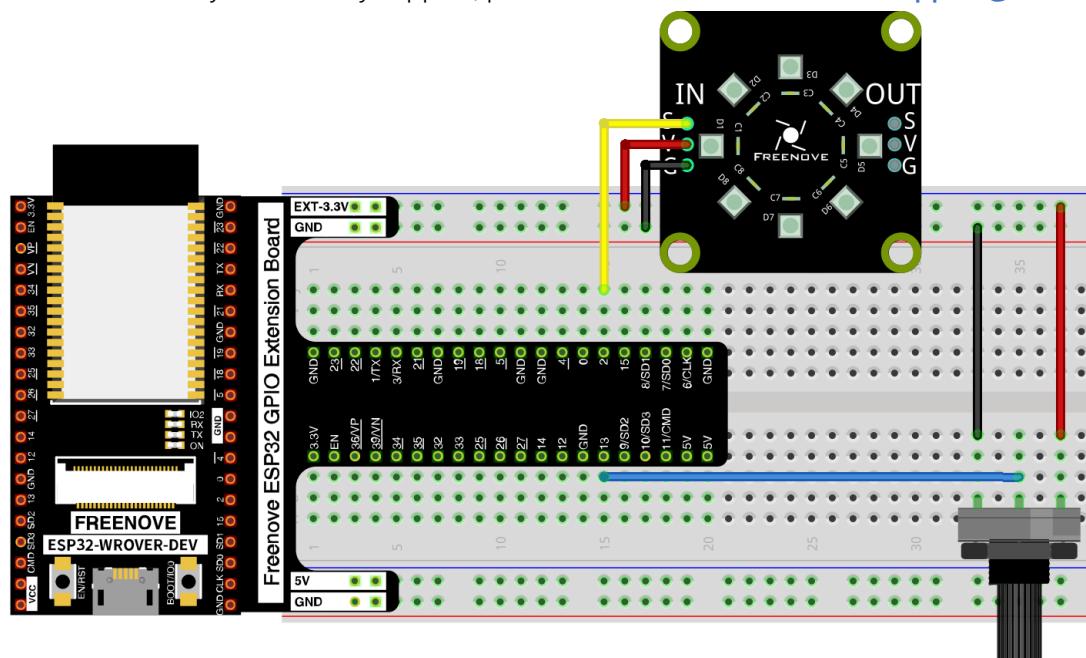
ESP32-WROVER x1	GPIO Extension Board x1	
Breadboard x1		
Freenove 8 RGB LED Module x1	Jumper F/M x3 Jumper M/M x3	

Circuit

Schematic diagram



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

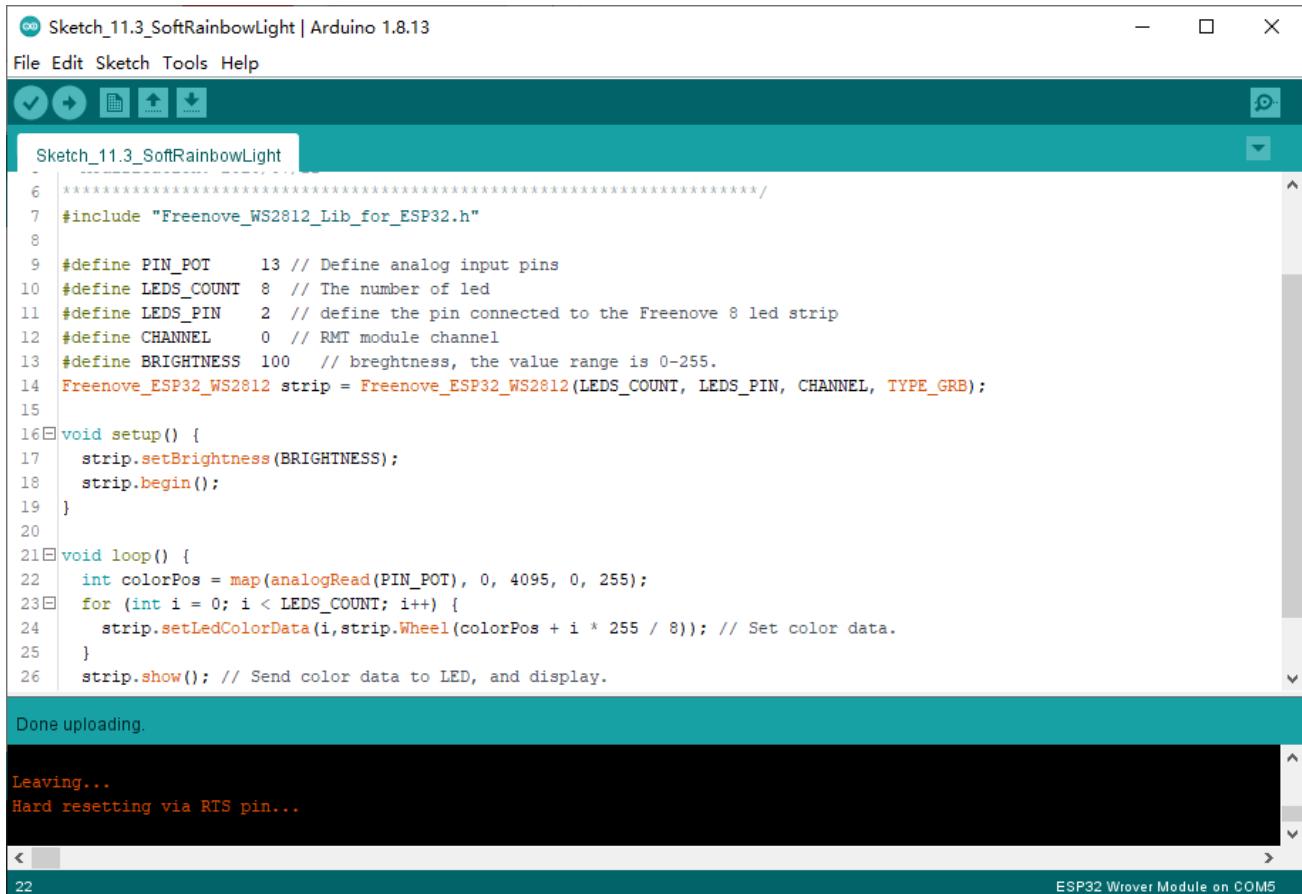


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Sketch

Sketch_11.3_Soft_Rainbow_Light

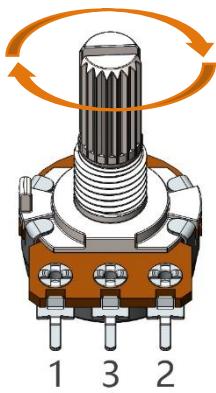


```

Sketch_11.3_SoftRainbowLight | Arduino 1.8.13
File Edit Sketch Tools Help
Sketch_11.3_SoftRainbowLight
6 ///////////////////////////////////////////////////////////////////
7 #include "Freenove_WS2812_Lib_for_ESP32.h"
8
9 #define PIN_POT      13 // Define analog input pins
10 #define LEDS_COUNT   8 // The number of led
11 #define LEDS_PIN      2 // define the pin connected to the Freenove 8 led strip
12 #define CHANNEL      0 // RMT module channel
13 #define BRIGHTNESS   100 // brightness, the value range is 0-255.
14 Freenove_ESP32_WS2812 strip = Freenove_ESP32_WS2812(LEDS_COUNT, LEDS_PIN, CHANNEL, TYPE_GRB);
15
16 void setup() {
17     strip.setBrightness(BRIGHTNESS);
18     strip.begin();
19 }
20
21 void loop() {
22     int colorPos = map(analogRead(PIN_POT), 0, 4095, 0, 255);
23     for (int i = 0; i < LEDS_COUNT; i++) {
24         strip.setLedColorData(i, strip.Wheel(colorPos + i * 255 / 8)); // Set color data.
25     }
26     strip.show(); // Send color data to LED, and display.
}
Done uploading.
Leaving...
Hard resetting via RTS pin...
< >
22
ESP32 Wrover Module on COM5

```

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



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The following is the program code:

```
1 #include "Freenove_WS2812_Lib_for_ESP32.h"
2
3 #define PIN_POT      13 // Define analog input pins
4 #define LEDS_COUNT   8 // The number of led
5 #define LEDS_PIN      2 // define the pin connected to the Freenove 8 led strip
6 #define CHANNEL       0 // RMT module channel
7 #define BRIGHTNESS    100 // 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.



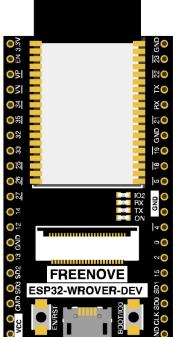
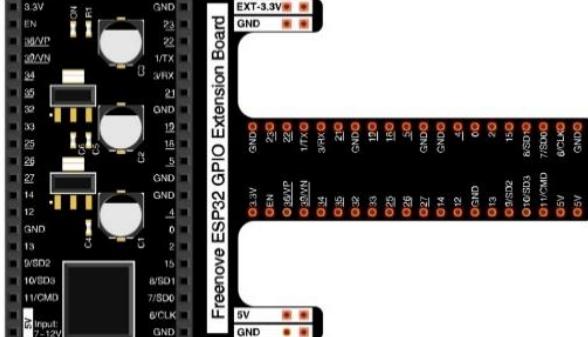
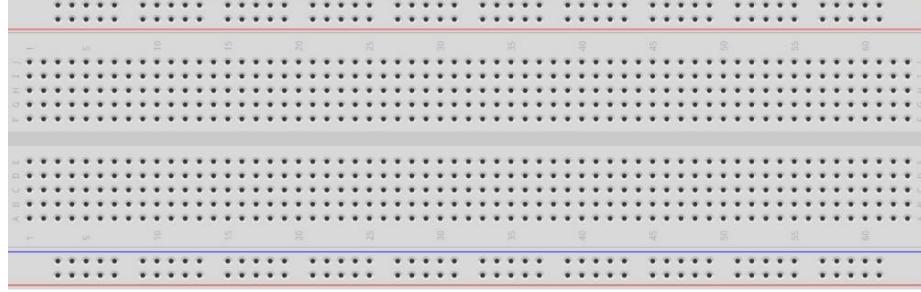
Chapter 12 Photoresistor & LED

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

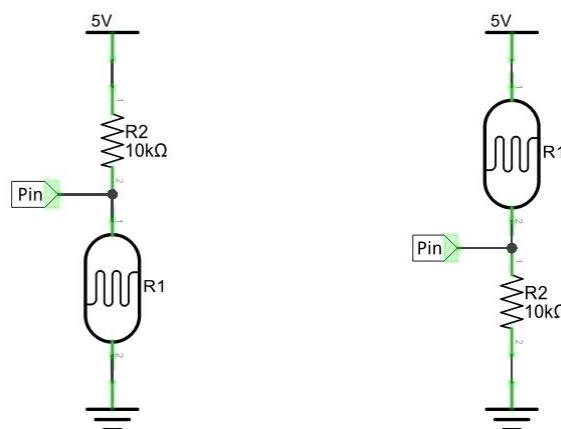
Component knowledge

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:

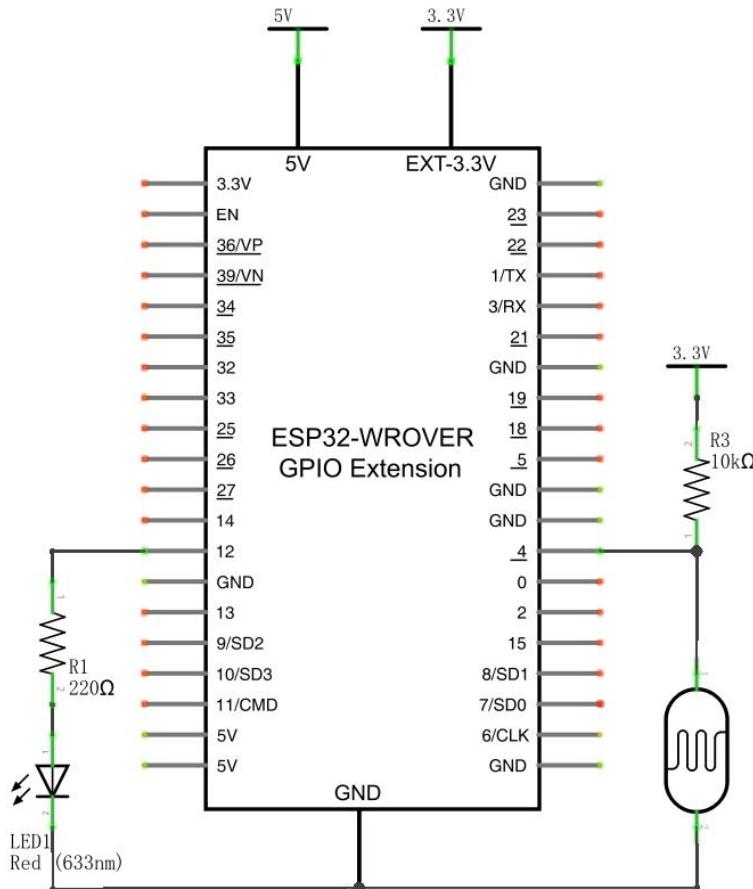


In the above circuit, when a photoresistor's resistance value changes due to a change in light intensity, the voltage between the photoresistor and resistor R1 will also change. Therefore, the intensity of the light can be obtained by measuring this voltage.

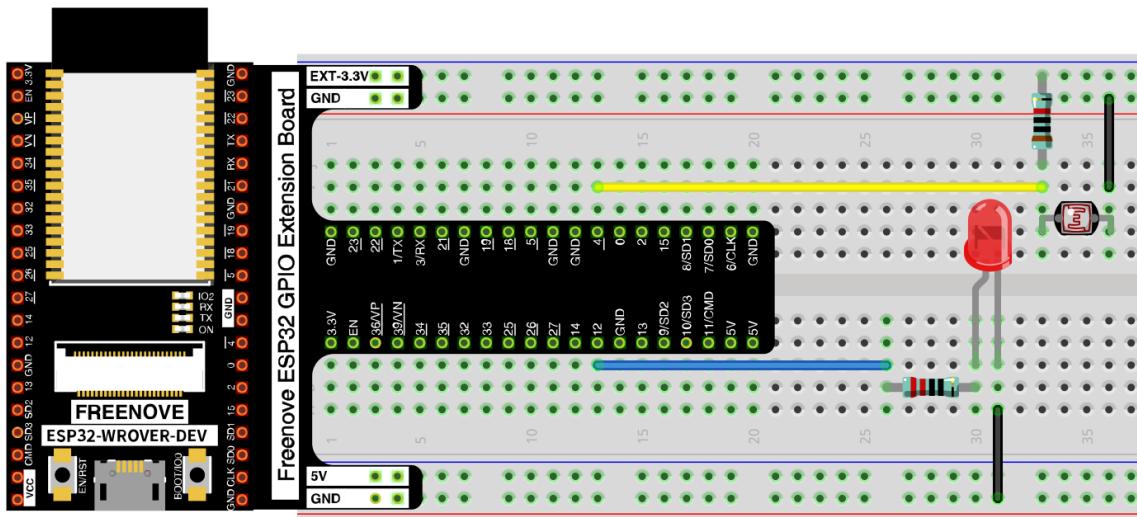
Circuit

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



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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 AIN0 pin of ADC changes from a potentiometer to a combination of a photoresistor and a resistor.

Sketch_12.1_Nightlamp

```
Sketch_12.1_NightLamp | Arduino 1.8.10
File Edit Sketch Tools Help
Sketch_12.1_NightLamp
3 Description : Controlling the brightness of LED by photoresistor.
4 Author      : www.freenove.com
5 Modification: 2020-1-15
6 ****
7 #define PIN_ANALOG_IN 4
8 #define PIN_LED        12
9 #define CHAN           0
10#define LIGHT_MIN       372
11#define LIGHT_MAX       2048
12 void setup() {
13   ledcSetup(CHAN, 1000, 12);
14   ledcAttachPin(PIN_LED, CHAN);
15 }
16
17 void loop() {
18   int adcVal = analogRead(PIN_ANALOG_IN); //read adc
19   int pwmVal = map(constrain(adcVal, LIGHT_MIN, LIGHT_MAX), LIGHT_MIN, LIGHT_MAX, 0, 4095); // adcVal re-map to pwmVal
20   ledcWrite(CHAN, pwmVal); // set the pulse width.
21   delay(10);
22 }

Done uploading.
Leaving...
Hard resetting via RTS pin...
18
ESP32 Dev Module on COM9
```

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

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The following is the program code:

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

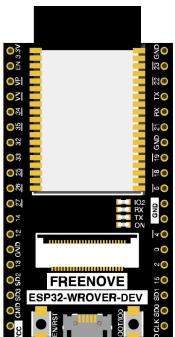
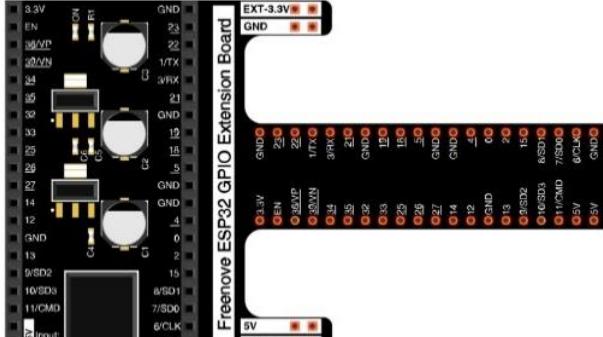
Chapter 13 Thermistor

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

Project 13.1 Thermometer

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

Component List

ESP32-WROVER x1	GPIO Extension Board x1	Breadboard x1	Thermistor x1	Resistor 10kΩ x1	Jumper M/M x3
					

Component knowledge

Thermistor

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



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

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

Where:

Rt is the thermistor resistance under T2 temperature;

R is the nominal resistance of thermistor under T1 temperature;

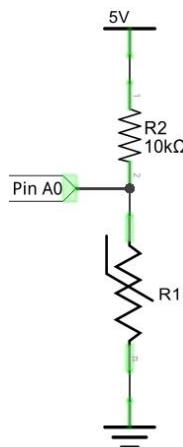
EXP[n] is nth power of E;

B is for thermal index;

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

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

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



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

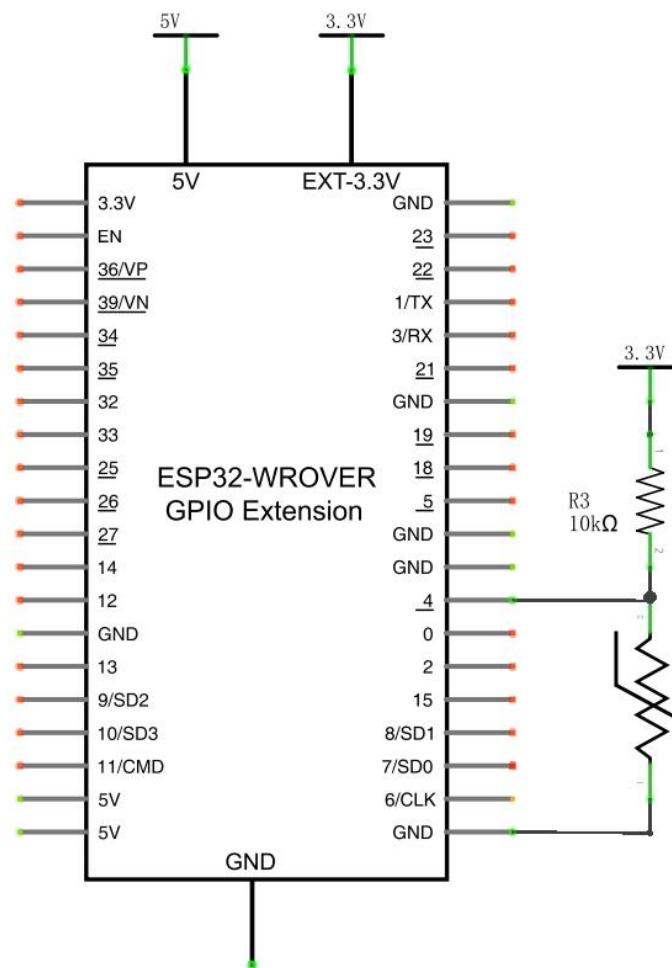
Therefore, the temperature formula can be derived as:

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

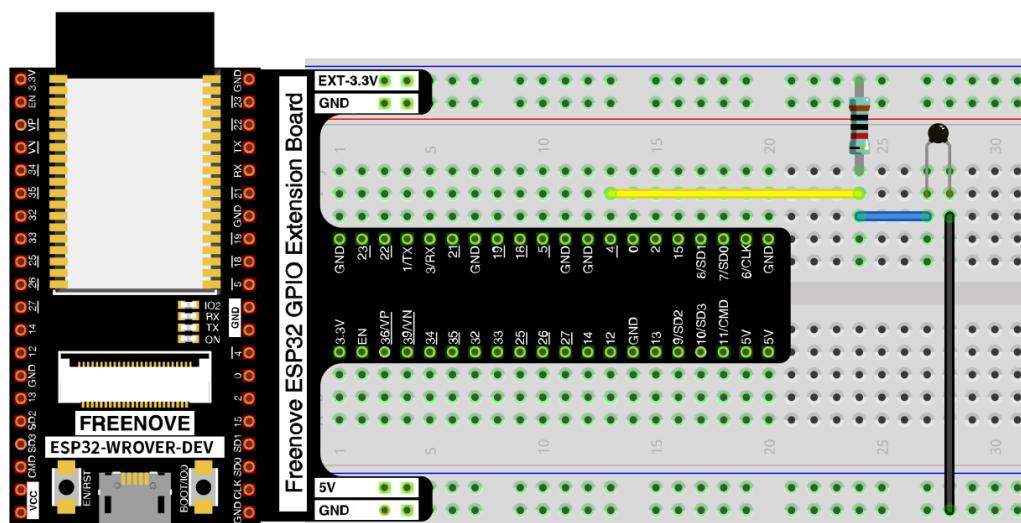
Circuit

The circuit of this project is similar to the one in the 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



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Sketch

Sketch_13.1_Thermometer



```

Sketch_13.1_Thermometer | Arduino 1.8.10
File Edit Sketch Tools Help
Sketch_13.1_Thermometer
1 //***** 
2 Filename : Thermometer.ino
3 Description : Making a thermometer by thermistor.
4 Author : www.freenove.com
5 Modification: 2020-1-15
6 *****
7 #define PIN_ANALOG_IN 4
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,\tVoltage : %.2fV, \tTemperature : %.2fC\n", adcValue, voltage, tempC);
19   delay(1000);
20 }

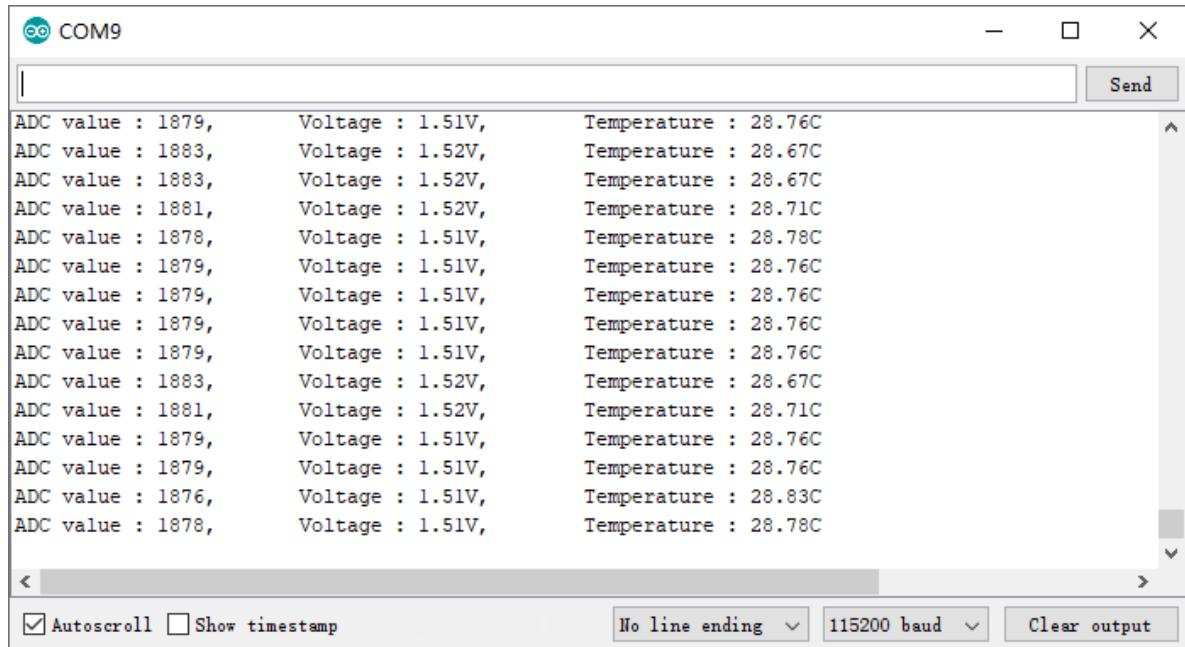
Done Saving.
Leaving...
Hard resetting via RTS pin...

```

11 ESP32 Dev Module on COM9

Download the code to ESP32-WROVER, 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.

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



ADC value	Voltage	Temperature
1879	1.51V	28.76C
1883	1.52V	28.67C
1883	1.52V	28.67C
1881	1.52V	28.71C
1878	1.51V	28.78C
1879	1.51V	28.76C
1883	1.52V	28.67C
1881	1.52V	28.71C
1879	1.51V	28.76C
1879	1.51V	28.76C
1876	1.51V	28.83C
1878	1.51V	28.78C

Autoscroll Show timestamp No line ending 115200 baud Clear output

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The following is the code:

```
1 #define PIN_ANALOG_IN 4
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 }
```

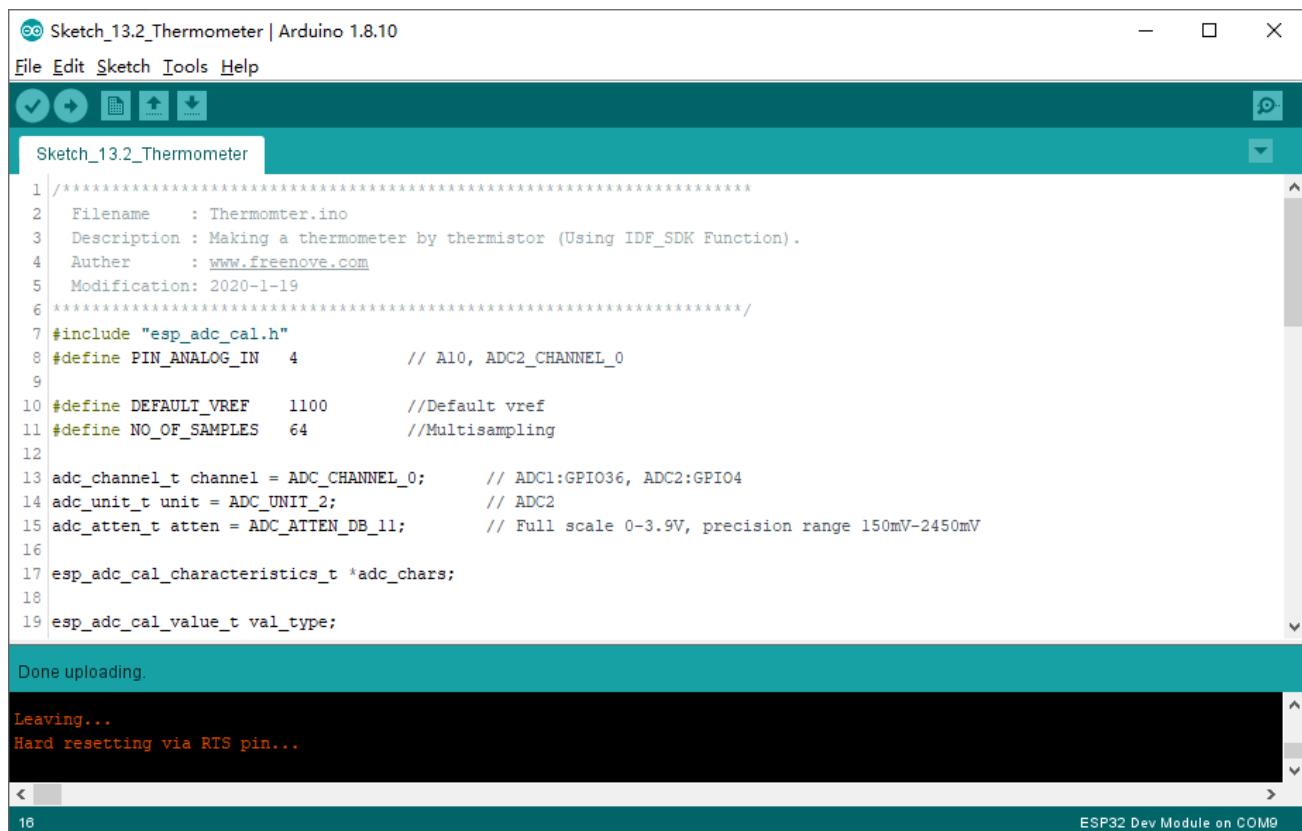
In the code, the ADC value of ADC module A0 port is read, and then calculates the voltage and the resistance of thermistor according to Ohms Law. Finally, it calculates the temperature sensed by the thermistor, according to the formula.

Project 13.2 Thermometer (use esp-idf)

This project uses the function in esp-idf to get more accurate temperature value. The circuit is exactly the same as the last project.

Sketch

Sketch_13.2_Thermometer



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

- Title Bar:** Sketch_13.2_Thermometer | Arduino 1.8.10
- Menu Bar:** File Edit Sketch Tools Help
- Toolbar:** Includes icons for upload, download, and other common functions.
- Sketch Area:** Displays the C++ code for the sketch. The code includes comments, defines, and variable declarations related to ADC calibration and thermistor reading.
- Status Bar:** Shows "Done uploading." and "Leaving... Hard resetting via RTS pin..." followed by a timestamp "16 ESP32 Dev Module on COM9".

Download the code to ESP32-WROVER, 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.

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

```

ADC value : 1795,      Voltage : 1.59V,      Temperature : 26.70C
ADC value : 1797,      Voltage : 1.59V,      Temperature : 26.67C
ADC value : 1797,      Voltage : 1.59V,      Temperature : 26.67C
ADC value : 1798,      Voltage : 1.59V,      Temperature : 26.65C
ADC value : 1797,      Voltage : 1.59V,      Temperature : 26.67C
ADC value : 1797,      Voltage : 1.59V,      Temperature : 26.67C
ADC value : 1798,      Voltage : 1.59V,      Temperature : 26.65C
ADC value : 1798,      Voltage : 1.59V,      Temperature : 26.65C
ADC value : 1877,      Voltage : 1.65V,      Temperature : 24.89C
ADC value : 1904,      Voltage : 1.68V,      Temperature : 24.29C
ADC value : 1904,      Voltage : 1.68V,      Temperature : 24.29C
ADC value : 1904,      Voltage : 1.68V,      Temperature : 24.29C
ADC value : 1903,      Voltage : 1.67V,      Temperature : 24.32C
ADC value : 1888,      Voltage : 1.66V,      Temperature : 24.65C
ADC value : 1887,      Voltage : 1.66V,      Temperature : 24.67C

```

Autoscroll Show timestamp No line ending 115200 baud Clear output

The following is the program code:

```

1 #include "esp_adc_cal.h"
2 #define PIN_ANALOG_IN 4           // A10, ADC2_CHANNEL_0
3
4 #define DEFAULT_VREF 1100        //Default vref
5 #define NO_OF_SAMPLES 64         //Multisampling
6
7 adc_channel_t channel = ADC_CHANNEL_0;      // ADC1:GPIO36, ADC2:GPIO4
8 adc_unit_t unit = ADC_UNIT_2;                 // ADC2
9 adc_atten_t atten = ADC_ATTEN_DB_11;          // Full scale 0-3.9V, precision range 150mV-2450mV
10
11 esp_adc_cal_characteristics_t *adc_chars;
12
13 esp_adc_cal_value_t val_type;
14
15 void setup() {
16     Serial.begin(115200);
17     if (unit == ADC_UNIT_1) {
18         adc1_config_width(ADC_WIDTH_BIT_12);
19         adc1_config_channel_atten((adc1_channel_t)channel, atten);
20     }
21     else {

```

Any concerns? ✉ support@freenove.com



```

22         adc2_config_channel_atten((adc2_channel_t)channel, atten);
23     }
24
25     //Characterize ADC
26     adc_chars = (esp_adc_cal_characteristics_t*)calloc(1,
27     sizeof(esp_adc_cal_characteristics_t));
28     esp_adc_cal_value_t val_type = esp_adc_cal_characterize(unit, atten, ADC_WIDTH_BIT_12,
29     DEFAULT_VREF, adc_chars);
30
31 }
32
33 void loop() {
34     uint32_t adc_reading = 0;
35     //Multisampling
36     for (int i = 0; i < NO_OF_SAMPLES; i++) {
37         if (unit == ADC_UNIT_1) {
38             adc_reading += adc1_get_raw((adc1_channel_t)channel);
39         }
40         else {
41             int raw;
42             adc2_get_raw((adc2_channel_t)channel, ADC_WIDTH_BIT_12, &raw);
43             adc_reading += raw;
44         }
45     }
46     adc_reading /= NUM_OF_SAMPLES;
47     //Convert adc_reading to voltage in mV
48     uint32_t voltage = esp_adc_cal_raw_to_voltage(adc_reading, adc_chars);
49     //printf("Raw: %d\tVoltage: %dmV\n", adc_reading, voltage);
50
51     double vol = voltage / 1000.0f;
52     double Rt = 10 * vol / (3.3 - vol); //calculate resistance value of thermistor
53     double tempK = 1 / (1 / (273.15 + 25) + log(Rt / 10) / 3950.0); //calculate temperature
54     (Kelvin)
55     double tempC = tempK - 273.15; //calculate temperature (Celsius)
56     Serial.printf("ADC value : %d, \tVoltage : %.2fV, \tTemperature : %.2fC\n", adc_reading,
57     vol, tempC);
58
59     delay(1000);
}

```

The part of the code that captures the ADC is consistent with the previous potentiometer section, and the part that calculates the temperature is consistent with the previous project.

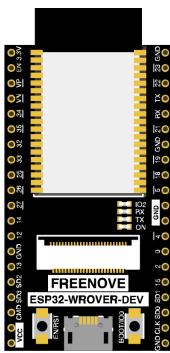
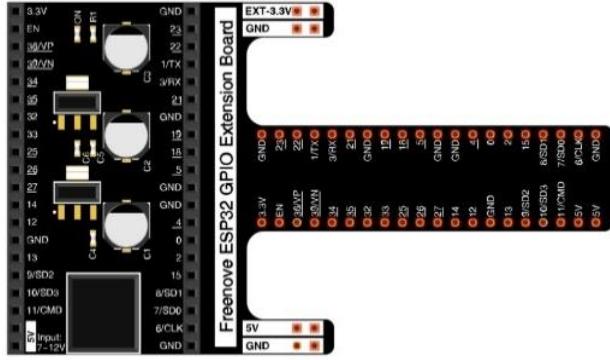
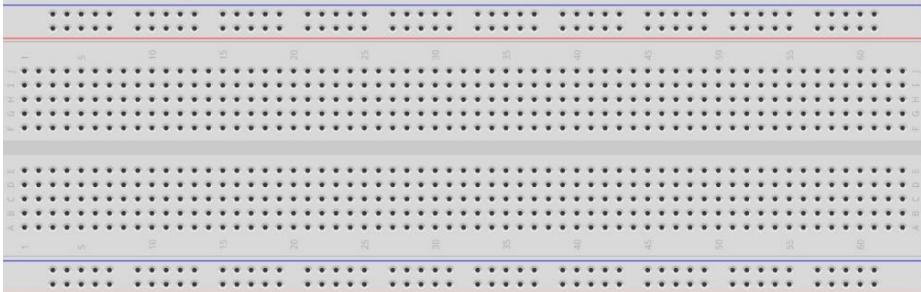
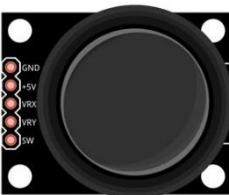
Chapter 14 Joystick

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

Project 14.1 Joystick

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

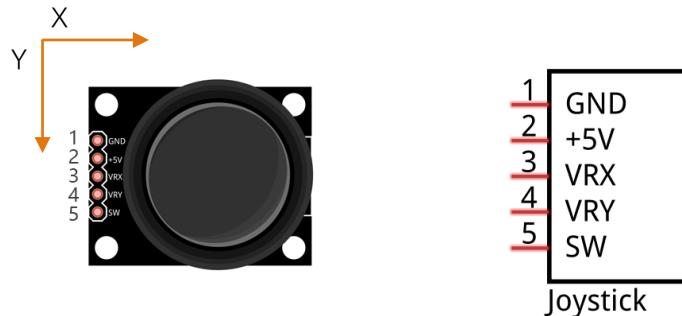
Component List

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

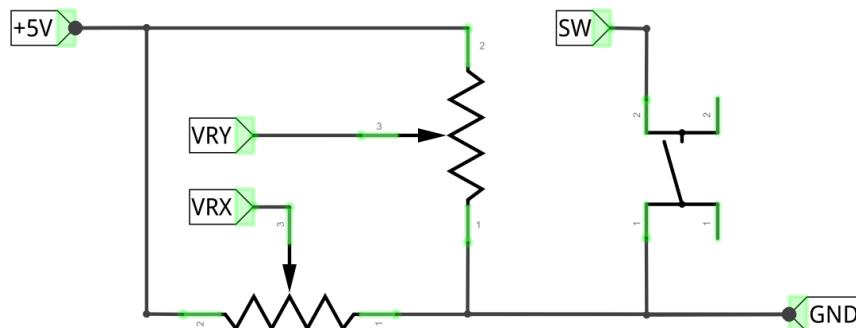
Component knowledge

Joystick

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



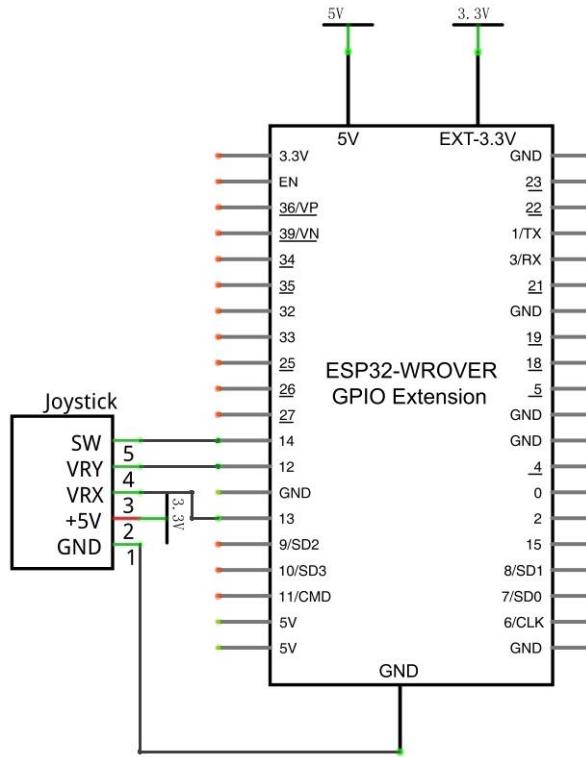
This is accomplished by incorporating two rotary potentiometers inside the joystick Module at 90 degrees of each other, placed in such a manner as to detect shifts in direction in two directions simultaneously and with a push button switch in the “vertical” axis, which can detect when a User presses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



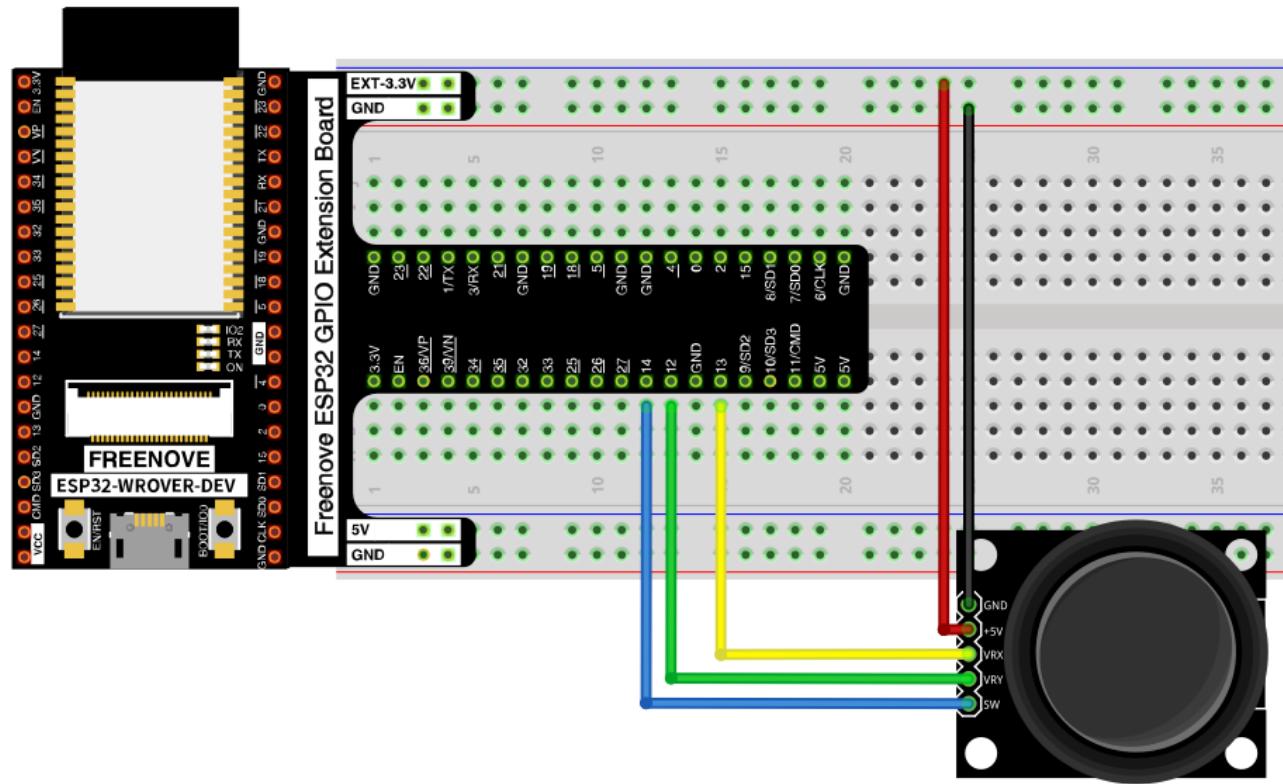
When the joystick data is read, there are some differences between the axes: data of X and Y axes is analog, which needs to use the ADC. The data of the Z axis is digital, so you can directly use the GPIO to read this data or you have the option to use the ADC to read this.

Circuit

Schematic diagram



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



Any concerns? ✉ support@freenove.com

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 1.8.10
File Edit Sketch Tools Help
Sketch_14.1_Joystick
1 //*****
2 Filename : Joystick.ino
3 Description : Read data from joystick.
4 Author : www.freenove.com
5 Modification: 2020-1-19
6 ****
7 int xyzPins[] = {13, 12, 14}; //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,%d,%d\n", xVal, yVal, zVal);
18   delay(500);
19 }

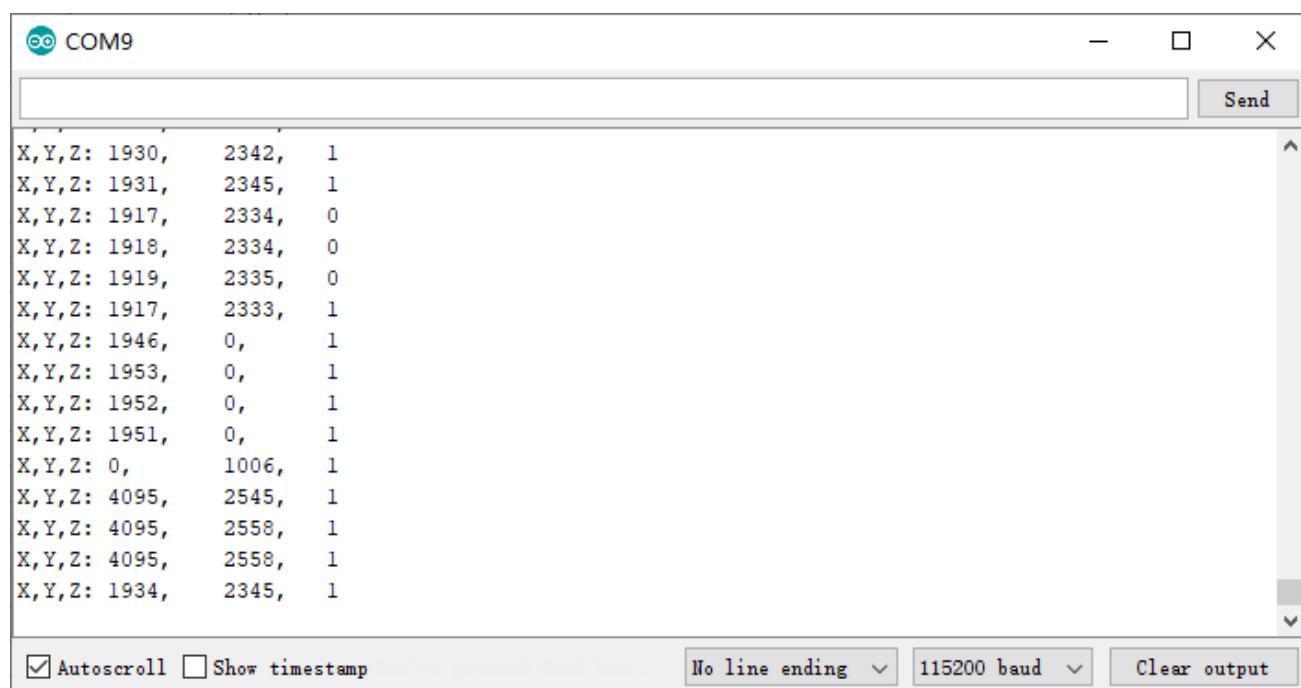
```

Done Saving.

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

ESP32 Dev Module on COM9

Download the code to ESP32-WROVER, 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.



X	Y	Z
1930	2342	1
1931	2345	1
1917	2334	0
1918	2334	0
1919	2335	0
1917	2333	1
1946	0	1
1953	0	1
1952	0	1
1951	0	1
0	1006	1
4095	2545	1
4095	2558	1
4095	2558	1
1934	2345	1

Autoscroll Show timestamp No line ending 115200 baud Clear output

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

The following is the code:

```
1 int xyzPins[] = {13, 12, 14}; //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 is occupied. More GPIO ports mean that more peripherals can be connected to ESP32, so GPIO resource is very precious. Can we make flowing water light with less GPIO? In this chapter, we will learn a component, 74HC595, which can achieve the target.

Project 15.1 Flowing Water Light

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

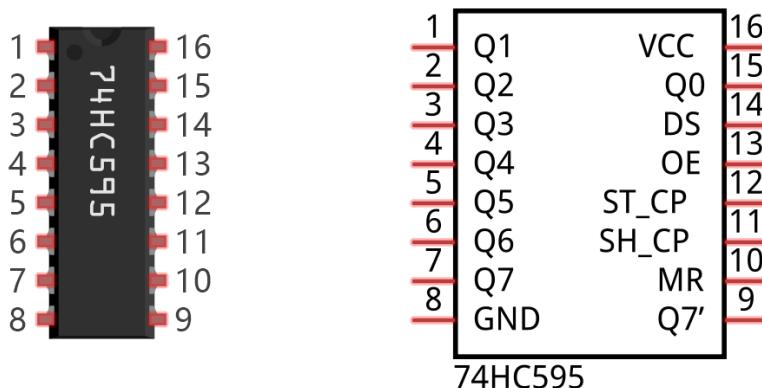
Component List

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

Related knowledge

74HC595

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



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

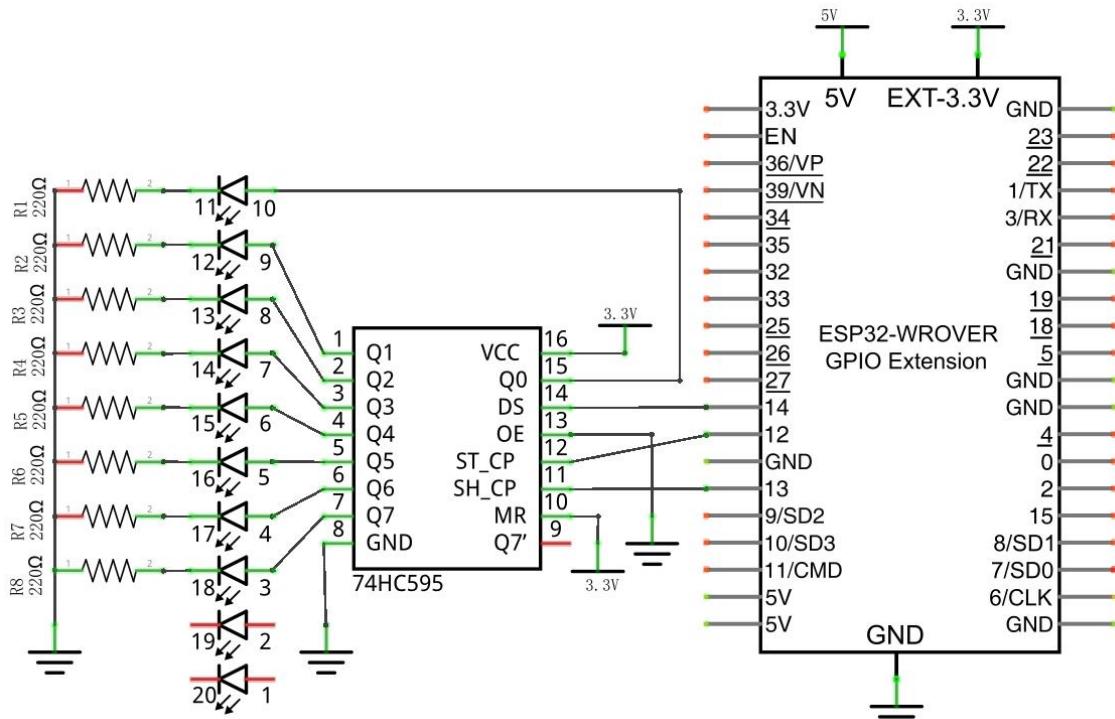
Pin name	GPIO number	Description
Q0-Q7	15, 1-7	Parallel data output
VCC	16	The positive electrode of power supply, the voltage is 2~6V
GND	8	The negative electrode of power supply
DS	14	Serial data Input
OE	13	Enable output, When this pin is in high level, Q0-Q7 is in high resistance state When this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

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

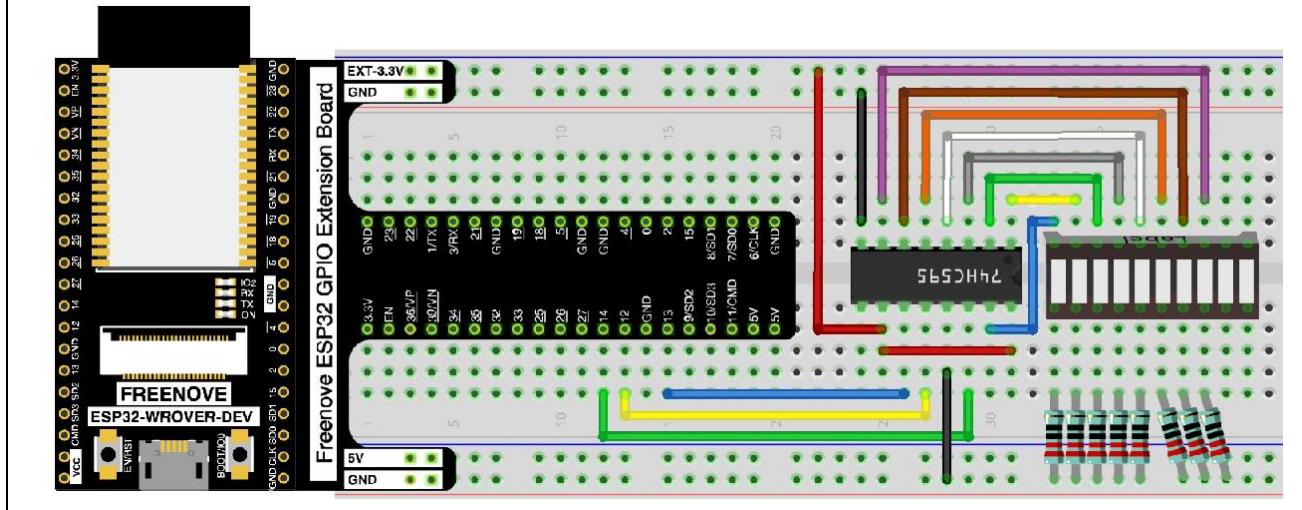


Circuit

Schematic diagram



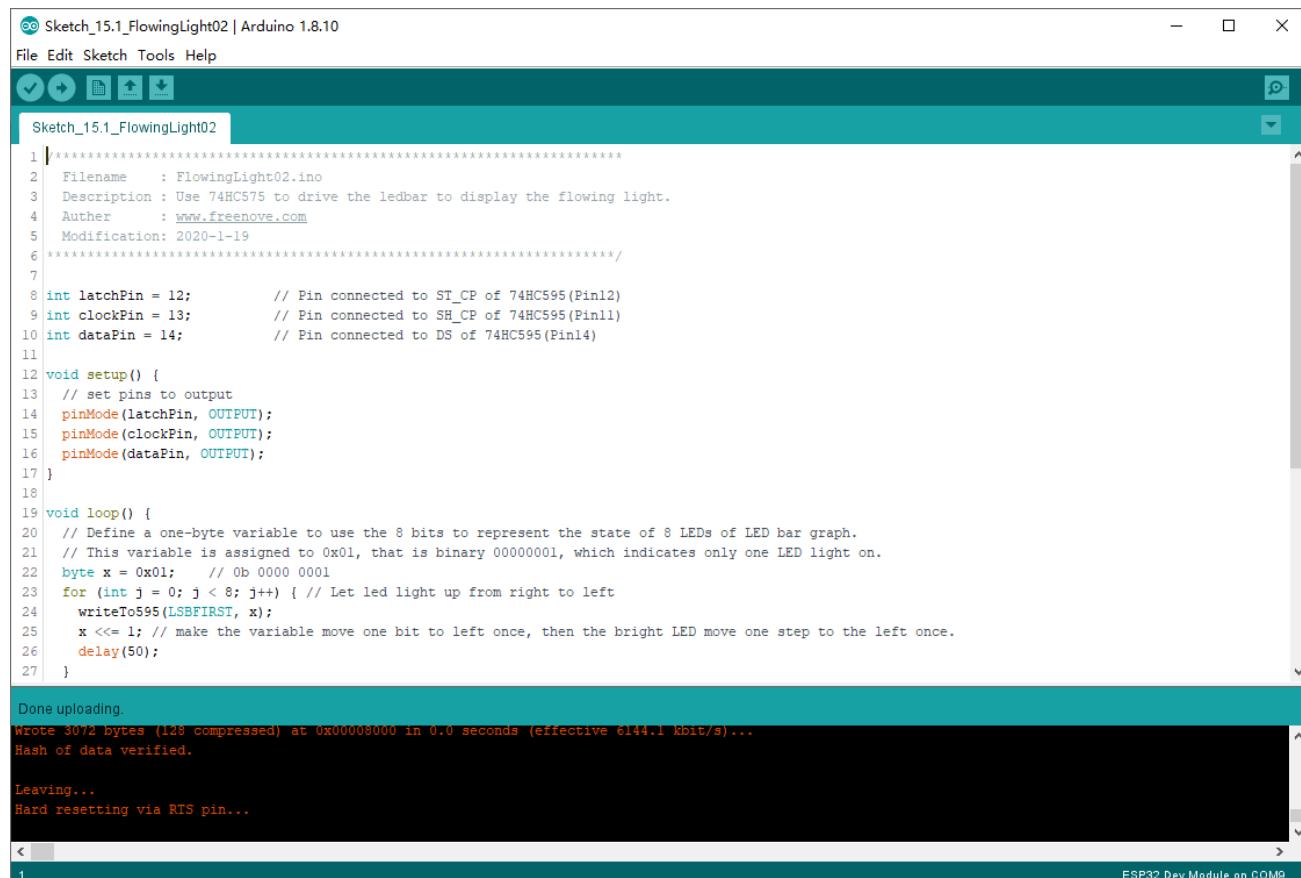
Hardware connection. If you need any support, please feel free to contact us via: support@freenove.com



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 1.8.10
File Edit Sketch Tools Help
Sketch_15.1_FlowingLight02
1 //XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
2 Filename : FlowingLight02.ino
3 Description : Use 74HC575 to drive the ledbar to display the flowing light.
4 Author : www.freenove.com
5 Modification: 2020-1-19
6 ******/ 
7
8 int latchPin = 12;           // Pin connected to ST_CP of 74HC595(Pin12)
9 int clockPin = 13;          // Pin connected to SH_CP of 74HC595(Pin11)
10 int dataPin = 14;           // 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   }
}
Done uploading.
Wrote 3072 bytes (128 compressed) at 0x00008000 in 0.0 seconds (effective 6144.1 kbit/s)...
Hash of data verified.

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

```

Download the code to ESP32-WROVER. 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

The following is the program code:

```

1 int latchPin = 12;           // Pin connected to ST_CP of 74HC595(Pin12)
2 int clockPin = 13;          // Pin connected to SH_CP of 74HC595(Pin11)
3 int dataPin = 14;           // 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() {

```

Any concerns? ✉ support@freenove.com



```

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.

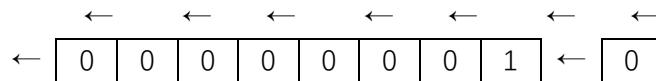
The subfunction writeTo595() is used to write data to 74HC595 and immediately output on the port of 74HC595.

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;

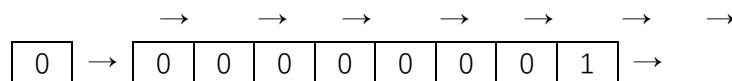


The result of x is 2 (binary 00000010).



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/shifout/>



Chapter 16 74HC595 & 7-Segment Display.

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

Project 16.1 7-Segment Display.

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

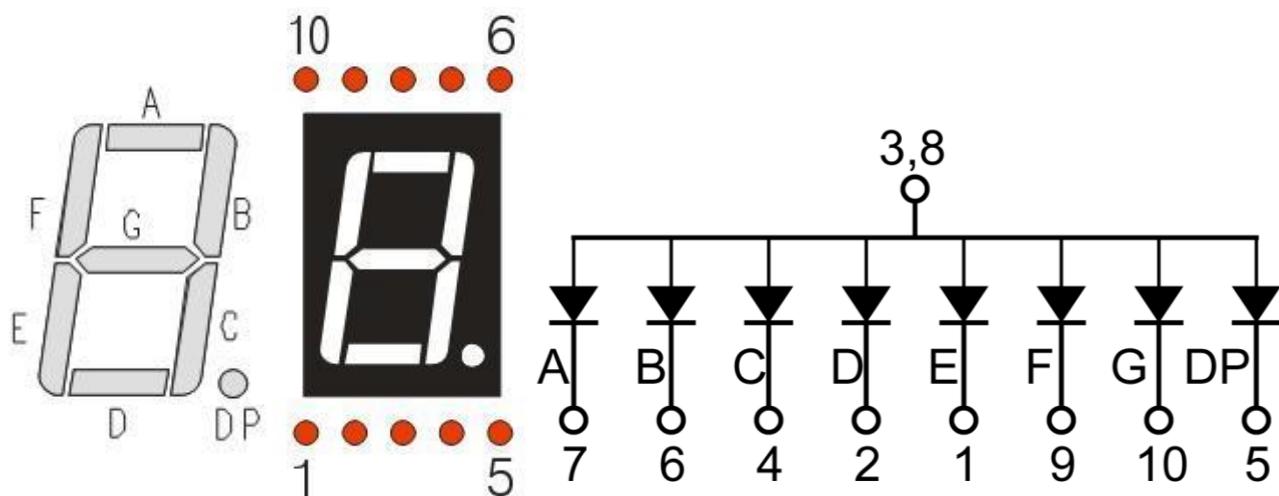
Component List

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

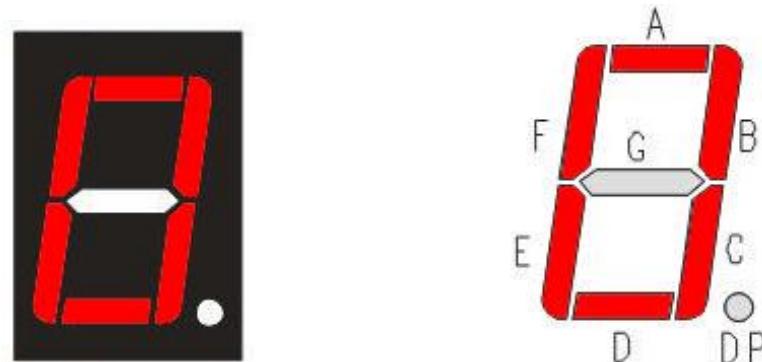
Component knowledge

7-segment display

A 7-segment display is a digital electronic display device. There is a figure "8" and a decimal point represented, which consists of 8 LEDs. The LEDs have a common anode and individual cathodes. Its internal structure and pin designation diagram is shown below:



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



In this project, we will use a 7-Segment Display with a common anode. Therefore, when there is an input low level to 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: $1100\ 0000_2 = 0xc0$.

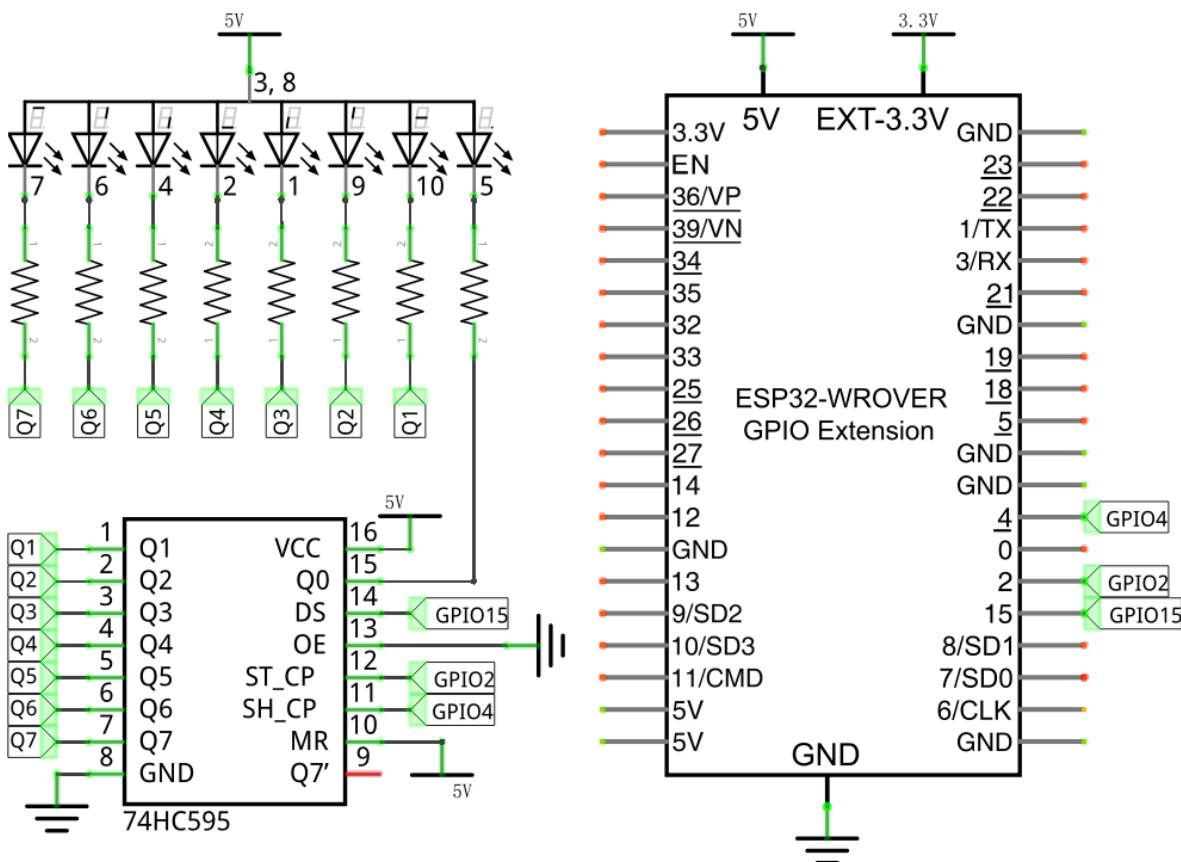


For detailed code values, please refer to the following table (common anode).

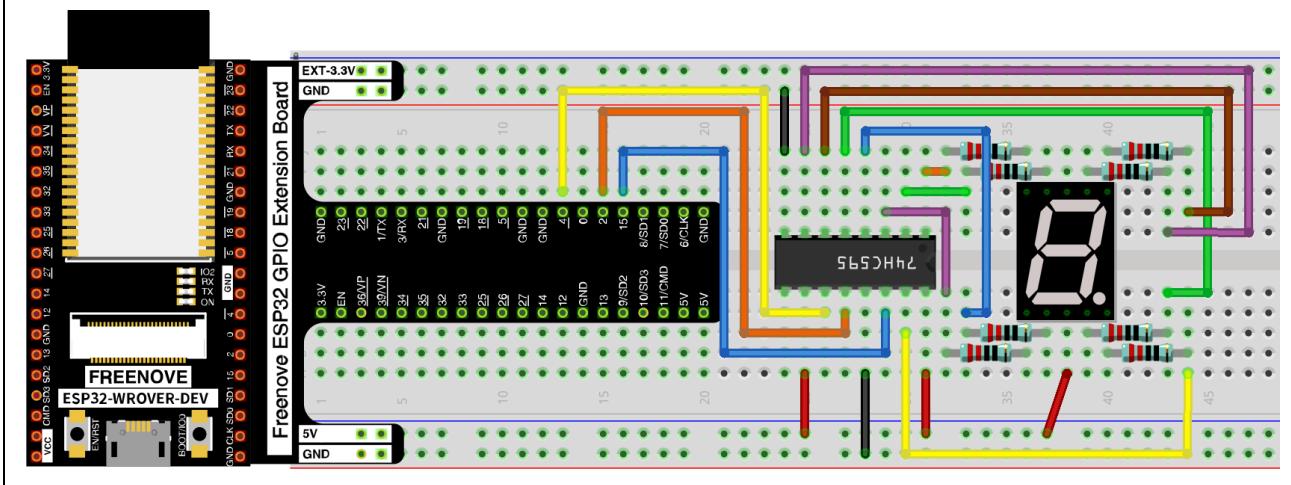
CHAR	DP	G	F	E	D	C	B	A	Hex	ASCII
0	1	1	0	0	0	0	0	0	0xc0	1100 0000
1	1	1	1	1	1	0	0	1	0xf9	1111 1001
2	1	0	1	0	0	1	0	0	0xa4	1010 0100
3	1	0	1	1	0	0	0	0	0xb0	1011 0000
4	1	0	0	1	1	0	0	1	0x99	1001 1001
5	1	0	0	1	0	0	1	0	0x92	1001 0010
6	1	0	0	0	0	0	1	0	0x82	1000 0010
7	1	1	1	1	1	0	0	0	0xf8	1111 1000
8	1	0	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 free to contact us via: 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 1.8.13 Hourly Build 2020/02/19 03:33
File Edit Sketch Tools Help
Sketch_16.1_1_Digit_7-Segment_Display
1 // *****
2   Filename : 1 Digital 7 Segment Display
3   Description : Use 74HC595 to drive the digital display
4   Author : www.freenove.com
5   Modification: 2020-3-3
6 *****
7   int dataPin = 15;           // Pin connected to DS of 74HC595 (Pin14)
8   int latchPin = 2;          // Pin connected to ST_CP of 74HC595 (Pin12)
9   int clockPin = 4;          // 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, 0x11, 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 }
```

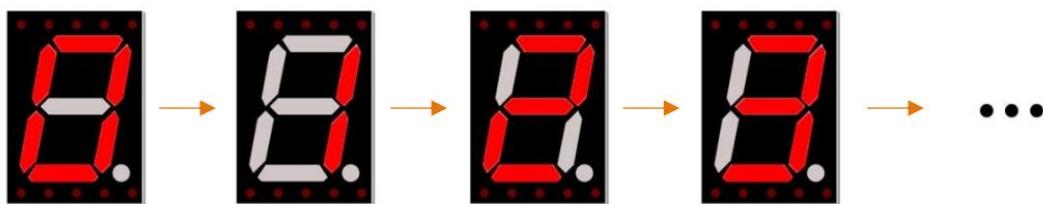
Done uploading.

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

< >

14 ESP32 Wrover Module on COM8

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 = 15;           // Pin connected to DS of 74HC595 (Pin14)
2 int latchPin = 2;           // Pin connected to ST_CP of 74HC595 (Pin12)
3 int clockPin = 4;           // 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.

```

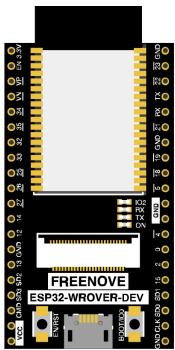
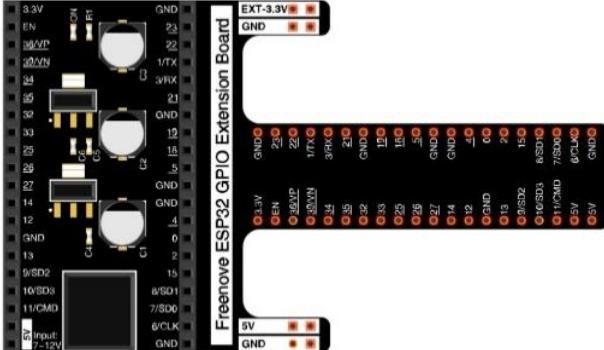
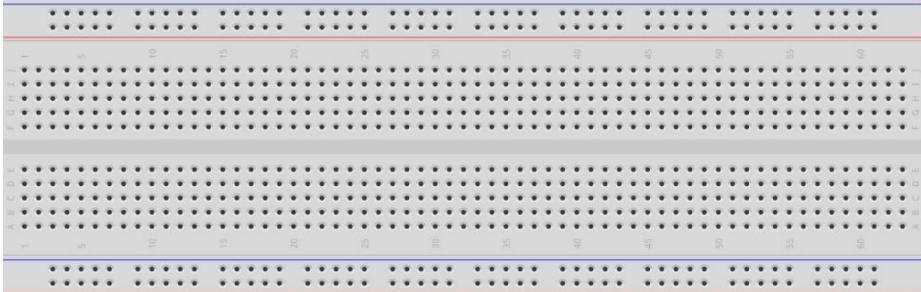
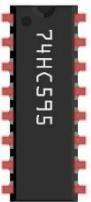
30 shiftOut(dataPin, clockPin, LSBFIRST, value & 0x7f);

```

Project 16.2 4-Digit 7-Segment Display

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

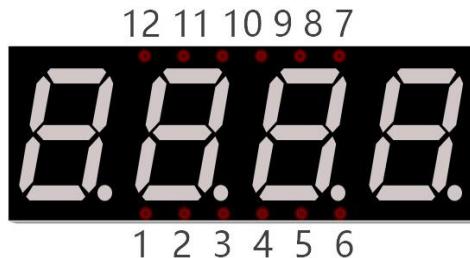
Component List

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

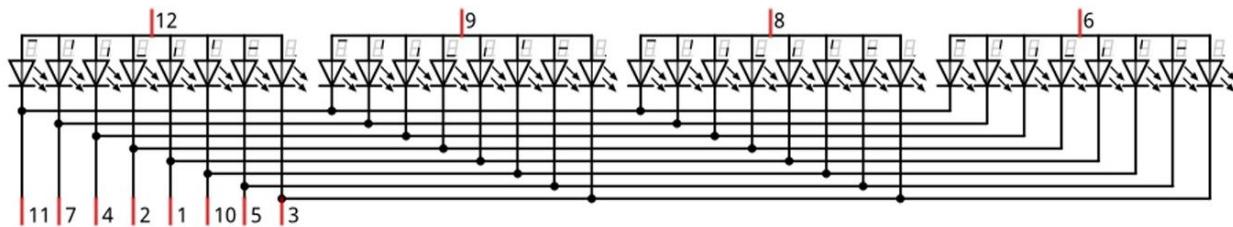
Component knowledge

4 Digit 7-Segment Display

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



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

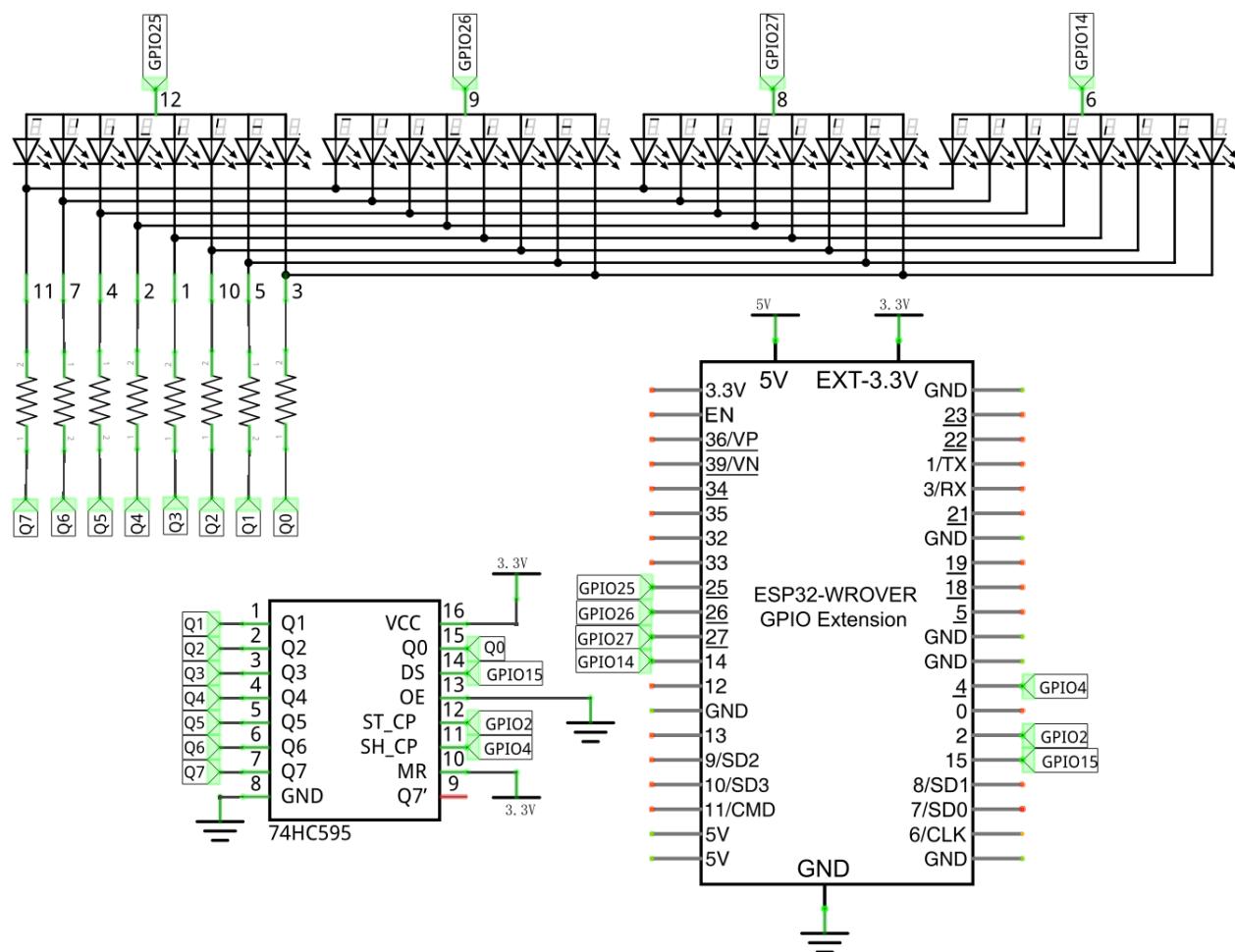


Display method of 4 digit 7-segment display is similar to 1 digit 7-segment display. The difference between them is that the 4-digit displays each Digit is visible in turn, one by one and not together. We need to first send high level to the common end of the first digit display, and send low level to 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.

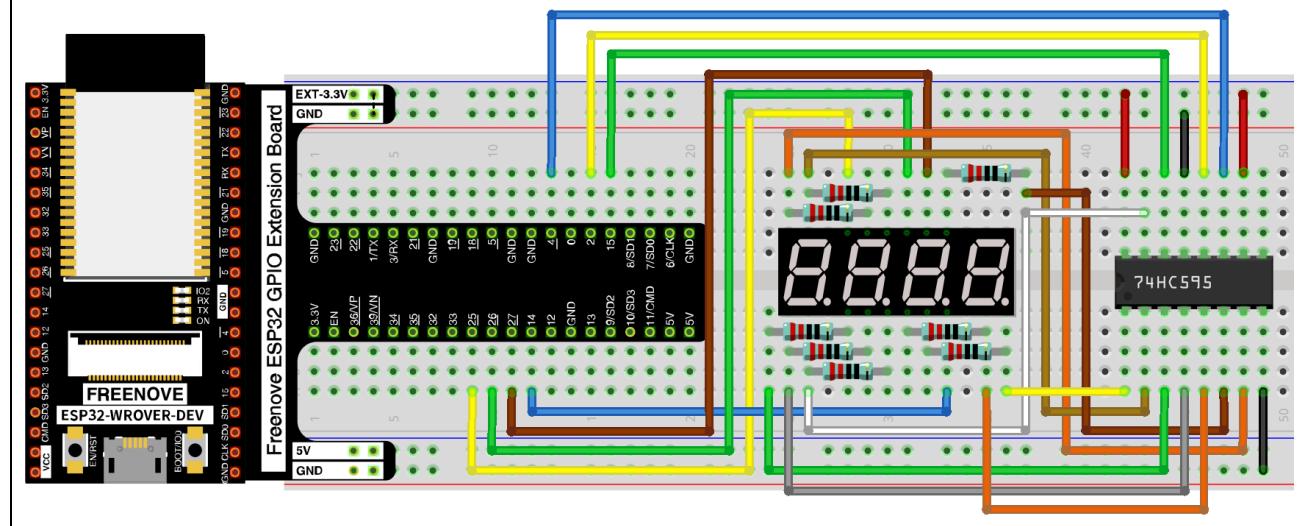
Similarly, the second, third and fourth 7-segment displays will show visible content in turn by scanning the display. Although the four number characters are displayed in turn separately, this process is so fast that it is imperceptible to the naked eye. This is due to the principle of optical afterglow 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



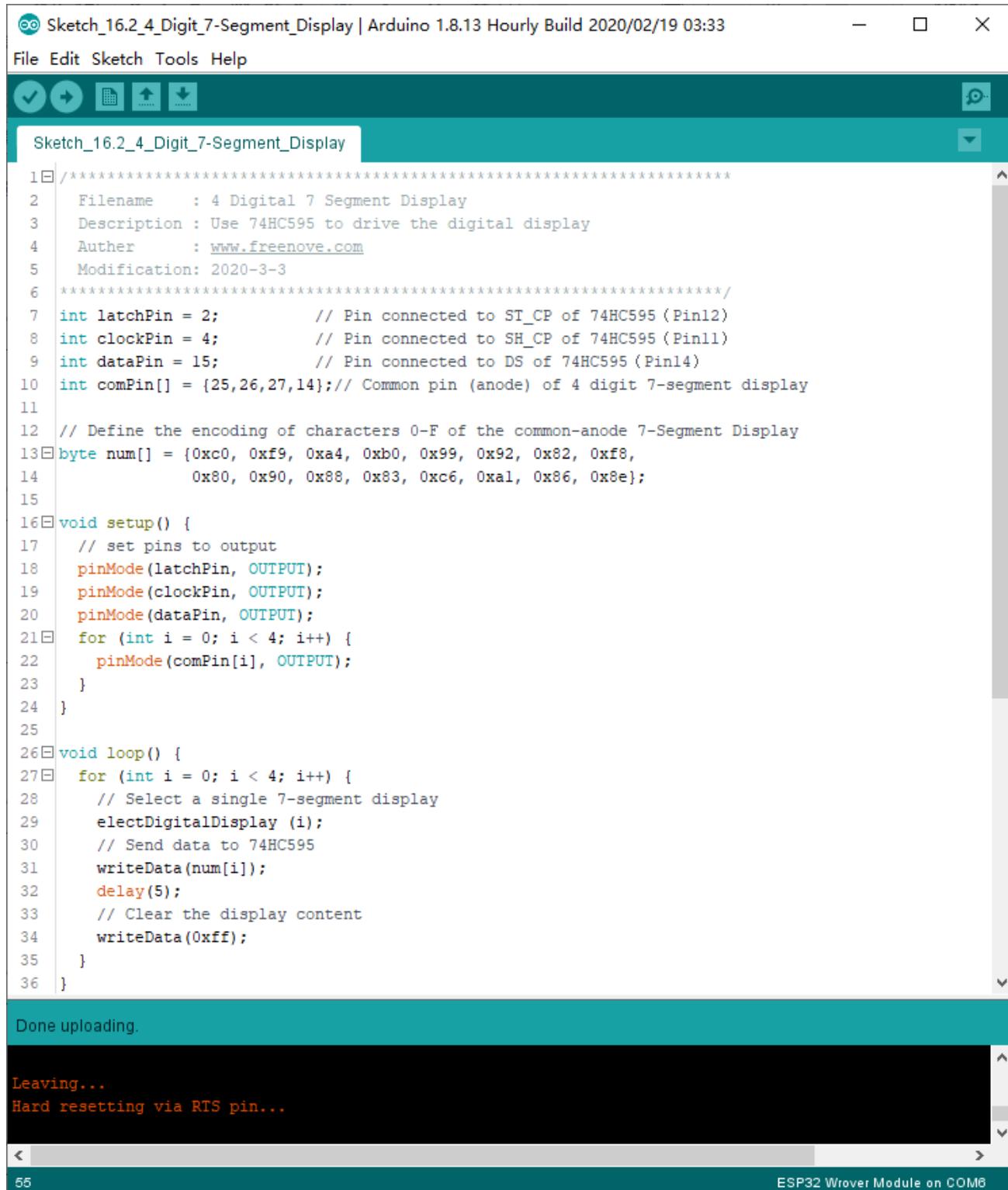
Hardware connection:



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 1.8.13 Hourly Build 2020/02/19 03:33
- Menu Bar:** File Edit Sketch Tools Help
- Toolbar:** Standard toolbar icons for file operations.
- Code Editor:** The main area contains the C++ code for the sketch. The code defines pin connections, character encodings, and the setup and loop functions for a 4-digit 7-segment display using a 74HC595 chip.

```
1 // ****
2 Filename : 4 Digital 7 Segment Display
3 Description : Use 74HC595 to drive the digital display
4 Author : www.freenove.com
5 Modification: 2020-3-3
6 ****
7 int latchPin = 2;           // Pin connected to ST_CP of 74HC595 (Pin12)
8 int clockPin = 4;          // Pin connected to SH_CP of 74HC595 (Pin11)
9 int dataPin = 15;          // Pin connected to DS of 74HC595 (Pin14)
10 int comPin[] = {25,26,27,14}; // 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);
23     }
24 }
25
26 void loop() {
27     for (int i = 0; i < 4; i++) {
28         // Select a single 7-segment display
29         electDigitalDisplay (i);
30         // Send data to 74HC595
31         writeData(num[i]);
32         delay(5);
33         // Clear the display content
34         writeData(0xff);
35     }
36 }
```

- Status Bar:** Shows "Done uploading.", "Leaving...", "Hard resetting via RTS pin...", and "ESP32 Wrover Module on COM6".

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



The following is the program code:

```
1 int latchPin = 2;           // Pin connected to ST_CP of 74HC595 (Pin12)
2 int clockPin = 4;          // Pin connected to SH_CP of 74HC595 (Pin11)
3 int dataPin = 15;          // Pin connected to DS of 74HC595 (Pin14)
4 int comPin[] = {25, 26, 27, 14}; // 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         electDigitalDisplay (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 electDigitalDisplay(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);
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 = 2;           // Pin connected to ST_CP of 74HC595 (Pin12)
2 int clockPin = 4;          // Pin connected to SH_CP of 74HC595 (Pin11)
3 int dataPin = 15;          // Pin connected to DS of 74HC595 (Pin14)
4 int comPin[] = {25, 26, 27, 14}; // 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 electDigitalDisplay(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         electDigitalDisplay(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);
```

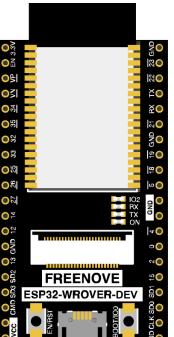
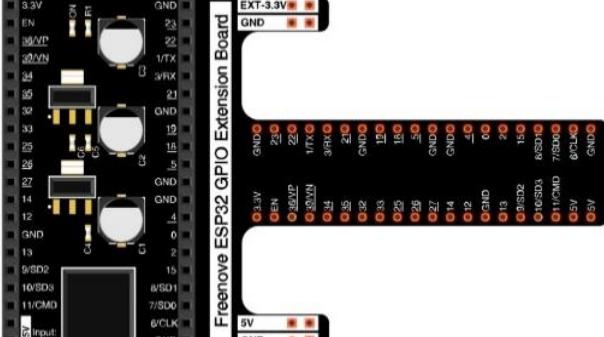
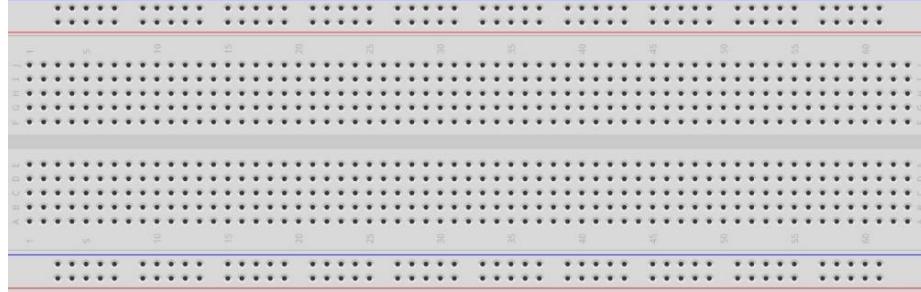
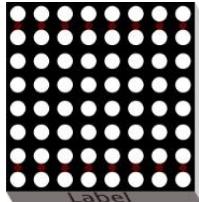
Chapter 16 74HC595 & LED Matrix

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.

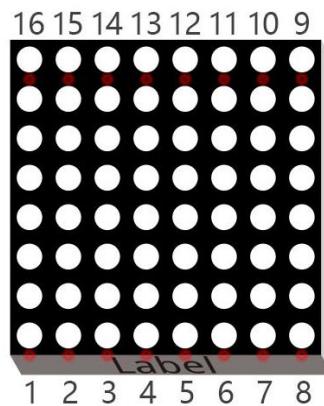
Component List

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

Component knowledge

LED Matrix

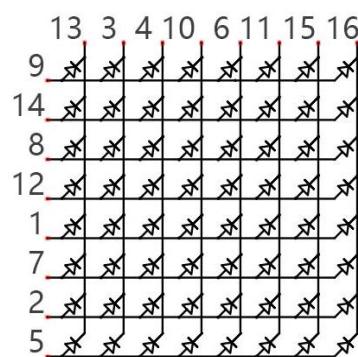
A LED matrix is a rectangular display module that consists of a uniform grid of LEDs. The following is an 8X8 monochrome (one color) LED matrix containing 64 LEDs (8 rows by 8 columns).



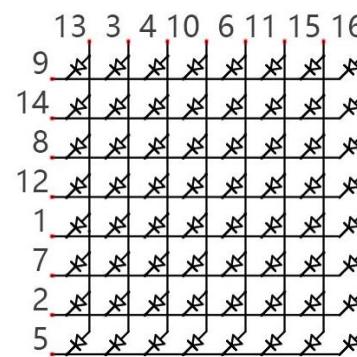
In order to facilitate the operation and reduce the number of ports required to drive this component, the positive poles of the LEDs in each row and negative poles of the LEDs in each column are respectively connected together inside the LED matrix module, which is called a common anode. There is another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

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

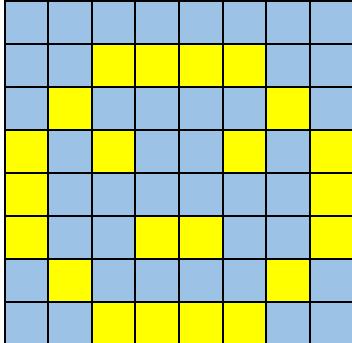
Connection mode of common anode



Connection mode of common cathode



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



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

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

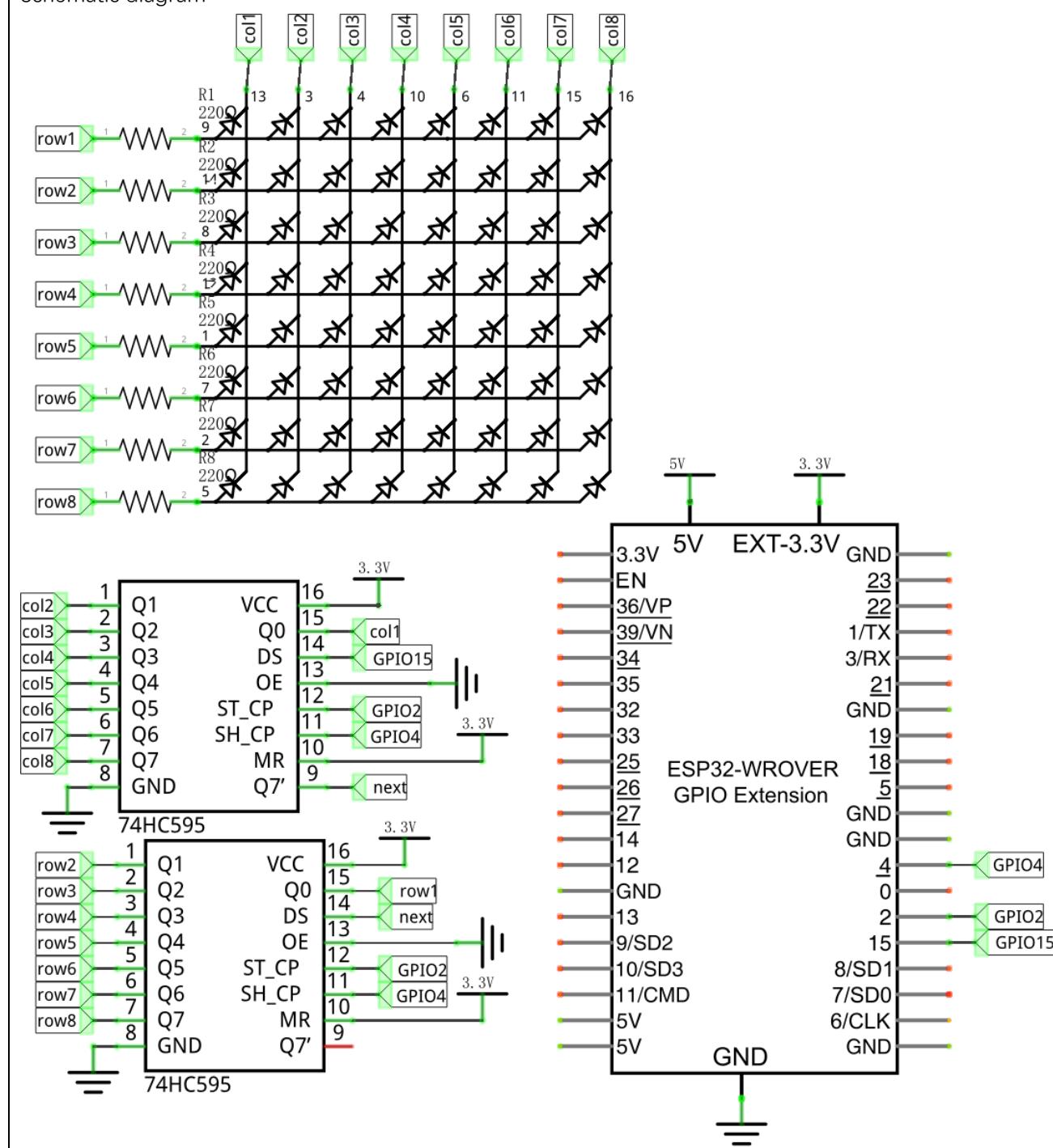
To begin, display the first column, then turn off the first column and display the second column. (and so on) turn off the seventh column and display the 8th column, and then start the process over from the first column again like the control of LED bar graph project. The whole process will be repeated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

Then, to save the number of GPIO, we use a 74HC595. When the first column is turned ON, set the lights that need to be displayed in the first column to "1", otherwise to "0", as shown in the above example, where the value of the first column is 0x1c. This value is sent to 74HC595 to control the display of the first column of the 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.

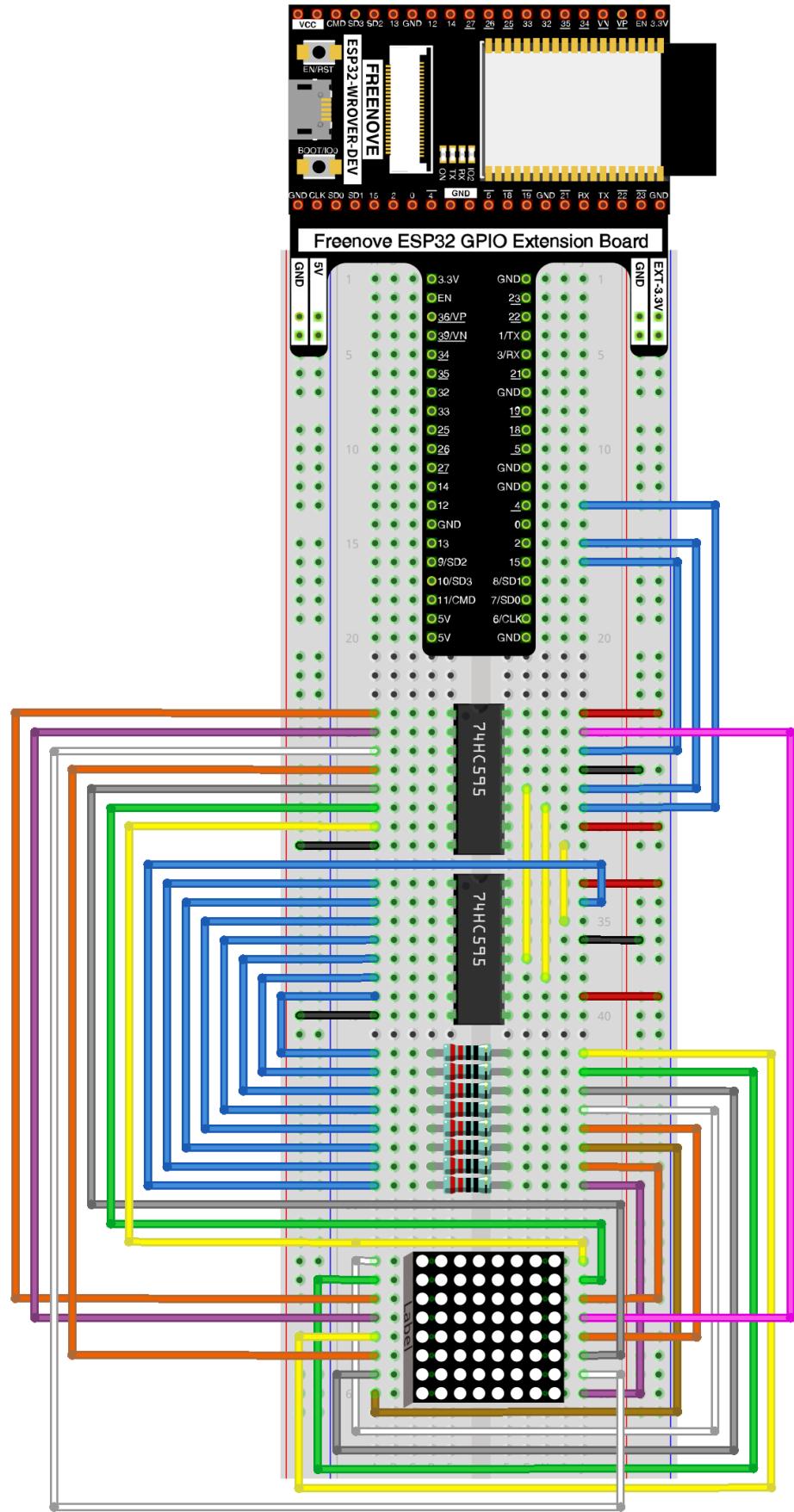
Circuit

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:



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

Sketch

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

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

- Title Bar:** Sketch_16.3_LED_Matrix | Arduino 1.8.13 Hourly Build 2020/02/19 03:33
- Menu Bar:** File Edit Sketch Tools Help
- Toolbar:** Standard Arduino toolbar icons.
- Code Editor:** The main area contains the Arduino sketch code for driving a 2x8 LED matrix using two 74HC595 chips. The code includes definitions for pin connections, a smiling face pattern, and a data array for numbers/letters. It sets up pins and loops to display the patterns.
- Status Bar:** Shows "Done uploading.", "Hash of data verified.", "Leaving...", "Hard resetting via RTS pin...", and "ESP32 Wrover Module on COM6".
- Bottom Left:** Line number 47.



Download the code to ESP32-WROVER, 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 = 2;           // Pin connected to ST_CP of 74HC595 (Pin12)
2 int clockPin = 4;          // Pin connected to SH_CP of 74HC595 (Pin11)
3 int dataPin = 15;          // 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         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 void matrixRowsVal(int value) {
67     // make latchPin output low level
68     digitalWrite(latchPin, LOW);
69     // Send serial data to 74HC595
70     shiftOut(dataPin, clockPin, LSBFIRST, value);
71     // make latchPin output high level, then 74HC595 will update the data to parallel output
72     digitalWrite(latchPin, HIGH);
73 }

74 }

75 void matrixColsVal(int value) {
76     // make latchPin output low level
77     digitalWrite(latchPin, LOW);
78     // Send serial data to 74HC595
79     shiftOut(dataPin, clockPin, MSBFIRST, value);
80     // make latchPin output high level, then 74HC595 will update the data to parallel output
81     digitalWrite(latchPin, HIGH);
82 }

83 }
```



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     cols = 0x01; // Assign 0x01(binary 00000001) to the variable, which represents the first
44     // column is selected.
45     for (int i = 0; i < 8; i++) { // display 8 column data by scanning
46         matrixRowsVal(smilingFace[i]); // display the data in this column
47         matrixColsVal(~cols); // select this column
48         delay(1); // display them for a period of time
49         cols <= 1; // shift "cols" 1 bit left to select the next column
50     }
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 is limited, so you need to find ways to save pins. If you use ESP32'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.

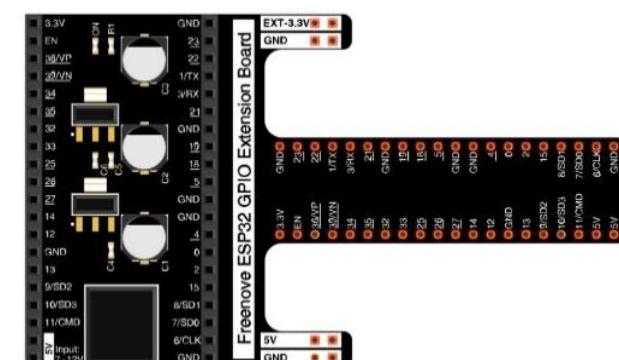
Chapter 17 Relay & Motor

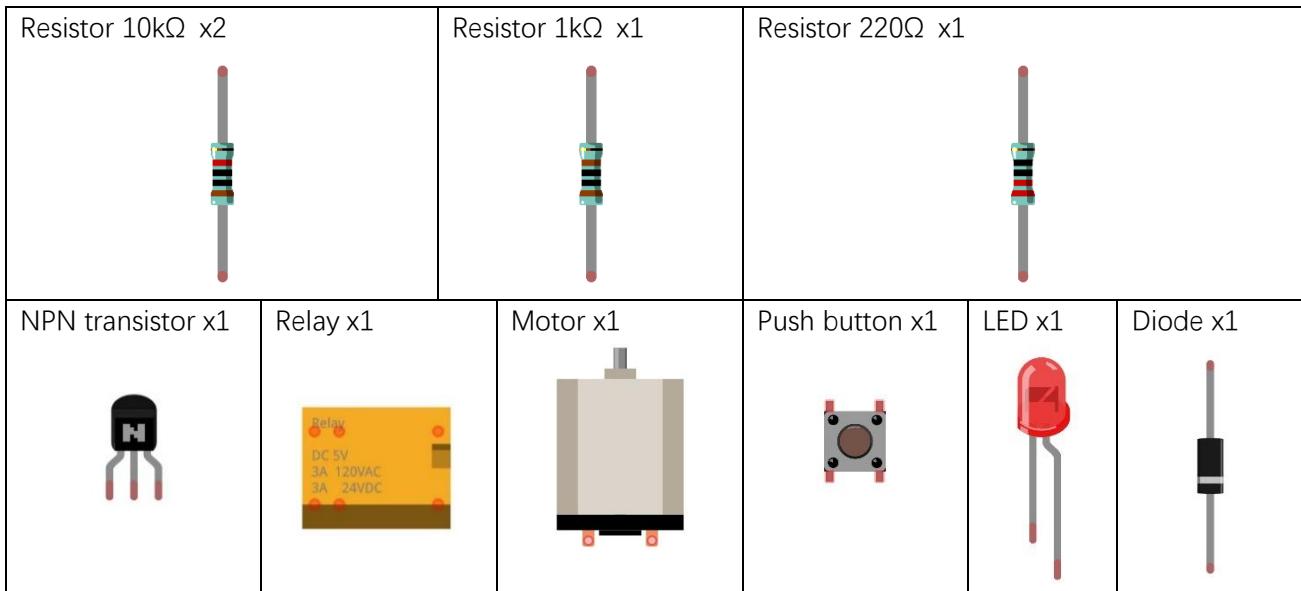
In this chapter, we will learn a kind of special switch module, relay module.

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-WROVER x1	
Breadboard x1	
Jumper M/M	
9V battery (prepared by yourself) & battery line	

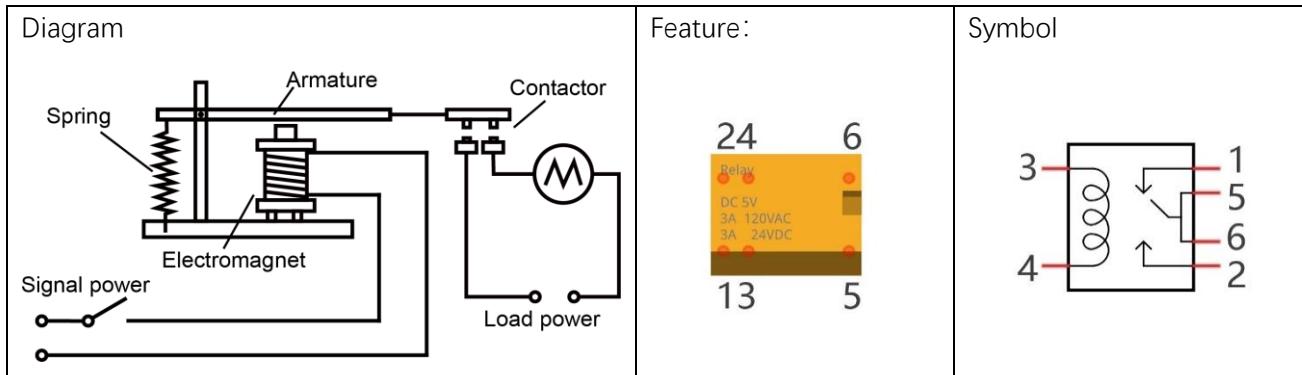


Component knowledge

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 to 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.

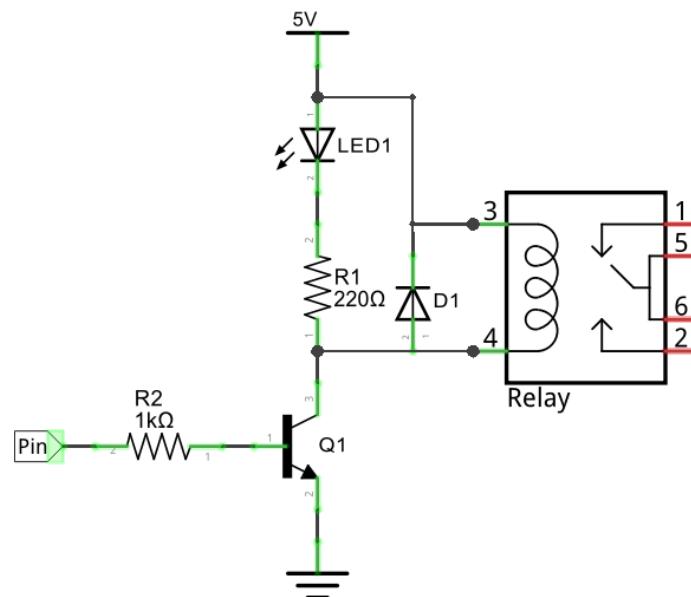
Inductor

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.

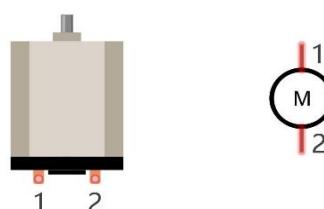


The reference circuit for relay is as follows. The coil of relays can be equivalent to that of inductors, when the transistor disconnects power supply of the relay, the current in the coil of the relay can't stop immediately, causing an impact on power supply. So a parallel diode will get connected to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

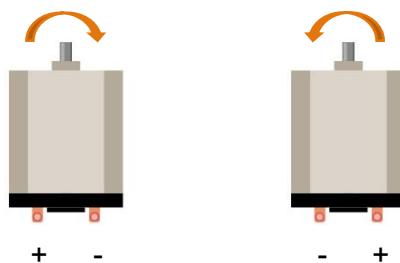


Motor

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.

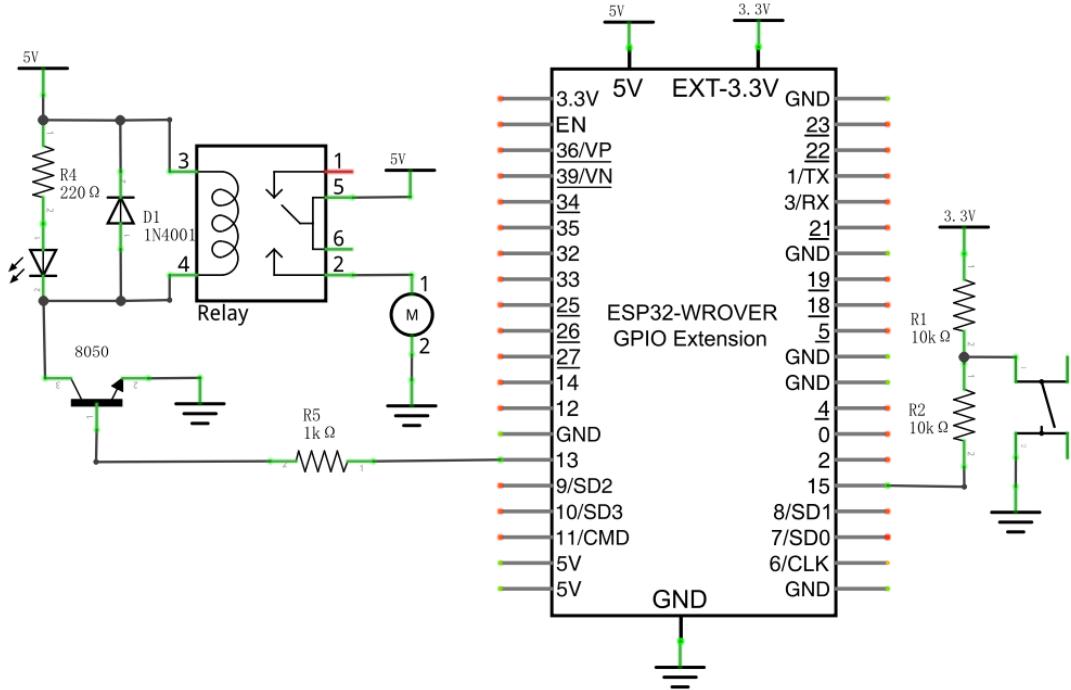


When a motor gets connected to the power supply, it will rotate in one direction. Reverse the polarity of power supply, then the motor rotates in opposite direction.

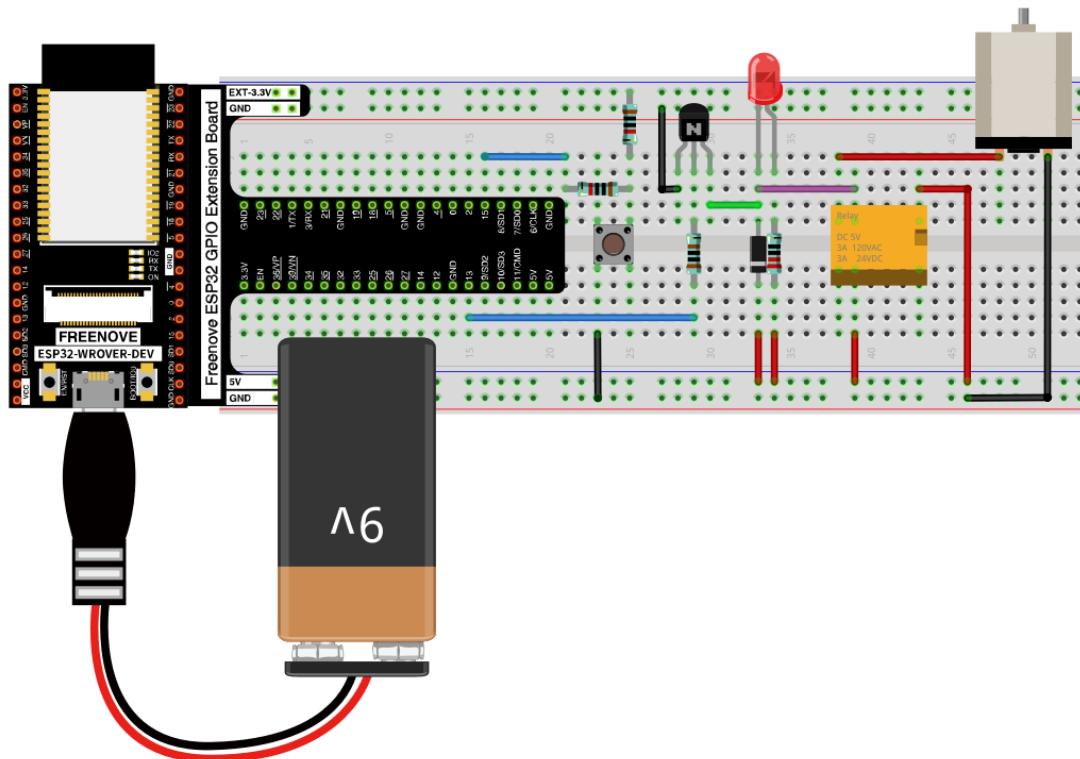


Circuit

Schematic diagram



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

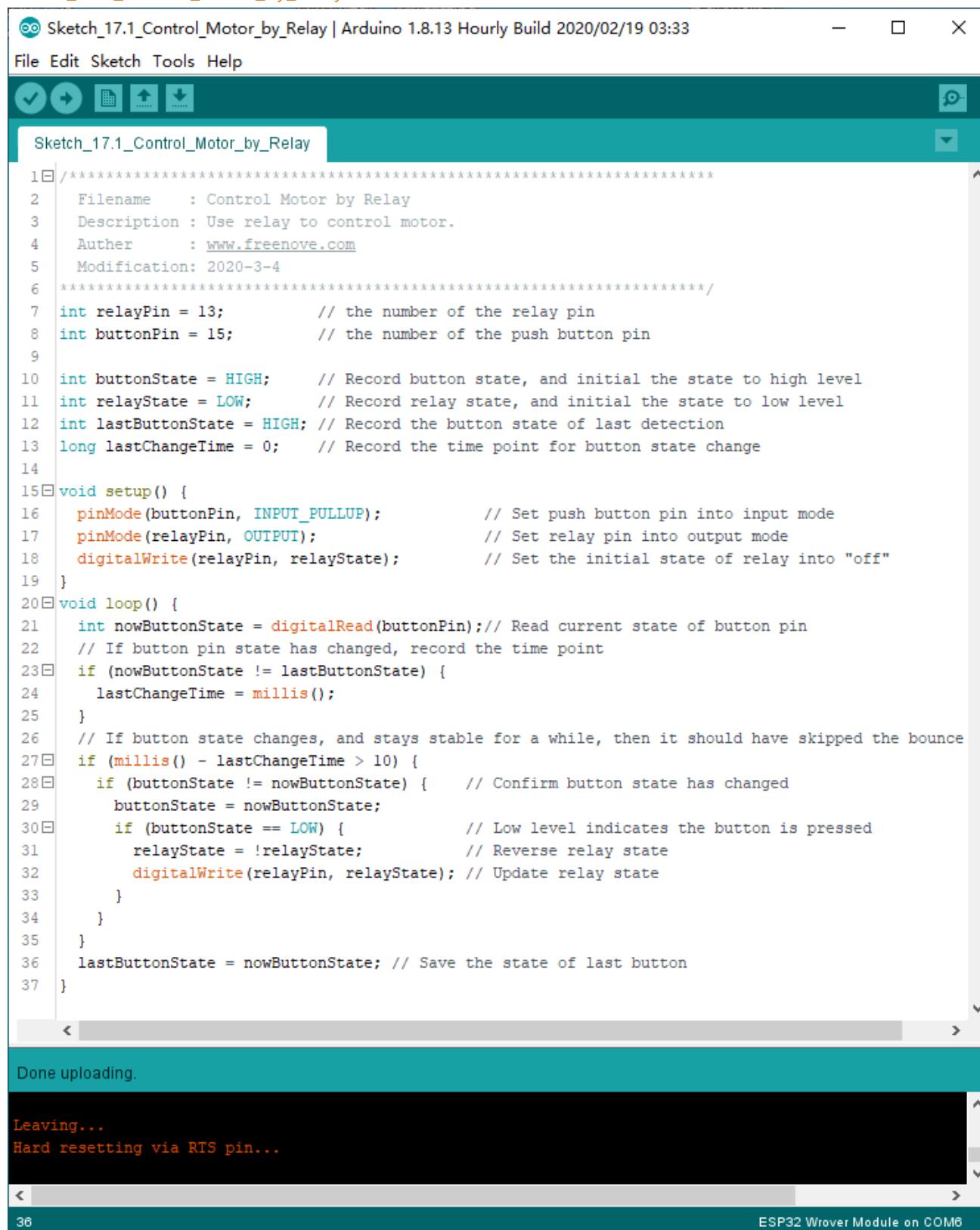


Note: the motor circuit uses a large current, about 0.2-0.3A without load. We recommend that you use a 9V battery to power the extension board.

Sketch

Use buttons to control the relays and motors.

Sketch_17.1_Control_Motor_by_Relay



```
Sketch_17.1_Control_Motor_by_Relay | Arduino 1.8.13 Hourly Build 2020/02/19 03:33
File Edit Sketch Tools Help
Sketch_17.1_Control_Motor_by_Relay
1 // ****
2   Filename    : Control Motor by Relay
3   Description : Use relay to control motor.
4   Author      : www.freenove.com
5   Modification: 2020-3-4
6 ****
7   int relayPin = 13;          // the number of the relay pin
8   int buttonPin = 15;         // 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
27   if (millis() - lastChangeTime > 10) {
28     if (buttonState != nowButtonState) { // Confirm button state has changed
29       buttonState = nowButtonState;
30     }
31     if (buttonState == LOW) {           // Low level indicates the button is pressed
32       relayState = !relayState;        // Reverse relay state
33       digitalWrite(relayPin, relayState); // Update relay state
34     }
35   }
36   lastButtonState = nowButtonState; // Save the state of last button
37 }
```

Done uploading.

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

36 ESP32 Wrover Module on COM6



Download the code to ESP32-WROVER. 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 = 13;           // the number of the relay pin
2 int buttonPin = 15;          // 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
```

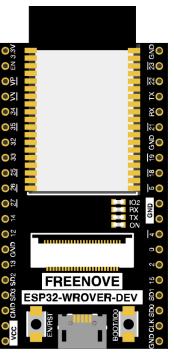
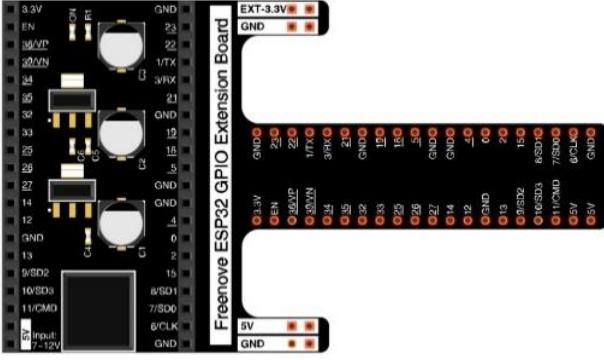
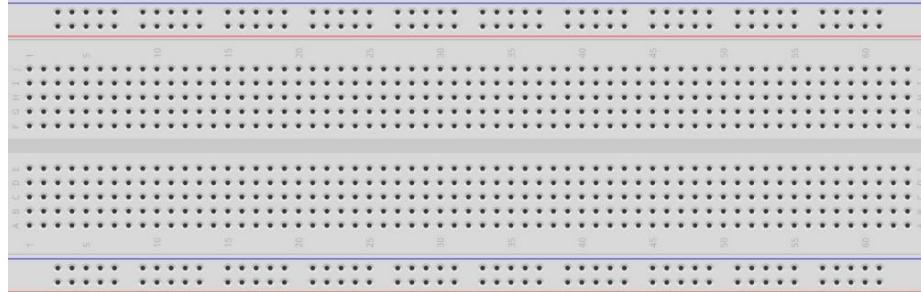
Chapter 17.2 Motor & Driver

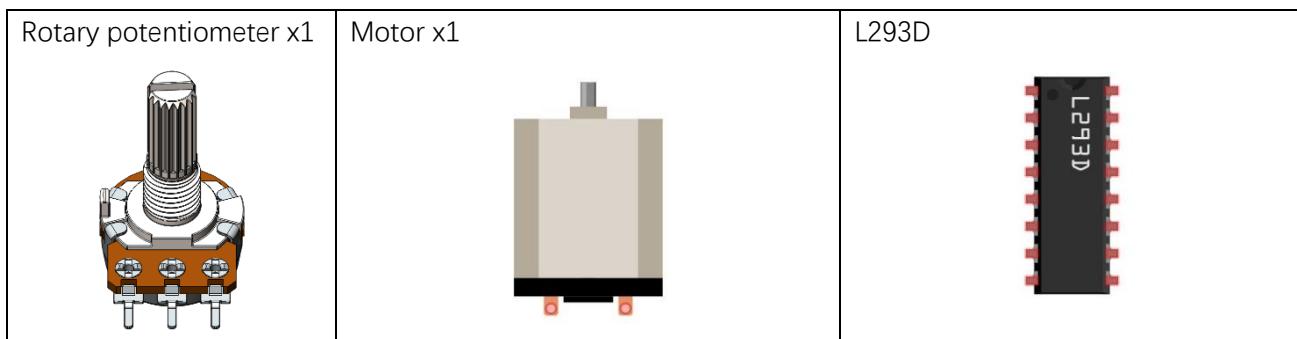
In this chapter, we will learn about DC motors and DC motor drivers and how to control the speed and direction of a DC motor.

Project 17.2 Control Motor with Potentiometer

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

Component List

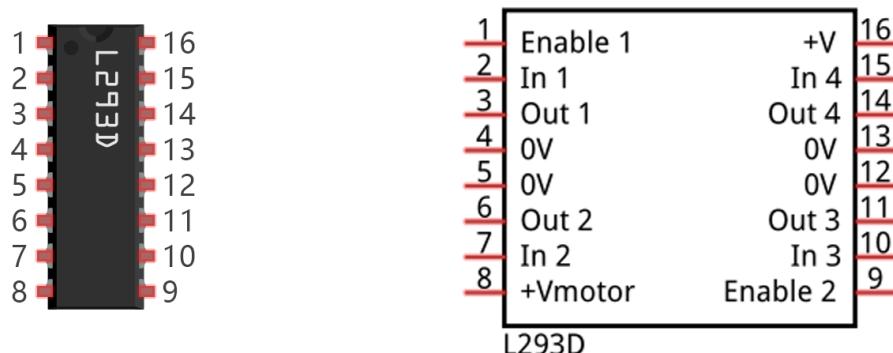
ESP32-WROVER x1		GPIO Extension Board x1	
Breadboard x1			
Jumper M/M			
	9V battery (prepared by yourself) & battery line		



Component knowledge

L293D

L293D is an IC chip (Integrated Circuit Chip) with a 4-channel motor drive. You can drive a unidirectional DC motor with 4 ports or a bi-directional DC motor with 2 ports or a stepper motor (stepper motors are covered later in this Tutorial).



Port description of L293D module is as follows:

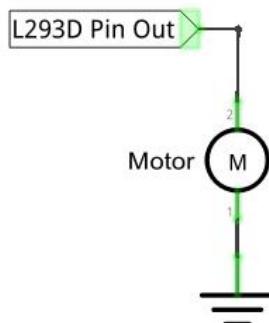
Pin name	Pin number	Description
In x	2, 7, 10, 15	Channel x digital signal input pin
Out x	3, 6, 11, 14	Channel x output pin, input high or low level according to In x pin, get connected to +Vmotor or 0V
Enable1	1	Channel 1 and channel 2 enable pin, high level enable
Enable2	9	Channel 3 and channel 4 enable pin, high level enable
0V	4, 5, 12, 13	Power cathode (GND)
+V	16	Positive electrode (VCC) of power supply, supply voltage 3.0~36V
+Vmotor	8	Positive electrode of load power supply, provide power supply for the Out pin x, the supply voltage is +V~36V

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

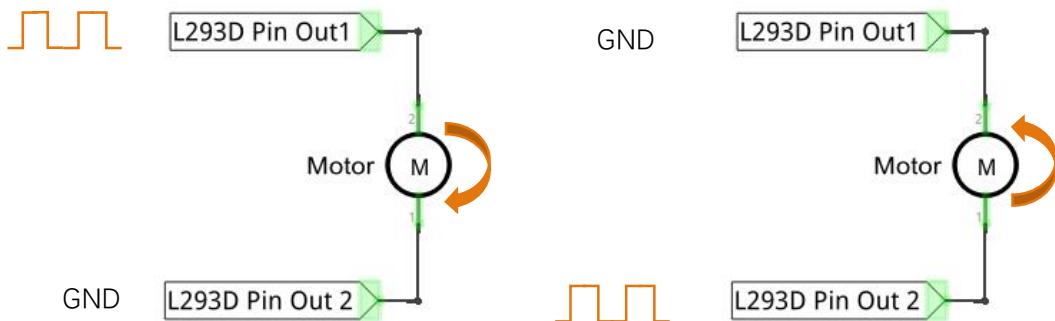


When using L293D to drive DC motor, there are usually two connection options.

The following connection option uses one channel of the L293D, which can control motor speed through the PWM, However the motor then can only rotate in one direction.



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

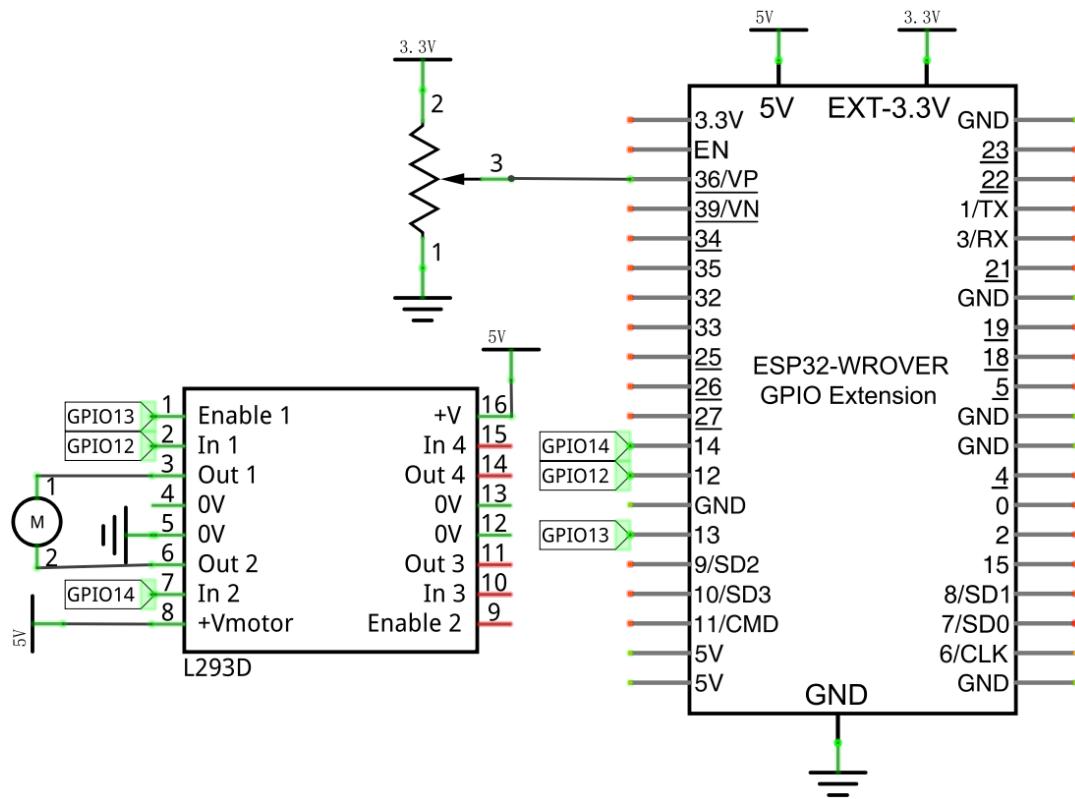


In practical use the motor is usually connected to channel 1 and 2 by outputting different levels to in1 and in2 to control the rotational direction of the motor, and output to the PWM wave to Enable1 port to control the motor's rotational speed. If the motor is connected to channel 3 and 4 by outputting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

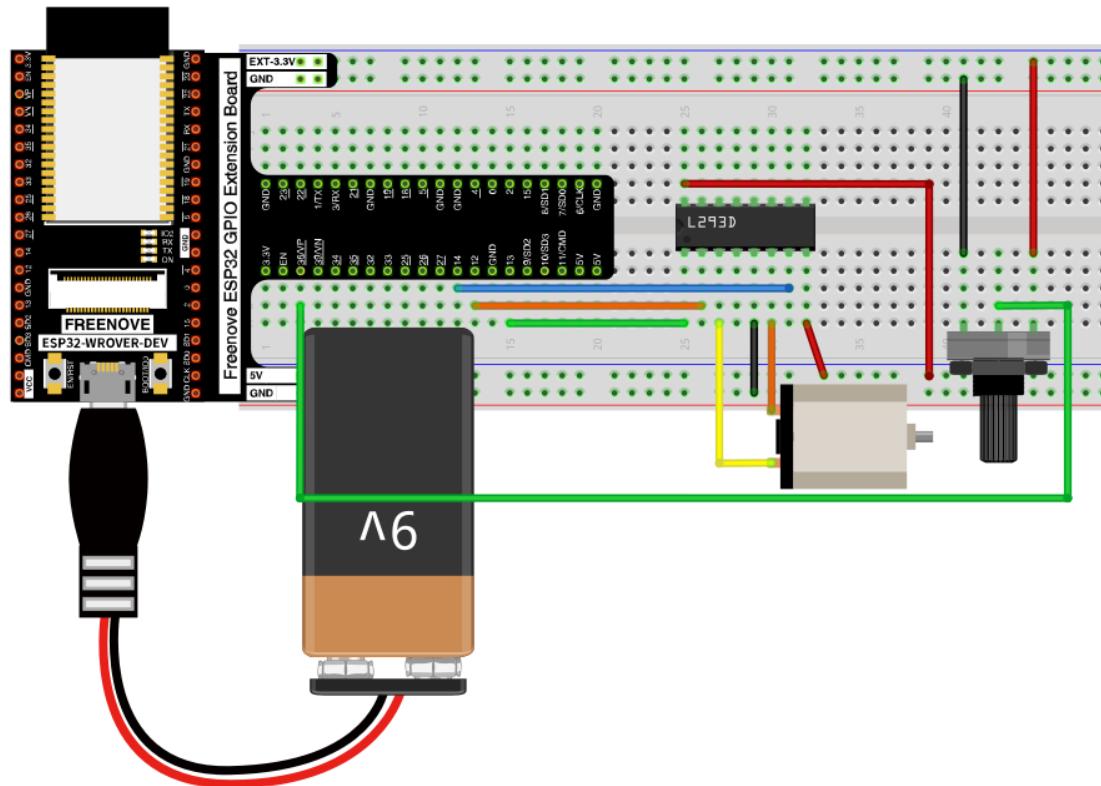
Circuit

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

Schematic diagram



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

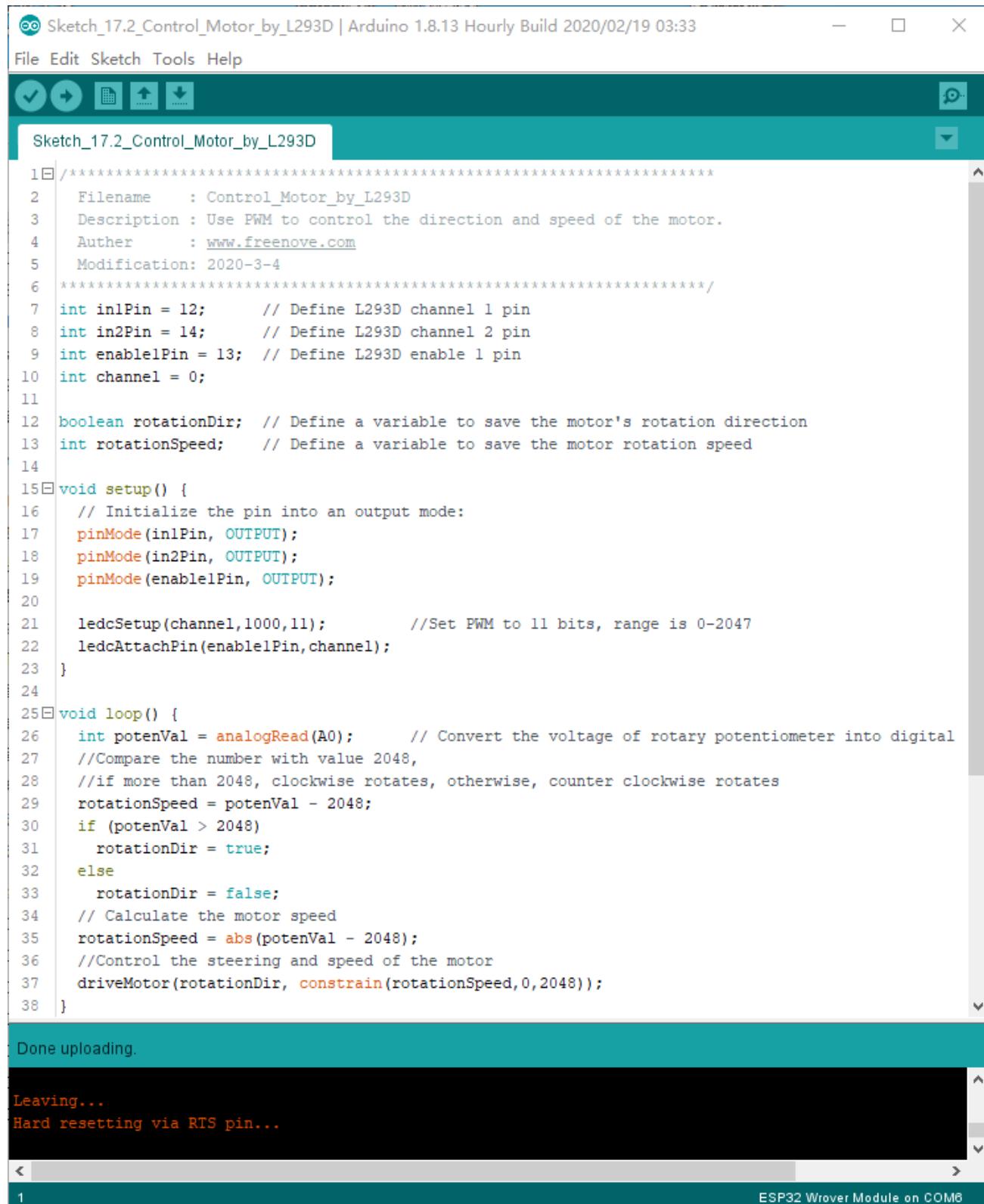


Note: the motor circuit uses A large current, about 0.2-0.3A without load. We recommend that you use a 9V battery to power the extension board.

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

Sketch

Sketch_17.2_Control_Motor_by_L293D



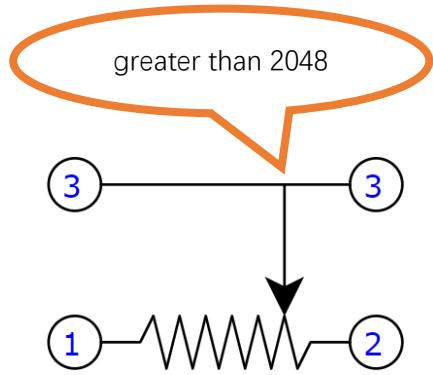
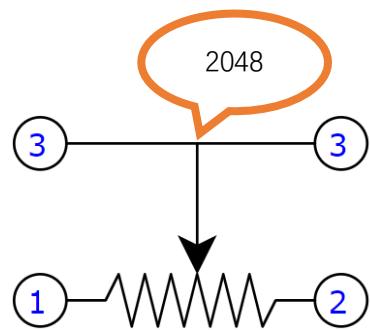
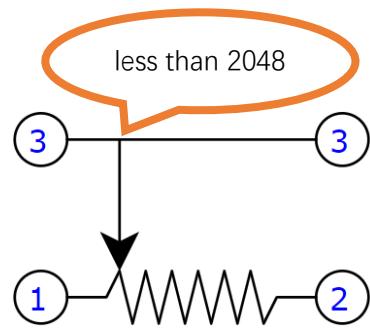
```
Sketch_17.2_Control_Motor_by_L293D | Arduino 1.8.13 Hourly Build 2020/02/19 03:33
File Edit Sketch Tools Help
Sketch_17.2_Control_Motor_by_L293D
1 // ****
2   Filename      : Control_Motor_by_L293D
3   Description   : Use PWM to control the direction and speed of the motor.
4   Author        : www.freenove.com
5   Modification: 2020-3-4
6 ****
7 int in1Pin = 12;      // Define L293D channel 1 pin
8 int in2Pin = 14;      // Define L293D channel 2 pin
9 int enablePin = 13;   // 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   // Initialize the pin into an output mode:
17   pinMode(in1Pin, OUTPUT);
18   pinMode(in2Pin, OUTPUT);
19   pinMode(enablePin, OUTPUT);
20
21   ledcSetup(channel,1000,11);          //Set PWM to 11 bits, range is 0-2047
22   ledcAttachPin(enablePin,channel);
23 }
24
25 void loop() {
26   int potenVal = analogRead(A0);      // Convert the voltage of rotary potentiometer into digital
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;
34   // Calculate the motor speed
35   rotationSpeed = abs(potenVal - 2048);
36   //Control the steering and speed of the motor
37   driveMotor(rotationDir, constrain(rotationSpeed,0,2048));
38 }
```

Done uploading.

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

1 ESP32 Wrover Module on COM6

Download code to ESP32-WROVER, 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 = 12;      // Define L293D channel 1 pin
2 int in2Pin = 14;      // Define L293D channel 2 pin
3 int enable1Pin = 13; // 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
15    ledcSetup(channel, 1000, 11); //Set PWM to 11 bits, range is 0-2047
16    ledcAttachPin(enable1Pin, channel);
17 }
18
19 void loop() {
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 }
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(channel, spd); // Control motor rotation speed
42 }
```

The ADC of ESP32 has a 12-bit accuracy, corresponding to a range from 0 to 4095. In this program, set the

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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(channel, spd);
46 }
```

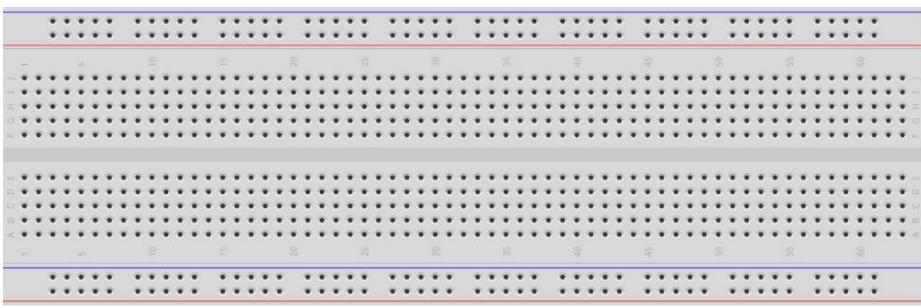
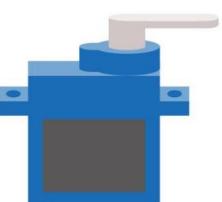
Chapter 18 Servo

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-WROVER x1	GPIO Extension Board x1
	
Breadboard x1	
Servo x1	Jumper M/M x3
	

Component knowledge

Servo

Servo is a compact package which consists of a DC motor, a set of reduction gears to provide torque, a sensor and control circuit board. Most servos only have a 180-degree range of motion via their "horn". Servos can output higher torque than a simple DC motor alone and they are widely used to control motion in model cars, model airplanes, robots, etc. Servos have three wire leads which usually terminate to a male or female 3-pin plug. Two leads are for electric power: positive (2-VCC, Red wire), negative (3-GND, Brown wire), and the signal line (1-Signal, Orange wire), as represented in the Servo provided in your Kit.



We will use a 50Hz PWM signal with a duty cycle in a certain range to drive the Servo. The 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

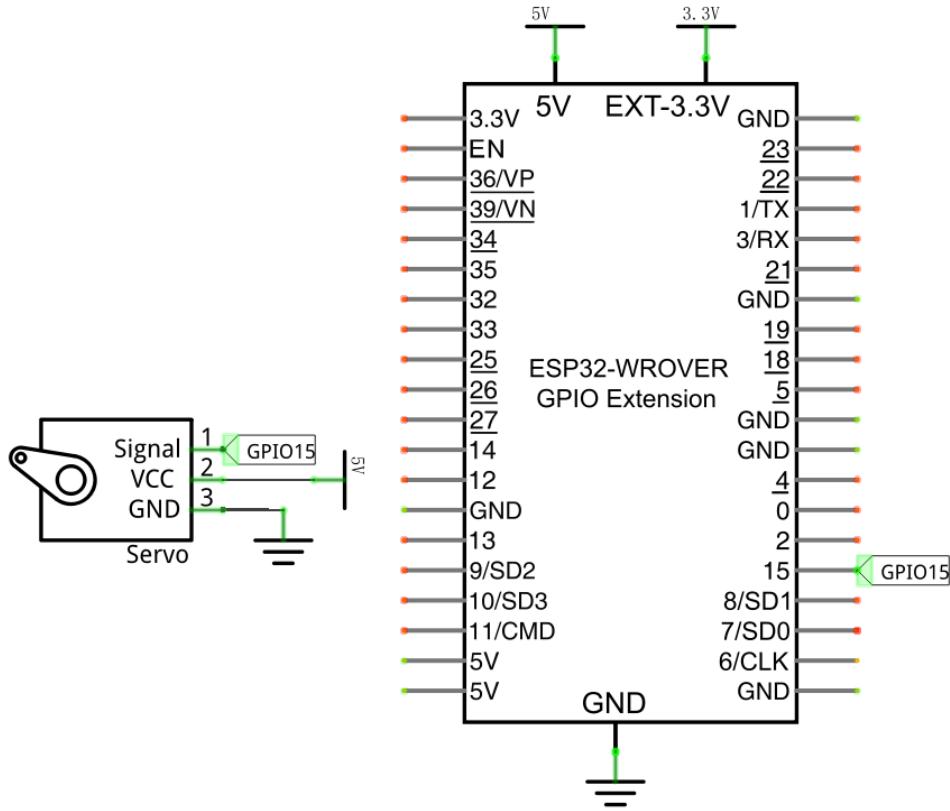
When you change the servo signal value, the servo will rotate to the designated angle.



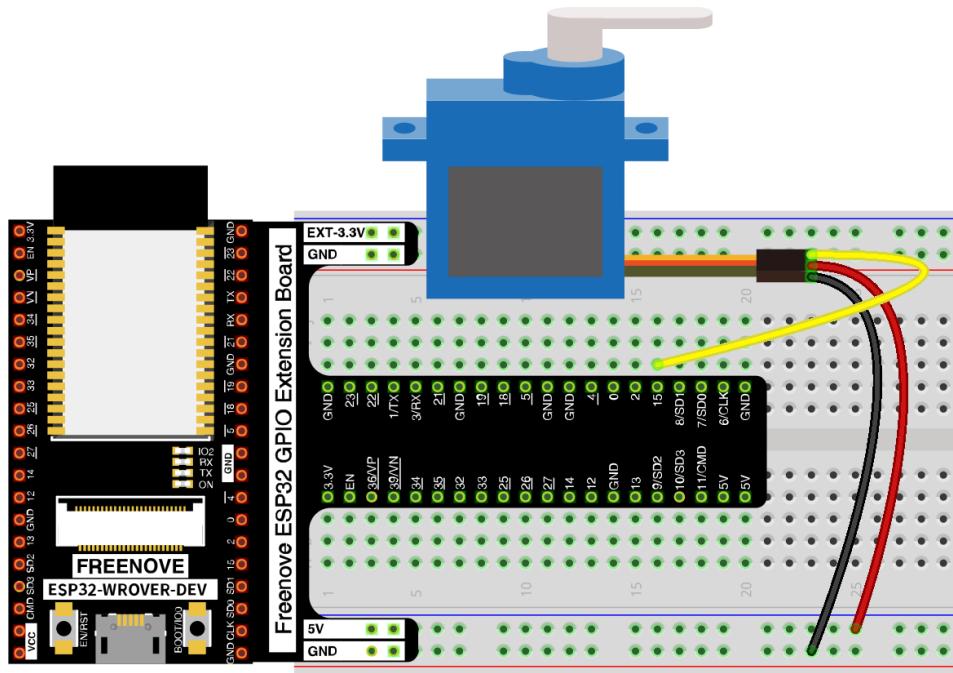
Circuit

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



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

Sketch

How to install the library

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 " ESP32Servo" in the search bar and select "ESP32Servo" for installation. Refer to the following operations:



Use the ESP32Servo library to control the servo motor and let the servo motor rotate back and forth.

Sketch_18.1_Servo_Sweep



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

- Title Bar:** Sketch_18.1_Servo_Sweep | Arduino 1.8.13 Hourly Build 2020/02/19 03:33
- Menu Bar:** File Edit Sketch Tools Help
- Toolbar:** Standard toolbar icons for file operations.
- Code Editor:**

```

1 // ****
2   Filename    : Servo Sweep
3   Description : Control the servo motor for sweeping
4   Author     : www.freenove.com
5   Modification: 2020-3-4
6 ****
7 #include <ESP32Servo.h>
8
9 Servo myservo; // create servo object to control a servo
10
11 int posVal = 0; // variable to store the servo position
12 int servoPin = 15; // Servo motor pin
13
14 void setup() {
15   myservo.setPeriodHertz(50); // standard 50 hz servo
16   myservo.attach(servoPin, 500, 2500); // attaches the servo on servoPin to the servo object
17 }
18 void loop() {
19
20   for (posVal = 0; posVal <= 180; posVal += 1) { // goes from 0 degrees to 180 degrees
21     // in steps of 1 degree
22     myservo.write(posVal); // tell servo to go to position in variable 'pos'
23     delay(15); // waits 15ms for the servo to reach the position
24   }
25   for (posVal = 180; posVal >= 0; posVal -= 1) { // goes from 180 degrees to 0 degrees
26     myservo.write(posVal); // tell servo to go to position in variable 'pos'
27     delay(15); // waits 15ms for the servo to reach the position
28   }
29 }
```
- Status Bar:**
 - Done uploading.
 - Leaving...
 - Hard resetting via RTS pin...

Compile and upload the code to ESP32-WROVER, 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 #include <ESP32Servo.h>
2
3 Servo myservo; // create servo object to control a servo
4 int posVal = 0; // variable to store the servo position
5 int servoPin = 15; // Servo motor pin
6 void setup() {
7     myservo.setPeriodHertz(50); // standard 50 hz servo
8     myservo.attach(servoPin, 500, 2500); // attaches the servo on servoPin to the servo
9     object
10 }
11 void loop() {
12     for (posVal = 0; posVal <= 180; posVal += 1) { // goes from 0 degrees to 180 degrees
13         // in steps of 1 degree
14         myservo.write(posVal); // tell servo to go to position in variable 'pos'
15         delay(15); // waits 15ms for the servo to reach the position
16     }
17     for (posVal = 180; posVal >= 0; posVal -= 1) { // goes from 180 degrees to 0 degrees
18         myservo.write(posVal); // tell servo to go to position in variable 'pos'
19         delay(15); // waits 15ms for the servo to reach the position
20     }
}

```

Servo uses the ESP32Servo library, like the following reference to ESP32Servo library:

```
1 #include <ESP32Servo.h>
```

ESP32Servo library provides the ESP32Servo class that controls it. ESP32Servo class must be instantiated before using:

```
3 Servo myservo; // create servo object to control a servo
```

Set the control servo motor pin, the time range of high level.

```
8 myservo.attach(servoPin,500,2500);
```

After initializing the servo, you can control the servo to rotate to a specific angle:

```
17 myservo.write(posVal);
```

Reference

```
class Servo
```

Servo class must be instantiated when used, that is, define an object of Servo type, for example:

```
Servo myservo;
```

The function commonly used in the servo class is as follows:

setPeriodHertz(data): Set the frequency of the servo motor.

attach(pin,low,high): Initialize the servo,

pin: the port connected to servo signal line.

low: set the time of high level corresponding to 0 degree.

high: set the time of high level corresponding to 180 degrees.

write(angle): Control servo to rotate to the specified angle.



Project 18.2 Servo Knop

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

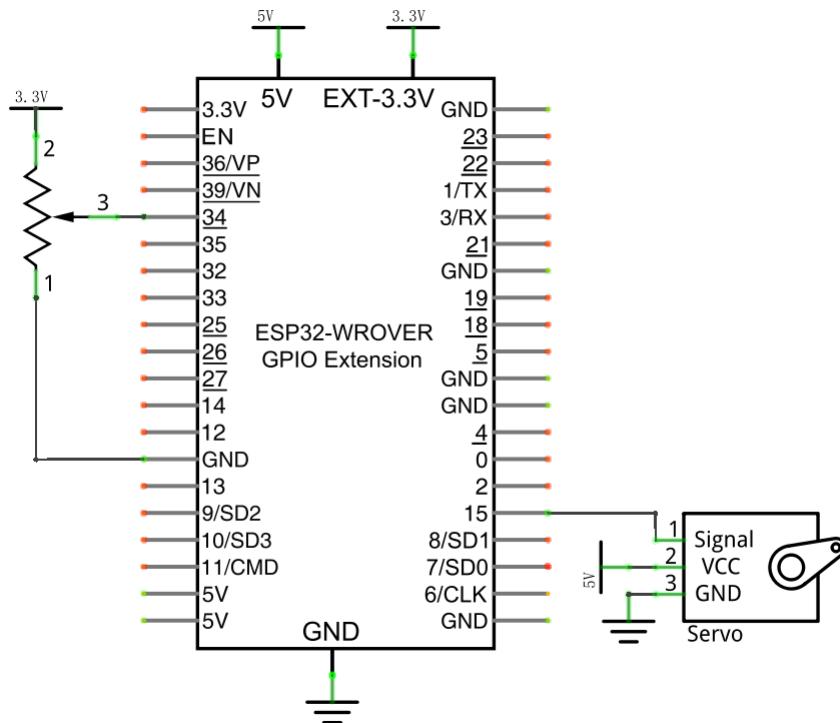
Component List

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

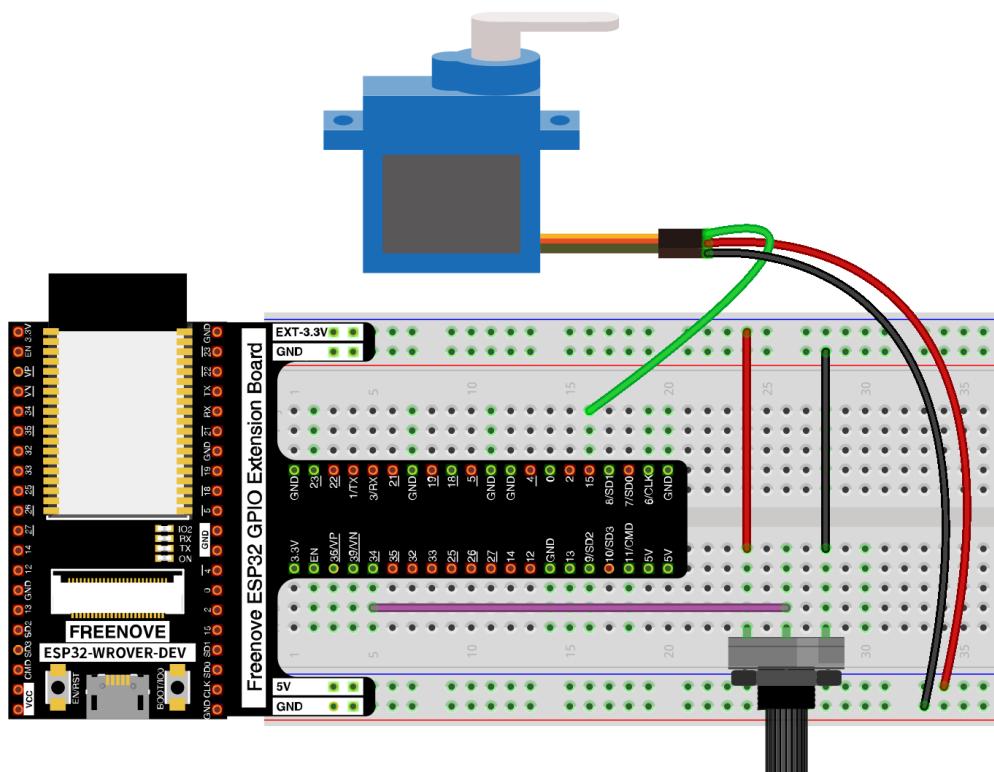
Circuit

Use caution when supplying power to the servo, it should be 5V. Make sure you do not make any errors when connecting the servo to the power supply.

Schematic diagram



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



Any concerns? ✉ support@freenove.com



Sketch

Sketch_18.2_Servo_Sweep

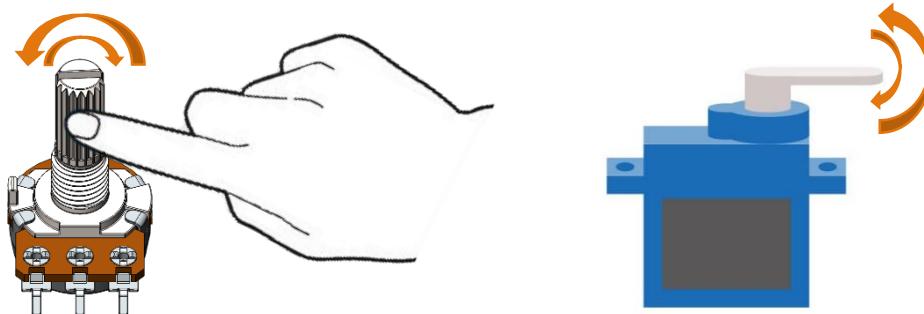
The screenshot shows the Arduino IDE interface with the following details:

- Title Bar:** Sketch_18.2_Control_Servo_by_Potentiometer | Arduino 1.8.13 Hourly Build 2020/02/19 03:33
- Menu Bar:** File Edit Sketch Tools Help
- Toolbar:** Includes icons for Save, Run, Stop, Upload, and Download.
- Code Editor:** Displays the C++ code for controlling a servo motor via a potentiometer. The code includes comments explaining the variables and functions used.
- Serial Monitor:** Shows the output of the uploaded sketch, indicating "Done uploading." followed by "Leaving..." and "Hard resetting via RTS pin...".
- Status Bar:** Shows "ESP32 Wrover Module on COM6".

```
1 // ****
2   Filename    : Control Servo by Potentiometer
3   Description : Use potentiometer to control the rotation of servo motor.
4   Author     : www.freenove.com
5   Modification: 2020-3-4
6 ****
7 #include <ESP32Servo.h>
8 #define ADC_Max 4095    // This is the default ADC max value on the ESP32 (12 bit ADC width);
9
10 Servo myservo; // create servo object to control a servo
11
12 int servoPin = 15;      // GPIO pin used to connect the servo control (digital out)
13 int potPin = 34;        // GPIO pin used to connect the potentiometer (analog in)
14 int potVal;            //variable to read the value from the analog pin
15
16 void setup()
17 {
18   myservo.setPeriodHertz(50); // Standard 50hz servo
19   // attaches the servo on servoPin to the servo object
20   myservo.attach(servoPin, 500, 2500);
21   Serial.begin(115200);
22 }
23
24 void loop() {
25   // read the value of the potentiometer (value between 0 and 4095)
26   potVal = analogRead(potPin);
27   Serial.printf("potVal_1: %d\t",potVal);
28   // scale it to use it with the servo (value between 0 and 180)
29   potVal = map(potVal, 0, ADC_Max, 0, 180);
30   // set the servo position according to the scaled value
31   myservo.write(potVal);
32   Serial.printf("potVal_2: %d\n",potVal);
33   delay(15); // wait for the servo to get there
34 }
```

Done uploading.
Leaving...
Hard resetting via RTS pin...

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



The following is the program code:

```

1 #include <ESP32Servo.h>
2 #define ADC_Max 4095 // This is the default ADC max value on the ESP32 (12 bits ADC width);
3
4 Servo myservo; // create servo object to control a servo
5
6 int servoPin = 15; // GPIO pin used to connect the servo control (digital out)
7 int potPin = 34; // GPIO pin used to connect the potentiometer (analog in)
8 int potVal; //variable to read the value from the analog pin
9
10 void setup()
11 {
12     myservo.setPeriodHertz(50); // Standard 50hz servo
13     myservo.attach(servoPin, 500, 2500); // attaches the servo on servoPin to the servo object
14     Serial.begin(115200);
15 }
16
17 void loop() {
18     potVal = analogRead(potPin); // read the value of the potentiometer (value
19     // between 0 and 1023)
20     Serial.printf("potVal_1: %d\t", potVal);
21     potVal = map(potVal, 0, ADC_Max, 0, 180); // scale it to use it with the servo (value between
22     // 0 and 180)
23     myservo.write(potVal); // set the servo position according to the scaled
24     // value
25     Serial.printf("potVal_2: %d\n", potVal);
26     delay(15); // wait for the servo to get there
27 }
```

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

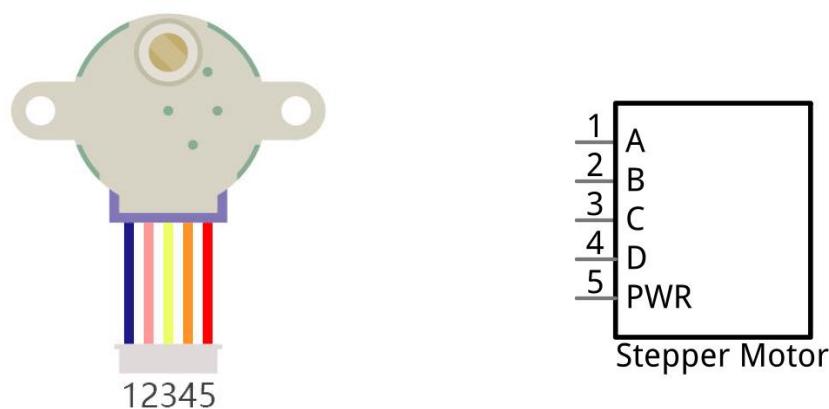
Component List

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

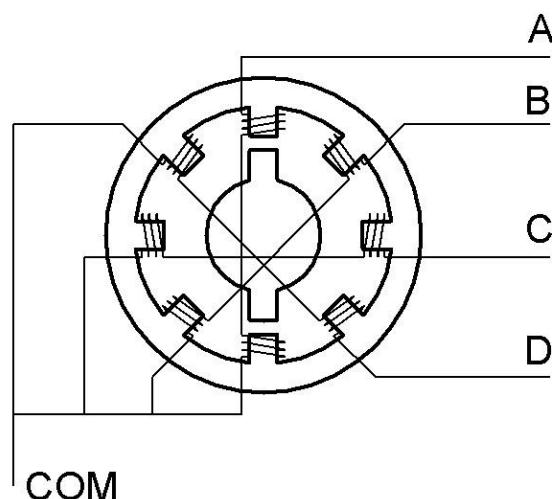
Component knowledge

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:

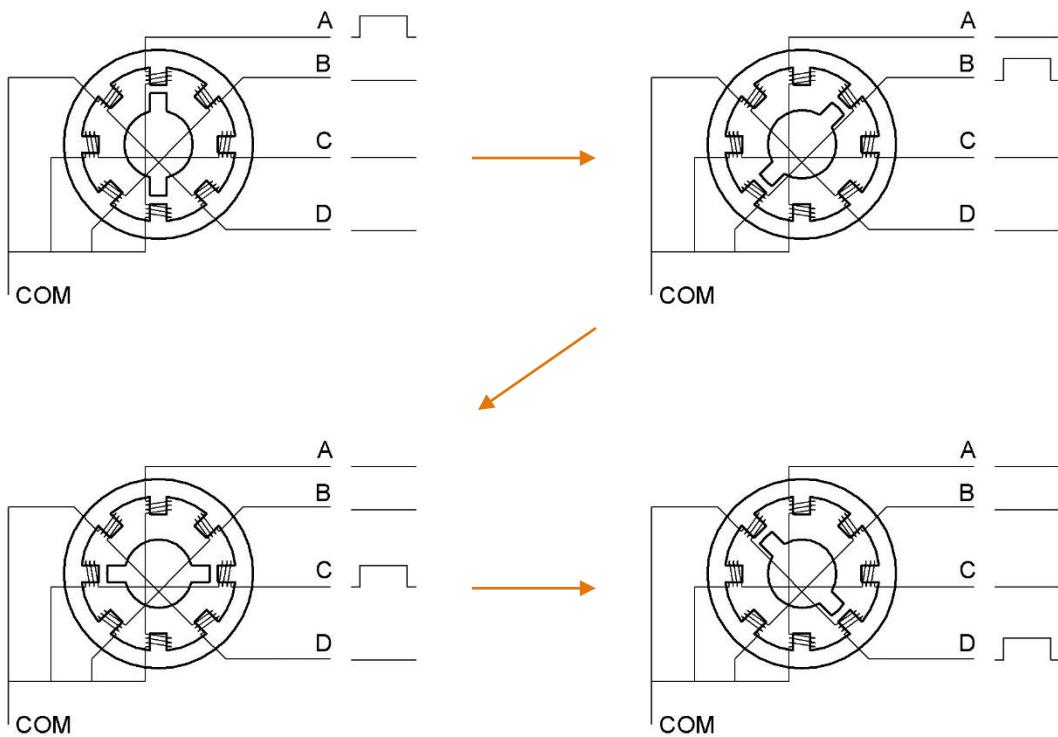


The electronic schematic diagram of a four-phase stepper motor is shown below:



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:



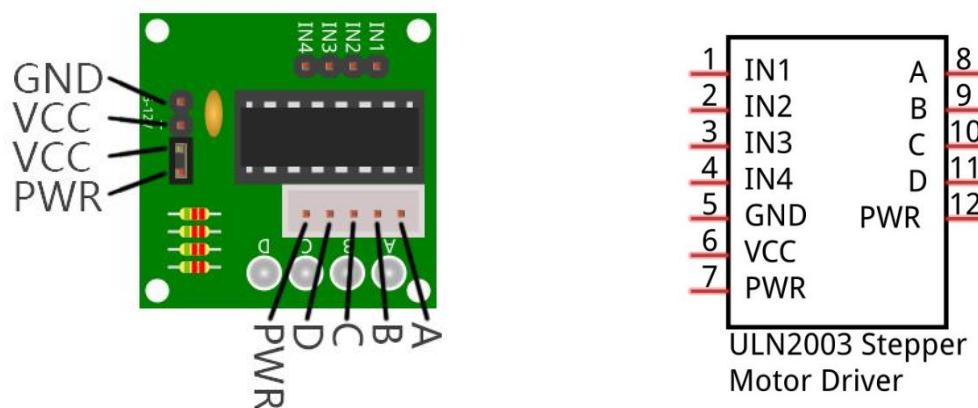
In the course above, the stepper motor rotates a certain angle once, which is called a step. By controlling the number of rotation steps, you can control the stepper motor rotation angle. By controlling the time between two steps, you can control the stepper motor rotation speed. When rotating clockwise,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

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

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

ULN2003 Stepper motor driver

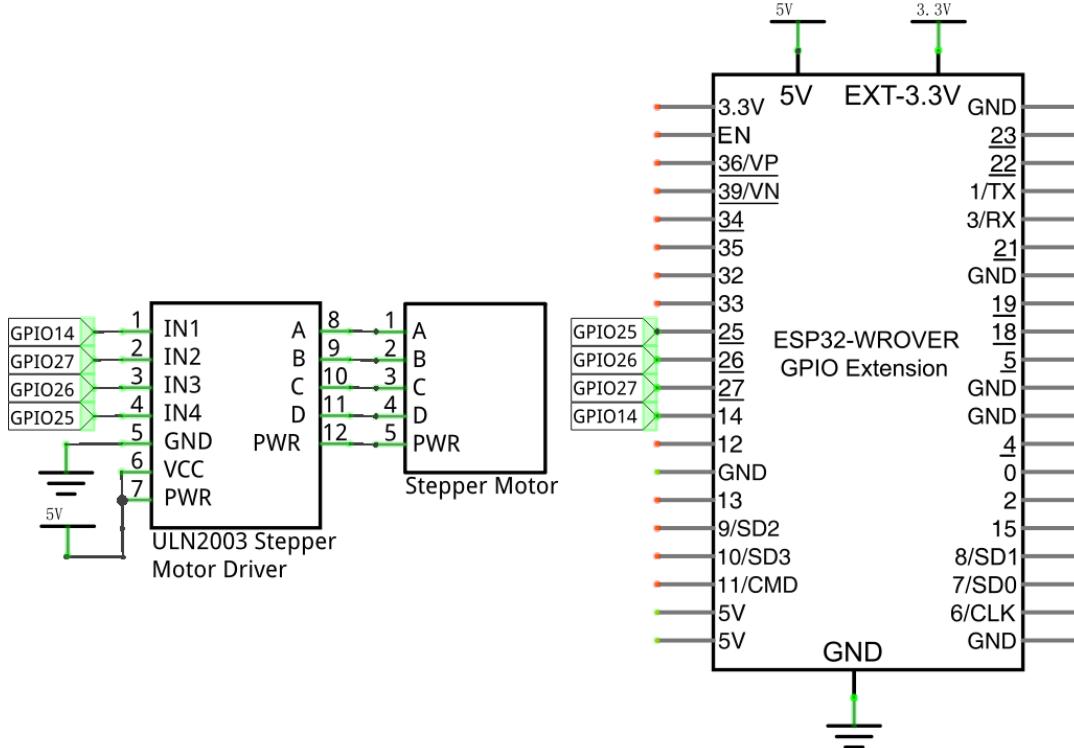
A ULN2003 stepper motor driver is used to convert weak signals into more powerful control signals in order to drive the stepper motor. In the illustration below, the input signal IN1-IN4 corresponds to the output signal A-D, and 4 LEDs are integrated into the board to indicate the state of these signals.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



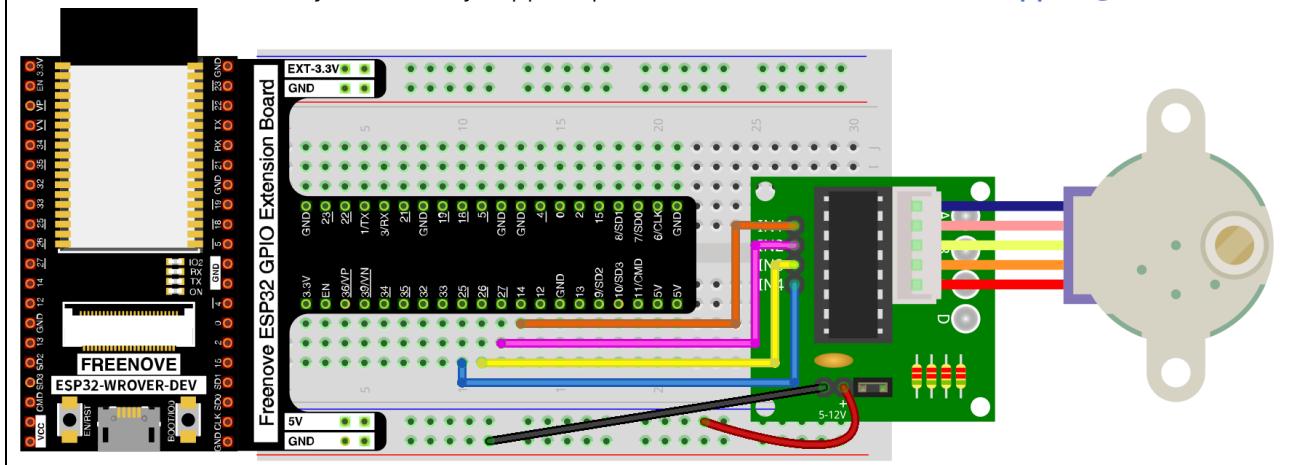
Circuit

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.

Schematic diagram



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

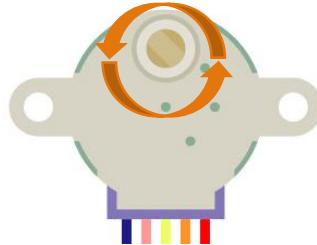
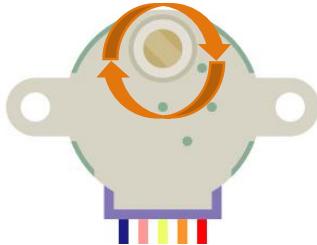
The screenshot shows the Arduino IDE interface with the following details:

- Title Bar:** Sketch_19.1_Drive_Stepper_Motor | Arduino 1.8.13 Hourly Build 2020/02/19 03:33
- Menu Bar:** File Edit Sketch Tools Help
- Toolbar:** Includes icons for Save, Run, Upload, and Download.
- Code Editor:** Displays the C++ code for the stepper motor driver. The code includes comments for the file's purpose, author, and modification date. It defines pin numbers for the stepper driver and implements setup() and loop() functions to rotate the motor in both directions.
- Serial Monitor:** Shows the message "Done uploading." followed by "Leaving... Hard resetting via RTS pin..."
- Status Bar:** Shows the text "16" and "ESP32 Wrover Module on COM5".

```
1 //*****
2 // Filename : Drive Stepper Motor
3 // Description : Use ULN2003 to drive the stepper motor.
4 // Author : www.freenove.com
5 // Modification: 2020-3-4
6 ****/
7 // Connct the port of the stepper motor driver
8 int outPorts[] = {14, 27, 26, 25};
9
10 void setup() {
11     // set pins to output
12     for (int i = 0; i < 4; i++) {
13         pinMode(outPorts[i], OUTPUT);
14     }
15 }
16
17 void loop()
18 {
19     // Rotate a full turn
20     moveSteps(true, 32 * 64, 3);
21     delay(1000);
22     // Rotate a full turn towards another direction
23     moveSteps(false, 32 * 64, 3);
24     delay(1000);
25 }
26
27 //Suggestion: the motor turns precisely when the ms range is between 3 and 20
28 void moveSteps(bool dir, int steps, byte ms) {
29     for (unsigned long i = 0; i < steps; i++) {
30         moveOneStep(dir); // Rotate a step
31         delay(constrain(ms,3,20)); // Control the speed
32     }
33 }
```



Compile and upload the code to the ESP32-WROVER, 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, 27, 26, 25};
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 }
```

```

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, 27, 26, 25};
```

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 }
```

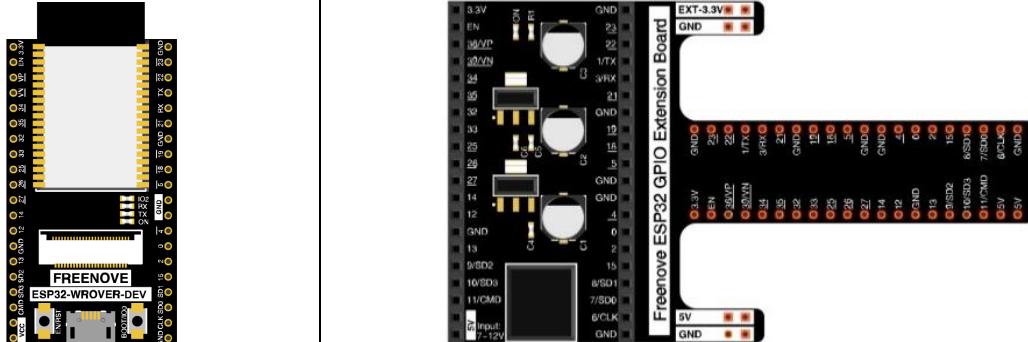
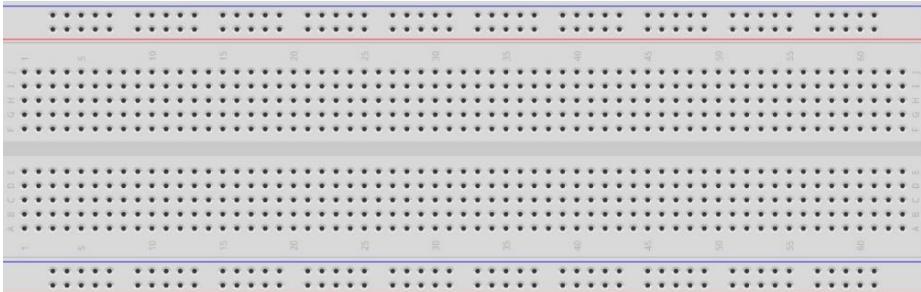
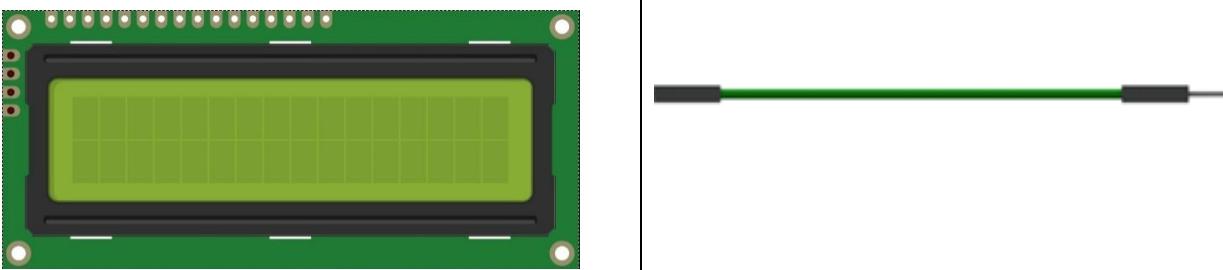
Chapter 20 LCD1602

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-WROVER x1	GPIO Extension Board x1
	
Breadboard x1	
	
LCD1602 Module x1	Jumper F/M x4
	



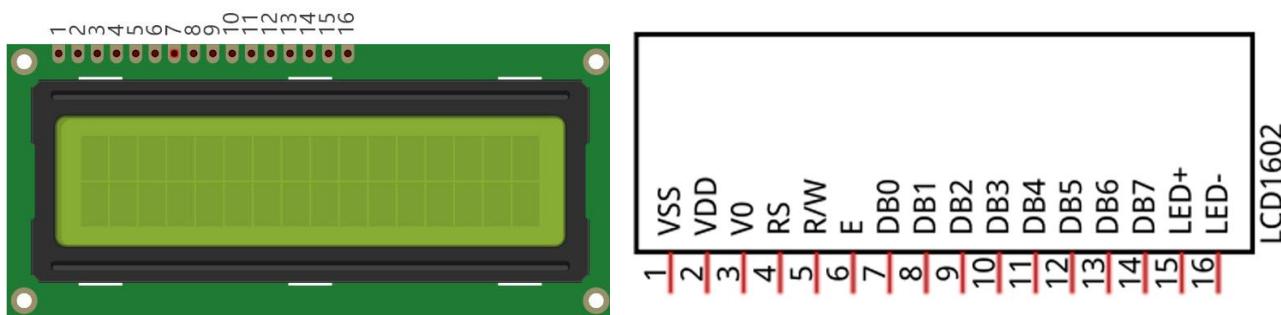
Component knowledge

I2C communication

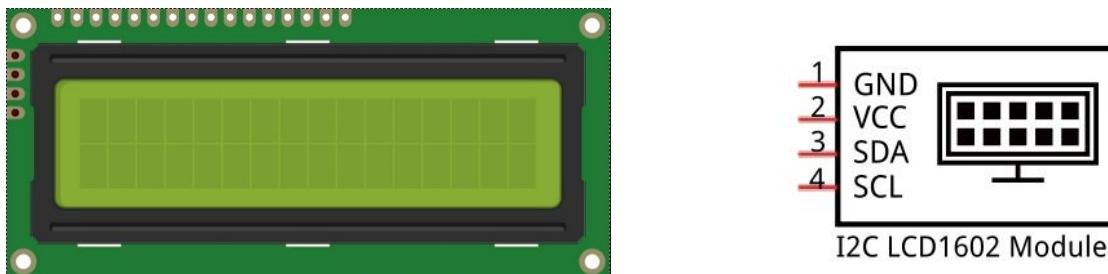
I2C (Inter-Integrated Circuit) is a two-wire serial communication mode, which can be used for the connection of micro controllers and their peripheral equipment. Devices using I2C communication must be connected to the serial data (SDA) line, and serial clock (SCL) line (called I2C bus). Each device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

LCD1602 communication

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

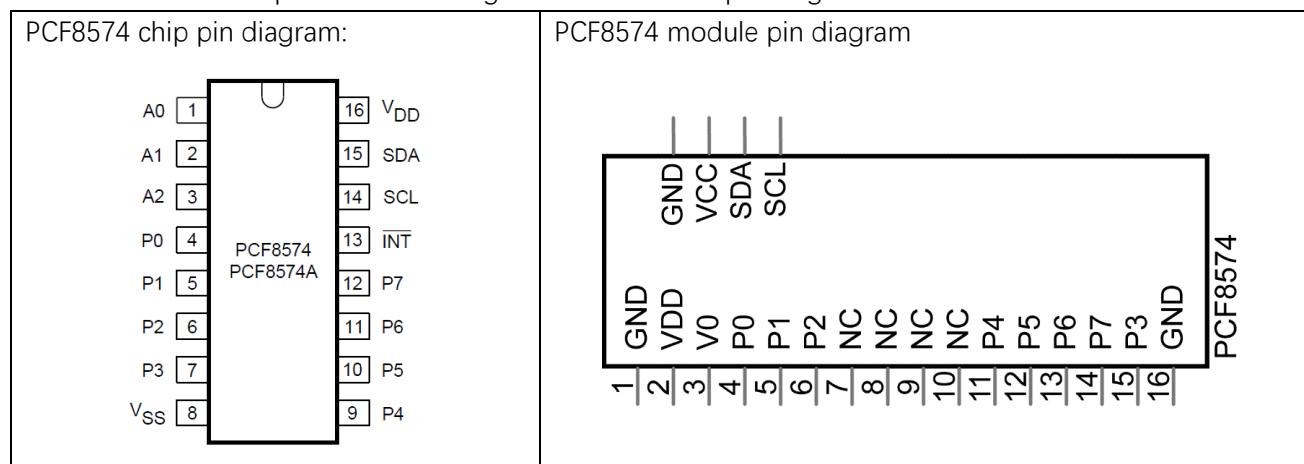


I2C LCD1602 display screen integrates a I2C interface, which connects the serial-input & parallel-output module to the LCD1602 display screen. This allows us to only use 4 lines to operate the LCD1602.

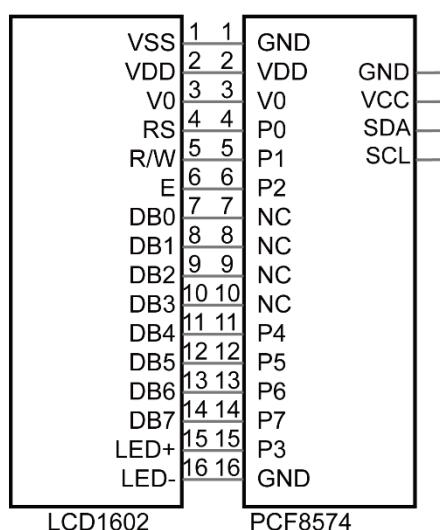


The serial-to-parallel IC chip used in this module is PCF8574T (PCF8574AT), and its default I2C address is 0x27(0x3F).

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:

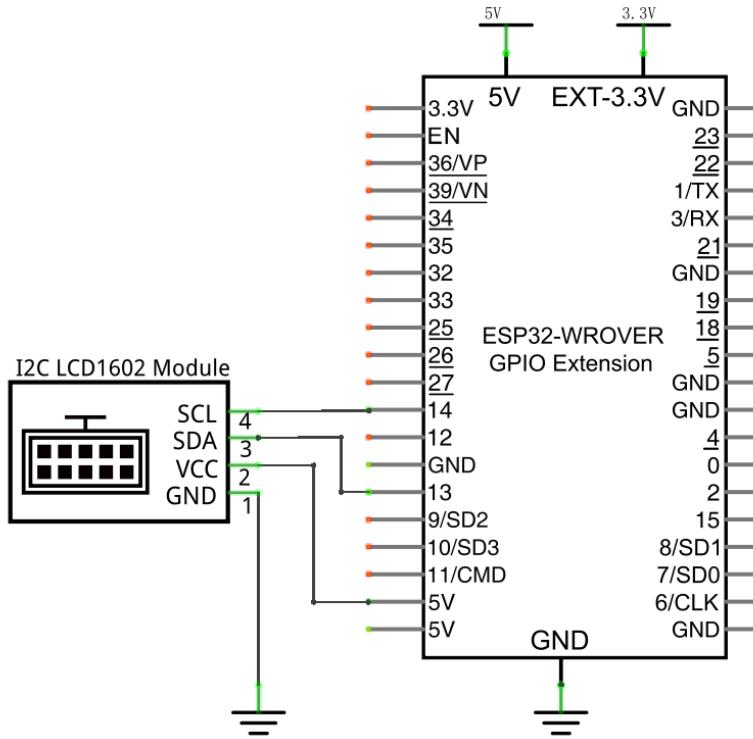


LCD1602 PCF8574

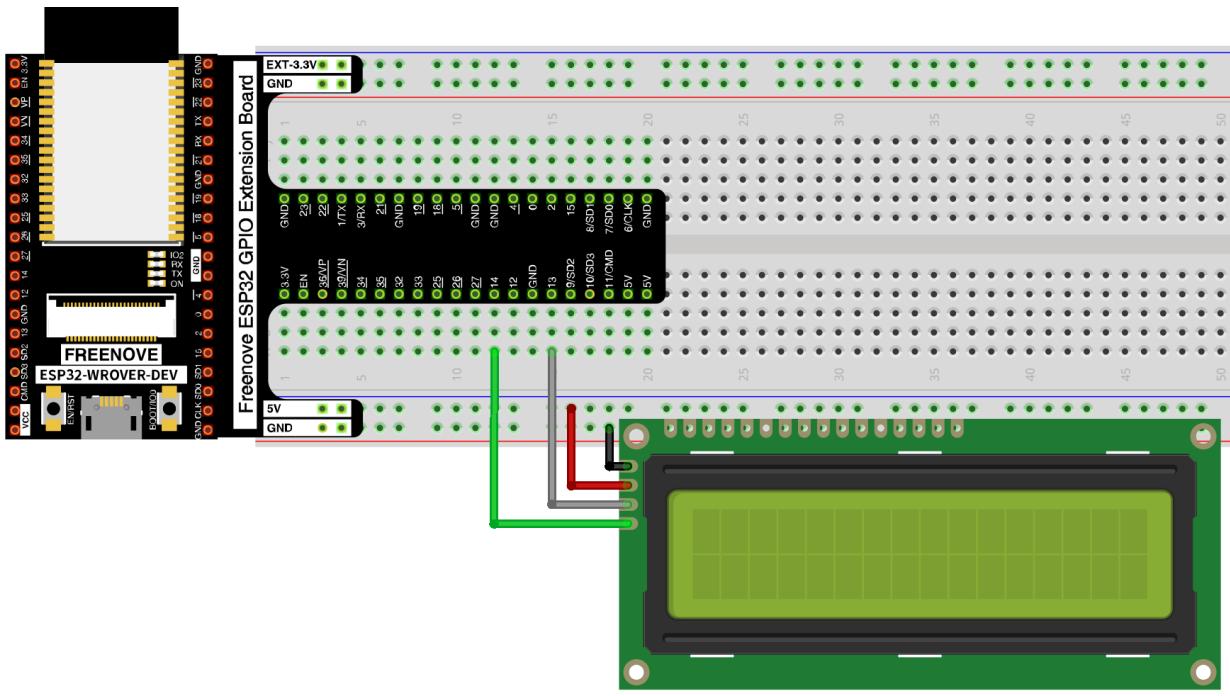
So we only need 4 pins to control the 16 pins of the LCD1602 display screen through the I₂C interface. In this project, we will use the I₂C LCD1602 to display some static characters and dynamic variables.

Circuit

Schematic diagram



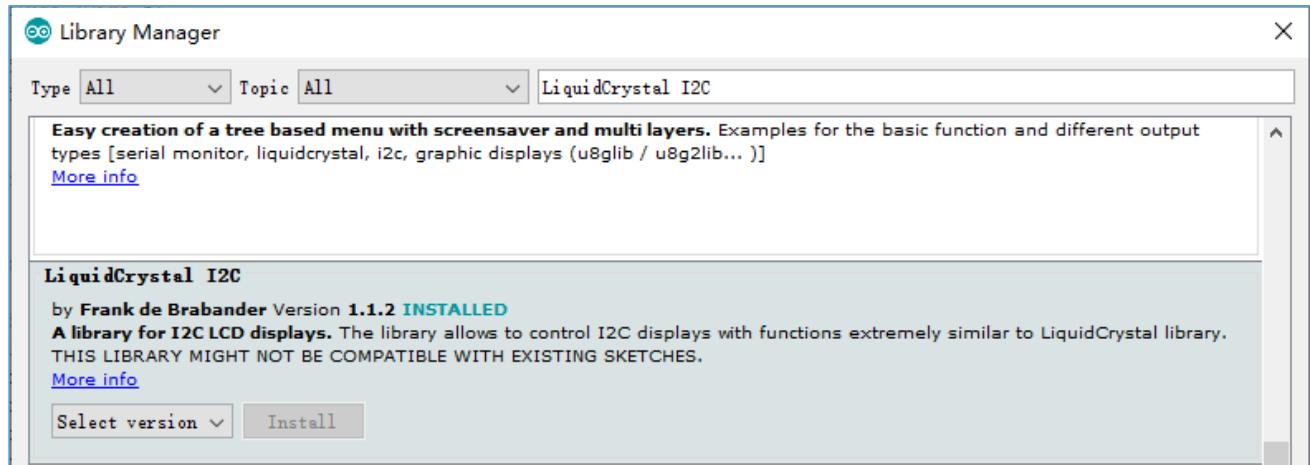
Hardware connection. If you need any support, please feel free to contact us via: support@freenove.com



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-> Manage libraries. Enter " LiquidCrystal I2C" in the search bar and select " LiquidCrystal I2C " for installation.



Use I2C LCD 1602 to display characters and variables.



Sketch_20.1_Display_the_string_on_LCD1602

Sketch_20.1_Display_the_string_on_LCD1602 | Arduino 1.8.13 Hourly Build 2020/02/19 03:33

File Edit Sketch Tools Help

Sketch_20.1_Display_the_string_on_LCD1602

```

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: 2020-3-4
6 *****/
7 #include <LiquidCrystal_I2C.h>
8 #include <Wire.h>
9
10 #define SDA 13           //Define SDA pins
11 #define SCL 14           //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
24 }
25
26 void loop() {
27   lcd.setCursor(0,1);           // Move the cursor to row 1, column 0
28   lcd.print("Counter:");        // The count is displayed every second
29   lcd.print(millis() / 1000);
30   delay(1000);
31 }
```

Done uploading.

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

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



If you cannot see anything on the display or the display is not clear, try rotating the white knob on back of LCD1602 slowly, which adjusts the contrast, until the screen can display clearly.



The following is the program code:

```
1 #include <LiquidCrystal_I2C.h>
2
3
4 #define SDA 13           //Define SDA pins
5 #define SCL 14           //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
13 void setup() {
14     Wire.begin(SDA, SCL);          // attach the IIC pin
15     lcd.init();                   // LCD driver initialization
16     lcd.backlight();              // Turn on the backlight
17     lcd.setCursor(0, 0);          // Move the cursor to row 0, column 0
18     lcd.print("hello, world! ");
19 }
20
21 void loop() {
22     lcd.setCursor(0, 1);          // Move the cursor to row 1, column 0
23     lcd.print("Counter:");
24     lcd.print(millis() / 1000);
25     delay(1000);
26 }
```

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.

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

Initialize I2C and set its pins as 13,14. And then initialize LCD1602 and turn on the backlight of LCD.

```
14 Wire.begin(SDA, SCL);           // attach the IIC pin
15 lcd.init();                   // LCD driver initialization
16 lcd.backlight();              // Turn on the backlight
```

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

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

Print the number on the second line of LCD1602.

```
12 void loop() {
13     //set the cursor to column 0, line 1
14     //(note:parameter "0" is the first columns,
15     //parameter "1" is the second row, since counting begins with 0)
16     lcd.setCursor(0, 1); //0 stand for column, 1 stand for row
17     // print the number of seconds since reset:
18     lcd.print("Counter:");
19     lcd.print(millis() / 1000);
20 }
```

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

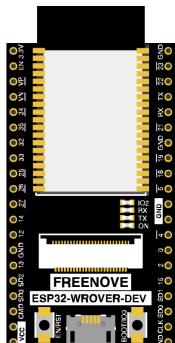
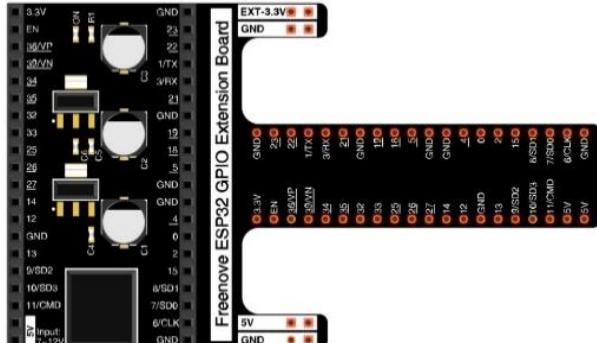
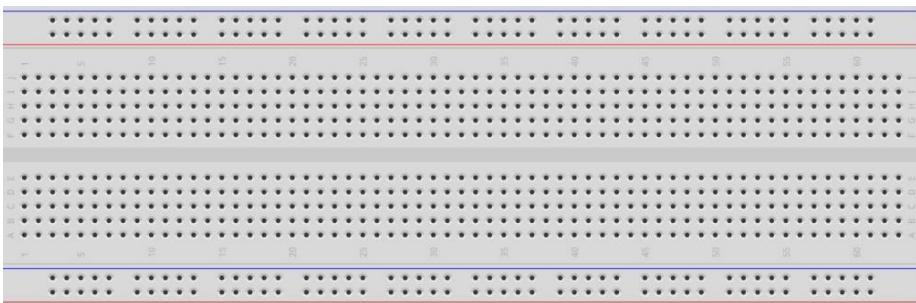
Chapter 21 Ultrasonic Ranging

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.

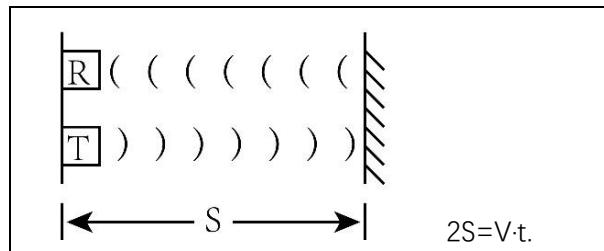
Component List

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

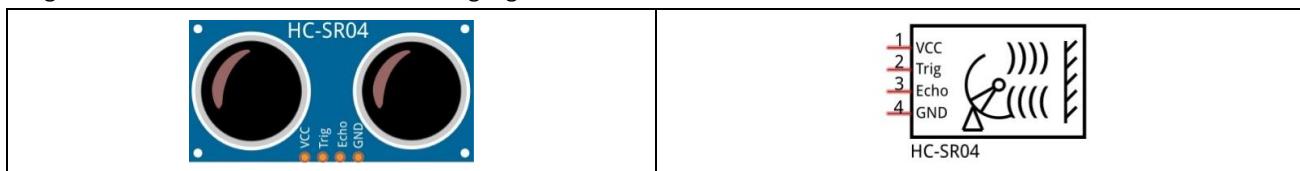


Component Knowledge

The ultrasonic ranging module uses the principle that ultrasonic waves will 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:

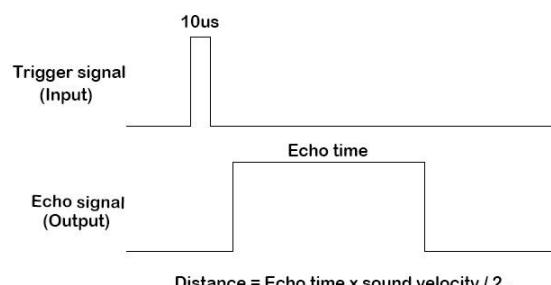
Working voltage: 5V

Working current: 12mA

Minimum measured distance: 2cm

Maximum measured distance: 200cm

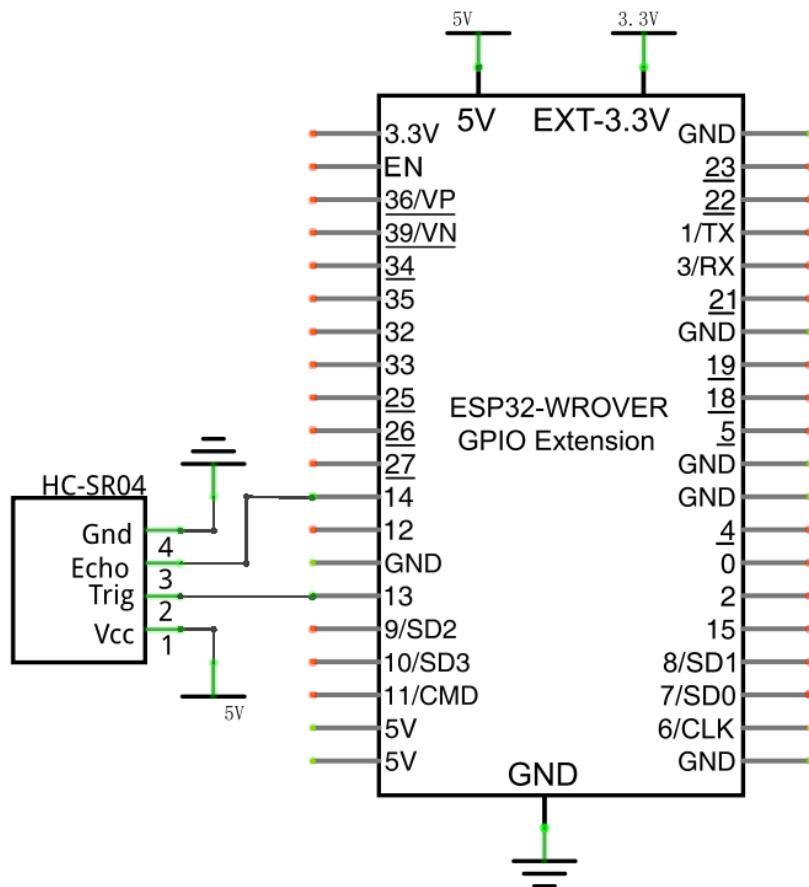
Instructions for use: output a high-level pulse in Trig pin lasting for least 10us, the module begins to transmit ultrasonic waves. At the same time, the Echo pin is pulled up. When the module receives the returned ultrasonic waves from encountering an obstacle, the Echo pin will be pulled down. The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



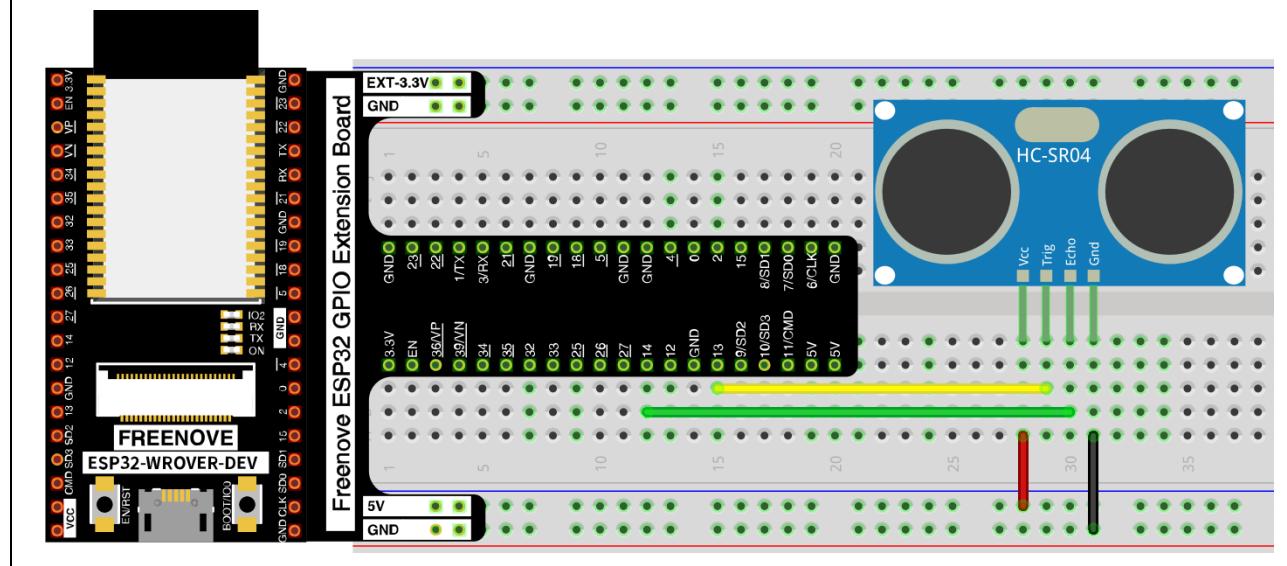
Circuit

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



Any concerns? ✉ support@freenove.com

Sketch

Sketch_21.1_Ultrasonic_Ranging

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

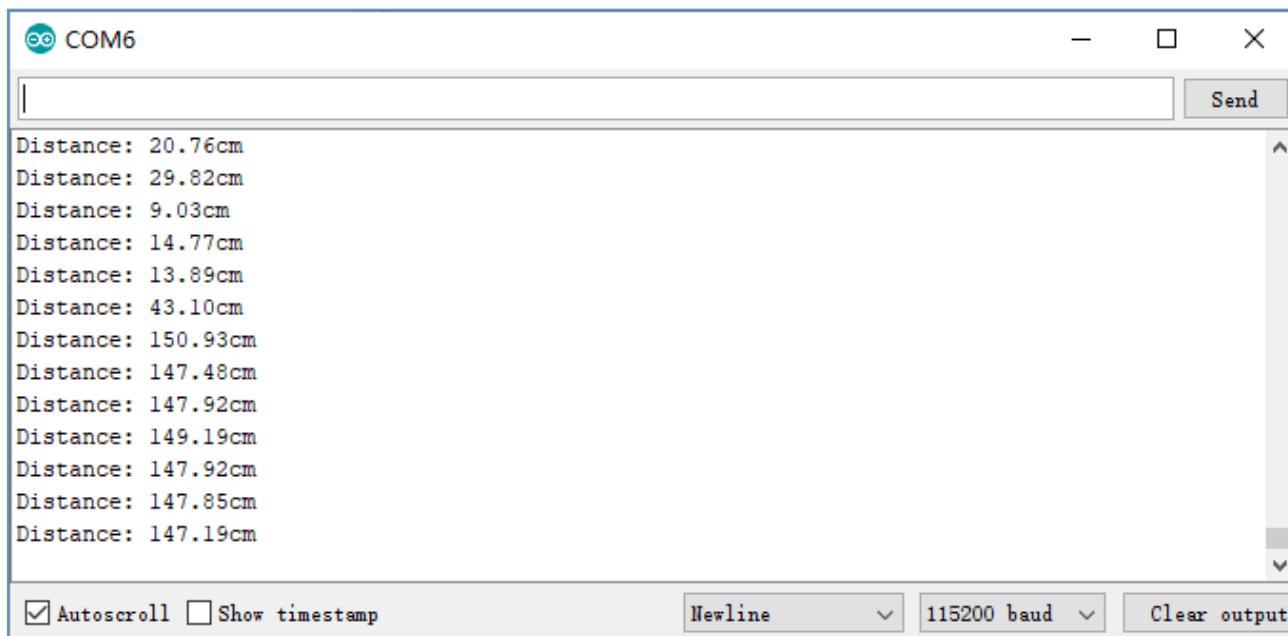
- Title Bar:** Sketch_21.1_Ultrasonic_Ranging | Arduino 1.8.13 Hourly Build 2020/02/19 03:33
- Menu Bar:** File Edit Sketch Tools Help
- Toolbar:** Standard toolbar icons for file operations.
- Sketch Area:** The code for `Sketch_21.1_Ultrasonic_Ranging`. The code is as follows:

```
1 // ****
2   Filename    : Ultrasonic Ranging
3   Description : Use the ultrasonic module to measure the distance.
4   Author      : www.freenove.com
5   Modification: 2020-3-4
6 ****
7 #define trigPin 13 // define TrigPin
8 #define echoPin 14 // define EchoPin.
9 #define MAX_DISTANCE 700 // Maximum sensor distance is rated at 400-500cm.
10 //timeOut= 2*MAX_DISTANCE /100 /340 *1000000 = MAX_DISTANCE*58.8
11 float timeOut = MAX_DISTANCE * 60;
12 int soundVelocity = 340; // define sound speed=340m/s
13
14 void setup() {
15   pinMode(trigPin,OUTPUT);// set trigPin to output mode
16   pinMode(echoPin,INPUT); // set echoPin to input mode
17   Serial.begin(115200); // Open serial monitor at 115200 baud to see ping results.
18 }
19
20 void loop() {
21   delay(100); // Wait 100ms between pings (about 20 pings/sec).
22   Serial.print("Distance: ");
23   Serial.print(getSonar()); // Send ping, get distance in cm and print result
24   Serial.println("cm");
25 }
26
27 float getSonar() {
28   unsigned long pingTime;
29   float distance;
30   // make trigPin output high level lasting for 10us to trigger HC_SR04
31   digitalWrite(trigPin, HIGH);
32   delayMicroseconds(10);
33   digitalWrite(trigPin, LOW);
34   // Wait HC-SR04 returning to the high level and measure out this waiting time
35   pingTime = pulseIn(echoPin, HIGH, timeOut);
36   // calculate the distance according to the time
37   distance = (float)pingTime * soundVelocity / 2 / 10000;
38   return distance; // return the distance value
39 }
```

Bottom Status Bar:

- Done Saving.
- Leaving...
- Hard resetting via RTS pin...
- 30
- ESP32 Wrover Module on COM6

Download the code to ESP32-WROVER, 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= $2 \times \text{MAX_DISTANCE} / 100 / 340 \times 1000000$. 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 10 μs 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

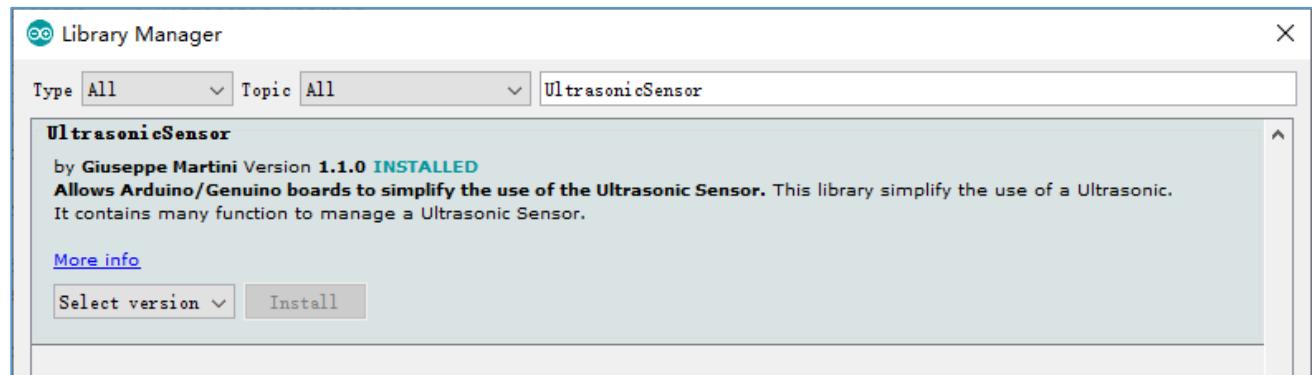
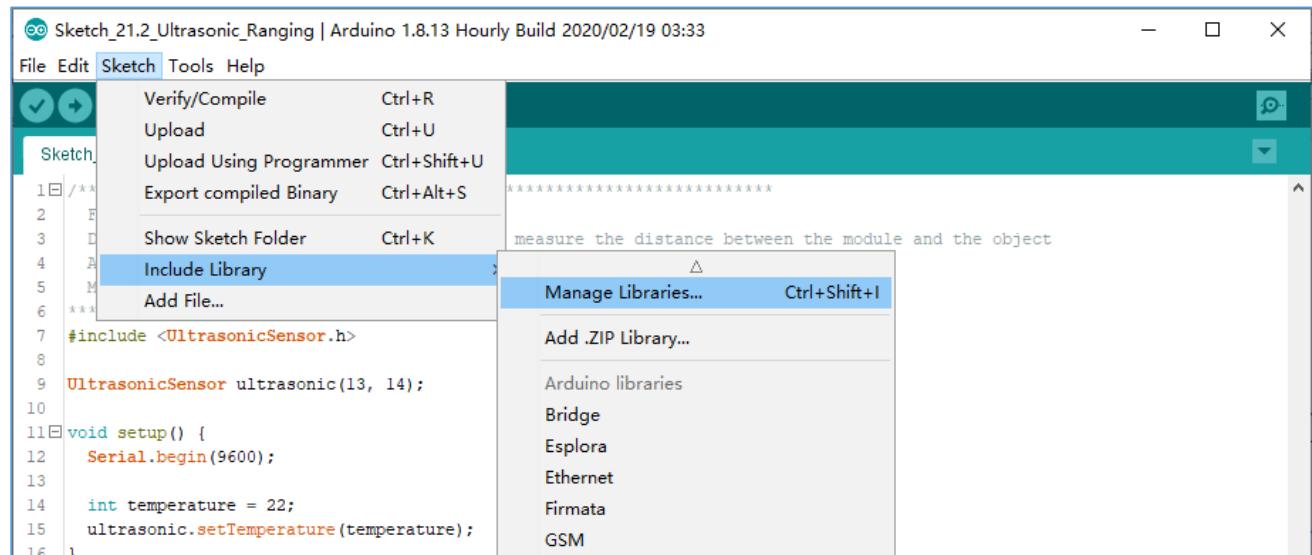
Component List and Circuit

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

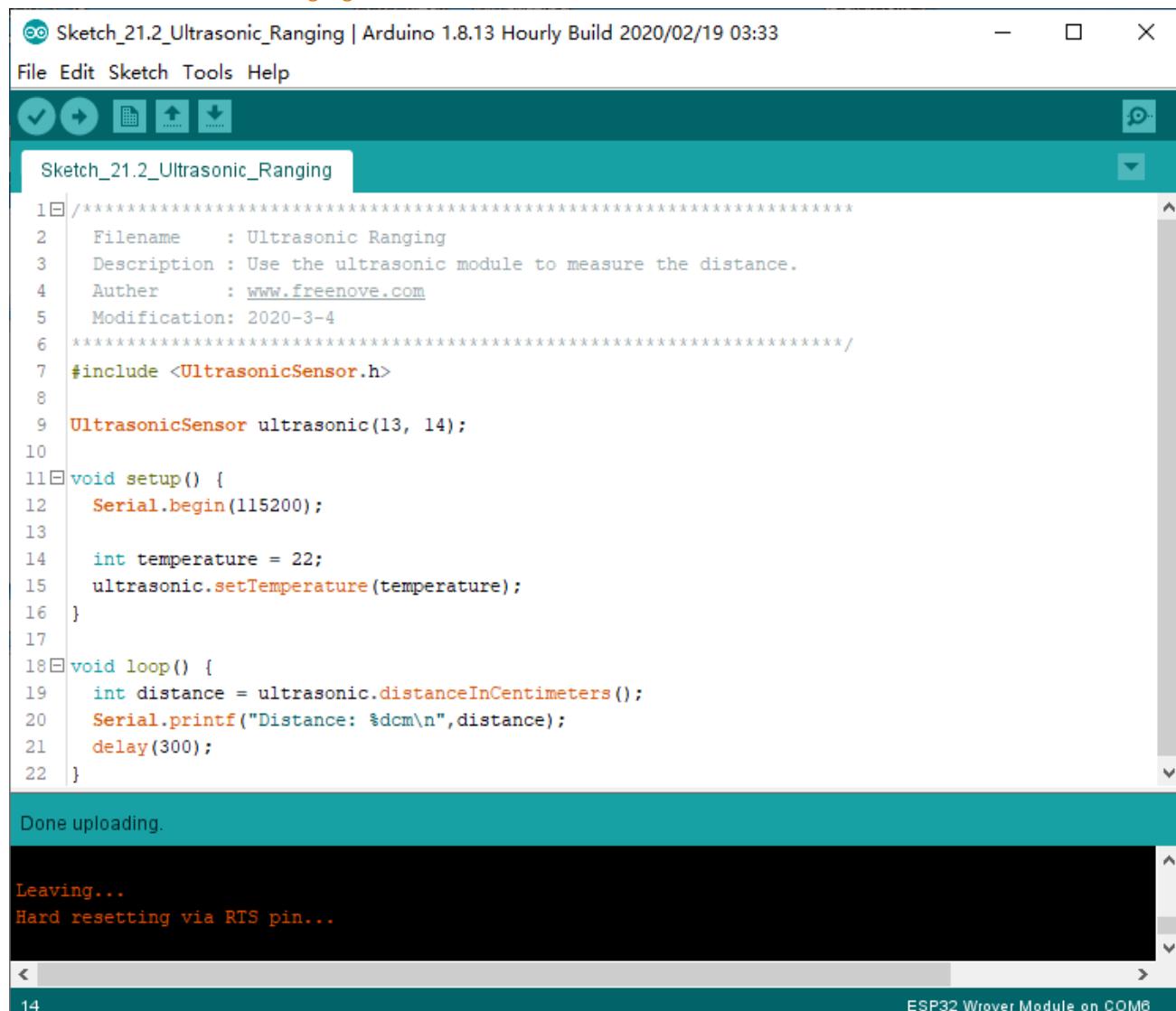
Sketch

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:



Sketch_21.2_Ultrasonic_Ranging



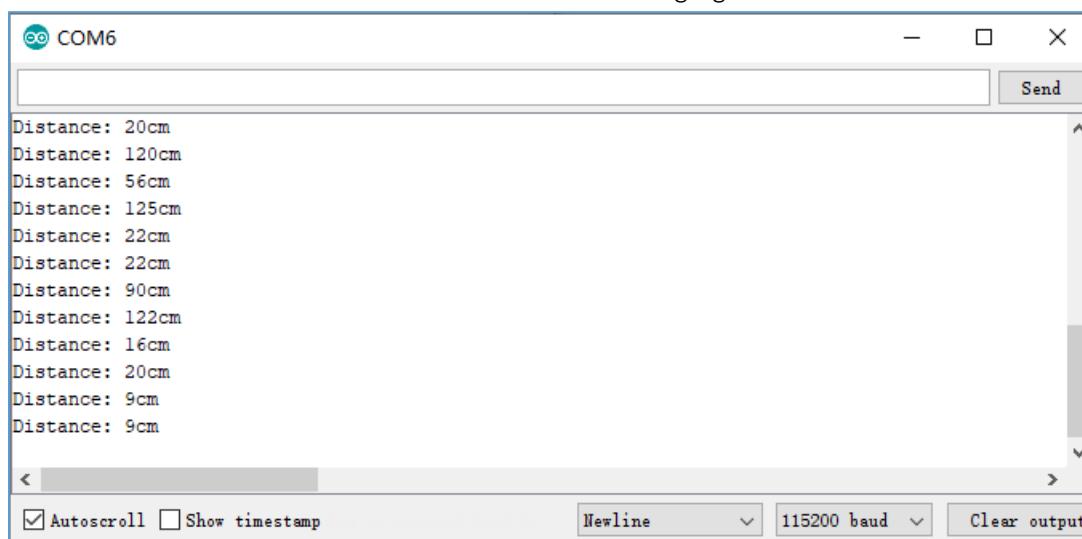
```

1 // ****
2   Filename    : Ultrasonic Ranging
3   Description : Use the ultrasonic module to measure the distance.
4   Author      : www.freenove.com
5   Modification: 2020-3-4
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 }
17
18 void loop() {
19   int distance = ultrasonic.distanceInCentimeters();
20   Serial.printf("Distance: %dcm\n",distance);
21   delay(300);
22 }
```

Done uploading.

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

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



```

Distance: 20cm
Distance: 120cm
Distance: 56cm
Distance: 125cm
Distance: 22cm
Distance: 22cm
Distance: 90cm
Distance: 122cm
Distance: 16cm
Distance: 20cm
Distance: 9cm
Distance: 9cm
```

Autoscroll Show timestamp Newline 115200 baud Clear output

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.

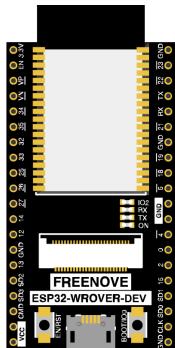
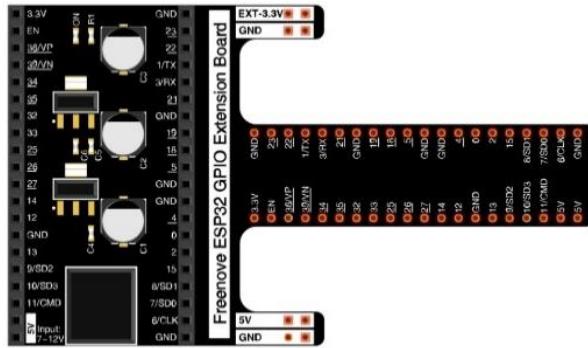
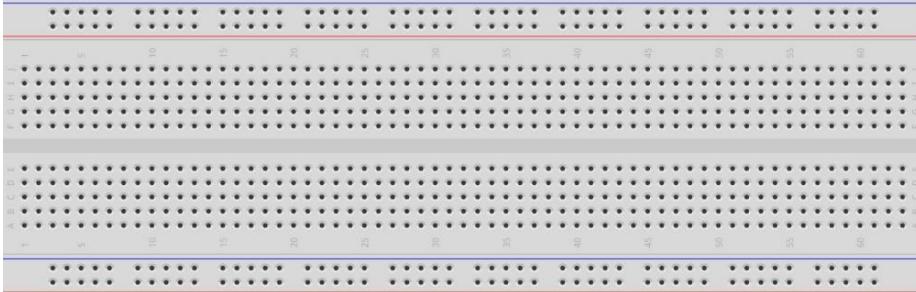
Chapter 22 Matrix Keypad

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.

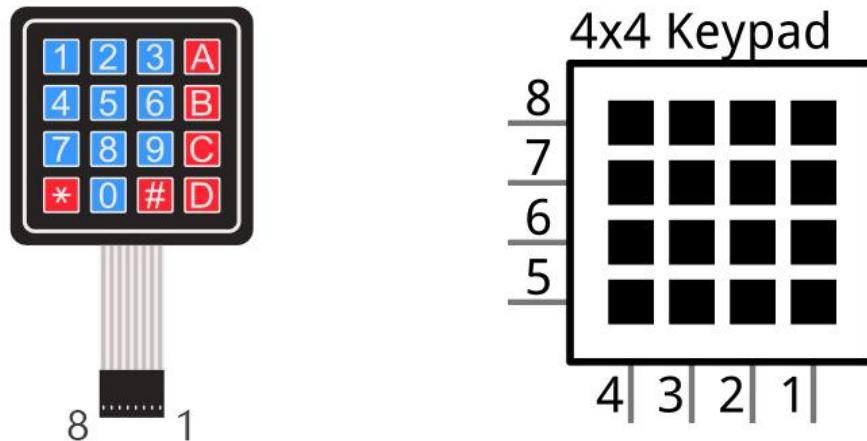
Component List

ESP32-WROVER x1	GPIO Extension Board x1
	
Breadboard x1	
Jumper M/M x8	4x4 Matrix Keypad x1
	

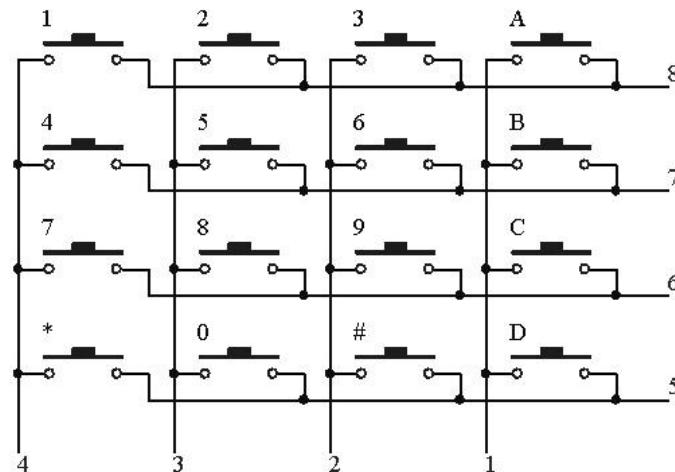
Component knowledge

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:



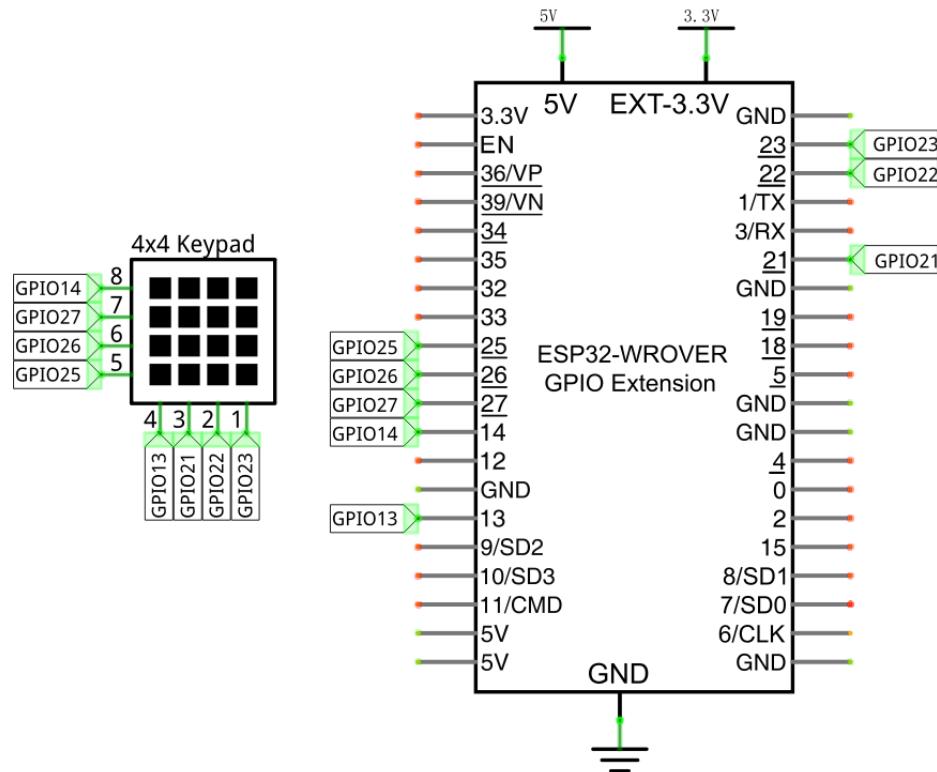
Similar to the integration of a LED matrix, the 4x4 keypad matrix has each row of keys connected with one pin and this is the same for the columns. Such efficient connections reduce the number of processor ports required. The internal circuit of the Keypad Matrix is shown below.



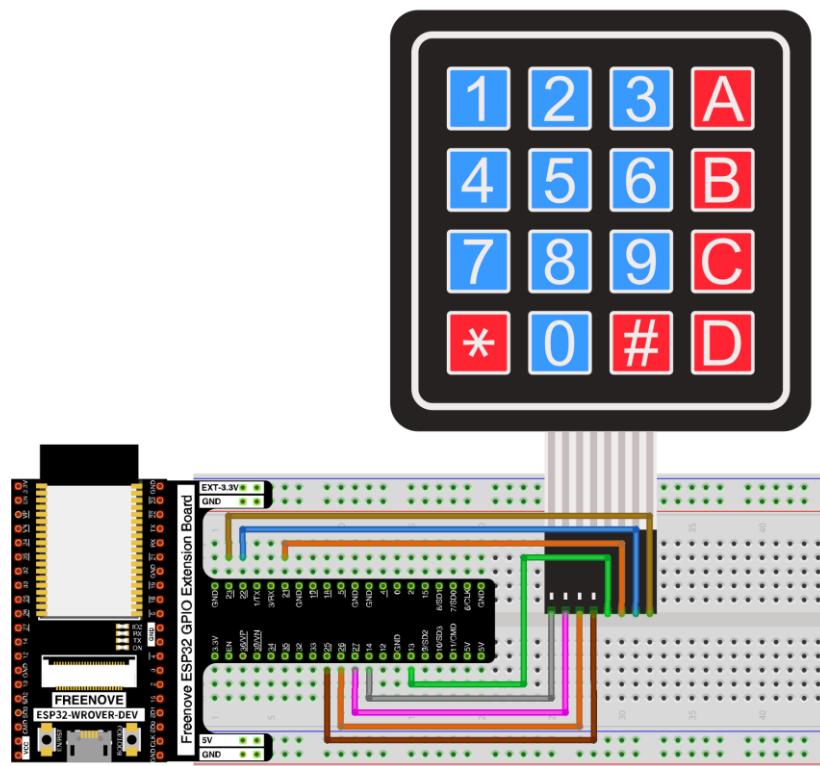
The usage is similar to the LED matrix, using a row or column scanning method to detect the state of each key's position by column and row. Take column scanning method as an example, send low level to the first 1 column (Pin1), detect level state of row 5, 6, 7, 8 to judge whether the key A, B, C, D 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



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

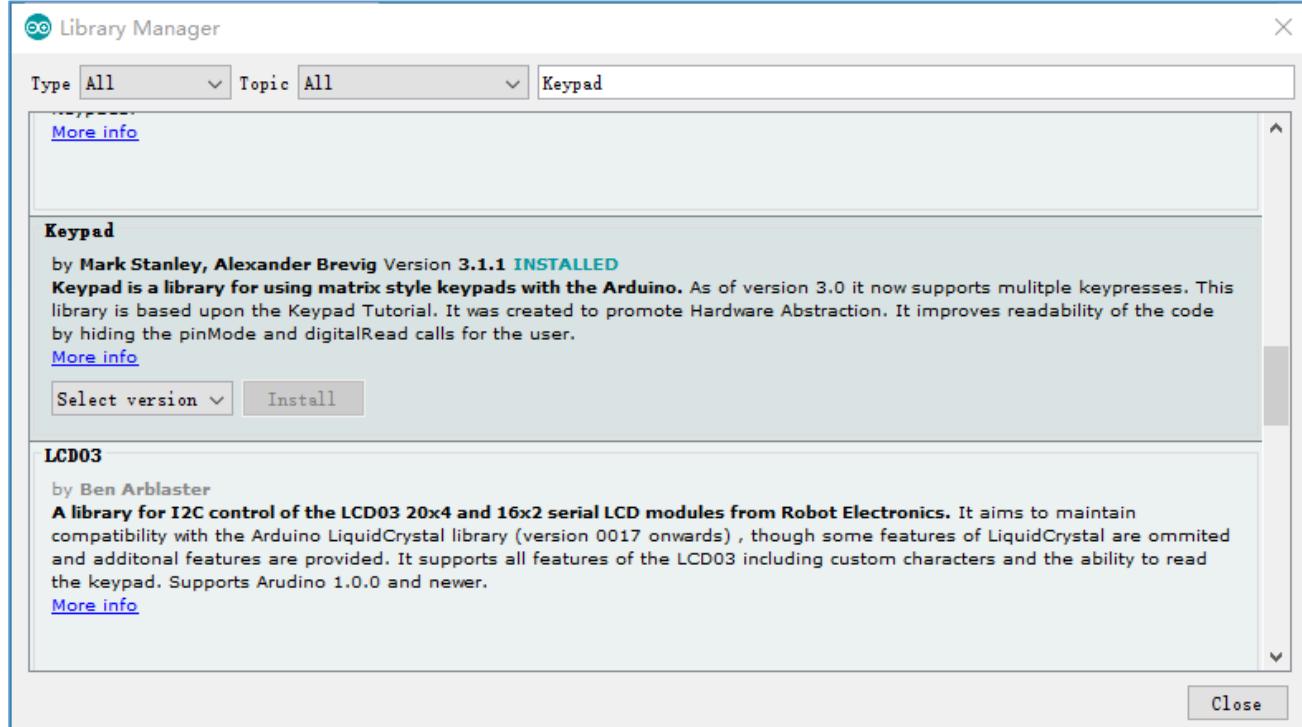
Sketch

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:

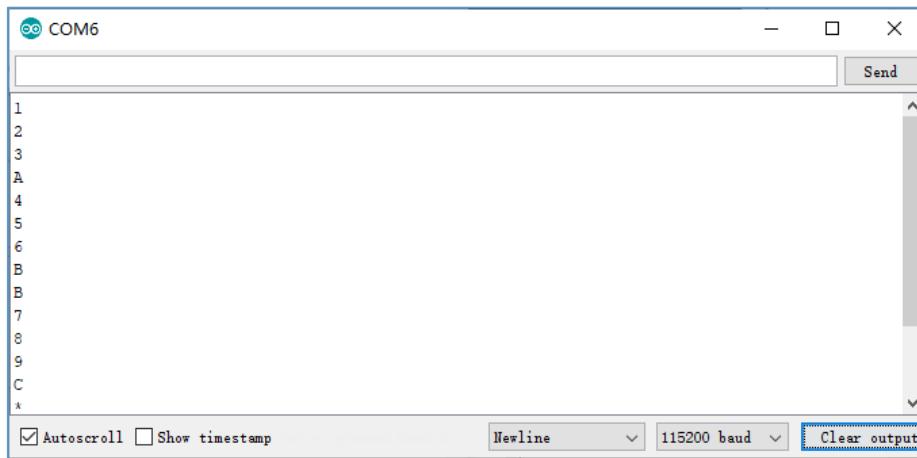
- Title Bar:** Sketch_22.1_Get_Input_Characters | Arduino 1.8.13 Hourly Build 2020/02/19 03:33
- Menu Bar:** File Edit Sketch Tools Help
- Toolbar:** Standard icons for file operations.
- Sketch Area:** Displays the C++ code for the sketch. The code initializes a 4x4 keypad connected to pins 14-27 and 13-23, and prints key presses to the serial port.

```
1 // *****
2   Filename      : Get Input Characters
3   Description   : Call the Keypad function to set the matrix keyboard and get the keys for the matrix
4   Author        : www.freenove.com
5   Modification  : 2020-3-5
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, 27, 26, 25}; // connect to the row pinouts of the keypad
18 byte colPins[4] = {13, 21, 22, 23}; // 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("ESP32 is ready!"); // Print the string "UNO is ready!"
26 }
27
28 void loop() {
29     // Get the character input
30     char keyPressed = myKeypad.getKey();
31     // If there is a character input, sent it to the serial port
32     if (keyPressed) {
33         Serial.println(keyPressed);
34     }
35 }
```

- Serial Monitor:** Shows the text "Done uploading." followed by "Leaving..." and "Hard resetting via RTS pin...".
- Status Bar:** Shows "24" on the left and "ESP32 Wrover Module on COM6" on the right.



Download the code to ESP32-WROVER, 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, 27, 26, 25}; // connect to the row pinouts of the keypad
10 byte colPins[4] = {13, 21, 22, 23}; // 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("ESP32 is ready!"); // Print the string "ESP32 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, 27, 26, 25}; // connect to the row pinouts of the keypad
10 byte colPins[4] = {13, 21, 22, 23}; // 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

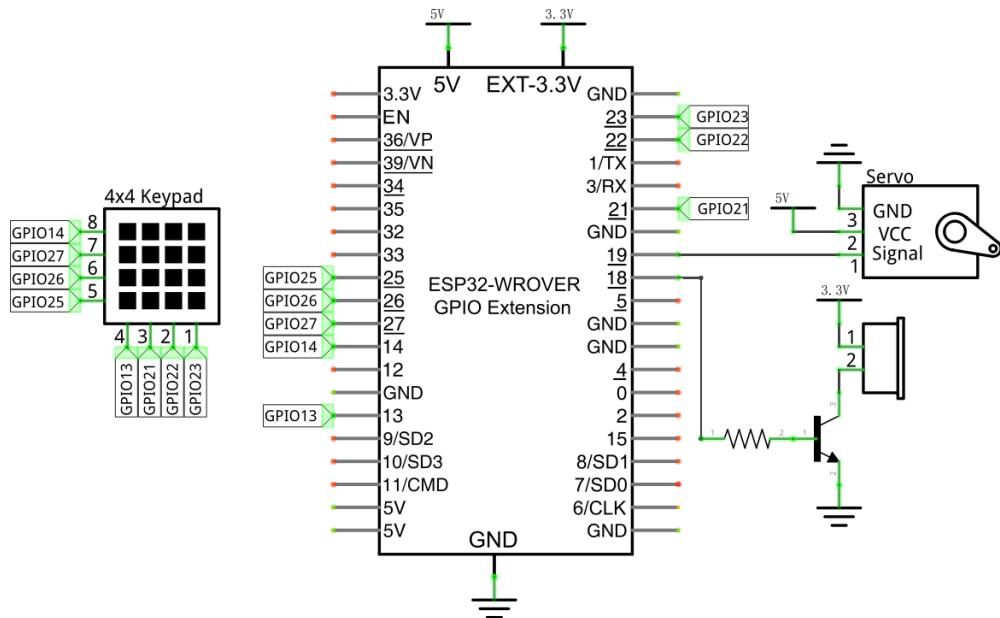
In this project, we use keypad as a keyboard to control the action of the servo motor.

Component List

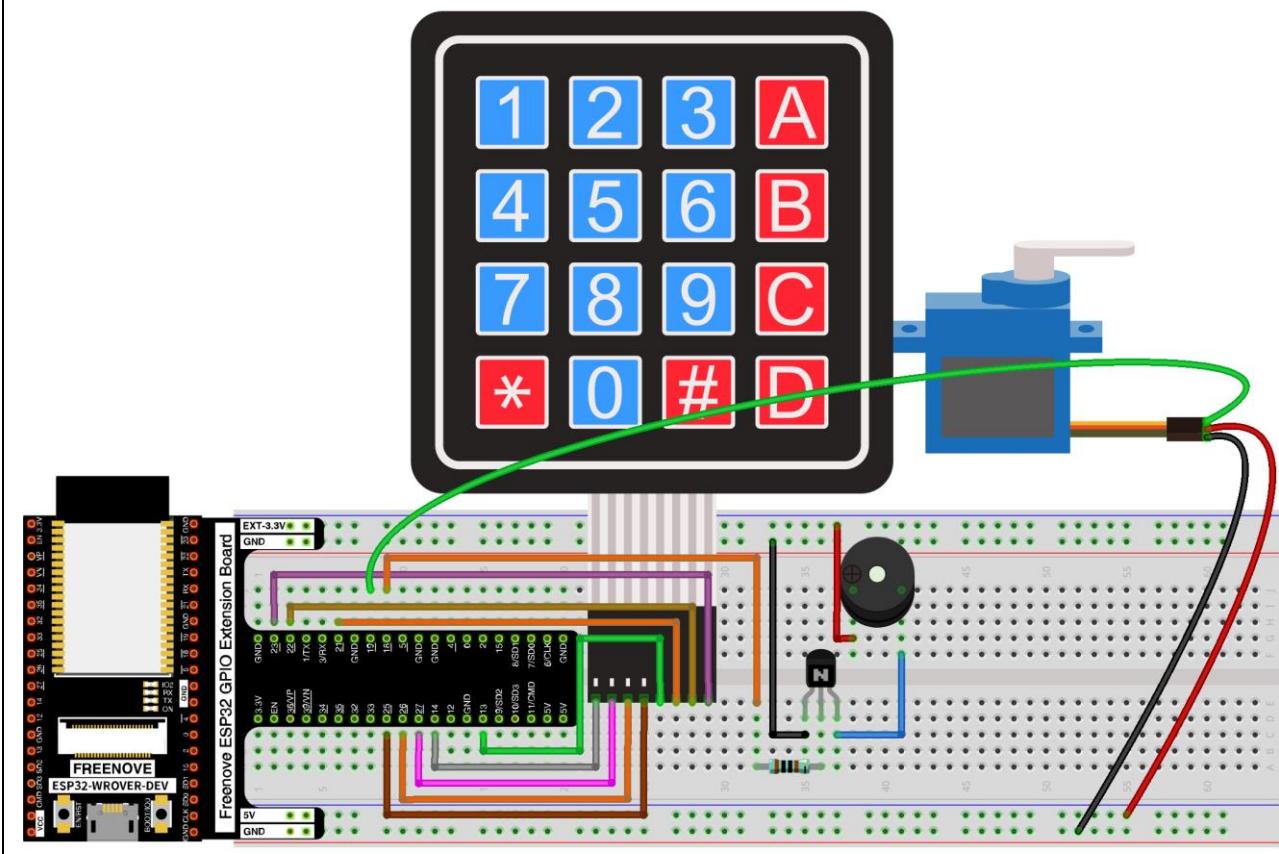
ESP32-WROVER x1	GPIO Extension Board x1	
A black rectangular ESP32 development board with a central microcontroller chip, two yellow header pins, and various component markings.	A white rectangular extension board with multiple pins and labels for pins 0 through 34, 5V, GND, and various digital and analog pins.	
Breadboard x1		A schematic diagram of a breadboard showing its grid of 40 columns and 24 rows of connection points.
Jumper M/M	Servo x1	4x4 Matrix Keypad x1
A simple black and green two-pin jumper cable.	A blue servo motor with a black plastic housing and a grey metal gear.	A black rectangular keypad with a 4x4 grid of buttons labeled with numbers 0-9, *, #, and letters A-D.
NPN transistor x1 (S8050)	Active buzzer x1	Resistor 1kΩ x1
A black NPN transistor with three pins.	A black circular active buzzer with a small green LED on top.	A cylindrical resistor with a red band indicating 1k ohms.

Circuit

Schematic diagram



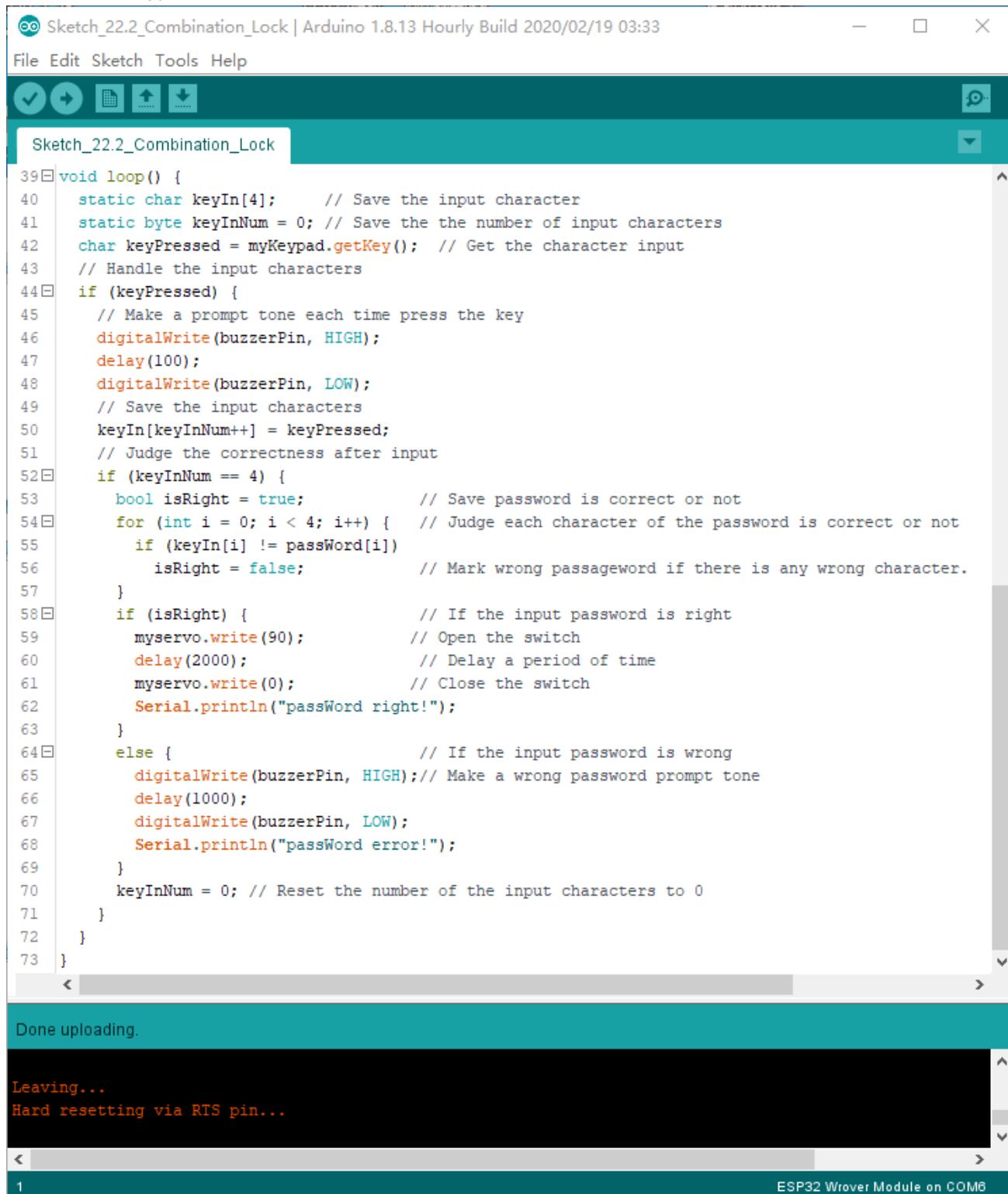
Hardware connection. If you need any support, please feel free to contact us via: support@freenove.com



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

Sketch

Sketch_22.2_Kepad_Door



```

Sketch_22.2_Combination_Lock | Arduino 1.8.13 Hourly Build 2020/02/19 03:33
File Edit Sketch Tools Help
Sketch_22.2_Combination_Lock
39 void loop() {
40     static char keyIn[4];      // Save the input character
41     static byte keyInNum = 0; // Save the number of input characters
42     char keyPressed = myKeypad.getKey(); // Get the character input
43     // Handle the input characters
44     if (keyPressed) {
45         // Make a prompt tone each time press the key
46         digitalWrite(buzzerPin, HIGH);
47         delay(100);
48         digitalWrite(buzzerPin, LOW);
49         // Save the input characters
50         keyIn[keyInNum++] = keyPressed;
51         // Judge the correctness after input
52         if (keyInNum == 4) {
53             bool isRight = true;           // Save password is correct or not
54             for (int i = 0; i < 4; i++) { // Judge each character of the password is correct or not
55                 if (keyIn[i] != password[i])
56                     isRight = false;        // Mark wrong password if there is any wrong character.
57             }
58             if (isRight) {              // If the input password is right
59                 myservo.write(90);      // Open the switch
60                 delay(2000);          // Delay a period of time
61                 myservo.write(0);       // Close the switch
62                 Serial.println("password right!");
63             }
64             else {                    // If the input password is wrong
65                 digitalWrite(buzzerPin, HIGH); // Make a wrong password prompt tone
66                 delay(1000);
67                 digitalWrite(buzzerPin, LOW);
68                 Serial.println("password error!");
69             }
70             keyInNum = 0; // Reset the number of the input characters to 0
71         }
72     }
73 }

```

Done uploading.

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

1 ESP32 Wrover Module on COM6

Verify and upload the code to the ESP32-WROVER 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 #include <ESP32Servo.h>
3
4 // define the symbols on the buttons of the keypad
5 char keys[4][4] = {
6     {'1', '2', '3', 'A'},
7     {'4', '5', '6', 'B'},
8     {'7', '8', '9', 'C'},
9     {'*', '0', '#', 'D'}
10};
11
12 byte rowPins[4] = {14, 27, 26, 25}; // connect to the row pinouts of the keypad
13 byte colPins[4] = {13, 21, 22, 23}; // connect to the column pinouts of the keypad
14
15 // initialize an instance of class NewKeypad
16 Keypad myKeypad = Keypad(makeKeymap(keys), rowPins, colPins, 4, 4);
17
18 Servo myservo; // Create servo object to control a servo
19 int servoPin = 19; // Define the servo pin
20 int buzzerPin = 18; // Define the buzzer pin
21
22 char passWord[] = {"1234"}; // Save the correct password
23
24 void setup() {
25     myservo.setPeriodHertz(50); // standard 50 hz servo
26     myservo.attach(servoPin, 500, 2500); // attaches the servo on servoPin to the servo object
27                                         // set the high level time range of the servo motor
28     for an accurate 0°-180° sweep
29         myservo.write(0); // Set the starting position of the servo motor
30         pinMode(buzzerPin, 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 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(buzzerPin, HIGH);
42         delay(100);
43         digitalWrite(buzzerPin, 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
50         not
51         if (keyIn[i] != passWord[i])
52             isRight = false;        // Mark wrong password if there is any wrong character.
53     }
54     if (isRight) {                // If the input password is right
55         myservo.write(90);        // Open the switch
56         delay(2000);            // Delay a period of time
57         myservo.write(0);         // Close the switch
58         Serial.println("passWord right! ");
59     }
60     else {                      // If the input password is wrong
61         digitalWrite(buzzerPin, HIGH); // Make a wrong password prompt tone
62         delay(1000);
63         digitalWrite(buzzerPin, LOW);
64         Serial.println("passWord error! ");
65     }
66     keyInNum = 0; // Reset the number of the input characters to 0
67 }
68 }
69 }
70

```

First, we need to set the value of the password.

22	<code>char passWord[] = {"1234"}; // Save the correct password</code>
----	---

Second, each time the key is pressed, the buzzer makes a short sound and stores the key value entered.

37	<code>char keyPressed = myKeypad.getKey(); // Get the character input</code>
38	<code>// Handle the input characters</code>
39	<code>if (keyPressed) {</code>
40	<code> // Make a prompt tone each time press the key</code>
41	<code> digitalWrite(buzzerPin, HIGH);</code>
42	<code> delay(100);</code>
43	<code> digitalWrite(buzzerPin, LOW);</code>
44	<code> // Save the input characters</code>
45	<code> keyIn[keyInNum++] = keyPressed;</code>

Third, if the button has been pressed for four times, ESP32 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             }  
54 }
```

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.

```
55     if (isRight) {                  // If the input password is right  
56         myservo.write(90);          // Open the switch  
57         delay(2000);              // Delay a period of time  
58         myservo.write(0);          // Close the switch  
59         Serial.println("passWord right!");  
60     }  
61     else {                      // If the input password is wrong  
62         digitalWrite(buzzerPin, HIGH); // Make a wrong password prompt tone  
63         delay(1000);  
64         digitalWrite(buzzerPin, LOW);  
65         Serial.println("passWord error!");  
66     }
```

Finally, remember to empty the keyInNum every time.

```
67     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-WROVER x1	GPIO Extension Board x1
Breadboard x1	
Jumper M/M x4	Infrared Remote x1 (May need CR2025 battery x1, please check the holder)
Infrared Remote x1	Resistor 10kΩ x1

Component knowledge

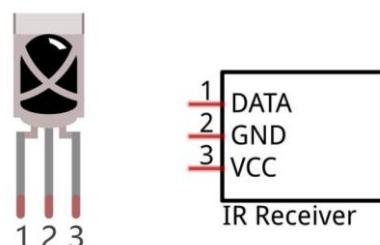
Infrared Remote

An infrared(IR) remote control is a device with a certain number of buttons. Pressing down different buttons will make the infrared emission tube, which is located in the front of the remote control, send infrared ray with different command. Infrared remote control technology is widely used in electronic products such as TV, air conditioning, etc. Thus making it possible for you to switch TV programs and adjust the temperature of the air conditioning when away from them. The remote control we use is shown below:



Infrared receiver

An infrared(IR) receiver is a component which can receive the infrared light, so we can use it to detect the signal emitted by the infrared remote control. DATA pin here outputs the received infrared signal.





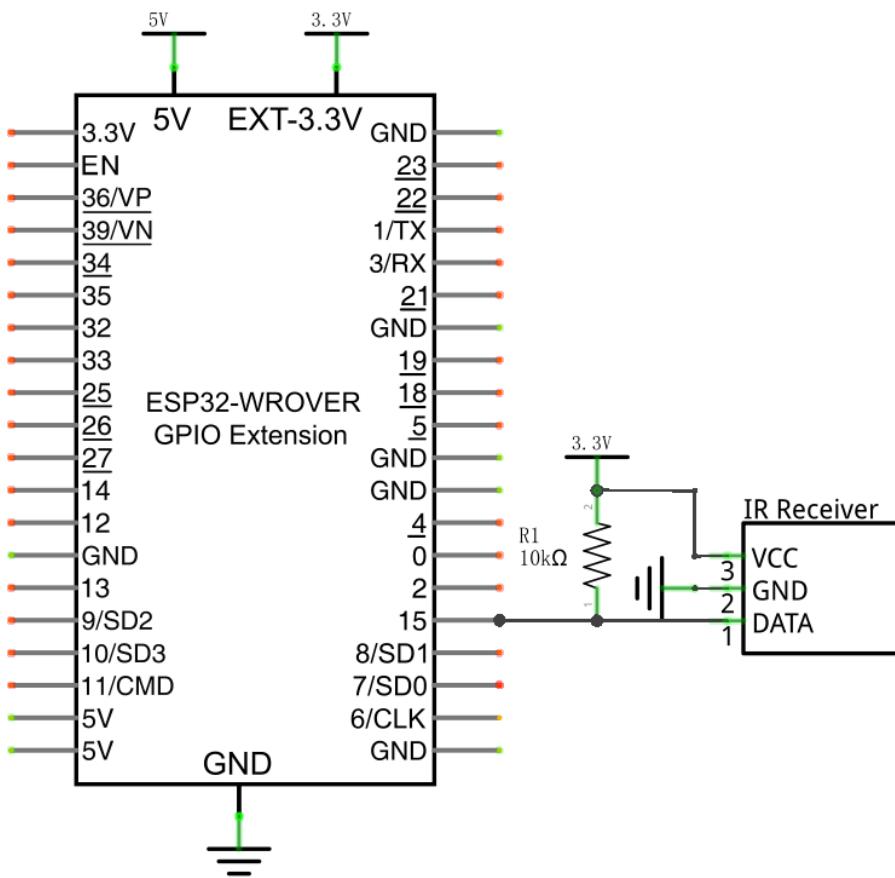
When you use the infrared remote control, the infrared remote control sends a key value to the receiving circuit according to the pressed keys. We can program the ESP32-WROVER to do things like lighting, when a key value is received.

The following is the key value that the receiving circuit will receive when each key of the infrared remote control is pressed.

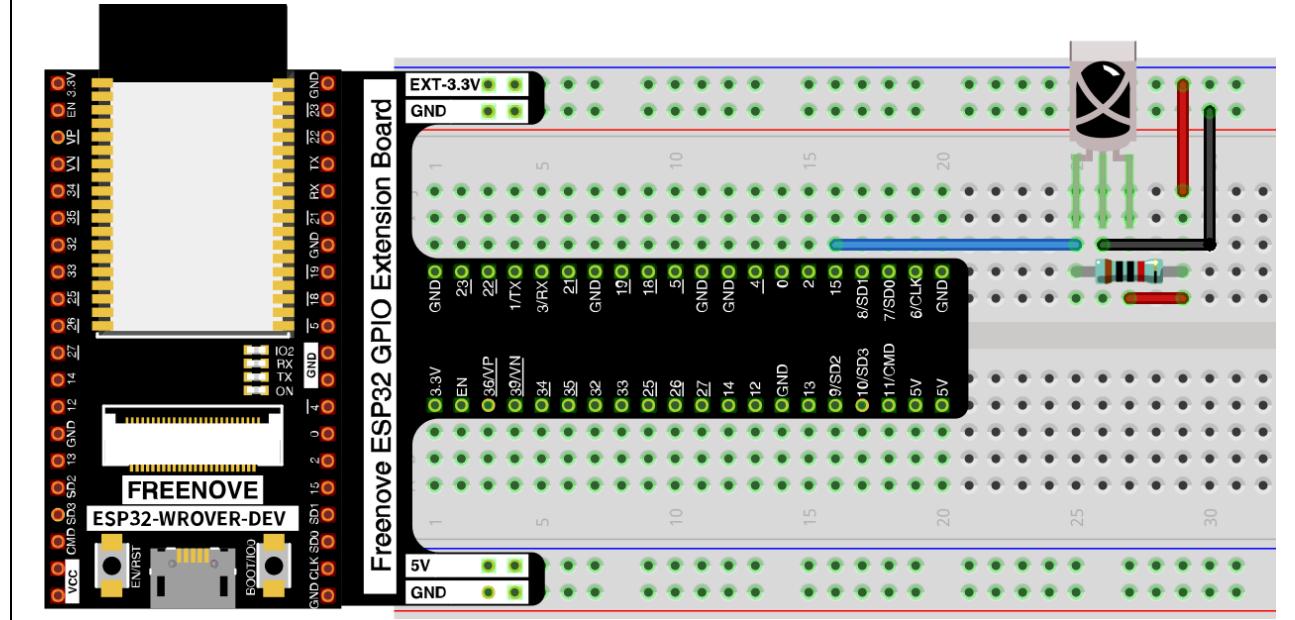
ICON	KEY Value	ICON	KEY Value
	FFA25D		FFB04F
	FFE21D		FF30CF
	FF22DD		FF18E7
	FF02FD		FF7A85
	FFC23D		FF10EF
	FFE01F		FF38C7
	FFA857		FF5AA5
	FF906F		FF42BD
	FF6897		FF4AB5
	FF9867		FF52AD

Circuit

Schematic diagram



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



Any concerns? ✉ support@freenove.com



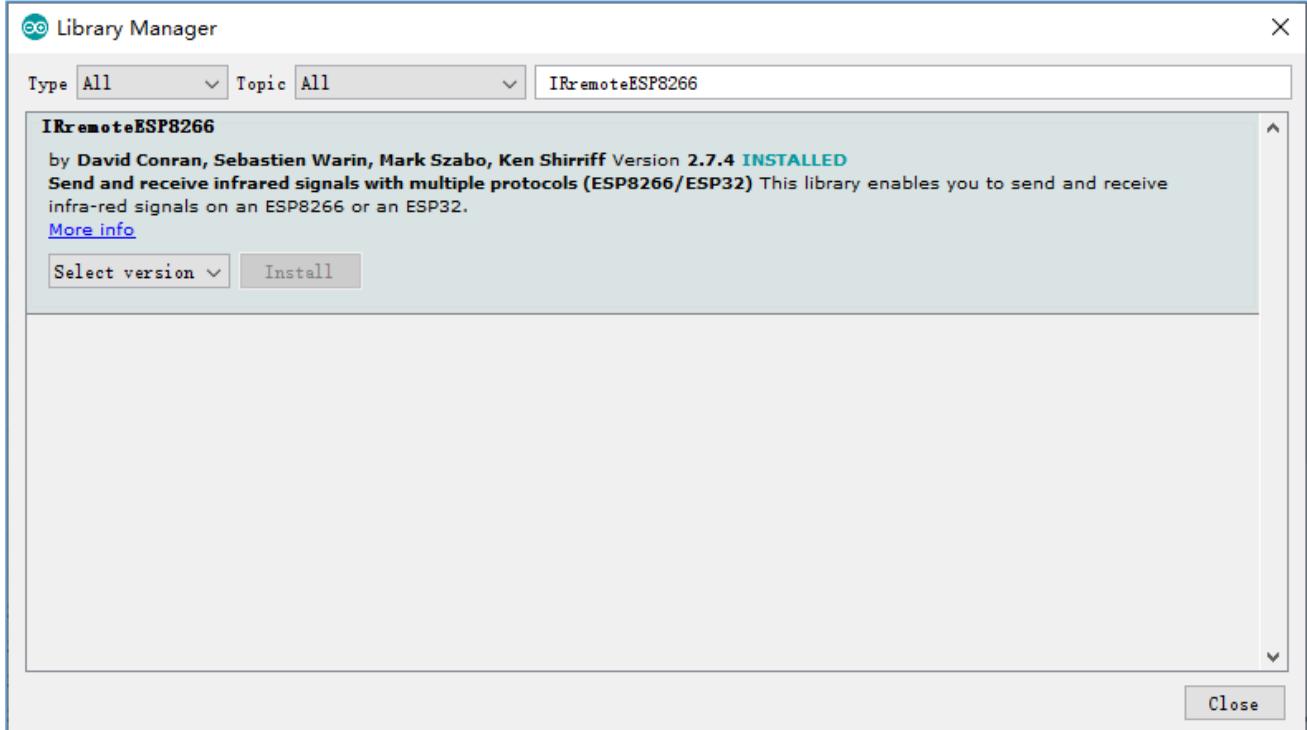
Sketch

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 1.8.13 Hourly Build 2020/02/19 03:33
File Edit Sketch Tools Help
Sketch_23.1_Infrared_Remote_Control
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: 2020-3-5
6 *****
7 #include <Arduino.h>
8 #include <IRremoteESP8266.h>
9 #include <IRrecv.h>
10 #include <IRUtils.h>
11
12 const uint16_t recvPin = 15; // Infrared receiving pin
13 IRrecv irrecv(recvPin);      // Create a class object used to receive class
14 decode_results results;     // Create a decoding results class object
15
16 void setup() {
17   Serial.begin(115200);       // Initialize the serial port and set the baud rate to 115200
18   irrecv.enableIRIn();        // Start the receiver
19   while (!Serial)            // Wait for the serial connection to be established.
20     delay(50);
21   Serial.println();
22   Serial.print("IRrecvDemo is now running and waiting for IR message on Pin ");
23   Serial.println(recvPin);   // Print the infrared receiving pin
24 }
25
26 void loop() {
27   if (irrecv.decode(&results)) {           // Waiting for decoding
28     serialPrintUint64(results.value, HEX); // Print out the decoded results
29     Serial.println("");
30     irrecv.resume();                      // Release the IRremote. Receive the next value
31   }
32   delay(1000);
33 }

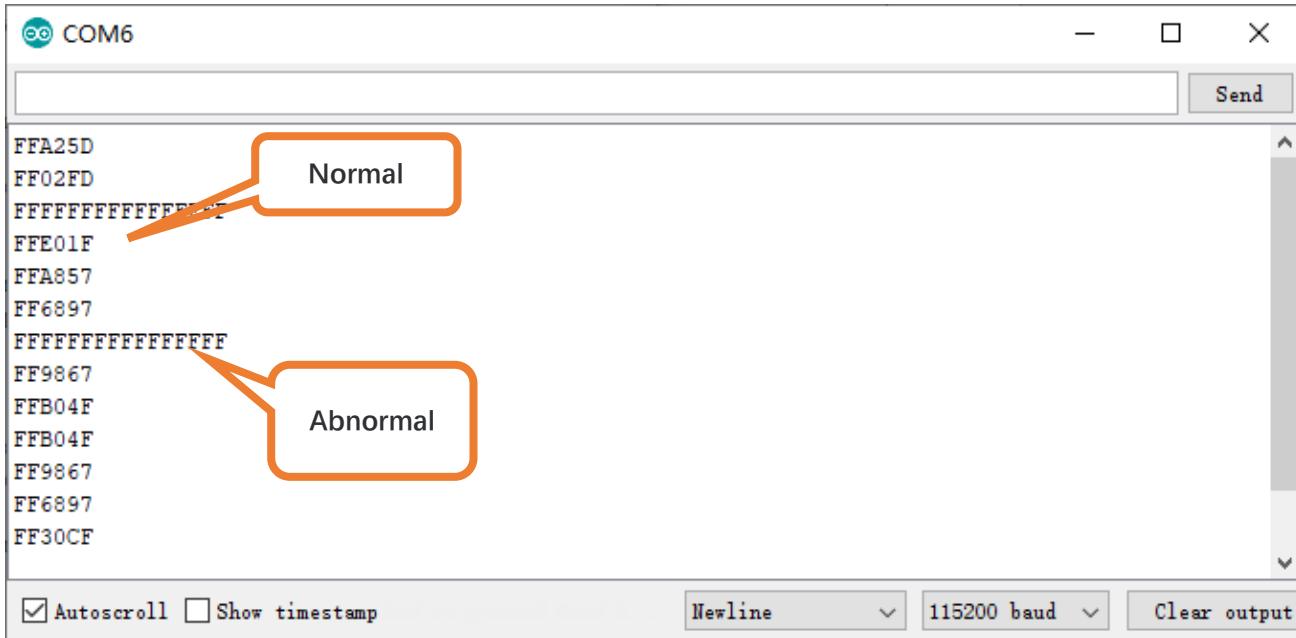
```

Done uploading.

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

20 ESP32 Wrover Module on COM6

Download the code to ESP32-WROVER, 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")



The following is the program code:

```

1 #include <Arduino.h>
2 #include <IRremoteESP8266.h>
3 #include <IRrecv.h>
4 #include <IRUtils.h>
5
6 const uint16_t recvPin = 15; // Infrared receiving pin
7 IRrecv irrecv(recvPin); // Create a class object used to receive class
8 decode_results results; // Create a decoding results class object
9
10 void setup() {
11     Serial.begin(115200); // Initialize the serial port and set the baud rate to 115200
12     irrecv.enableIRIn(); // Start the receiver
13     while (! Serial) // Wait for the serial connection to be established.
14         delay(50);
15     Serial.println();
16     Serial.print("IRrecvDemo is now running and waiting for IR message on Pin ");
17     Serial.println(recvPin); //print the infrared receiving pin
18 }
19
20 void loop() {
21     if (irrecv.decode(&results)) { // Waiting for decoding
22         serialPrintUint64(results.value, HEX); // Print out the decoded results
23         Serial.println("");
24         irrecv.resume(); // Release the IRremote. Receive the next value
25     }
26     delay(1000);
27 }
```

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 <Arduino.h>
2 #include <IRremoteESP8266.h>
3 #include <IRrecv.h>
4 #include <IRutils.h>
```

Second, define an infrared receive pin and associates it with the receive class. Apply a decode_results to decode the received infrared value.

```
6 const uint16_t RecvPin = 15; // Infrared receiving pin
7 IRrecv irrecv(RecvPin);      // Create a class object used to receive class
8 decode_results results;     // Create a decoding results class object
```

Third, enable infrared reception function, if you do not use this function, you won't receive the value from the infrared remote control.

```
12 irrecv.enableIRIn();          // Start the receiver
```

Finally, put the received data into the results class and print out the data through the serial port. Note that you must use **resume()** to release the infrared receive function every time when you receive data, otherwise you can only use the infrared receive function once and cannot receive the data next time.

```
20 void loop() {
21     if (irrecv.decode(&results)) {           // Waiting for decoding
22         serialPrintUint64(results.value, HEX); // Print out the decoded results
23         Serial.println("");
24         irrecv.resume();                   // Release the IRremote. Receive the next value
25     }
26     delay(1000);
27 }
```

Reference

class IRrecv You need to add the library each time you use the Infrared Reception.

IRrecv irrecv(Pin): Create a class object used to receive class, and associated with **Pin**.

enableIRIn(): Before using the infrared decoding function, enable the infrared receiving function. Otherwise the correct data will not be received.

decode(&results): Determine whether the infrared has received data, and if so, return true and store the data in the decode_results class. If no data is received, false is returned.

resume(): Release the IRremote. Or, the infrared reception and decoding function cannot be used again.

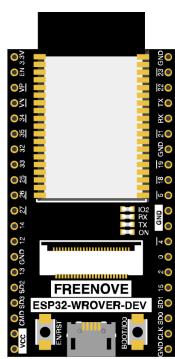
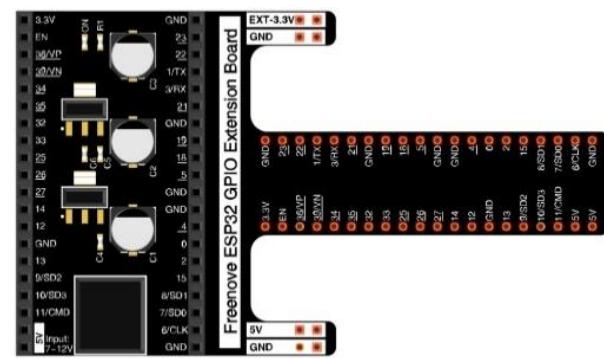
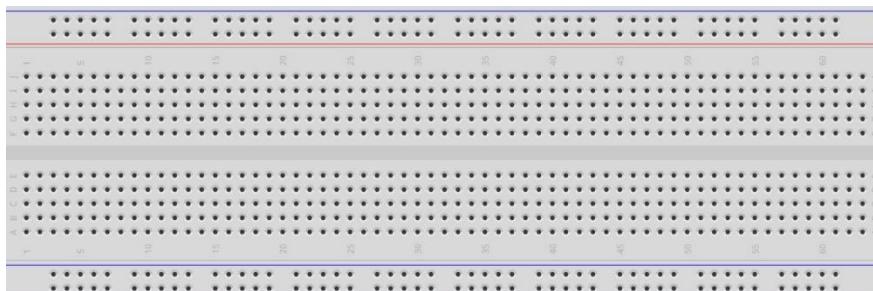
For more information about Infrared Remote Control, please visit:

<https://github.com/crankyoldgit/IRremoteESP8266/tree/master/src>

Project 23.2 Control LED through Infrared Remote

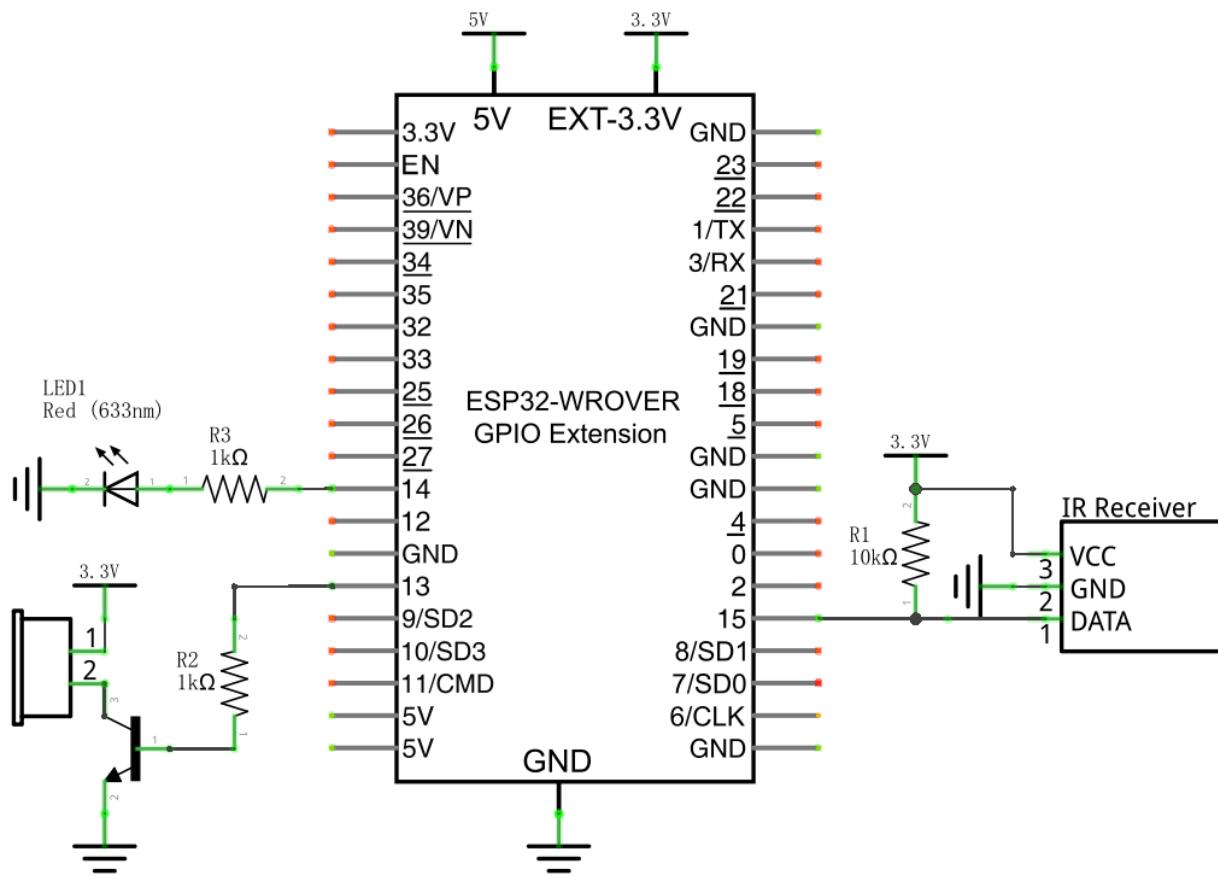
In this project, we will control the brightness of LED lights through an infrared remote control.

Component List

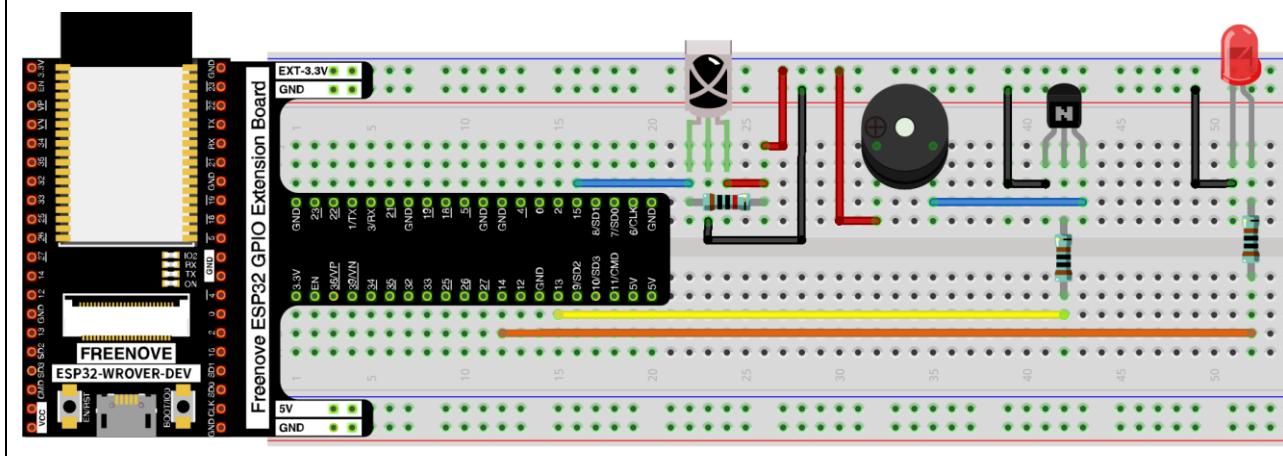
ESP32-WROVER x1	GPIO Extension Board x1			
				
Breadboard x1				
				
Jumper M/M x10	Infrared Remote x1 (May need CR2025 battery x1, please check the holder)			
				
LED x1	Resistor 1kΩ x2	Resistor 10k Ω x1		
				
Infrared receiver x1	NPN transistor x1 (S8050)	Active buzzer x1		
				

Circuit

Schematic diagram



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



Sketch

The sketch controls the brightness of the LED by determining the key value of the infrared received.

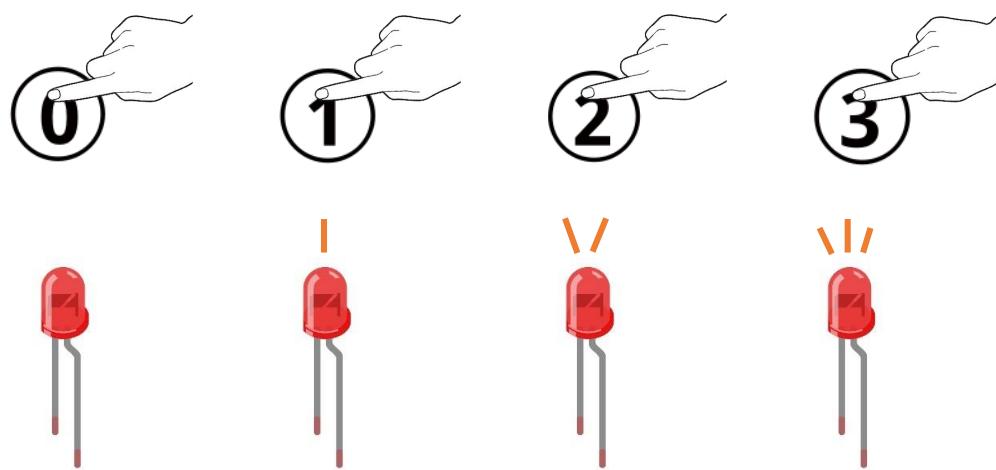
Sketch_23.2_Control_LED_through_Infrared_Remote

```
Sketch_23.2_Control_LED_through_Infrared_Remote | Arduino 1.8.13 (Windows Store 1.8.42.0)
File Edit Sketch Tools Help
Sketch_23.2_Control_LED_through_Infrared_Remote
1 // ****
2   Filename      : Control LED through Infrared Remote
3   Description   : Remote control the LED with the infrared remote control.
4   Author        : www.freenove.com
5   Modification: 2020/07/11
6 ****
7 #include <Arduino.h>
8 #include <IRremoteESP8266.h>
9 #include <IRrecv.h>
10 #include <IRUtils.h>
11
12 const uint16_t recvPin = 15; // Infrared receiving pin
13 IRrecv irrecv(recvPin);      // Create a class object used to receive class
14 decode_results results;     // Create a decoding results class object
15
16 int ledPin = 14;             // the number of the LED pin
17 int buzzerPin = 13;          // the number of the buzzer pin
18
19 void setup()
20 {
21   //Initialize the ledc configuration
22   ledcSetup(0,1000,8);           //set the channel,frequency,esolution_bits
23   ledcAttachPin(ledPin,0);        //attach the channel to GPIO pin
24   pinMode(buzzerPin, OUTPUT);    // set buzzer pin into output mode
25   irrecv.enableIRIn();           // Start the receiver
26 }
27
28 void loop() {
29   if (irrecv.decode(&results)) {    // Waiting for decoding
30     handleControl(results.value);    // Handle the commands from remote control
31     irrecv.resume();                 // Receive the next value
32   }
33 }
```

Done uploading.

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

Compile and upload the code to the ESP32-WROVER. 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 <Arduino.h>
2 #include <IRremoteESP8266.h>
3 #include <IRrecv.h>
4 #include <IRUtils.h>
5
6 const uint16_t recvPin = 15; // Infrared receiving pin
7 IRrecv irrecv(recvPin); // Create a class object used to receive class
8 decode_results results; // Create a decoding results class object
9
10 int ledPin = 14; // the number of the LED pin
11 int buzzerPin = 13; // the number of the buzzer pin
12
13 void setup()
14 {
15     //Initialize the ledc configuration
16     ledcSetup(0, 1000, 8); // set the channel, frequency, esolution_bits
17     ledcAttachPin(ledPin, 0); // attach the channel to GPIO pin
18     pinMode(buzzerPin, OUTPUT); // set buzzer pin into output mode
19     irrecv.enableIRIn(); // Start the receiver
20 }
21
22 void loop() {
23     if (irrecv.decode(&results)) { // Waiting for decoding
24         handleControl(results.value); // Handle the commands from remote control
25         irrecv.resume(); // Receive the next value
26     }
27 }
```

```

28 void handleControl(unsigned long value) {
29     // Make a sound when it receives commands
30     digitalWrite(buzzerPin, HIGH);
31     delay(100);
32     digitalWrite(buzzerPin, LOW);
33     // respond to the commands
34     switch (value) {
35         case 0xFF6897:           // Receive the number '0'
36             ledcWrite(0, 0);      // Turn off LED
37             break;
38         case 0xFF30CF:           // Receive the number '1'
39             ledcWrite(0, 7);      // Dimmest brightness
40             break;
41         case 0xFF18E7:           // Receive the number '2'
42             ledcWrite(0, 63);     // Medium brightness
43             break;
44         case 0xFF7A85:           // Receive the number '3'
45             ledcWrite(0, 255);    // Strongest brightness
46             break;
47     }
48 }
```

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.

```

28 void handleControl(unsigned long value) {
29     // Make a sound when it receives commands
30     digitalWrite(buzzerPin, HIGH);
31     delay(100);
32     digitalWrite(buzzerPin, LOW);
33     // respond to the commands
34     switch (value) {
35         case 0xFF6897:           // Receive the number '0'
36             ledcWrite(0, 0);      // Turn off LED
37             break;
38         case 0xFF30CF:           // Receive the number '1'
39             ledcWrite(0, 7);      // Dimmest brightness
40             break;
41         case 0xFF18E7:           // Receive the number '2'
42             ledcWrite(0, 63);     // Medium brightness
43             break;
44         case 0xFF7A85:           // Receive the number '3'
45             ledcWrite(0, 255);    // Strongest brightness
46             break;
```

```
47 }  
48 }
```

Each time when the command is received, the function above will be called in the loop() function.

```
22 void loop() {  
23     if (irrecv.decode(&results)) {          // Waiting for decoding  
24         handleControl(results.value);        // Handle the commands from remote control  
25         irrecv.resume();                      // Receive the next value  
26     }  
27 }
```

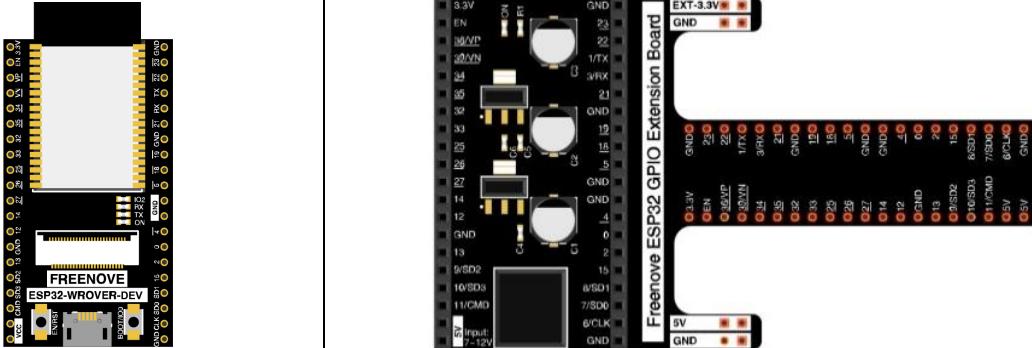
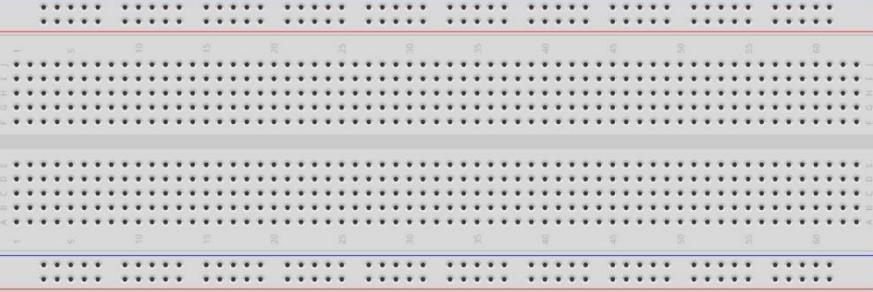
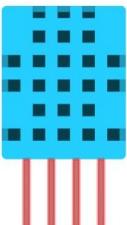
Chapter 24 Hygrothermograph DHT11

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

Project 24.1 Hygrothermograph

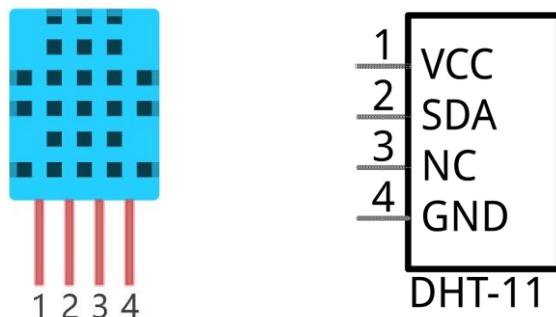
Hygrothermograph is an important tool in our lives to give us data on the temperature and humidity in our environment. In this project, we will use the ESP32 to read temperature and humidity data of the DHT11 Module.

Component List

ESP32-WROVER x1	GPIO Extension Board x1
	
Breadboard x1	
Jumper M/M x4	DHT11 x1
	
	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.

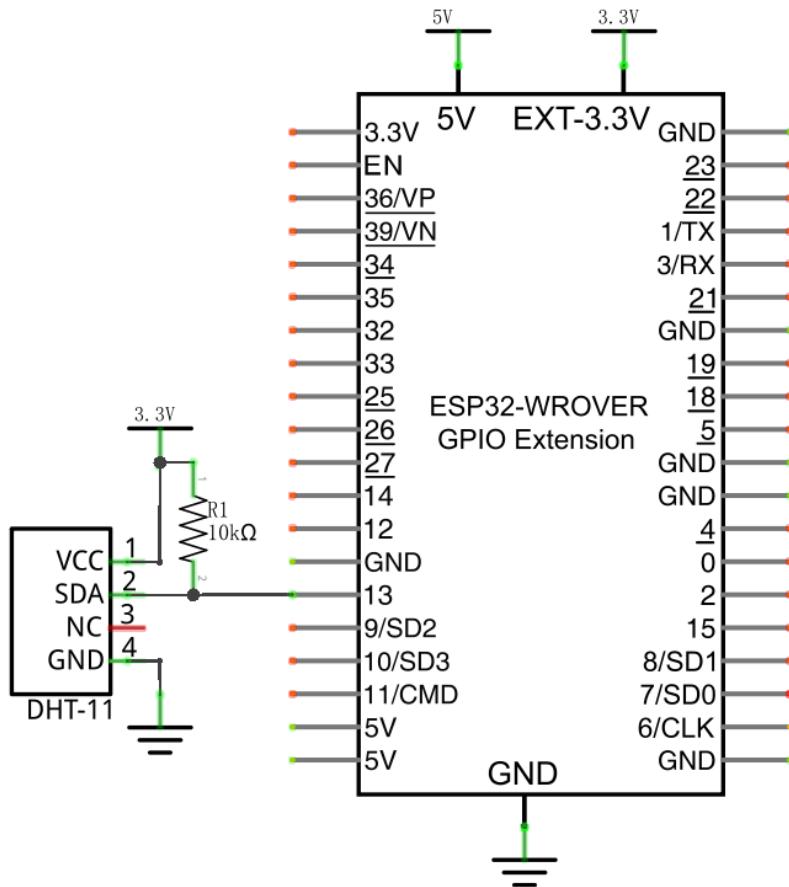
After being powered up, it will initialize in 1s. Its operating voltage is within the range of 3.3V-5.5V.

The SDA pin is a data pin, which is used to communicate with other devices.

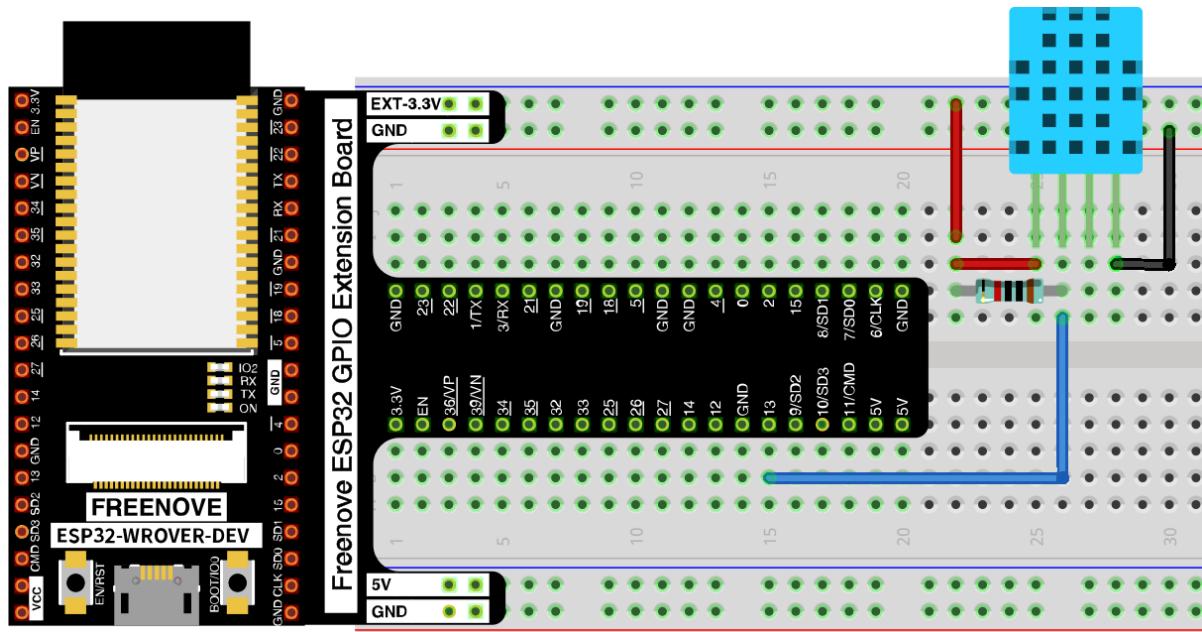
The NC pin (Not Connected Pin) is a type of pin found on various integrated circuit packages. Those pins have no functional purpose to the outside circuit (but may have an unknown functionality during manufacture and test). Those pins should not be connected to any of the circuit connections.

Circuit

Schematic diagram



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



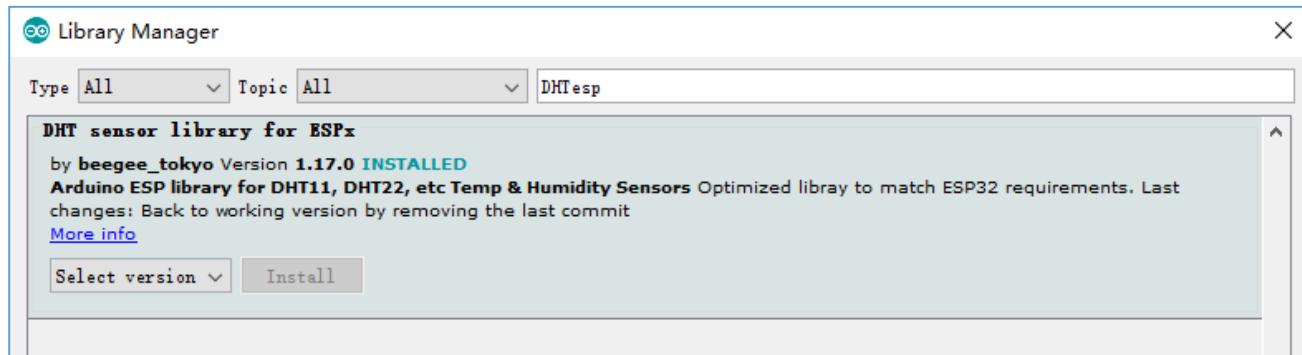
Sketch

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 " DHTesp " in the search bar and select " DHTesp " for installation.

Refer to the following operations:





Sketch_24.1_Temperature_and_Humidity_Sensor

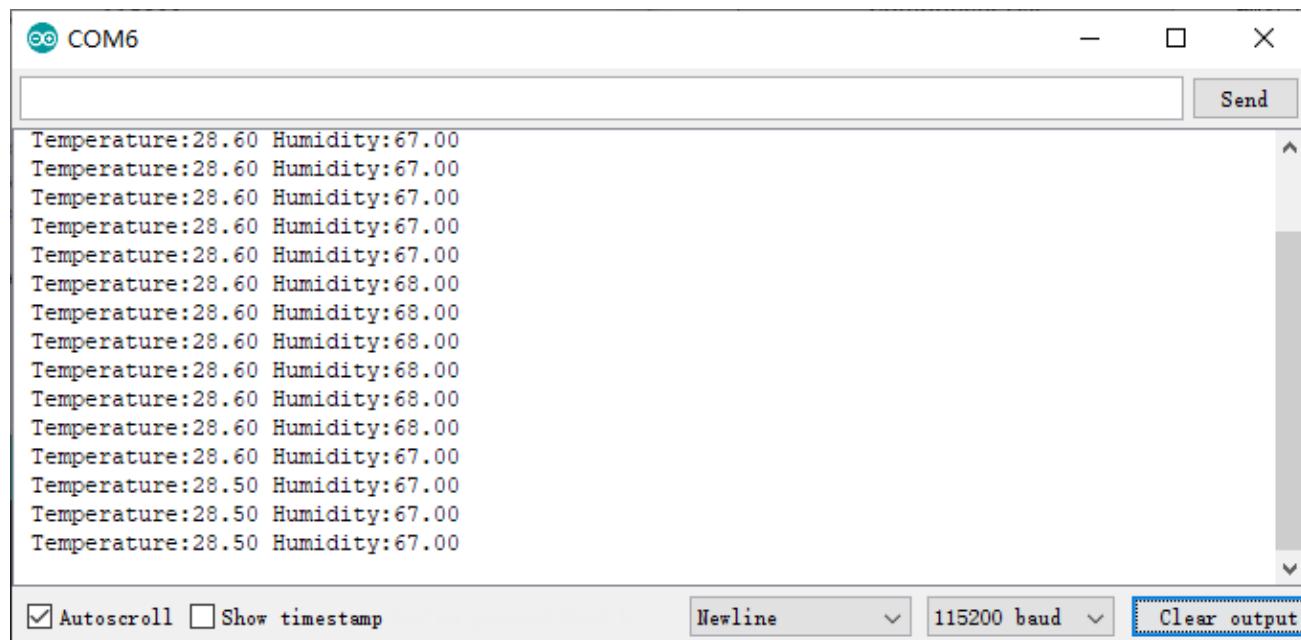
The screenshot shows the Arduino IDE interface with the following details:

- Title Bar:** Sketch_24.1_Temperature_and_Humidity_Sensor | Arduino 1.8.18
- Menu Bar:** File Edit Sketch Tools Help
- Toolbar:** Includes icons for Save, Run, Stop, Upload, and Refresh.
- Code Editor:** Displays the C++ code for the sketch. The code reads temperature and humidity from a DHT11 sensor connected to pin 13 and prints the results to the serial port.

```
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: 2020/07/11
6 ****
7 #include "DHTesp.h"
8
9 DHTesp dht;      //Define the DHT object
10 int dhtPin = 13;//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 }
```

- Serial Monitor:** Shows the message "Save Canceled." followed by "Leaving..." and "Hard resetting via RTS pin...".
- Status Bar:** Shows "11" and "ESP32 Wrover Module, No OTA (2MB APP/2MB SPIFFS), QIO, 80MHz, 921600, None on COM3".

Compile and upload the code to the ESP32-WROVER, 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 following is the program code:

```
1 #include "DHTesp.h"
2
3 DHTesp dht;      //Define the DHT object
4 int dhtPin = 13;//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.

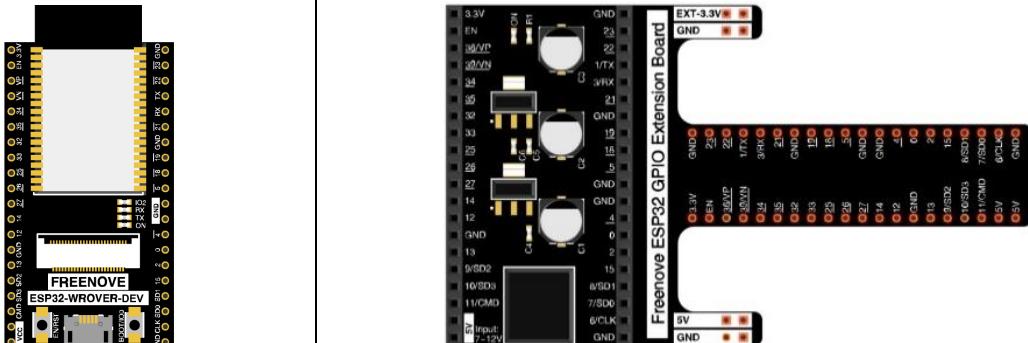
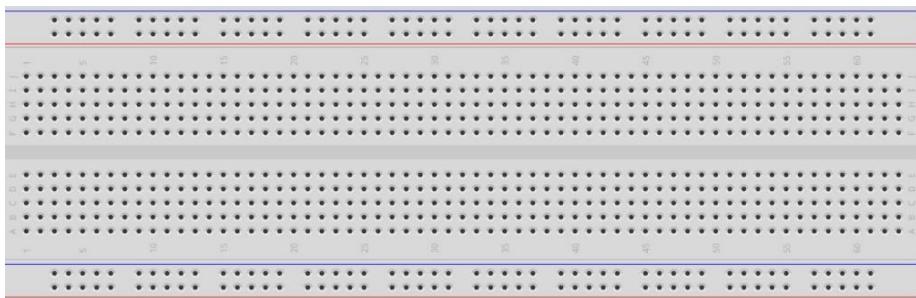
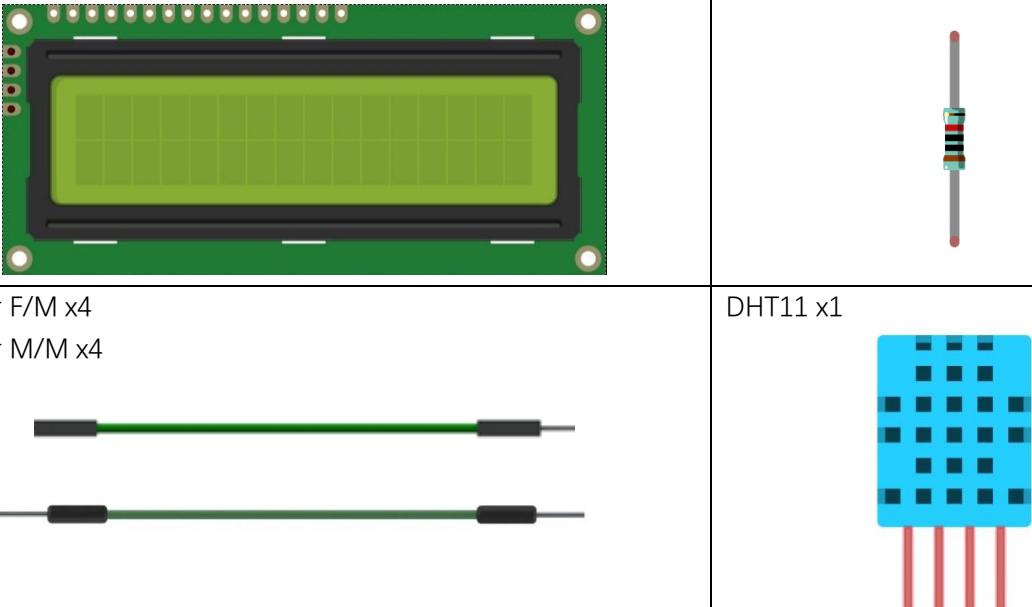
getTempAndHumidity(): Obtain temperature and humidity data. The received data must be stored in the 'TempAndHumidity' class.

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

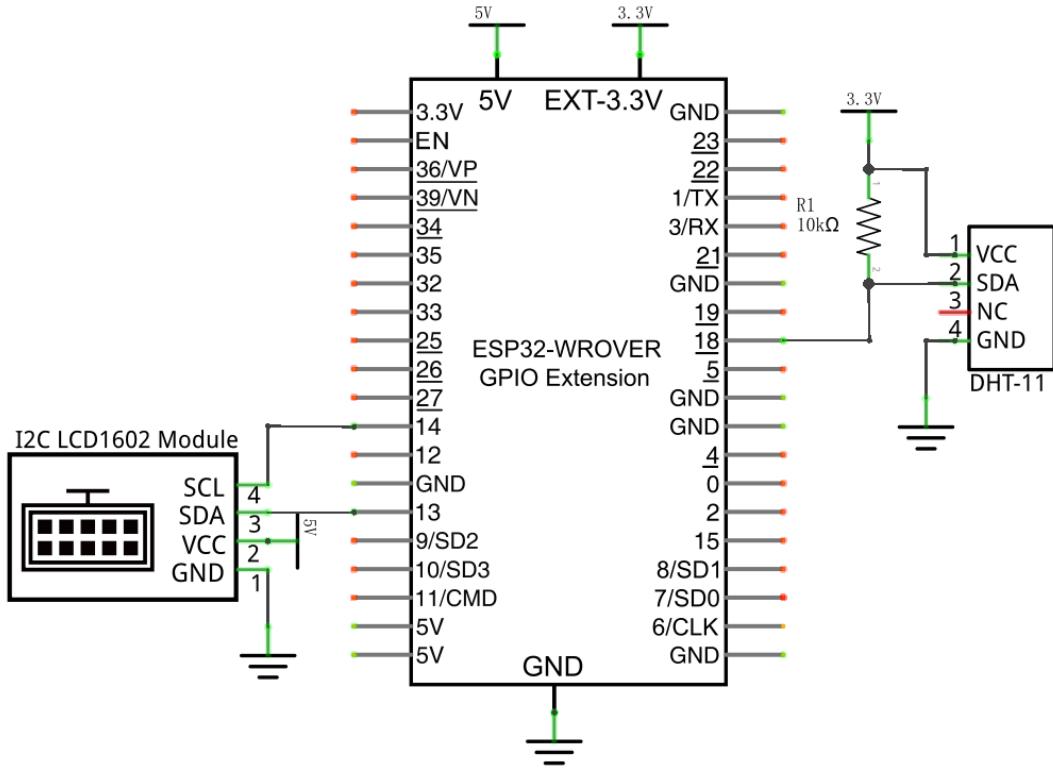
In this project, we use L2C-LCD1602 to display data collected by DHT11.

Component List

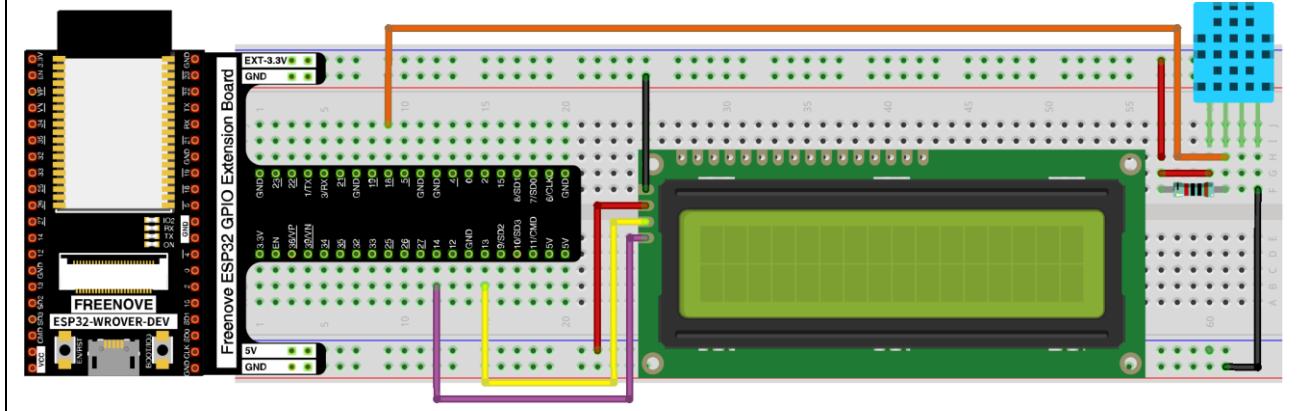
ESP32-WROVER x1	GPIO Extension Board x1
 <p>The image shows two boards: the top one is the Freenove ESP32-WROVER-DEV board, which is a development board for the ESP32 chip. It has a central ESP32 chip, a晶振 (crystal oscillator), and various pins labeled with their functions. The bottom one is the Freenove GPIO Extension Board, which provides additional pins for the ESP32. It has a central ESP32 chip, a晶振 (crystal oscillator), and various pins labeled with their functions.</p>	
Breadboard x1	
 <p>A standard breadboard with two rows of 40 pins each, used for prototyping electronic circuits.</p>	
LCD1602 Module x1	Resistor 10kΩ x1
Jumper F/M x4 Jumper M/M x4	DHT11 x1
 <p>The image shows four jumper wires (two female-to-male and two male-to-male) and a DHT11 digital temperature and humidity sensor. The DHT11 is a small blue square component with four red引脚 (pins).</p>	

Circuit

Schematic diagram



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

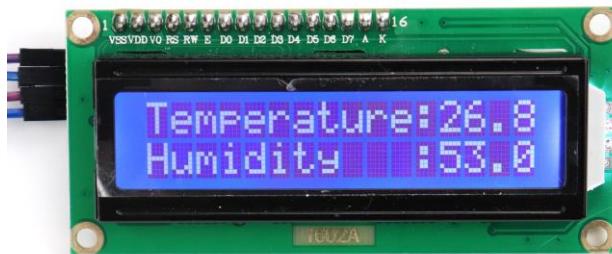
```
Sketch_24.2_Temperature_and_Humidity_Sensor | Arduino 1.8.13 Hourly Build 2020/02/19 03:33
File Edit Sketch Tools Help
Sketch_24.2_Temperature_and_Humidity_Sensor
1 // *****
2   Filename      : Temperature and Humidity Sensor
3   Description   : Use DHT11 to measure temperature and humidity. Print the result to the LCD1602. por
4   Author        : www.freenove.com
5   Modification  : 2020-3-5
6 *****/
7 #include <Wire.h>
8 #include <LiquidCrystal_I2C.h>
9 #include "DHTesp.h"
10
11 #define SDA 13           //Define SDA pins
12 #define SCL 14           //Define SCL pins
13
14 DHTesp dht;           // create dht object
15 LiquidCrystal_I2C lcd(0x27,16,2); //initialize the LCD
16 int dhtPin = 18;       // the number of the DHT11 sensor pin
17
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   dht.setup(dhtPin, DHTesp::DHT11); //attach the dht pin and initialize it
23 }
24
25 void loop() {
26   // read DHT11 data and save it
27   flag:TempAndHumidity DHT = dht.getTempAndHumidity();
28   if (dht.getStatus() != 0) {      //Determine if the read is successful, and if it fails, go back to the
29     goto flag;
30   }
31   lcd.setCursor(0, 0);           //set the cursor to column 0, line 1
32   lcd.print("Temperature:");
33   lcd.print(DHT.temperature);    //display the Humidity on the LCD1602
34   lcd.setCursor(0, 1);           //set the cursor to column 0, line 0
35   lcd.print("Humidity   :");
36   lcd.print(DHT.humidity);      //display the Humidity on the LCD1602
37 }
```

Done uploading.

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

1 ESP32 Wrover Module on COM8

Download the code to ESP32-WROVER. 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 13           //Define SDA pins
6 #define SCL 14           //Define SCL pins
7
8 DHTesp dht;           // create dht object
9 LiquidCrystal_I2C lcd(0x27, 16, 2); //initialize the LCD
10 int dhtPin = 18;      // the number of the DHT11 sensor pin
11
12 void setup() {
13     Wire.begin(SDA, SCL);          // attach the IIC pin
14     lcd.init();                   // LCD driver initialization
15     lcd.backlight();             // Turn on the backlight
16     dht.setup(dhtPin, DHTesp::DHT11); //attach the dht pin and initialize it
17 }
18
19 void loop() {
20     // read DHT11 data and save it
21     flag:TempAndHumidity DHT = dht.getTempAndHumidity();
22     if (dht.getStatus() != 0) {      //Determine if the reading is successful, and if it
23         fails, go back to flag and re-read the data
24         delay(2000);
25         goto flag;
26     }
27     lcd.setCursor(0, 0);           //set the cursor to column 0, line 1
28     lcd.print("Temperature:");
29     lcd.print(DHT.temperature);
30     lcd.setCursor(0, 1);           //set the cursor to column 0, line 0
31     lcd.print("Humidity :");
32     lcd.print(DHT.humidity);

```

```
    delay(2000);  
}
```

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 = 18; // the number of the DHT11 sensor pin  
11  
12 void setup() {  
13     Wire.begin(SDA, SCL); // attach the IIC pin  
14     lcd.init(); // LCD driver initialization  
15     lcd.backlight(); // Turn on the backlight  
16     dht.setup(dhtPin, DHTesp::DHT11); //attach the dht pin and initialize it  
17 }
```

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.

```
21 flag:TempAndHumidity DHT = dht.getTempAndHumidity();  
22 if (dht.getStatus() != 0) { //Determine if the reading is successful, and if it  
23 fails, go back to flag and re-read the data  
24     goto flag;  
25 }  
26 lcd.setCursor(0, 0); //set the cursor to column 0, line 1  
27 lcd.print("Temperature:"); //display the Humidity on the LCD1602  
28 lcd.print(DHT.temperature);  
29 lcd.setCursor(0, 1); //set the cursor to column 0, line 0  
30 lcd.print("Humidity :"); //display the Humidity on the LCD1602  
31 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.

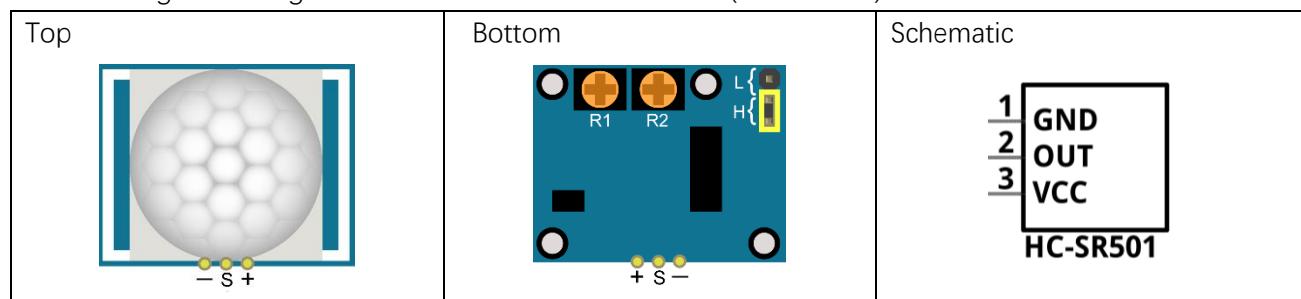
This infrared motion sensor can detect the infrared spectrum (heat signatures) emitted by living humans and animals.

Component List

ESP32-WROVER x1	GPIO Extension Board x1				
Breadboard x1					
HC SR501 x1	LED x1	Resistor 220Ω x1	Jumper F/M x3	Jumper M/M x2	

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

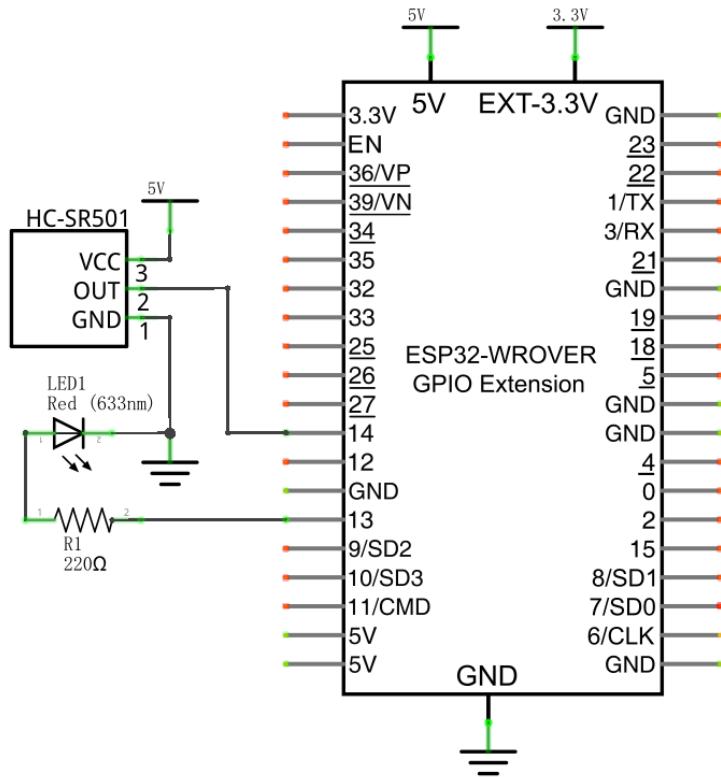
Initialization time: the module needs about 1 minute to initialize after being powered ON. During this period, it will alternately output high or low level.

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.

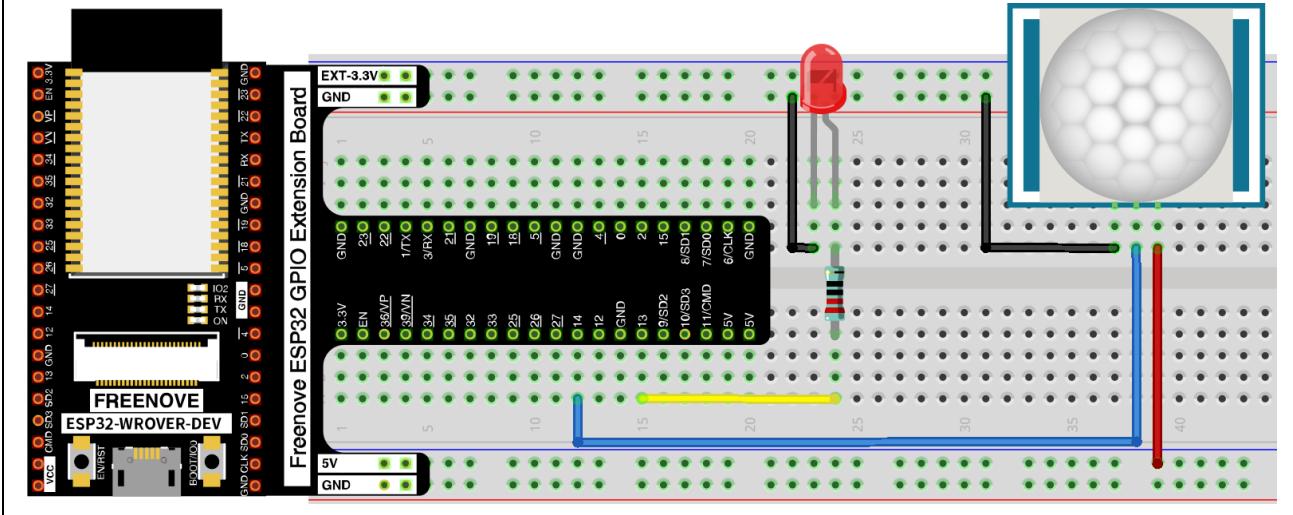
We can regard this sensor as a simple inductive switch when in use.

Circuit

Schematic diagram



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



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. The top bar displays the title "Sketch_25.1_Infrared_Motion_Sensor | Arduino 1.8.13 Hourly Build 2020/02/19 03:33" and the menu bar includes File, Edit, Sketch, Tools, Help. Below the menu is a toolbar with icons for upload, download, and other functions. The main code editor window contains the following code:

```
1 //*****
2 // Filename : Infrared Motion Sensor
3 // Description : LED lamp is controlled by Infrared Motion Sensor
4 // Author : www.freenove.com
5 // Modification: 2020-3-6
6 ****
7 int sensorPin = 14; // the number of the infrared motion sensor pin
8 int ledPin = 13; // the number of the LED pin
9
10 void setup() {
11     pinMode(sensorPin, INPUT); // initialize the sensor pin as input
12     pinMode(ledPin, OUTPUT); // initialize the LED pin as output
13 }
14
15 void loop() {
16     // Turn on or off LED according to Infrared Motion Sensor
17     digitalWrite(ledPin, digitalRead(sensorPin));
18     delay(1000); // wait for a second
19 }
```

The status bar at the bottom indicates "Done uploading." and "Leaving... Hard resetting via RTS pin...". The bottom right corner shows "ESP32 Wrover Module on COM6".

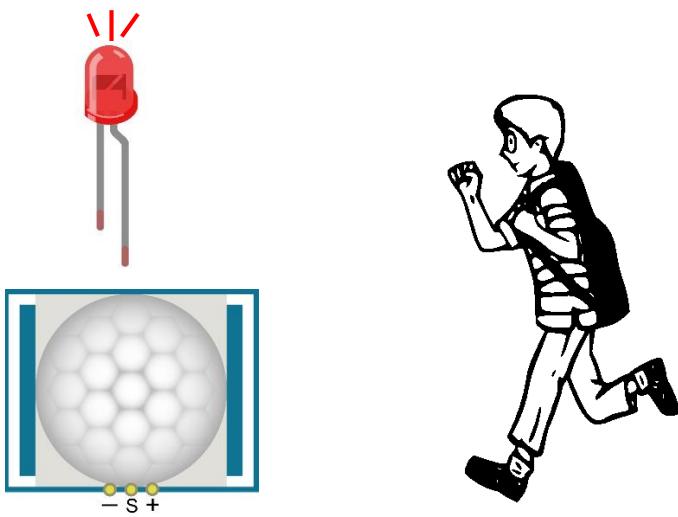
Verify and upload the code, and put the sensor on a stationary table and wait for about a minute. Then try to move away from or move closer to the infrared motion sensor and observe whether the LED turns ON or OFF automatically.

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.

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

Move to the Infrared Motion Sensor



Move away from the Infrared Motion Sensor



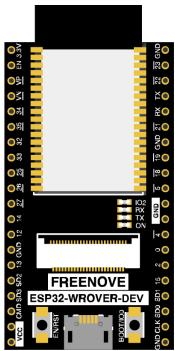
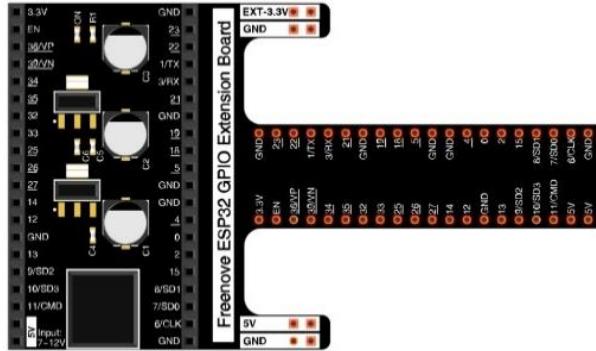
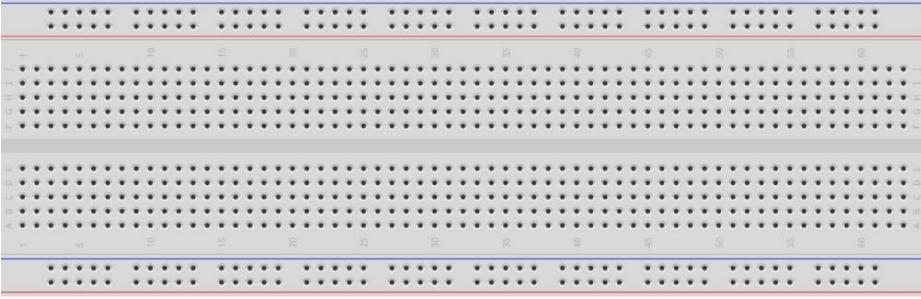
Chapter 26 Attitude Sensor MPU6050

In this chapter, we will learn about a MPU6050 attitude sensor which integrates an accelerometer and gyroscope.

Project 26.1 Read a MPU6050 Sensor Module

In this project, we will read acceleration and gyroscope data of the MPU6050 sensor

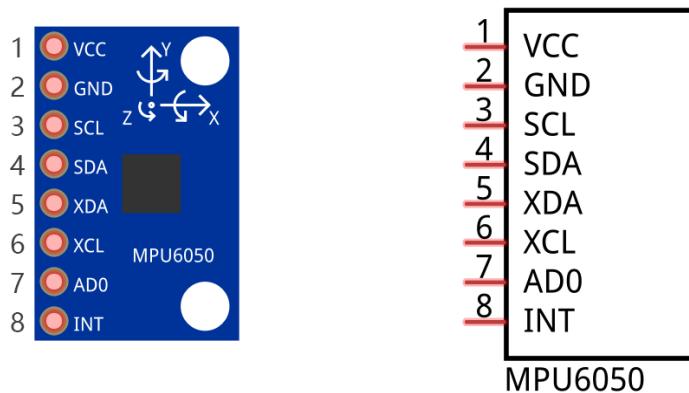
Component List

ESP32-WROVER x1	GPIO Extension Board x1
	
Breadboard x1	
Jumper F/M x4	MPU6050 x1
	

Component knowledge

MPU6050

MPU6050 sensor module is a complete 6-axis motion tracking device. It combines a 3-axis gyroscope, a 3-axis accelerometer and a DMP (Digital Motion Processor) all in a small package. The settings of the accelerometer and gyroscope of MPU6050 can be changed. A precision wide range digital temperature sensor is also integrated to compensate data readings for changes in temperature, and temperature values can also be read. The MPU6050 Module follows the I2C communication protocol and the default address is 0x68. MPU6050 is widely used to assist with balancing vehicles, robots and aircraft, mobile phones and other products which require stability to control stability and attitude or which need to sense same.



The port description of the MPU6050 module is as follows:

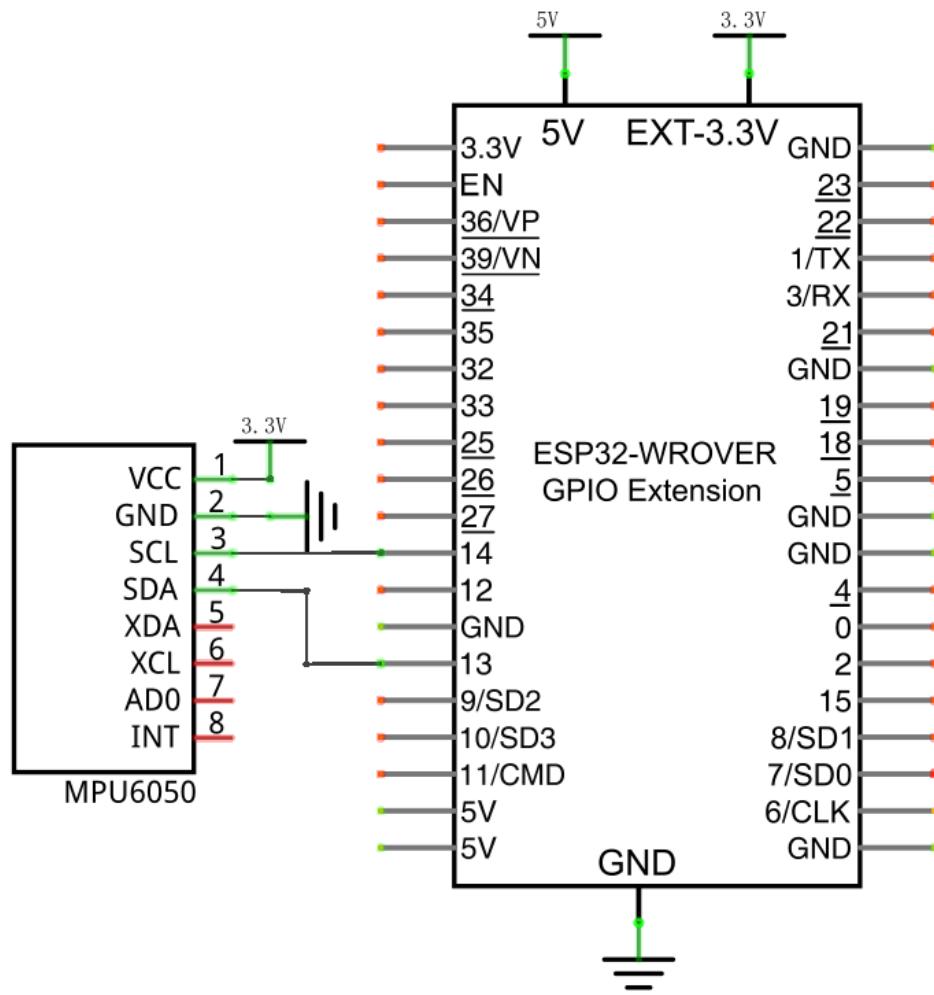
Pin name	Pin number	Description
VCC	1	Positive pole of power supply with voltage 5V
GND	2	Negative pole of power supply
SCL	3	I2C communication clock pin
SDA	4	I2C communication data pin
XDA	5	I2C host data pin which can be connected to other devices.
XCL	6	I2C host clock pin which can be connected to other devices.
AD0	7	I2C address bit control pin. Low level: the device address is 0x68 High level: the device address is 0x69
INT	8	Output interrupt pin

For more detail, please refer to datasheet.

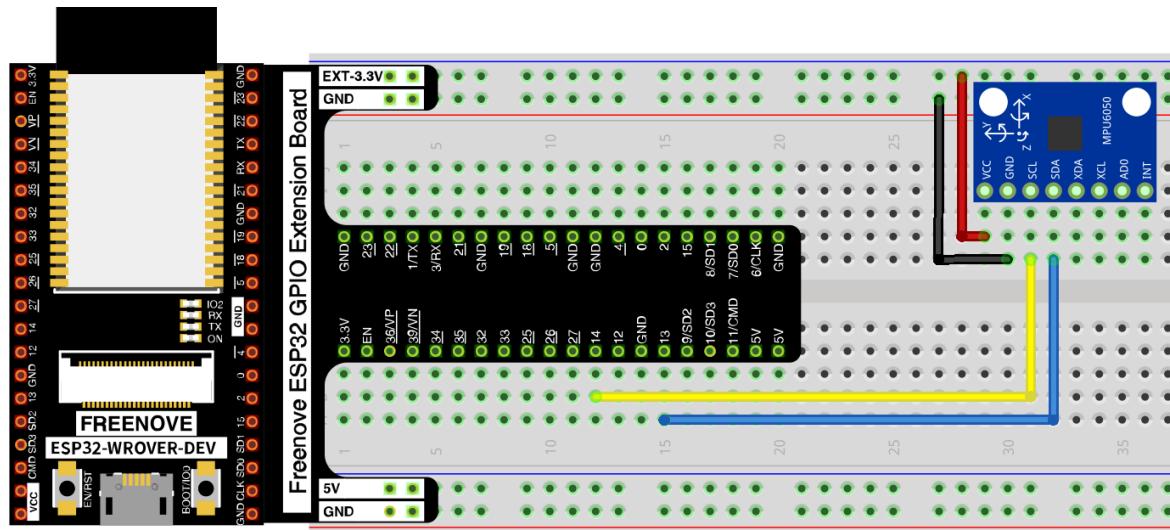
Circuit

Note that the power supply voltage for MPU6050 module is 5V in the circuit.

Schematic diagram



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



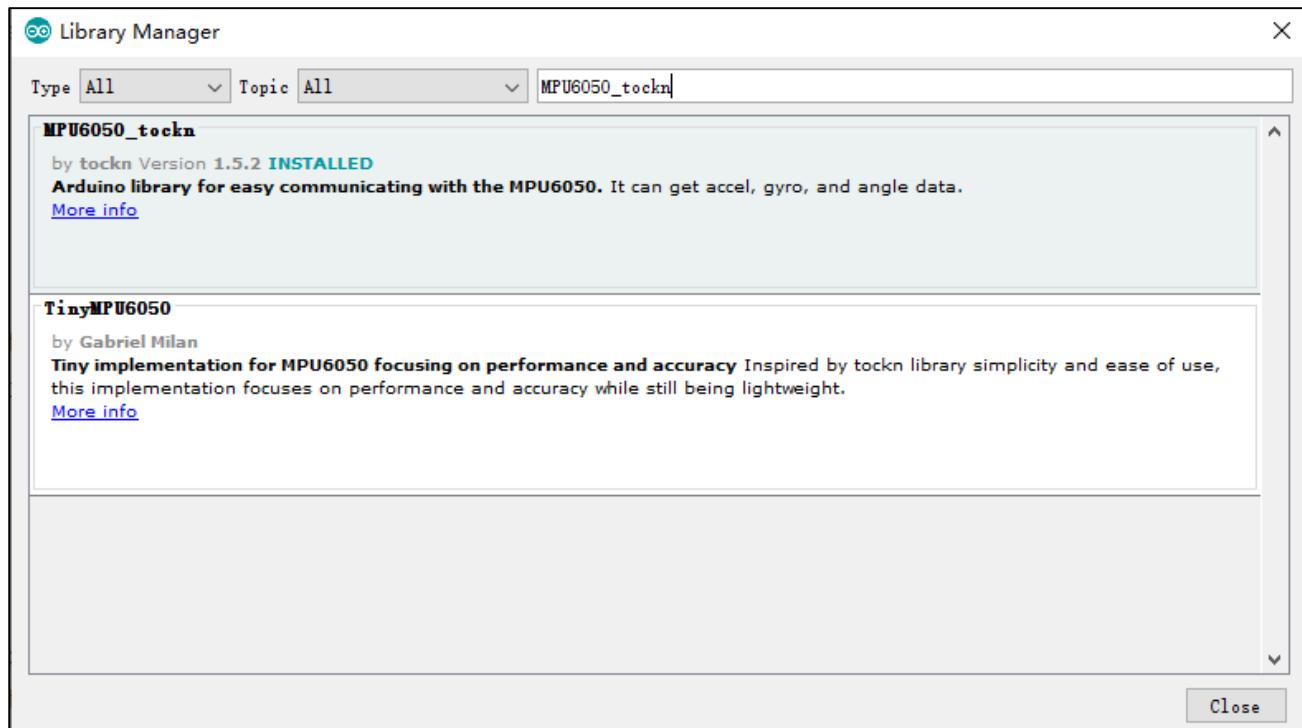
Sketch

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

```
Sketch_26.1_Acceleration_Detection | Arduino 1.8.13 Hourly Build 2020/02/19 03:33
File Edit Sketch Tools Help
Sketch_26.1_Acceleration_Detection
26 void loop() {
27     if(millis() - timer > 1000){ //each second printf the data
28         mpu6050.update(); //update the MPU6050
29         getMotion6(); //gain the values of Acceleration and Gyroscope value
30         Serial.print("\na/g:\t");
31         Serial.print(ax); Serial.print("\t");
32         Serial.print(ay); Serial.print("\t");
33         Serial.print(az); Serial.print("\t");
34         Serial.print(gx); Serial.print("\t\t");
35         Serial.print(gy); Serial.print("\t\t");
36         Serial.println(gz);
37         Serial.print("a/g:\t");
38         Serial.print((float)ax / 16384); Serial.print("g\t");
39         Serial.print((float)ay / 16384); Serial.print("g\t");
40         Serial.print((float)az / 16384); Serial.print("g\t");
41         Serial.print((float)gx / 131); Serial.print("d/s \t");
42         Serial.print((float)gy / 131); Serial.print("d/s \t");
43         Serial.print((float)gz / 131); Serial.print("d/s \n");
44         timer = millis();
45     }
46 }
47 void getMotion6(void){
48     ax=mpu6050.getRawAccX(); //gain the values of X axis acceleration raw data
49     ay=mpu6050.getRawAccY(); //gain the values of Y axis acceleration raw data
50     az=mpu6050.getRawAccZ(); //gain the values of Z axis acceleration raw data
51     gx=mpu6050.getRawGyroX(); //gain the values of X axis Gyroscope raw data
52     gy=mpu6050.getRawGyroY(); //gain the values of Y axis Gyroscope raw data
53     gz=mpu6050.getRawGyroZ(); //gain the values of Z axis Gyroscope raw data
54 }
```

Done uploading.

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

1 ESP32 Wrover Module on COM6

Download the code to ESP32-WROVER, 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:

```

=====
Calculating gyro offsets
DO NOT MOVE MPU6050...
Done!
X : -2.91
Y : 1.89
Z : -0.68
Program will start after 3 seconds
=====

a/g:    1464      -116     15928      -194          -194          -194
a/g:    0.09g     -0.01g    0.97g     -1.48d/s   -1.48d/s   -1.48d/s

a/g:    1484      -76      15872      -191          -191          -191
a/g:    0.09g     -0.00g    0.97g     -1.46d/s   -1.46d/s   -1.46d/s

a/g:    1588      -40      16000      -193          -193          -193
a/g:    0.10g     -0.00g    0.98g     -1.47d/s   -1.47d/s   -1.47d/s
=====

 Autoscroll  Show timestamp Newline 115200 baud Clear output

```

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	<code>MPU6050 mpu6050(Wire); //Attach the IIC</code>
---	--

In the setup function, IIC and **MPU6050** are initialized and the offset difference of **MPU6050** is obtained.

13	<code>void setup() {</code>
----	-----------------------------

```

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	<code>void getMotion6(void){</code>
----	-------------------------------------

```

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 }
```

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/a/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.

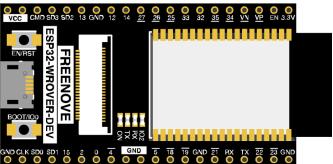
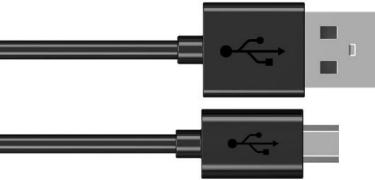
Chapter 27 Bluetooth

This chapter mainly introduces how to make simple data transmission through Bluetooth of ESP32-WROVER and mobile phones.

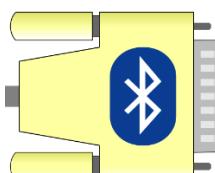
Project 27.1 is classic Bluetooth and Project 27.2 is low power Bluetooth. If you are an iPhone user, please start with Project 27.2.

Project 27.1 Bluetooth Passthrough

Component List

ESP32-WROVER x1	Micro USB Wire x1
	

In this tutorial we need to use a Bluetooth APP called Serial Bluetooth Terminal to assist in the experiment. If you've not installed it yet, please do so by clicking: <https://www.appsapk.com/serial-bluetooth-terminal/> The following is its logo.





Component knowledge

ESP32'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.

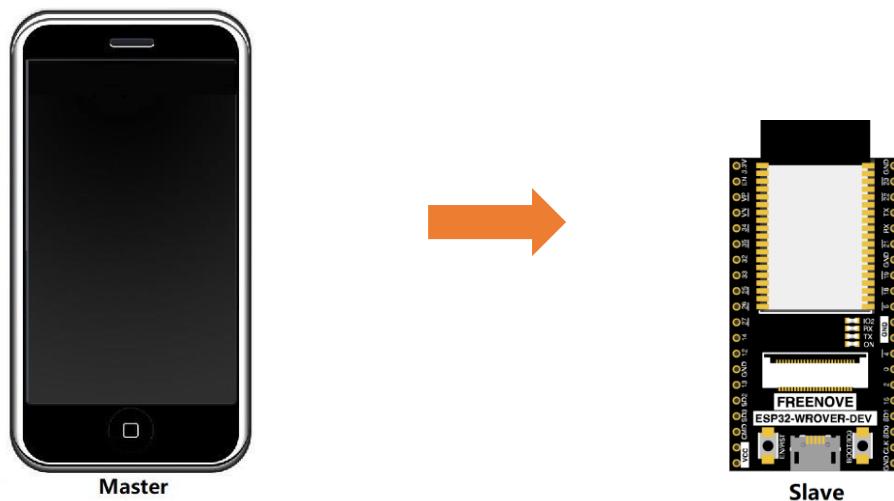
Master mode

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

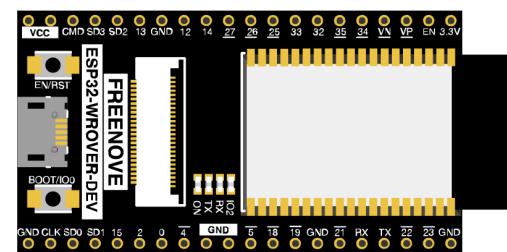
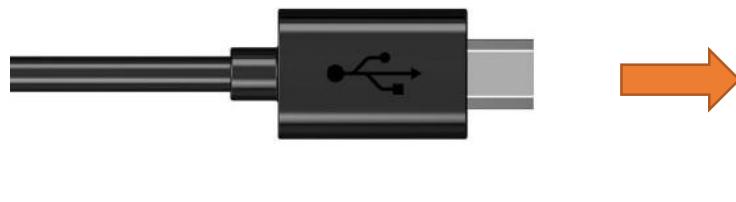
The Bluetooth module in slave mode can only accept connection request from a host computer, but cannot initiate a connection request. After connecting with a host device, it can send data to or receive from the host device.

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, they are usually in master mode and ESP32 in slave mode.



Circuit

Connect Freenove ESP32 to the computer using the USB cable.



Sketch

Sketch_27.1_SerialToSerialBT

A screenshot of the Arduino IDE interface. The title bar says "SerialToSerialBT | Arduino 1.8.13 Hourly Build 2020/02/19 03:33". The menu bar includes File, Edit, Sketch, Tools, and Help. The toolbar has icons for checkmark, play, file, upload, and download. The code editor window contains the following sketch:

```
1 #include "BluetoothSerial.h"
2
3 BluetoothSerial SerialBT;
4 String buffer;
5 void setup() {
6     Serial.begin(115200);
7     SerialBT.begin("ESP32test"); //Bluetooth device name
8     Serial.println("\nThe device started, now you can pair it with bluetooth!");
9 }
10
11 void loop() {
12     if (Serial.available()) {
13         SerialBT.write(Serial.read());
14     }
15     if (SerialBT.available()) {
16         Serial.write(SerialBT.read());
17     }
18     delay(20);
19 }
```

The status bar at the bottom shows "Done Saving." followed by "Leaving... Hard resetting via RTS pin...".

Any concerns? ✉ support@freenove.com

Compile and upload the code to the ESP32-WROVER, open the serial monitor, and set the baud rate to 115200. When you see the serial printing out the character string as below, it indicates that the Bluetooth of ESP32 is ready and waiting to connect with the mobile phone.

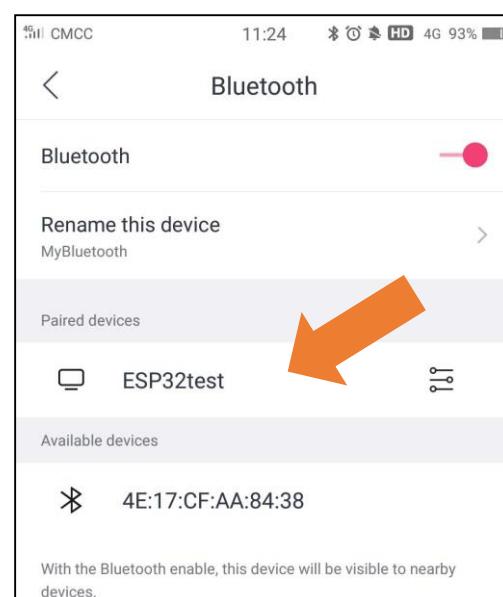
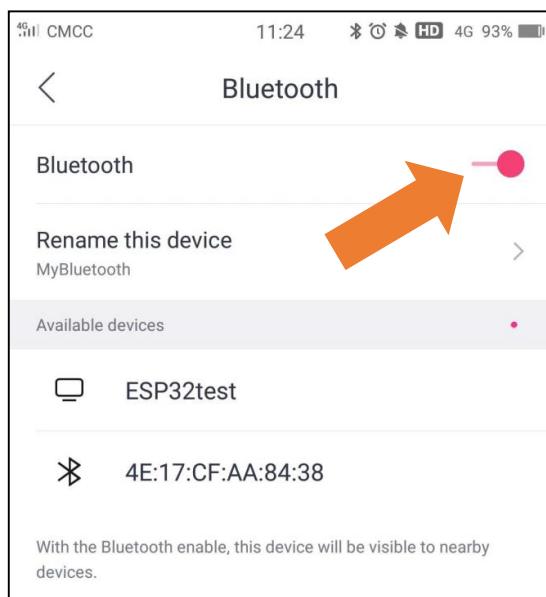
```
The device started, now you can pair it with bluetooth!
```

Autoscroll Show timestamp Newline 115200 baud Clear output

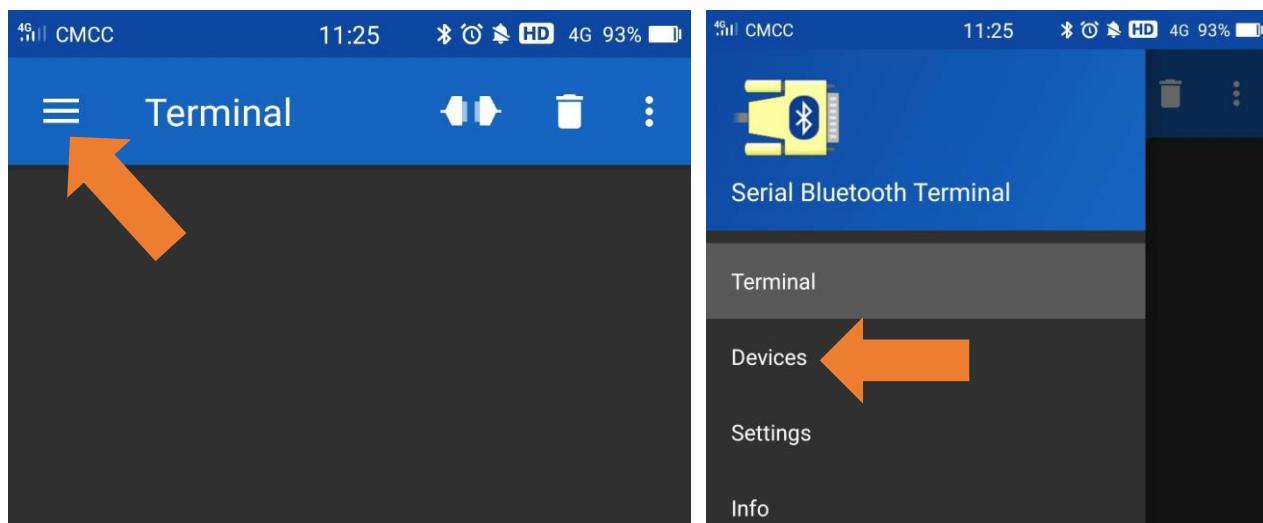
Make sure that the Bluetooth of your phone has been turned on and Serial Bluetooth Terminal has been installed.



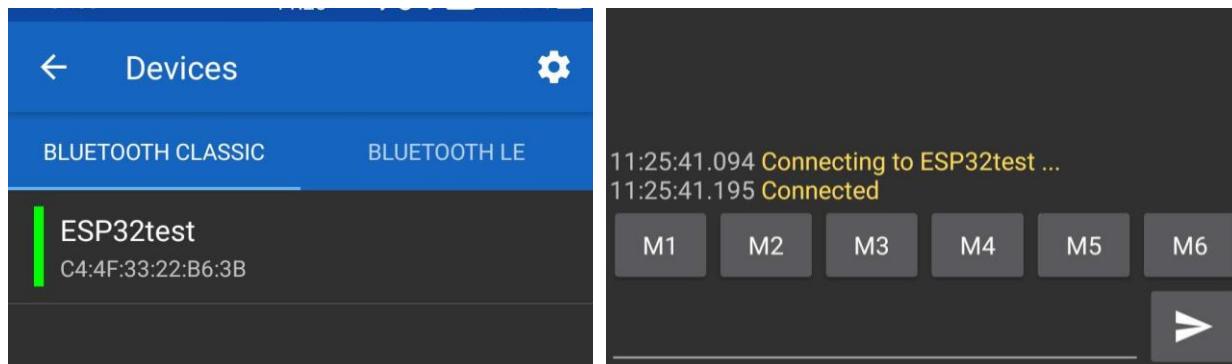
Click "Search" to search Bluetooth devices nearby and select "ESP32 test" to connect to.



Turn on software APP, click the left of the terminal. Select "Devices"

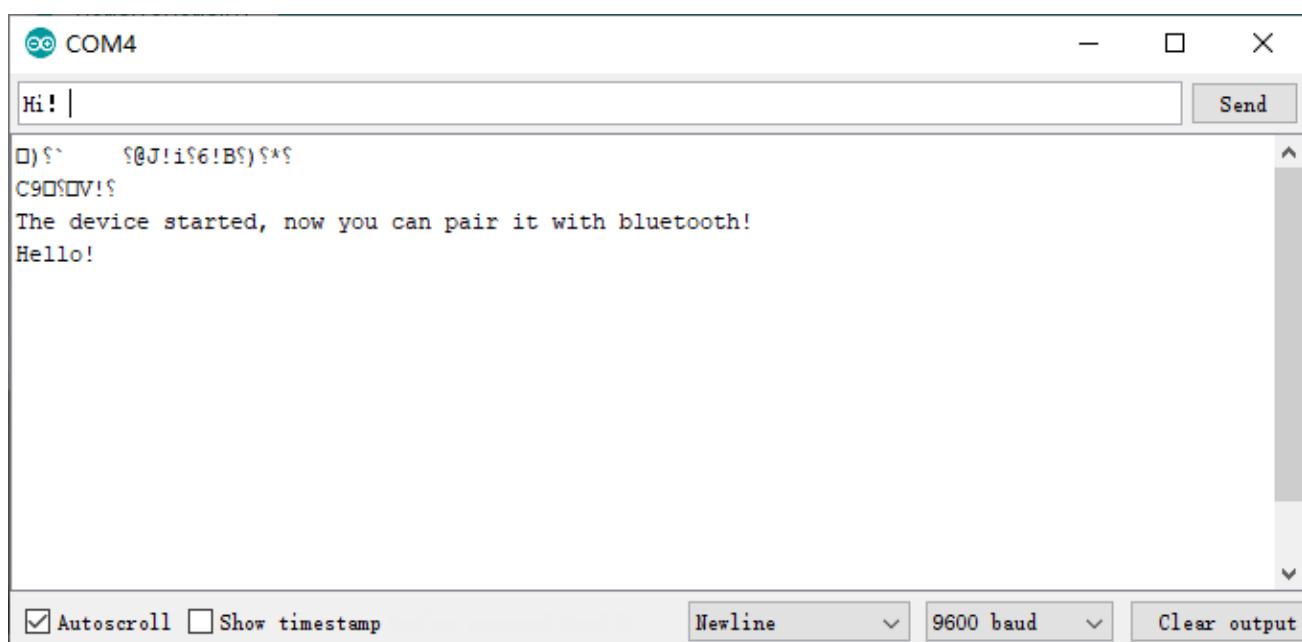


Select ESP32test in classic Bluetooth mode, and a successful connecting prompt will appear as shown on the right illustration.

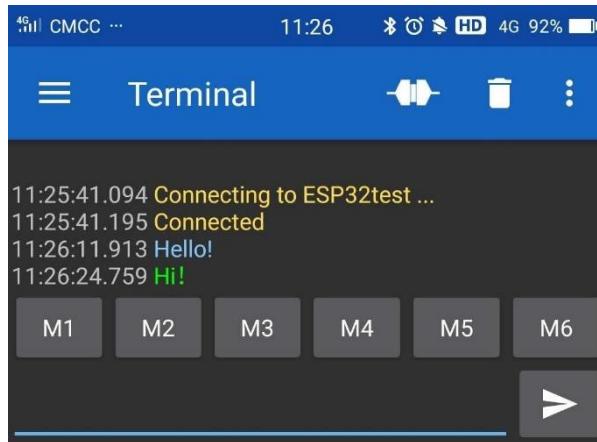


And now data can be transferred between your mobile phone and computer via ESP32-WROVER.

Send 'Hello!' from your phone, when the computer receives it, reply "Hi" to your phone.



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



Reference

Class BluetoothSerial

This is a class library used to operate **BluetoothSerial**, which can directly read and set **BluetoothSerial**.

Here are some member functions:

begin(localName, isMaster): Initialization function of the Bluetooth

name: name of Bluetooth module; Data type: String

isMaster: bool type, whether to set Bluetooth as Master. By default, it is false.

available(): acquire digits sent from the buffer, if not, return 0.

read(): read data from Bluetooth, data type of return value is int.

readString(): read data from Bluetooth, data type of return value is String.

write(val): send an int data val to Bluetooth.

write(str): send an SString data str to Bluetooth.

write(buf, len): Sends the first len data in the buf Array to Bluetooth.

setPin(const char *pin): set a four-digit Bluetooth pairing code. By default, it is 1234

connect(remoteName): connect a Bluetooth named remoteName, data type: String

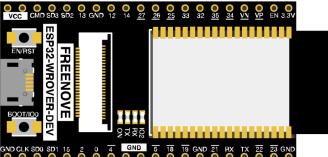
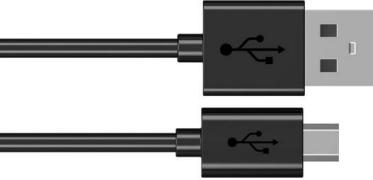
connect(remoteAddress []): connect the physical address of Bluetooth, data type: uint8-t.

disconnect(): disconnect all Bluetooth devices.

end(): disconnect all Bluetooth devices and turn off the Bluetooth, release all occupied space

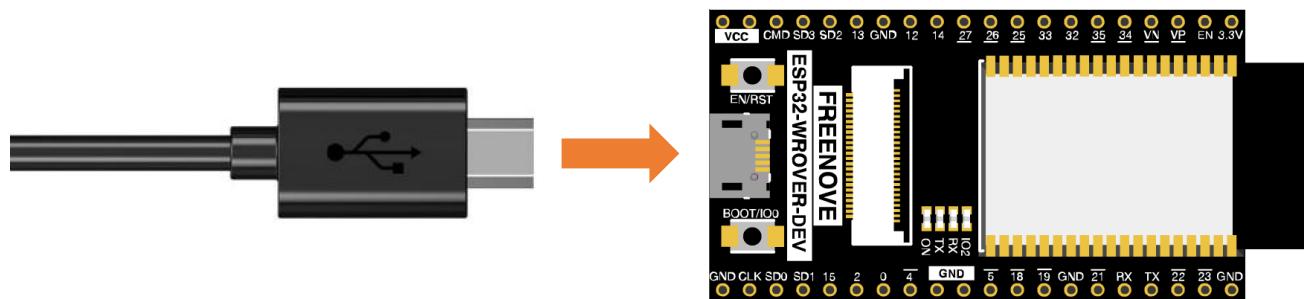
Project 27.2 Bluetooth Low Energy Data Passthrough

Component List

ESP32-WROVER x1	Micro USB Wire x1
	

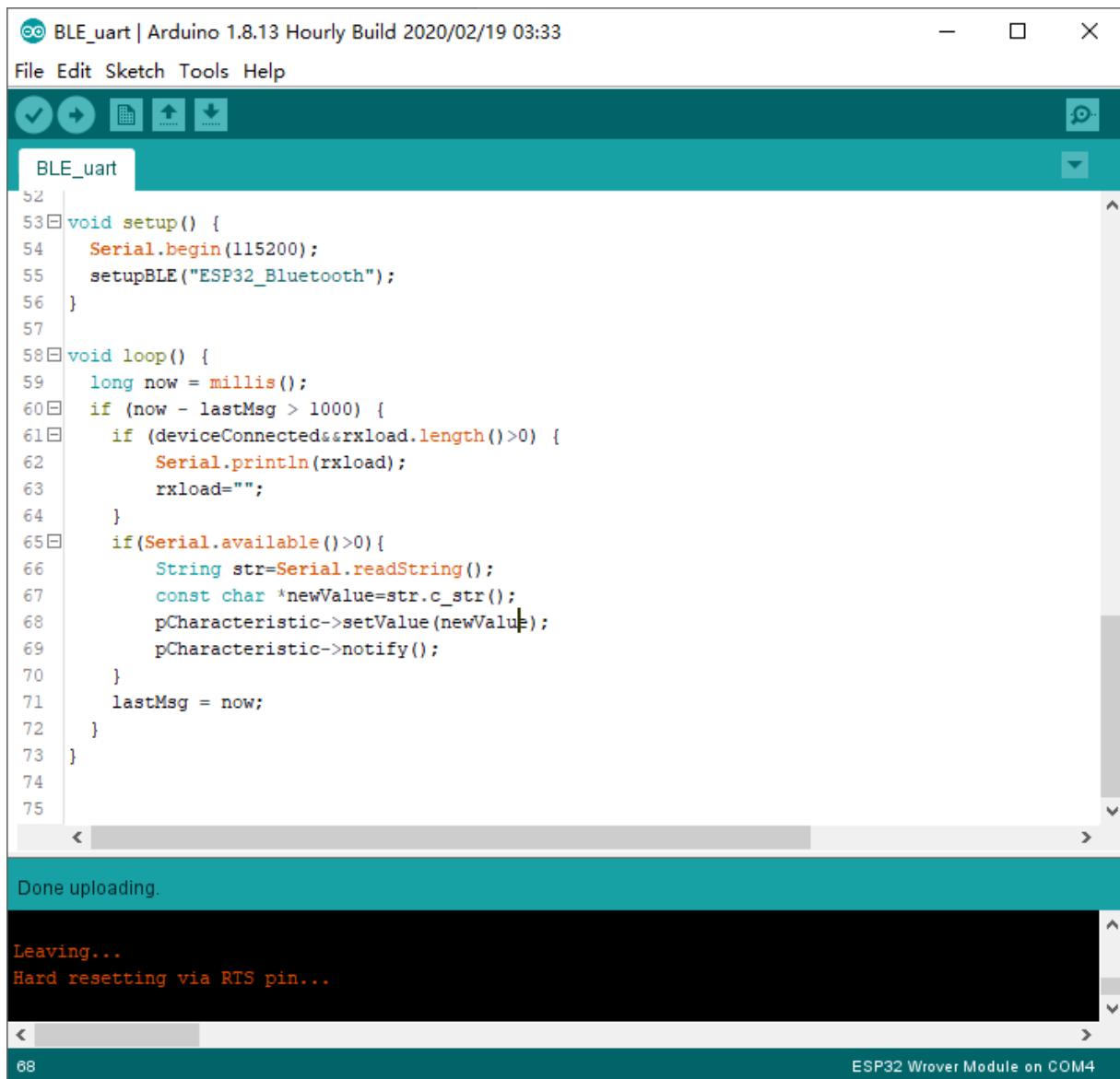
Circuit

Connect Freenove ESP32 to the computer using the USB cable.



Sketch

Sketch_27.2_BLE



```

BLE_uart | Arduino 1.8.13 Hourly Build 2020/02/19 03:33
File Edit Sketch Tools Help
BLE_uart
52
53 void setup() {
54     Serial.begin(115200);
55     setupBLE("ESP32_Bluetooth");
56 }
57
58 void loop() {
59     long now = millis();
60     if (now - lastMsg > 1000) {
61         if (deviceConnected&&rxload.length()>0) {
62             Serial.println(rxload);
63             rxload="";
64         }
65         if(Serial.available()>0){
66             String str=Serial.readString();
67             const char *newValue=str.c_str();
68             pCharacteristic->setValue(newValue);
69             pCharacteristic->notify();
70         }
71         lastMsg = now;
72     }
73 }
74
75
Done uploading.

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

```

ESP32 Wrover Module on COM4

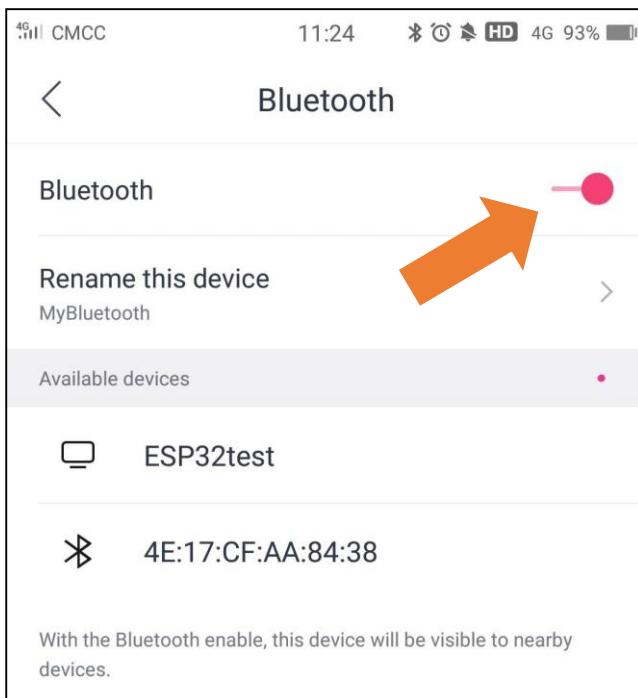
Serial Bluetooth

Compile and upload code to ESP32, the operation is similar to the last section.

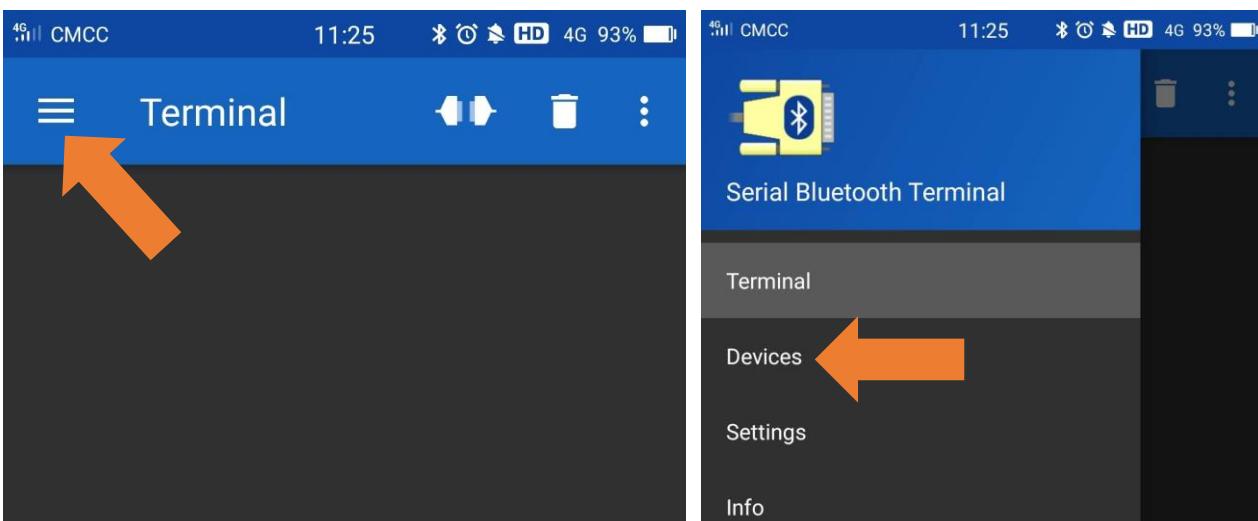
First, make sure you've turned on the mobile phone Bluetooth, and then open the software.



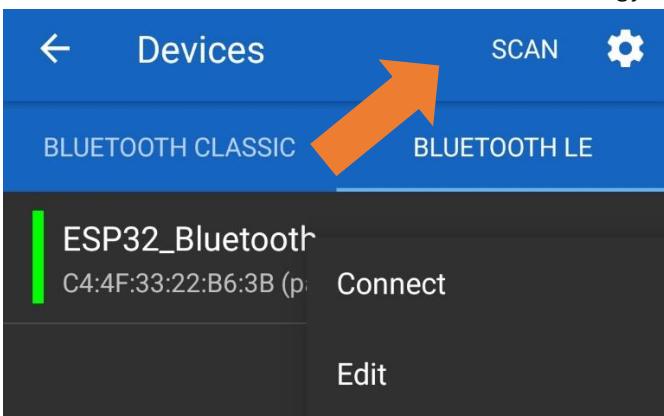
Click "Search" to search Bluetooth devices nearby and select "ESP32 test" to connect to.



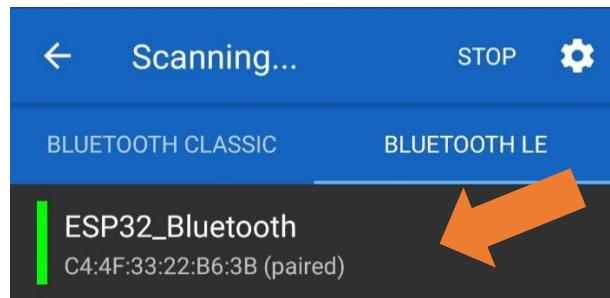
Turn on software APP, click the left of the terminal. Select "Devices"



Select BLUETOOTHLE, click SCAN to scan Low Energy Bluetooth devices nearby.



Select "ESP32-Bluetooth"



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 Project27.2 to ESP32.

Step2. Click on serial monitor.

```

Sketch_27_2_BLE_USART | Arduino 1.8.13
File Edit Sketch Tools Help
Sketch_27_2_BLE_USART
1 // This sketch shows how to use BLE and USART on the same chip.
2 // ESP32 communicates with the phone by BLE and sends incoming data via a serial port
3 // www.freenove.com
4 // Modification: 2020/07/11
5
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 String rxload="Test\r\n";
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"

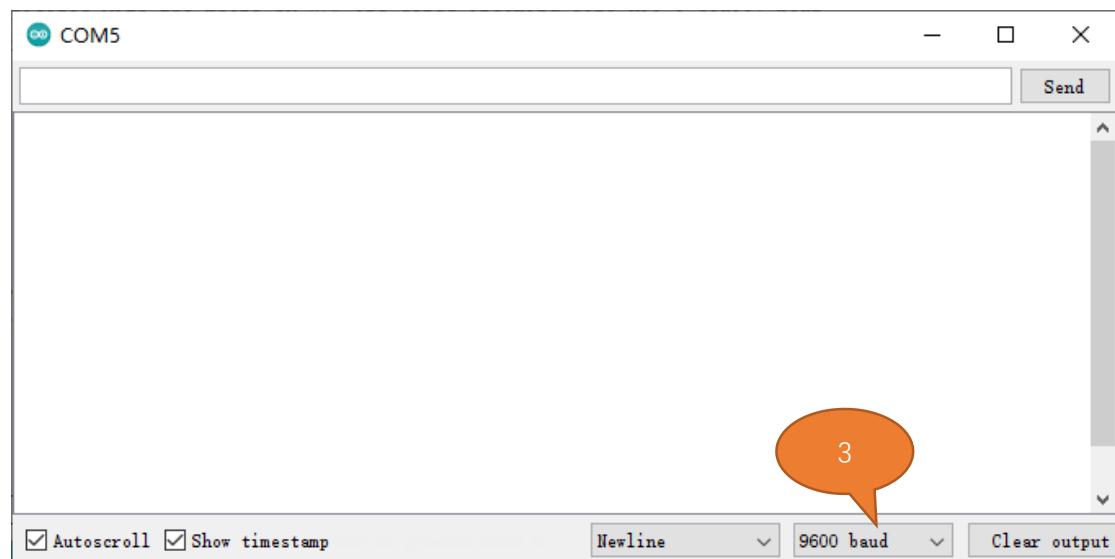
```

Compiling sketch...

E:\arduino\arduino-1.8.13\arduino-builder -dump-prefs -logger=machine -hardware E:\arduino\arduino-1.8.13\hardware -hardware C:\Users\PCVA\Documents\Arduino\Hardware\esp32-esp-wrover-hardware

ESP32 Wrover Module, Default, QIO, 80MHz, 921600, None on COM5

Step3. Set baud rate to 9600.

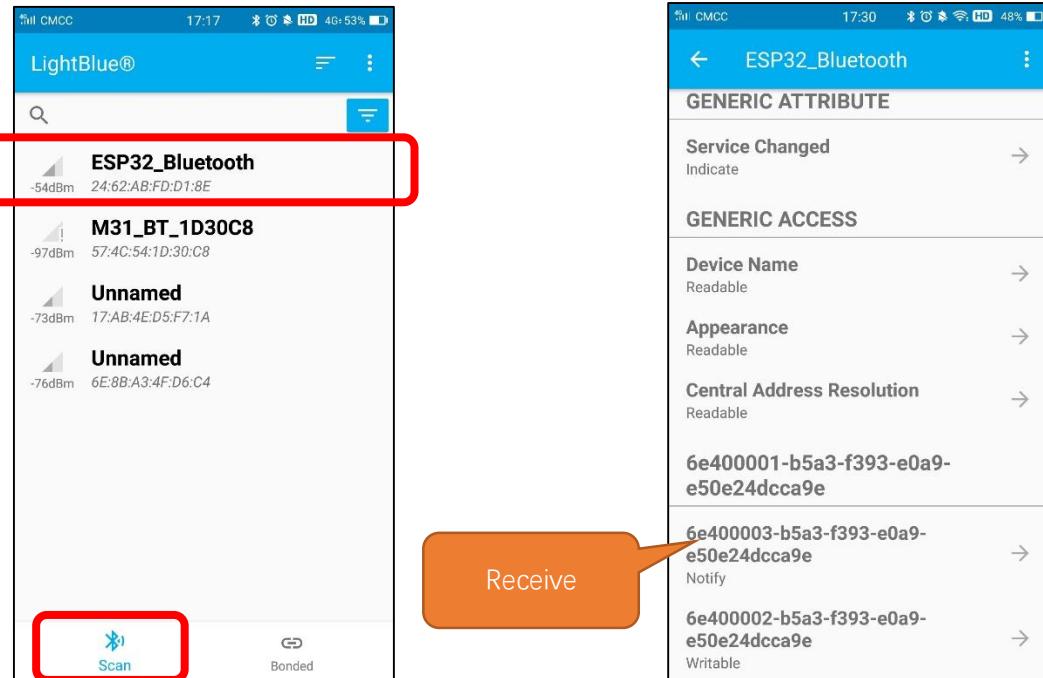


Turn ON Bluetooth on your phone, and open the Lightblue APP.

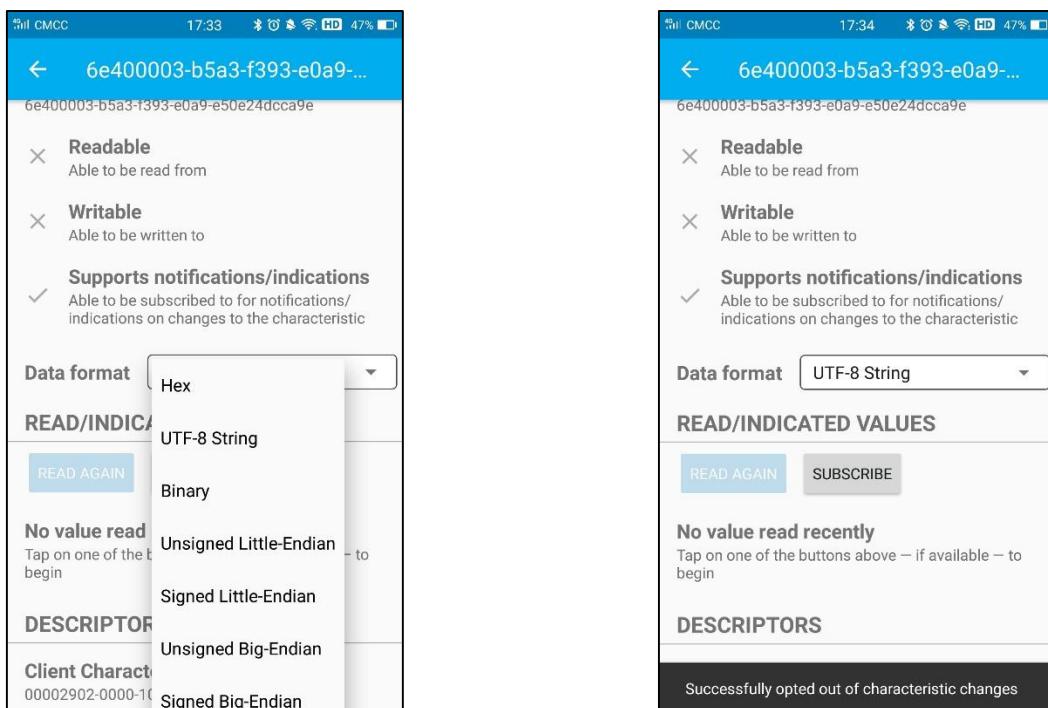


Any concerns? [✉ support@freenove.com](mailto:support@freenove.com)

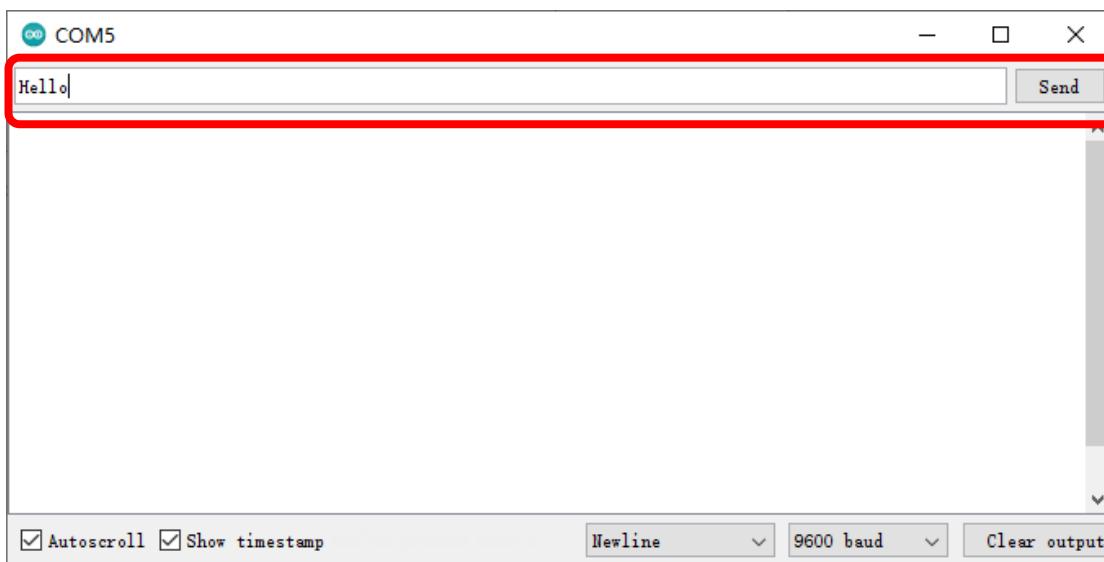
In the Scan page, swipe down to refresh the name of Bluetooth that the phone searches for. Click ESP32_Bluetooth.



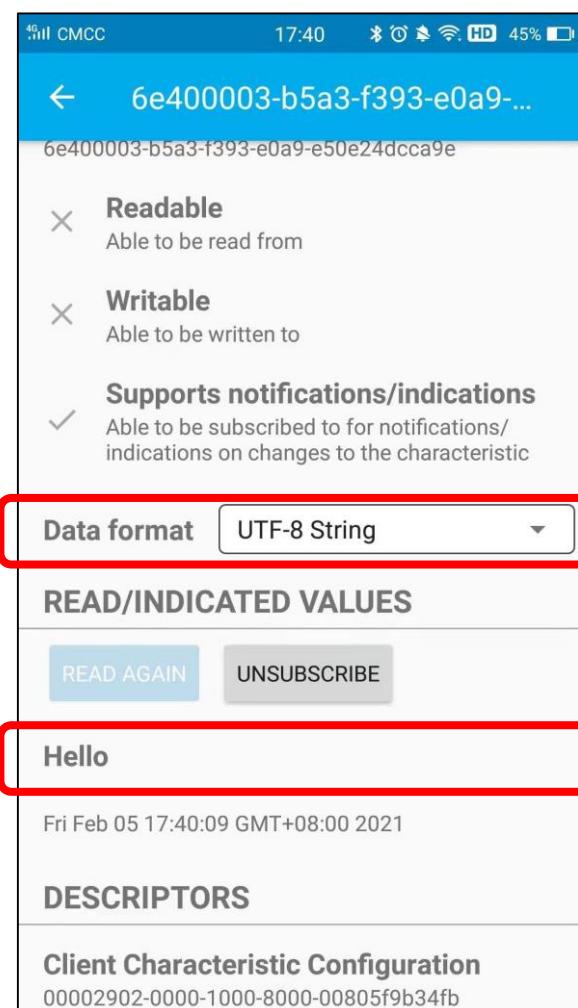
Click "Receive". Select the appropriate Data format in the box to the right of Data Format. For example, HEX for hexadecimal, utf-string for character, Binary for Binary, etc. Then click SUBSCRIBE.



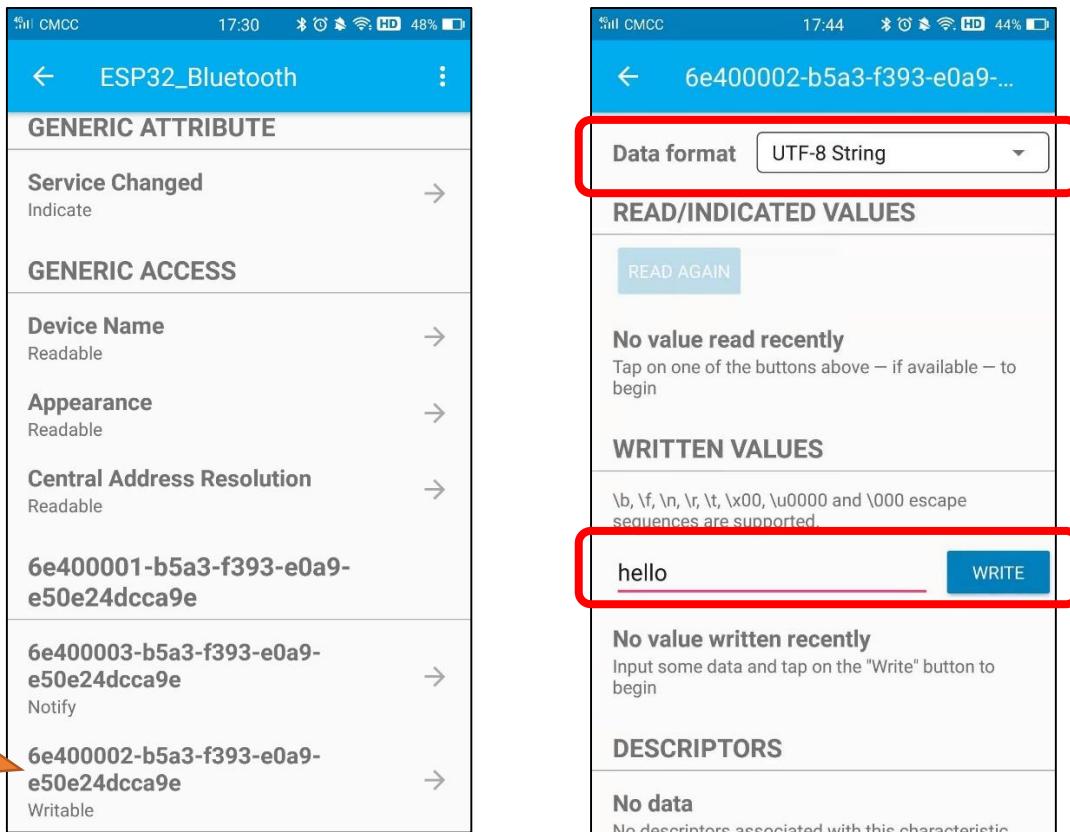
Back to the serial monitor on your computer. You can type anything in the left border of Send, and then click Send.



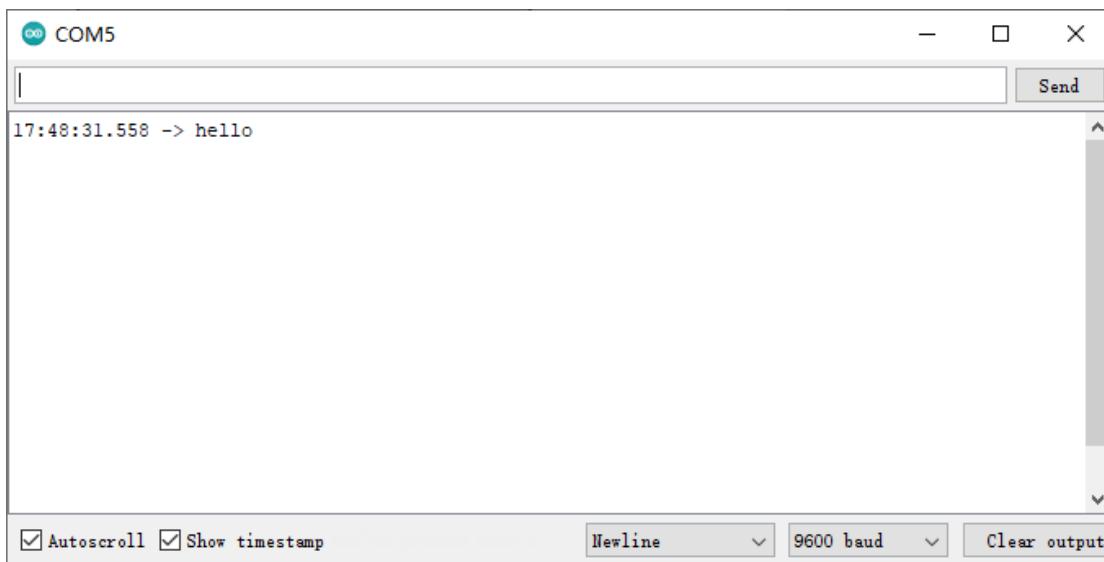
And then you can see the mobile Bluetooth has received the message.



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.



And now data can be transferred between your mobile phone and computer via ESP32-WROVER.

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 String rxload="Test\n";
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
17 class MyServerCallbacks: public BLEServerCallbacks {
18     void onConnect(BLEServer* pServer) {
19         deviceConnected = true;
20     };
21     void onDisconnect(BLEServer* pServer) {
22         deviceConnected = false;
23     }
24 };
25
26 class MyCallbacks: public BLECharacteristicCallbacks {
27     void onWrite(BLECharacteristic *pCharacteristic) {
28         std::string rxValue = pCharacteristic->getValue();
29         if (rxValue.length() > 0) {
30             rxload="";
31             for (int i = 0; i < rxValue.length(); i++) {
32                 rxload +=(char)rxValue[i];
33             }
34         }
35     }
36 };
37
38 void setupBLE(String BLEName) {
39     const char *ble_name=BLEName.c_str();
40     BLEDevice::init(ble_name);
41     BLEServer *pServer = BLEDevice::createServer();
42     pServer->setCallbacks(new MyServerCallbacks());
```

Any concerns? ✉ support@freenove.com

```

43    BLEService *pService = pServer->createService(SERVICE_UUID);
44    pCharacteristic=
45    pService->createCharacteristic(CHARACTERISTIC_UUID_RX,BLECharacteristic::PROPERTY_NOTIFY);
46    pCharacteristic->addDescriptor(new BLE2902());
47    BLECharacteristic *pCharacteristic =
48    pService->createCharacteristic(CHARACTERISTIC_UUID_RX,BLECharacteristic::PROPERTY_WRITE);
49    pCharacteristic->setCallbacks(new MyCallbacks());
50    pService->start();
51    pServer->getAdvertising()->start();
52    Serial.println("Waiting a client connection to notify..."); 
53 }
54
55 void setup() {
56   Serial.begin(9600);
57   setupBLE("ESP32_Bluetooth");
58 }
59
60 void loop() {
61   long now = millis();
62   if (now - lastMsg > 1000) {
63     if (deviceConnected&&rxload.length()>0) {
64       Serial.println(rxload);
65       rxload="";
66     }
67     if(Serial.available()>0) {
68       String str=Serial.readString();
69       const char *newValue=str.c_str();
70       pCharacteristic->setValue(newValue);
71       pCharacteristic->notify();
72     }
73     lastMsg = now;
74   }
75 }
```

Define the specified UUID number for BLE vendor.

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"

Write a Callback function for BLE server to manage connection of BLE.

```

17 class MyServerCallbacks: public BLEServerCallbacks {
18     void onConnect(BLEServer* pServer) {
19         deviceConnected = true;
20     };
21     void onDisconnect(BLEServer* pServer) {
22         deviceConnected = false;
23     }
24 };

```

Write Callback function with BLE features. When it is called, as the mobile terminal send data to ESP32, it will store them into reload.

```

26 class MyCallbacks: public BLECharacteristicCallbacks {
27     void onWrite(BLECharacteristic *pCharacteristic) {
28         std::string rxValue = pCharacteristic->getValue();
29         if (rxValue.length() > 0) {
30             rxload="";
31             for (int i = 0; i < rxValue.length(); i++) {
32                 rxload +=(char)rxValue[i];
33             }
34         }
35     }
36 };

```

Initialize the BLE function and name it.

```
55 setupBLE("ESP32_Bluetooth");
```

When the mobile phone send data to ESP32 via BLE Bluetooth, it will print them out with serial port; When the serial port of ESP32 receive data, it will send them to mobile via BLE Bluetooth.

```

59 long now = millis();
60 if (now - lastMsg > 1000) {
61     if (deviceConnected&&rxload.length()>0) {
62         Serial.println(rxload);
63         rxload="";
64     }
65     if(Serial.available()>0) {
66         String str=Serial.readString();
67         const char *newValue=str.c_str();
68         pCharacteristic->setValue(newValue);
69         pCharacteristic->notify();
70     }
71     lastMsg = now;
72 }

```



The design for creating the BLE server is:

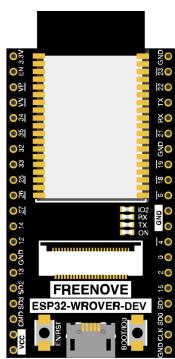
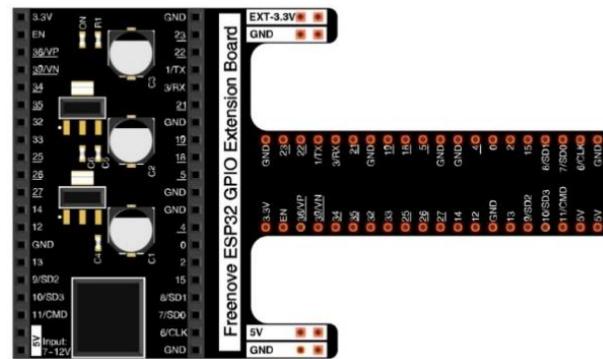
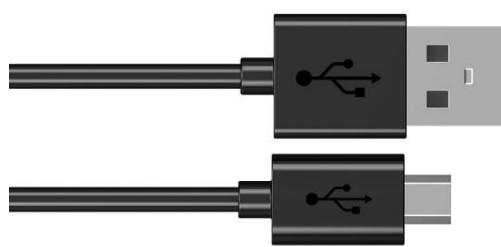
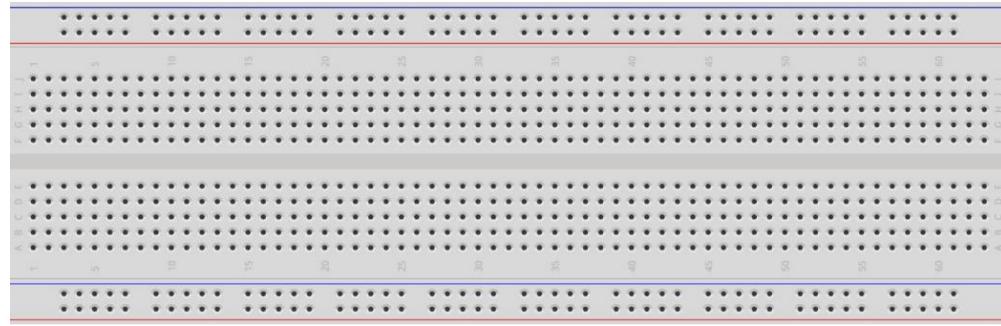
1. Create a BLE Server
2. Create a BLE Service
3. Create a BLE Characteristic on the Service
4. Create a BLE Descriptor on the characteristic
5. Start the service.
6. Start advertising.

```
38 void setupBLE(String BLEName) {  
39     const char *ble_name=BLEName.c_str();  
40     BLEDevice::init(ble_name);  
41     BLEServer *pServer = BLEDevice::createServer();  
42     pServer->setCallbacks(new MyServerCallbacks());  
43     BLEService *pService = pServer->createService(SERVICE_UUID);  
44     pCharacteristic=  
45         pService->createCharacteristic(CHARACTERISTIC_UUID_TX,BLECharacteristic::PROPERTY_NOTIFY);  
46     pCharacteristic->addDescriptor(new BLE2902());  
47     BLECharacteristic *pCharacteristic =  
48         pService->createCharacteristic(CHARACTERISTIC_UUID_RX,BLECharacteristic::PROPERTY_WRITE);  
49     pCharacteristic->setCallbacks(new MyCallbacks());  
50     pService->start();  
51     pServer->getAdvertising()->start();  
52     Serial.println("Waiting a client connection to notify...");  
53 }
```

Project 27.3 Bluetooth Control LED

In this section, we will control the LED with Bluetooth.

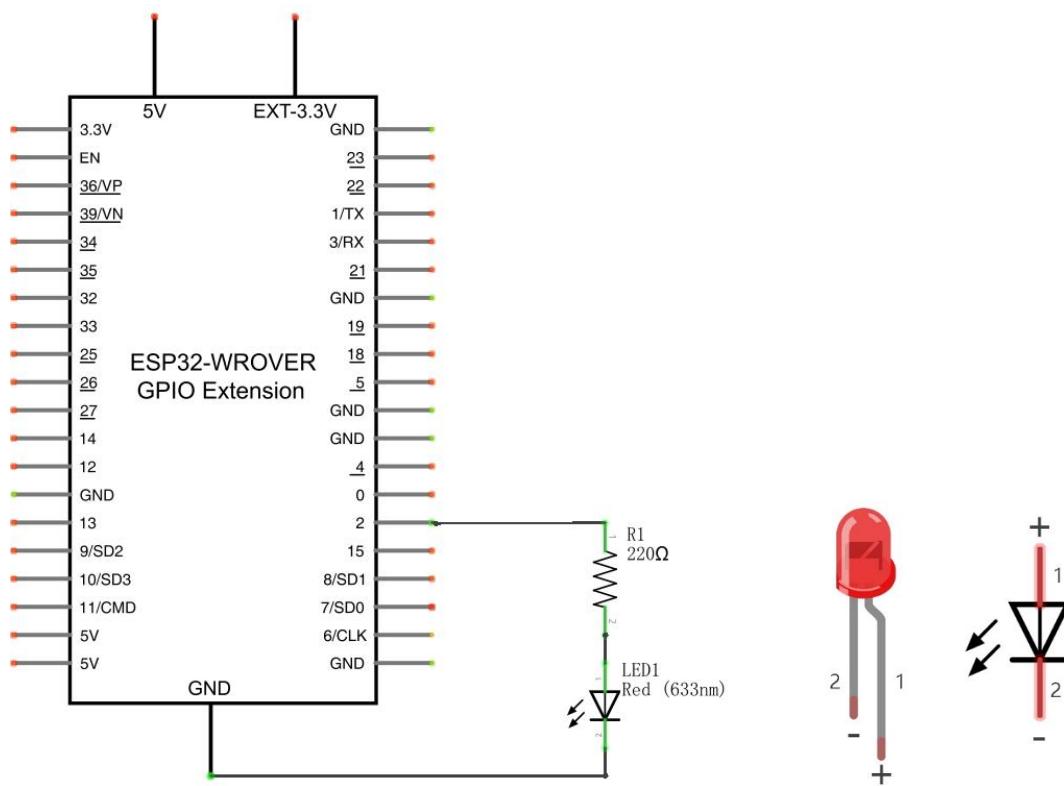
Component List

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

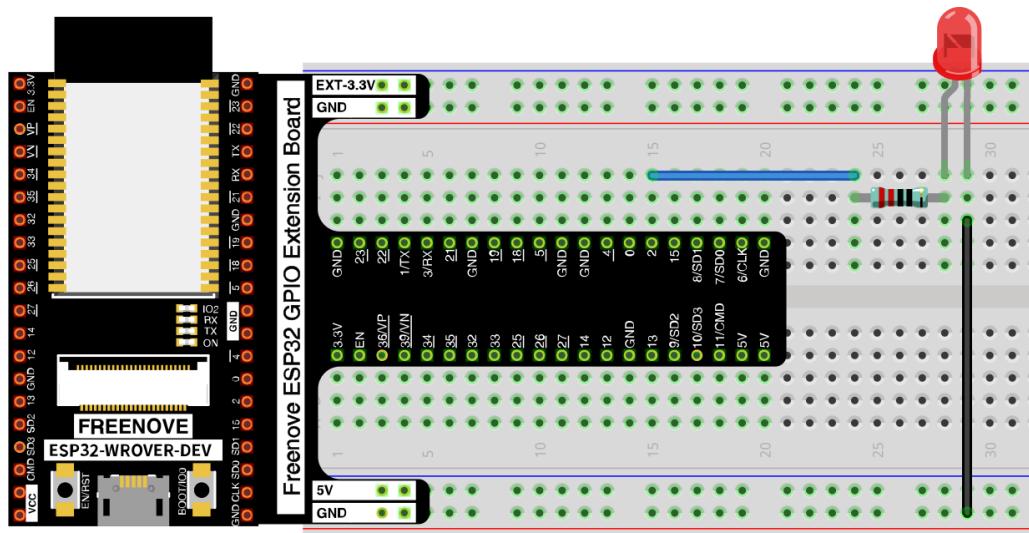
Circuit

Connect Freenove ESP32 to the computer using a USB cable.

Schematic diagram



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



Sketch

Sketch_27.3_Bluetooth_Control_LED

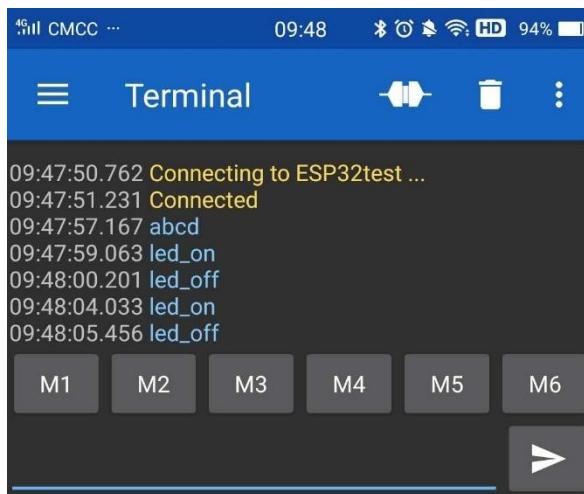
The screenshot shows the Arduino IDE interface with the following details:

- Title Bar:** bluetoothToLed | Arduino 1.8.13 Hourly Build 2020/02/19 03:33
- Menu Bar:** File Edit Sketch Tools Help
- Toolbar:** Includes icons for Save, Run, Stop, Upload, and Download.
- Sketch Name:** bluetoothToLed
- Code Area:** The code is a C++ program for an ESP32. It includes headers for `BluetoothSerial.h` and `string.h`. It defines a LED pin (pin 2) and uses a `BluetoothSerial` object named `SerialBT`. A buffer of size 20 is used to store incoming data. The `setup()` function initializes the LED pin as an output and starts the SerialBT and Serial ports at 115200 bps. It prints a message to the serial port indicating the device is started and ready to be paired. The `loop()` function reads data from the SerialBT port into the buffer. If the buffer contains "led_on", it turns the LED on (HIGH). If it contains "led_off", it turns the LED off (LOW). After processing, the buffer is cleared and reset to zero. Line numbers are present on the left side of the code.
- Serial Monitor:** Shows the text "Leaving..." followed by "Hard resetting via RTS pin...".
- Status Bar:** Shows "ESP32 Wrover Module on COM4".

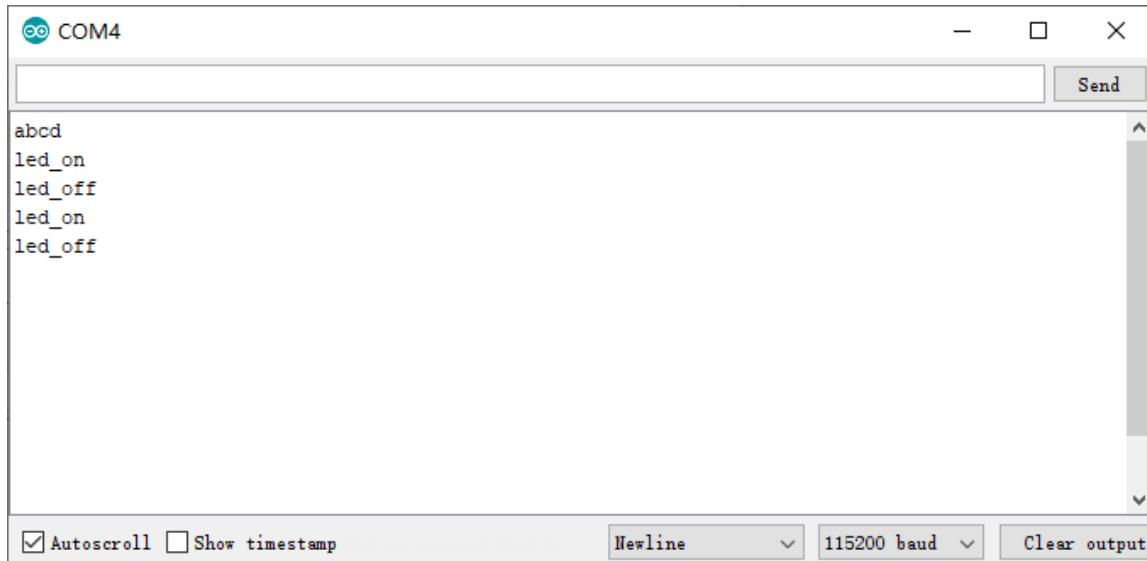


Compile and upload code to ESP32. The operation of the APP is the same as 27.1, you only need to change the sending content to "led_on" and "led_off" to operate LEDs on the ESP32-WROVER.

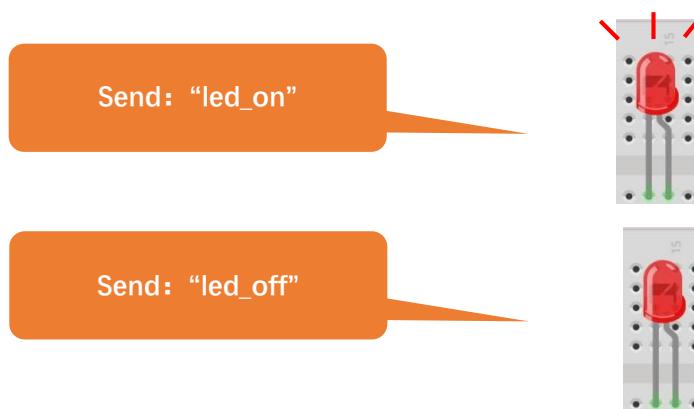
Data sent from mobile APP:



Display on the serial port of the computer:



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 "BluetoothSerial.h"
2 #include "string.h"
3 #define LED 2
4 BluetoothSerial SerialBT;
5 char buffer[20];
6 static int count = 0;
7 void setup() {
8     pinMode(LED, OUTPUT);
9     SerialBT.begin("ESP32test"); //Bluetooth device name
10    Serial.begin(115200);
11    Serial.println("\The device started, now you can pair it with Bluetooth! ");
12 }
13
14 void loop() {
15     while(SerialBT.available())
16     {
17         buffer[count] = SerialBT.read();
18         count++;
19     }
20     if(count>0){
21         Serial.print(buffer);
22         if(strncmp(buffer, "led_on", 6)==0) {
23             digitalWrite(LED, HIGH);
24         }
25         if(strncmp(buffer, "led_off", 7)==0) {
26             digitalWrite(LED, LOW);
27         }
28         count=0;
29         memset(buffer, 0, 20);
30     }
31 }
```

Use character string to handle function header file.

```
1 #include "string.h"
```

Define a buffer to receive data from Bluetooth, and use "count" to record the bytes of data received.

```
17 char buffer[20];
18 static int count = 0;
```

Initialize the classic Bluetooth and name it as "ESP32test"

```
26 SerialBT.begin("ESP32test"); //Bluetooth device name
```

When receive data, read the Bluetooth data and store it into buffer array.

```
15   while(SerialBT.available()) {
16       buffer[count] = SerialBT.read();
17       count++;
18   }
```

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.

```
22   if(strncmp(buffer, "led_on", 6)==0) {
23       digitalWrite(LED, HIGH);
24   }
25   if(strncmp(buffer, "led_off", 7)==0) {
26       digitalWrite(LED, LOW);
27   }
```

After comparing the content of array, to ensure successful transmission next time, please empty the array and set the count to zero.

```
28   count=0;
29   memset(buffer, 0, 20);
```

Reference

strncmp() functions are often used for string comparisons, which are accurate and stable.

```
int strncmp(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 Bluetooth Media by DAC

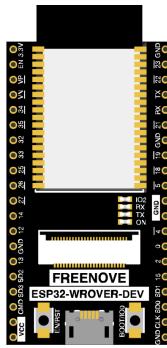
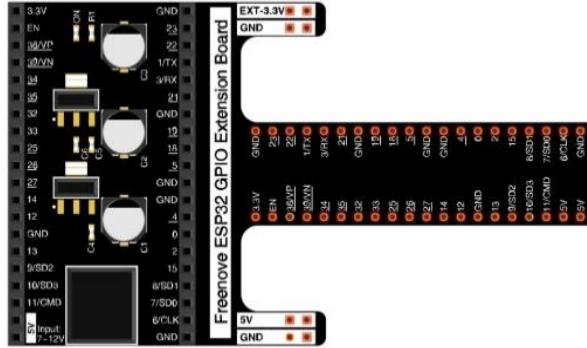
ESP32 integrates Classic Bluetooth and Bluetooth Low Energy(BLE). It can transmit not only simple data and orders, but also files including texts and audios. In this section, we will utilize the audio's receiving function of Bluetooth to receive music from mobile phones and play it.

Project 28.1 Playing Bluetooth Music through DAC

Use the Bluetooth audio receiving function of ESP32 to transcode the audio data from mobile phones and play the music through DAC output pin.

The accuracy of ESP32's DAC is only eight bits, so the music would be distorted to some extent using this tutorial.

Component List

ESP32-WROVER x1	GPIO Extension Board x1
	

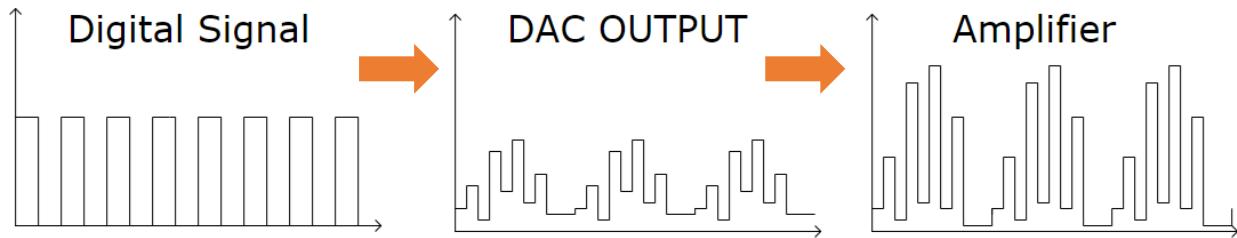
Micro USB Wire x1	Speaker
	



Component knowledge

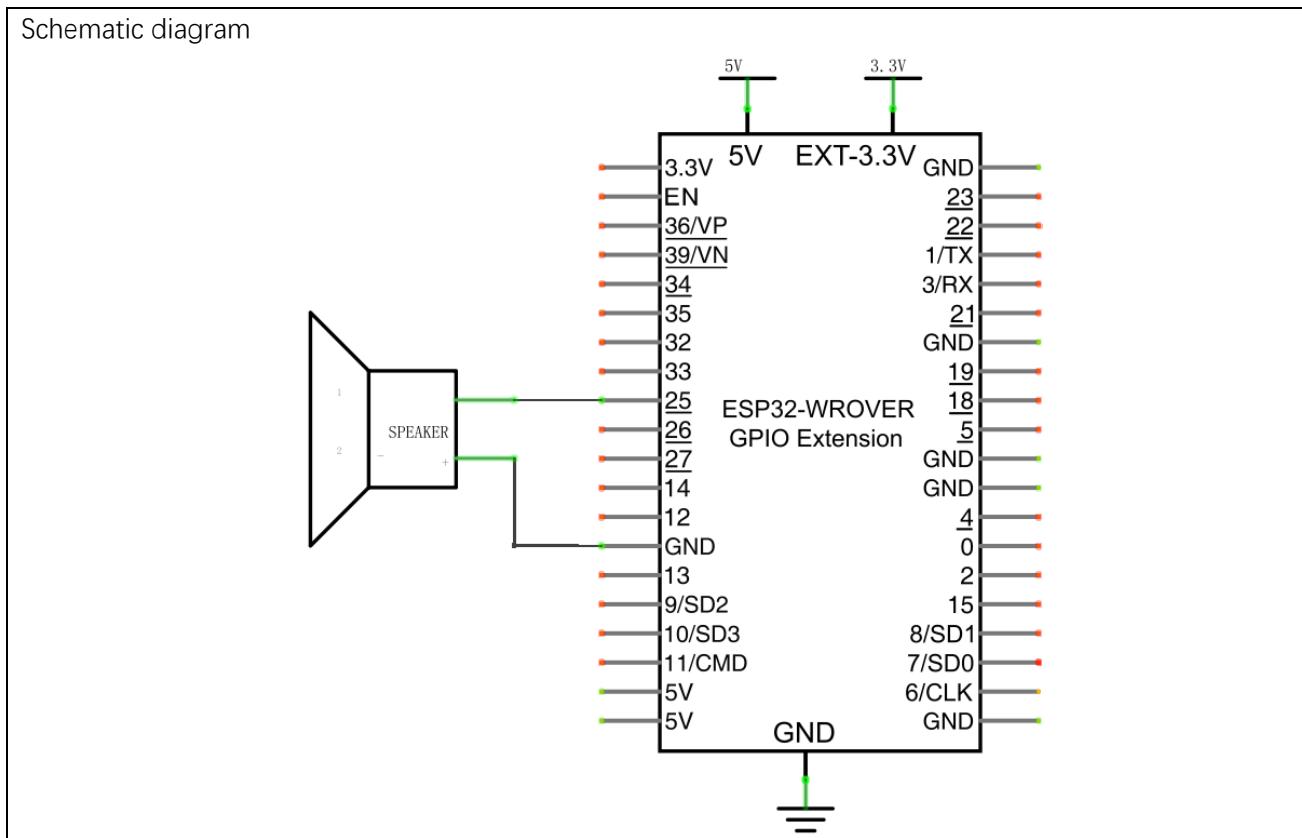
signal conversion

Bluetooth devices receive music data from mobile devices, which cannot play through earphones and speakers directly. To output DAC signal, Bluetooth devices need to decode these data with I2S decoding chip. The power of these audio signals is so small that it can only drive low-power music listening devices, such as earphone. Amplify the power of these DAC signals with power amplifier chip, so that it can drive relatively bigger-power music playing devices, such as speakers.

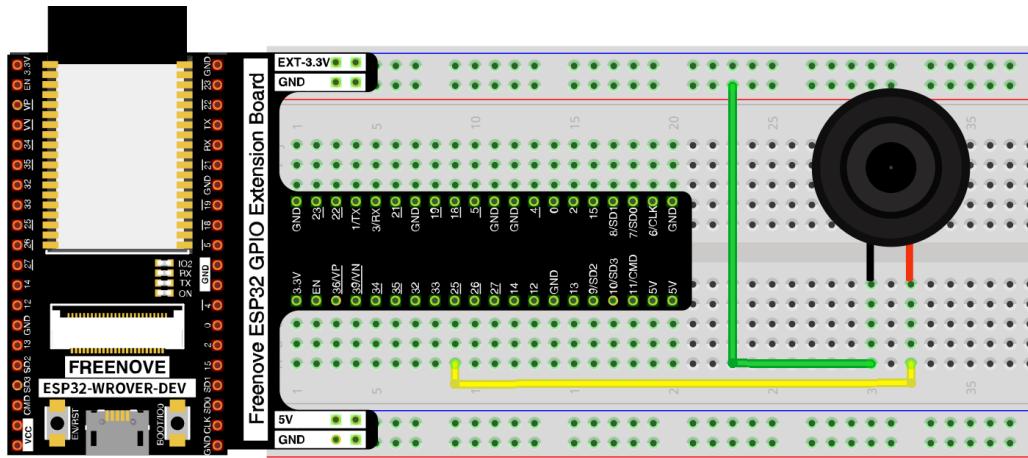


In this chapter, we use ESP32-WROVER's built-in audio decoding feature to convert the received Bluetooth data directly into an audio signal and output it via ESP32-WROVER's DAC pin.

Circuit



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



Sketch

Before compiling the code, follow these steps for the setting:

- 1, "Tools" → "Partition Scheme" → "Huge APP (3MB No OTA/1MB SPIFFS)";
- 2, "Tools" → "Flash Mode" → "DOUT";
- 3, "Tools" → "Flash Frequency" → "80MHz";

You can refer to the following picture for configuration

[Sketch_28.1_Bluetooth_Music_by_DAC](#)

Note: ESP32 board support packages are different and will cause compilation failures. We provide two codes, if you can't use it, please change another code.

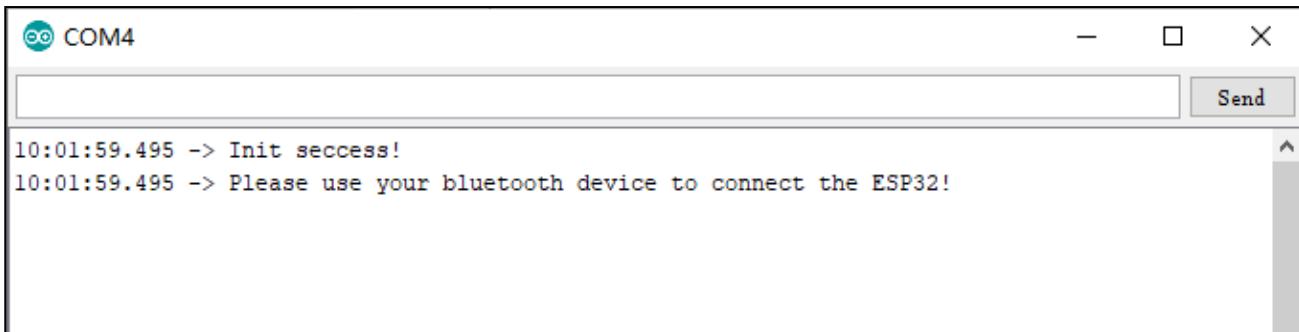
```

28.1 | Arduino 1.8.12
File Edit Sketch Tools Help
28.1 bt_api
34 void setup()
35 Serial.begin(9600);
36 SerialBT.begin();
37 Serial.println("bt_api");
38
39 esp_err_t
40 if (err == ESP_EOK)
41 err = i2s_config();
42
43 i2s_config_t i2s_config;
44 i2s_config.ticks_per_sample = 1024;
45 i2s_config.tx_pin_bit_order = I2S_PIN_ORDER_LSB;
46 i2s_config.tx_pinmux = I2S_PINMUX_0;
47 i2s_config.tx_baudrate = 44100;
48 i2s_config.tx_channel_map = I2S_CHANNEL_MAP_BOTH_CHANNELS;
49 i2s_config.tx_trig_src = I2S_TRIGGER_SOURCE_SOFTWARE;
50 i2s_config.tx_trig_level = I2S_TRIGGER_LEVEL_LOW;
51 i2s_config.tx_trig_polarity = I2S_TRIGGER_POLARITY_RISING;
52 i2s_config.tx_trig_invert = false;
53 i2s_config.tx_trig_invert = false;

```

Any concerns? ✉ support@freenove.com

Compile and upload the code to the ESP32-WROVER and open the serial monitor. ESP32 takes a few seconds to initialize the program. When you see the prompt as shown in the figure below, it means that the Bluetooth function of ESP32 is ready and waiting for the connection of other Bluetooth devices.



The screenshot shows a Windows-style serial monitor window titled "COM4". The text area contains two lines of blue text: "10:01:59.495 -> Init seccess!" and "10:01:59.495 -> Please use your bluetooth device to connect the ESP32!". A "Send" button is visible in the top right corner.

Please use your mobile phone to search and connect a Bluetooth device named "ESP32". After the connection is successful, you can use ESP32 to play the audio files in your mobile phone.



The following is the program code:

```
1 #include "BluetoothSerial.h"
2 #include "driver/i2s.h"
3 #include "nvs.h"
4 #include "nvs_flash.h"
5 #include "esp_bt.h"
6 #include "bt_app_core.h"
7 #include "bt_app_av.h"
8 #include "esp_bt_main.h"
9 #include "esp_bt_device.h"
10 #include "esp_gap_bt_api.h"
11 #include "esp_a2dp_api.h"
12 #include "esp_avrc_api.h"
13
14 #define CONFIG_CLASSIC_BT_ENABLED
15 #define CONFIG_BT_ENABLED
16 #define CONFIG_BLUEDROID_ENABLED
17
18 BluetoothSerial SerialBT;
19
20 static void bt_av_hdl_stack_evt(uint16_t event, void *p_param) {
```

```
21 if(event==0) {
22     /* initialize A2DP sink */
23     esp_a2d_register_callback(&bt_app_a2d_cb);
24     esp_a2d_sink_register_data_callback(bt_app_a2d_data_cb);
25     esp_a2d_sink_init();
26     /* initialize AVRCP controller */
27     esp_avrc_ct_init();
28     esp_avrc_ct_register_callback(bt_app_rc_ct_cb);
29     /* set discoverable and connectable mode, wait to be connected */
30     esp_bt_gap_set_scan_mode(ESP_BT_SCAN_MODE_CONNECTABLE_DISCOVERABLE);
31 }
32 }
33
34 void setup() {
35     Serial.begin(115200);
36     SerialBT.begin("ESP32");
37     Serial.println("Init secess! ");
38
39     esp_err_t err = nvs_flash_init();
40     if (err == ESP_ERR_NVS_NO_FREE_PAGES || err == ESP_ERR_NVS_NEW_VERSION_FOUND) {
41         ESP_ERROR_CHECK(nvs_flash_erase());
42         err = nvs_flash_init();
43     }
44     i2s_config_t i2s_config;
45     i2s_config.mode = (i2s_mode_t)(I2S_MODE_MASTER | I2S_MODE_TX | I2S_MODE_DAC_BUILT_IN);
46     i2s_config.bits_per_sample = I2S_BITS_PER_SAMPLE_24BIT;
47     i2s_config.sample_rate = 44100;
48     i2s_config.channel_format = I2S_CHANNEL_FMT_RIGHT_LEFT; //2-channels
49     i2s_config.communication_format = I2S_COMM_FORMAT_I2S_MSB;
50     i2s_config.intr_alloc_flags = 0;
51     i2s_config.dma_buf_count = 6;
52     i2s_config.dma_buf_len = 60;
53     i2s_config.tx_desc_auto_clear = true;
54     i2s_driver_install(I2S_NUM_0, &i2s_config, 0, NULL);
55     i2s_set_dac_mode(I2S_DAC_CHANNEL_BOTH_EN);
56     i2s_set_pin(I2S_NUM_0, NULL);
57
58     esp_bluedroid_init();
59     esp_bluedroid_enable();
60     bt_app_task_start_up();
61     bt_app_work_dispatch(bt_av_hdl_stack_evt, 0, NULL, 0, NULL);
62     Serial.println("Please use your Bluetooth device to connect the ESP32! ");
63 }
64 }
```

```

65 void loop() {
66     ;
67 }
```

Add program files related to Bluetooth and API interface files.

```

1 #include "BluetoothSerial.h"
2 #include "driver/i2s.h"
3 #include "nvs.h"
4 #include "nvs_flash.h"
5 #include "esp_bt.h"
6 #include "bt_app_core.h"
7 #include "bt_app_av.h"
8 #include "esp_bt_main.h"
9 #include "esp_bt_device.h"
10 #include "esp_gap_bt_api.h"
11 #include "esp_a2dp_api.h"
12 #include "esp_avrc_api.h"
```

Set the Bluetooth in slave mode through macro definition and use it to receive data from other devices.

```

14 #define CONFIG_CLASSIC_BT_ENABLED
15 #define CONFIG_BT_ENABLED
16 #define CONFIG_BLUEDROID_ENABLED
```

Initialize the serial port and set the baud rate to 115200; initialize Bluetooth and name it as "ESP32".

```

35 Serial.begin(115200);
36 SerialBT.begin("ESP32");
37 Serial.println("Init secess! ");
```

Define an I2S interface variable and initialize it.

```

44 i2s_config_t i2s_config;
45 i2s_config.mode = (i2s_mode_t)(I2S_MODE_MASTER | I2S_MODE_TX | I2S_MODE_DAC_BUILT_IN);
46 i2s_config.bits_per_sample = I2S_BITS_PER_SAMPLE_24BIT;
47 i2s_config.sample_rate = 44100;           // sampling frequency of audio data
48 i2s_config.channel_format = I2S_CHANNEL_FMT_RIGHT_LEFT; //Left and right channels
49 i2s_config.communication_format = I2S_COMM_FORMAT_I2S_MSB;
50 i2s_config.intr_alloc_flags = 0;           //Set interrupt priority
51 i2s_config.dma_buf_count = 6;             //Set up DMA data partitions
52 i2s_config.dma_buf_len = 60;              //Set the DMA capacity for each partition
53 i2s_config.tx_desc_auto_clear = true;      //Set automatic clearing of DMA data
54 i2s_driver_install(I2S_NUM_0, &i2s_config, 0, NULL); //Initialize I2S function
55 i2s_set_dac_mode(I2S_DAC_CHANNEL_BOTH_EN); //Set the DAC to dual channel mode
56 i2s_set_pin(I2S_NUM_0, NULL);            //Set the output pin as GPIO25
```

Initialize the Bluetooth hardware device, establish a Bluetooth thread task, and print out messages to prompt the user to take the next step.

```

58 esp_bluedroid_init();
59 esp_bluedroid_enable();
60 bt_app_task_start_up();
```

```
61     bt_app_work_dispatch(bt_av_hdl_stack_evt, 0, NULL, 0, NULL);  
62     Serial.println("Please use your Bluetooth device to connect the ESP32! ");
```

Bluetooth thread task: Set Bluetooth to slave mode; initialize Bluetooth command resolution function; set Bluetooth to be visible to other devices and in waiting for connection mode.

```
20 static void bt_av_hdl_stack_evt(uint16_t event, void *p_param) {  
21     if(event==0) {  
22         /* initialize A2DP sink */  
23         esp_a2d_register_callback(&bt_app_a2d_cb);  
24         esp_a2d_sink_register_data_callback(bt_app_a2d_data_cb);  
25         esp_a2d_sink_init();  
26         /* initialize AVRCP controller */  
27         esp_avrc_ct_init();  
28         esp_avrc_ct_register_callback(bt_app_rc_ct_cb);  
29         /* set discoverable and connectable mode, wait to be connected */  
30         esp_bt_gap_set_scan_mode(ESP_BT_SCAN_MODE_CONNECTABLE_DISCOVERABLE);  
31     }  
32 }
```



Chapter 29 Bluetooth Media by PCM5102A

In the previous section, ESP32's own DAC was used to output the audio signal, and obviously there was some distortion in the sound quality. In this section, with the help of PCM5102A chip, you will enjoy higher-quality music.

Project 29.1 Playing Bluetooth Music through PCM5102A

In this project, we will use PCM5102A chip to transcode audio data into stereo and output it.

Component List

ESP32-WROVER x1	GPIO Extension Board x1
Micro USB Wire x1	Audio Converter & Amplifier
Jumper F/M x4 Jumper F/F x2	

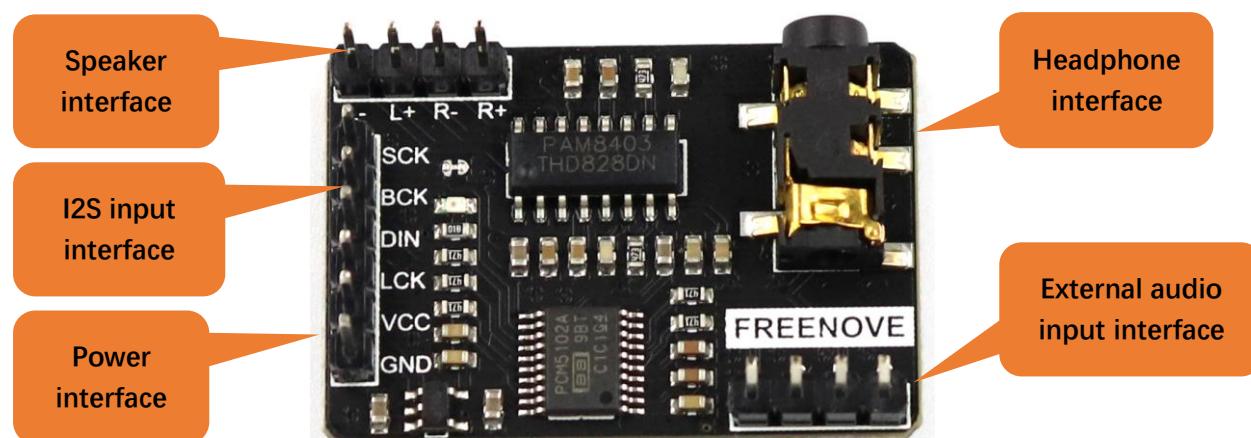
Component knowledge

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.

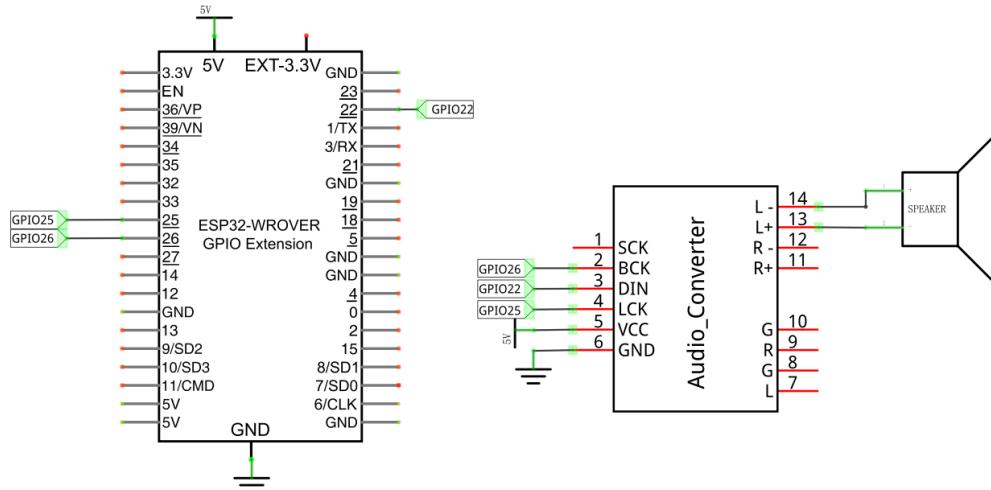
I2S input interface: connect to the device with I2S. Used to transcode audio data into DAC audio signals.

External audio input interface: connect to external audio equipment. Used to amplify externally input audio signals.

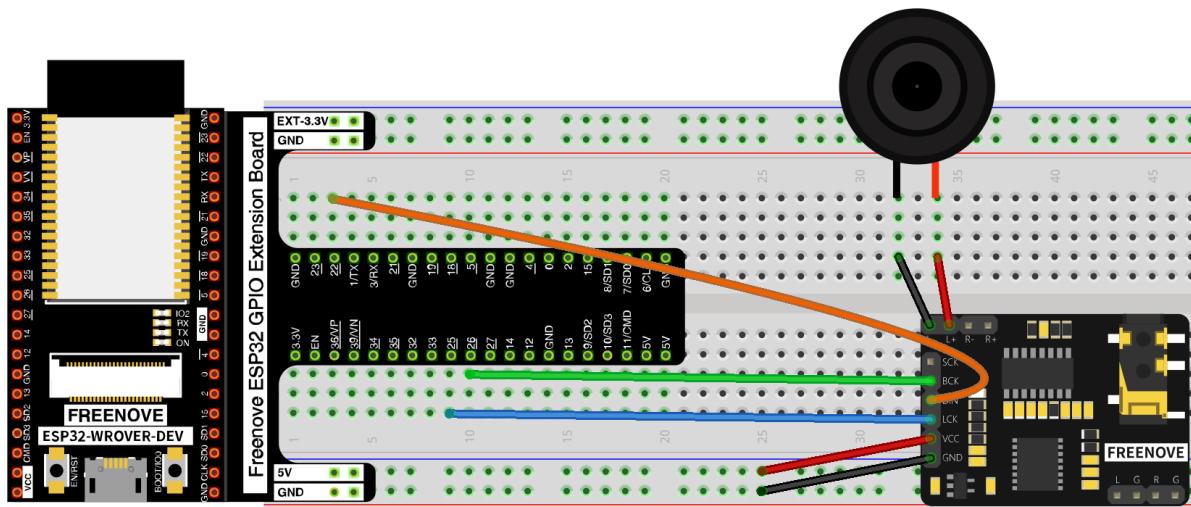
Power interface: connect to external power supply. External power supply selection range: 3.3V-5.0V.

Circuit

Schematic diagram



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

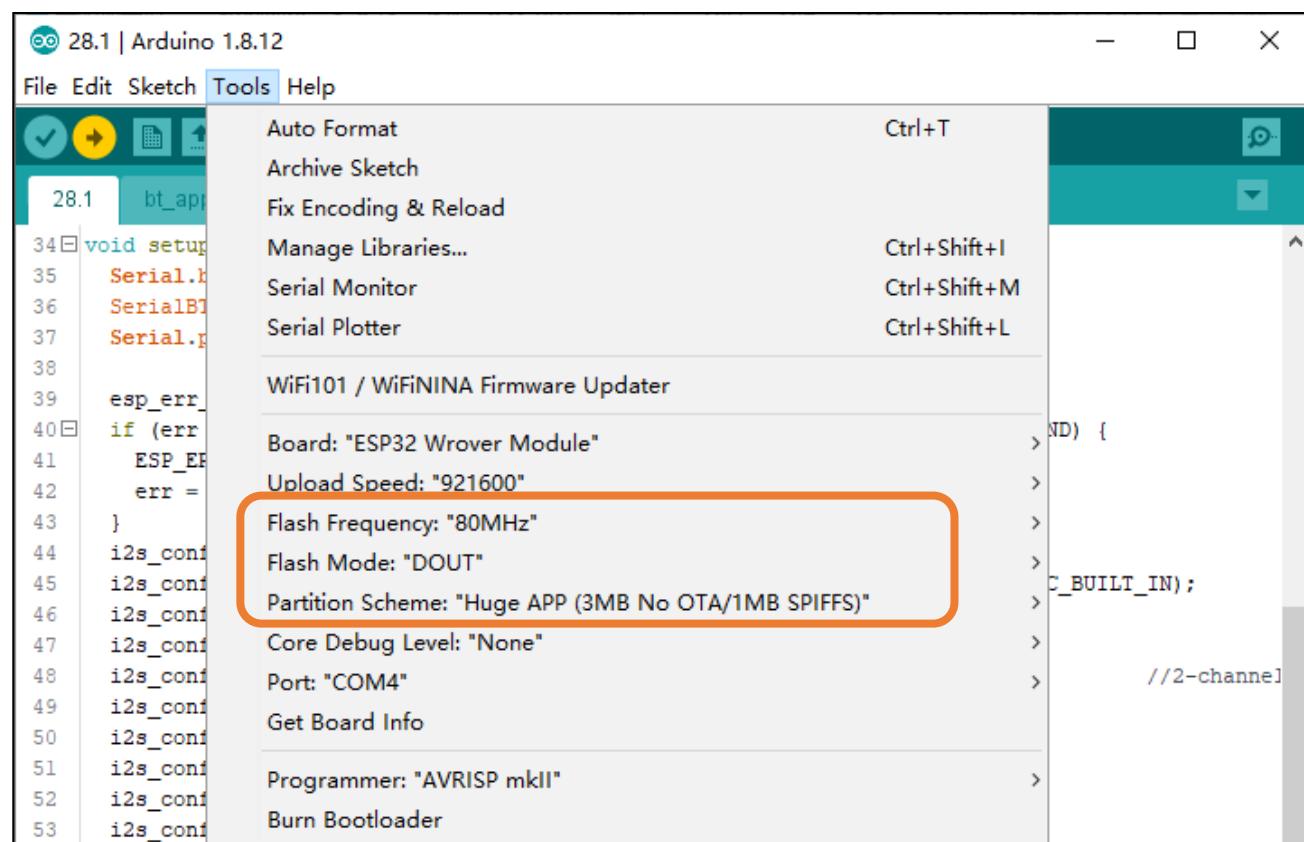


Sketch

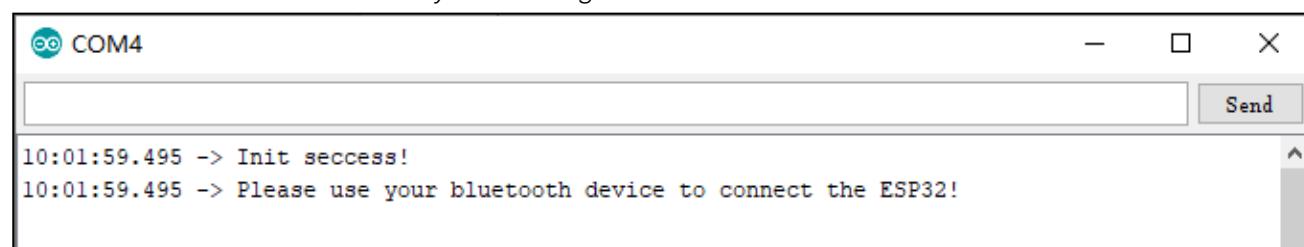
Before compiling and upload the program, please check whether your configuration conforms with the following illustration.

Sketch_29.1_Bluetooth_Music_by_PCM5102A

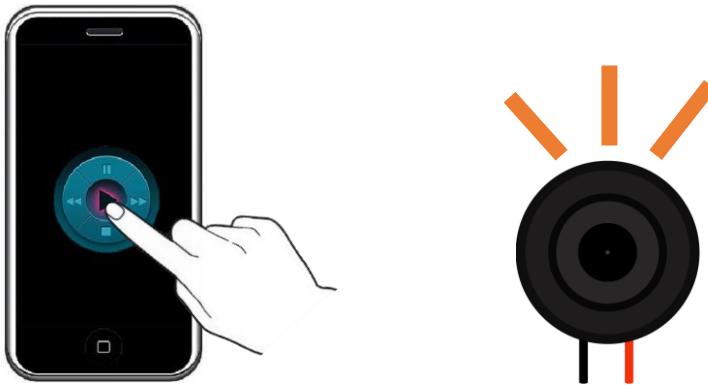
Note: ESP32 board support packages are different and will cause compilation failures. We provide two codes, if you can't use it, please change another code.



Compile and upload the code to the ESP32-WROVER and open the serial monitor. ESP32 takes a few seconds to initialize the program. When you see the prompt as shown in the figure below, it means that the Bluetooth function of ESP32 is ready and waiting for the connection of other Bluetooth devices.



Please use your mobile phone to search and connect a Bluetooth device named "ESP32". After the connection is successful, you can use ESP32 to play the audio files in your mobile phone.



The following is the program code:

```
1 #include "BluetoothSerial.h"
2 #include "driver/i2s.h"
3 #include "nvs.h"
4 #include "nvs_flash.h"
5 #include "esp_bt.h"
6 #include "bt_app_core.h"
7 #include "bt_app_av.h"
8 #include "esp_bt_main.h"
9 #include "esp_bt_device.h"
10 #include "esp_gap_bt_api.h"
11 #include "esp_a2dp_api.h"
12 #include "esp_avrc_api.h"
13
14 #define CONFIG_I2S_LRCK_PIN 25
15 #define CONFIG_I2S_BCK_PIN 26
16 #define CONFIG_I2S_DATA_PIN 22
17 BluetoothSerial SerialBT;
18
19 void setup() {
20     Serial.begin(115200);
21     SerialBT.begin("ESP32");
22     Serial.println("Init seccess! ");
23
24     esp_err_t err = nvs_flash_init();
25     if (err == ESP_ERR_NVS_NO_FREE_PAGES || err == ESP_ERR_NVS_NEW_VERSION_FOUND) {
26         ESP_ERROR_CHECK(nvs_flash_erase());
27         err = nvs_flash_init();
28     }
29
30     i2s_config_t i2s_config;
31     i2s_config.mode = (i2s_mode_t)(I2S_MODE_MASTER | I2S_MODE_TX);
32     i2s_config.bits_per_sample = I2S_BITS_PER_SAMPLE_32BIT;
33     i2s_config.sample_rate = 44100;
```

```

34 i2s_config.channel_format = I2S_CHANNEL_FMT_RIGHT_LEFT;
35 i2s_config.communication_format = I2S_COMM_FORMAT_I2S_MSB;
36 i2s_config.intr_alloc_flags = 0;
37 i2s_config.dma_buf_count = 6;
38 i2s_config.dma_buf_len = 60;
39 i2s_config.tx_desc_auto_clear = true;
40 i2s_driver_install(I2S_NUM_0, &i2s_config, 0, NULL);
41 i2s_pin_config_t pin_config;
42 pin_config.bck_io_num = CONFIG_I2S_BCK_PIN;
43 pin_config.ws_io_num = CONFIG_I2S_LRCK_PIN;
44 pin_config.data_out_num = CONFIG_I2S_DATA_PIN;
45 pin_config.data_in_num = -1;
46 i2s_set_pin(I2S_NUM_0, &pin_config);
47
48 bt_app_task_start_up();
49
50 /* initialize A2DP sink */
51 esp_a2d_register_callback(&bt_app_a2d_cb);
52 esp_a2d_sink_register_data_callback(bt_app_a2d_data_cb);
53 esp_a2d_sink_init();
54 /* initialize AVRCP controller */
55 esp_avrc_ct_init();
56 esp_avrc_ct_register_callback(bt_app_rc_ct_cb);
57 /* set discoverable and connectable mode, wait to be connected */
58 esp_bt_gap_set_scan_mode(ESP_BT_SCAN_MODE_CONNECTABLE_DISCOVERABLE);
59 Serial.println("Please use your Bluetooth device to connect the ESP32!");
60 }
61
62 void loop() {
63 ;
64 }
```

Define an I2S configuration class and initialize it; define an I2S pin configuration class and associate I2S signals with these pins.

```

30 i2s_config_t i2s_config;
31 i2s_config.mode = (i2s_mode_t)(I2S_MODE_MASTER | I2S_MODE_TX);
32 i2s_config.bits_per_sample = I2S_BITS_PER_SAMPLE_32BIT;
33 i2s_config.sample_rate = 44100;
34 i2s_config.channel_format = I2S_CHANNEL_FMT_RIGHT_LEFT;
35 i2s_config.communication_format = I2S_COMM_FORMAT_I2S_MSB;
36 i2s_config.intr_alloc_flags = 0;
37 i2s_config.dma_buf_count = 6;
38 i2s_config.dma_buf_len = 60;
39 i2s_config.tx_desc_auto_clear = true;
40 i2s_driver_install(I2S_NUM_0, &i2s_config, 0, NULL); //
```

```
41 i2s_pin_config_t pin_config;
42 pin_config.bck_io_num = CONFIG_I2S_BCK_PIN;
43 pin_config.ws_io_num = CONFIG_I2S_LRCK_PIN;
44 pin_config.data_out_num = CONFIG_I2S_DATA_PIN;
45 pin_config.data_in_num = -1;
46 i2s_set_pin(I2S_NUM_0, &pin_config);
```

In this chapter, the procedure is very similar to the previous section. The difference only lies in the I2S configuration. The audio quality of the DAC output from the PCM5102 chip after decoding is significantly higher than that of the ESP32's own 8-bit precision DAC.

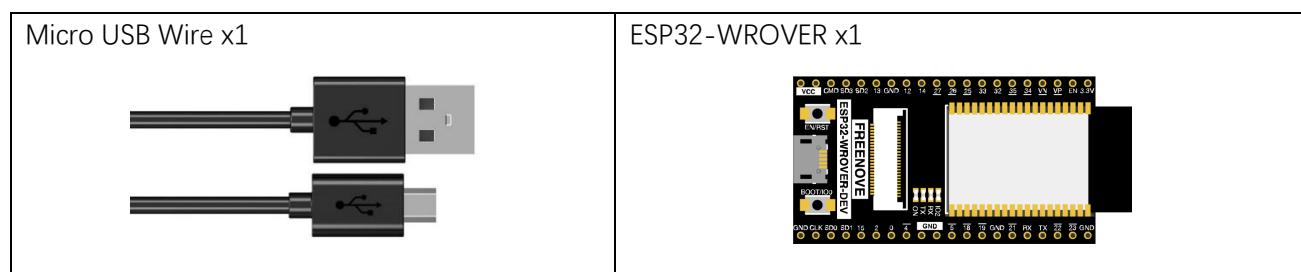
Chapter 30 WiFi Working Modes

In this chapter, we'll focus on the WiFi infrastructure for ESP32-WROVER.

ESP32-WROVER has 3 different WiFi operating modes: station mode, AP mode and AP+station mode. All WiFi programming projects must be configured with WiFi operating mode before using WiFi, otherwise WiFi cannot be used.

Project 30.1 Station mode

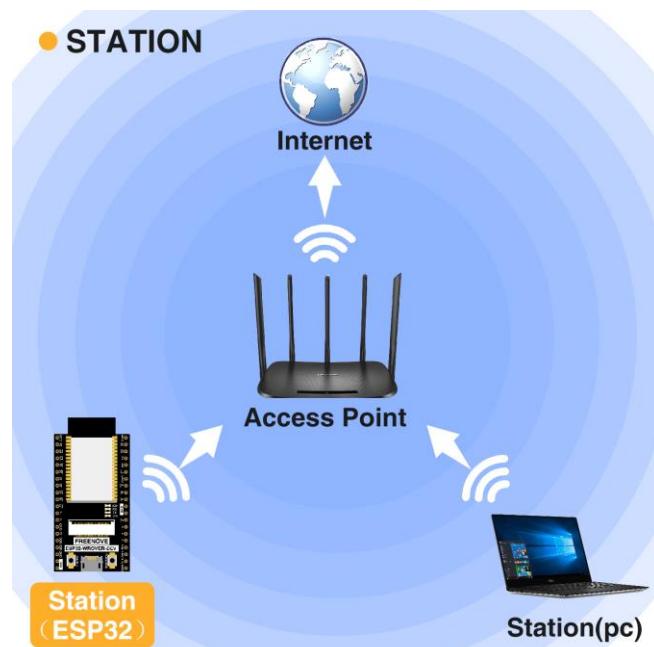
Component List



Component knowledge

Station mode

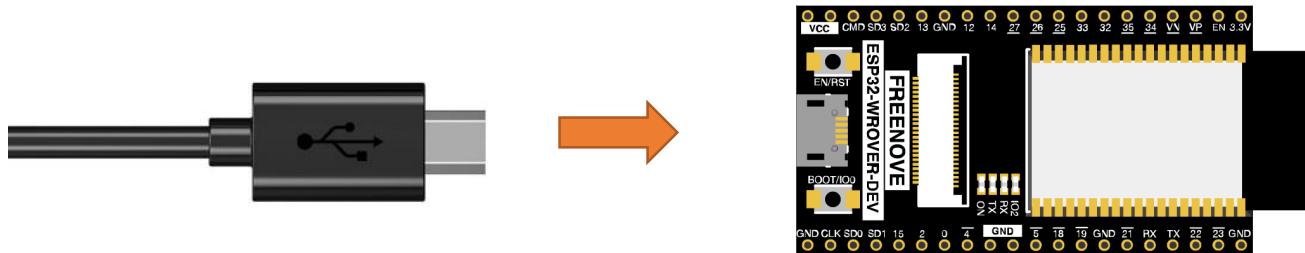
When ESP32 selects Station mode, it acts as a WiFi client. It can connect to the router network and communicate with other devices on the router via WiFi connection. As shown below, the PC is connected to the router, and if ESP32 wants to communicate with the PC, it needs to be connected to the router.



Any concerns? ✉ support@freenove.com

Circuit

Connect Freenove ESP32 to the computer using the USB cable.



Sketch

Sketch_30.1_Station_mode

The screenshot shows the Arduino IDE interface with the sketch named "Sketch_30.1_WiFi_Station". The code includes declarations for WiFi credentials and a setup loop for connecting to a router. A callout bubble highlights the password declaration with the instruction "Enter the correct Router name and password."

```

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 }

```

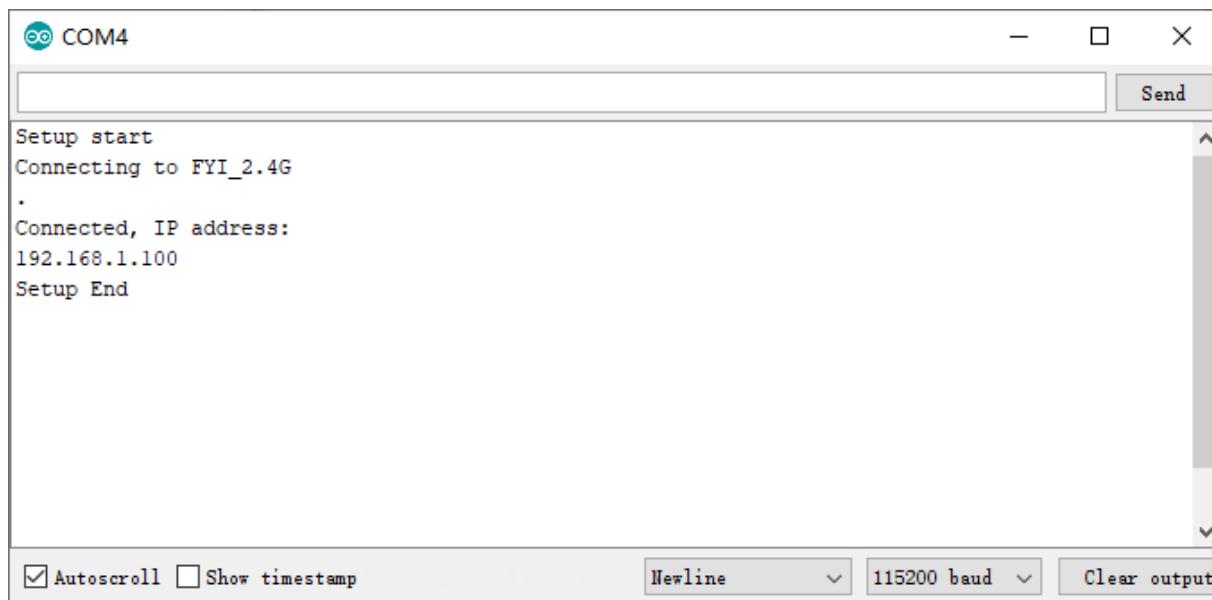
Done uploading.

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

ESP32 Wrover Module on COM5

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-WROVER, open serial monitor and set baud rate to 115200. And then it will display as follows:



When ESP32-WROVER successfully connects to "ssid_Router", serial monitor will print out the IP address assigned to ESP32-WROVER 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.

```
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 in Station mode and connect it to your router.

```
10 WiFi.begin(ssid_Router, password_Router);
```

Check whether ESP32 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-WROVER

```
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 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 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(): obtian IP address in Station mode

disconnect(): disconnect wifi

setAutoConnect(boolean): set automatic connection Every time ESP32 is power on, it will connect WiFi automatically.

setAutoReconnect(boolean): set automatic reconnection Every time ESP32 disconnects WiFi, it will reconnect to WiFi automatically.

Project 30.2 AP mode

Component List & Circuit

Component List & Circuit are the same as in Section 30.1.

Component knowledge

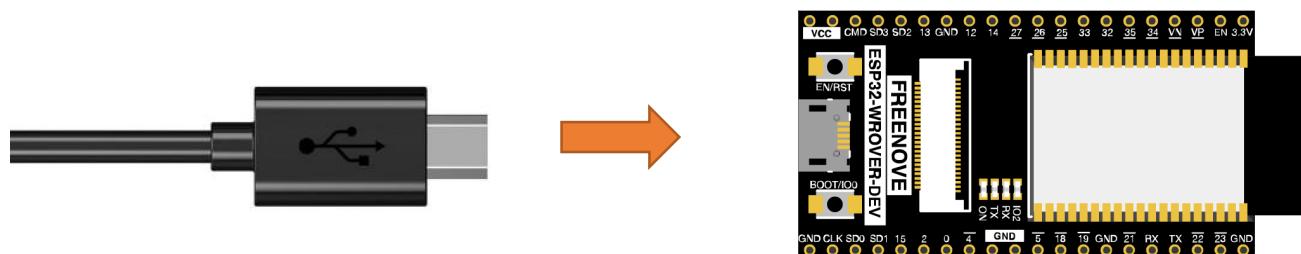
AP mode

When ESP32 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 is used as a hotspot. If a mobile phone or PC wants to communicate with ESP32, it must be connected to the hotspot of ESP32. Only after a connection is established with ESP32 can they communicate.



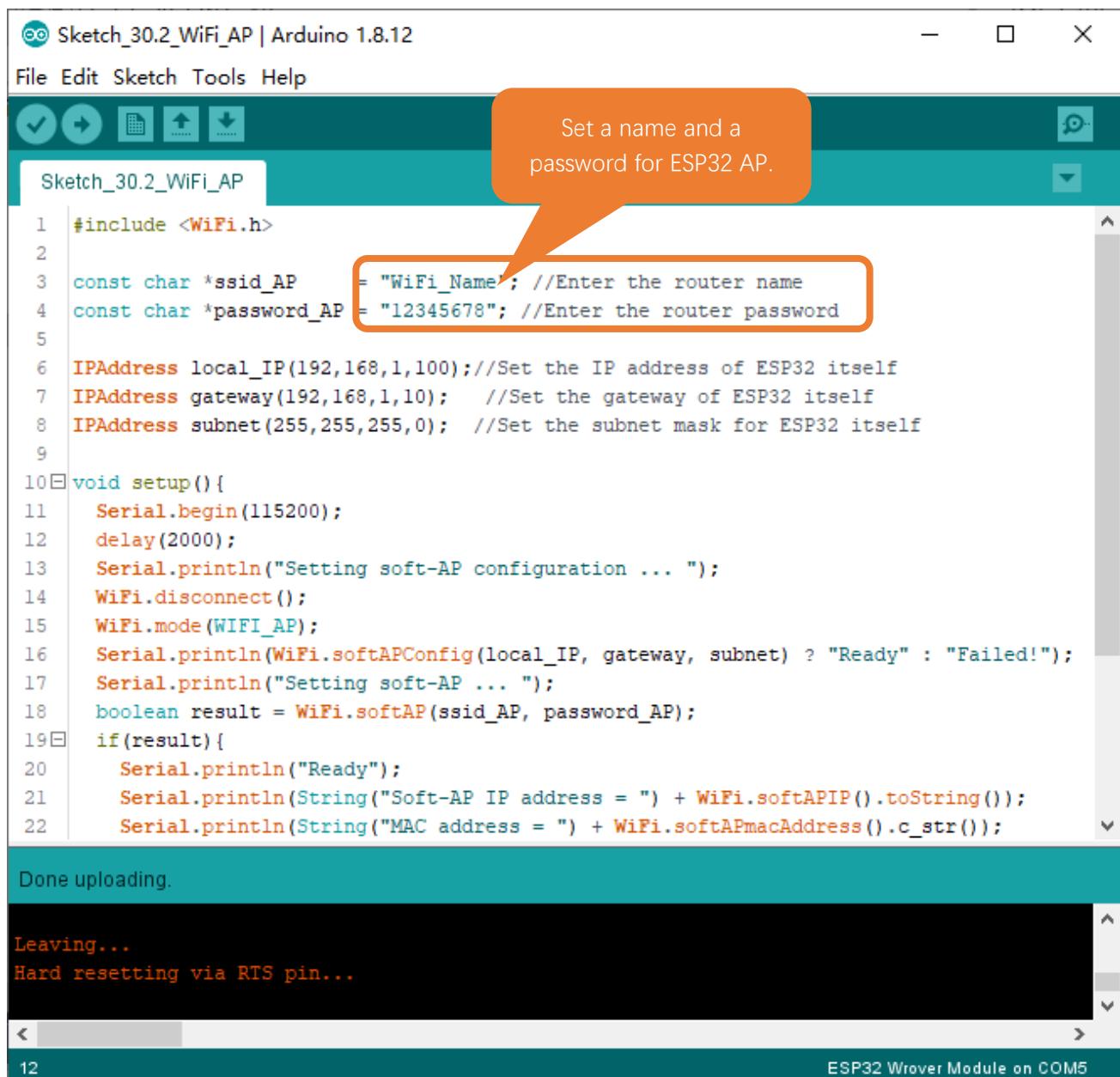
Circuit

Connect Freenove ESP32 to the computer using the USB cable.



Any concerns? ✉ support@freenove.com

Sketch



The screenshot shows the Arduino IDE interface with the sketch titled "Sketch_30.2_WiFi_AP". The code is as follows:

```
#include <WiFi.h>

const char *ssid_AP = "WiFi_Name"; //Enter the router name
const char *password_AP = "12345678"; //Enter the router password

IPAddress local_IP(192,168,1,100); //Set the IP address of ESP32 itself
IPAddress gateway(192,168,1,10); //Set the gateway of ESP32 itself
IPAddress subnet(255,255,255,0); //Set the subnet mask for ESP32 itself

void setup() {
    Serial.begin(115200);
    delay(2000);
    Serial.println("Setting soft-AP configuration ... ");
    WiFi.disconnect();
    WiFi.mode(WIFI_AP);
    Serial.println(WiFi.softAPConfig(local_IP, gateway, subnet) ? "Ready" : "Failed!");
    Serial.println("Setting soft-AP ... ");
    boolean result = WiFi.softAP(ssid_AP, password_AP);
    if(result){
        Serial.println("Ready");
        Serial.println(String("Soft-AP IP address = ") + WiFi.softAPIP().toString());
        Serial.println(String("MAC address = ") + WiFi.softAPmacAddress().c_str());
    }
}
```

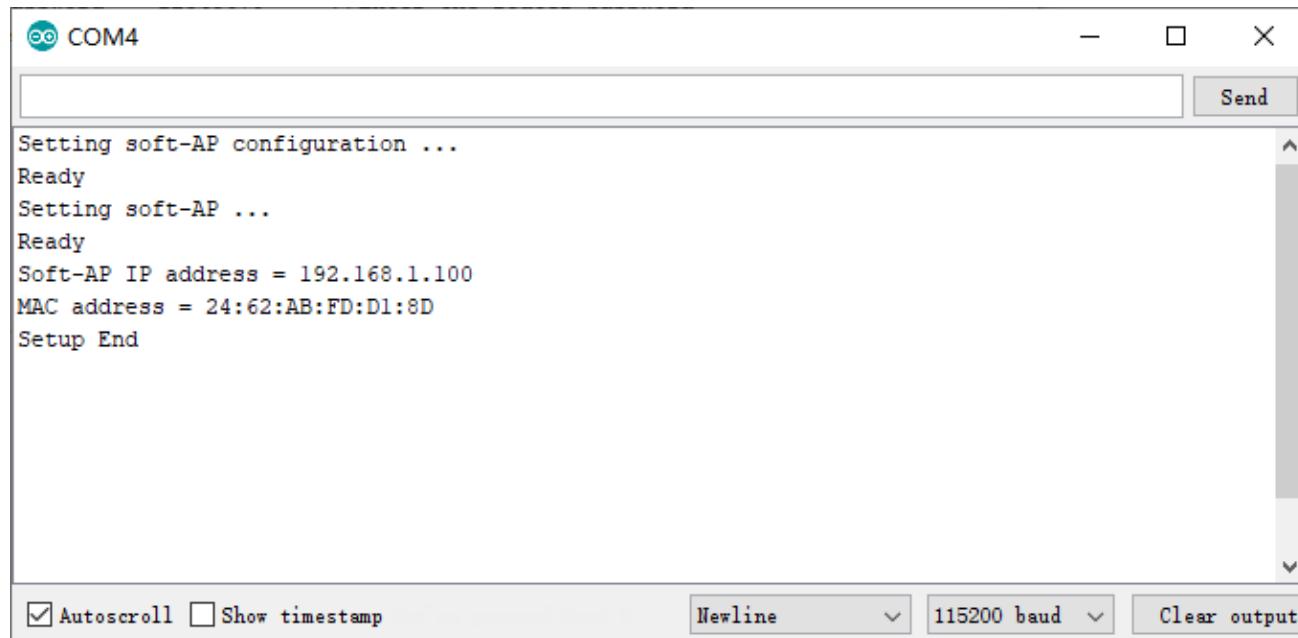
A callout bubble with the text "Set a name and a password for ESP32 AP." points to the line of code defining the AP SSID and password.

The serial monitor window shows the message "Done uploading." followed by "Leaving... Hard resetting via RTS pin...".

The status bar at the bottom right indicates "ESP32 Wrover Module on COM5".

Before the Sketch runs, you can make any changes to the AP name and password for ESP32 in the box as shown in the illustration above. Of course, you can leave it alone by default.

Compile and upload codes to ESP32-WROVER, open the serial monitor and set the baud rate to 115200. And then it will display as follows.

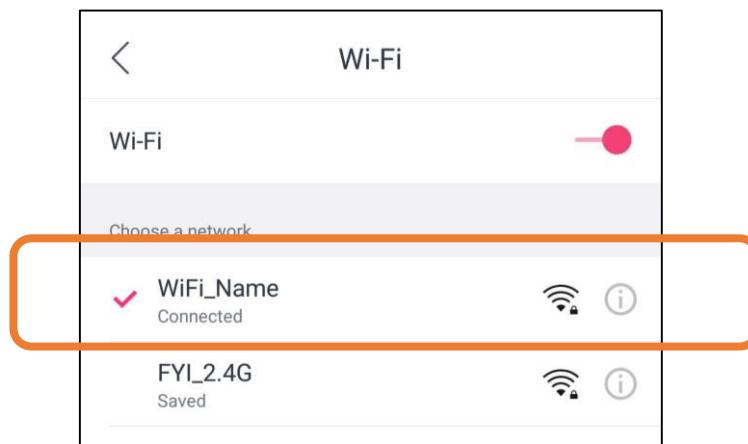


The screenshot shows a Windows-style serial monitor window titled "COM4". The text area contains the following output:

```
Setting soft-AP configuration ...
Ready
Setting soft-AP ...
Ready
Soft-AP IP address = 192.168.1.100
MAC address = 24:62:AB:FD:D1:8D
Setup End
```

At the bottom, there are several control buttons: "Autoscroll" (checked), "Show timestamp" (unchecked), "Newline" (dropdown menu), "115200 baud" (selected), and "Clear output".

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, 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 itself
7 IPAddress gateway(192, 168, 1, 10); //Set the gateway of ESP32 itself
8 IPAddress subnet(255, 255, 255, 0); //Set the subnet mask for ESP32 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.

```
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 in AP mode.

```
15 WiFi.mode(WIFI_AP);
```

Configure IP address, gateway and subnet mask for ESP32.

```
16 WiFi.softAPConfig(local_IP, gateway, subnet)
```

Turn on an AP in ESP32, 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. 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

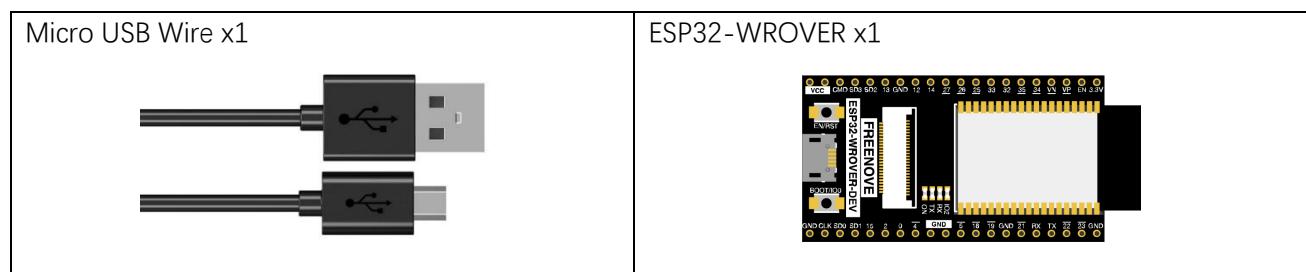
subnet: subnet mask

softAP(): obtain IP address in AP mode

softAPdisconnect (): disconnect AP mode.

Project 30.3 AP+Station mode

Component List



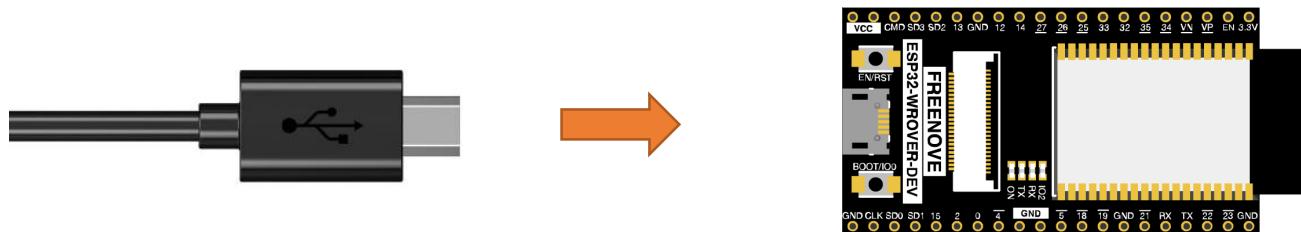
Component knowledge

AP+Station mode

In addition to AP mode and station mode, ESP32 can also use AP mode and station mode at the same time. This mode contains the functions of the previous two modes. Turn on ESP32's station mode, connect it to the router network, and it can communicate with the Internet via the router. At the same time, turn on its AP mode to create a hotspot network. Other WiFi devices can choose to connect to the router network or the hotspot network to communicate with ESP32.

Circuit

Connect Freenove ESP32 to the computer using the USB cable.



Sketch

Sketch_30.3_AP_Station_mode

Please enter the correct names and passwords of Router and AP.

```

7 #include <WiFi.h>
8
9 const char *ssid_Router
10 const char *password_Route
11 const char *ssid_AP
12 const char *password_AP
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     }
}

```

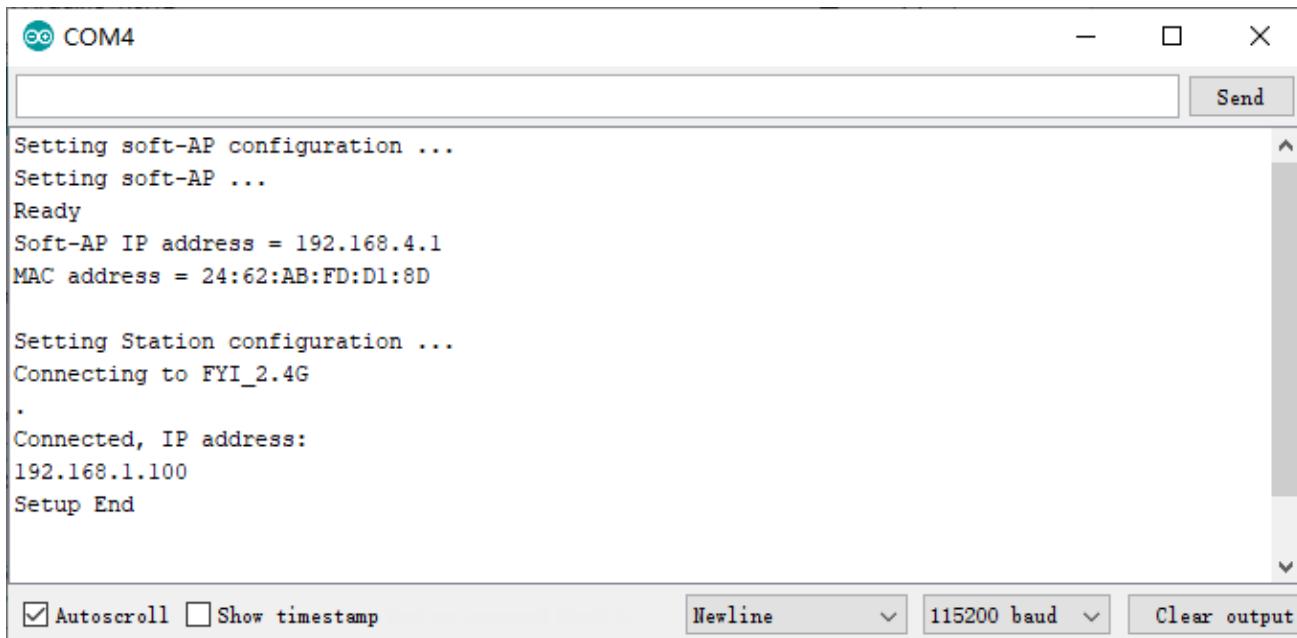
Done uploading.

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

It is analogous to project 30.1 and project 30.2. Before running the Sketch, you need to modify ssid_Router, password_Route, ssid_AP and password_AP shown in the box of the illustration above.

Any concerns? ✉ support@freenove.com

After making sure that Sketch is modified correctly, compile and upload codes to ESP32-WROVER, open serial monitor and set baud rate to 115200. And then it will display as follows:



The screenshot shows the Arduino Serial Monitor window titled "COM4". The text output is as follows:

```

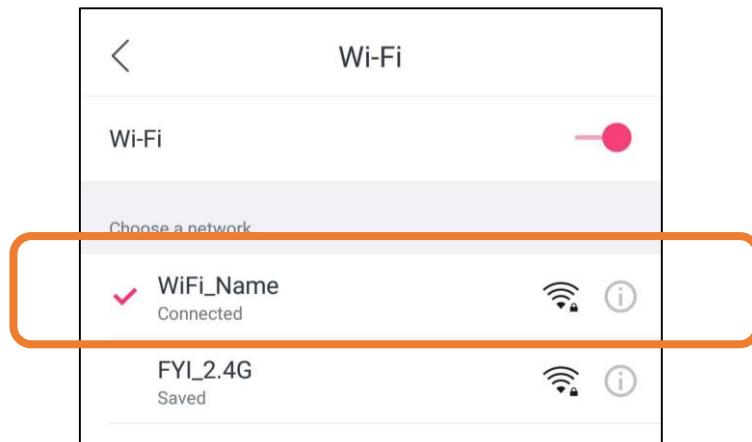
Setting soft-AP configuration ...
Setting soft-AP ...
Ready
Soft-AP IP address = 192.168.4.1
MAC address = 24:62:AB:FD:D1:8D

Setting Station configuration ...
Connecting to FYI_2.4G
.
Connected, IP address:
192.168.1.100
Setup End

```

At the bottom, there are checkboxes for "Autoscroll" and "Show timestamp", and buttons for "Newline", "115200 baud", and "Clear output".

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.



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 }
```

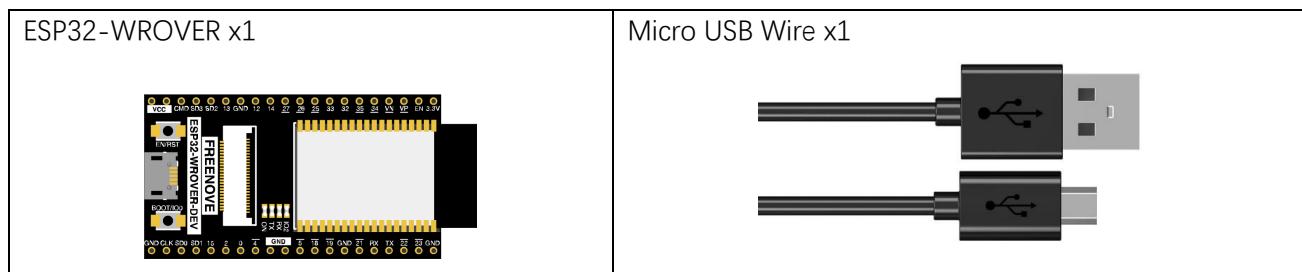
Chapter 31 TCP/IP

In this chapter, we will introduce how ESP32 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 is used as Client to connect Server on the same LAN and communicate with it.

Component List



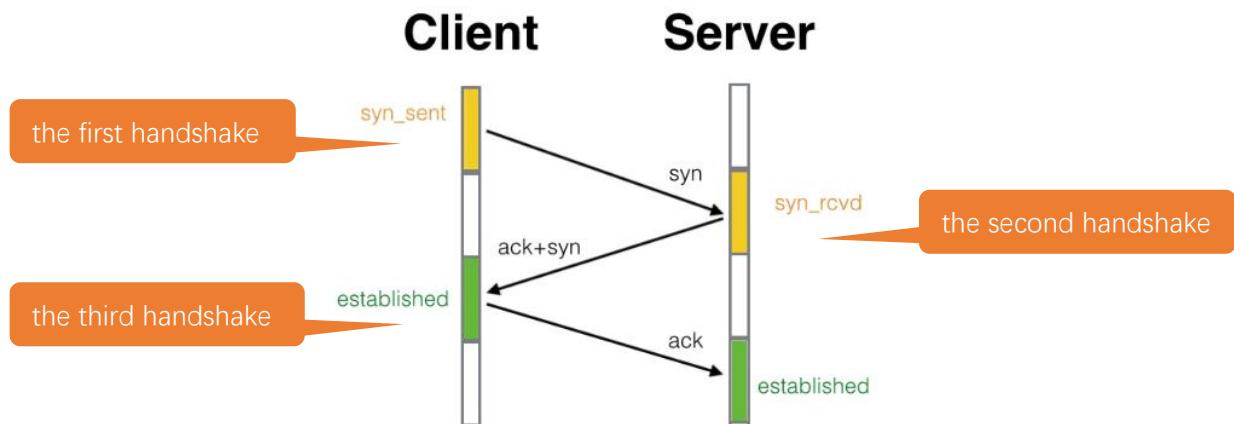
Component knowledge

TCP connection

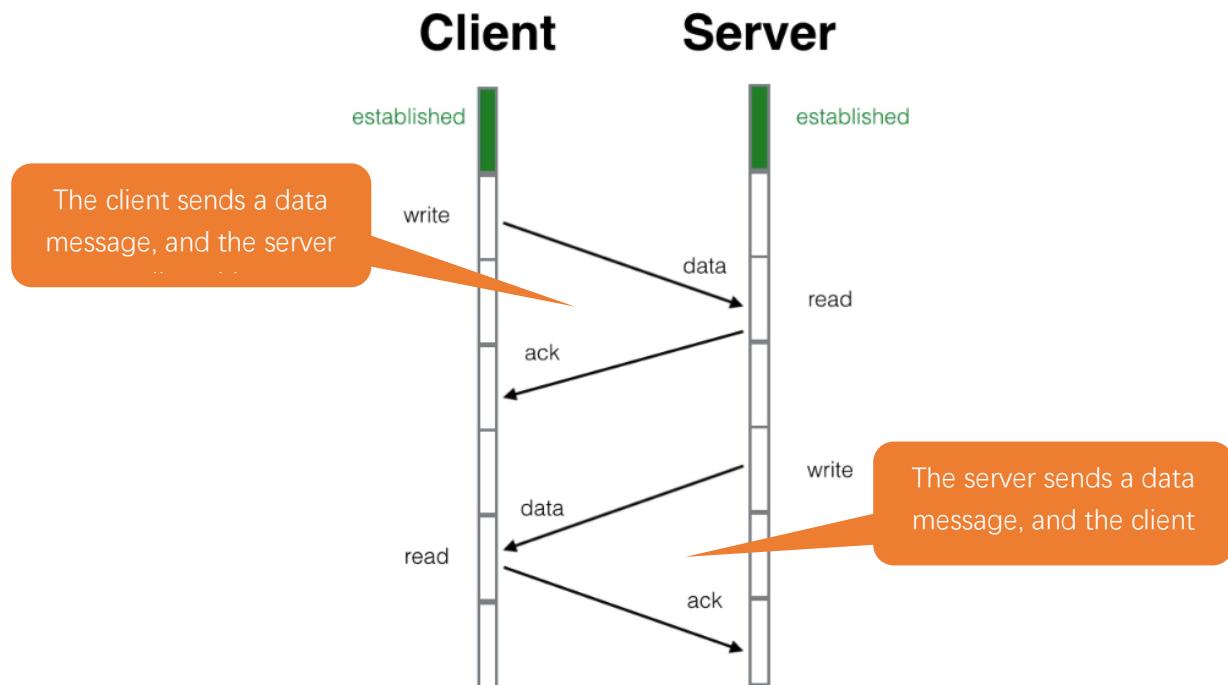
Before transmitting data, TCP needs to establish a logical connection between the sending end and the receiving end. It provides reliable and error-free data transmission between the two computers. In the TCP connection, the client and the server must be clarified. The client sends a connection request to the server, and each time such a request is proposed, a "three-times handshake" is required.

Three-times handshake: In the TCP protocol, during the preparation phase of sending data, the client and the server interact three times to ensure the reliability of the connection, which is called "three-times handshake". The first handshake, the client sends a connection request to the server and waits for the server to confirm. The second handshake, the server sends a response back to the client informing that it has received the connection request.

The third handshake, the client sends a confirmation message to the server again to confirm the connection.



TCP is a connection-oriented, low-level transmission control protocol. After TCP establishes a connection, the client and server can send and receive messages to each other, and the connection will always exist as long as the client or server does not initiate disconnection. Each time one party sends a message, the other party will reply with an ack signal.





Install Processing

In this tutorial, we use Processing to build a simple TCP/IP communication platform.

If you've not installed Processing, you can download it by clicking <https://processing.org/download/>. You can choose an appropriate version to download according to your PC system.

The screenshot shows the official Processing website's download section. At the top, there are navigation links for "Processing", "p5.js", "Processing.py", "Processing for Android", "Processing for Pi", and "Processing Foundation". A search bar is located in the top right corner. The main content area features a large "Processing" logo on the left and a descriptive text on the right: "Download Processing. Processing is available for Linux, Mac OS X, and Windows. Select your choice to download the software below." Below this, a large circular logo with a stylized "P" is displayed. To the right of the logo, the version "3.5.4 (17 January 2020)" is shown, followed by download links for "Windows 64-bit", "Windows 32-bit", "Linux 64-bit", and "Mac OS X". On the far left, a sidebar lists various links: Cover, Download, Donate, Exhibition, Reference, Libraries, Tools, Environment, Tutorials, Examples, Books, Overview, and People. Under "Tutorials", there are links to "» Github", "» Report Bugs", "» Wiki", "» Supported Platforms", and a note about "Read about the changes in 3.0. The list of revisions covers the differences between releases in detail."

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

core	2020/1/17 12:16
java	2020/1/17 12:17
lib	2020/1/17 12:16
modes	2020/1/17 12:16
tools	2020/1/17 12:16
processing.exe	2020/1/17 12:16
processing-java.exe	2020/1/17 12:16
revisions.txt	2020/1/17 12:16

Use Server mode for communication

Install ControlP5.

The image consists of three vertically stacked screenshots from the Processing IDE and its Contribution Manager.

Screenshot 1: Processing Sketch Menu
A screenshot of the Processing sketch window titled "sketch_170328a | Processing 3.3". The "Sketch" menu is open, showing options like Run, Present, Tweak, Stop, Import Library..., Show Sketch Folder, and Add File... . The "Import Library..." option is highlighted with a blue selection bar. A mouse cursor is hovering over the "Add Library..." option in the submenu.

Screenshot 2: Contribution Manager
A screenshot of the Contribution Manager window. The "Libraries" tab is selected. A search bar at the top contains the text "Filter". Below it is a table with columns: Status, Name, and Author. The table lists several libraries:

Status	Name	Author
	Computational Geometry A simple, lightweight librar...	Mark Collins & Toru Hasegawa
	Console A console, which can be drawn to the screen.	Mathias Markl
	ControlP5 A GUI library to build custom user interface...	Andreas Schlegel
	CountdownTimer A countdown timer which triggers c...	Dong Hyun Choi
	Culebra Behavior Library for Processing A collection o...	Luis Quinones

Screenshot 3: ControlP5 Library Details
A screenshot of the ControlP5 library details page in the Contribution Manager. It shows the library's name, author (Andreas Schlegel), a brief description ("A GUI library to build custom user interfaces for desktop and android mode."), and three action buttons: "Install" (highlighted with a blue border), "Update", and "Remove". A status message "2.2.6 available" is displayed above the "Update" button.

Open the “**Freenove_Ultimate_Starter_Kit_for_ESP32\Sketches\Sketches\Sketch_31.1_WiFiClient\sketchWiFi\sketchWiFi.pde**”, and click “Run”.

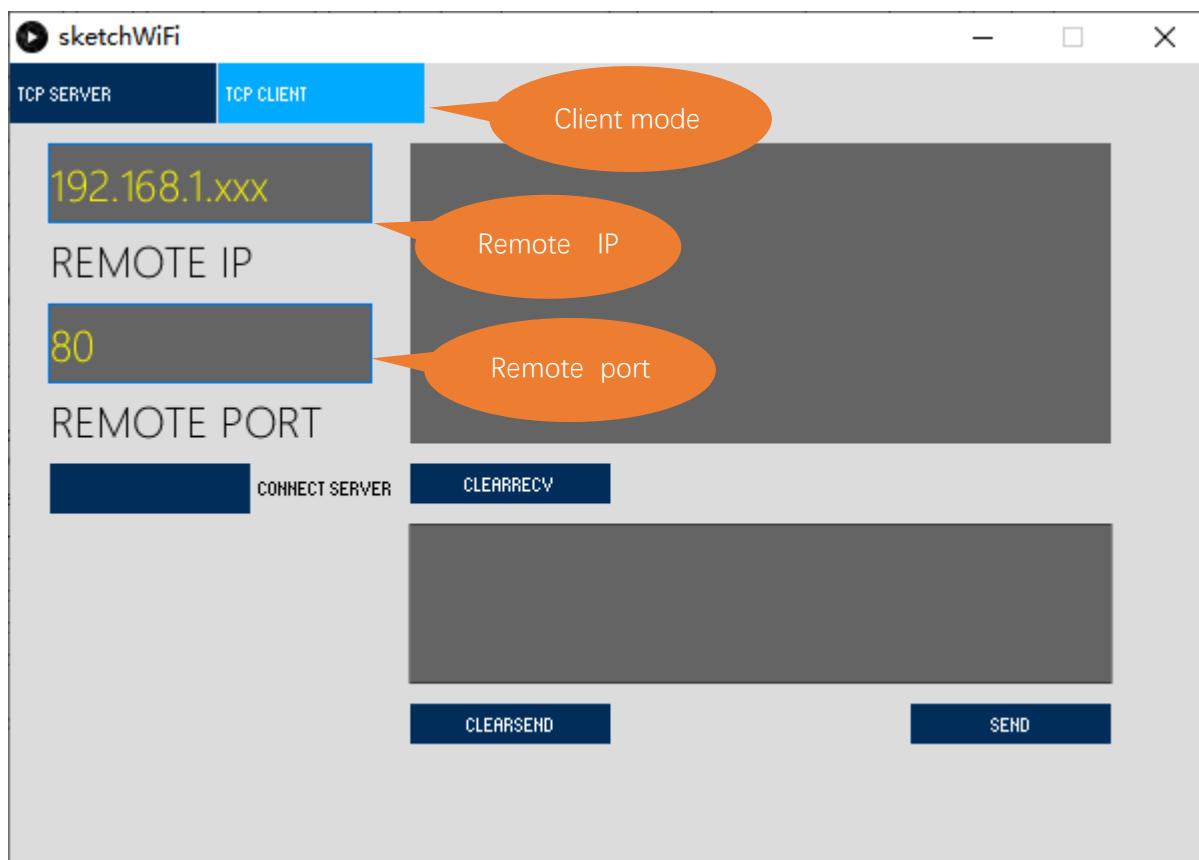


The new pop-up interface is as follows. If ESP32 is used as client, select TCP SERVER mode for sketchWiFi.



When sketchWiFi selects TCP SERVER mode, ESP32 Sketch needs to be changed according to sketchWiFi's displaying of LOCAL IP or LOCAL PORT.

If ESP32 serves as server, select TCP CLIENT mode for sketchWiFi.



When sketchWiFi selects TCP CLIENT mode, the LOCAL IP and LOCAL PORT of sketchWiFi need to be changed according to the IP address and port number printed by the serial monitor.

Mode selection: select **Server mode/Client mode**.

IP address: In server mode, this option does not need to be filled in, and the computer will automatically obtain the IP address.

In client mode, fill in the remote IP address to be connected.

Port number: In server mode, fill in a port number for client devices to make an access connection.

In client mode, fill in port number given by the Server devices to make an access connection.

Start button: In server mode, push the button, then the computer will serve as server and open a port number for client to make access connection. During this period, the computer will keep monitoring.

In client mode, before pushing the button, please make sure the server is on, remote IP address and remote port number is correct; push the button, and the computer will make access connection to the remote port number of the remote IP as a client.

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

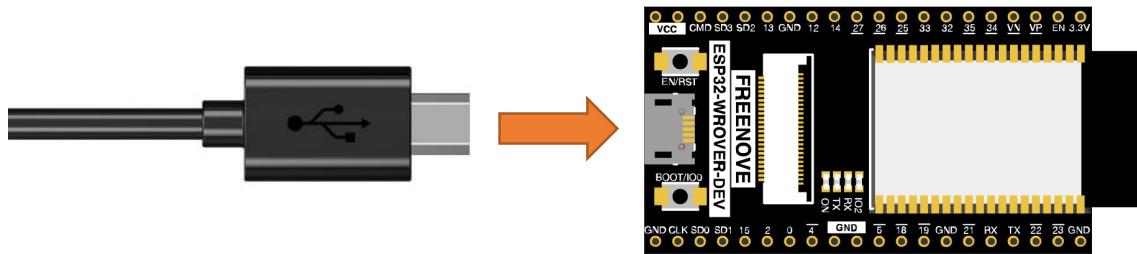
clear send: clear out the content in the sending text box

Sending button: push the sending button, the computer will send the content in the text box to others.

Circuit

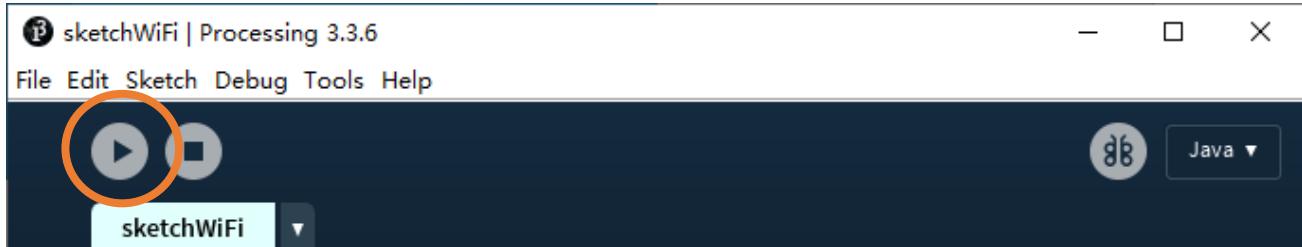
Connect Freenove ESP32 to the computer using USB cable.

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

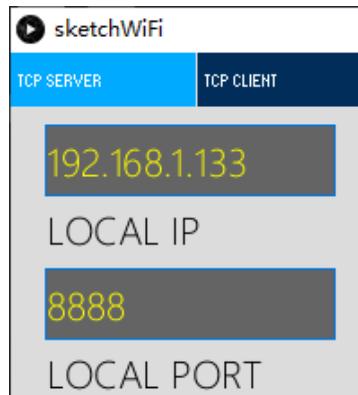


Sketch

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.

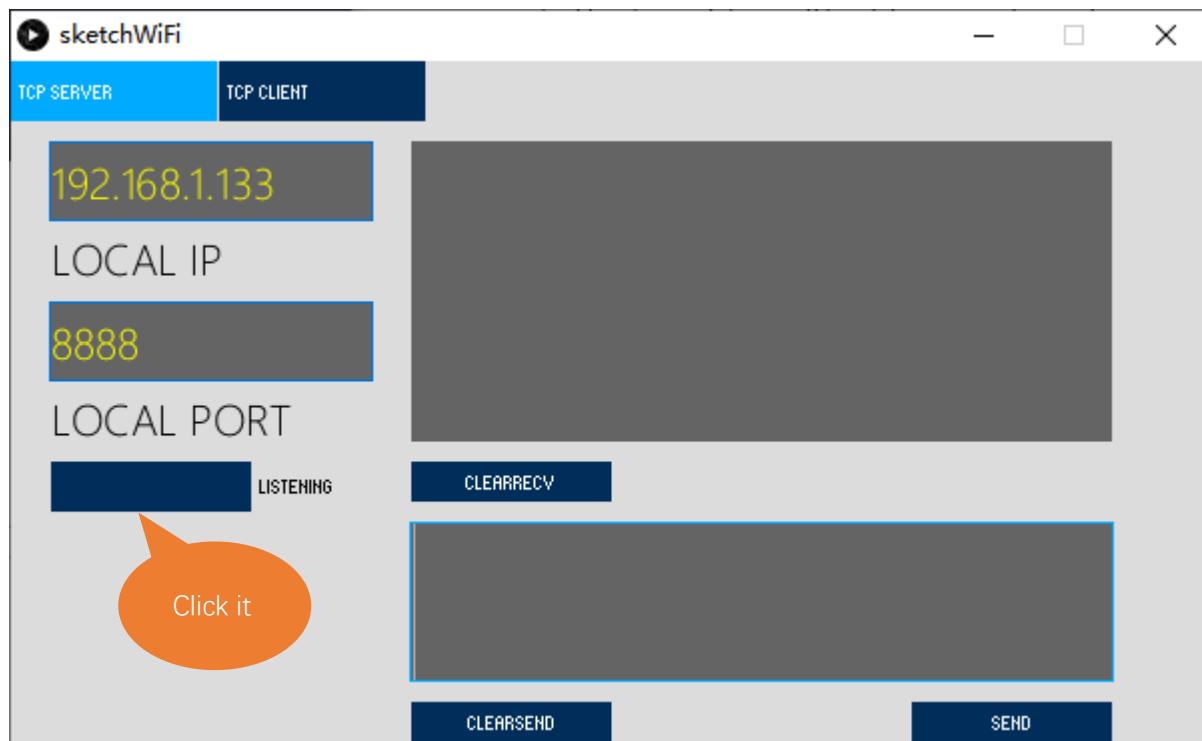
```

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 provide
13 WiFiClient client;
14

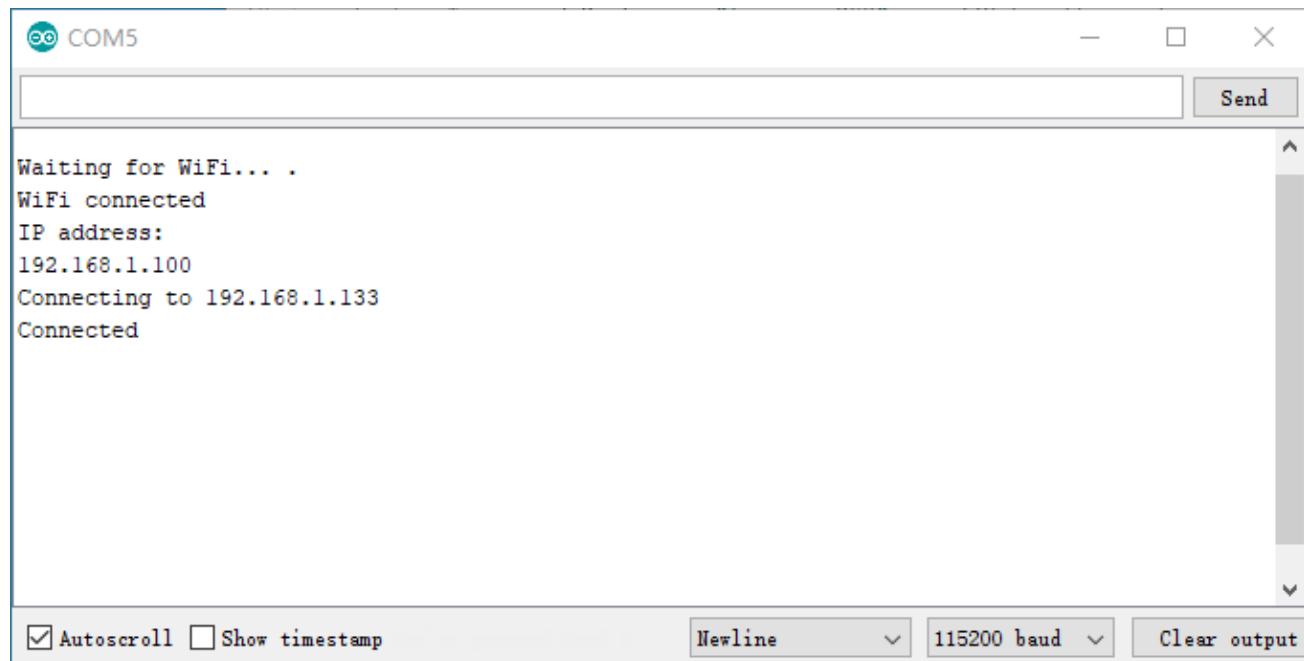
```

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 to connect.

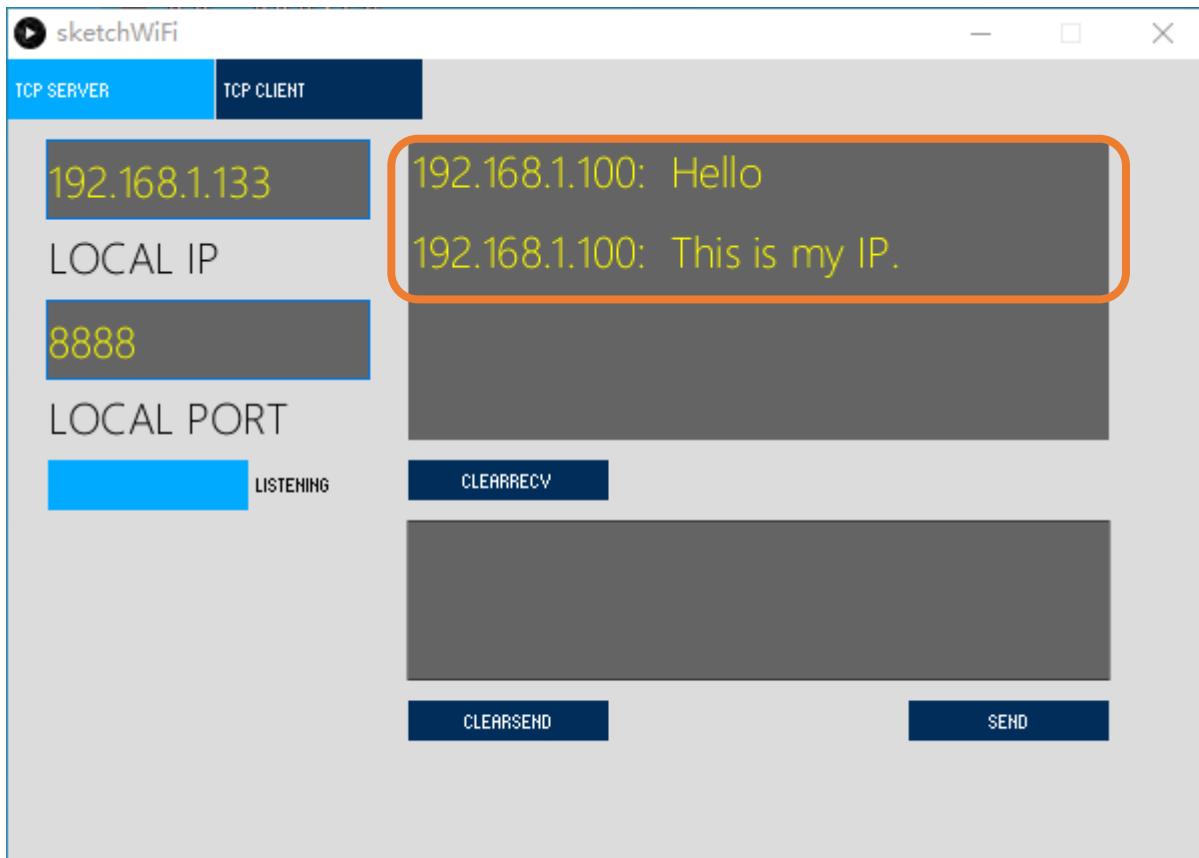


Compile and upload code to ESP32-WROVER, open the serial monitor and set the baud rate to 115200. ESP32 connects router, obtains IP address and sends access request to server IP address on the same LAN till the connection is successful. When connect successfully, ESP32 can send messages to server.





ESP32 connects with TCP SERVER, and TCP SERVER receives messages from ESP32, 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 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 }
```

```
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.

```
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

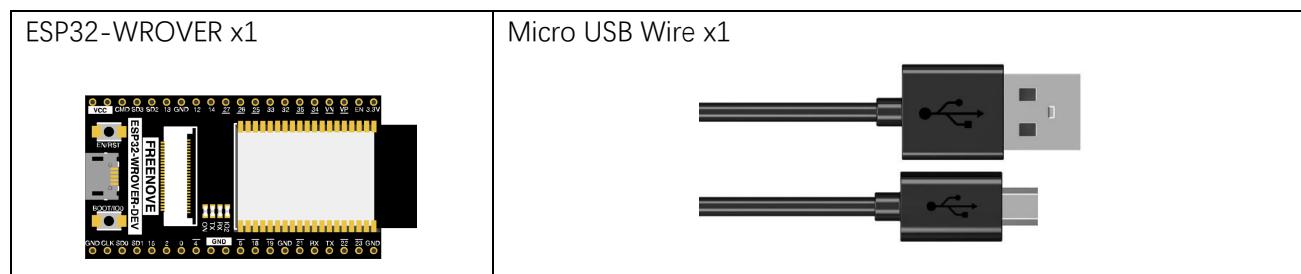
readString(): read string in receive buffer



Project 31.2 As Server

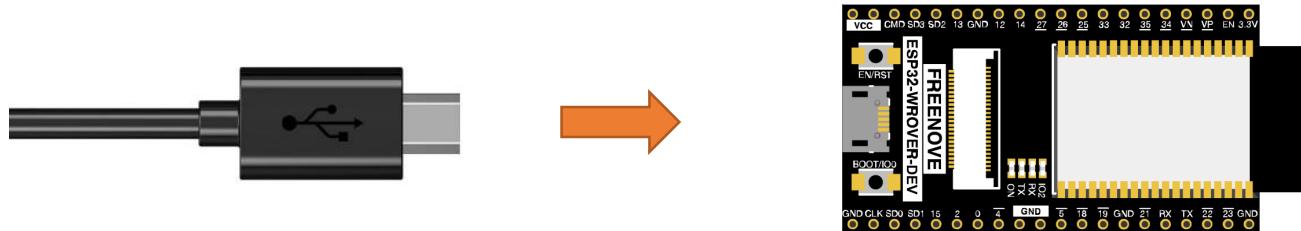
In this section, ESP32 is used as a server to wait for the connection and communication of client on the same LAN.

Component List



Circuit

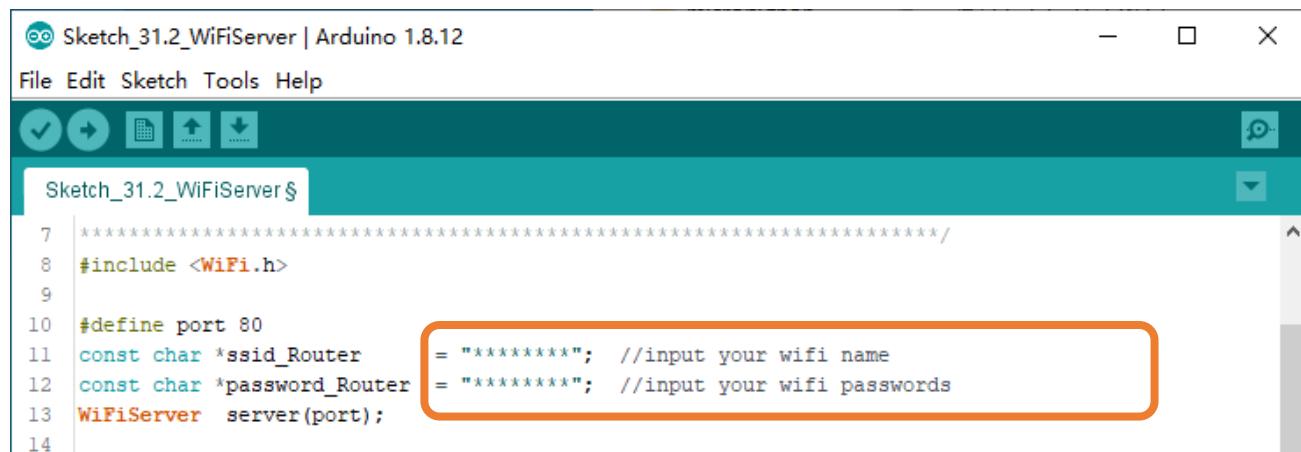
Connect Freenove ESP32 to the computer using a USB cable.



Sketch

Before running Sketch, please modify the contents of the box below first.

Sketch_31.2_As_Server



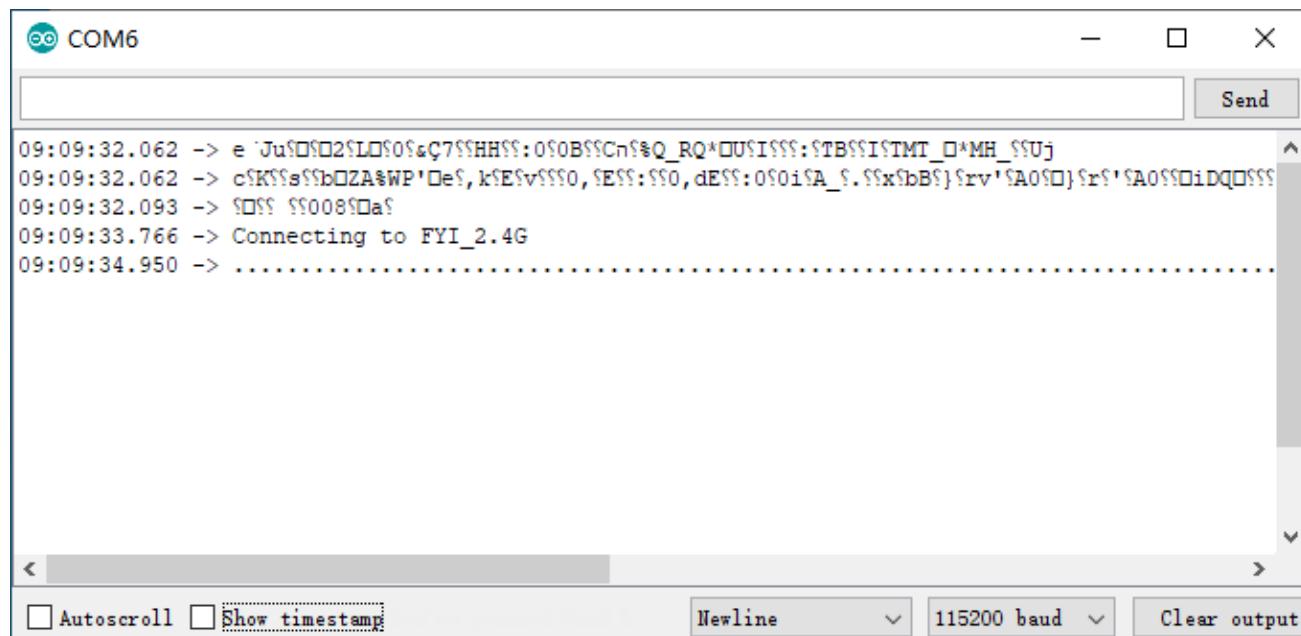
```

Sketch_31.2_WiFiServer | Arduino 1.8.12
File Edit Sketch Tools Help
Sketch_31.2_WiFiServer §
7 ****
8 #include <WiFi.h>
9
10 #define port 80
11 const char *ssid_Router
12 const char *password_Router
13 WiFiServer server(port);
14

```

Compile and upload code to ESP32-WROVER board, open the serial monitor and set the baud rate to 115200. Turn on server mode for ESP32, 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 fails to connect to router, press the reset button as shown below and wait for ESP32 to run again.



```

COM6
Send
09:09:32.062 -> e 'Ju{09029L0909eç799HH99:090B99Ch9%Q_RQ*0U9I999:9TB99I9TMT_0*MH_99Uj
09:09:32.062 -> c9K99s99b99A9WP'Def, k9E9v9990, 9ESS:990, dESS:090iSA_9.99x9bB9}9rv'9A099}9r9'S9A0999iD9Q999
09:09:32.093 -> 9999 9900899af
09:09:33.766 -> Connecting to FYI_2.4G
09:09:34.950 -> .....

```

Autoscroll Show timestamp Newline 115200 baud Clear output



Serial Monitor

The screenshot shows the Arduino Serial Monitor window titled "COM6". The text output is as follows:

```

hello
Connecting to FYI_2.4G
WiFi connected.
IP address: 192.168.1.123
IP port: 80
Client connected.
nice to meet you
  
```

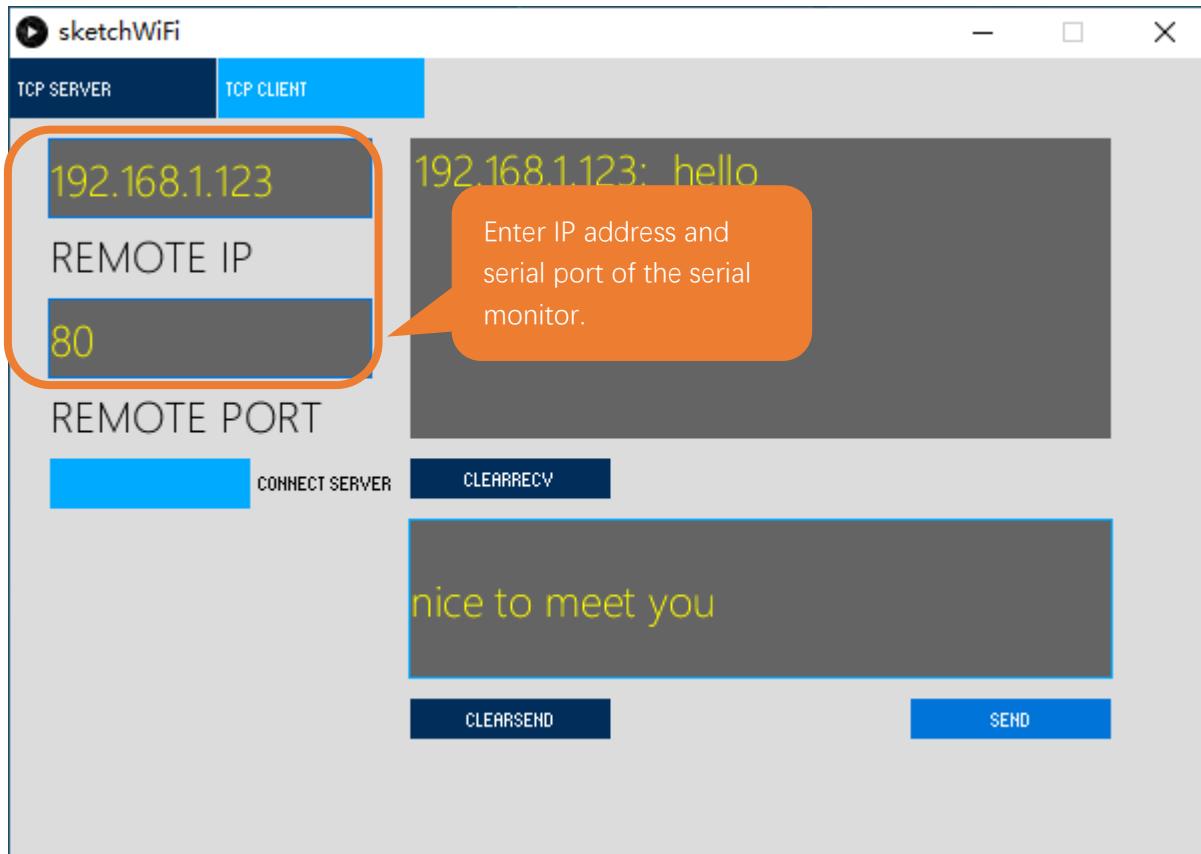
An orange box highlights the line "IP address: 192.168.1.123". An orange callout bubble points to this line with the text "IP address and serial port".

At the bottom of the window, there are checkboxes for "Autoscroll" and "Show timestamp", a "Newline" dropdown set to "115200 baud", and a "Clear output" button.

Processing:

Open the "Freenove_Ultimate_Starter_Kit_for_ESP32\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.setAutoConnect(true);
27    WiFi.setAutoReconnect(true);
28 }
29
30 void loop() {
31    WiFiClient client = server.available();           // listen for incoming clients
32    if (client) {                                     // if you get a client
33        Serial.println("Client connected.");
34        while (client.connected()) {                  // loop while the client's connected
35            if (client.available()) {                // if there's bytes to read from the
36                Serial.println(client.readStringUntil('\n'));// print it out the serial monitor
37                while(client.read()>0);                 // clear the wifi receive area cache
38            }
39            if(Serial.available()){                   // if there's bytes to read from the
36 serial monitor
37                client.print(Serial.readStringUntil('\n'));// print it out the client.
38                while(Serial.read()>0);                  // clear the wifi receive area cache
39            }
40        }
41    }
42 }
```

Any concerns? ✉ support@freenove.com

```

42     }
43   }
44   client.stop();           // stop the client connecting.
45   Serial.println("Client Disconnected.");
46 }
47 }
```

Apply for method class of WiFiServer.

6	<code>WiFiServer server(port);</code> //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.

22	<code>Serial.print("IP address: ");</code>	
23	<code>Serial.println(WiFi.localIP());</code>	//print out IP address of ESP32
24	<code>Serial.printf("IP port: %d\n", port);</code>	//Print out ESP32's port number

Turn on server mode of ESP32, start automatic connection and turn on automatic reconnection.

25	<code>server.begin();</code>	//Turn ON ESP32 as Server mode
26	<code>WiFi.setAutoConnect(true);</code>	
27	<code>WiFi.setAutoReconnect(true);</code>	

When ESP32 receive messages from servers, it will print them out via serial port; Users can also send messages to servers from serial port.

35	<code>if (client.available()) {</code>	// if there's bytes to read from the
36	<code> client</code>	
37	<code> Serial.println(client.readStringUntil('\n'));</code>	// print it out the serial monitor
38	<code> while(client.read()>0);</code>	// clear the wifi receive area cache
39	<code>}</code>	
40	<code>if(Serial.available()){</code>	// if there's bytes to read from the
41	<code> serial monitor</code>	
42	<code> client.print(Serial.readStringUntil('\n'));</code>	// print it out the client.
	<code> while(Serial.read()>0);</code>	// clear the wifi receive area cache
	<code>}</code>	

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.

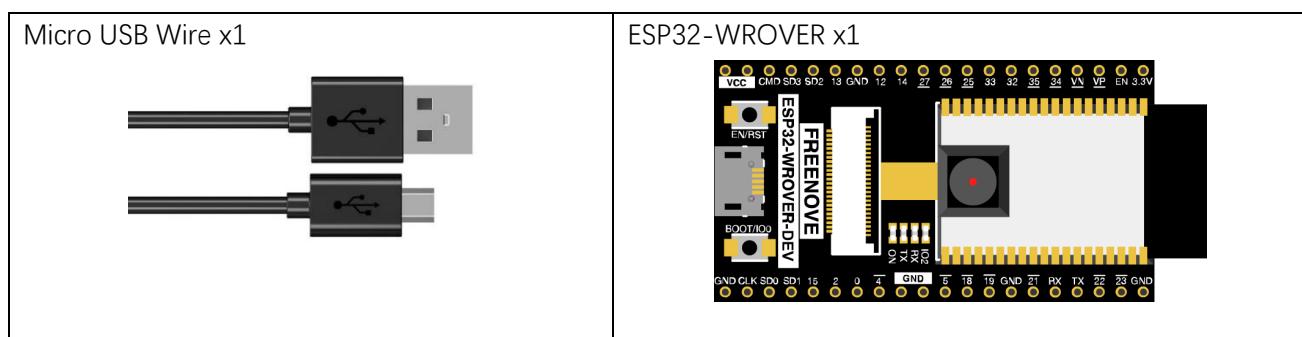
Chapter 32 Camera Web Server

In this section, we'll use ESP32's video function as an example to study.

Project 32.1 Camera Web Server

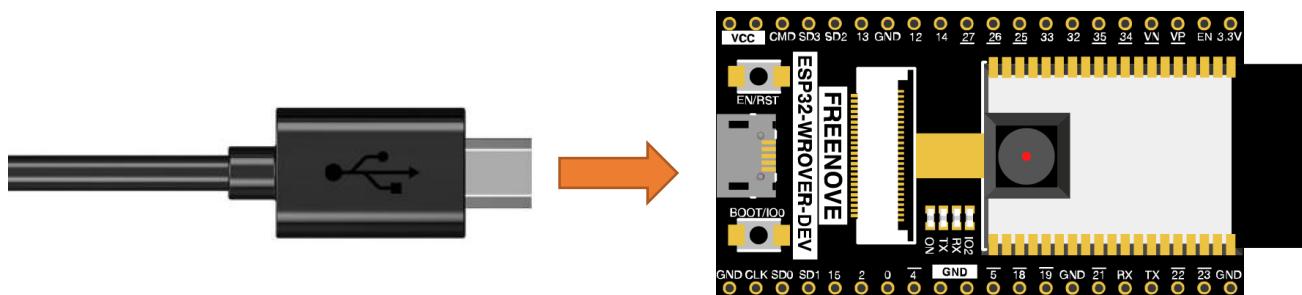
Connect ESP32 using USB and check its IP address through serial monitor. Use web page to access IP address to obtain video and image data.

Component List



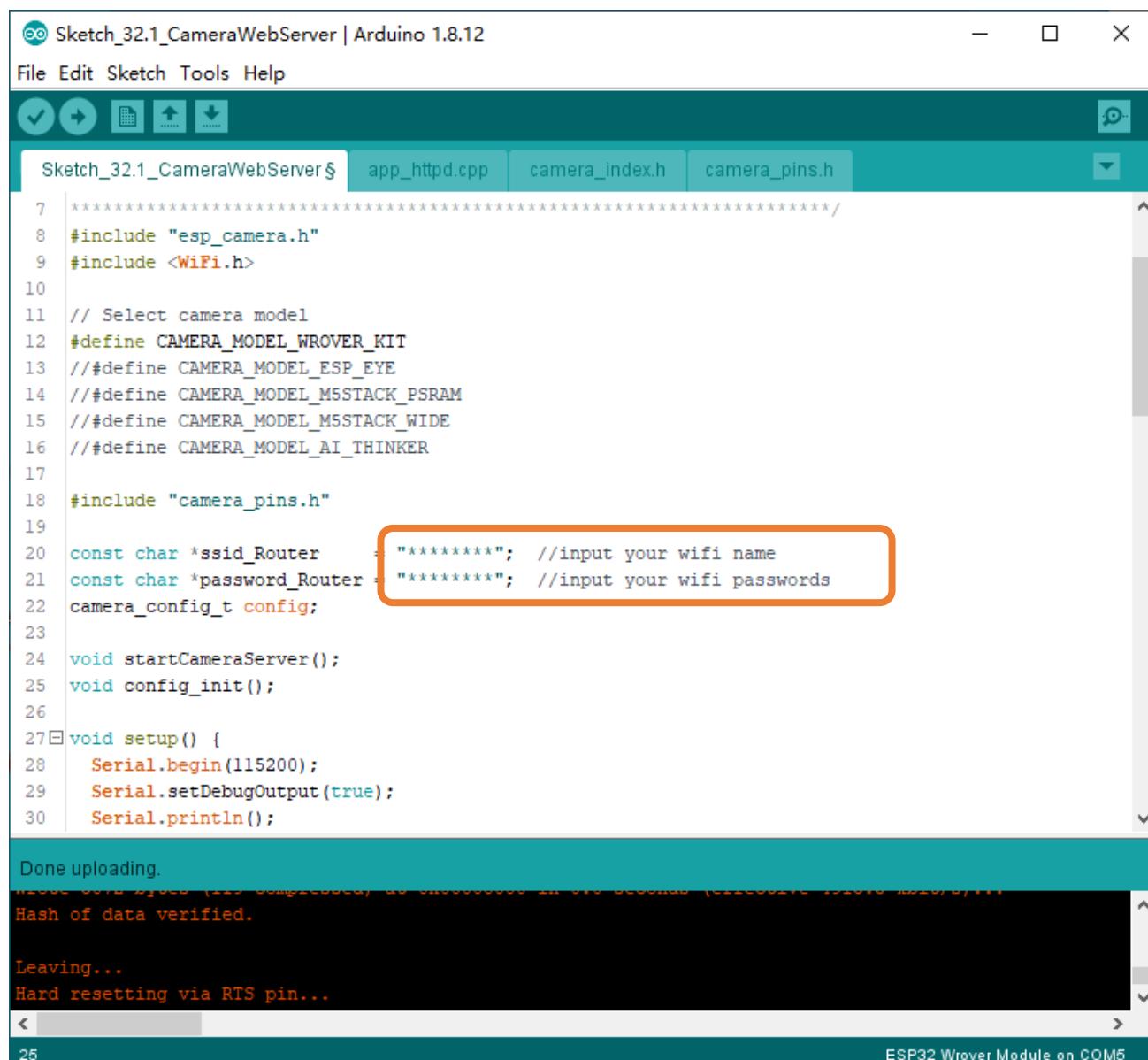
Circuit

Connect Freenove ESP32 to the computer using USB cable.



Sketch

Sketch_32.1_As_CameraWebServer



```
Sketch_32.1_CameraWebServer | Arduino 1.8.12
File Edit Sketch Tools Help
Sketch_32.1_CameraWebServer app_httpd.cpp camera_index.h camera_pins.h
7  ****
8 #include "esp_camera.h"
9 #include <WiFi.h>
10
11 // Select camera model
12 #define CAMERA_MODEL_WROVER_KIT
13 // #define CAMERA_MODEL_ESP_EYE
14 // #define CAMERA_MODEL_M5STACK_PSRAM
15 // #define CAMERA_MODEL_M5STACK_WIDE
16 // #define CAMERA_MODEL_AI_THINKER
17
18 #include "camera_pins.h"
19
20 const char *ssid_Router      = "*****"; //input your wifi name
21 const char *password_Router = "*****"; //input your wifi passwords
22 camera_config_t config;
23
24 void startCameraServer();
25 void config_init();
26
27 void setup() {
28     Serial.begin(115200);
29     Serial.setDebugOutput(true);
30     Serial.println();
```

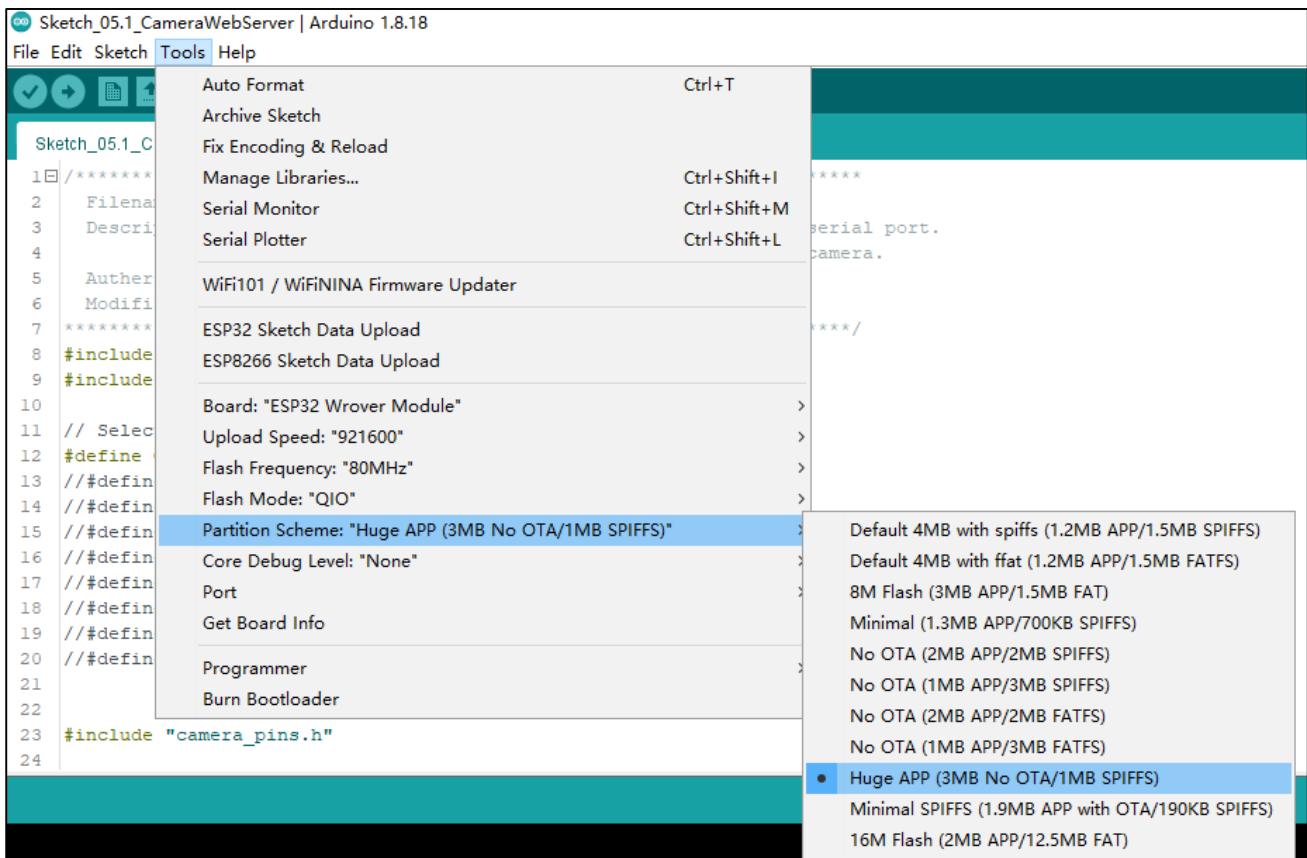
Done uploading.
Hash of data verified.

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

ESP32 Wrover Module on COM5

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.

If your Arduino IDE prompts you that your sketch is out of your project's storage space, compile the code again as configured below.



Compile and upload codes to ESP32, open the serial monitor and set the baud rate to 115200, and the serial monitor will print out a network link address.

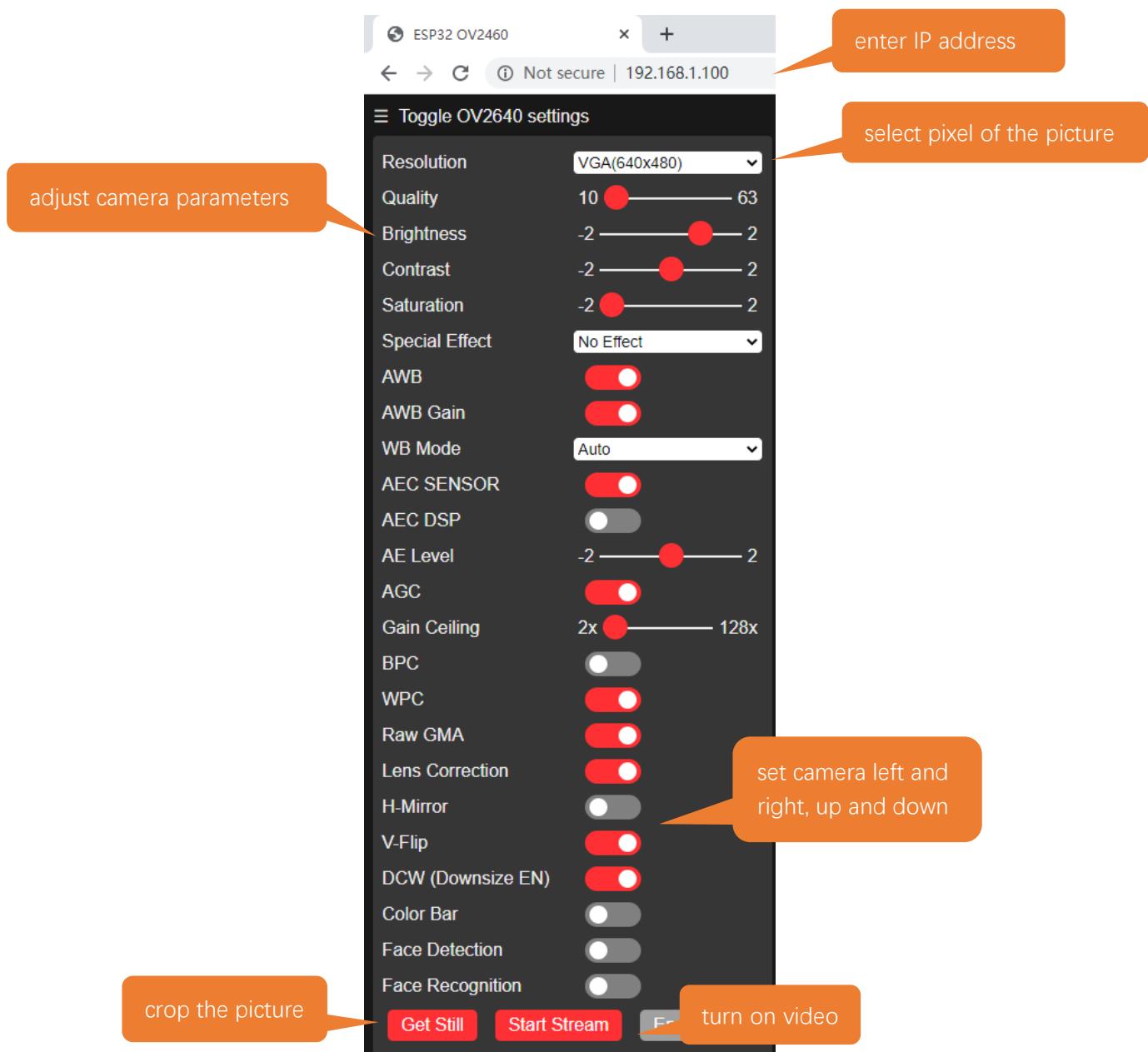
```

COM4
Send
{
.
WiFi connected
Starting web server on port: '80'
Starting stream server on port: '81'
Camera Ready! Use 'http://192.168.1.100' to connect

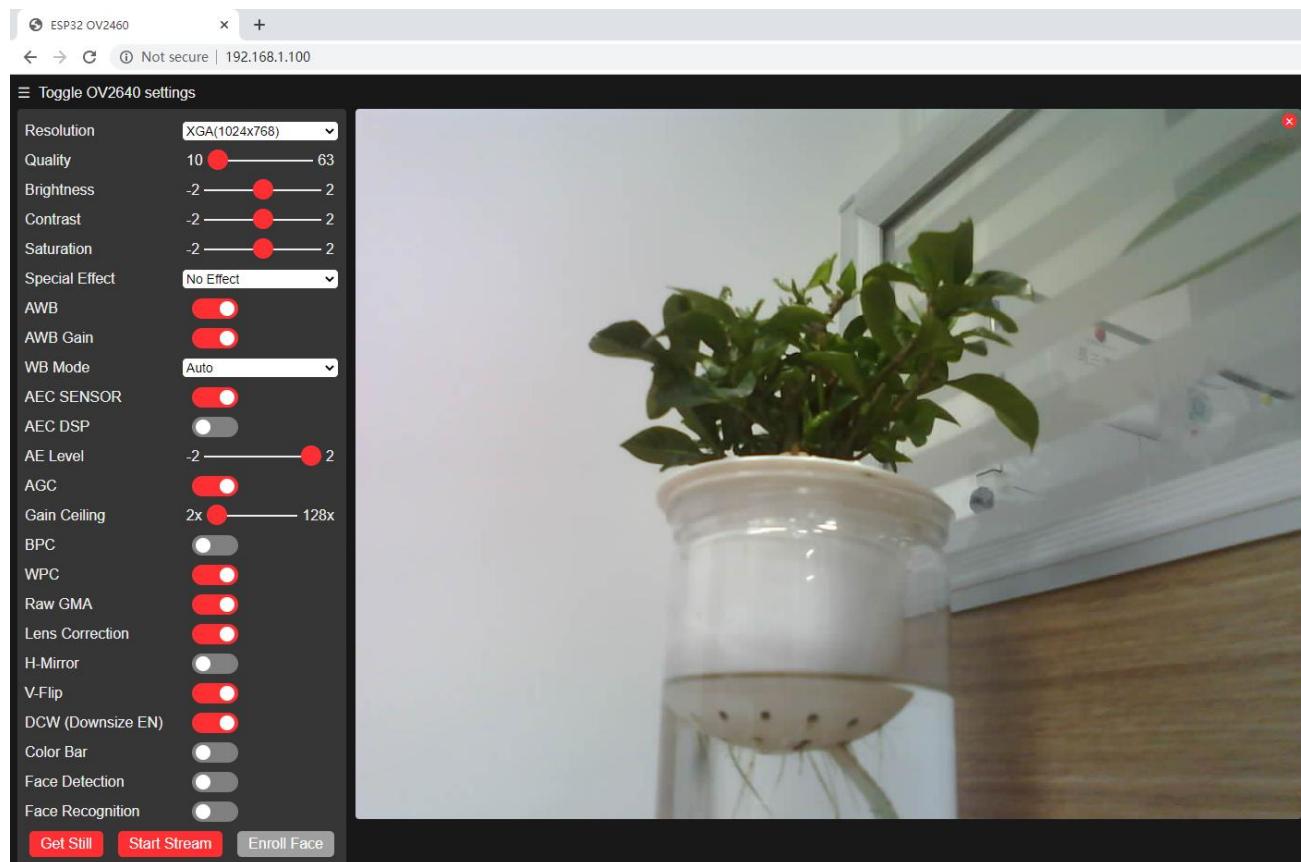
```

If your ESP32 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-WROVER to wait for a successful connection prompt.

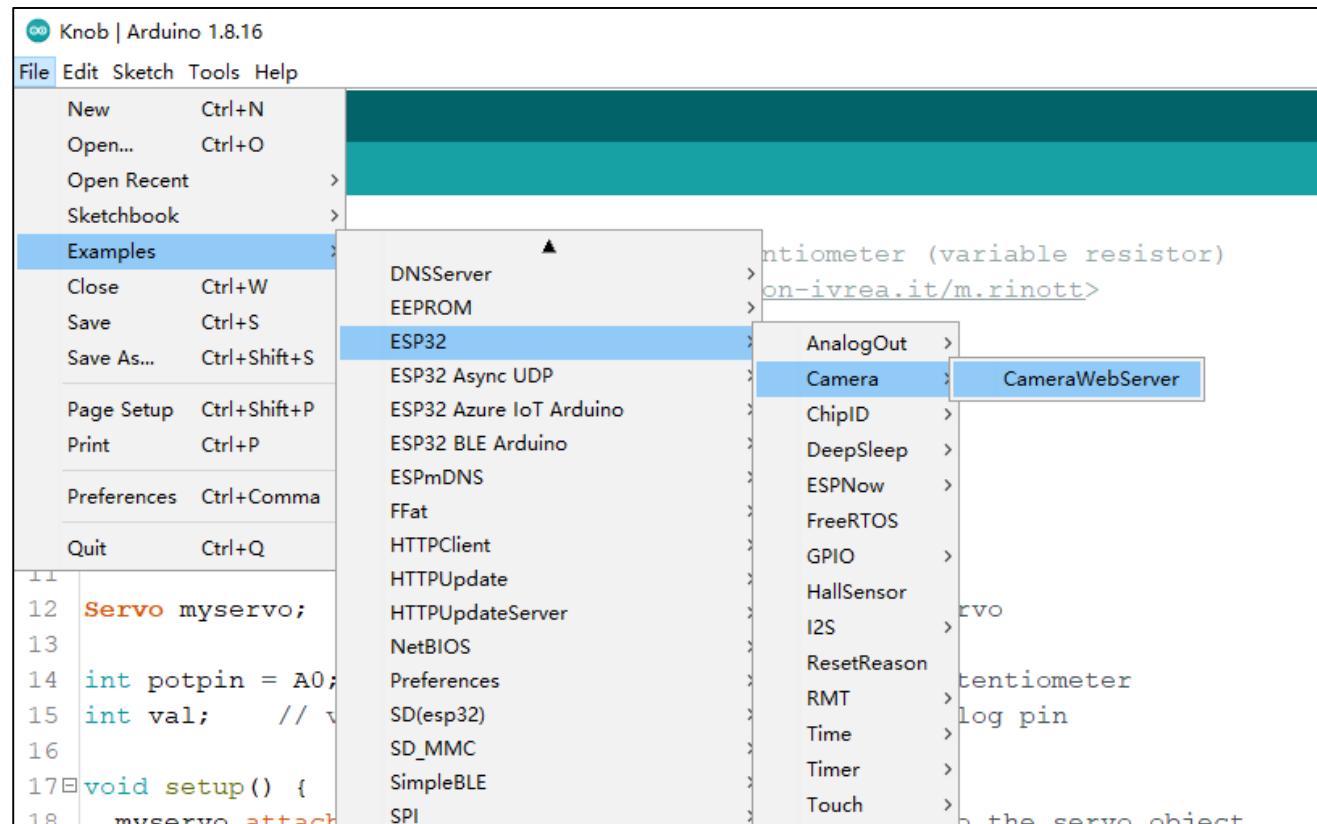
Open a web browser, enter the IP address printed by the serial monitor in the address bar, and access it. Taking the Google browser as an example, here's what the browser prints out after successful access to ESP32's IP.



Click on Start Stream. The effect is shown in the image below.



Note: If sketch compilation fails due to ESP32 support package, follow the steps of the image to open the CameraWebServer. This sketch is the same as described in the tutorial above.



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

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_WROVER_KIT
6 // #define CAMERA_MODEL_ESP_EYE
7 // #define CAMERA_MODEL_M5STACK_PSRAM
8 // #define CAMERA_MODEL_M5STACK_WIDE
9 // #define CAMERA_MODEL_AI_THINKER
10
11 #include "camera_pins.h"
12
13 const char *ssid_Router      = "*****"; //input your wifi name
14 const char *password_Router = "*****"; //input your wifi passwords
15 camera_config_t config;
16
17 void startCameraServer();
18 void config_init();
19
20 void setup() {
21     Serial.begin(115200);
22     Serial.setDebugOutput(true);
23     Serial.println();
24
25     config_init();
26     config.frame_size = FRAMESIZE_VGA;
27     config.jpeg_quality = 10;
28
29     // camera init
30     esp_err_t err = esp_camera_init(&config);
31     if (err != ESP_OK) {
32         Serial.printf("Camera init failed with error 0x%x", err);
33         return;
34     }
35
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
40
41     WiFi.begin(ssid_Router, password_Router);
42     while (WiFi.status() != WL_CONNECTED) {
```

```
43     delay(500);
44     Serial.print(".");
45 }
46 Serial.println("");
47 Serial.println("WiFi connected");
48
49 startCameraServer();
50
51 Serial.print("Camera Ready! Use 'http://");
52 Serial.print(WiFi.localIP());
53 Serial.println(" to connect");
54 }
55
56 void loop() {
57 ;
58 }
59
60 void config_init() {
61 config.ledc_channel = LEDC_CHANNEL_0;
62 config.ledc_timer = LEDC_TIMER_0;
63 config.pin_d0 = Y2_GPIO_NUM;
64 config.pin_d1 = Y3_GPIO_NUM;
65 config.pin_d2 = Y4_GPIO_NUM;
66 config.pin_d3 = Y5_GPIO_NUM;
67 config.pin_d4 = Y6_GPIO_NUM;
68 config.pin_d5 = Y7_GPIO_NUM;
69 config.pin_d6 = Y8_GPIO_NUM;
70 config.pin_d7 = Y9_GPIO_NUM;
71 config.pin_xclk = XCLK_GPIO_NUM;
72 config.pin_pclk = PCLK_GPIO_NUM;
73 config.pin_vsync = VSYNC_GPIO_NUM;
74 config.pin_href = HREF_GPIO_NUM;
75 config.pin_sscb_sda = SIOD_GPIO_NUM;
76 config.pin_sscb_scl = SIOC_GPIO_NUM;
77 config.pin_pwdn = PWDN_GPIO_NUM;
78 config.pin_reset = RESET_GPIO_NUM;
79 config.xclk_freq_hz = 20000000;
80 config.pixel_format = PIXFORMAT_JPEG;
81 config.fb_count = 1;
82 }
```

Add procedure files and API interface files related to ESP32 camera.

```

1 #include "esp_camera.h"
2 #include <WiFi.h>
3
4 // Select camera model
5 #define CAMERA_MODEL_WROVER_KIT
6 // #define CAMERA_MODEL_ESP_EYE
7 // #define CAMERA_MODEL_M5STACK_PSRAM
8 // #define CAMERA_MODEL_M5STACK_WIDE
9 // #define CAMERA_MODEL_AI_THINKER
10
11 #include "camera_pins.h"
```

Enter the name and password of the router

```

13 const char *ssid_Router      = "*****"; //input your wifi name
14 const char *password_Router = "*****"; //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.

```

60 void config_init() {
61     config.ledc_channel = LEDC_CHANNEL_0;
62     config.ledc_timer = LEDC_TIMER_0;
63     config.pin_d0 = Y2_GPIO_NUM;
64     config.pin_d1 = Y3_GPIO_NUM;
65     config.pin_d2 = Y4_GPIO_NUM;
66     config.pin_d3 = Y5_GPIO_NUM;
67     config.pin_d4 = Y6_GPIO_NUM;
68     config.pin_d5 = Y7_GPIO_NUM;
69     config.pin_d6 = Y8_GPIO_NUM;
70     config.pin_d7 = Y9_GPIO_NUM;
71     config.pin_xclk = XCLK_GPIO_NUM;
72     config.pin_pclk = PCLK_GPIO_NUM;
73     config.pin_vsync = VSYNC_GPIO_NUM;
74     config.pin_href = HREF_GPIO_NUM;
75     config.pin_sscb_sda = SIOD_GPIO_NUM;
76     config.pin_sscb_scl = SIOC_GPIO_NUM;
77     config.pin_pwdn = PWDN_GPIO_NUM;
78     config.pin_reset = RESET_GPIO_NUM;
79     config.xclk_freq_hz = 20000000;
80     config.pixel_format = PIXFORMAT_JPEG;
81     config.fb_count = 1;
82 }
```



ESP32 connects to the router and prints a successful connection prompt. If it has not been successfully connected, press the reset key on the ESP32-WROVER.

```

41 WiFi.begin(ssid_Router, password_Router);
42 while (WiFi.status() != WL_CONNECTED) {
43     delay(500);
44     Serial.print(".");
45 }
46 Serial.println("");
47 Serial.println("WiFi connected");

```

Open the video streams server function of the camera and print its IP address via serial port.

```

49 startCameraServer();
50
51 Serial.print("Camera Ready! Use 'http://'");
52 Serial.print(WiFi.localIP());
53 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;

```

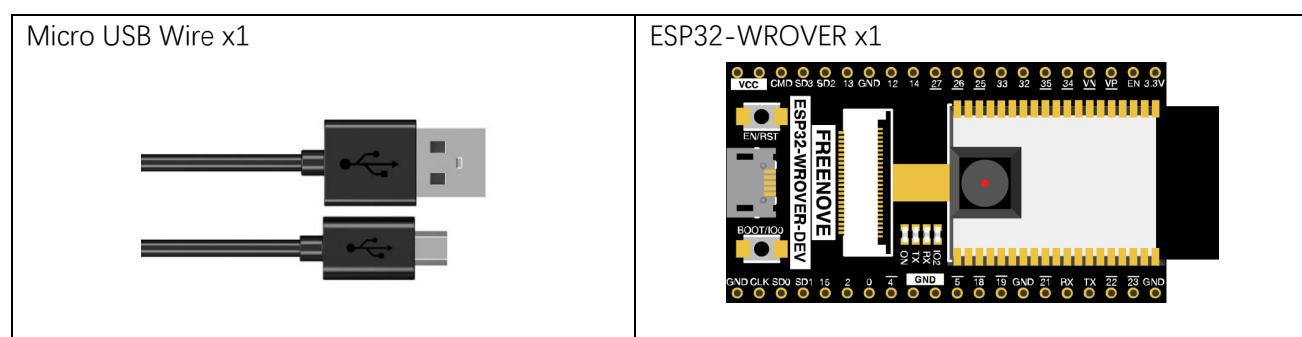
Reference

Image resolution	Sharpness	Image resolution	Sharpness
FRAMESIZE_QQVGA	160x120	FRAMESIZE_VGA	640x480
FRAMESIZE_QQVGA2	128x160	FRAMESIZE_SVGA	800x600
FRAMESIZE_QCIF	176x144	FRAMESIZE_XGA	1024x768
FRAMESIZE_HQVGA	240x176	FRAMESIZE_SXGA	1280x1024
FRAMESIZE_QVGA	320x240	FRAMESIZE_UXGA	1600x1200
FRAMESIZE_CIF	400x296	FRAMESIZE_QXGA	2048x1536

Project 32.2 Video Web Server

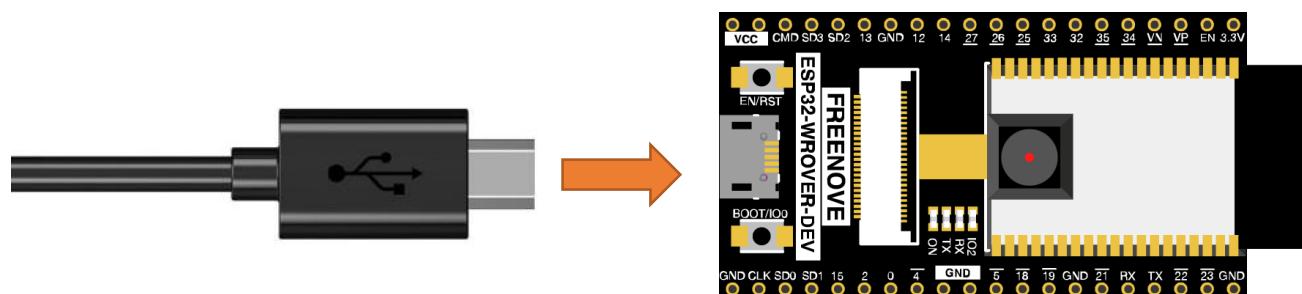
Connect to ESP32 using USB and view its IP address through a serial monitor. Access IP addresses through web pages to obtain real-time video data.

Component List



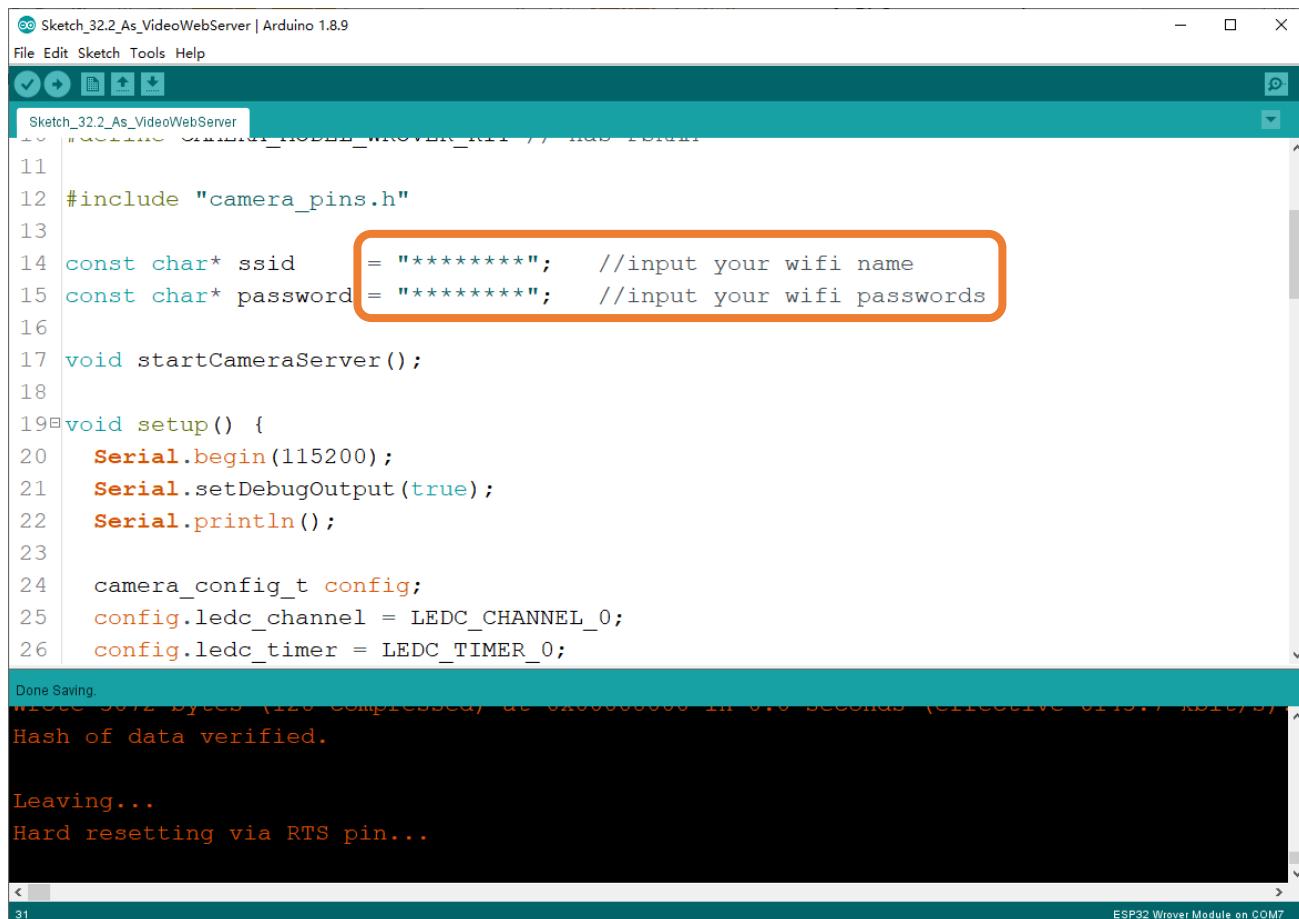
Circuit

Connect Freenove ESP32 to the computer using USB cable.



Sketch

Sketch_32.2_As_VideoWebServer



```

Sketch_32.2_As_VideoWebServer | Arduino 1.8.9
File Edit Sketch Tools Help
Sketch_32.2_As_VideoWebServer
11
12 #include "camera_pins.h"
13
14 const char* ssid      = "*****";      //input your wifi name
15 const char* password = "*****";      //input your wifi passwords
16
17 void startCameraServer();
18
19 void setup() {
20   Serial.begin(115200);
21   Serial.setDebugOutput(true);
22   Serial.println();
23
24   camera_config_t config;
25   config.ledc_channel = LEDC_CHANNEL_0;
26   config.ledc_timer = LEDC_TIMER_0;

```

Done Saving.
Wrote 3072 bytes (120 compressed) at 0x00000000 in 0.0 seconds (effective 0.157 ms/sec).

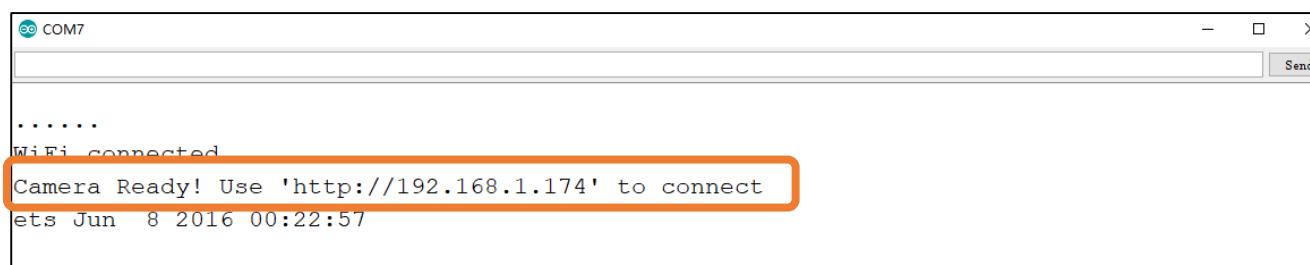
Hash of data verified.

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

ESP32 Wrover Module on COM7

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, open the serial monitor and set the baud rate to 115200, and the serial monitor will print out a network link address.



```

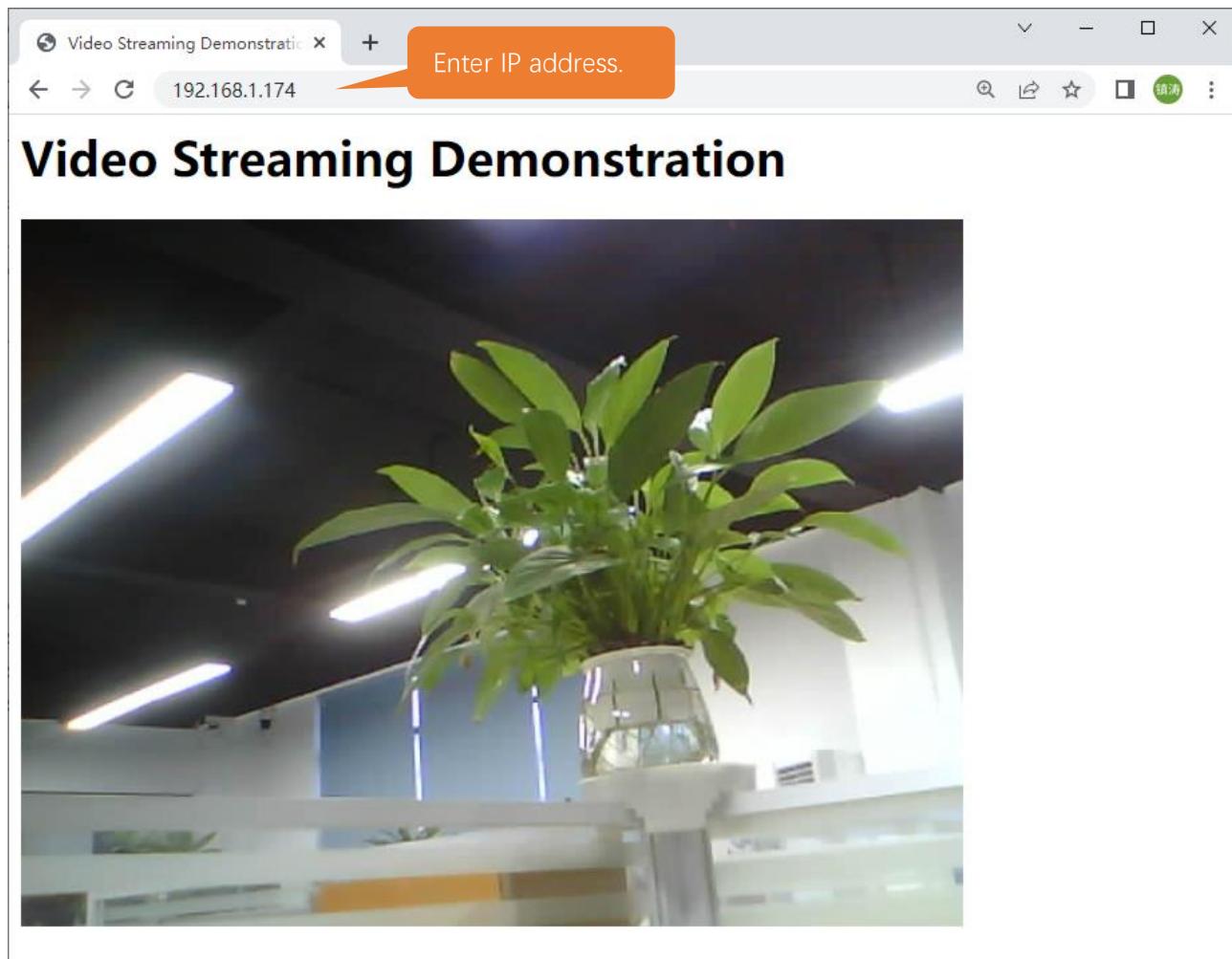
COM7
.....
WiFi connected
Camera Ready! Use 'http://192.168.1.174' to connect
ets Jun 8 2016 00:22:57

```

If your ESP32 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-WROVER 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'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 // WARNING!!! PSRAM IC required for UXGA resolution and high JPEG quality
5 //           Ensure ESP32 Wrover Module or other board with PSRAM is selected
6 //           Partial images will be transmitted if image exceeds buffer size
7 //
8
9 // Select camera model
10 #define CAMERA_MODEL_WROVER_KIT // Has PSRAM
11
```

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

```
12 #include "camera_pins.h"
13
14 const char* ssid      = "*****";    //input your wifi name
15 const char* password = "*****";    //input your wifi passwords
16
17 void startCameraServer();
18
19 void setup() {
20     Serial.begin(115200);
21     Serial.setDebugOutput(true);
22     Serial.println();
23
24     camera_config_t config;
25     config.ledc_channel = LEDC_CHANNEL_0;
26     config.ledc_timer = LEDC_TIMER_0;
27     config.pin_d0 = Y2_GPIO_NUM;
28     config.pin_d1 = Y3_GPIO_NUM;
29     config.pin_d2 = Y4_GPIO_NUM;
30     config.pin_d3 = Y5_GPIO_NUM;
31     config.pin_d4 = Y6_GPIO_NUM;
32     config.pin_d5 = Y7_GPIO_NUM;
33     config.pin_d6 = Y8_GPIO_NUM;
34     config.pin_d7 = Y9_GPIO_NUM;
35     config.pin_xclk = XCLK_GPIO_NUM;
36     config.pin_pclk = PCLK_GPIO_NUM;
37     config.pin_vsync = VSYNC_GPIO_NUM;
38     config.pin_href = HREF_GPIO_NUM;
39     config.pin_sscb_sda = SIOD_GPIO_NUM;
40     config.pin_sscb_scl = SIOC_GPIO_NUM;
41     config.pin_pwdn = PWDN_GPIO_NUM;
42     config.pin_reset = RESET_GPIO_NUM;
43     config.xclk_freq_hz = 20000000;
44     config.pixel_format = PIXFORMAT_JPEG;
45
46     // if PSRAM IC present, init with UXGA resolution and higher JPEG quality
47     //                                for larger pre-allocated frame buffer.
48     if(psramFound()){
49         config.frame_size = FRAMESIZE_UXGA;
50         config.jpeg_quality = 10;
51         config.fb_count = 2;
52     } else {
53         config.frame_size = FRAMESIZE_SVGA;
54         config.jpeg_quality = 12;
55         config.fb_count = 1;
```

```
56 }
57
58 // camera init
59 esp_err_t err = esp_camera_init(&config);
60 if (err != ESP_OK) {
61     Serial.printf("Camera init failed with error 0x%x", err);
62     return;
63 }
64
65 sensor_t * s = esp_camera_sensor_get();
66 // drop down frame size for higher initial frame rate
67 s->set_framesize(s, FRAMESIZE_QVGA);
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.

```
24 camera_config_t config;
25 config.ledc_channel = LEDC_CHANNEL_0;
26 config.ledc_timer = LEDC_TIMER_0;
27 config.pin_d0 = Y2_GPIO_NUM;
28 config.pin_d1 = Y3_GPIO_NUM;
29 config.pin_d2 = Y4_GPIO_NUM;
30 config.pin_d3 = Y5_GPIO_NUM;
31 config.pin_d4 = Y6_GPIO_NUM;
```

```

32 config.pin_d5 = Y7_GPIO_NUM;
33 config.pin_d6 = Y8_GPIO_NUM;
34 config.pin_d7 = Y9_GPIO_NUM;
35 config.pin_xclk = XCLK_GPIO_NUM;
36 config.pin_pclk = PCLK_GPIO_NUM;
37 config.pin_vsync = VSYNC_GPIO_NUM;
38 config.pin_href = HREF_GPIO_NUM;
39 config.pin_sscb_sda = SIOD_GPIO_NUM;
40 config.pin_sscb_scl = SIOC_GPIO_NUM;
41 config.pin_pwdn = PWDN_GPIO_NUM;
42 config.pin_reset = RESET_GPIO_NUM;
43 config.xclk_freq_hz = 20000000;
44 config.pixel_format = PIXFORMAT_JPEG;

```

ESP32 connects to the router and prints a successful connection prompt. If it has not been successfully connected, press the reset key on the ESP32-WROVER.

```

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.

```

78 startCameraServer();
79
80 Serial.print("Camera Ready! Use 'http://");
81 Serial.print(WiFi.localIP());
82 Serial.println(" to connect");

```

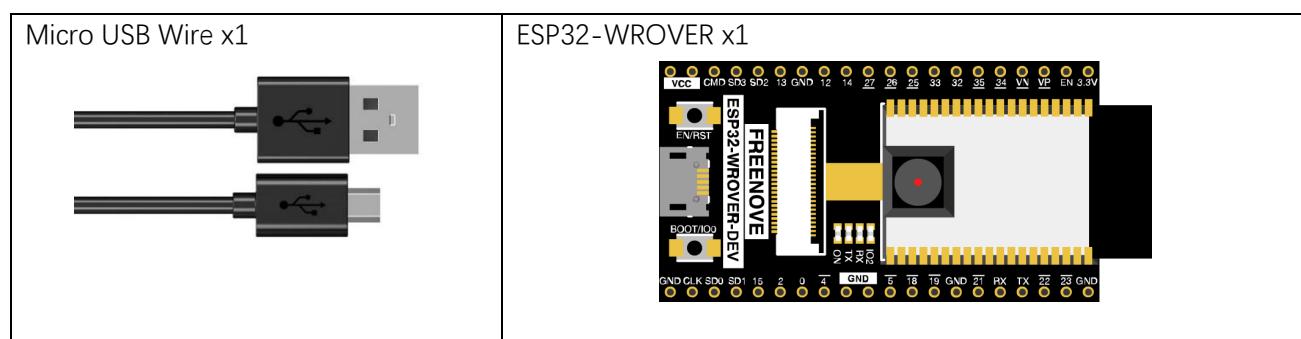
Chapter 33 Camera Tcp Server

In the previous section, we used web page to display the video data captured by ESP32, and in this section, we will use a mobile phone to display it.

Project 33.1 Camera Tcp Server

Connect ESP32 using USB and check its IP address through serial monitor. Use a mobile phone to obtain video and image data.

Component List

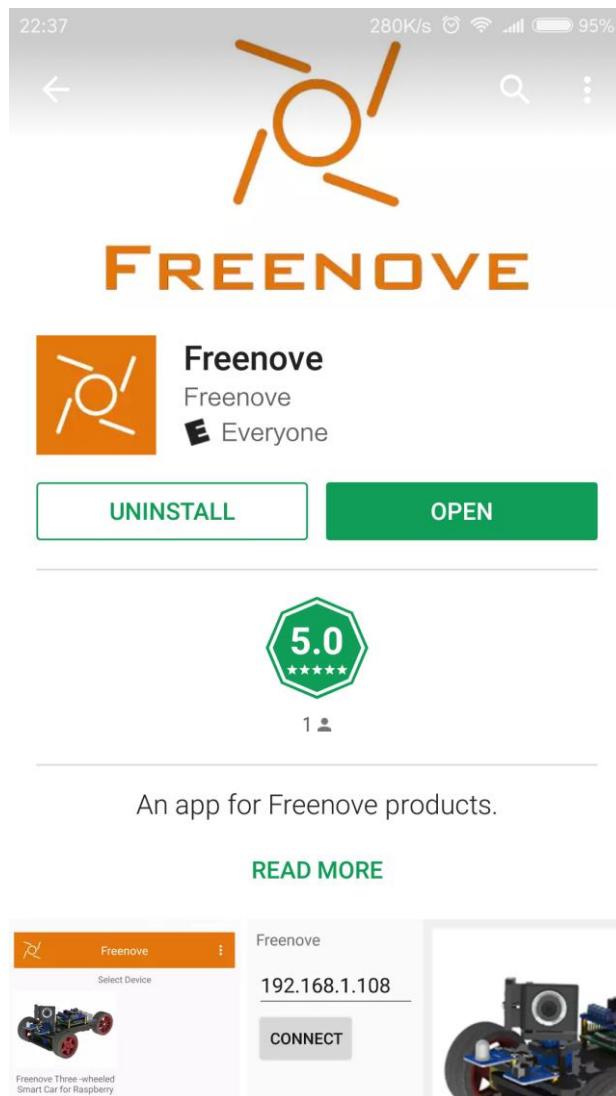


Install Freenove app

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](mailto:support@freenove.com)

Method 2

Visit <https://play.google.com/store/apps/details?id=com.freenove.suhayl.Freenove>, and click install.



Freenove

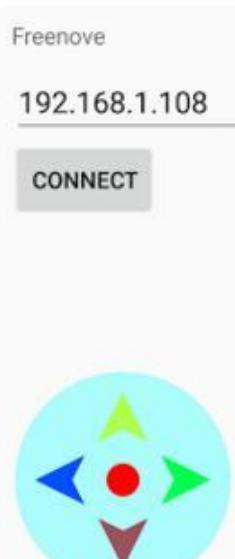
Freenove Tools

★★★★★ 1 person

E Everyone

This app is compatible with all of your devices.

Installed





Method 3

Visit https://github.com/Freenove/Freenove_app_for_Android, download the files in this library, and install freenove.apk to your Android phone manually.

Apply to Freenove products. Edit

Branch: master New pull request Create new file Upload files Find file Clone or download

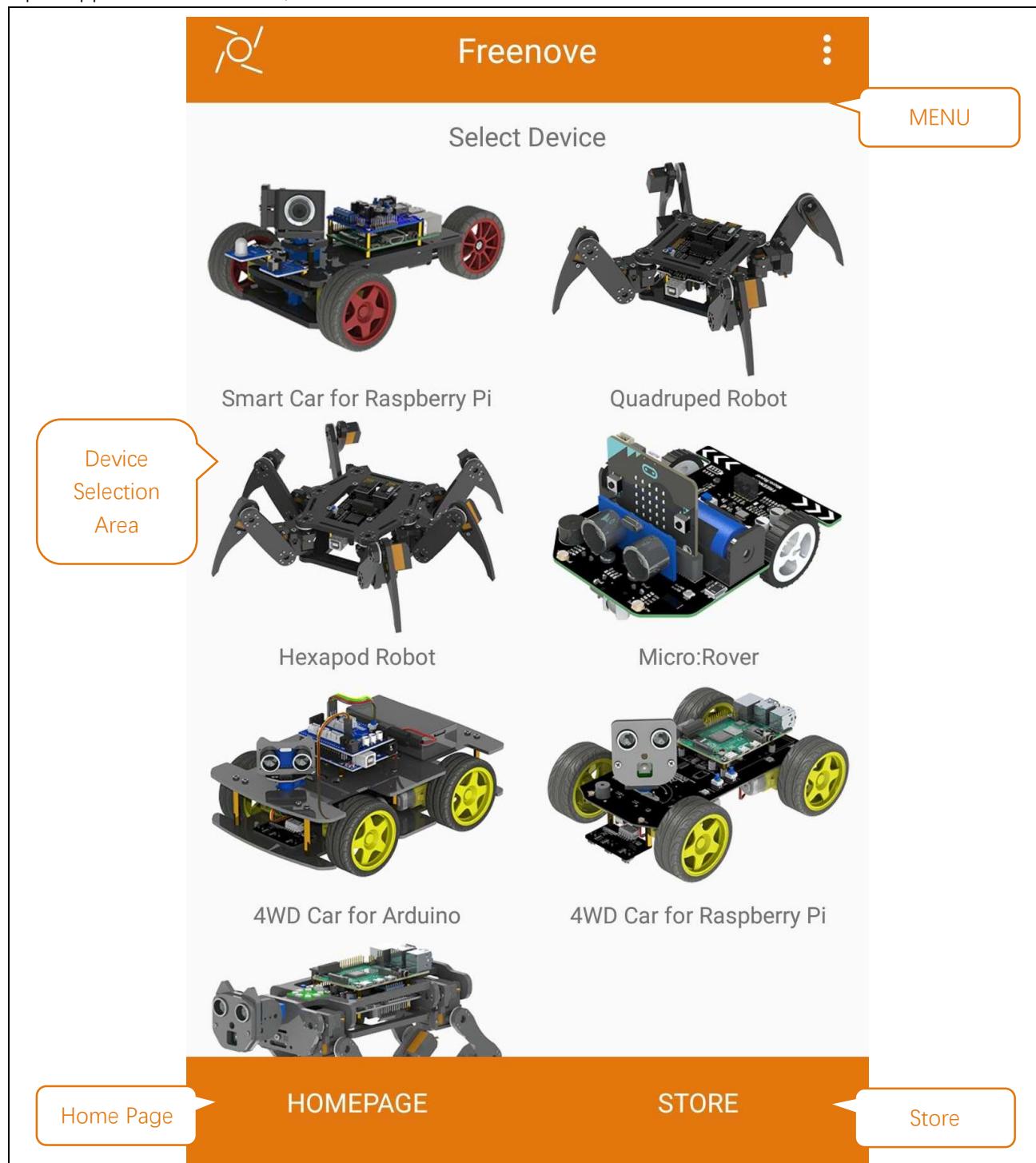
SuhaylZhao	First Publish.	...
Readme.txt	First Publish.	3 minutes ago
freenove.apk	First Publish.	3 minutes ago

Latest commit 0723fc5 3 minutes ago

Click here to download.

Menu

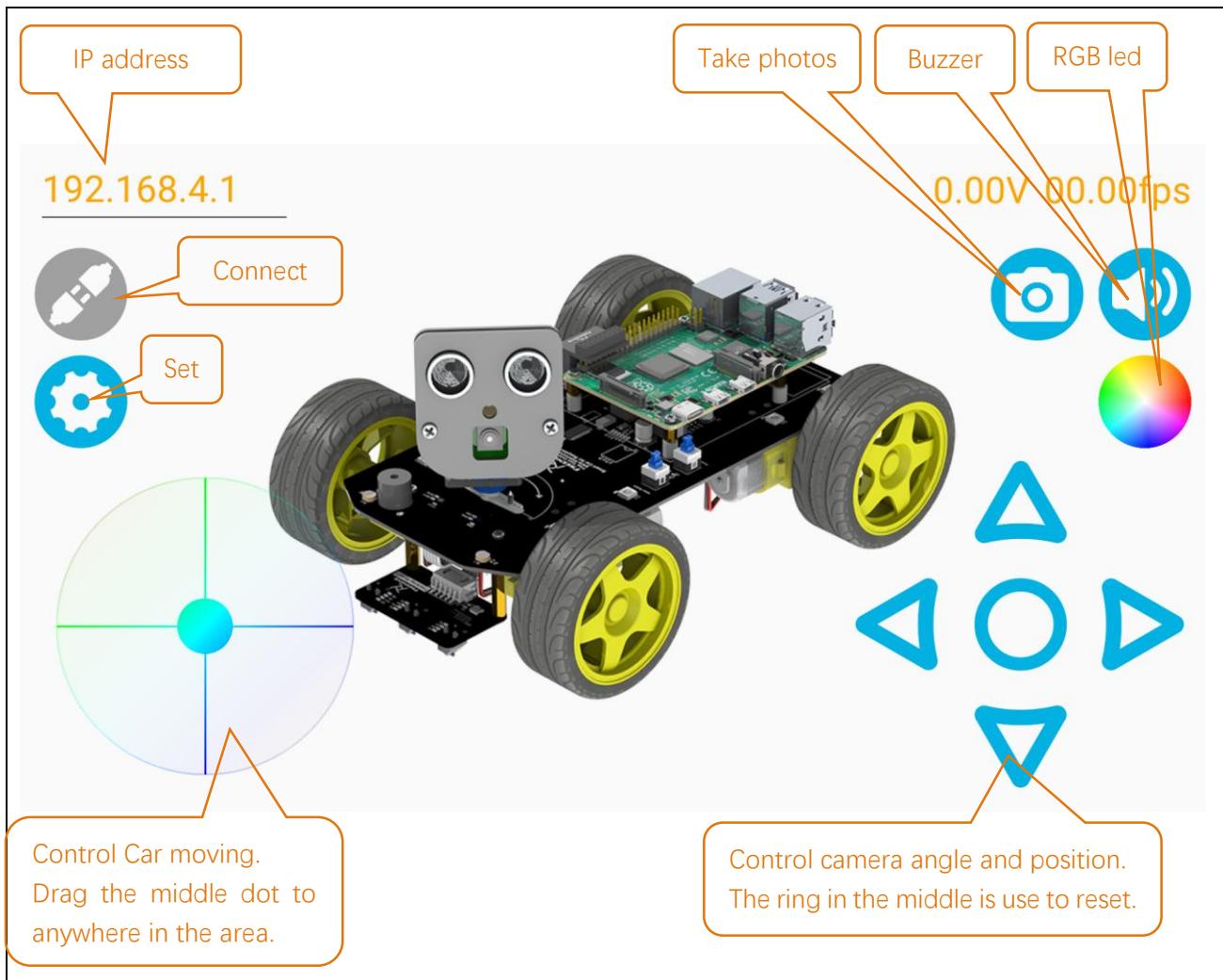
Open application “Freenove”, as shown below:





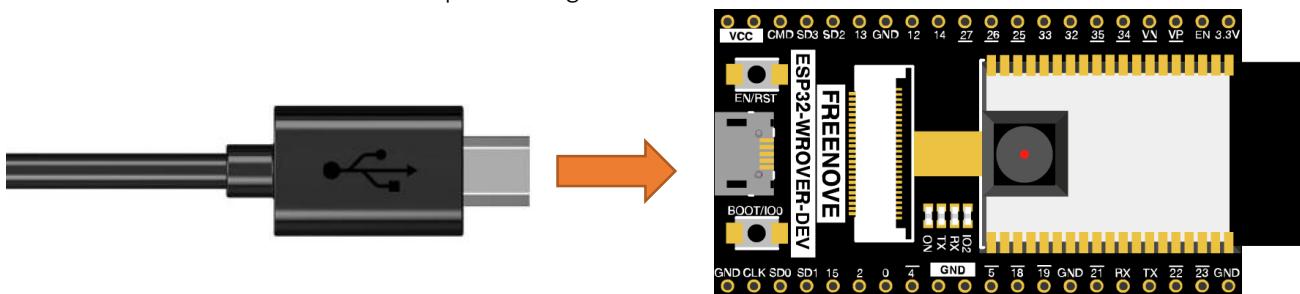
Freenove 4WD Car for Raspberry Pi

In this chapter, we use Freenove 4WD Car for Raspberry Pi, so it is necessary to understand the interface of this mode.



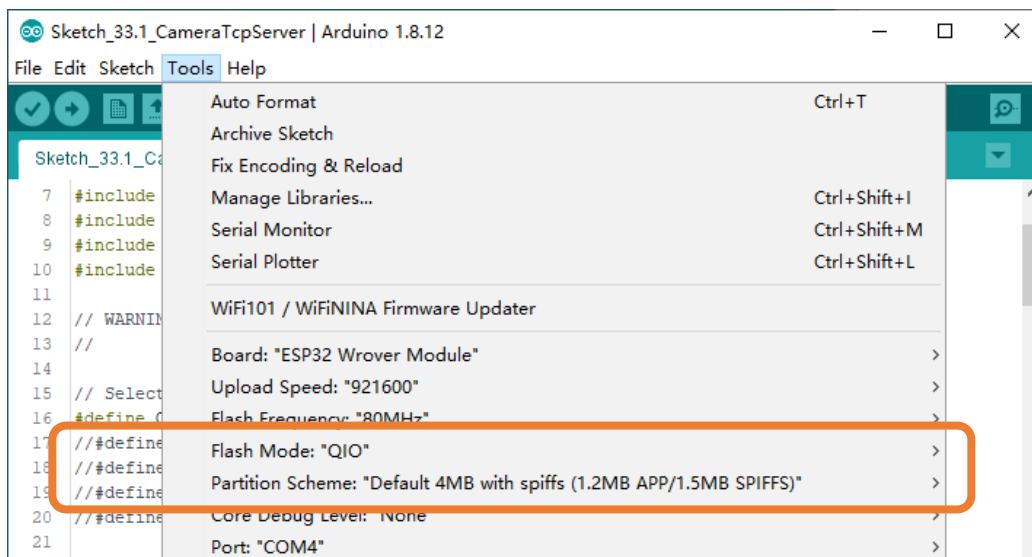
Circuit

Connect Freenove ESP32 to the computer using USB cable.



Sketch

Click Tools in the menu bar, select Flash Mode: "QIO", and select Partition Scheme:" Huge APP (3MB No OTA/1MB SPIFFS) ", as shown in the figure below.



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.

```

#include "esp_camera.h"
#include <WiFi.h>
#include <WiFiClient.h>
#include <WiFiAP.h>

#define CAMERA_MODEL_WROVER_KIT
#include "camera_pins.h"
#define LED_BUILT_IN 2

const char* ssid_Router      = "*****";
const char* password_Router = "*****";
const char *ssid_AP          = "*****";
const char *password_AP      = "*****";

```

The screenshot shows the Arduino IDE with the title 'CameraTcpServer | Arduino 1.8.12'. The code editor displays the 'CameraTcpServer' sketch. At the top of the code, there is a configuration section with several lines of code that define WiFi credentials. These lines are highlighted with a red box. The code includes #include statements for esp_camera.h, WiFi.h, WiFiClient.h, WiFiAP.h, and camera_pins.h, along with defines for CAMERA_MODEL_WROVER_KIT, LED_BUILT_IN, and const variables for ssid_Router, password_Router, ssid_AP, and password_AP, all containing placeholder asterisks.

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, and they are freely set by the user. When all settings are correct, compile and upload the code to ESP32, turn on the serial port monitor, and set the baud rate to 115200. The serial monitor will print out two IP addresses.



The screenshot shows the Freenove Serial Monitor window titled "COM5". The text area contains the following output:

```
Camera configuration complete!
AP IP address: 192.168.4.1
Connecting FYI_2.4G..
WiFi connected
Camera Ready! Use '192.168.4.1 or 192.168.1.100' to connect in Freenove app.
Task Cmd_Server is starting ...
Task Blink is starting ...
```

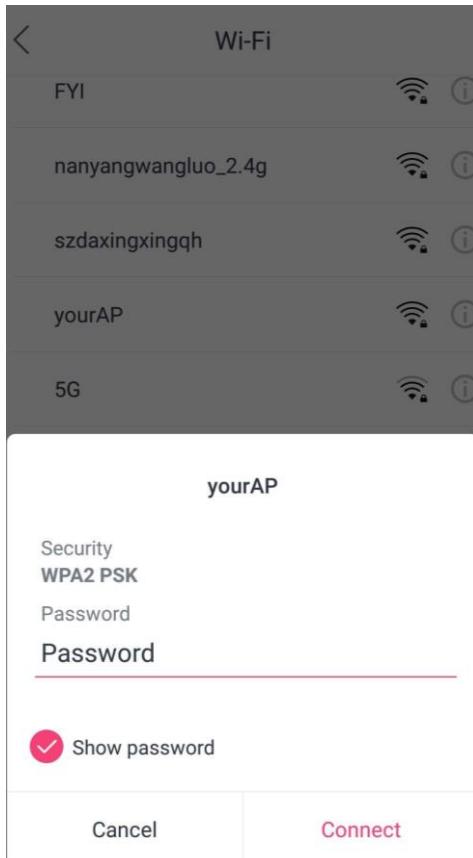
The text from "Camera configuration complete!" to "Task Blink is starting ..." is highlighted with an orange rectangle.

At the bottom of the window, there are checkboxes for "Autoscroll" and "Show timestamp", a "Newline" dropdown set to "Newline", a "115200 baud" dropdown, and a "Clear output" button.

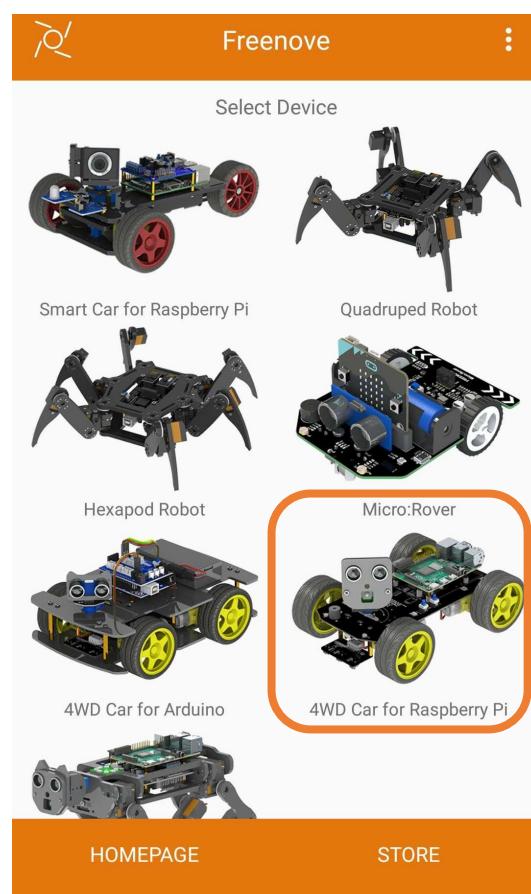
There are two methods for you to check camera data of ESP32 via mobile phone APP.

Method 1:

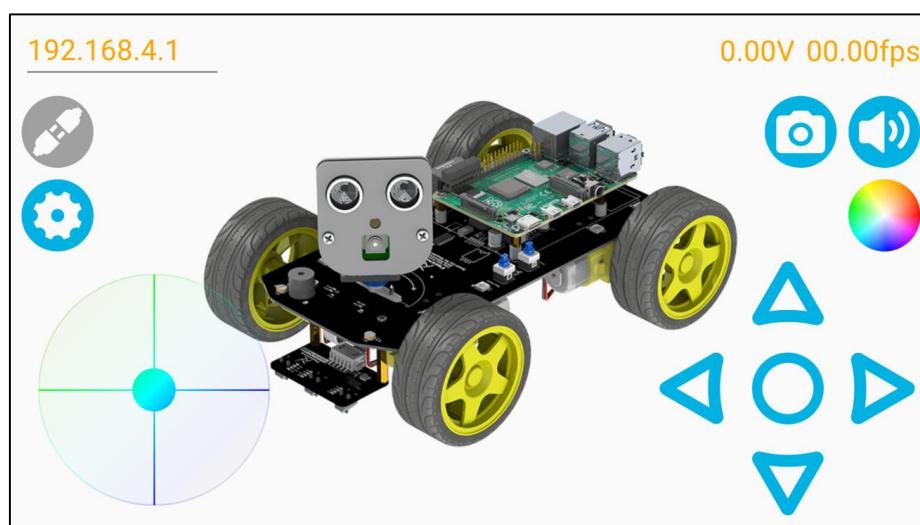
Using your phone's WiFi function, select the WiFi name represented by ssid_AP in Sketch and enter the password "password_AP" to connect.



Next, open Freenove app and select 4WD Car for Raspberry Pi mode.



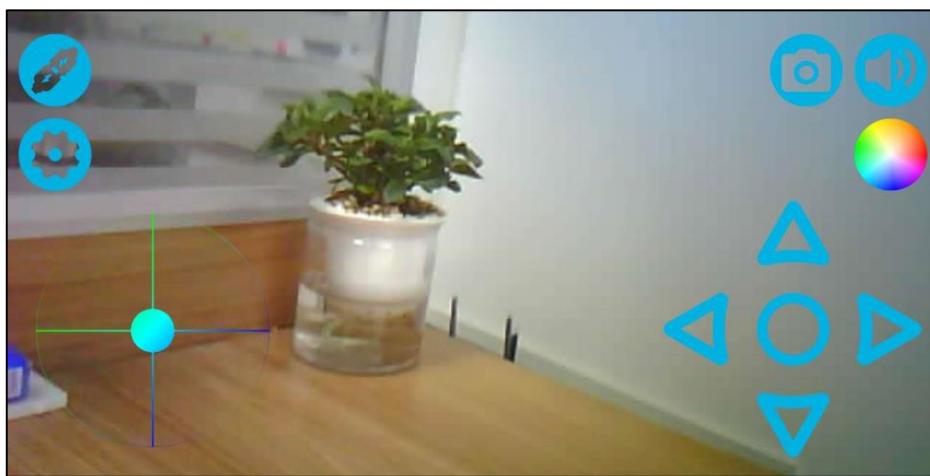
Enter the IP address printed by serial port in the new interface, which generally is "192.168.4.1"



Any concerns? ✉ support@freenove.com



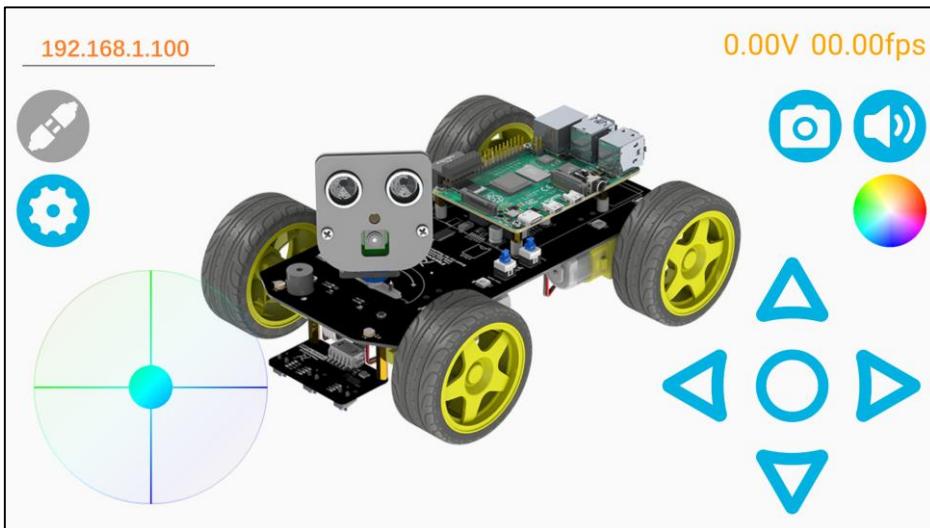
Click “Connect”.



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_WROVER_KIT

```

```
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.status() != WL_CONNECTED) {
37         delay(500);
38         Serial.print(".");
39         WiFi.begin(ssid_Router, password_Router);
40     }
41     Serial.println("");
42     Serial.println("WiFi connected");
43     /////////////////////////////////
44     Serial.print("Camera Ready! Use '");
45     Serial.print(WiFi.softAPIP());
46     Serial.print(" or ");
47     Serial.print(WiFi.localIP());
48     Serial.println("' to connect in Freenove app.");
49
50     disableCore0WDT();
```



```

51     xTaskCreateUniversal(loopTask_Cmd, "loopTask_Cmd", 8192, NULL, 1, &loopTaskHandle, 0);
52     //loopTask_Cmd uses core 0.
53     xTaskCreateUniversal(loopTask_Blink, "loopTask_Blink", 8192, NULL, 1, &loopTaskHandle,
54 )//loopTask_Blink uses core 0.
55 }
56 //task loop uses core 1.
57 void loop() {
58     WiFiClient client = server_Camera.available();           // listen for incoming clients
59     if (client) {                                         // if you get a client,
60         Serial.println("Camera Server connected to a client."); // print a message out the
61         serial port
62         String currentLine = ""; // make a String to hold incoming data from the client
63         while (client.connected()) { // loop while the client's connected
64             camera_fb_t * fb = NULL;
65             while (client.connected()) {
66                 fb = esp_camera_fb_get();
67                 if (fb != NULL) {
68                     uint8_t slen[4];
69                     slen[0] = fb->len >> 0;
70                     slen[1] = fb->len >> 8;
71                     slen[2] = fb->len >> 16;
72                     slen[3] = fb->len >> 24;
73                     client.write(slen, 4);
74                     client.write(fb->buf, fb->len);
75                 }
76                 else {
77                     Serial.println("Camera Error");
78                 }
79             }
80             // close the connection:
81             client.stop();
82             Serial.println("Camera Client Disconnected.");
83         }
84     }
85
86 void loopTask_Cmd(void *pvParameters) {
87     Serial.println("Task Cmd_Server is starting ... ");
88     while (1) {
89         WiFiClient client = server_Cmd.available(); // listen for incoming clients
90         if (client) {                               // if you get a client,
91             Serial.println("Command Server connected to a client."); // print a message out
92             the serial port
93             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);
97             Serial.write(c);        // print it out the serial monitor
98             if (c == '\n') {          // if the byte is a newline character
99                 currentLine = "";
100            }
101            else {
102                currentLine += c;    // add it to the end of the currentLine
103            }
104        }
105    }
106    // close the connection:
107    client.stop();
108    Serial.println("Command Client Disconnected.");
109}
110}
111}
112void 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}
119
120void cameraSetup() {
121    camera_config_t config;
122    config.ledc_channel = LEDC_CHANNEL_0;
123    config.ledc_timer = LEDC_TIMER_0;
124    config.pin_d0 = Y2_GPIO_NUM;
125    config.pin_d1 = Y3_GPIO_NUM;
126    config.pin_d2 = Y4_GPIO_NUM;
127    config.pin_d3 = Y5_GPIO_NUM;
128    config.pin_d4 = Y6_GPIO_NUM;
129    config.pin_d5 = Y7_GPIO_NUM;
130    config.pin_d6 = Y8_GPIO_NUM;
131    config.pin_d7 = Y9_GPIO_NUM;
132    config.pin_xclk = XCLK_GPIO_NUM;
133    config.pin_pclk = PCLK_GPIO_NUM;
134    config.pin_vsync = VSYNC_GPIO_NUM;
135    config.pin_href = HREF_GPIO_NUM;
136    config.pin_sscb_sda = SIOD_GPIO_NUM;
```

```

137 config.pin_sscb_scl = SIOC_GPIO_NUM;
138 config.pin_pwdn = PWDN_GPIO_NUM;
139 config.pin_reset = RESET_GPIO_NUM;
140 config.xclk_freq_hz = 20000000;
141 config.pixel_format = PIXFORMAT_JPEG;
142
143 psramFound();
144 config.frame_size = FRAMESIZE_QVGA;
145 config.jpeg_quality = 10;
146 config.fb_count = 1;
147
148 // camera init
149 esp_err_t err = esp_camera_init(&config);
150 if (err != ESP_OK) {
151     Serial.printf("Camera init failed with error 0x%x", err);
152     return;
153 }
154 Serial.println("Camera configuration complete!");
155 }
```

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_WROVER_KIT
7 #include "camera_pins.h"
8 #define LED_BUILT_IN 2
```

Set name and password for router that ESP32 needs to connect to. And set ESP32 to open two servers, whose port are 82 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'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.

```
120 void cameraSetup() {  
121     camera_config_t config;  
122     config.ledc_channel = LEDC_CHANNEL_0;  
123     config.ledc_timer = LEDC_TIMER_0;  
124     config.pin_d0 = Y2_GPIO_NUM;  
125     config.pin_d1 = Y3_GPIO_NUM;  
126     config.pin_d2 = Y4_GPIO_NUM;  
127     config.pin_d3 = Y5_GPIO_NUM;  
128     config.pin_d4 = Y6_GPIO_NUM;  
129     config.pin_d5 = Y7_GPIO_NUM;  
130     config.pin_d6 = Y8_GPIO_NUM;  
131     config.pin_d7 = Y9_GPIO_NUM;  
132     config.pin_xclk = XCLK_GPIO_NUM;  
133     config.pin_pclk = PCLK_GPIO_NUM;  
134     config.pin_vsync = VSYNC_GPIO_NUM;  
135     config.pin_href = HREF_GPIO_NUM;  
136     config.pin_sscb_sda = SIOD_GPIO_NUM;  
137     config.pin_sscb_scl = SIOC_GPIO_NUM;  
138     config.pin_pwdn = PWDN_GPIO_NUM;  
139     config.pin_reset = RESET_GPIO_NUM;  
140     config.xclk_freq_hz = 20000000;  
141     config.pixel_format = PIXFORMAT_JPEG;  
142  
143     psramFound();  
144     config.frame_size = FRAMESIZE_QVGA;  
145     config.jpeg_quality = 10;  
146     config.fb_count = 1;  
147  
148     // camera init  
149     esp_err_t err = esp_camera_init(&config);  
150     if (err != ESP_OK) {  
151         Serial.printf("Camera init failed with error 0x%x", err);  
152         return;  
153     }  
154     Serial.println("Camera configuration complete!");  
155 }
```

Loop function will constantly send camera data obtained to mobile phone APP.

```

62     while (client.connected()) {      // loop while the client's connected
63         camera_fb_t * fb = NULL;
64         while (client.connected()) {
65             fb = esp_camera_fb_get();
66             if (fb != NULL) {
67                 uint8_t slen[4];
68                 slen[0] = fb->len >> 0;
69                 slen[1] = fb->len >> 8;
70                 slen[2] = fb->len >> 16;
71                 slen[3] = fb->len >> 24;
72                 client.write(slen, 4);
73                 client.write(fb->buf, fb->len);
74             }
75             else {
76                 Serial.println("Camera Error");
77             }
78         }
79     }

```

The loopTask_Cmd() function sends the received instruction back to the phone app and prints it out through a serial port.

```

86 void loopTask_Cmd(void *pvParameters) {
87     Serial.println("Task Cmd_Server is starting ... ");
88     while (1) {
89         WiFiClient client = server_Cmd.available(); // listen for incoming clients
90         if (client) {                                // if you get a client,
91             Serial.println("Command Server connected to a client."); // print a message out
the 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);
97                     Serial.write(c); // print it out the serial monitor
98                     if (c == '\n') { // if the byte is a newline character
99                         currentLine = "";
100                     }
101                 else {
102                     currentLine += c; // add it to the end of the currentLine
103                 }
104             }
105         }
106         // close the connection:
107         client.stop();

```

Any concerns? ✉ support@freenove.com

```

108         Serial.println("Command Client Disconnected.");
109     }
110 }
111 }
```

loopTask_Blink()function will control the blinking of LED. When you see LED blinking, it indicates that ESP32 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_BUILTIN, !digitalRead(LED_BUILTIN));
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. 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.status() != WL_CONNECTED) {
37     delay(500);
38     Serial.print(".");
39     WiFi.begin(ssid_Router, password_Router);
40 }
41 Serial.println("");
42 Serial.println("WiFi connected");
43 ///////////////////////////////////////////////////////////////////
```

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

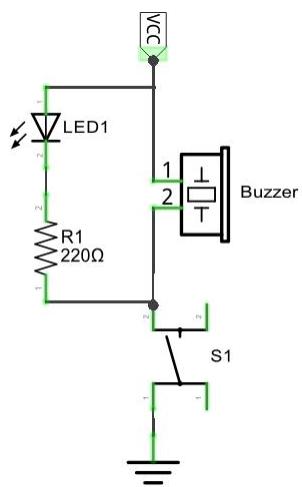
Pin header x2	LED x1	Resistor 220Ω x1	Active buzzer x1	Push button x1
				

AA Battery Holder x1


Circuit

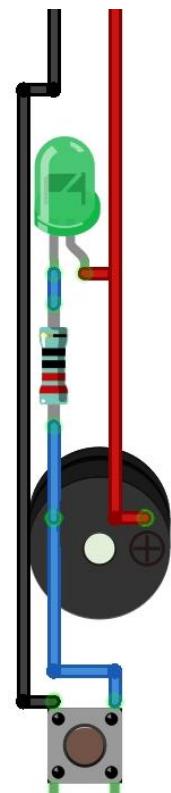
We will solder the following circuit on the main board.

Schematic diagram



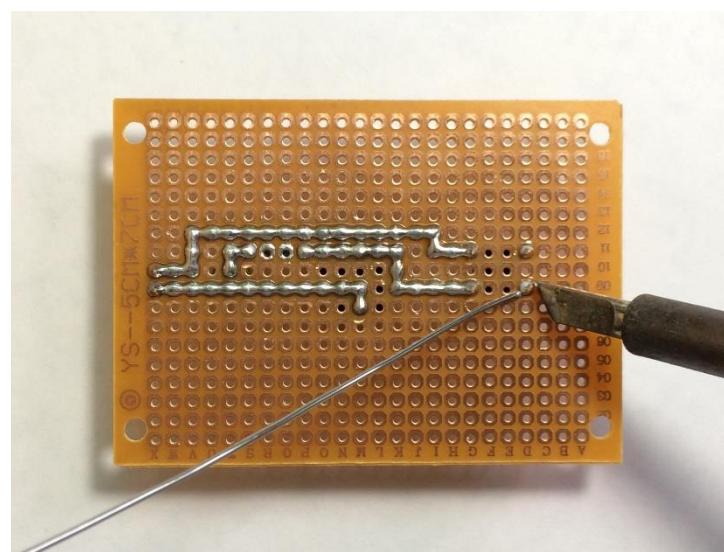
Hardware connection.

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

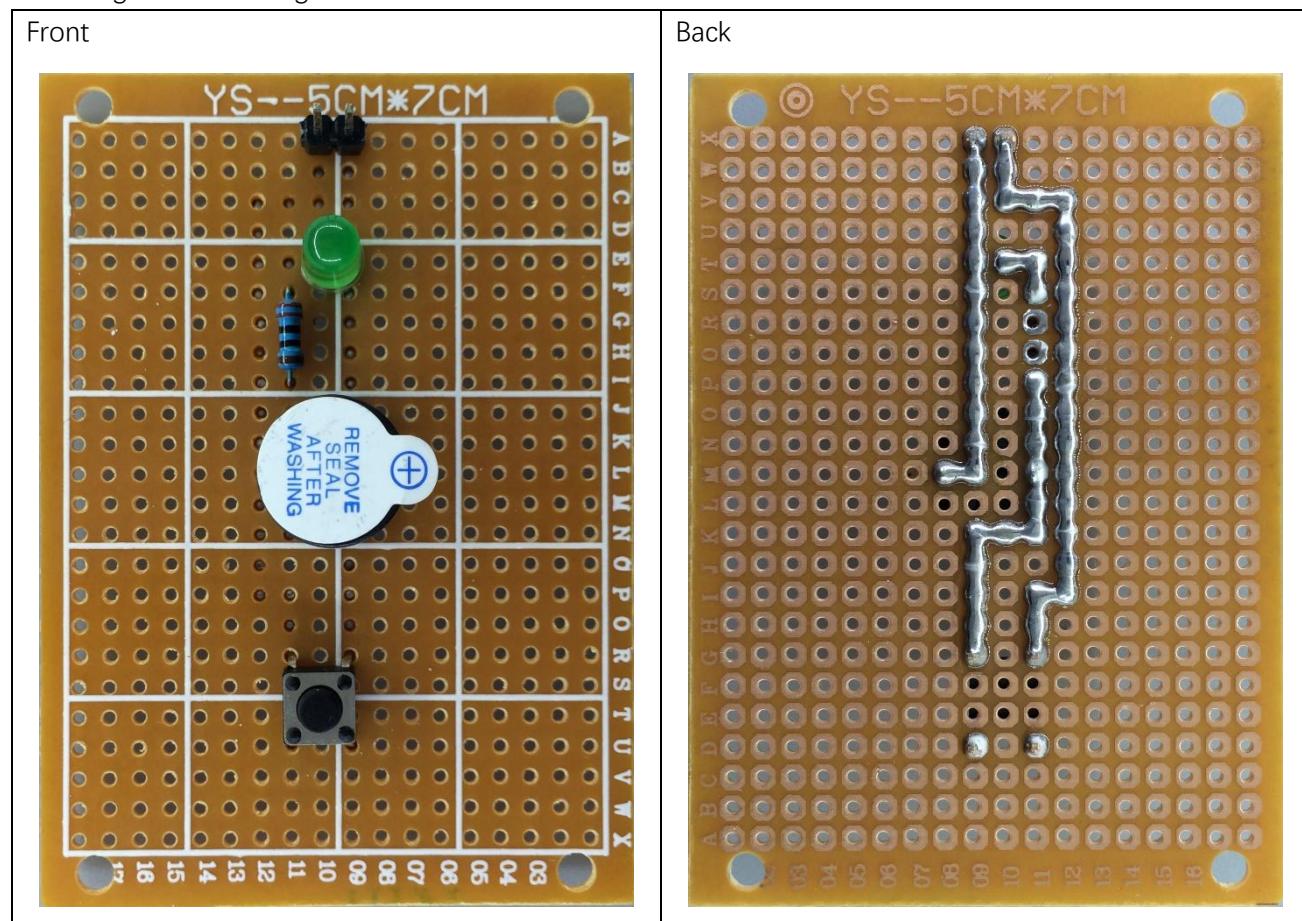


Soldering the Circuit

Insert the components on the main board and solder the circuit on its back.



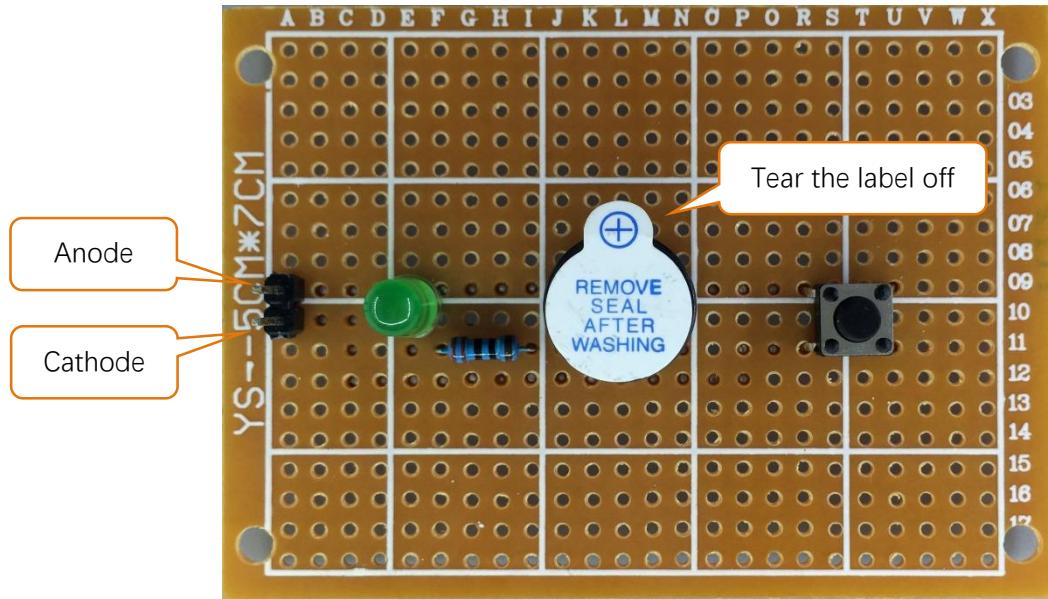
rendering after soldering:





Testing circuit

Connect the circuit board to power supply (3~5V). You can use ESP32 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

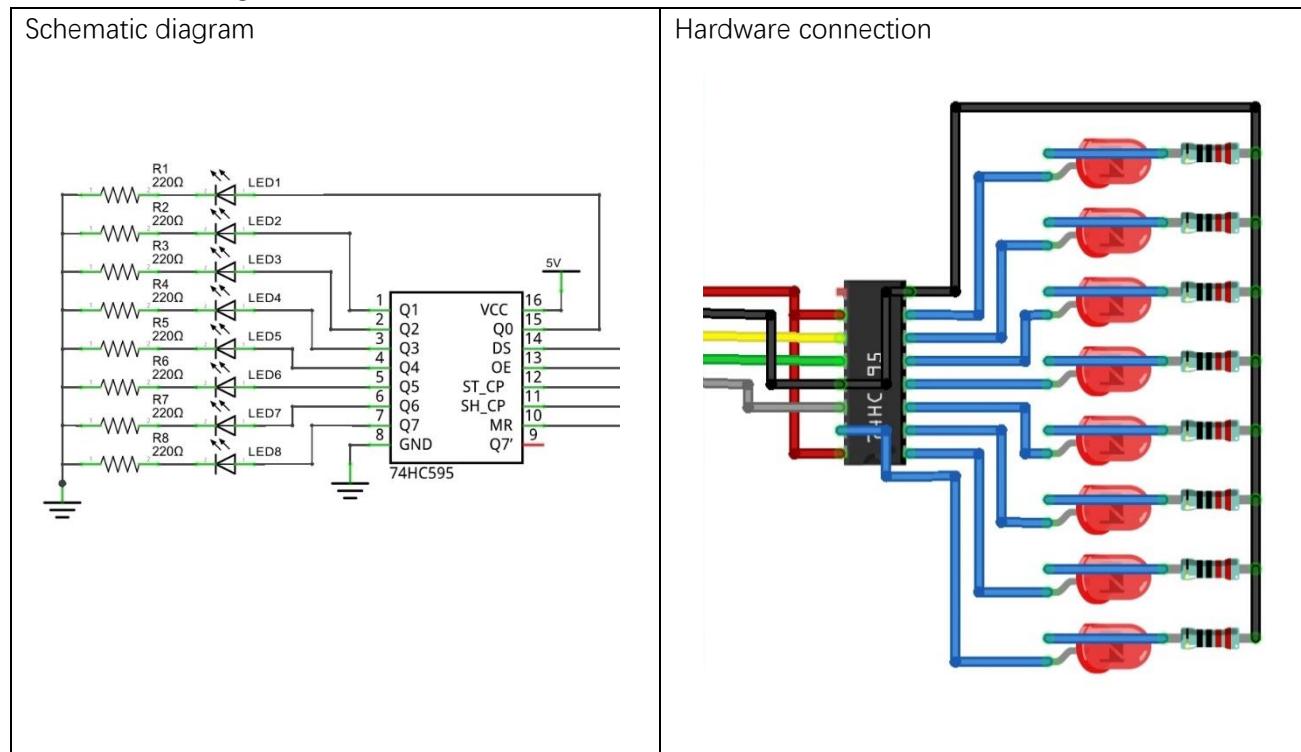
From previous chapter, we have learned to make a flowing water light with LED. Now, we will solder a circuit board, and use the improved code to make a more interesting flowing water light.

Component List

Pin header x5	Resistor 220Ω x8	LED x1	74HC595 x1

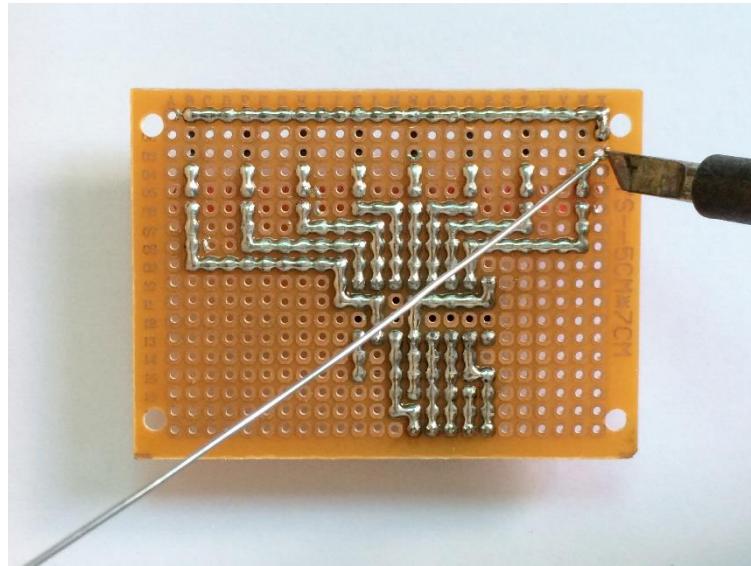
Circuit

Solder the following circuit on the main board.

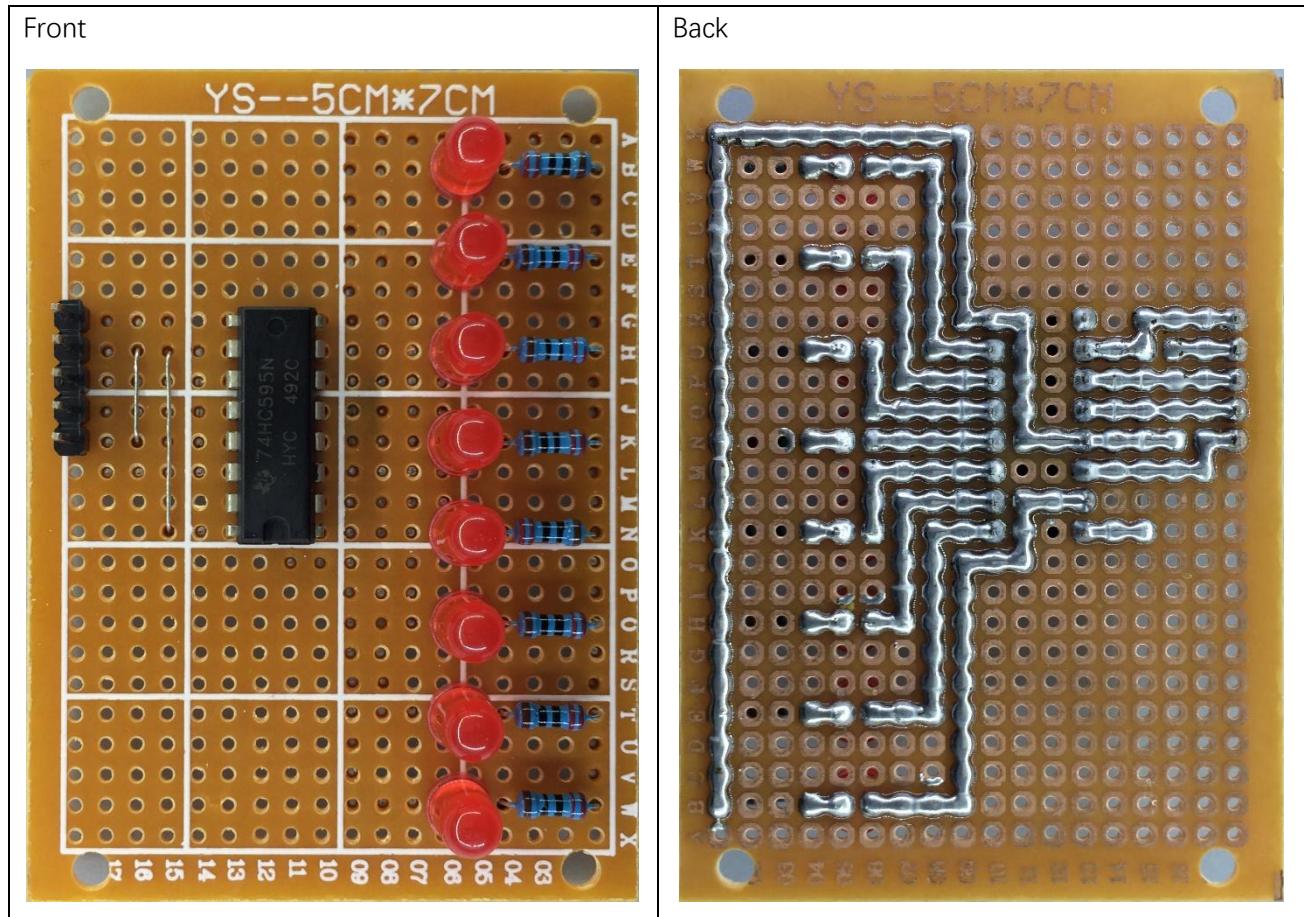


Soldering the Circuit

Insert the components on the main board and solder the circuit on its back.

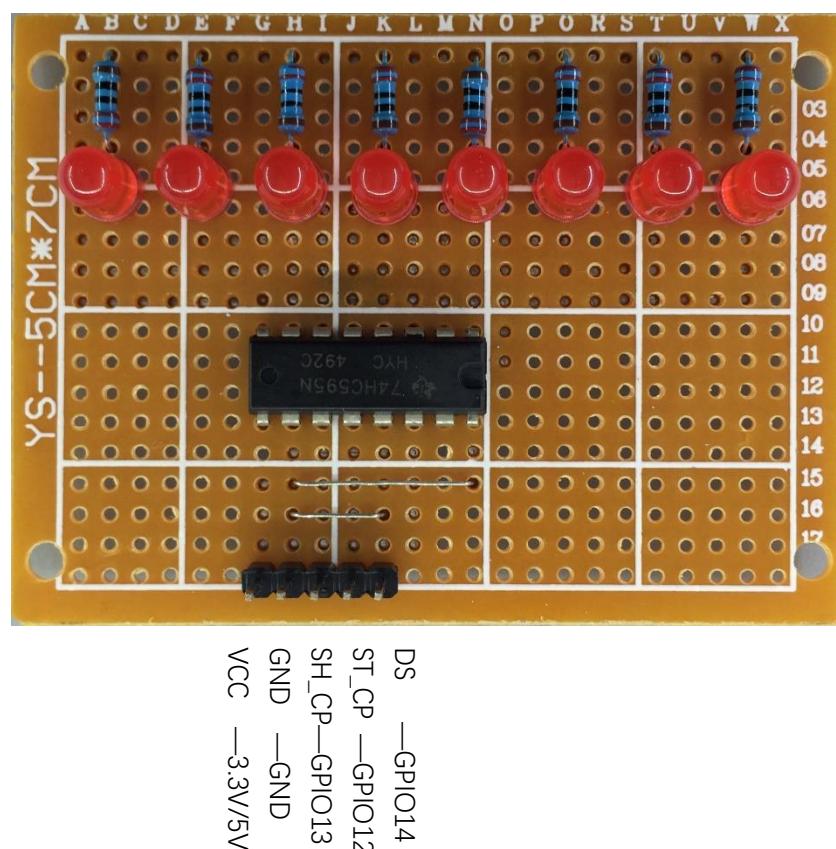


Rendering after soldering:



Connecting the Circuit

Connect the board to ESP32 with jumper wire in the following way.



Sketch

The following is the program code:

```

1 int latchPin = 12;           // Pin connected to ST_CP of 74HC595(Pin12)
2 int clockPin = 13;           // Pin connected to SH_CP of 74HC595(Pin13)
3 int dataPin = 14;            // 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

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\C\Processing.pdf**](#)

If you want to learn more about Arduino, Raspberry Pi, smart cars, robots and other interesting products in science and technology, please continue to focus on our website. We will continue to launch cost-effective, innovative and exciting products.

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End of the Tutorial

Thank you again for choosing Freenove products.

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