

Important Information

Thank you for choosing Freenove products!

Getting Started

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

https://github.com/Freenove/Freenove_ESP32_S3_Display

Get Support and Offer Input

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

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

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

support@freenove.com

Safety and Precautions

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

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

About Freenove

Freenove provides open source electronic products and services worldwide.

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

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

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

<http://www.freenove.com>

sale@freenove.com

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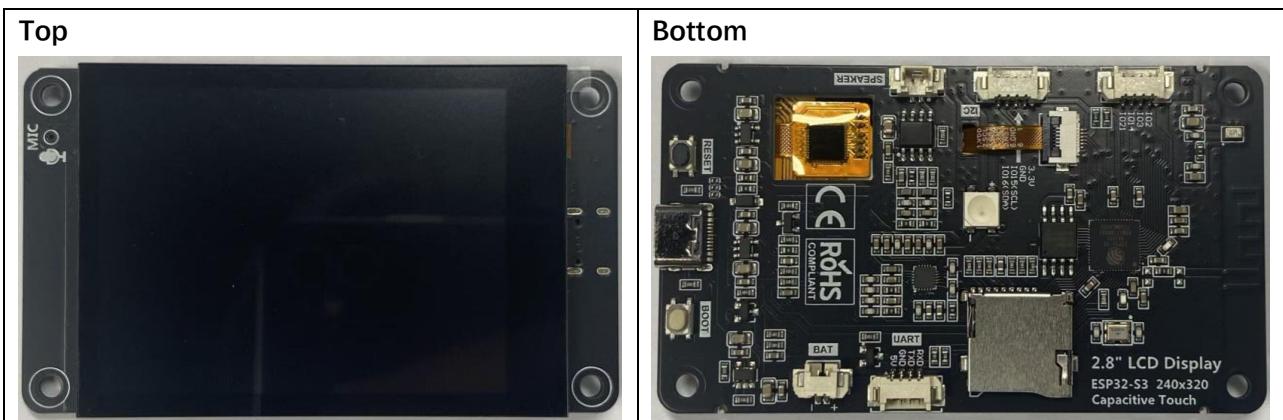
List

If you have any concerns, please feel free to contact us via support@freenove.com

Freenove ESP32 Display x 1 	USB-C Data Cable x 1 
Battery adapter cable x1 	Speaker x1 
Jumper Wire x1 	

Preface

Freenove ESP32S3 Display

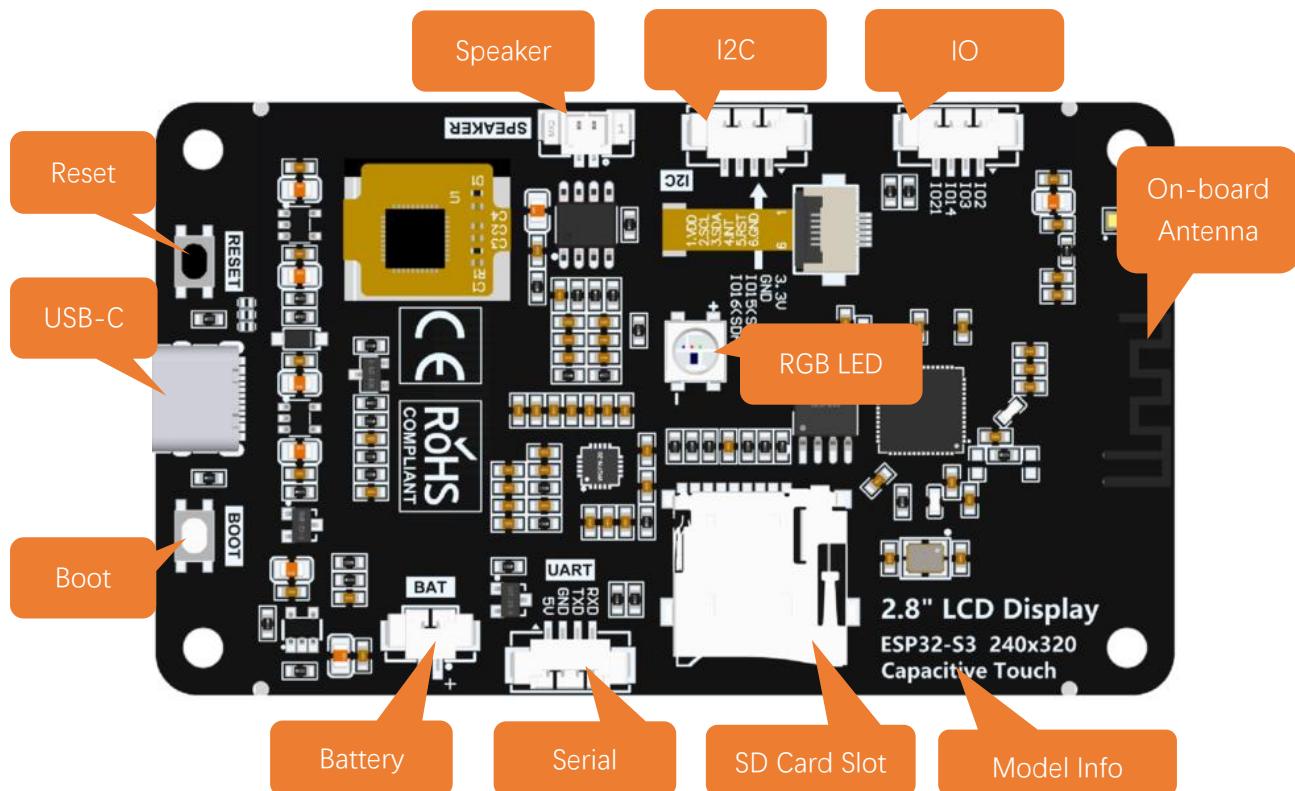


Freenove ESP32 S3 Display is available in five different models. While they may vary in drivers, resolution, or screen size, this guide applies to all of them. For detailed model specifications, please click [here](#).

For datasheet of the ESP32 S3 module, please visit:

https://www.espressif.com.cn/sites/default/files/documentation/esp32-wroom-32e_esp32-wroom-32ue_datasheet_en.pdf

Hardware Interfaces



Battery (Optional)

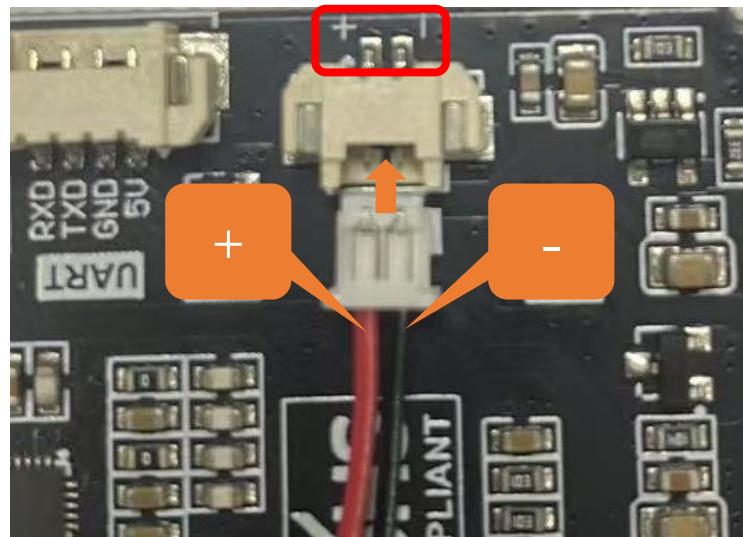
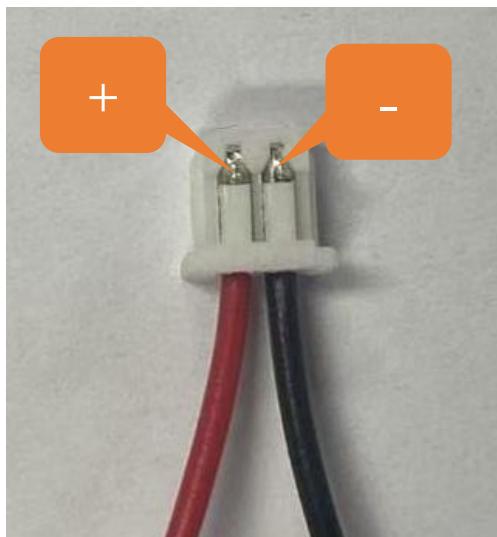
Please note that this product does not come with lithium batteries; please purchase them yourself.

This device supports both **USB-powered and lithium battery-powered operation**. For optimal safety, USB power is recommended. Due to the **hazardous nature of lithium batteries**, we advise against their use unless absolutely necessary.

This device features an **MX1.25mm** connector and supports lithium batteries of various capacities. Note: The input voltage must be maintained within **3.7-4.2V** range.

Market-available batteries may feature **two distinct wiring configurations where the positive (+) and negative (-) terminals are reversed between models**. Please verify the battery's wiring matches the product requirements (refer to the diagram below) to prevent equipment failure or safety risks due to improper connection.

The red cable is the positive terminal while the black one is negative.

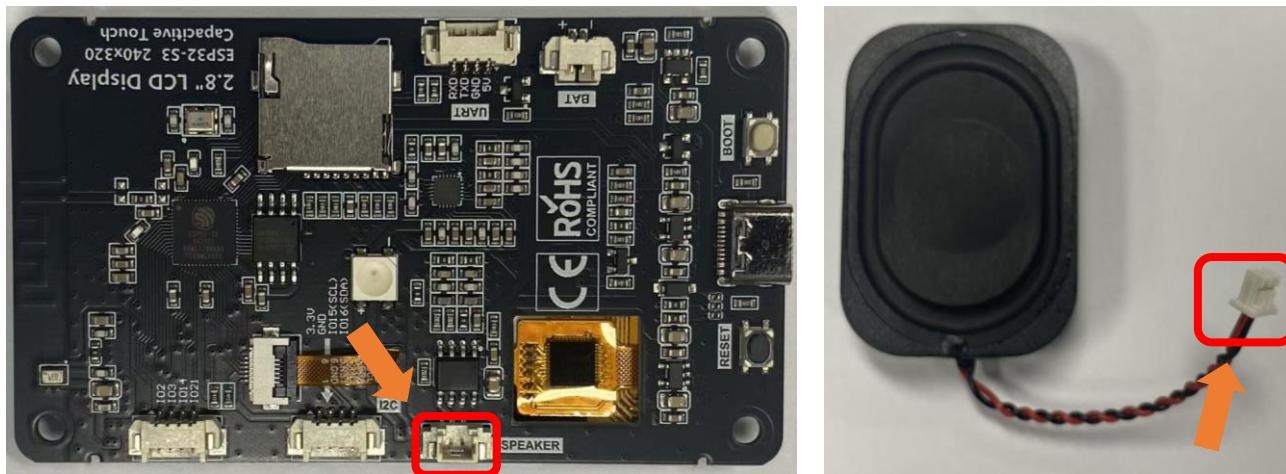


We recommend using a charger specially designed for lithium batteries. Due to various specifications and quality of lithium batteries, using a proper charger helps ensure peak performance, safety, and battery longevity.

While our product also supports USB charging as a backup option, please note that this method does not support fast charging and is limited to standard slow charging.

Speaker

There is a speaker connector (PH1.25mm) on the Freenove ESP32 S3 Display.



SD Card

The connector circuit uses SPI communication and supports high-speed Micro SD card storage.

Item	Pins	Definition
SD Card	GPIO23	SD_CMD
	GPIO18	SD_CLK
	GPIO19	SD_D0
	GPIO5	SD_CS

Note: This product does not include SD cards or SD card readers. Please buy them yourself



TFT Screen

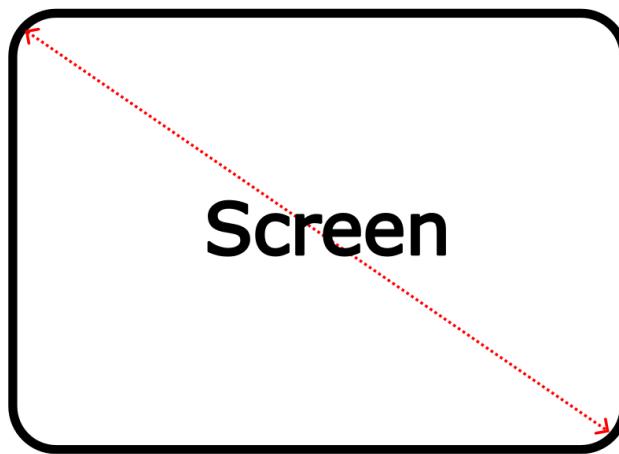
Freenove ESP32 S3 Display is available in five different models with various TFT screen. This guide applies to all of them. For detailed model specifications, please click [here](#).

Item	Pins	Definition
TFT Screen	GPIO13	LCD_MOSI
	GPIO12	LCD_MISO
	GPIO14	LCD_SCK
	GPIO2	LCD_RS
	GPIO15	LCD_CS

Screen Size

An internationally recognized unit of length, the **inch** (equivalent to 2.54 centimeters) has been the standard measurement for screen sizes in the display industry with a long history. This convention originated in the early television era when British manufacturers first adopted inches to measure cathode-ray tube (CRT) dimensions. The practice quickly became the global norm and remains the industry standard today.

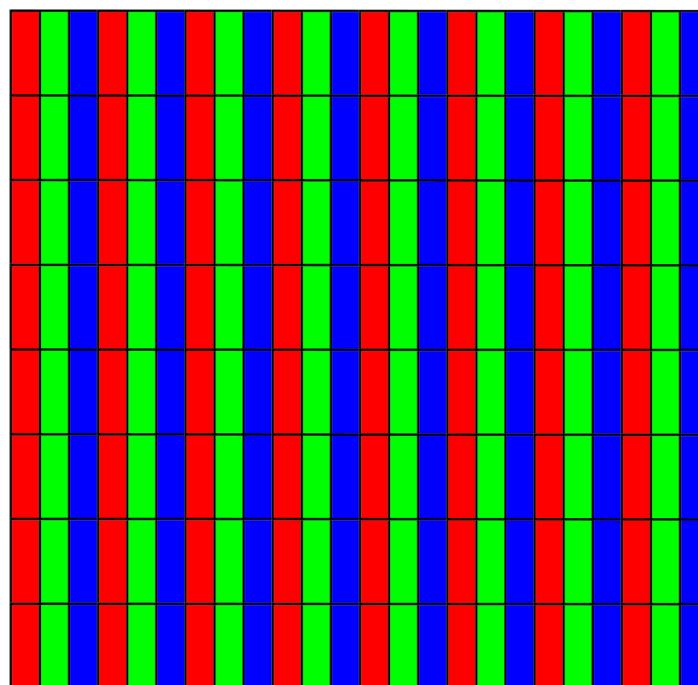
A critical clarification: screen size always refers to **the diagonal measurement of the display panel**. For instance, a 3.5-inch display features a 3.5-inch (8.89 cm) diagonal, ensuring standardized and comparable sizing across all devices.



Resolution

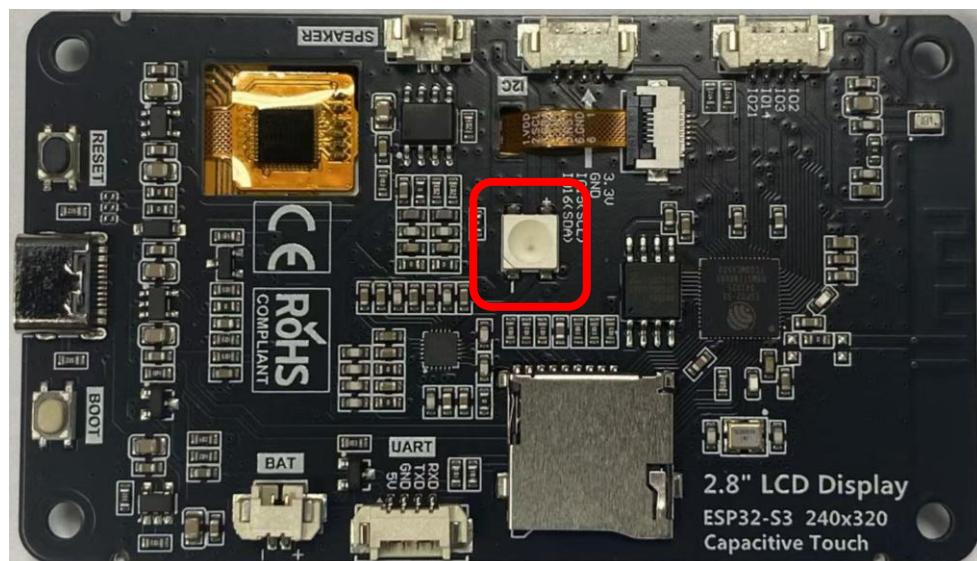
Screen resolution quantifies a display's pixel density along its horizontal and vertical axes, expressed as **width × height** (e.g., 320 × 480). This specification applies universally across displays, such as smartphones, monitors, and television screens.

- **Pixel:** The smallest unit of a display, composed of red (R), green (G), and blue (B) subpixels. Through precise brightness variation, these subpixels generate the complete color spectrum.
- **Resolution vs. Clarity:** Higher resolution means more pixels per unit area, resulting in sharper and more detailed imagery.



RGB LED

The Freenove ESP32 S3 Display includes an RGB LED (red, green, blue) that can blend colors to create various lighting effects.



Item	Pins
R	GPIO22
G	GPIO16
B	GPIO17





GPIO Pinout Table

To learn what each GPIO corresponds to, please refer to the following table.

The functions of the pins are allocated as follows:

ESP32-S3 N16R8	Functions	Description
GPIO22	R	RGB
GPIO16	G	
GPIO17	B	
GPIO13	LCD_MOSI	TFT_LCD
GPIO12	LCD_MISO	
GPIO14	LCD_SCK	
GPIO2	LCD_RS	
GPIO15	LCD_CS	
GPIO23	SD_CMD	SD Card
GPIO18	SD_CLK	
GPIO19	SD_D0	
GPIO5	SD_CS	

For more information, refer to the schematic.

If you have any concerns, please feel free to contact us via support@freenove.com

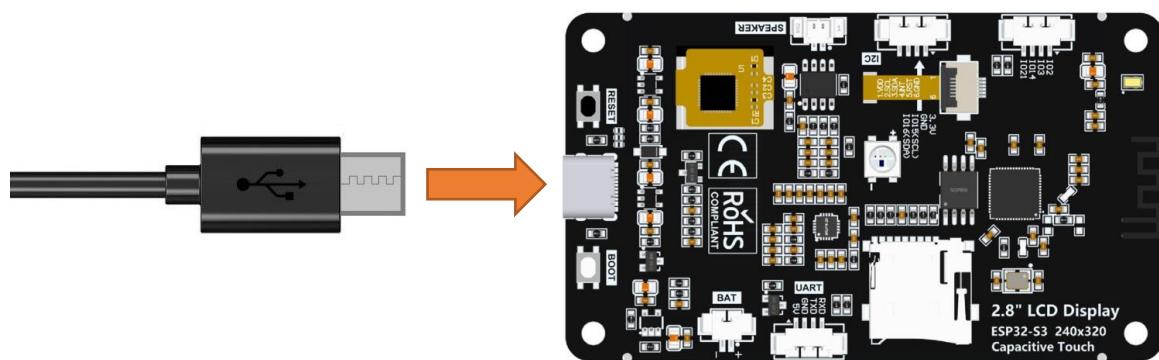
CH343 (Required)

ESP32-S3 WROOM uses CH343 to download code. Therefore, before using the device, it is necessary to install the CH343 driver on your computer.

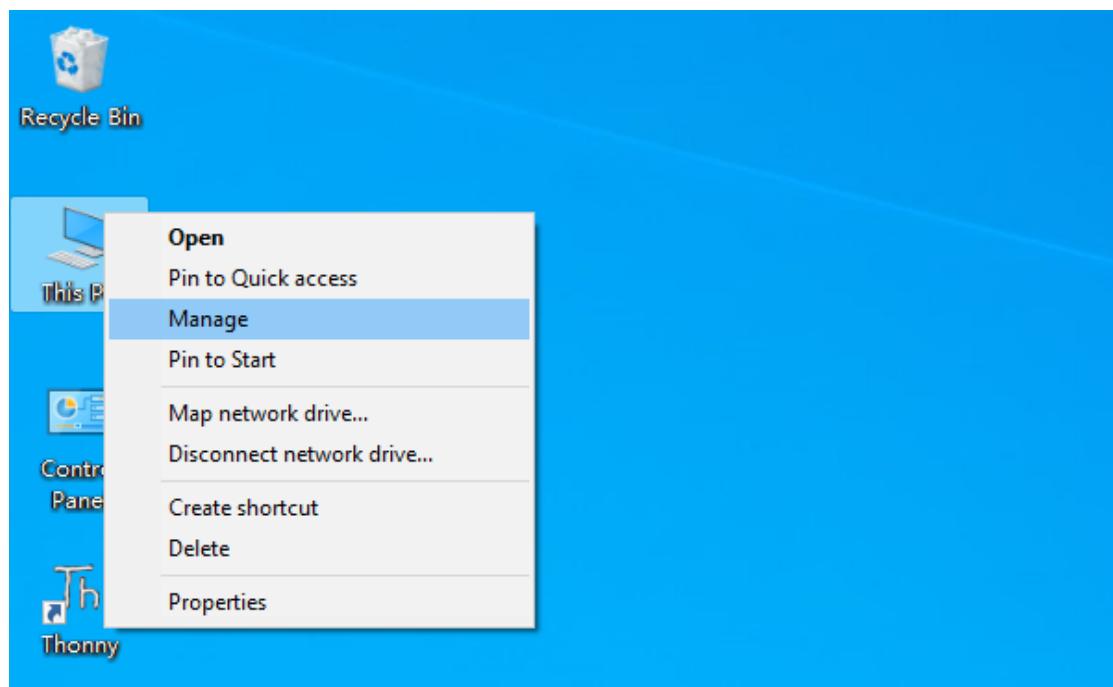
Windows

Check whether CH343 has been installed

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

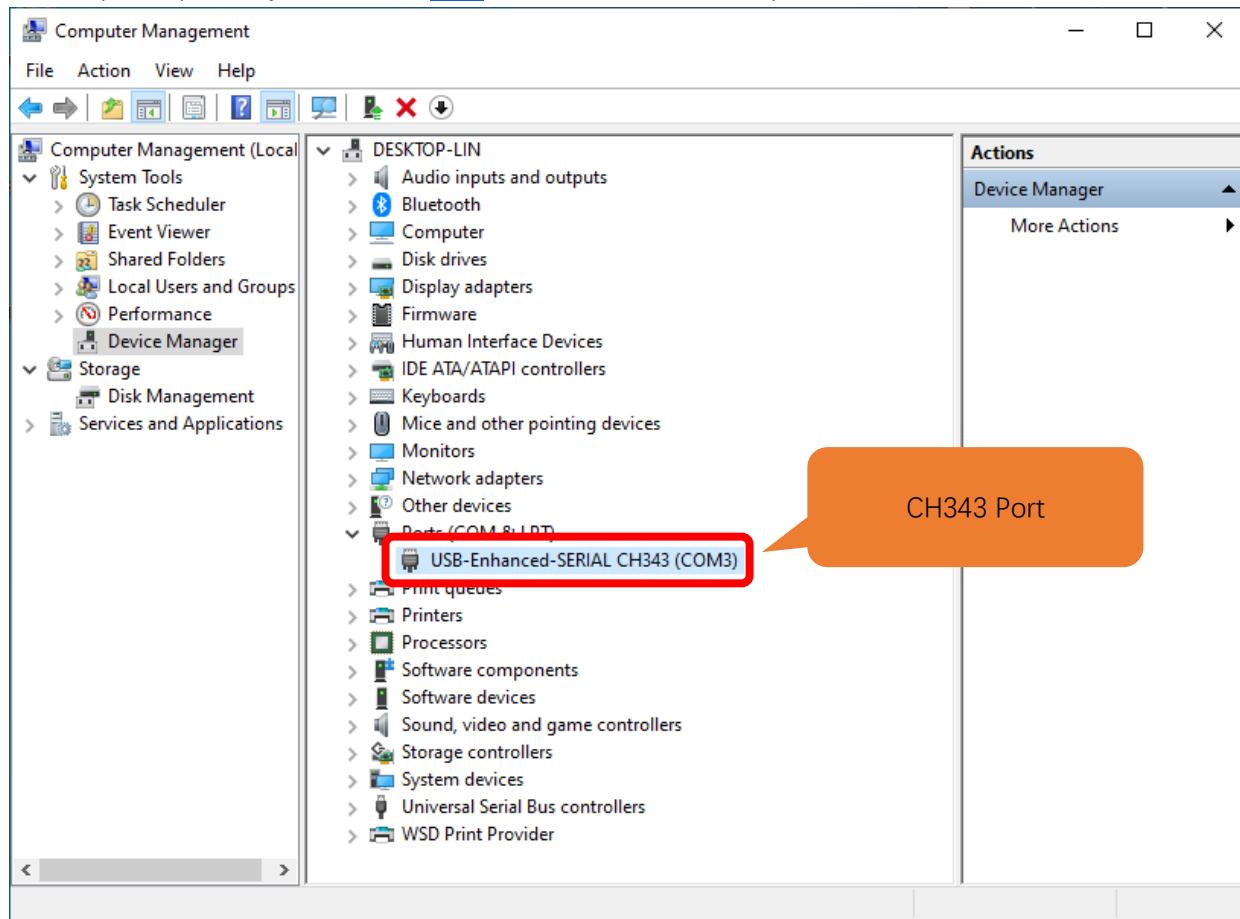


2. Turn to the main interface of your computer, select “This PC” and right-click to select “Manage”.





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



Installing CH343

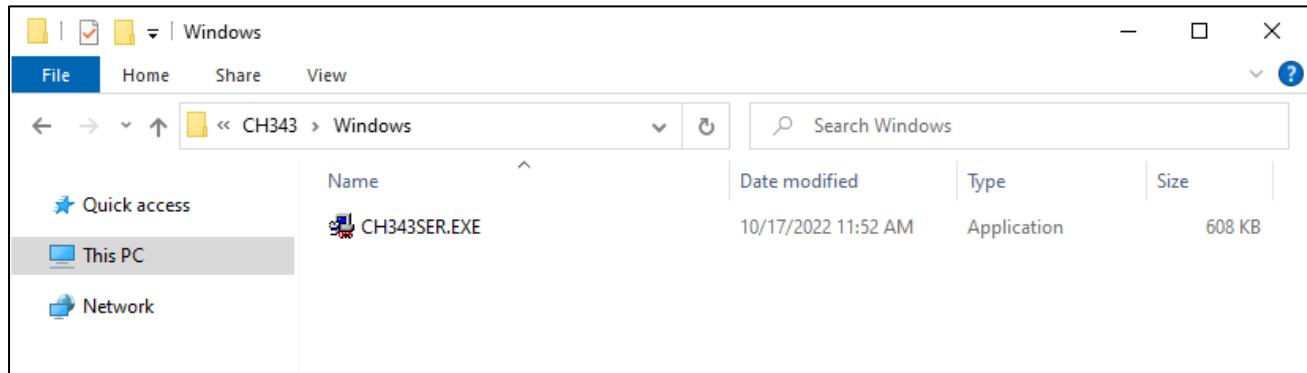
- First, download CH343 driver, click <http://www.wch-ic.com/search?t=all&q=ch343> to download the appropriate one based on your operating system.

file category	file content	upload version	time
DataSheet			
CH343DS1.PDF	CH343 datasheet, USB to single serial port, supports up to 6M baud rate, serial port signals support 5V/3.3V/2.5V/1.8V, built-in crystal oscillator. CH343 supports built-in CDC driver in operating system or multi-functional high-speed VCP manufacture driver.	1.5	2021-11-18
Driver&Tools			
CH343SER.ZIP	For CH342/CH343/CH344/CH347/CH9101/CH9102/CH9103/CH9143, USB to high-speed serial port VCP vendor driver, supports Windows 11/10/8.1/8/7/VISTA/XP/2000	1.61	2022-05-13
CH343CDC.ZIP	For CH342/CH343/CH344/CH347/CH910X/CH9143/CH9340, USB to CDC serial port driver, supports Windows 11/10/8.1/8/7/VISTA/XP/2000	1.4	2022-05-13
CH343SER.EXE	For CH342/CH343/CH344/CH347/CH9101/CH9102/CH9103/CH9143, USB to high-speed serial port VCP vendor driver, supports Windows 11/10/8.1/8/7/VISTA/XP/2000	1.61	2022-05-13
CH34XSER_MAC.ZIP	For CH340/CH342/CH343/CH344/CH347/CH910X/CH9143, USB to serial port VCP vendor driver of macOS	1.7	2022-05-13
CH343CDC.EXE	For CH342/CH343/CH344/CH347/CH910X/CH9143/CH9340, USB to CDC serial port driver, supports Windows 11/10/8.1/8/7/VISTA/XP/2000	1.4	2022-05-13

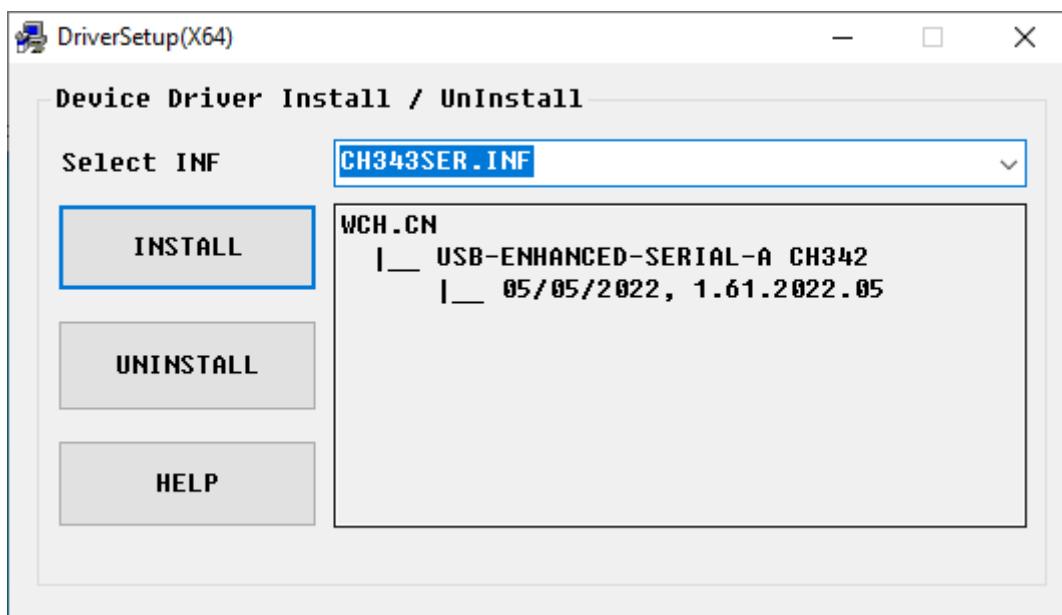
If you would not like to download the installation package, you can open “**Freenove_Media_Kit_for_ESP32-S3/CH343**”, we have prepared the installation package.

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

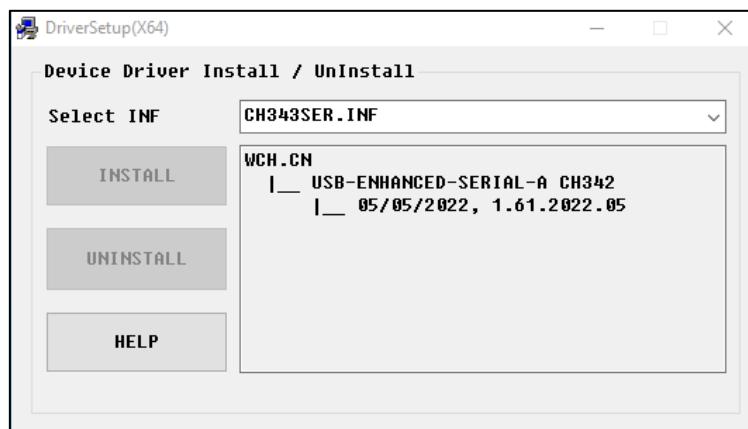
2. Open the folder “**Freenove_ESP32_S3_Display/CH343/Windows/**”



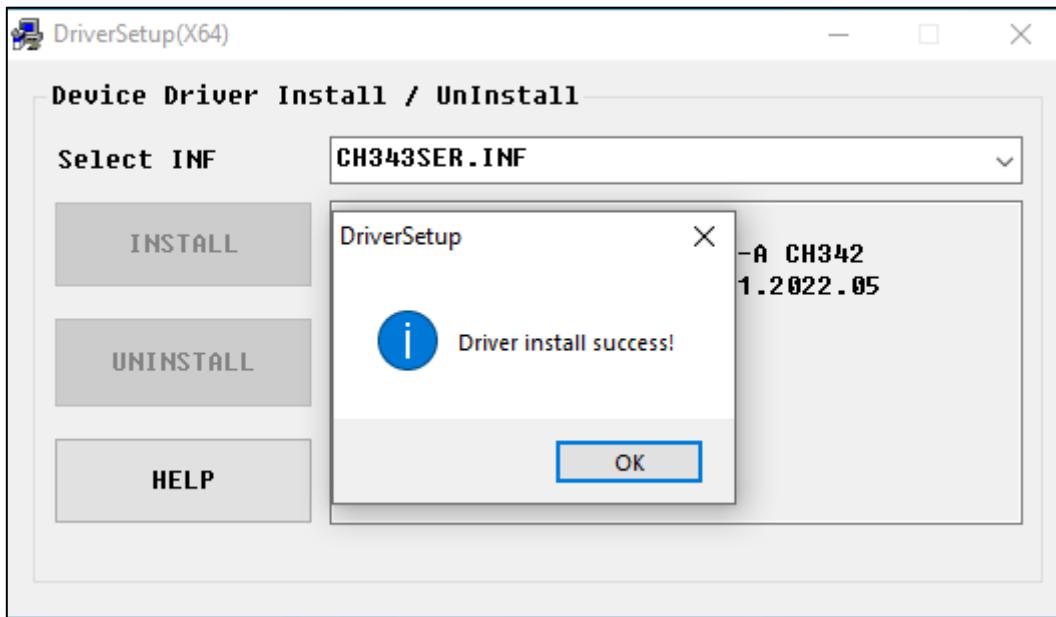
3. Double click “**CH343SER.EXE**”.



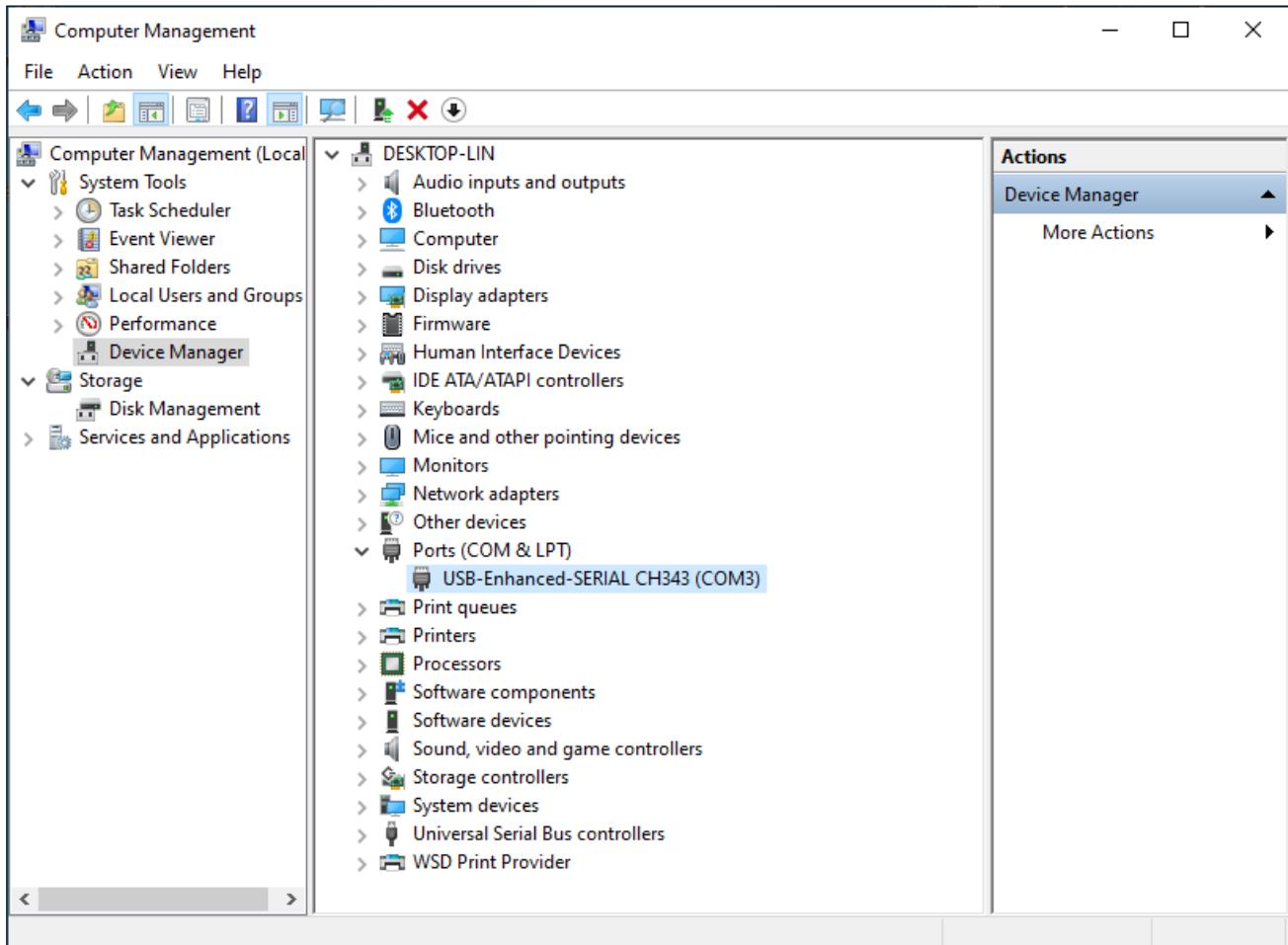
4. Click “**INSTALL**” and wait for the installation to complete.



5. Install successfully. Close all interfaces.



6. When ESP32-S3 WROOM is connected to computer, select "This PC", right-click to select "Manage" and click "Device Manager" in the newly pop-up dialog box, and you can see the following interface.



7. So far, CH343 has been installed successfully. Close all dialog boxes.

MAC

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

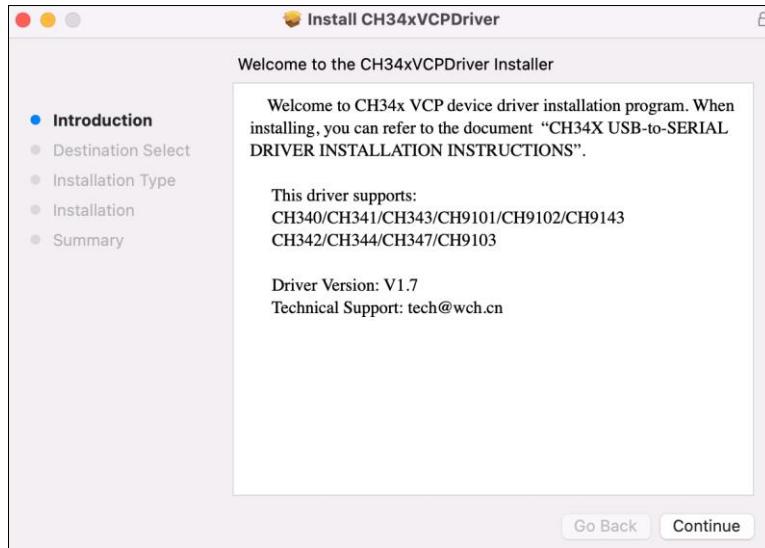
keyword ch343				
Downloads(8)				
file category	file content	version	upload time	
DataSheet				
CH343DS1.PDF	CH343 datasheet, USB to single serial port, supports up to 6M baud rate, serial port signals support 5V/3.3V/2.5V/1.8V, built-in crystal oscillator. CH343 supports built-in CDC driver in operating system or multi-functional high-speed VCP manufacture driver.	1.5	2021-11-18	
Driver&Tools				
CH343SER.ZIP	For CH342/CH343/CH344/CH347/CH9101/CH9102/CH9103/CH9143, USB to high-speed serial port VCP vendor driver, supports Windows 11/10/8.1/8/7/VISTA/XP/2000	1.61	2022-05-13	
CH343CDC.ZIP	For CH342/CH343/CH344/CH347/CH910X/CH9143/CH9340, USB to CDC serial port	1.4	2022-05-13	
CH343SER.EXE	For CH342/CH343/CH344/CH347/CH9101/CH9102/CH9103/CH9143, USB to high-speed serial port VCP vendor driver, supports Windows 11/10/8.1/8/7/VISTA/XP/2000	1.61	2022-05-13	
CH34XSER_MAC.ZI...	For MAC CH343/CH344/CH347/CH9101/CH9102/CH9103/CH9143, USB to serial port VCP vendor driver of macOS	1.7	2022-05-13	
CH343CDC.EXE	For CH342/CH343/CH344/CH347/CH910X/CH9143/CH9340, USB to CDC serial port driver, supports Windows 11/10/8.1/8/7/VISTA/XP/2000	1.4	2022-05-13	

If you would not like to download the installation package, you can open “**Freenove_Media_Kit_for_ESP32-S3/CH343**”. We have prepared the installation package.

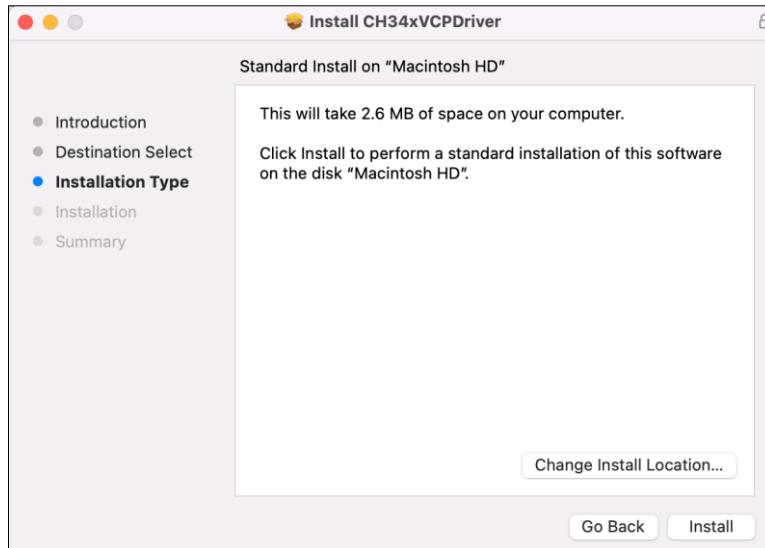
Second, open the folder “**Freenove_Media_Kit_for_ESP32-S3/CH343/MAC/**”



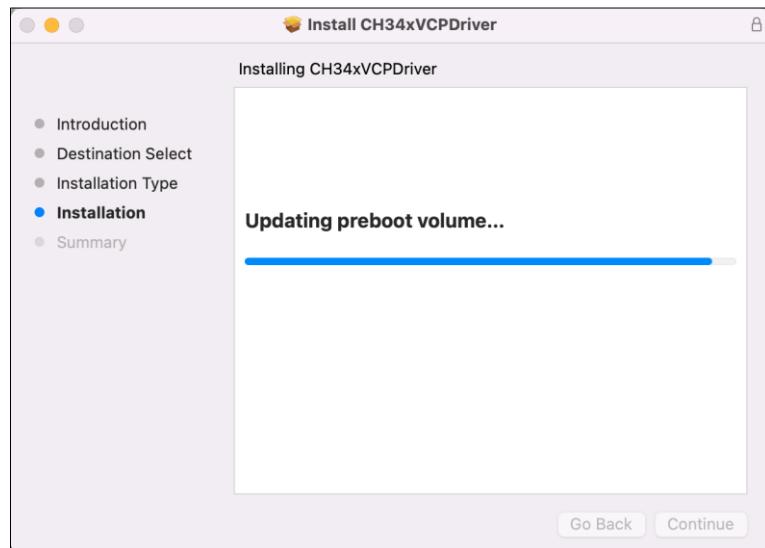
Third, click Continue.



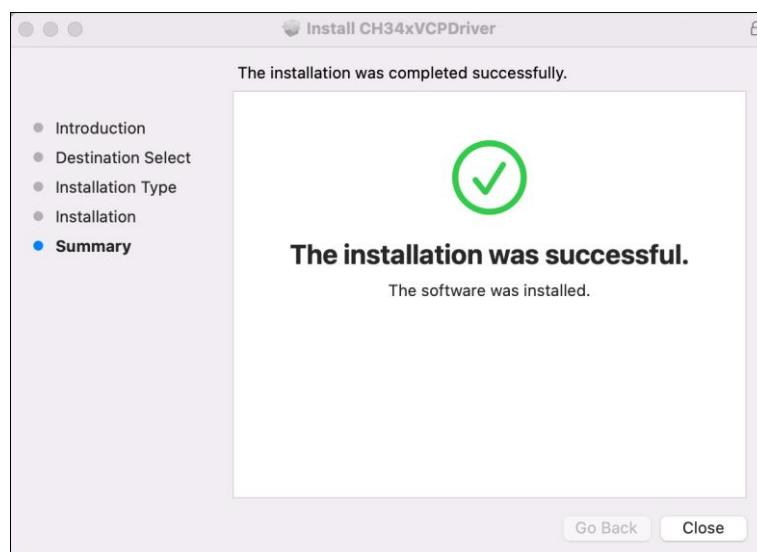
Fourth, click Install.



Then, waiting Finsh.



Finally, restart your PC.

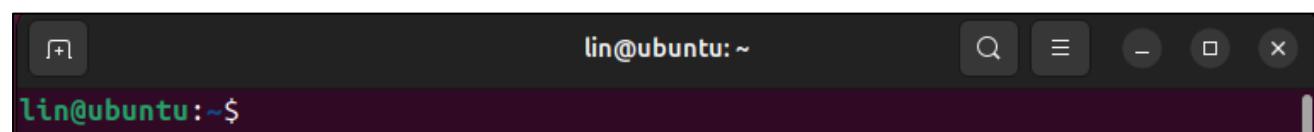


If it fails to be installed with the above steps, you can refer to `readme.pdf` to install it.



Linux

Here we take Ubuntu system as an example. Open the Terminal.



Run "lsusb" to check the port.

```
lsusb
```

```
ls /dev/tty*
```



```
lin@lin-virtual-machine:~$ lsusb
Bus 002 Device 001: ID 1d6b:0002 Linux Foundation 2.0 root hub
Bus 001 Device 004: ID 1a86:55d3 QinHeng Electronics USB Single Serial
Bus 001 Device 003: ID 0e0f:0002 VMware, Inc. Virtual USB Hub
Bus 001 Device 002: ID 0e0f:0003 VMware, Inc. Virtual Mouse
Bus 001 Device 001: ID 1d6b:0001 Linux Foundation 1.1 root hub
```

```
lin@lin-virtual-machine:~$ ls /dev/tty*
/dev/tty    /dev/tty23   /dev/tty39   /dev/tty54   /dev/ttyS1   /dev/ttyS25
/dev/tty0   /dev/tty24   /dev/tty4    /dev/tty55   /dev/ttyS10  /dev/ttyS26
/dev/tty1   /dev/tty25   /dev/tty40   /dev/tty56   /dev/ttyS11  /dev/ttyS27
/dev/tty10  /dev/tty26   /dev/tty41   /dev/tty57   /dev/ttyS12  /dev/ttyS28
/dev/tty11  /dev/tty27   /dev/tty42   /dev/tty58   /dev/ttyS13  /dev/ttyS29
/dev/tty12  /dev/tty28   /dev/tty43   /dev/tty59   /dev/ttyS14  /dev/ttyS3
/dev/tty13  /dev/tty29   /dev/tty44   /dev/tty6    /dev/ttyS15  /dev/ttyS30
/dev/tty14  /dev/tty3    /dev/tty45   /dev/tty60   /dev/ttyS16  /dev/ttyS31
/dev/tty15  /dev/tty30   /dev/tty46   /dev/tty61   /dev/ttyS17  /dev/ttyS4
/dev/tty16  /dev/tty31   /dev/tty47   /dev/tty62   /dev/ttyS18  /dev/ttyS5
/dev/tty17  /dev/tty32   /dev/tty48   /dev/tty63   /dev/ttyS19  /dev/ttyS6
/dev/tty18  /dev/tty33   /dev/tty49   /dev/tty7    /dev/ttyS2   /dev/ttyS7
/dev/tty19  /dev/tty34   /dev/tty5    /dev/tty8    /dev/ttyS20  /dev/ttyS8
/dev/tty2   /dev/tty35   /dev/tty50   /dev/tty9    /dev/ttyS21  /dev/ttyS9
/dev/tty20  /dev/tty36   /dev/tty51   /dev/ttyACM0  /dev/ttyS22
/dev/tty21  /dev/tty37   /dev/tty52   /dev/ttyprintk /dev/ttyS23
/dev/tty22  /dev/tty38   /dev/tty53   /dev/tty50   /dev/ttyS24
lin@lin-virtual-machine:~$
```

CH343 is fully compliant to the Communications Device Class (CDC) standard, they will work with a standard CDC-ACM driver (CDC - Abstract Control Model). Linux operating systems supply a default CDC-ACM driver that can be used with these USB UART devices. In Linux, this driver file name is cdc-acm.

If your computer does not recognise the ESP32S3's port, you can do as follows to install the ch343 driver. Install the CH343 driver with the following command.

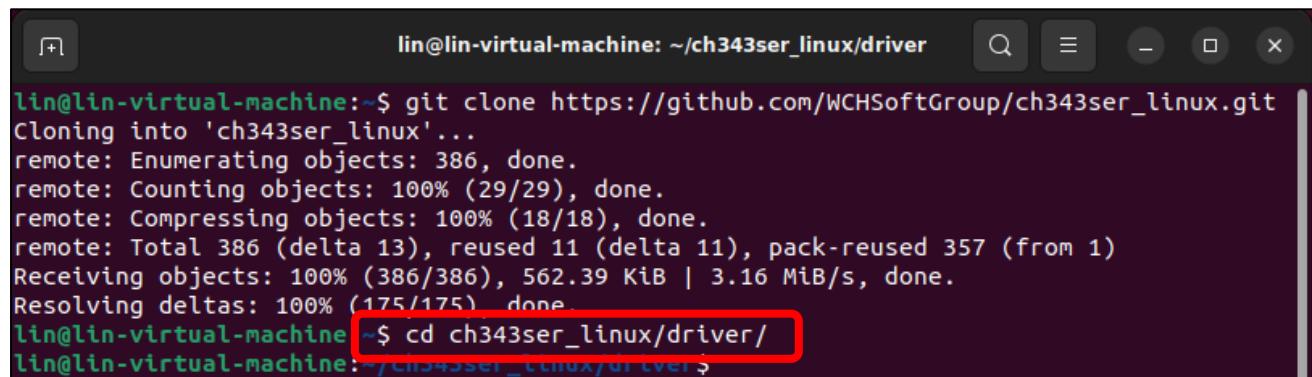
```
git clone https://github.com/WCHSoftGroup/ch343ser_linux.git
```

The screenshot shows a terminal window with the following text:

```
lin@lin-virtual-machine:~$ git clone https://github.com/WCHSoftGroup/ch343ser_linux.git
Cloning into 'ch343ser_linux'...
remote: Enumerating objects: 386, done.
remote: Counting objects: 100% (29/29), done.
remote: Compressing objects: 100% (18/18), done.
remote: Total 386 (delta 13), reused 11 (delta 11), pack-reused 357 (from 1)
Receiving objects: 100% (386/386), 562.39 KiB | 3.16 MiB/s, done.
Resolving deltas: 100% (175/175), done.
lin@lin-virtual-machine:~$
```

Enter the folder.

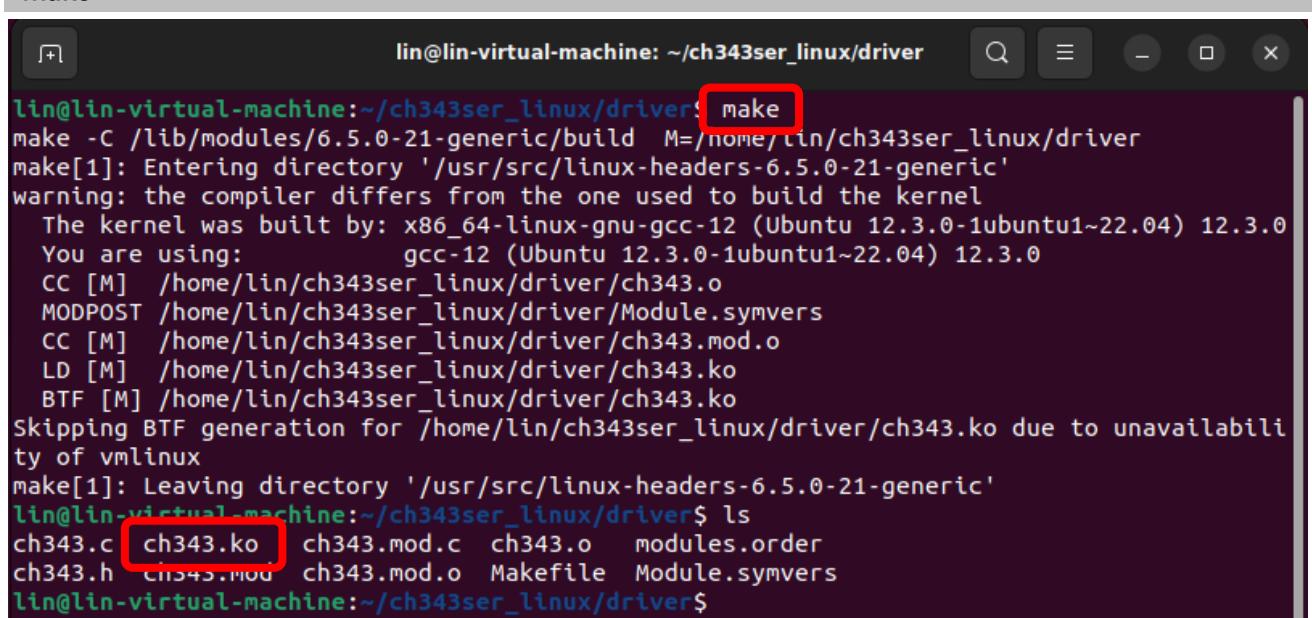
```
cd ch343ser_linux/driver/
```



```
lin@lin-virtual-machine:~$ git clone https://github.com/WCHSoftGroup/ch343ser_linux.git
Cloning into 'ch343ser_linux'...
remote: Enumerating objects: 386, done.
remote: Counting objects: 100% (29/29), done.
remote: Compressing objects: 100% (18/18), done.
remote: Total 386 (delta 13), reused 11 (delta 11), pack-reused 357 (from 1)
Receiving objects: 100% (386/386), 562.39 KiB | 3.16 MiB/s, done.
Resolving deltas: 100% (175/175) done.
lin@lin-virtual-machine:~/ch343ser_linux$ cd ch343ser_linux/driver/
lin@lin-virtual-machine:~/ch343ser_linux/driver$
```

Compile and generate the ch343.ko file.

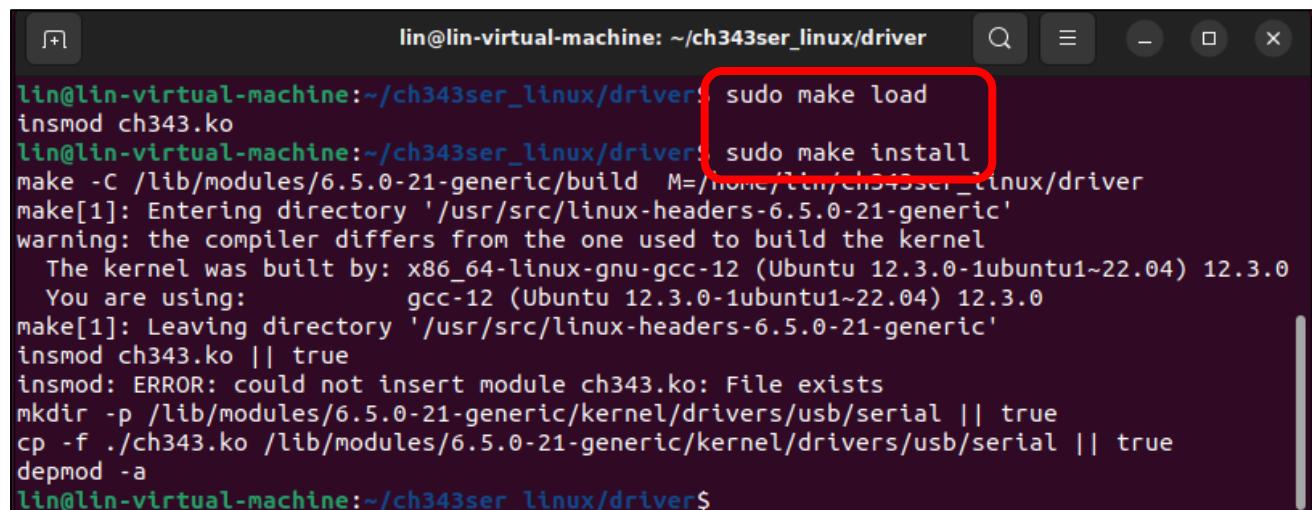
```
make
```



```
lin@lin-virtual-machine:~/ch343ser_linux/driver$ make
make -C /lib/modules/6.5.0-21-generic/build M=/home/lin/ch343ser_linux/driver
make[1]: Entering directory '/usr/src/linux-headers-6.5.0-21-generic'
warning: the compiler differs from the one used to build the kernel
  The kernel was built by: x86_64-linux-gnu-gcc-12 (Ubuntu 12.3.0-1ubuntu1~22.04) 12.3.0
  You are using:           gcc-12 (Ubuntu 12.3.0-1ubuntu1~22.04) 12.3.0
  CC [M]  /home/lin/ch343ser_linux/driver/ch343.o
  MODPOST /home/lin/ch343ser_linux/driver/Module.symvers
  CC [M]  /home/lin/ch343ser_linux/driver/ch343.mod.o
  LD [M]  /home/lin/ch343ser_linux/driver/ch343.ko
  BTF [M] /home/lin/ch343ser_linux/driver/ch343.ko
Skipping BTF generation for /home/lin/ch343ser_linux/driver/ch343.ko due to unavailability of vmlinux
make[1]: Leaving directory '/usr/src/linux-headers-6.5.0-21-generic'
lin@lin-virtual-machine:~/ch343ser_linux/driver$ ls
ch343.c  ch343.ko  ch343.mod.c  ch343.o  modules.order
ch343.h  ch343.mod  ch343.mod.o  Makefile  Module.symvers
lin@lin-virtual-machine:~/ch343ser_linux/driver$
```

Load the generated file to the system.

```
sudo make load
sudo make install
```



```
lin@lin-virtual-machine:~/ch343ser_linux/driver$ sudo make load
insmod ch343.ko
lin@lin-virtual-machine:~/ch343ser_linux/driver$ sudo make install
make -C /lib/modules/6.5.0-21-generic/build M=/home/lin/ch343ser_linux/driver
make[1]: Entering directory '/usr/src/linux-headers-6.5.0-21-generic'
warning: the compiler differs from the one used to build the kernel
  The kernel was built by: x86_64-linux-gnu-gcc-12 (Ubuntu 12.3.0-1ubuntu1~22.04) 12.3.0
  You are using:           gcc-12 (Ubuntu 12.3.0-1ubuntu1~22.04) 12.3.0
make[1]: Leaving directory '/usr/src/linux-headers-6.5.0-21-generic'
insmod ch343.ko || true
insmod: ERROR: could not insert module ch343.ko: File exists
mkdir -p /lib/modules/6.5.0-21-generic/kernel/drivers/usb/serial || true
cp -f ./ch343.ko /lib/modules/6.5.0-21-generic/kernel/drivers/usb/serial || true
depmod -a
lin@lin-virtual-machine:~/ch343ser_linux/driver$
```



Connect the ESP32S3 to your computer, check the port with the following command and you should see the port.

```
ls /dev/tty*
```

```
(myenv) lin@ubuntu:~/Upload_Xiaozhi_Bin$ ls /dev/tty*
/dev/tty  /dev/tty2  /dev/tty31  /dev/tty43  /dev/tty55  /dev/ttyACM0  /dev/ttyS19  /dev/ttyS30
/dev/tty0  /dev/tty20  /dev/tty32  /dev/tty44  /dev/tty56  /dev/cdc_ply0  /dev/ttyS2  /dev/ttyS31
/dev/tty1  /dev/tty21  /dev/tty33  /dev/tty45  /dev/tty57  /dev/ttyS0  /dev/ttyS20  /dev/ttyS4
/dev/tty10 /dev/tty22  /dev/tty34  /dev/tty46  /dev/tty58  /dev/ttyS1  /dev/ttyS21  /dev/ttyS5
/dev/tty11 /dev/tty23  /dev/tty35  /dev/tty47  /dev/tty59  /dev/ttyS10  /dev/ttyS22  /dev/ttyS6
/dev/tty12 /dev/tty24  /dev/tty36  /dev/tty48  /dev/tty6  /dev/ttyS11  /dev/ttyS23  /dev/ttyS7
/dev/tty13 /dev/tty25  /dev/tty37  /dev/tty49  /dev/tty60  /dev/ttyS12  /dev/ttyS24  /dev/ttyS8
/dev/tty14 /dev/tty26  /dev/tty38  /dev/tty5  /dev/tty61  /dev/ttyS13  /dev/ttyS25  /dev/ttyS9
/dev/tty15 /dev/tty27  /dev/tty39  /dev/tty50  /dev/tty62  /dev/ttyS14  /dev/ttyS26
/dev/tty16 /dev/tty28  /dev/tty4  /dev/tty51  /dev/tty63  /dev/ttyS15  /dev/ttyS27
/dev/tty17 /dev/tty29  /dev/tty40  /dev/tty52  /dev/tty7  /dev/ttyS16  /dev/ttyS28
/dev/tty18 /dev/tty3  /dev/tty41  /dev/tty53  /dev/tty8  /dev/ttyS17  /dev/ttyS29
/dev/tty19 /dev/tty30  /dev/tty42  /dev/tty54  /dev/tty9  /dev/ttyS18  /dev/ttyS3
(myenv) lin@ubuntu:~/Upload_Xiaozhi_Bin$
```

Accessing "ttyACM0" in Ubuntu requires higher privileges, so permission escalation via command is mandatory.

```
sudo usermod -a -G dialout $USER
sudo reboot
```

```
lin@ubuntu:~/ch343ser_linux/driver$ sudo usermod -a -G dialout $USER
lin@ubuntu:~/ch343ser_linux/driver$ sudo reboot
```

Please note that the configuration takes effect after rebooting.

Programming Software

We use the Arduino Software (IDE) to write and upload the code for this product.

First, install Arduino Software (IDE): visit <https://www.arduino.cc/en/software/>, Select and download corresponding installer according to your operating system. If you are a Windows user, please select the "Windows" to download and install it correctly.

Arduino IDE 2.3.6
Release notes

The new major release of the Arduino IDE is faster and even more powerful! In addition to a more modern editor and a more responsive interface it features autocomplete, code navigation, and even a live debugger. For more details, check the [Arduino IDE 2.0 documentation](#).

Windows Win 10 or newer (64-bit)

Windows Win 10 or newer (64-bit)

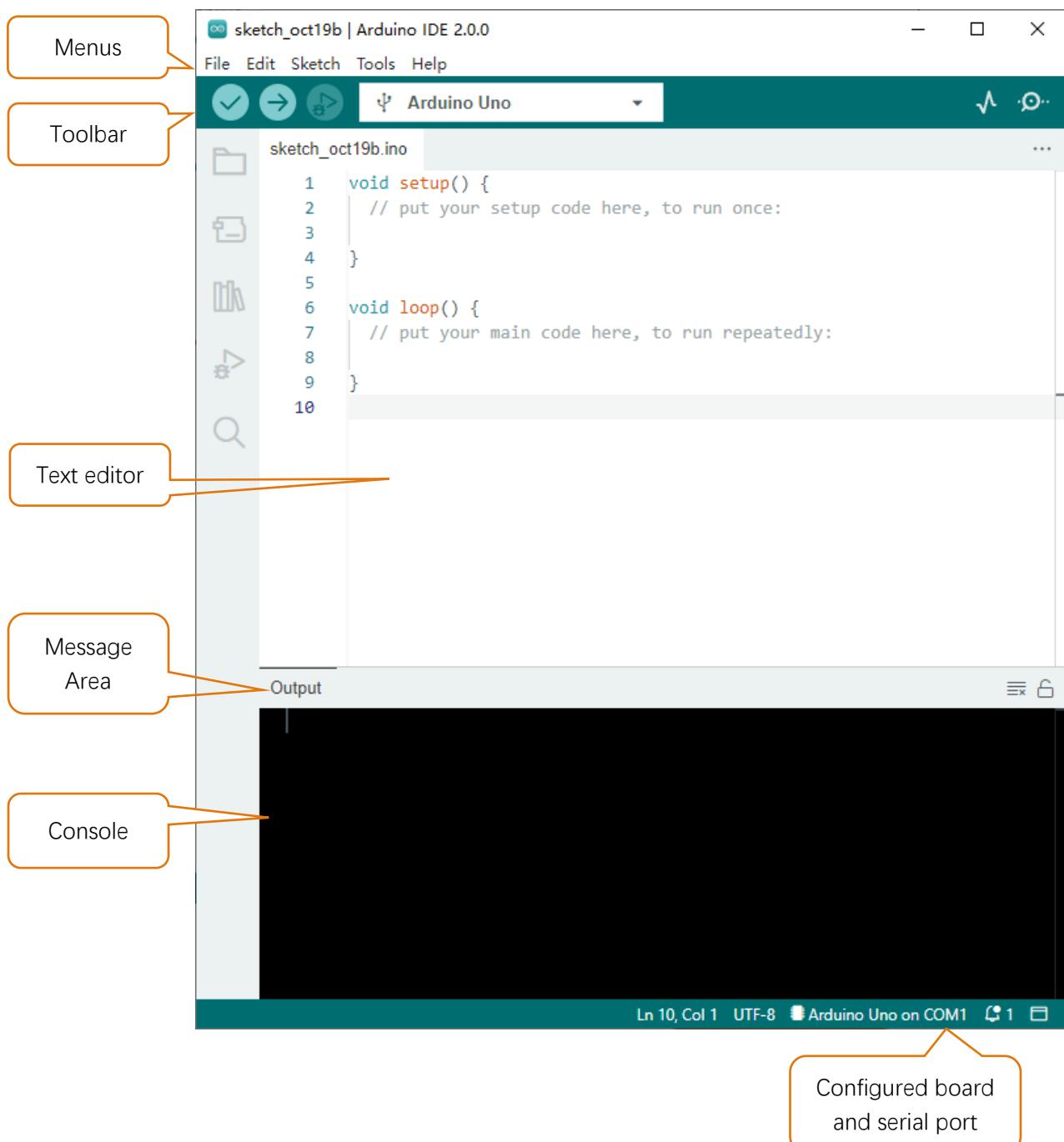
- Windows MSI installer
- Windows ZIP file
- Linux AppImage (64-bit X86-64)
- Linux ZIP file (64-bit X86-64)
- macOS Intel 10.15 Catalina or newer (64-bit)
- macOS Apple Silicon 11 Big Sur or newer (64-bit)

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 completes, 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 features text cutting/pasting and searching/replacing. The message area gives feedback while saving and exporting and also displays errors. The console displays text output by the Arduino Software (IDE), including complete error messages and other information. The bottom right-hand corner of the window displays the configured board and serial port. The toolbar buttons allow you to verify and upload programs, create, open, and save sketches, and open the serial monitor.

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

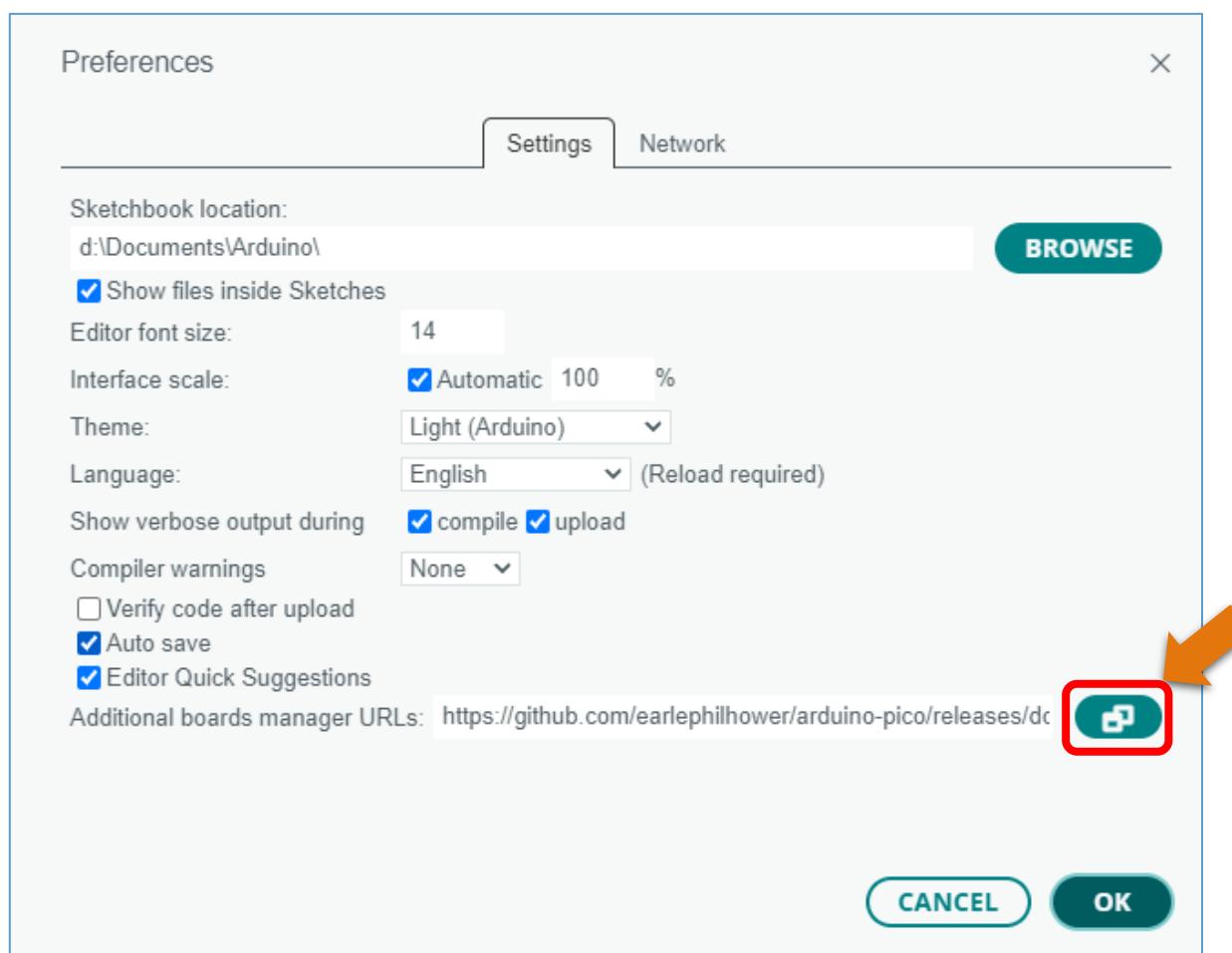
Additional commands are found within the five menus: File, Edit, Sketch, Tools, Help. The menus are context sensitive, which means only those items relevant to the work currently being carried out are available.

Environment Configuration

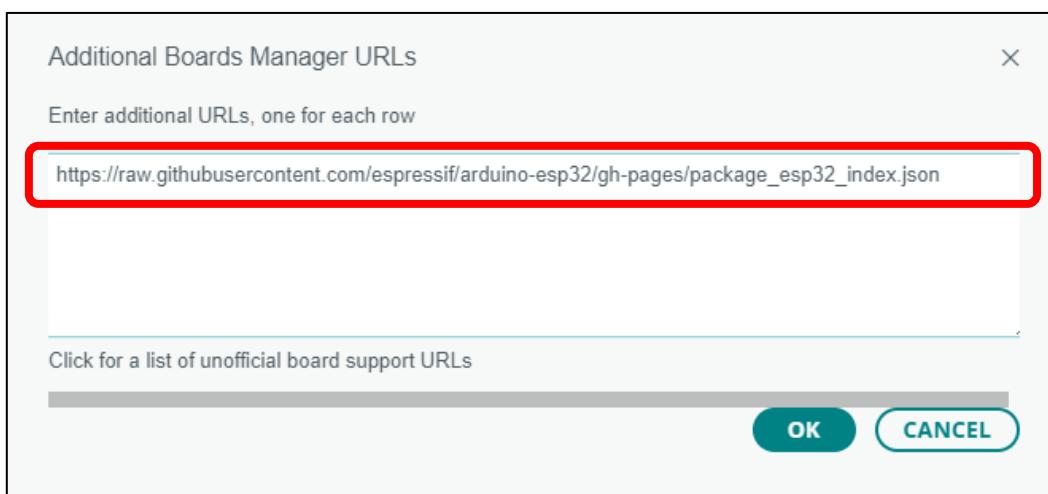
First, open the software platform Arduino, and then click File in Menus and select Preferences.



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

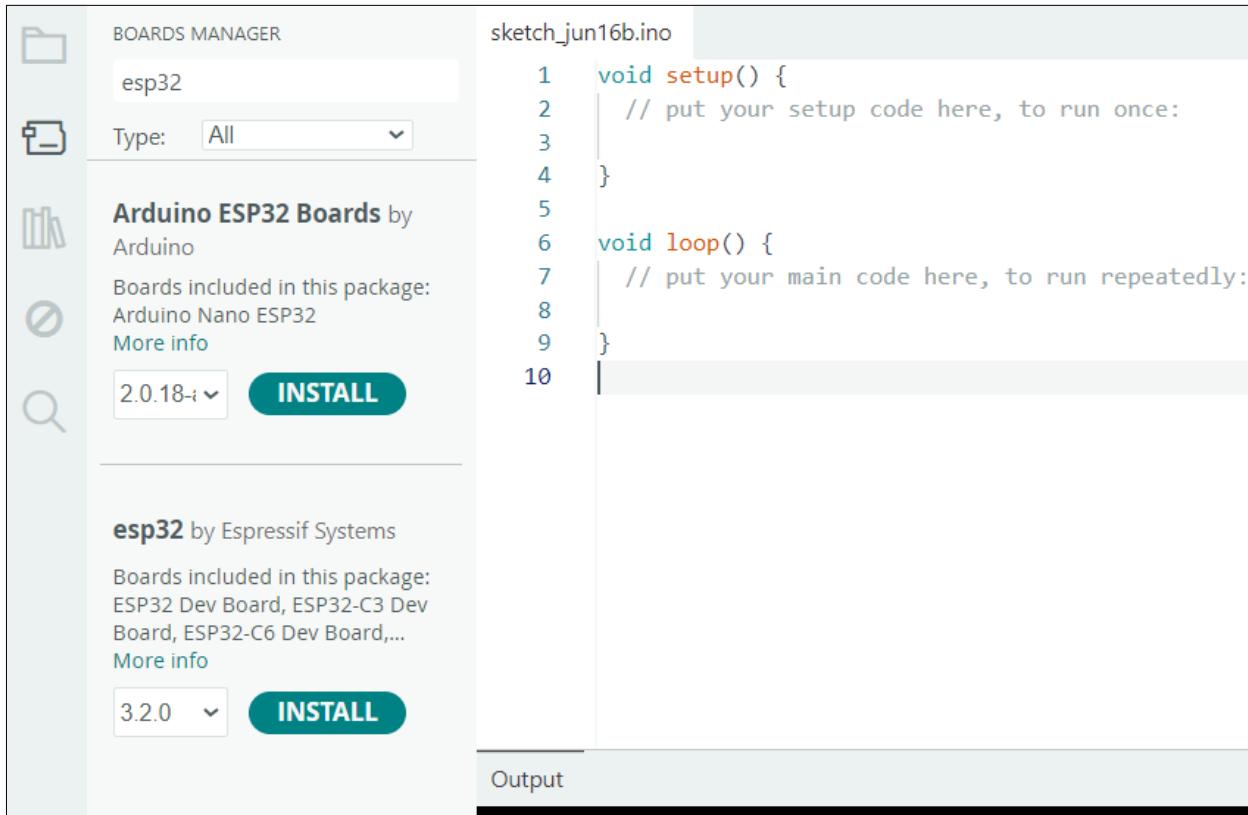


Third, fill in https://raw.githubusercontent.com/espressif/arduino-esp32/gh-pages/package_esp32_index.json in the new window, click OK, and click OK on the Preferences window again.



Note: if you copy and paste the URL directly, you may lose the "-". Please check carefully to make sure the link is correct.

Fourth, click "Boards Manager". Enter "esp32" in Boards manager, select 3.2.0, and click "INSTALL".



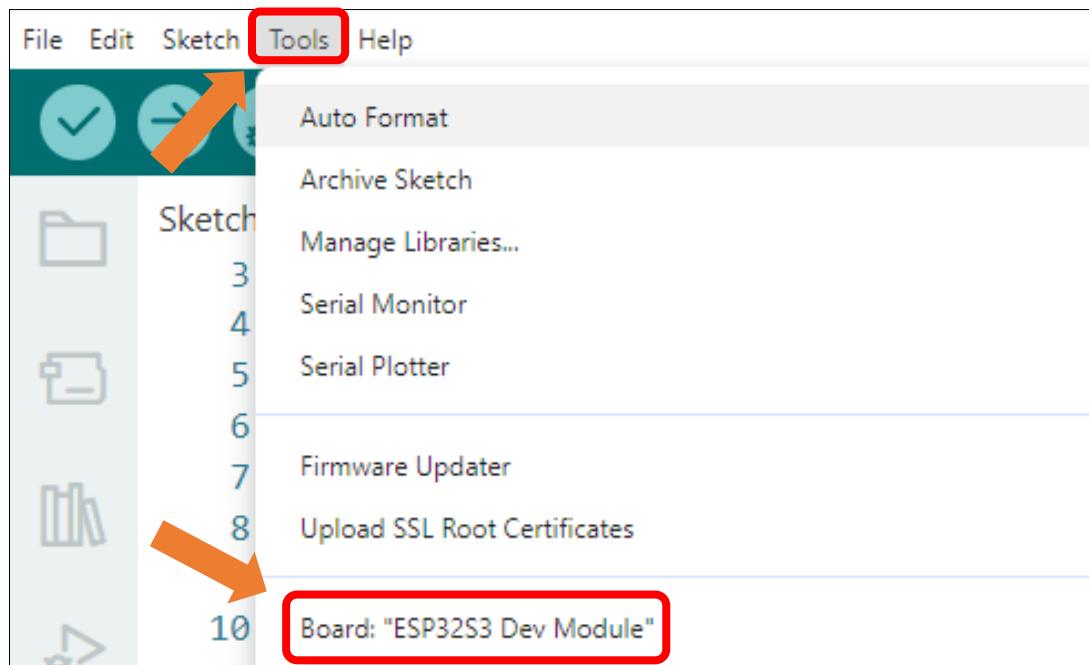
Arduino will download these files automatically. Wait for the installation to complete.

The screenshot shows the Arduino IDE's Output window. It displays the command-line logs of the installation process. An orange arrow points from the text "Successfully installed platform esp32:3.2.0" to the status message. The logs include:

```
Configuring tool.
esp32:riscv32-esp-elf-gdb@14.2_20240403 installed
Installing esp32:openocd-esp32@v0.12.0-esp32-20241016
Configuring tool.
esp32:openocd-esp32@v0.12.0-esp32-20241016 installed
Installing esp32:esptool_py@4.9.dev3
Configuring tool.
esp32:esptool_py@4.9.dev3 installed
Installing esp32:mkspiffs@0.2.3
Configuring tool.
esp32:mkspiffs@0.2.3 installed
Installing esp32:mklittlefs@3.0.0-gnu12-dc7f933
Configuring tool.
esp32:mklittlefs@3.0.0-gnu12-dc7f933 installed
Installing platform esp32:esp32@3.2.0
Configuring platform.
Platform esp32:esp32@3.2.0 installed
```

At the bottom right of the output window, a message says "Successfully installed platform esp32:3.2.0".

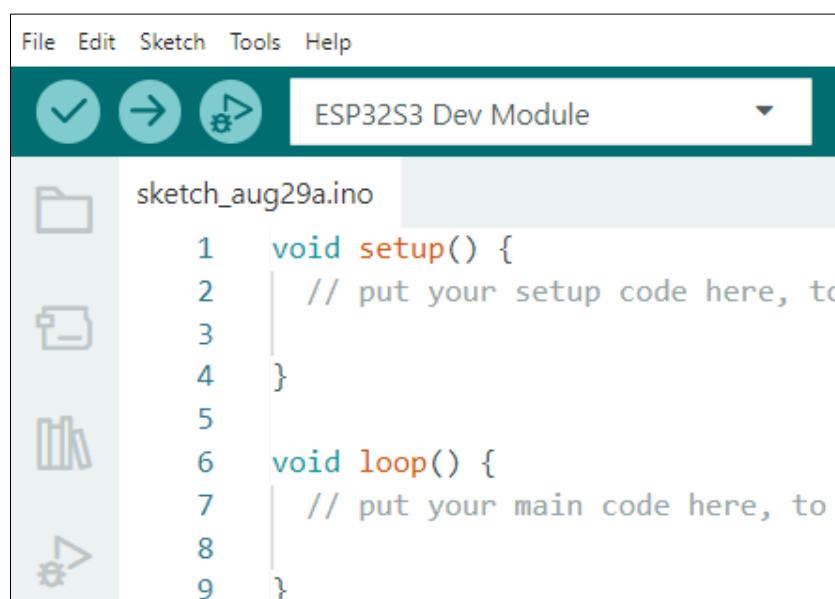
When finishing installation, click Tools in the Menus again and select Board: "ESP32S3 Dev Module", and then you can see information of ESP32S3.



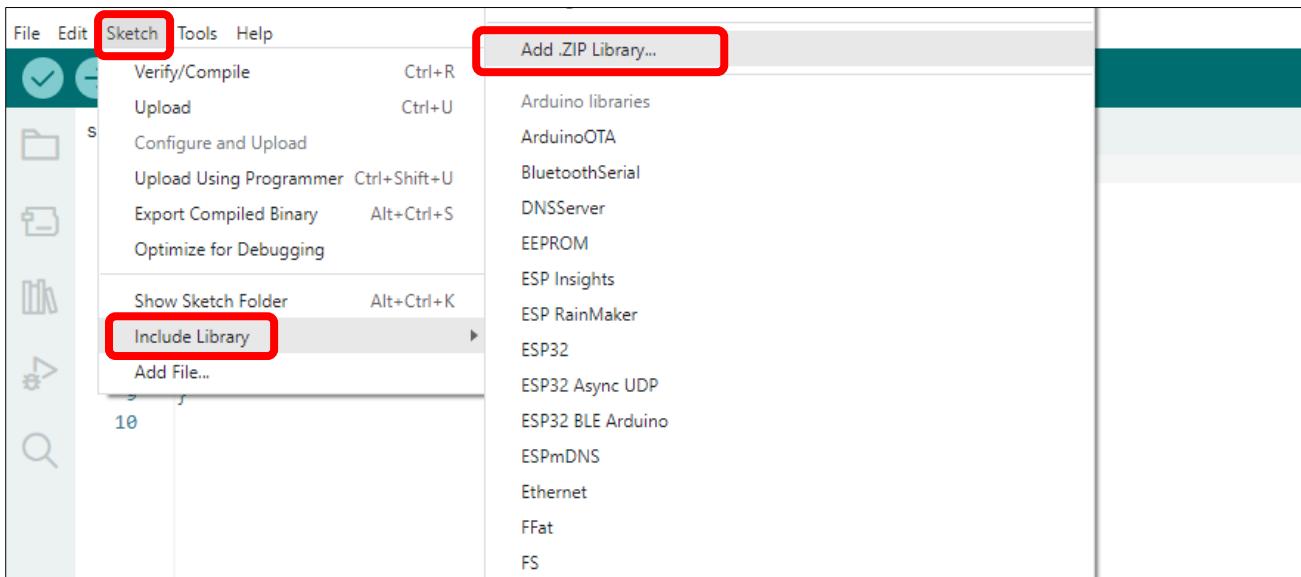
Library Installation

Before starting the learning process, it is necessary to install some libraries in advance to enable the code to be compiled properly. For convenience, we have already packaged these libraries and placed them in the **Freenove_ESP32_S3_Display/Libraries** folder. Please refer to the following steps to install these libraries into the Arduino IDE.

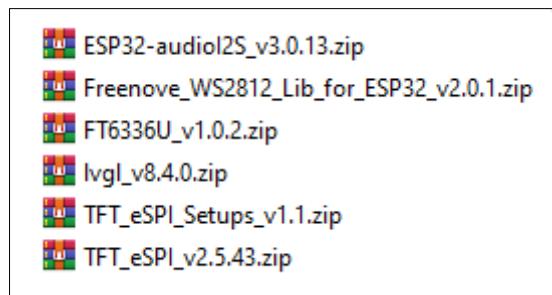
1. Open Arduino IDE.



2. Select Sketch->Include Library->Add .ZIP library….

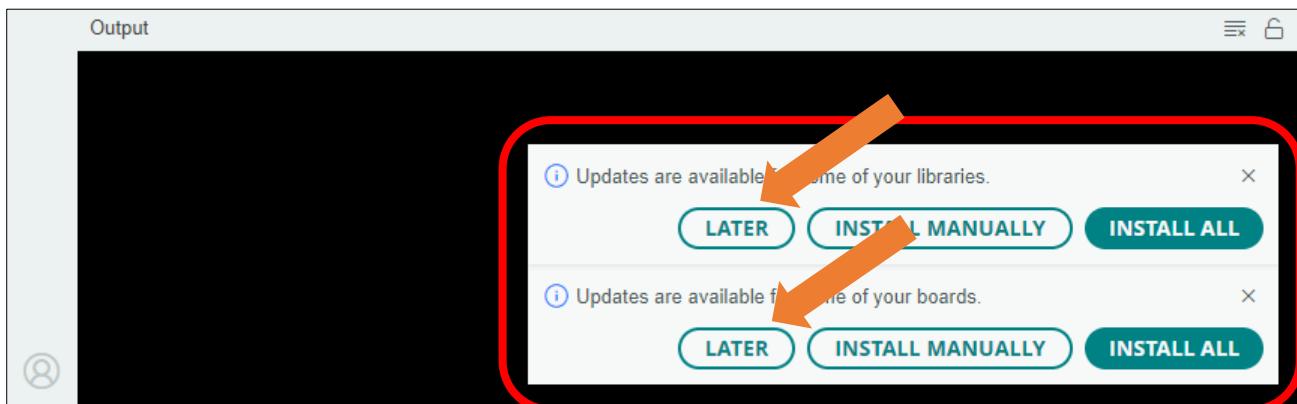


3. On the newly pop-up window, select the files from the **Freenove_ESP32_S3_Display /Libraries**. Click Open to install the library.



4. **Repeat the above steps until all the six libraries are installed to Arduino.** So far, all libraries have been installed.

Note: Some libraries are not the latest version. Please do not update them even if it prompts every time you open the IDE. Just click LATER. Otherwise, it may lead to compilation failure.



Chapter 1 Serial

Project 1.1 SerialRW

Related Knowledge

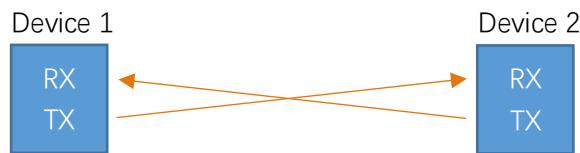
Serial and parallel communication

Serial communication uses one data cable to transfer data one bit by another in turn, while parallel communication means that the data is transmitted simultaneously on multiple cables. Serial communication takes only a few cables to exchange information between systems, which is especially suitable for computers to computer, long distance communication between computers and peripherals. Parallel communication is faster, but it requires more cables and higher cost, so it is not appropriate for long distance communication.



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 use is as follows:



Before serial communication starts, the baud rate in both sides must be the same. Only use the same baud rate can the communication between devices be normal. The baud rates commonly used are 9600 and 115200.

Component List

Freenove ESP32 S3 Display x 1

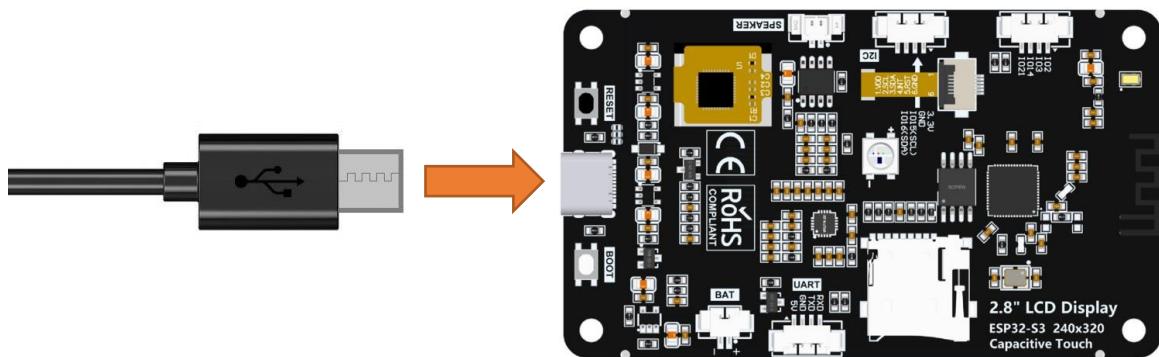


USB cable x1



Circuit

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



Sketch

Open “**Sketch_01.1_SerialRW**” folder under “**Freenove_ESP32_S3_Display\Sketches**” and double-click “**Sketch_01.1_SerialRW.ino**”.

Sketch_01.1_SerialRW

```

1  /*
2   * @ File: Sketch_01.1_SerialRW.ino
3   * @ Author: [Zhentao Lin]
4   * @ Date: [2025-08-19]
5   */
6
7   String inputString = ""; //a String to hold incoming data
8   bool stringComplete = false; // whether the string is complete
9
10  void setup() {
11      Serial.begin(115200);
12      Serial.println(String("\nESP32-S3 initialization completed!\n"))

```

```

13     + String("Please input some characters, \n")
14     + String("select \"Newline\" below and click send button. \n"));
15 }
16
17 void loop() {
18     if (Serial.available()) {           // judge whether data has been received
19         char inChar = Serial.read();    // read one character
20         inputString += inChar;
21         if (inChar == '\n') {
22             stringComplete = true;
23         }
24     }
25     if (stringComplete) {
26         Serial.printf("InputString: %s", inputString);
27         inputString = "";
28         stringComplete = false;
29     }
30 }
```

Code Explanation

Set the baud rate to 115200.

```
8 Serial.begin(115200);
```

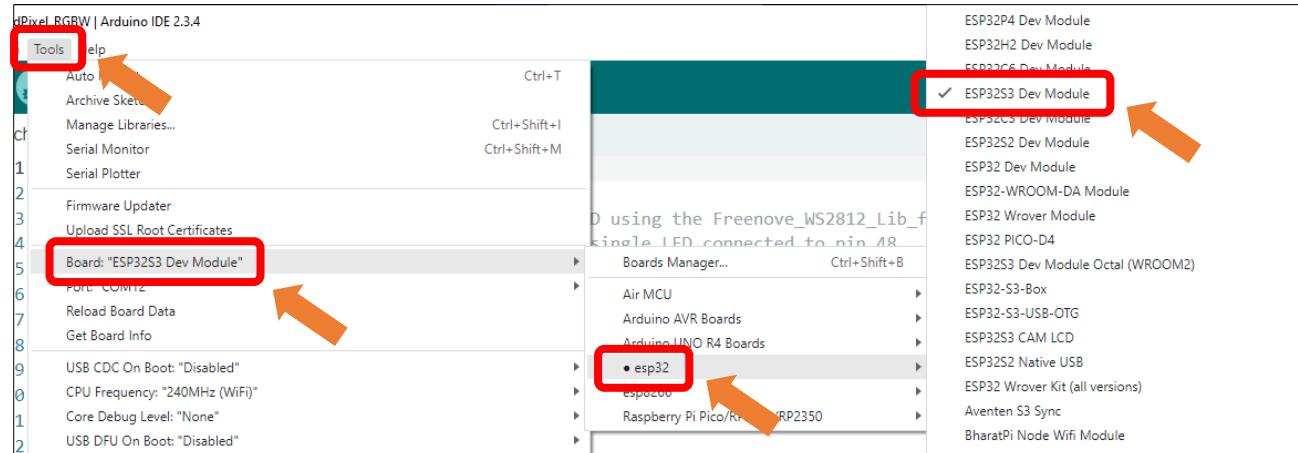
Determine whether there is data in the serial port buffer.

```
8 if (Serial.available())
```

Receive serial port data and save it in the inputString string.

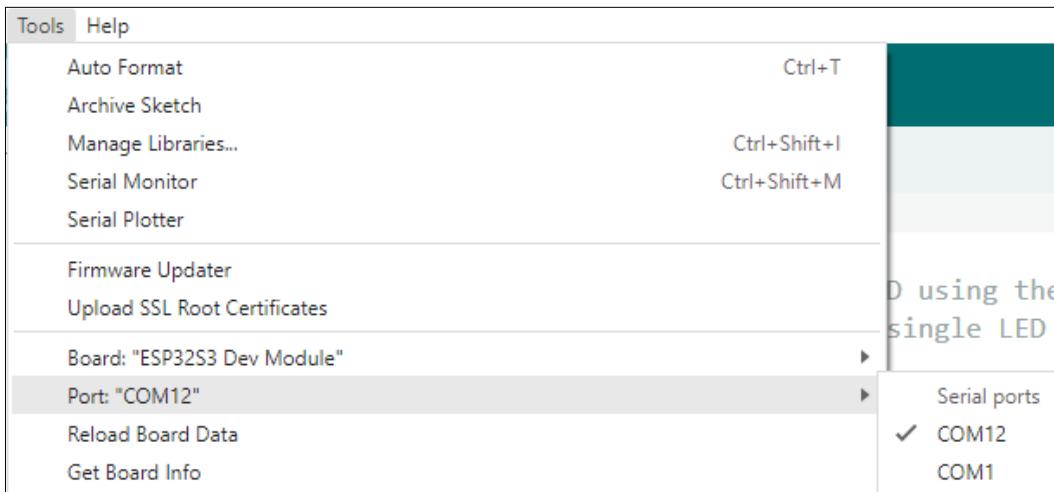
```
19 char inChar = Serial.read();           // read one character
20 inputString += inChar;
```

Select Tools → Board → esp32 -> ESP32S3 Dev Module.

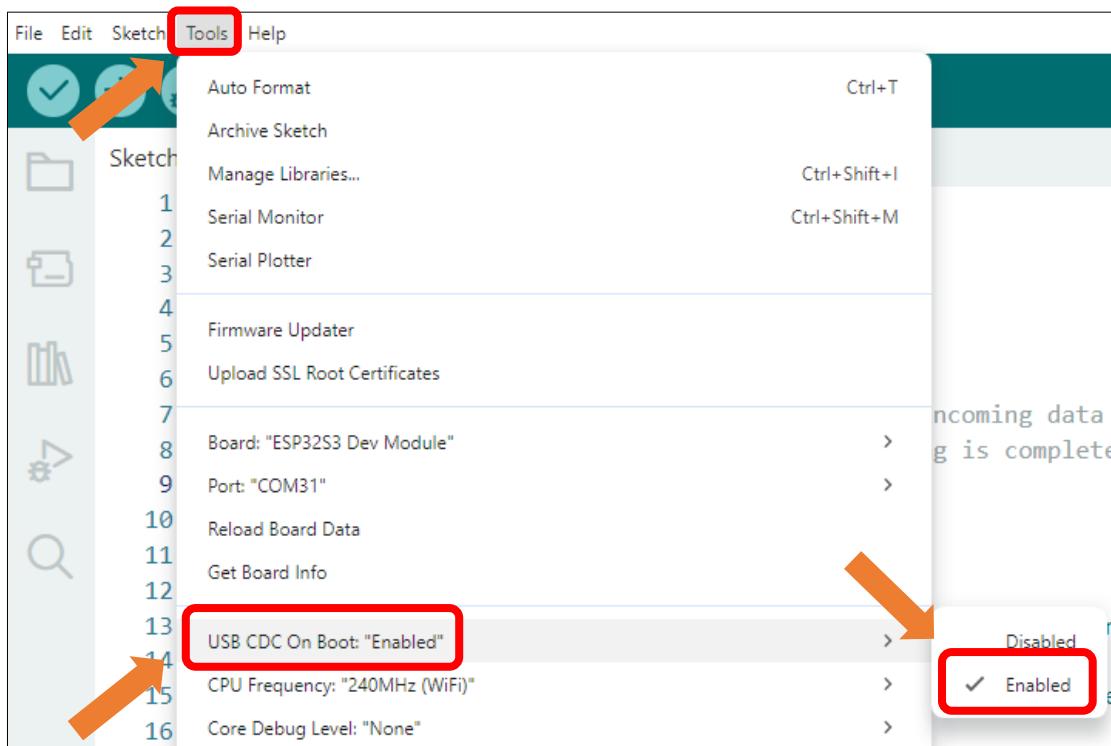


After connecting the Freenove Media Kit for ESP32-S3, the system will assign a serial communication port named in the format 'COMx' (**where 'x' is a numeric ID that may vary across computers**). You must select the correct port under Tools → Port.

Note: COM1 is typically NOT the port used by the Freenove Media Kit for ESP32-S3.



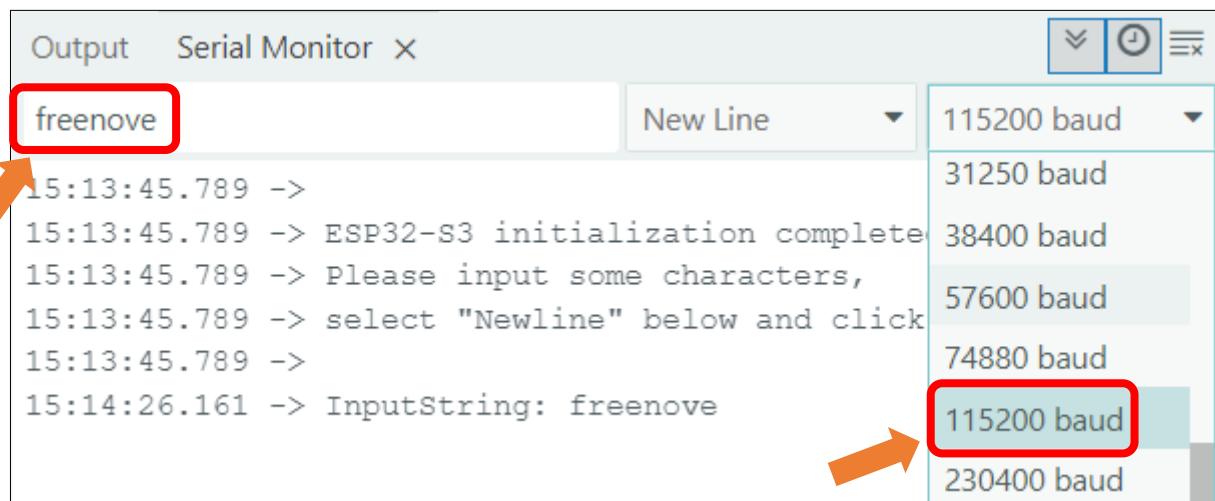
Enable the "USB CDC On Boot" feature.



The purpose of this code is to display data on the serial monitor. Click "Upload" to upload the code to Freenove ESP32 S3 Display.



After downloading the code, open the serial port monitor, and set the baud rate to **115200**, input any data in the messages bard and press Enter key, Freenove ESP32 S3 Display will print the received data.



Reference

int available()

Serial.available() checks the number of bytes currently available to read in the Serial receive buffer. It returns the number of bytes available (int type), or 0 if the buffer is empty.

int read ()

Serial.read() reads one byte of data from the Serial receive buffer and returns it as an int. If no data is available to read, it returns -1.

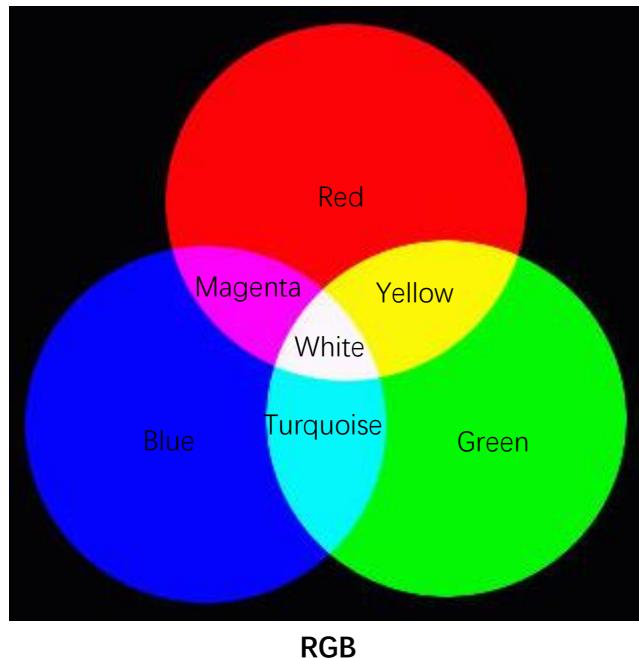


Chapter 2 RGB

Project 2.1 RGB

Related Knowledge

Red, green, and blue are called the three primary colors. When you combine these three primary colors of different brightness, it can produce almost all kinds of visible light.



The onboard RGB LED can emit three basic colors of red, green and blue, and supports 256-level brightness adjustment, which means that it can emit $2^{24}=16,777,216$ different colors.

Component List

Freenove ESP32 S3 Display x 1

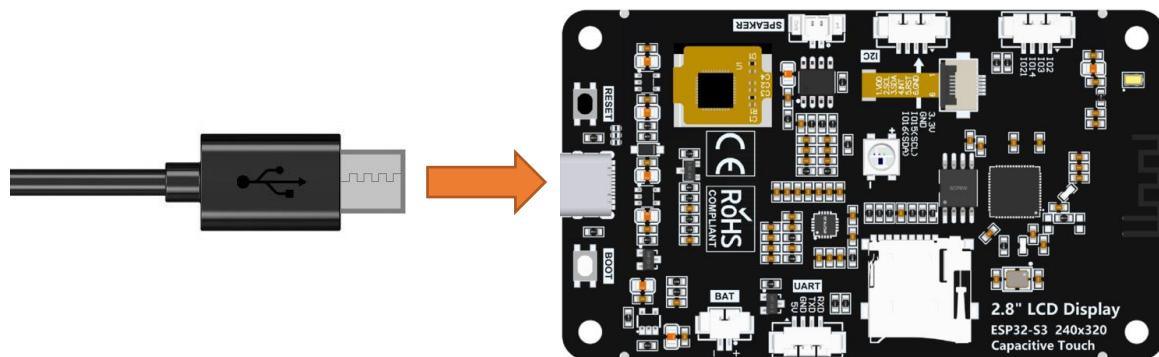


USB cable x1



Circuit

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

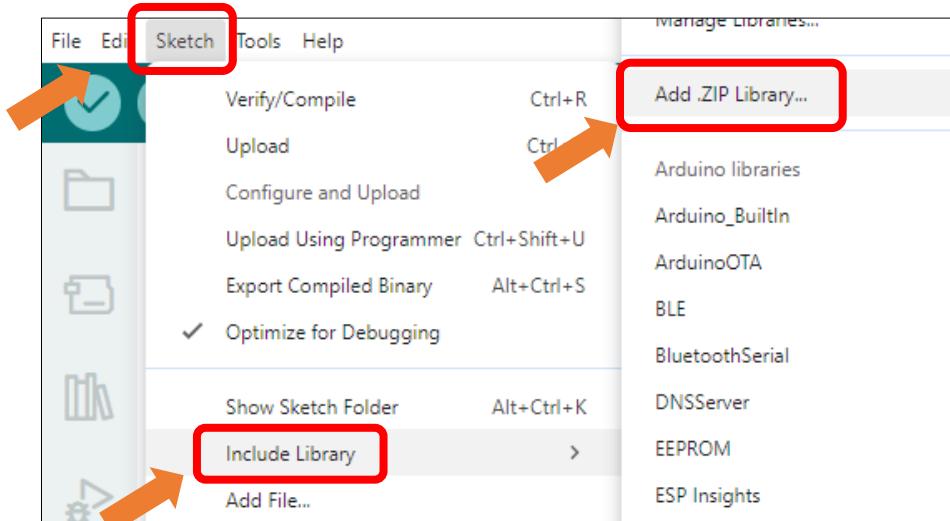


Sketch

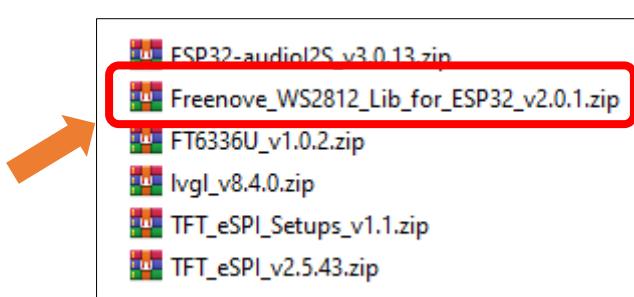
Open “Sketch_02.1_LedPixel” folder under “Freenove_ESP32_S3_Display\Sketches” and double-click “Sketch_02.1_LedPixel.ino”.

Install the needed libraries.

Click Sketch -> Include Library -> Add .ZIP Library...



Select Freenove_WS2812_Lib_for_ESP32_v2.0.1.zip





Sketch_02.1_LedPixel

The following is the program code:

```

1  /*
2   * @ File: Sketch_02.1_LedPixel.ino
3   * @ Author: [Zhentao Lin]
4   * @ Date: [2025-08-19]
5   */
6
7 #include "Freenove_WS2812_Lib_for_ESP32.h"
8
9 #define LEDS_COUNT 1
10 #define LEDS_PIN    42
11 #define CHANNEL     0
12
13 Freenove_ESP32_WS2812 strip = Freenove_ESP32_WS2812(LEDS_COUNT, LEDS_PIN, CHANNEL, TYPE_GRB);
14
15 uint8_t m_color[5][3] = { { 255, 0, 0 }, { 0, 255, 0 }, { 0, 0, 255 }, { 255, 255, 255 }, { 0,
16 0, 0 } };
17 int delayval = 100;
18
19 void setup() {
20     strip.begin();
21     strip.setBrightness(10);
22 }
23 void loop() {
24     for (int j = 0; j < 5; j++) {
25         for (int i = 0; i < LEDS_COUNT; i++) {
26             strip.setLedColorData(i, m_color[j][0], m_color[j][1], m_color[j][2]);
27             strip.show();
28             delay(delayval);
29         }
30         delay(500);
31     }
32 }
```

Code Explanation

Define the pins for the RGB LED.

```

9 #define LEDS_COUNT 1
10 #define LEDS_PIN    42
11 #define CHANNEL     0
```

Initialize the LED, set the brightness to 10

```

20 strip.begin();
21 strip.setBrightness(10);
```

Cycle through five different colors.

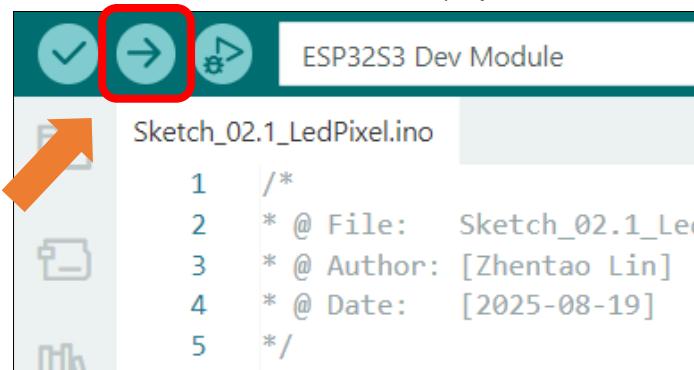
```

24 for (int j = 0; j < 5; j++) {
```

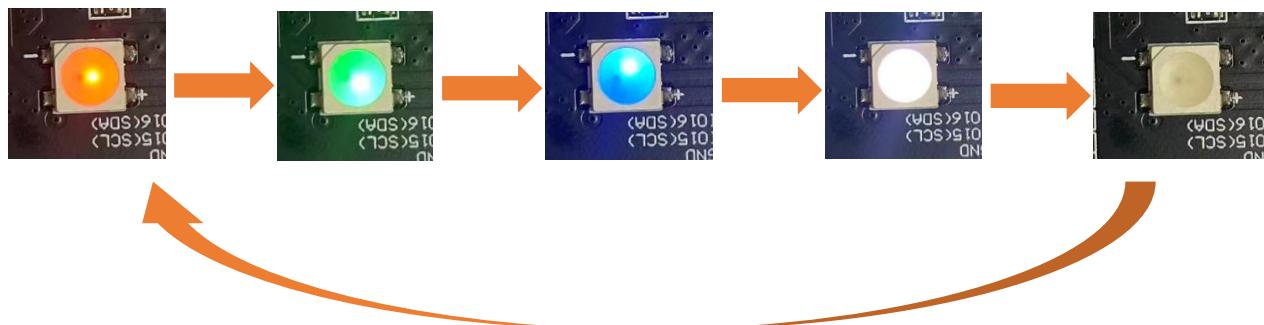
```

25   for (int i = 0; i < LEDS_COUNT; i++) {
26     strip.setLedColorData(i, m_color[j][0], m_color[j][1], m_color[j][2]);
27     strip.show();
28     delay(delayval);
29   }
30   delay(500);
31 }
```

Click “Upload” to upload the code to Freenove_ESP32_S3_Display.



The RGB LEDs will cycle through Red -> Green -> Blue -> White -> Off every 500ms after code upload.



Reference

Freenove_ESP32_WS2812(*u16 n* = 8, *u8 pin_gpio* = 2, *u8 chn* = 0, *LED_TYPE t* = TYPE_GRB)

Constructor to create a ws2812 object.

Before each use of the constructor, please add “#include "Freenove_WS2812_Lib_for_ESP32.h"

Parameters

n: The number of led.

pin_gpio: The pin connected to the LED.

Chn: RMT channel, which has eight channels, 0-7, and uses channel 0 by default. This means that you can use eight ws2812 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 ws2812 module loading color is red, green and blue.

TYPE_RBG: The sequence of ws2812 module loading color is red, blue and green.

TYPE_GRB: The sequence of ws2812 module loading color is green, red and blue.

TYPE_GBR: The sequence of ws2812 module loading color is green, blue and red.

TYPE_BRG: The sequence of ws2812 module loading color is blue, red and green.

TYPE_BGR: The sequence of ws2812 module loading color is blue, green and red.

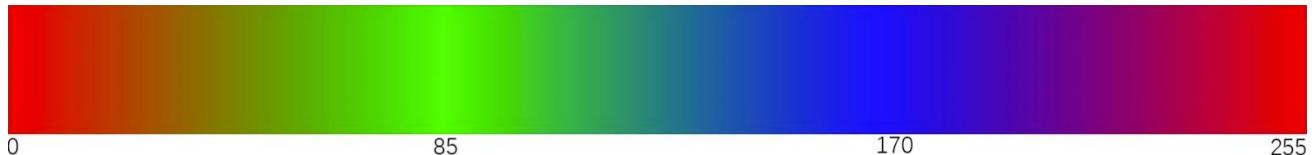


Project 2.2 Rainbow

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 LED and gradually change.



Component List

Freenove ESP32 S3 Display x 1

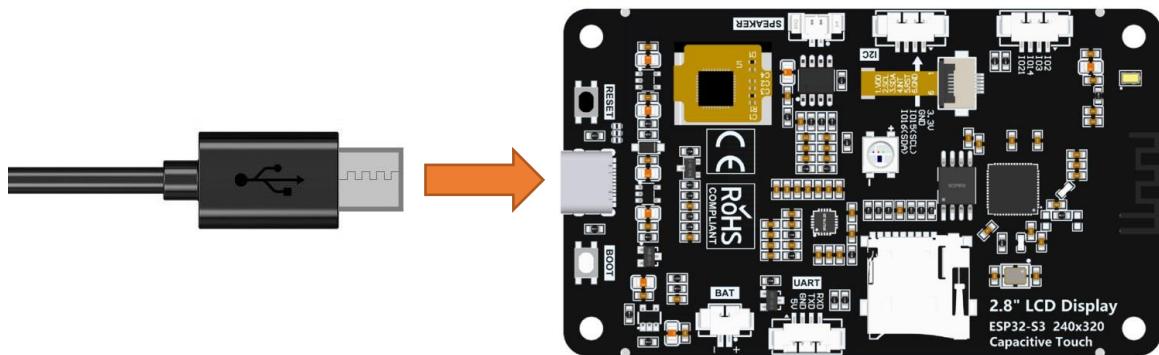


USB cable x1



Circuit

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



Sketch

Open “**Sketch_02.2_Rainbow**” folder under “**Freenove_ESP32_S3_Display\Sketches**” and double-click “**Sketch_02.2_Rainbow**”.

Sketch_02.2_Rainbow

The following is the program code:

```

1  /*
2  * @ File: Sketch_02.2_Rainbow.ino
3  * @ Author: [Zhentao Lin]
4  * @ Date: [2025-06-11]
5  */
6 #include "Freenove_WS2812_Lib_for_ESP32.h"
7
8 #define LEDS_COUNT 1
9 #define LEDS_PIN 42
10 #define CHANNEL 0
11
12 Freenove_ESP32_WS2812 strip = Freenove_ESP32_WS2812(LEDS_COUNT, LEDS_PIN, CHANNEL, TYPE_GRB);
13
14 void setup() {
15     strip.begin();
16     strip.setBrightness(20);
17 }
18
19 void loop() {
20     for (int j = 0; j < 255; j += 2) {
21         for (int i = 0; i < LEDS_COUNT; i++) {
22             strip.setLedColorData(i, strip.Wheel((i * 256 / LEDS_COUNT + j) & 255));
23         }
24         strip.show();
25         delay(10);
26     }
27 }
```

Code Explanation

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 $i+=2$ can be changed to change the color step distance. Changing the delay parameter changes the speed of the color change. `strip.Wheel((i * 256 / LEDS_COUNT + j) & 255)` will take color from the color model at equal intervals starting from i.

```

19 for (int j = 0; j < 255; j += 2) {
20     for (int i = 0; i < LEDS_COUNT; i++) {
21         strip.setLedColorData(i, strip.Wheel((i * 256 / LEDS_COUNT + j) & 255));
22     }
```

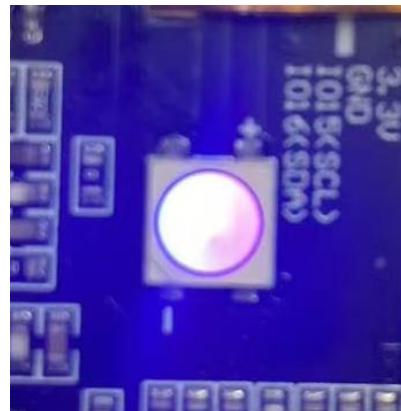
```

23     strip.show();
24     delay(10);
25 }
```

This code achieves the function of printing data on serial monitor. Click “**Upload**” to upload the code to Freenove_ESP32_S3_Display.



After uploading the code, the LED lights will display a smooth rainbow gradient effect.



Reference

```
bool ledcAttachChannel(uint8_t pin, uint32_t freq, uint8_t resolution, uint8_t channel);
```

This function binds the specified PWM channel to a GPIO pin and configures the frequency and resolution of the PWM signal.

Parameters:

pin: GPIO pin number to bind

freq: PWM signal frequency in Hz

resolution: Bit depth for PWM duty cycle resolution (range: 1-16 bits).

For example, 8 represents 2^8 (0~255) levels.

channel: PWM channel number to assign (integer)

```
void ledcWrite(uint8_t channel, uint32_t duty);
```

This function sets the duty cycle for a specified PWM channel to control output signal intensity.

Parameters:

channel: PWM channel number

duty: Duty cycle value (range determined by resolution bit depth)

Chapter 3 Button

The Boot button on the Freenove ESP32 S3 Display can be configured as a regular input button after the program starts.

Project 3.1 Button RGB

In the previous chapter, we learned about RGB LEDs. In this section, we will further explore how to integrate RGB LEDs with buttons.

Related Knowledge

Button

In embedded systems, buttons are one of the most common human-machine input devices. When a button is not pressed, its opposing contacts are connected while adjacent contacts remain disconnected.

Conversely, when the button is pressed, adjacent contacts connect while opposing contacts disconnect.

Usage of the Boot Button on the Freenove CYD Board:

Manual Entry into Download Mode:

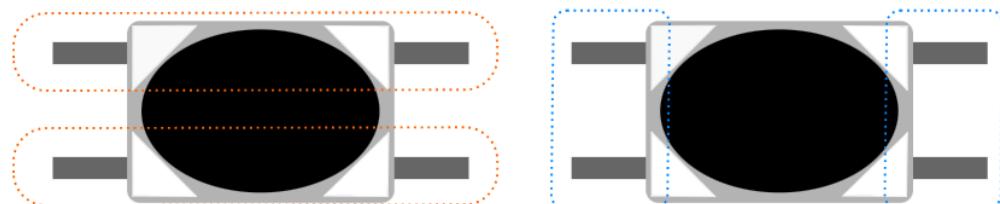
When the board is powered on or reset, pressing and holding the Boot button forces the board into download mode.

In this mode, users can upload programs to the board via the serial port.

Use as a Regular Input Button:

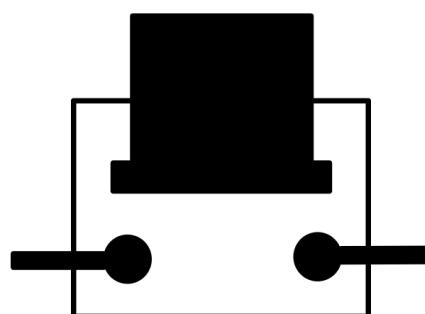
If the Boot button is not pressed during power-on or reset, the board enters normal operation mode.

Once in operation mode, the Boot button can function as GPIO0, typically configured as a standard input button for user interaction.



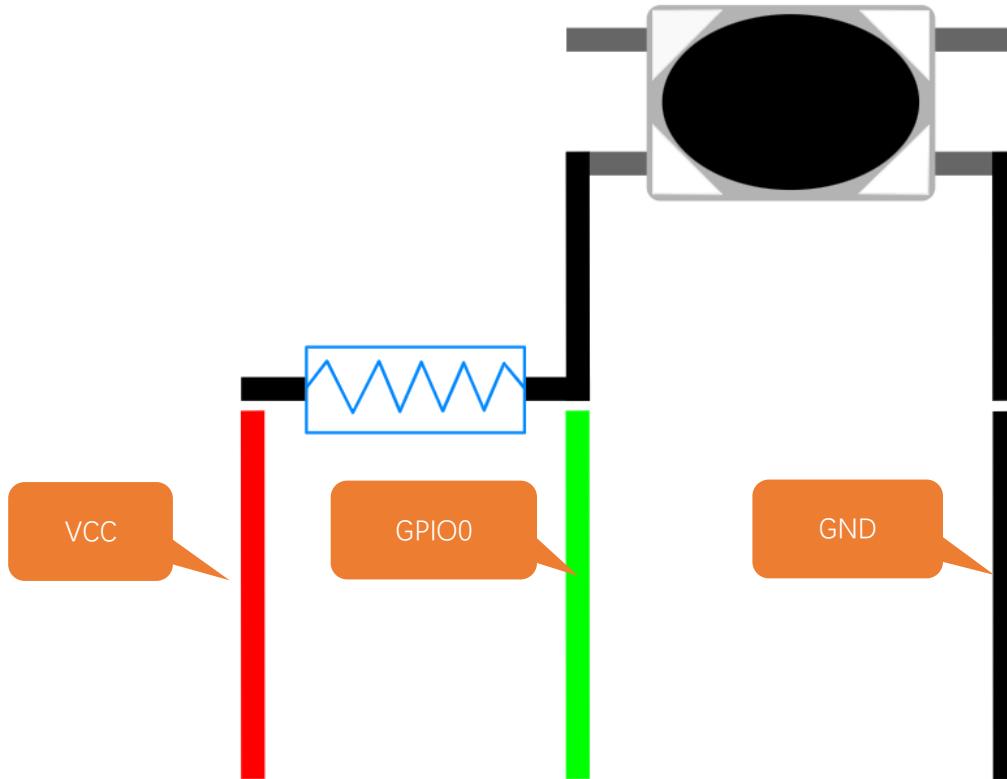
Before pressing

After pressing



Pull-up Resistor

The primary function of a pull-up resistor is to ensure that the button maintains a **stable high-level state** when not pressed, preventing false triggering caused by floating pins or signal noise. The pull-up resistor is connected between the GPIO pin and VCC.



When the button is not pressed, Vcc is connected to GPIO0 through the resistor, resulting in a high-level signal at this pin.

When the button is pressed, GPIO0 is connected to GND, resulting in a low-level signal.

Therefore, by reading the GPIO0 pin state, we can determine whether the button is pressed or not.

Component List

Freenove ESP32 S3 Display x 1

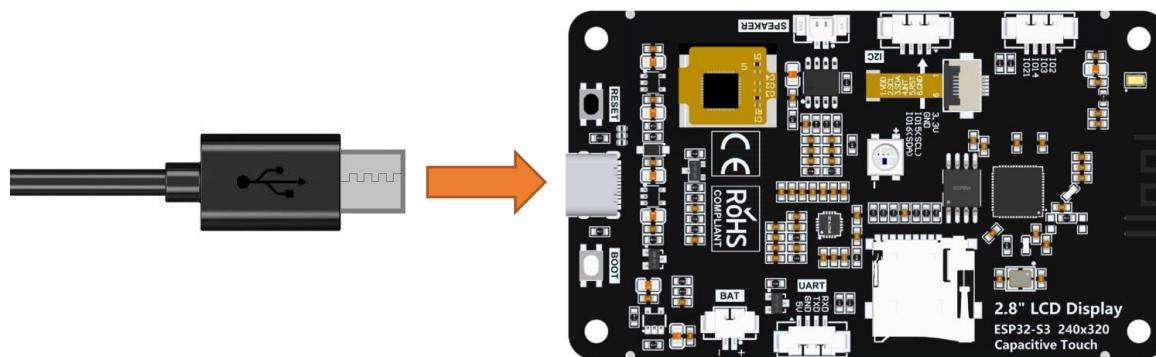


USB cable x1



Circuit

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



Sketch

Open “Sketch_03.1_Button_RGB” folder under “**Freenove_ESP32_S3_Display\Sketches**” and double-click “**Sketch_03.1_Button_RGB.ino**”.

Sketch_03.1_Button_RGB

The following is the program code:

```
1  /*
2   * @ File: Sketch_03.1_Button_RGB.ino
3   * @ Author: [Zhentao Lin]
4   * @ Date: [2025-08-19]
5   */
6
7 #include <Arduino.h>
8 #include "Freenove_WS2812_Lib_for_ESP32.h"
9
10 #define KEY_PIN 0
11 #define LEDS_COUNT 1
12 #define LEDS_PIN 42
13 #define CHANNEL 0
14
15 Freenove_ESP32_WS2812 strip = Freenove_ESP32_WS2812(LEDS_COUNT, LEDS_PIN, CHANNEL, TYPE_GRB);
16
17 uint8_t m_color[5][3] = { { 255, 0, 0 }, { 0, 255, 0 }, { 0, 0, 255 }, { 255, 255, 255 }, { 0,
18 0, 0 } };
19
20 static unsigned int keyCount = 0;
21 static unsigned int lastKeyCount = 1;
22
23 void buttonInit(void) {
```



```
24     pinMode(KEY_PIN, INPUT_PULLUP);
25 }
26
27 bool readButton(void) {
28     return digitalRead(KEY_PIN);
29 }
30
31 void switchRGB(int value) {
32     int colorIndex = value % 4;
33     switch (colorIndex) {
34         case 1:
35             strip.setLedColorData(0, m_color[0][0], m_color[0][1], m_color[0][2]);
36             strip.show();
37             break;
38         case 2:
39             strip.setLedColorData(0, m_color[1][0], m_color[1][1], m_color[1][2]);
40             strip.show();
41             break;
42         case 3:
43             strip.setLedColorData(0, m_color[2][0], m_color[2][1], m_color[2][2]);
44             strip.show();
45             break;
46         default:
47             strip.setLedColorData(0, m_color[4][0], m_color[4][1], m_color[4][2]);
48             strip.show();
49             break;
50     }
51 }
52
53 void setup() {
54     strip.begin();
55     strip.setBrightness(10);
56     buttonInit();
57     Serial.println("ESP32-S3 initialization completed!");
58 }
59
60 void loop() {
61     if (readButton() == 0) {
62         delay(20);
63         if (readButton() == 0) {
64             keyCount++;
65             while (!readButton());
66         }
67     }
}
```

```

68     if (keyCount != lastKeyCount) {
69         switchRGB(keyCount);
70         lastKeyCount = keyCount;
71     }
72 }
```

Code Explanation

Define the pins for the button and the RGB LED.

```

10 #define KEY_PIN 0
11 #define LEDS_COUNT 1
12 #define LEDS_PIN 42
13 #define CHANNEL 0
```

Initialize the RGB LED and the button.

```

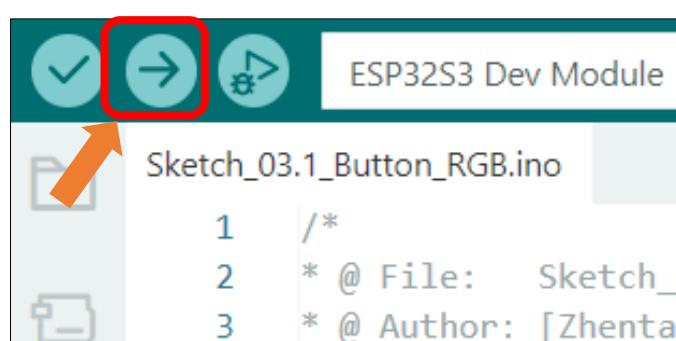
54 strip.begin();
55 strip.setBrightness(10);
56 buttonInit()
```

Control the color of the RGB LED through the button.

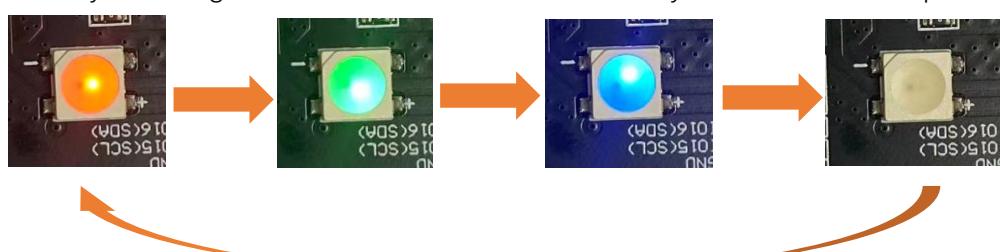
```

61 if (readButton() == 0) {
62     delay(20);
63     if (readButton() == 0) {
64         keyCount++;
65         while (!readButton());
66     }
67 }
68 if (keyCount != lastKeyCount) {
69     switchRGB(keyCount);
70     lastKeyCount = keyCount;
71 }
```

Click “Upload” to upload the code to Freenove_ESP32_S3_Display.



The RGB LEDs will cycle through Red -> Green -> Blue -> OFF every 500ms after code upload.





Chapter 4 Button Interrupt

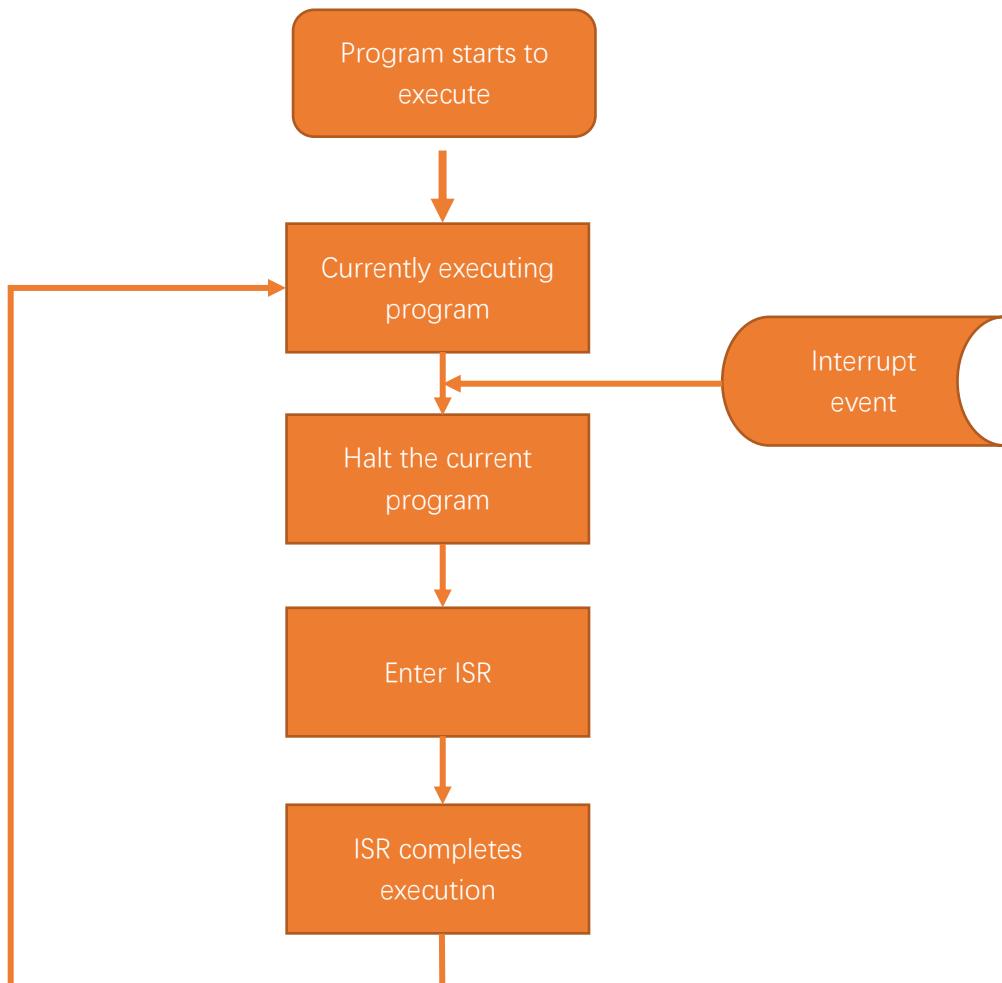
In this chapter will learn to use interrupt to detect the button state.

Project 4.1 Button Interrupt UART

Related Knowledge

How Interrupts Work

When an interrupt event is triggered, the Raspberry Pi Pico (W) receives an interrupt signal. At this moment, the Raspberry Pi Pico (W) pauses the currently executing program and instead executes the Interrupt Service Routine (ISR). The ISR contains the code that needs to be processed after the interrupt event occurs. Once the ISR execution is complete, the Raspberry Pi Pico will return to the state it was in before the interrupt occurred and continue executing the paused program, as shown in the diagram below.



Component List

Freenove ESP32 S3 Display x 1

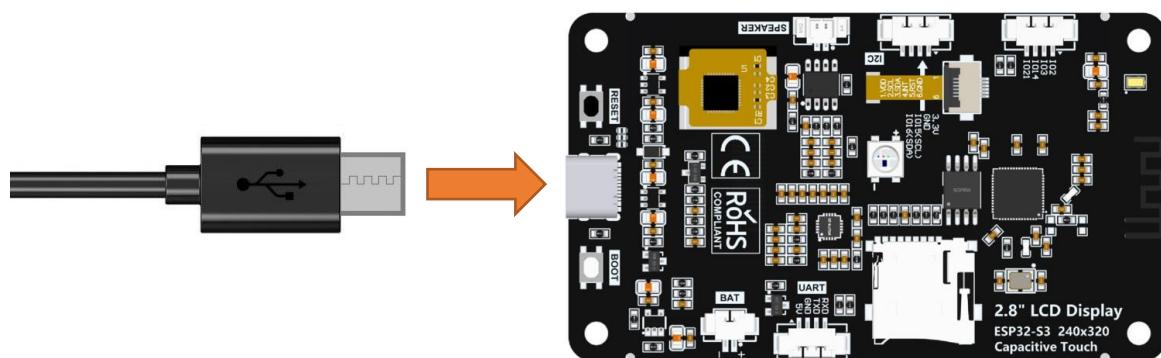


USB cable x1



Circuit

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



Sketch

Open “Sketch_04.1_Button_Interrupt_UART” folder under “Freenove_ESP32_S3_Display\Sketches” and double-click “Sketch_04.1_Button_Interrupt_UART.ino”.

Sketch_04.1_Button_Interrupt_UART

The following is the program code:

```
1  /*
2   * @ File: Sketch_04.1_Button_Interrupt_UART.ino
3   * @ Author: [Zhentao Lin]
4   * @ Date: [2025-08-19]
5   */
6
7 #include <Arduino.h>
8
9 #define KEY_PIN 0
10 volatile int interruptCounter = 0;
11 int lastValue = 0;
```

```

12 portMUX_TYPE mux = portMUX_INITIALIZER_UNLOCKED;
13
14 void buttonInit(void) {
15     pinMode(KEY_PIN, INPUT_PULLUP);
16     attachInterrupt(digitalPinToInterruption(KEY_PIN), handleInterrupt, FALLING);
17 }
18
19 void delayDebounce(unsigned int delayTime) {
20     unsigned int i = delayTime;
21     while (--i > 0) {
22         if (digitalRead(KEY_PIN) == HIGH) {
23             return;
24         }
25     }
26 }
27
28 void handleInterrupt(void) {
29     portENTER_CRITICAL_ISR(&mux);
30     interruptCounter++;
31     delayDebounce(20);
32     portEXIT_CRITICAL_ISR(&mux);
33 }
34
35 void setup() {
36     Serial.begin(115200);
37     buttonInit();
38     Serial.println("ESP32-S3 initialization completed!");
39 }
40
41 void loop() {
42     if (interruptCounter != lastValue) {
43         Serial.printf("interruptCounter: %d\r\n", interruptCounter);
44         lastValue = interruptCounter;
45     }
46 }

```

Code Explanation

Define the pin of the button.

9	#define KEY_PIN 0
---	-------------------

Configure the button pin hardware interrupt to trigger on the falling edge signal.

16	attachInterrupt(digitalPinToInterruption(KEY_PIN), handleInterrupt, FALLING);
----	---

The interrupt processing function, counting how many times the button is pressed.

28	void handleInterrupt(void) {
29	portENTER_CRITICAL_ISR(&mux);
30	interruptCounter++;

```

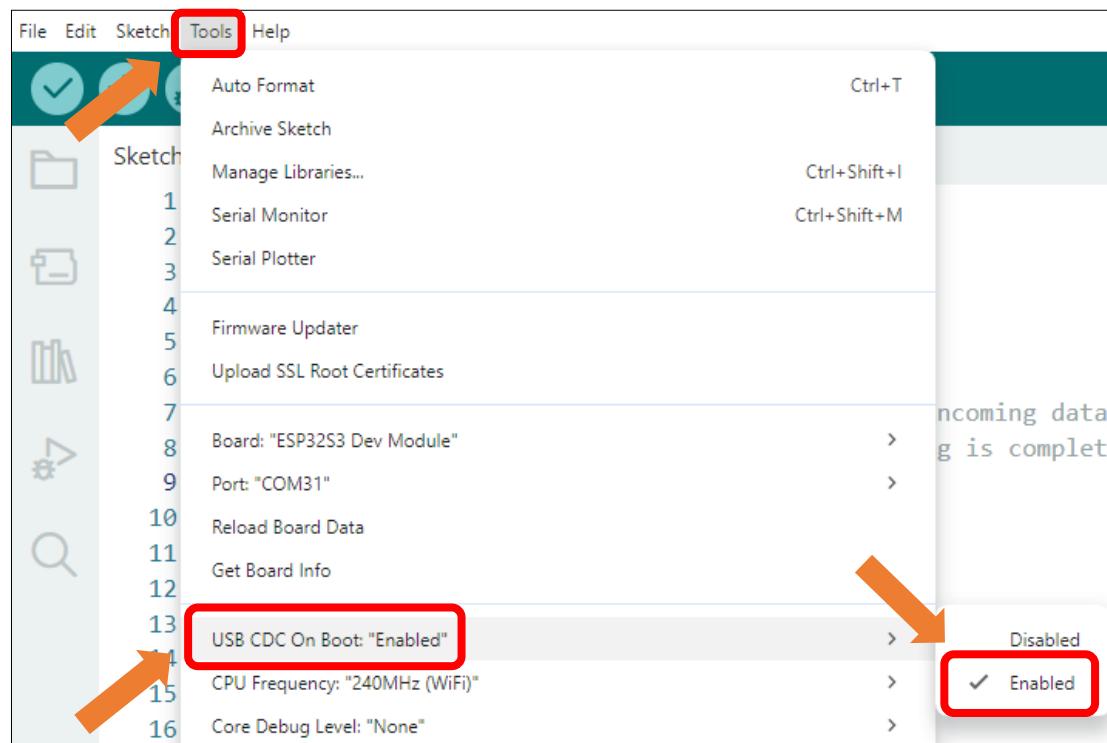
31     delayDebounce(20);
32     portEXIT_CRITICAL_ISR(&mux);
33 }
```

When the number of button presses changes, print new data in the serial monitor.

```

41 void loop() {
42     if (interruptCounter != lastValue) {
43         Serial.printf("interruptCounter: %d\r\n", interruptCounter);
44         lastValue = interruptCounter;
45     }
46 }
```

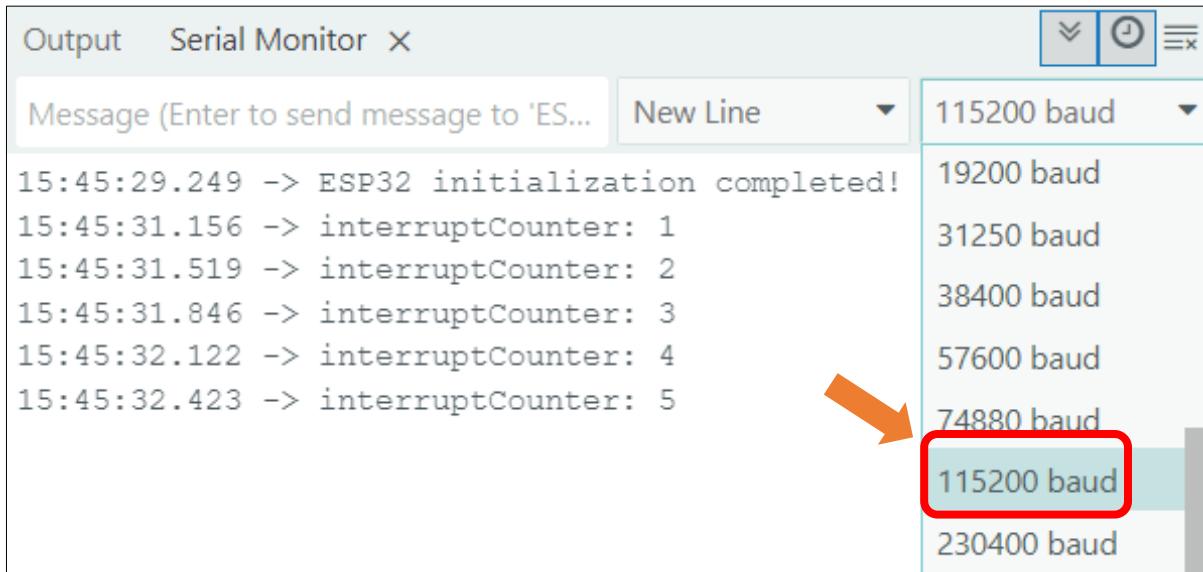
Enable the "USB CDC On Boot" feature.



Click "Upload" to upload the code to Freenove_ESP32_S3_Display.



When the code finishes uploading, open the serial monitor and set the baud rate to 115200. The serial monitor will print the number of button presses.



Reference

```
void attachInterrupt(uint8_t pin, void (*) (void), int mode);
```

external interrupts

Parameters:

pin: The digital pin number for the interrupt

void: The name of the interrupt function

mode:

LOW (trigger on low level)

CHANGE (trigger on change)

RISING (trigger on rising edge)

FALLING (trigger on falling edge)

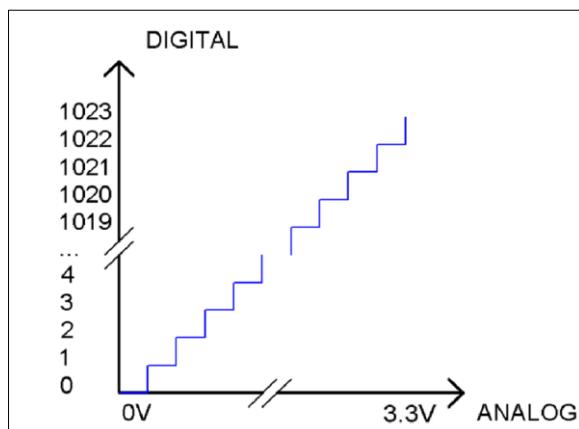
Chapter 5 Battery Voltage

Project 5.1 Battery Voltage

Related Knowledge

ADC

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 Raspberry Pi Pico (W) is 10 bits, which means the resolution is $2^{10}=1024$, and it represents a range (at 3.3V) will be divided equally to 1024 parts. The range of analog values corresponds to ADC values. So the more bits the ADC has, the denser the partition of analog will be and the greater the precision of the resulting conversion.



Subsection 1: the analog in rang of 0V---3.3/1023 V corresponds to digital 0;

Subsection 2: the analog in rang of 3.3/1023 V---2*3.3 /1023V corresponds to digital 1;

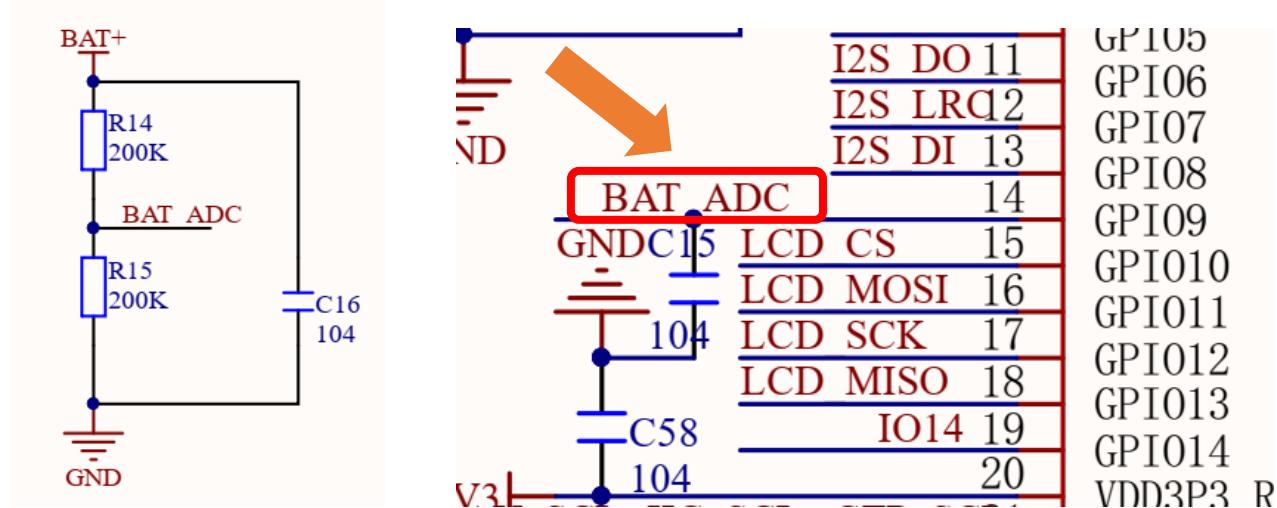
The following analog will be divided accordingly.

The conversion formula is as follows:

$$ADC\ Value = \frac{\text{Analog\ Voltage}}{3.3} * 1023$$

Battery Voltage

From the schematic diagram, we can know that Freenove_ESP32_S3_Display reads the battery voltage through the ADC pin (GPIO9).

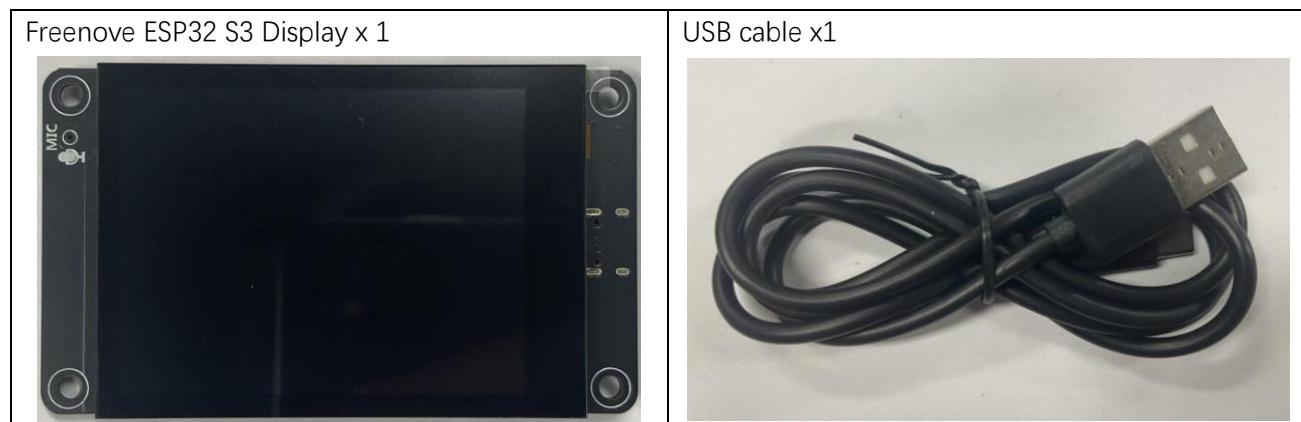


The ADC pin on this board has a voltage sampling range of 0~3.3V. However, when powered by a 3.7V lithium battery, the output voltage in a fully charged state can reach 4.2V, exceeding the ADC's rated input range.

To ensure accurate voltage measurement and ADC pin protection, the circuit employs a resistive voltage divider that scales the battery voltage down by a factor of 0.5. At a full charge (4.2V), the divided voltage at the ADC input is 2.1V, well within the safe operating range. This design enables reliable battery monitoring while preventing overvoltage damage to the ADC.

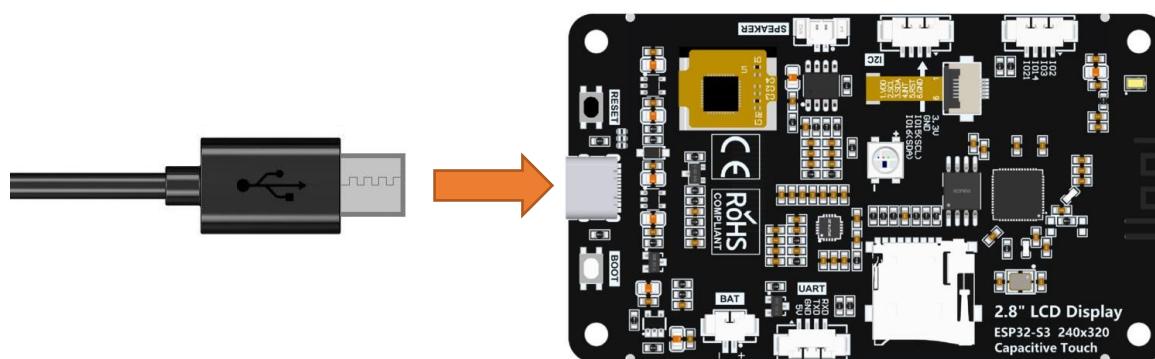
Please note that this kit does not include a lithium battery, please buy one yourself. For more information about battery, please refer to [Battery](#).

Component List



Circuit

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



Sketch

Next, we download the code to Freenove_ESP32_S3_Display to test Serial. Open “**Sketch_05.1_Battery_Voltage.ino**” folder under “**Freenove_ESP32_S3_Display\Sketches**” and double-click “**Sketch_05.1_Battery_Voltage.ino**”.

[Sketch_05.1_Battery_Voltage](#)

The following is the program code:

```

1  /*
2   * @ File: Sketch_05.1_Battery_Voltage.ino
3   * @ Author: [Zhentao Lin]
4   * @ Date: [2025-08-19]
5   */
6
7 #define BAT_ADC_PIN 9
8
9 void setup() {
10     Serial.begin(115200);
11     pinMode(BAT_ADC_PIN, INPUT);
12 }
13
14 void loop() {
15     int adcValue= analogRead(BAT_ADC_PIN);
16     float batteryVoltage = analogReadMilliVolts(BAT_ADC_PIN) * 2.0 / 1000;
17     Serial.printf("Reading on Pin(%d), adcValue=%d, batteryVoltage2=%fV\n", BAT_ADC_PIN,
18     adcValue, batteryVoltage);
19     delay(300);
20 }
```

Code Explanation

Define the pins for the button and RGB LED.

7	#define BAT_ADC_PIN 9
---	-----------------------



Set the baud rate to 115200.

```
10 Serial.begin(115200);
```

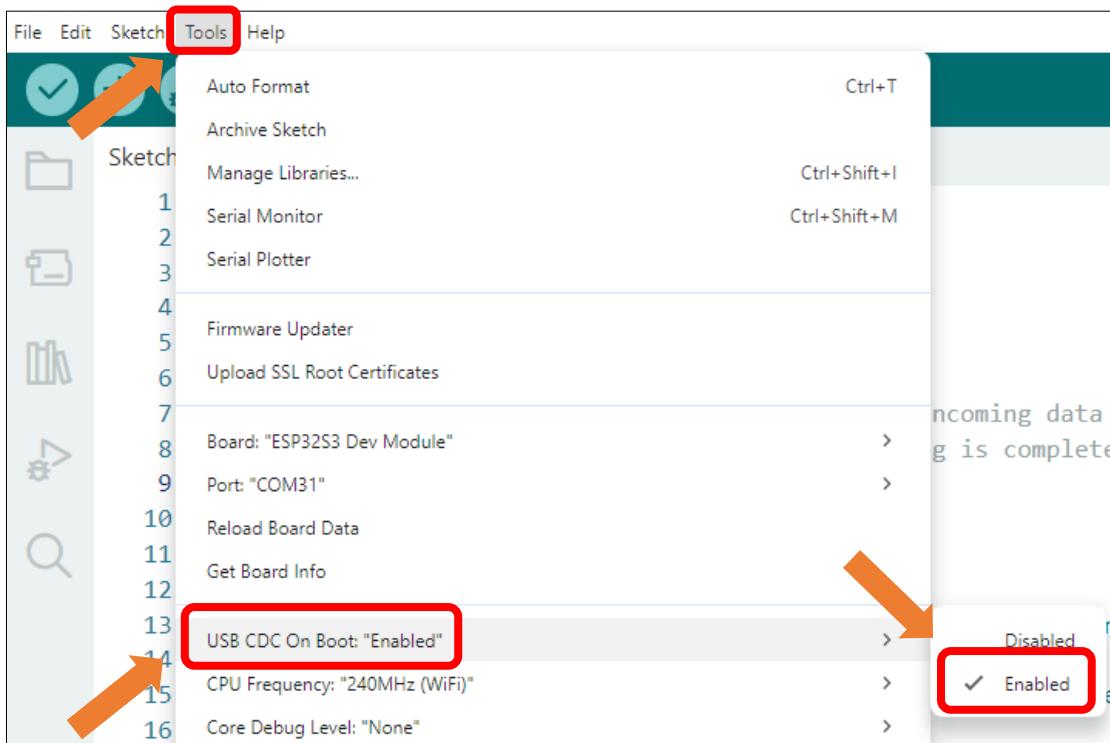
Set the battery voltage detecting pin to input mode.

```
11 pinMode(BAT_ADC_PIN, INPUT);
```

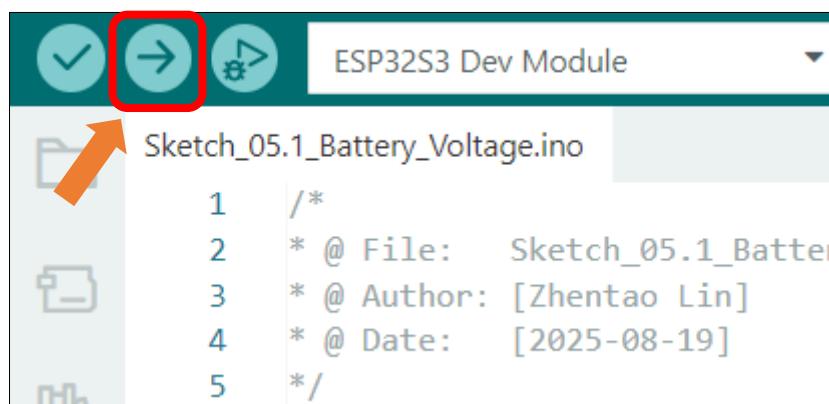
Measure the battery voltage every 300ms and outputs the reading to the serial monitor.

```
14 void loop() {
15     int adcValue= analogRead(BAT_ADC_PIN);
16     float batteryVoltage = analogReadMilliVolts(BAT_ADC_PIN) * 2.0 / 1000;
17     Serial.printf("Reading on Pin(%d), adcValue=%d, batteryVoltage2=%fV\n", BAT_ADC_PIN,
18     adcValue, batteryVoltage);
19     delay(300);
20 }
```

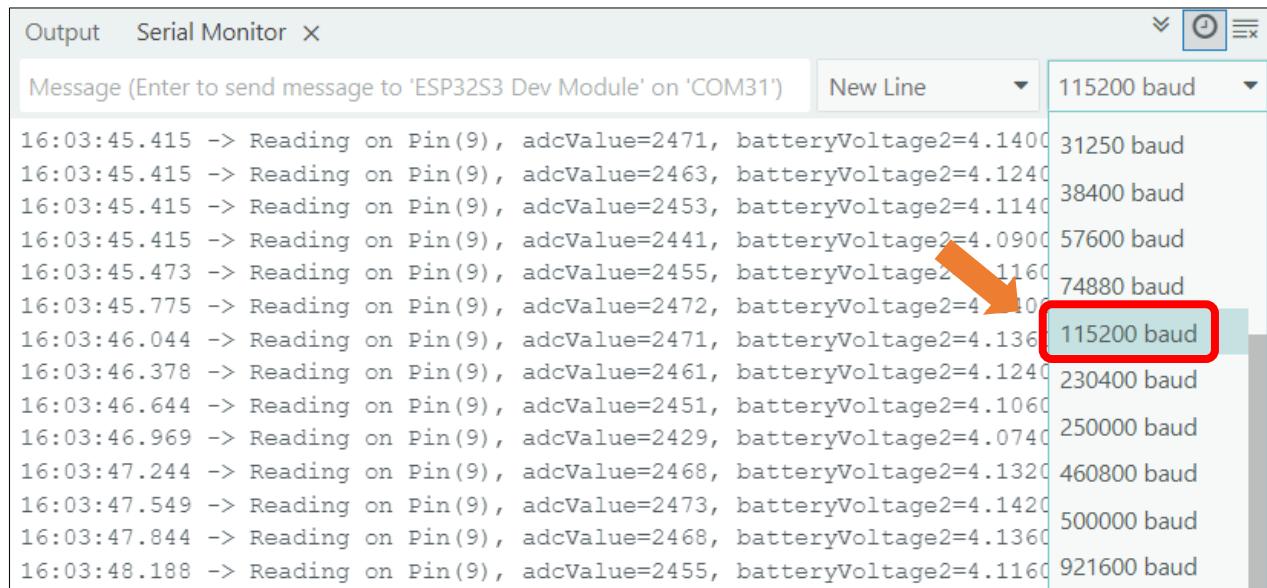
Enable the "USB CDC On Boot" feature.



Click “Upload” to upload the code to Freenove_ESP32_S3_Display.



Once the program starts, open the serial monitor to view the battery voltage readings, updated every 300ms.



```
Output Serial Monitor X
Message (Enter to send message to 'ESP32S3 Dev Module' on 'COM31') New Line 115200 baud
16:03:45.415 -> Reading on Pin(9), adcValue=2471, batteryVoltage2=4.140000 31250 baud
16:03:45.415 -> Reading on Pin(9), adcValue=2463, batteryVoltage2=4.124000 38400 baud
16:03:45.415 -> Reading on Pin(9), adcValue=2453, batteryVoltage2=4.114000 57600 baud
16:03:45.415 -> Reading on Pin(9), adcValue=2441, batteryVoltage2=4.090000 74880 baud
16:03:45.473 -> Reading on Pin(9), adcValue=2455, batteryVoltage2=4.116000 110000 baud
16:03:45.775 -> Reading on Pin(9), adcValue=2472, batteryVoltage2=4.100000 115200 baud
16:03:46.044 -> Reading on Pin(9), adcValue=2471, batteryVoltage2=4.136000 230400 baud
16:03:46.378 -> Reading on Pin(9), adcValue=2461, batteryVoltage2=4.124000 250000 baud
16:03:46.644 -> Reading on Pin(9), adcValue=2451, batteryVoltage2=4.106000 460800 baud
16:03:46.969 -> Reading on Pin(9), adcValue=2429, batteryVoltage2=4.074000 500000 baud
16:03:47.244 -> Reading on Pin(9), adcValue=2468, batteryVoltage2=4.132000 921600 baud
16:03:47.549 -> Reading on Pin(9), adcValue=2473, batteryVoltage2=4.142000
16:03:47.844 -> Reading on Pin(9), adcValue=2468, batteryVoltage2=4.136000
16:03:48.188 -> Reading on Pin(9), adcValue=2455, batteryVoltage2=4.116000
```

Reference

uint32_t analogReadMilliVolts(uint8_t pin)

This function reads the voltage directly from the analog pin and returns the value in millivolts (mV), with a maximum return value of 3300mV (3.3V)



Chapter 6 SD Card

Project 6.1 SD Test

Component List

Freenove ESP32 S3 Display x 1



USB cable x1



Please note that this kit does not include SD card and card reader, please buy them by yourself.

Component Knowledge

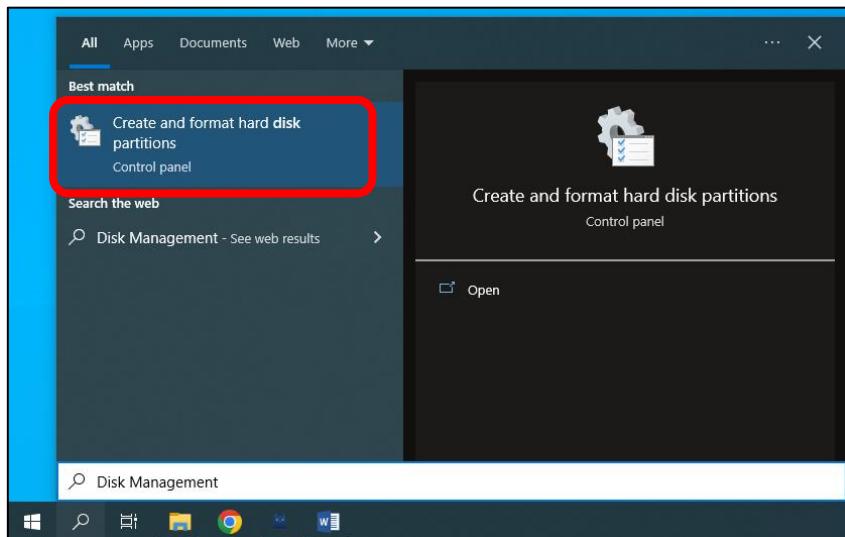
Format SD card

To initiate the project, you'll first need to prepare a blank SD card and a compatible card reader. The initial setup involves assigning a drive letter to the SD card and formatting it properly. Below you'll find system-specific instructions to complete these preparatory steps. Please follow the guide corresponding to your operating system.

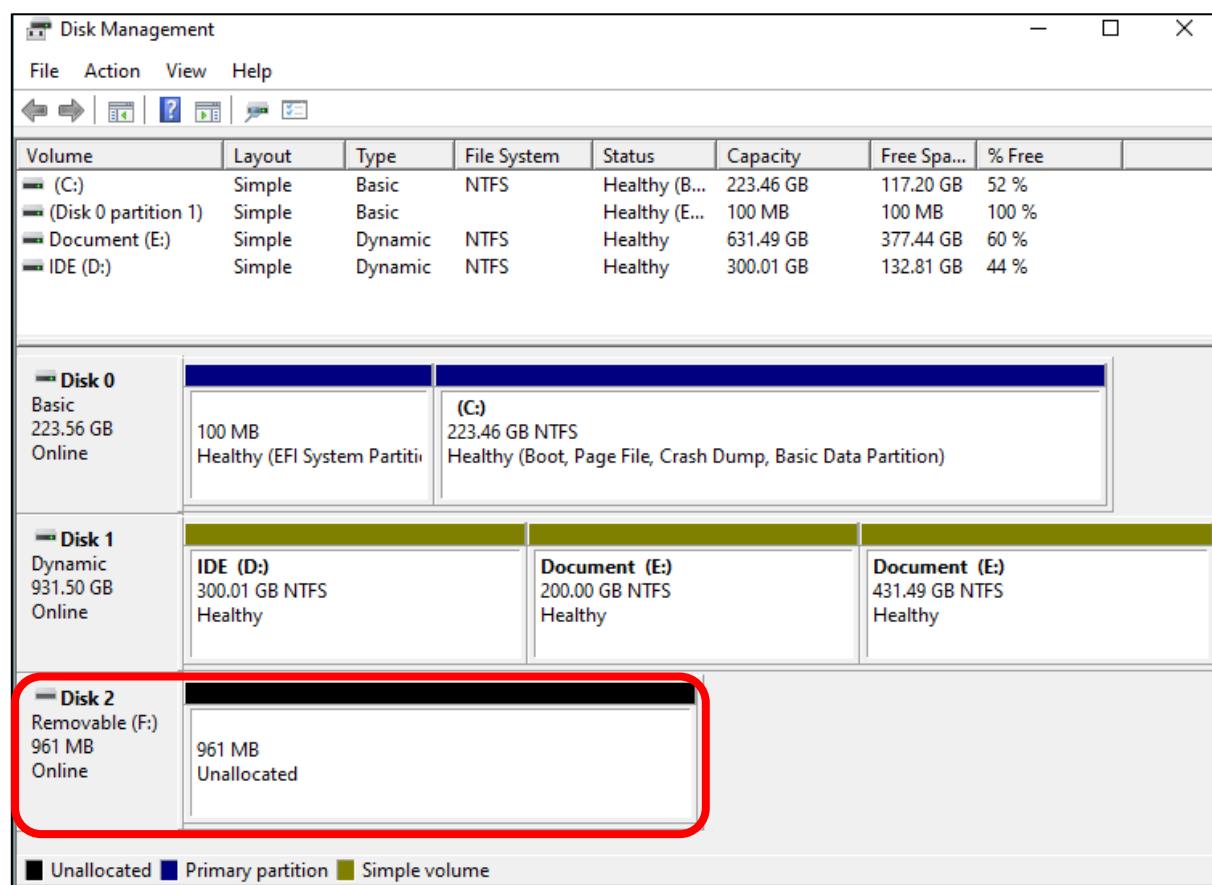
Windows

Insert the SD card into the card reader, and then insert the card reader into the computer.

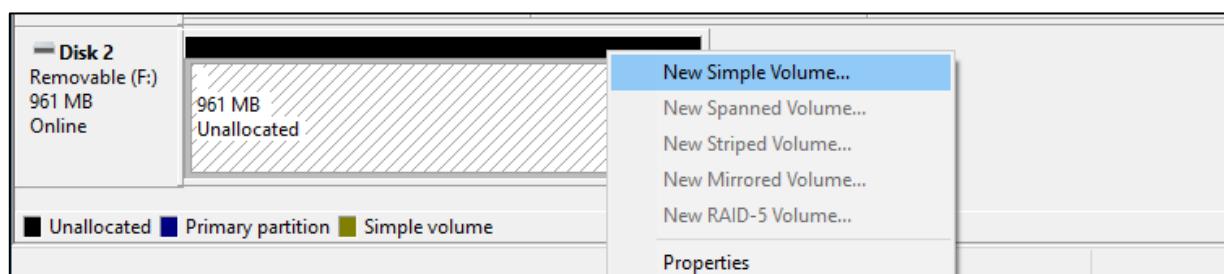
In the Windows search box, enter "Disk Management" and select "Create and format hard disk partitions".



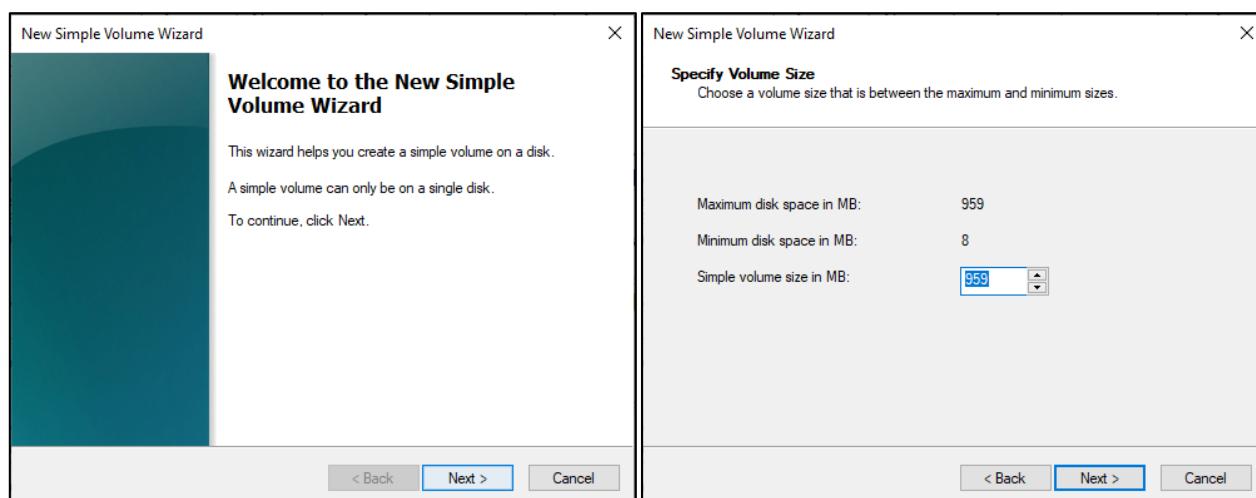
In the newly opened window, locate an unallocated volume with a size close to 1GB.



Click to select the volume, right-click and select "New Simple Volume".

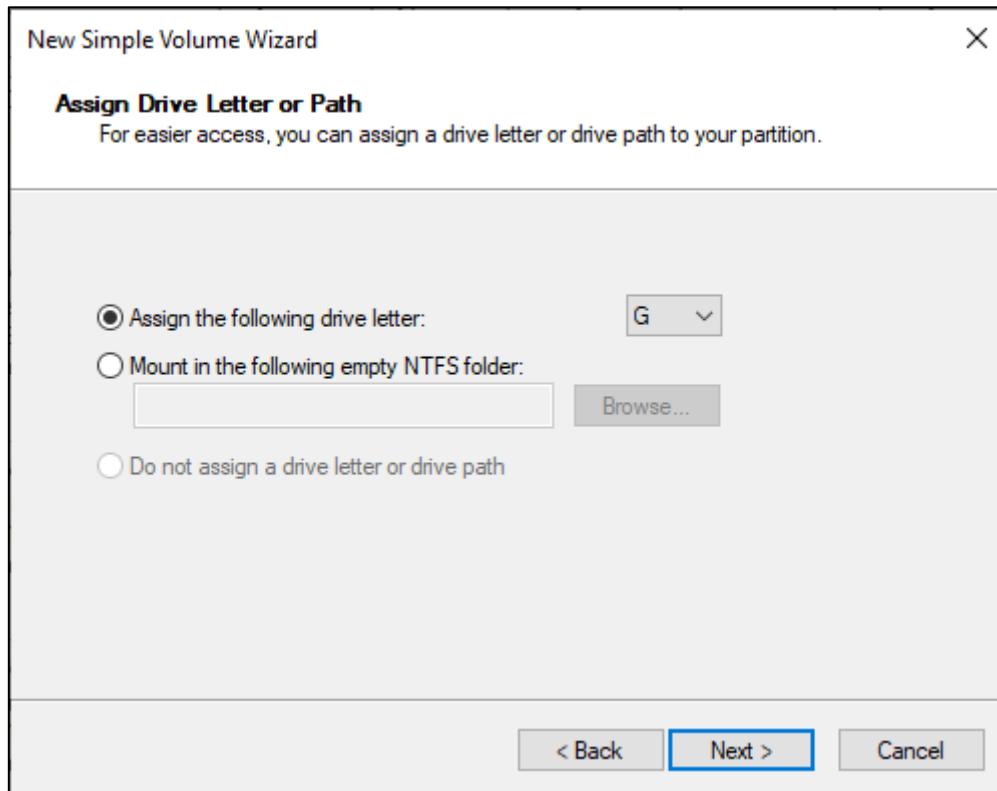


Click Next.

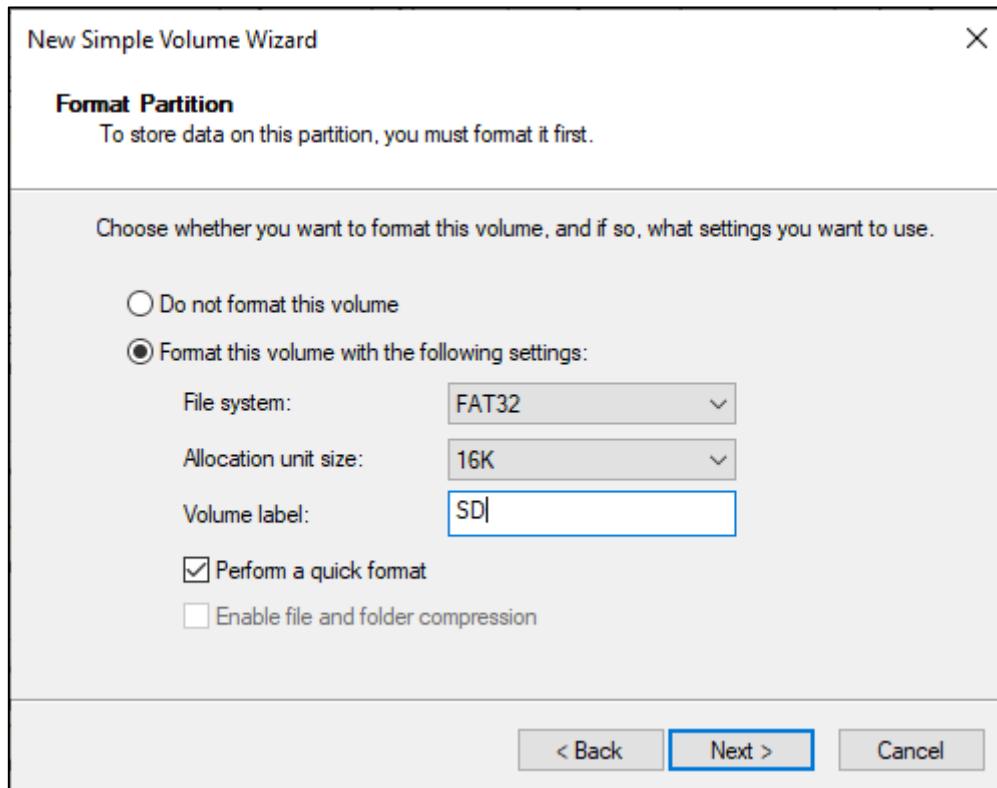




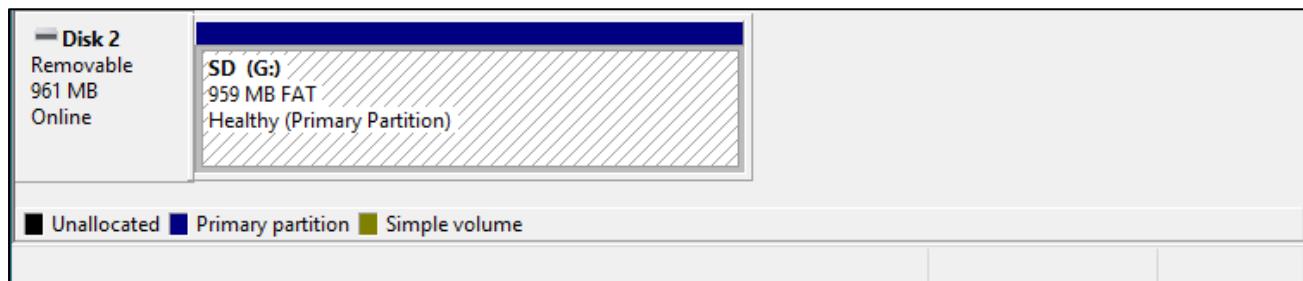
On the right-hand side, you can select a preferred drive letter for the SD card or simply proceed with the default setting by clicking on the "Next" button.



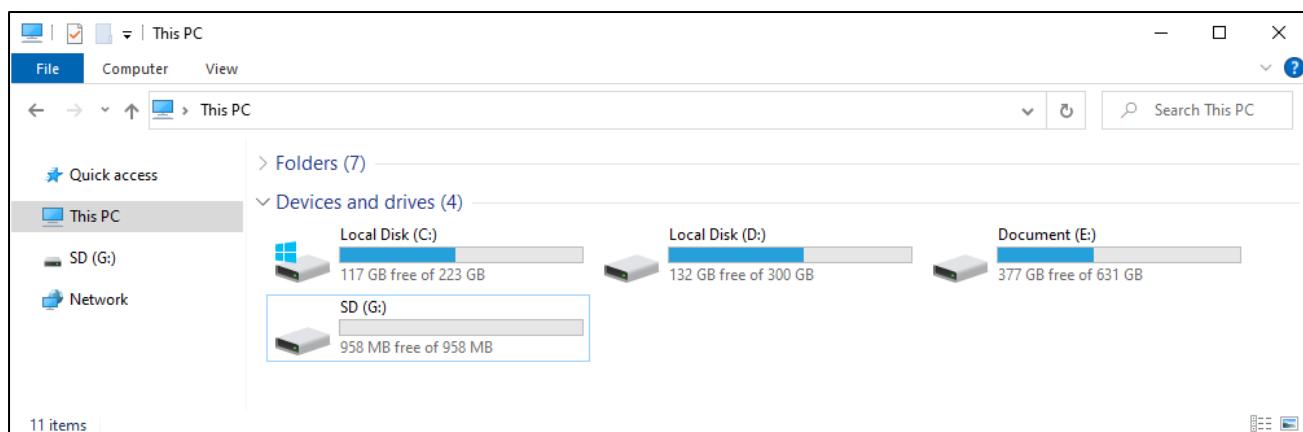
When formatting the SD card, select the file system as FAT (or FAT32) and set the allocation unit size to 16K. You can set the volume label to any name of your choice. Once you have made these selections, click on the "Next" button to proceed.



Click Finish. Wait for the SD card initialization to complete.



After completing the formatting process, you should be able to see the SD card in the "This PC" section of your computer.

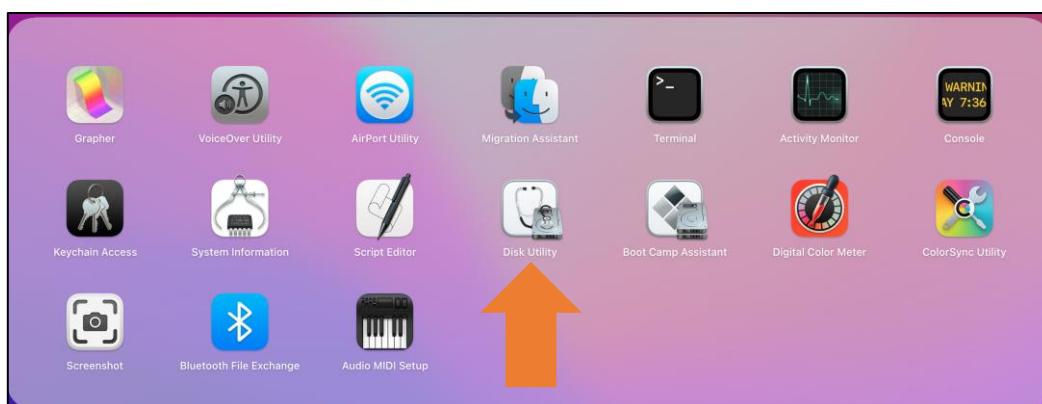


MAC

Insert the SD card into the card reader and then insert the card reader into your computer. Some computers may display a prompt with the following message. In this case, please click on the "Ignore" option to proceed.

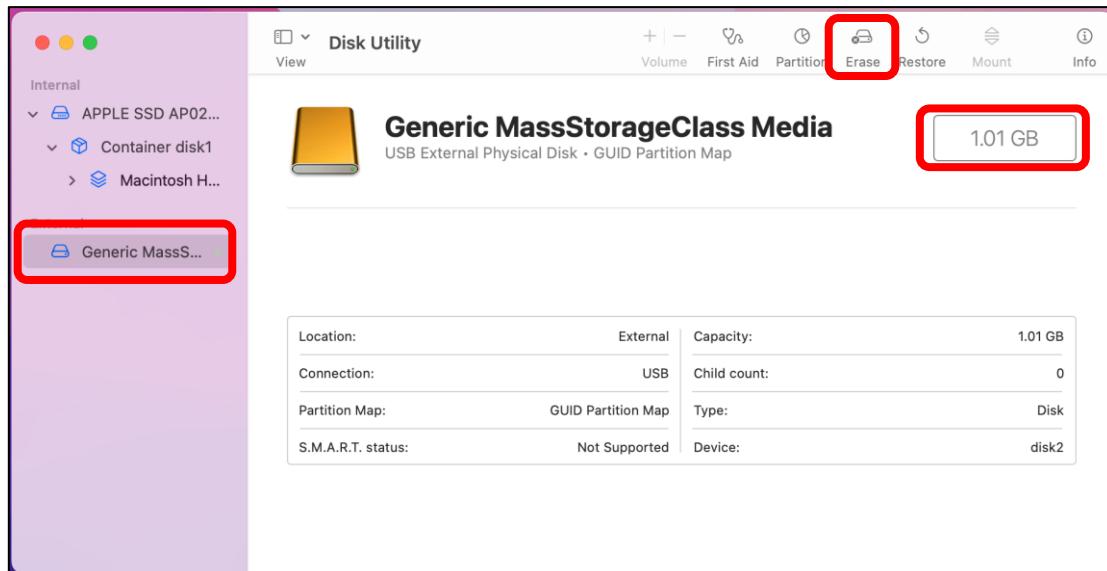


Find "Disk Utility" in the MAC system and click to open it.

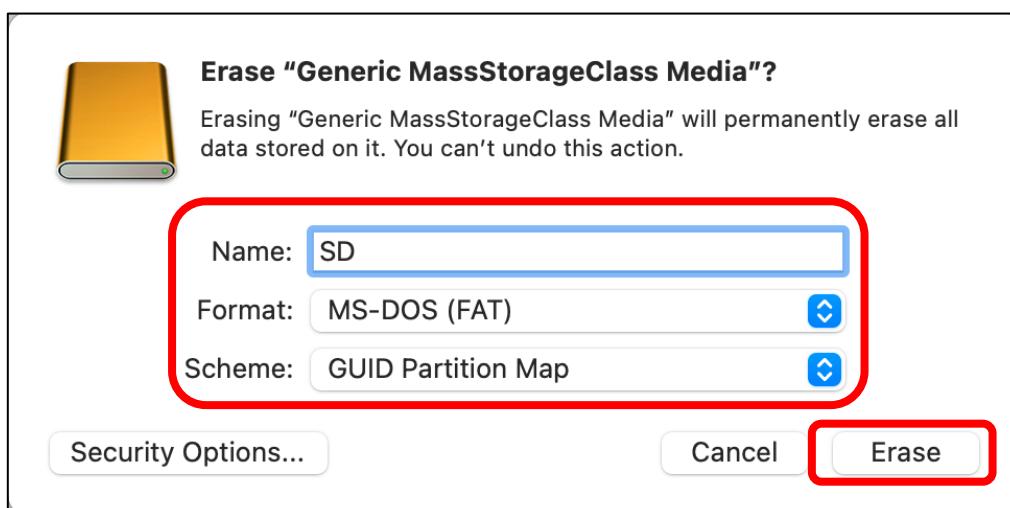




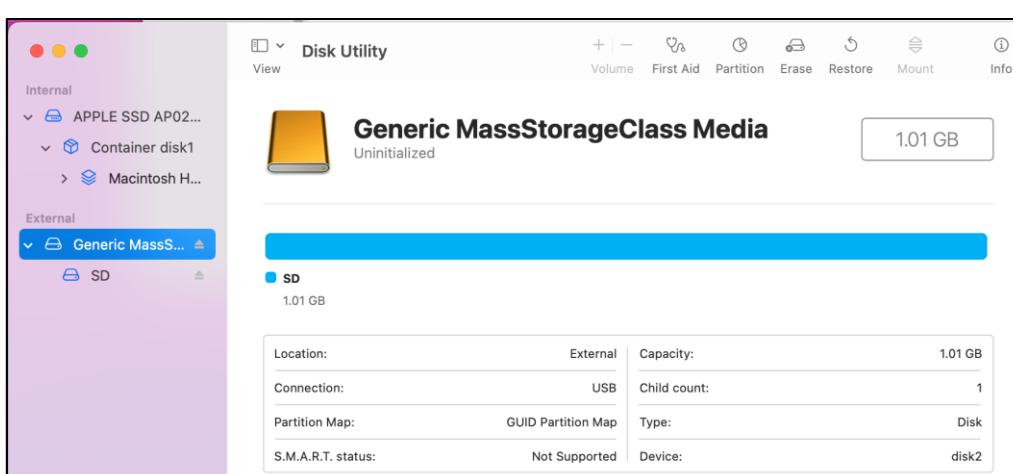
Select "Generic MassStorageClass Media", note that its size is about 1G. It is important to select the correct item to avoid accidentally erasing other device. Once you have verified that you have selected the correct device, click on the "Erase" button to proceed with erasing the SD card.



Select the configuration as shown in the figure below, and then click "Erase".



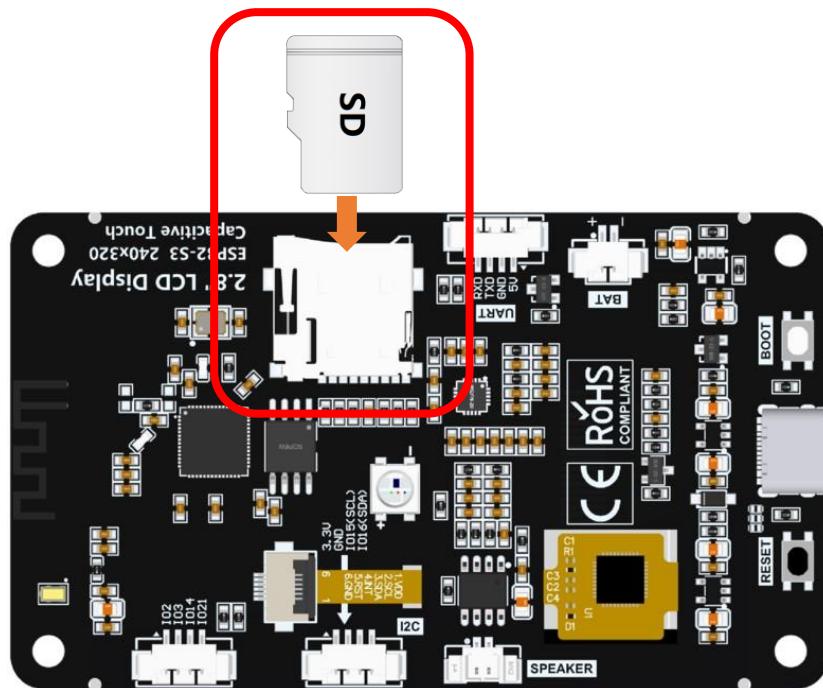
Please wait for the formatting process to complete. Once it is finished, the interface should resemble the image below. You should now be able to see a new disk named "SD" on your desktop.



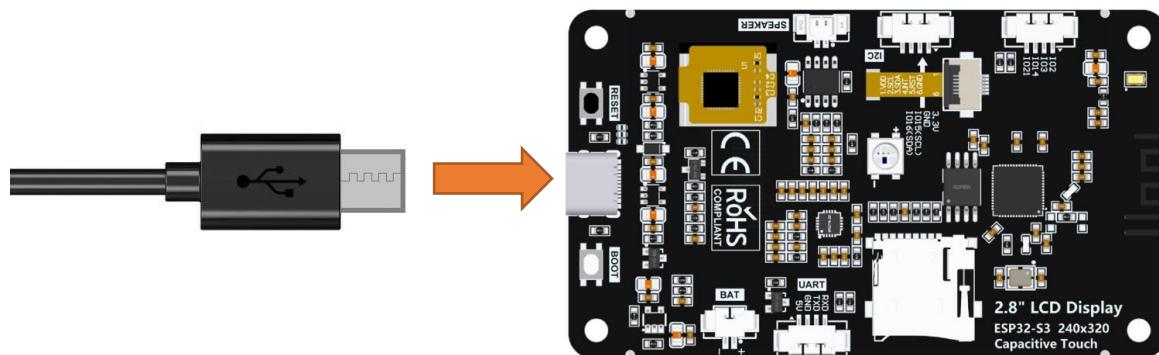
Circuit

Before connecting the USB cable, insert the SD card into the SD card slot on the back of the ESP32-S3.

Please note that this kit does not include SD card and card reader; please buy them yourself.



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



If you have any concerns, please feel free to contact us via support@freenove.com



Sketch

Next, we download the code to Freenove_ESP32_S3_Display to test Serial. Open “**Sketch_06.1_SD_Test.ino**” folder under “**Freenove_ESP32_S3_Display\Sketches**” and double-click “**Sketch_06.1_SD_Test.ino**”. Sketch_06.1_SD_Test

The following is the program code:

```
1  /*
2   * @ File:  Sketch_06.1_SDMMC_Test.ino
3   * @ Author: [Zhentao Lin]
4   * @ Date:  [2025-08-19]
5   */
6
7 #include "driver_sdmmc.h"
8
9 #define SD_MMC_CMD 40 // Please do not modify it.
10 #define SD_MMC_CLK 38 // Please do not modify it.
11 #define SD_MMC_D0 39 // Please do not modify it.
12 #define SD_MMC_D1 41 // Please do not modify it.
13 #define SD_MMC_D2 48 // Please do not modify it.
14 #define SD_MMC_D3 47 // Please do not modify it.
15
16 void setup() {
17     // Initialize serial communication at 115200 bits per second
18     Serial.begin(115200);
19     delay(3000);
20
21     // Initialize the SDMMC interface with the specified pins
22     sdmmc_init(SD_MMC_CLK, SD_MMC_CMD, SD_MMC_D0, SD_MMC_D1, SD_MMC_D2, SD_MMC_D3);
23
24     // List files in the root directory and print them
25     std::list<File_Entry> fileList = list_dir("/", 0);
26     print_file_list(fileList);
27
28     // Create a new directory and list files again
29     create_dir("/mydir");
30     fileList = list_dir("/", 0);
31     print_file_list(fileList);
32
33     // Remove the directory and list files again
34     remove_dir("/mydir");
35     fileList = list_dir("/", 2);
36     print_file_list(fileList);
37 }
```

```

38 // Write text to a new file
39 const char* text = "Hello ";
40 write_file("/foo.txt", (const uint8_t*)text, strlen(text));
41
42 // Append text to the existing file
43 text = "World!\n";
44 append_file("/foo.txt", (const uint8_t*)text, strlen(text));
45
46 // Read the file content into a buffer and print it
47 uint8_t buffer[100];
48 read_file("/foo.txt", buffer, sizeof(buffer));
49 Serial.write(buffer, strlen((char*)buffer));
50
51 // Rename the file and read the new file content
52 rename_file("/foo.txt", "/hello.txt");
53 read_file("/hello.txt", buffer, sizeof(buffer));
54 Serial.write(buffer, strlen((char*)buffer));
55
56 // Print SD card information
57 Serial.println("\r\nSD card info:");
58 Serial.printf("Total space: %lluMB\r\n", SD_MMC.totalBytes() / (1024 * 1024));
59 Serial.printf("Used space: %lluMB\r\n", SD_MMC.usedBytes() / (1024 * 1024));
60 }
61
62 void loop() {
63 // Delay for 10 seconds before the next iteration
64 delay(10000);
65 }
```

Code Explanation

Include necessary header files.

```
7 #include "driver_sdmmc.h"
```

Define SD card pins. In this example, we read and write the SD card via SPI.

```

9 #define SD_MMC_CMD 40 // Please do not modify it.
10 #define SD_MMC_CLK 38 // Please do not modify it.
11 #define SD_MMC_D0 39 // Please do not modify it.
12 #define SD_MMC_D1 41 // Please do not modify it.
13 #define SD_MMC_D2 48 // Please do not modify it.
14 #define SD_MMC_D3 47 // Please do not modify it.
```

Set the baud rate to 115200.

```
18 Serial.begin(115200);
```

Initialize the SD card

```
19 sdmmc_init(SD_MMC_CLK, SD_MMC_CMD, SD_MMC_D0, SD_MMC_D1, SD_MMC_D2, SD_MMC_D3);
```

List files in the root directory and print them

```
25 std::list<File_Entry> fileList = list_dir("/", 0);
```

```
26 print_file_list(fileList);
```

Create a directory named "mydir" and list all files under the root directory.

```
29 create_dir("/mydir");
30 fileList = list_dir("/", 0);
```

Delete the "mydir" directory and list all files under the root directory.

```
34 remove_dir("/mydir");
35 fileList = list_dir("/", 2);
```

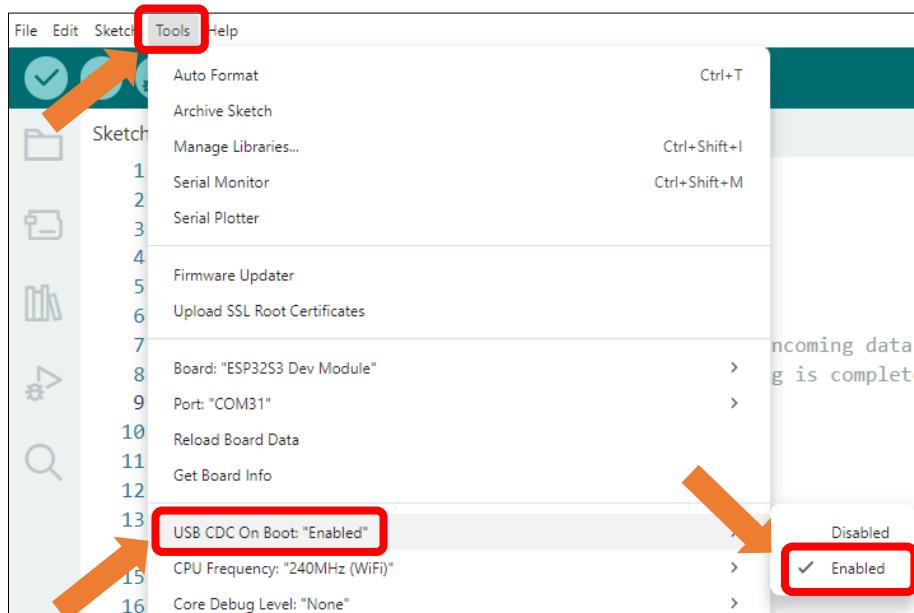
Write "Hello" in the hello.txt file, append "World!" to it, then read and print the file contents.

```
38 // Write text to a new file
39 const char* text = "Hello ";
40 write_file("/foo.txt", (const uint8_t*)text, strlen(text));
41
42 // Append text to the existing file
43 text = "World!\n";
44 append_file("/foo.txt", (const uint8_t*)text, strlen(text));
45
46 // Read the file content into a buffer and print it
47 uint8_t buffer[100];
48 read_file("/foo.txt", buffer, sizeof(buffer));
49 Serial.write(buffer, strlen((char*)buffer));
```

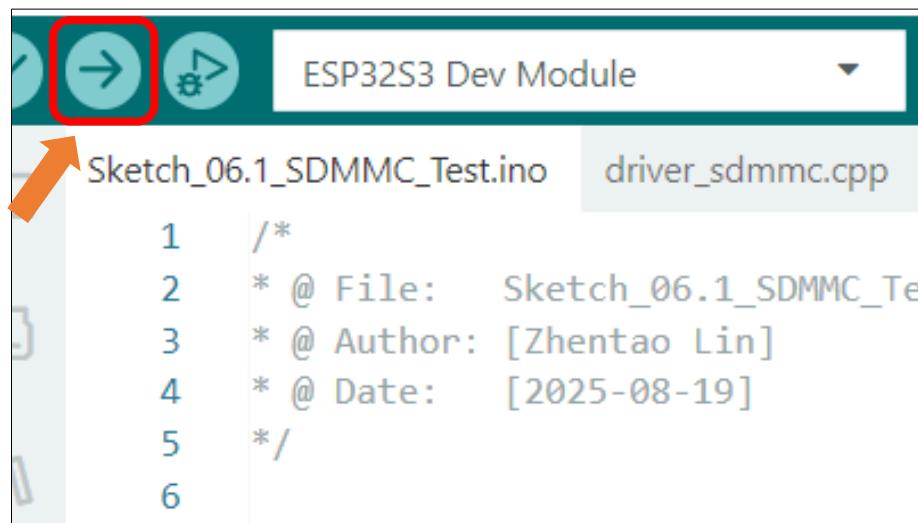
Rename foo.txt to hello.txt and read the file.

```
51 // Rename the file and read the new file content
52 rename_file("/foo.txt", "/hello.txt");
53 read_file("/hello.txt", buffer, sizeof(buffer));
54 Serial.write(buffer, strlen((char*)buffer));
```

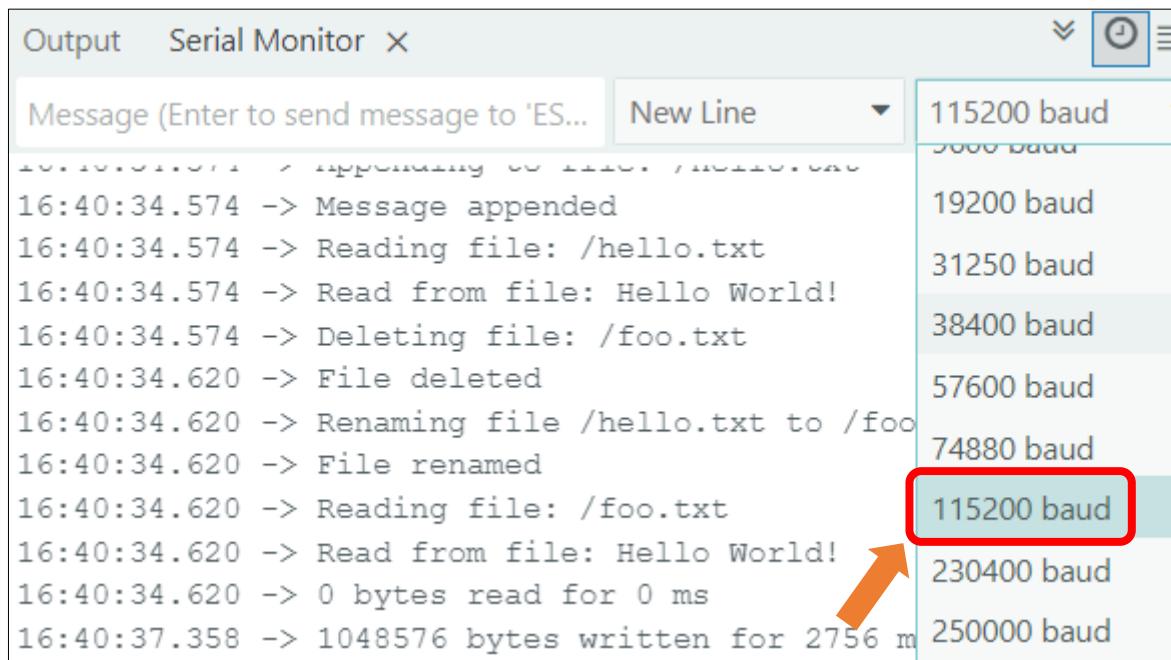
Enable the "USB CDC On Boot" feature.



Click "Upload" to upload the code to Freenove_ESP32_S3_Display.



Upon the code runs, open the serial and set the baud rate to 115200.





Chapter 7 Music

Project 7.1 Music

Component List

Freenove ESP32 S3 Display x 1



USB cable x1



Speaker x1

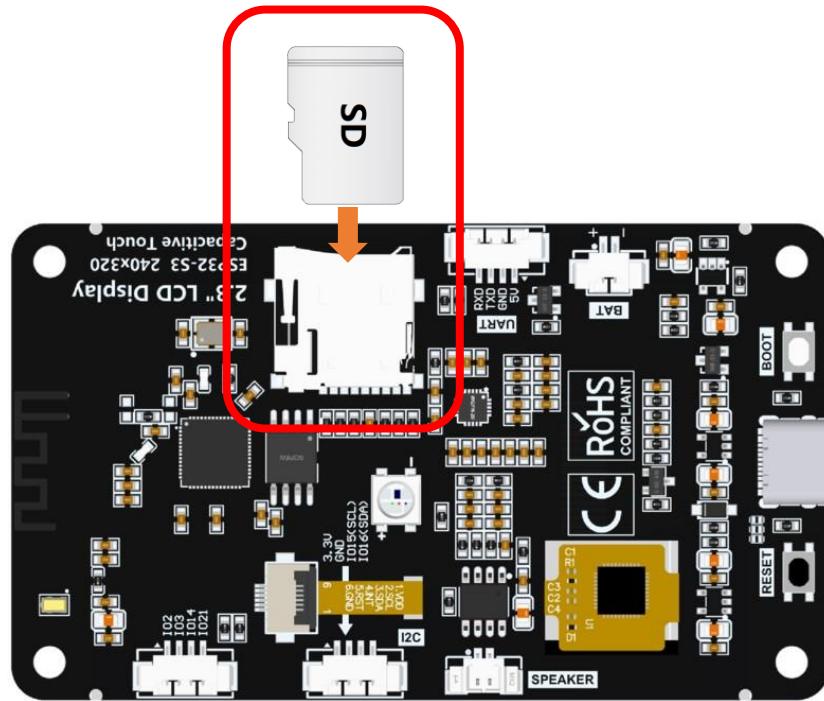


Please note that this kit does not include SD card and card reader, please buy them by yourself.

Circuit

Before connecting the USB cable, insert the SD card into the SD card slot on the back of the ESP32-S3.

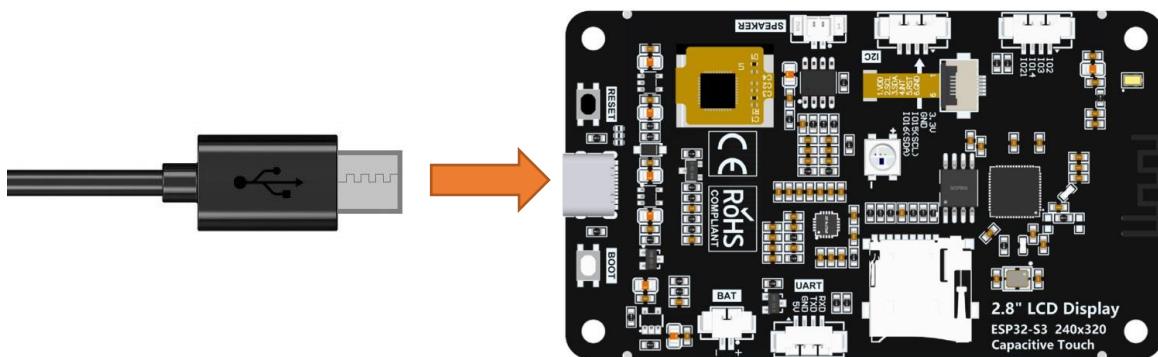
Please note that this kit does not include SD card and card reader; please buy them yourself.



Connect speaker



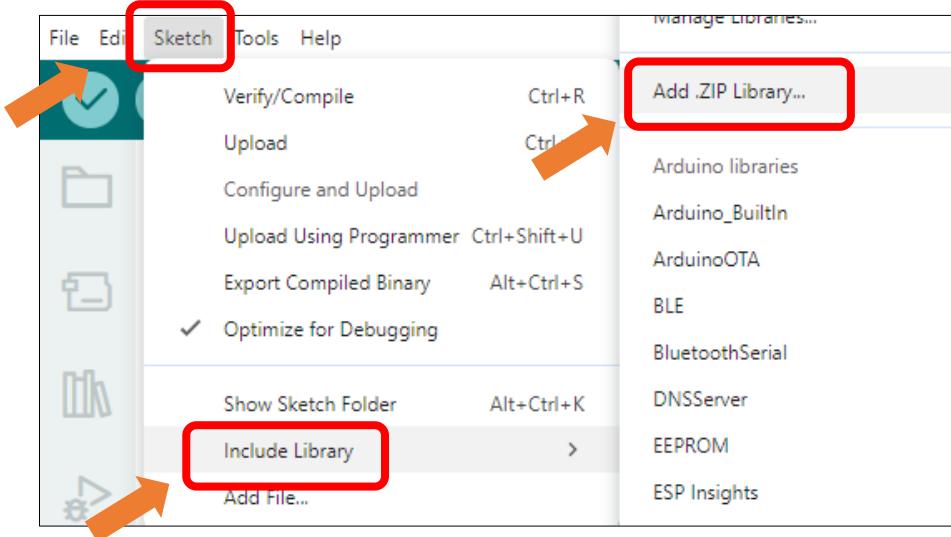
Connect Freenove ESP32-S3 to the computer using the USB cable.



Sketch

Install the needed libraries.

Click Sketch -> Include Library -> Add .ZIP Library...



Select **ESP32-audioI2S_v3.0.13.zip**

Name	Date modified
ESP32-audioI2S_v3.0.13.zip	2025/8/26 9:09
Freenove_WS2812_Lib_for_ESP32_v2.0.zip	2025/8/26 9:11
FT6336U_v1.0.2.zip	2025/8/26 9:10
lvgl_v8.4.0.zip	2025/8/18 15:04
TFT_eSPI_Setups_v1.1.zip	2025/8/26 9:10
TFT_eSPI_v2.5.43.zip	2025/8/19 10:49

Next, we download the code to Freenove_ESP32_S3_Display to test. Open "**Sketch_07.1_Music**" folder under "**Freenove_ESP32_S3_Display\Sketches**" and double-click "**Sketch_07.1_Music.ino**".

Sketch_07.1_Music

The following is the program code:

1	#include <Arduino.h>
2	#include "FS.h"

```
3 #include "SD_MMC.h"
4 #include "SPI.h"
5 #include "es8311.h"
6 #include "Audio.h"
7 #include "Wire.h"
8 #include "ESP_I2S.h"
9 #include "demo_music.h"
10
11 //ESP32-S3 IO Pin define
12 #define SD_SCK 38
13 #define SD_CMD 40
14 #define SD_D0 39
15 #define SD_D1 41
16 #define SD_D2 48
17 #define SD_D3 47
18
19 //I2S IO Pin define
20 #define I2S_MCK 4
21 #define I2S_BCK 5
22 #define I2S_DINT 6
23 #define I2S_DOUT 8
24 #define I2S_WS 7
25 #define AP_ENABLE 1
26 #define I2C_SCL 15      /*!< GPIO number used for I2C master clock */
27 #define I2C_SDA 16      /*!< GPIO number used for I2C master data */
28 #define I2C_SPEED 400000 /*!< I2C master clock frequency */
29
30 Audio audio;
31 I2SClass es8311_i2s;
32
33 void driver_es8311_init(void) {
34     pinMode(AP_ENABLE, OUTPUT);
35     digitalWrite(AP_ENABLE, LOW);
36
37     Wire.begin(I2C_SDA, I2C_SCL, I2C_SPEED);
38
39     es8311_i2s.setPins(I2S_BCK, I2S_WS, I2S_DOUT, I2S_DINT, I2S_MCK);
40     if (!es8311_i2s.begin(I2S_MODE_STD, 44100, I2S_DATA_BIT_WIDTH_16BIT, I2S_SLOT_MODE_STEREO,
41     I2S_STD_SLOT_LEFT)) {
42         Serial.println("Failed to initialize I2S bus!");
43     }
44 }
45
46 void setup() {
```



```

47     Serial.begin(115200);

48

49     //SD card init
50     if (!SD_MMC.setPins(SD_SCK, SD_CMD, SD_D0, SD_D1, SD_D2, SD_D3)) {
51         Serial.println("Pin change failed!");
52         return;
53     }
54     while (!SD_MMC.begin()) {
55         Serial.println("SD card does not exist, please insert SD card.");
56         delay(100);
57     }

58     driver_es8311_init();
59     if (es8311_codec_init() != ESP_OK) {
60         Serial.println("ES8311 init failed!");
61         return;
62     }
63     //audio init
64     audio.setPinout(I2S_BCK, I2S_WS, I2S_DOUT, I2S_MCK);
65     audio.setVolume(10);
66     if (!demo_music()) {
67         return;
68     }

69     //play music
70     demo_music_play(0);
71 }
72 }

73 void loop() {
74     audio.loop();
75 }
```

Code Explanation

Include necessary header files.

```

1 #include <Arduino.h>
2 #include "FS.h"
3 #include "SD_MMC.h"
4 #include "SPI.h"
5 #include "es8311.h"
6 #include "Audio.h"
7 #include "Wire.h"
8 #include "ESP_I2S.h"
```

Define the pins.

```

10 //ESP32-S3 IO Pin define
11 #define SD_SCK 38
```

```

12 #define SD_CMD 40
13 #define SD_D0 39
14 #define SD_D1 41
15 #define SD_D2 48
16 #define SD_D3 47
17
18 //I2S IO Pin define
19 #define I2S_MCK 4
20 #define I2S_BCK 5
21 #define I2S_DINT 6
22 #define I2S_DOUT 8
23 #define I2S_WS 7
24 #define AP_ENABLE 1
25 #define I2C_SCL 15
26 #define I2C_SDA 16
27 #define I2C_SPEED 400000

```

Declare an I2S object

```

30 Audio audio;
31 I2SClass es8311_i2s;

```

Set the baud rate to 115200

```

46 Serial.begin(115200);

```

SD card init

```

50 if (!SD_MMC.setPins(SD_SCK, SD_CMD, SD_D0, SD_D1, SD_D2, SD_D3)) {
51     Serial.println("Pin change failed!");
52     return;
53 }
54 while (!SD_MMC.begin()) {
55     Serial.println("SD card does not exist, please insert SD card.");
56     delay(100);
57 }
58
59 driver_es8311_init();
60 if (es8311_codec_init() != ESP_OK) {
61     Serial.println("ES8311 init failed!");
62     return;
63 }

```

Read audio data and play it.

```

65 audio.setPinout(I2S_BCK, I2S_WS, I2S_DOUT, I2S_MCK);
66 audio.setVolume(10);
67 if (!demo_music()) {
68     return;
69 }

```

play music

```

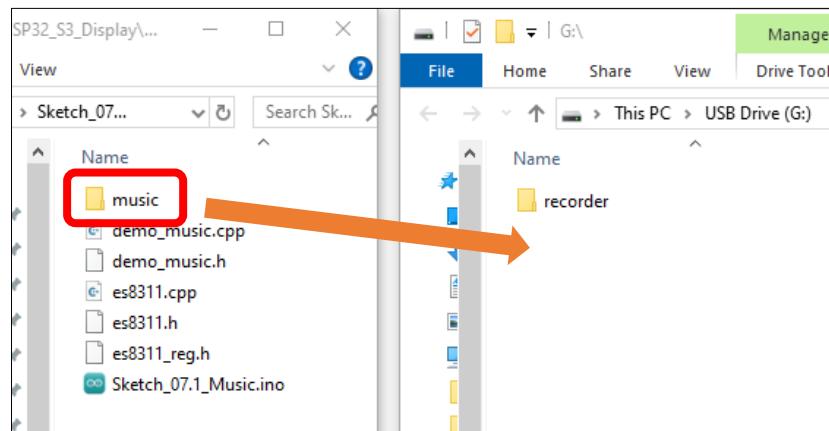
72 demo_music_play(1);

```



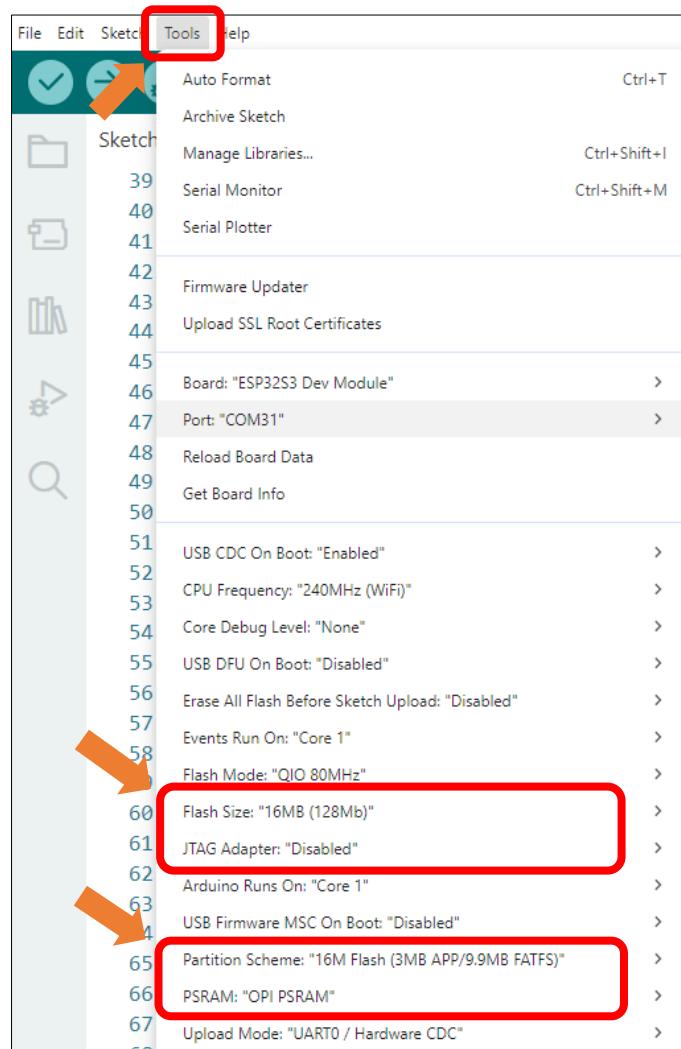
This product does not include SD card, and SD card reader, please buy them by yourself. For more information, please refer to [SD card](#) sections.

Before uploading the code, copy the music to the root directory of the SD card with the SD card reader.



It is necessary to change the settings in Arduino IDE before clicking the Uploading button, as shown below.

Caution: Incorrect settings will result in compilation error or uploading failure. To achieve desired result, please configure exactly the same as below.



Click “Upload” to upload the code to Freenove ESP32 S3 Display.



The speaker plays the music in the SD card.

Project 7.2 Echo

Component List

Freenove ESP32 S3 Display x 1		USB cable x1	
Speakerx1			

Please note that this kit does not include SD card and card reader, please buy them by yourself.

Component knowledge

MEMS-MIC

A MEMS Microphone (Micro-Electro-Mechanical Systems Microphone) is a miniature microphone manufactured using MEMS technology. It integrates mechanical sensing elements and electronic circuits on the same chip to achieve sound signal acquisition and conversion. Its working principle primarily involves a tiny vibrating diaphragm that detects sound pressure changes, then converts these mechanical vibrations into electrical signals, enabling sound capture and transmission.

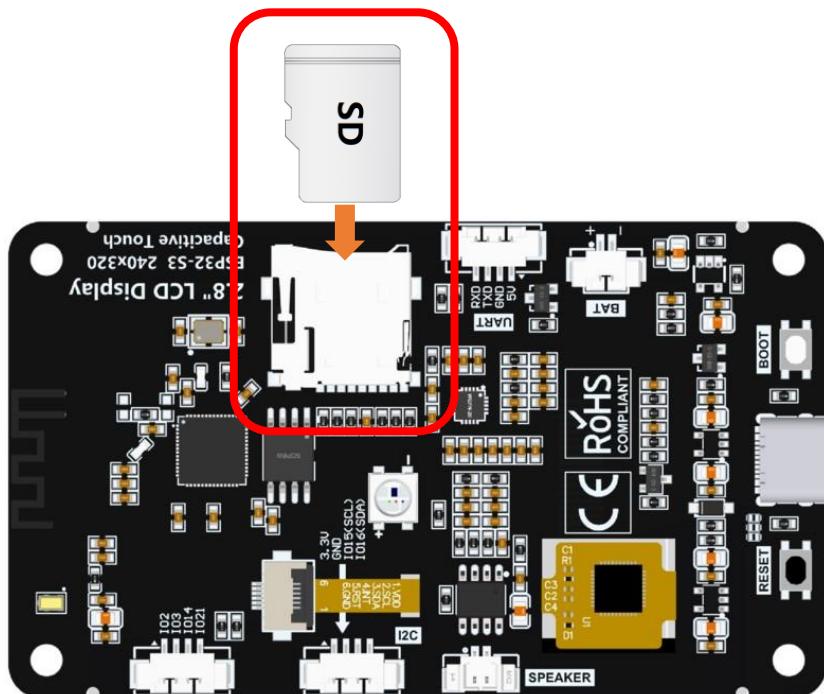
MEMS microphones are characterized by their compact size, high sensitivity, excellent stability, and ease of mass production. They are widely used in electronic devices such as smartphones, earphones, and smart speakers. Compared to traditional microphones, MEMS microphones better meet the dual demands of modern electronic products for both miniaturization and performance.



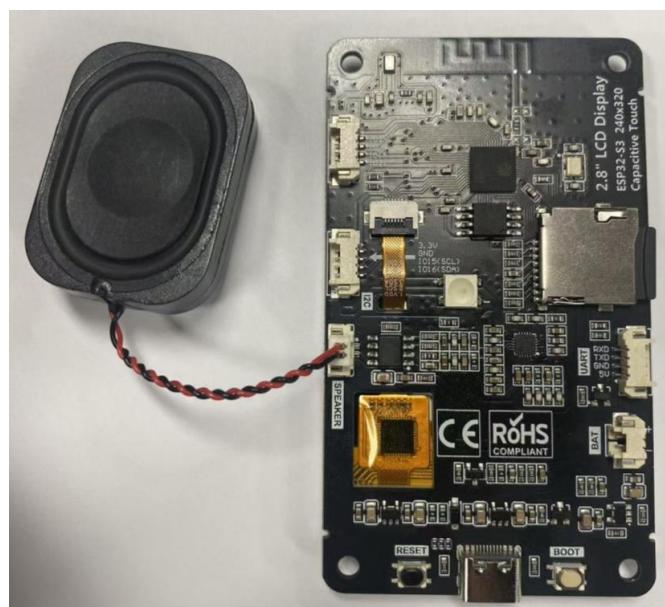
Circuit

Before connecting the USB cable, insert the SD card into the SD card slot on the back of the ESP32-S3.

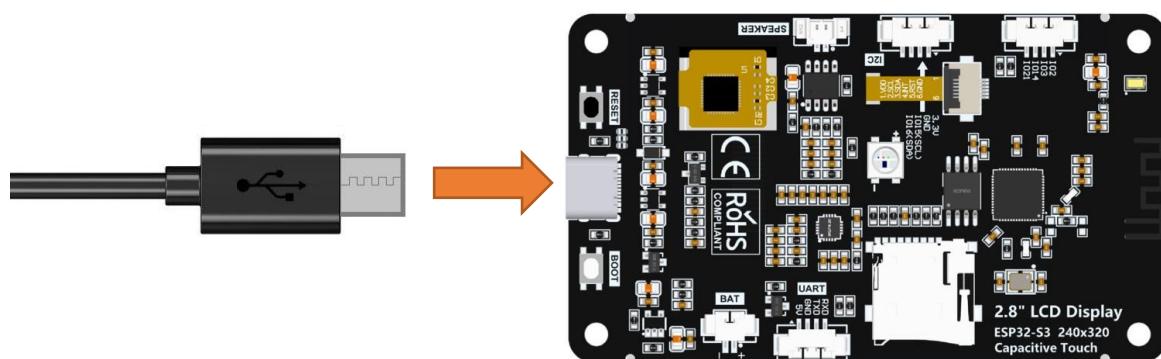
Please note that this kit does not include SD card and card reader; please buy them yourself.



Connect speaker



Connect Freenove ESP32 S3 Display to the computer using the USB cable.



Sketch

Sketch_07.2_Echo

The following is the program code:

```
1 #include <Arduino.h>
2 #include "FS.h"
3 #include "SD_MMC.h"
4 #include "SPI.h"
5 #include "es8311.h"
6 #include "Audio.h"
7 #include "Wire.h"
8 #include "ESP_I2S.h"
9
10 //ESP32-S3 IO Pin define
11 #define SD_SCK 38
12 #define SD_CMD 40
13 #define SD_DO 39
```

```
14 #define SD_D1 41
15 #define SD_D2 48
16 #define SD_D3 47
17
18 //I2S IO Pin define
19 #define I2S_MCK 4
20 #define I2S_BCK 5
21 #define I2S_DINT 6
22 #define I2S_DOUT 8
23 #define I2S_WS 7
24 #define AP_ENABLE 1
25 #define I2C_SCL 15
26 #define I2C_SDA 16
27 #define I2C_SPEED 400000
28
29 I2SClass es8311_i2s;
30
31 void driver_es8311_init(void) {
32     pinMode(AP_ENABLE, OUTPUT);
33     digitalWrite(AP_ENABLE, LOW);
34
35     Wire.begin(I2C_SDA, I2C_SCL, I2C_SPEED);
36
37     es8311_i2s.setPins(I2S_BCK, I2S_WS, I2S_DOUT, I2S_DINT, I2S_MCK);
38     if (!es8311_i2s.begin(I2S_MODE_STD, 44100, I2S_DATA_BIT_WIDTH_16BIT, I2S_SLOT_MODE_MONO,
39     I2S_STD_SLOT_LEFT)) {
40         Serial.println("Failed to initialize I2S bus!");
41     }
42 }
43
44 void setup()
45 {
46     Serial.begin(115200);
47     while (!Serial) {
48         delay(10);
49     }
50
51     Serial.println("Start initializing the audio device... ");
52     driver_es8311_init();
53     if (es8311_codec_init() != ESP_OK) {
54         Serial.println("ES8311 init failed!");
55         return;
56     }
57     delay(3000);
```

```
58     Serial.println("Initialization completed.");
59 }
60
61 void loop()
62 {
63     uint8_t *wav_buffer;
64     size_t wav_size;
65     // Record 5 seconds of audio data
66     Serial.println("Start recording for 5 seconds...");
67     wav_buffer = es8311_i2s.recordWAV(5, &wav_size);
68     Serial.println("Recording completed.");
69     delay(1000);
70
71     Serial.println("Start playing the recording...");
72     es8311_i2s.playWAV(wav_buffer, wav_size);
73     Serial.println("Playback has been completed.");
74     free(wav_buffer);
75     delay(1000);
76 }
```

Code Explanation

Include necessary header files.

```
1 #include <Arduino.h>
2 #include "FS.h"
3 #include "SD_MMC.h"
4 #include "SPI.h"
5 #include "es8311.h"
6 #include "Audio.h"
7 #include "Wire.h"
8 #include "ESP_I2S.h"
```

Define the pins.

```
10 //ESP32-S3 IO Pin define
11 #define SD_SCK 38
12 #define SD_CMD 40
13 #define SD_D0 39
14 #define SD_D1 41
15 #define SD_D2 48
16 #define SD_D3 47
17
18 //I2S IO Pin define
19 #define I2S_MCK 4
20 #define I2S_BCK 5
21 #define I2S_DINT 6
22 #define I2S_DOUT 8
23 #define I2S_WS 7
```

```
24 #define AP_ENABLE 1  
25 #define I2C_SCL 15  
26 #define I2C_SDA 16  
27 #define I2C_SPEED 400000
```

Declare an I2S object

```
19 I2SClass es8311_i2s;
```

Set the baud rate to 115200

```
36 Serial.begin(115200);
```

Initialize the audio device.

```
51 Serial.println("Start initializing the audio device...");  
52 driver_es8311_init();  
53 if (es8311_codec_init() != ESP_OK) {  
54     Serial.println("ES8311 init failed!");  
55     return;  
56 }
```

Implement audio recording and playback functionality

```
61 void loop()  
62 {  
63     uint8_t *wav_buffer;  
64     size_t wav_size;  
65     // Record 5 seconds of audio data  
66     Serial.println("Start recording for 5 seconds...");  
67     wav_buffer = es8311_i2s.recordWAV(5, &wav_size);  
68     Serial.println("Recording completed.");  
69     delay(1000);  
70  
71     Serial.println("Start playing the recording...");  
72     es8311_i2s.playWAV(wav_buffer, wav_size);  
73     Serial.println("Playback has been completed.");  
74     free(wav_buffer);  
75     delay(1000);  
76 }
```

Chapter 8 BLE

Project 8.1 BLE USART

Component List

Freenove ESP32 S3 Display x 1



USB cable x1



Component Knowledge

BLE (Bluetooth Low Energy)

Low Energy Bluetooth (BLE) is a new feature introduced in the Bluetooth 4.0 specification, specifically designed for low-power devices and suitable for applications involving intermittent transmission of small amounts of data.

The BLE architecture follows a client-server model and consists of the following key components:

GATT (Generic Attribute Protocol): The foundational protocol for BLE communication, defining a hierarchical data structure of services and characteristics.

Service: A collection of data that performs a specific function or feature, containing one or more characteristics.

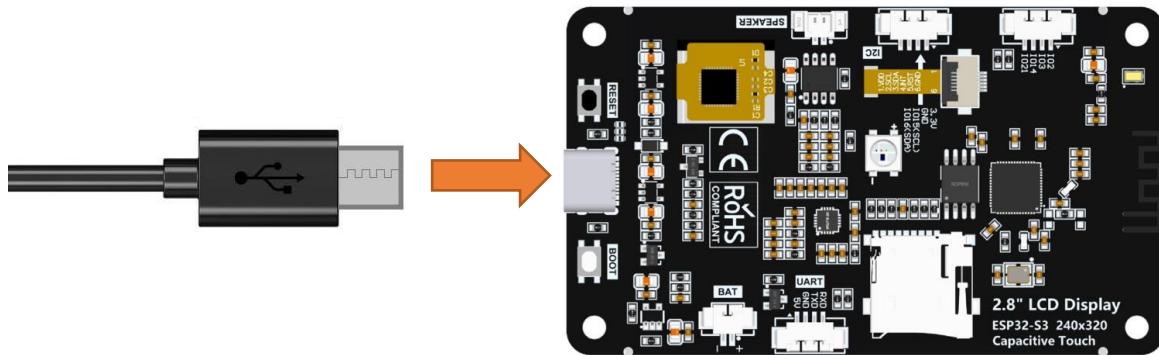
Characteristic: A specific data point within a service, consisting of a value and descriptors.

UUID: A 128-bit universally unique identifier used to distinguish services and characteristics.

BLE device can function simultaneously as a Peripheral (providing services) and a Central (connecting to peripherals). In this section, we will learn how to configure the Freenove_ESP32_S3_Display as a peripheral device to provide services.

Circuit

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



Sketch

Next, we download the code to Freenove_ESP32_S3_Display to test. Open “**Sketch_08.1_BLE_USART**” folder under “**Freenove_ESP32_S3_Display\Sketches**” and double-click “**Sketch_08.1_BLE_USART.ino**”.

Sketch_08.1_BLE_USART

The following is the program code:

```

1  /*
2   * @ File: Sketch_08.1_BLE_USART.ino
3   * @ Author: [Zhentao Lin]
4
5   * @ Date: [2025-06-14]
6   */
7
8 #include "BLEDevice.h"
9 #include "BLEServer.h"
10 #include "BLEUtils.h"
11 #include "BLE2902.h"
12 #include "String.h"
13
14 BLECharacteristic *pCharacteristic;
15 bool deviceConnected = false;
16 uint8_t txValue = 0;
17 long lastMsg = 0;
18 String rxload="Test\n";
19
20 #define SERVICE_UUID           "6E400001-B5A3-F393-E0A9-E50E24DCCA9E"
21 #define CHARACTERISTIC_UUID_RX "6E400002-B5A3-F393-E0A9-E50E24DCCA9E"
22 #define CHARACTERISTIC_UUID_TX "6E400003-B5A3-F393-E0A9-E50E24DCCA9E"
23

```

```
24 class MyServerCallbacks: public BLEServerCallbacks {
25     void onConnect(BLEServer* pServer) {
26         deviceConnected = true;
27     };
28     void onDisconnect(BLEServer* pServer) {
29         deviceConnected = false;
30     }
31 };
32
33 class MyCallbacks: public BLECharacteristicCallbacks {
34     void onWrite(BLECharacteristic *pCharacteristic) {
35         String rxValue = pCharacteristic->getValue();
36         if (rxValue.length() > 0) {
37             rxload="";
38             for (int i = 0; i < rxValue.length(); i++) {
39                 rxload +=(char)rxValue[i];
40             }
41         }
42     }
43 };
44
45 void setupBLE(String BLEName) {
46     const char *ble_name=BLEName.c_str();
47     BLEDevice::init(ble_name);
48     BLEServer *pServer = BLEDevice::createServer();
49     pServer->setCallbacks(new MyServerCallbacks());
50     BLEService *pService = pServer->createService(SERVICE_UUID);
51     pCharacteristic=
52     pService->createCharacteristic(CHARACTERISTIC_UUID_TX,BLECharacteristic::PROPERTY_NOTIFY);
53     pCharacteristic->addDescriptor(new BLE2902());
54     BLECharacteristic *pCharacteristic =
55     pService->createCharacteristic(CHARACTERISTIC_UUID_RX,BLECharacteristic::PROPERTY_WRITE);
56     pCharacteristic->setCallbacks(new MyCallbacks());
57     pService->start();
58     pServer->getAdvertising()->start();
59     Serial.println("Waiting a client connection to notify... ");
60 }
61
62 void setup() {
63     Serial.begin(115200);
64     setupBLE("ESP32S3_BLE");
65 }
66
67 void loop() {
```

```

68     long now = millis();
69     if (now - lastMsg > 100) {
70         if (deviceConnected&&rxload.length()>0) {
71             Serial.println(rxload);
72             rxload="";
73         }
74         if(Serial.available()>0) {
75             String str=Serial.readString();
76             const char *newValue=str.c_str();
77             pCharacteristic->setValue(newValue);
78             pCharacteristic->notify();
79         }
80         lastMsg = now;
81     }
82 }
```

Code Explanation

Include the necessary header libraries.

```

6 #include "BLEDevice.h"
7 #include "BLEServer.h"
8 #include "BLEUtils.h"
9 #include "BLE2902.h"
10 #include "String.h"
```

Define service UUID and characteristic UUID.

```

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"
```

The MyServerCallbacks class handles device connection and disconnection events and updates the deviceConnected status.

```

23 class MyServerCallbacks: public BLEServerCallbacks {
24     void onConnect(BLEServer* pServer) {
25         deviceConnected = true;
26     };
27     void onDisconnect(BLEServer* pServer) {
28         deviceConnected = false;
29     }
30 };
```

The MyServerCallbacks class handles the received data and save them to the rxload string.

```

32 class MyCallbacks: public BLECharacteristicCallbacks {
33     void onWrite(BLECharacteristic *pCharacteristic) {
34         String rxValue = pCharacteristic->getValue();
35         if (rxValue.length() > 0) {
36             rxload="";
37             for (int i = 0; i < rxValue.length(); i++) {
38                 rxload +=(char)rxValue[i];
```

```

39 }
40 }
41 }
42 };
```

Set the baud rate to 115200.

```
62 Serial.begin(115200);
```

BLE Device Initialization, Service Creation, and Characteristic Setup

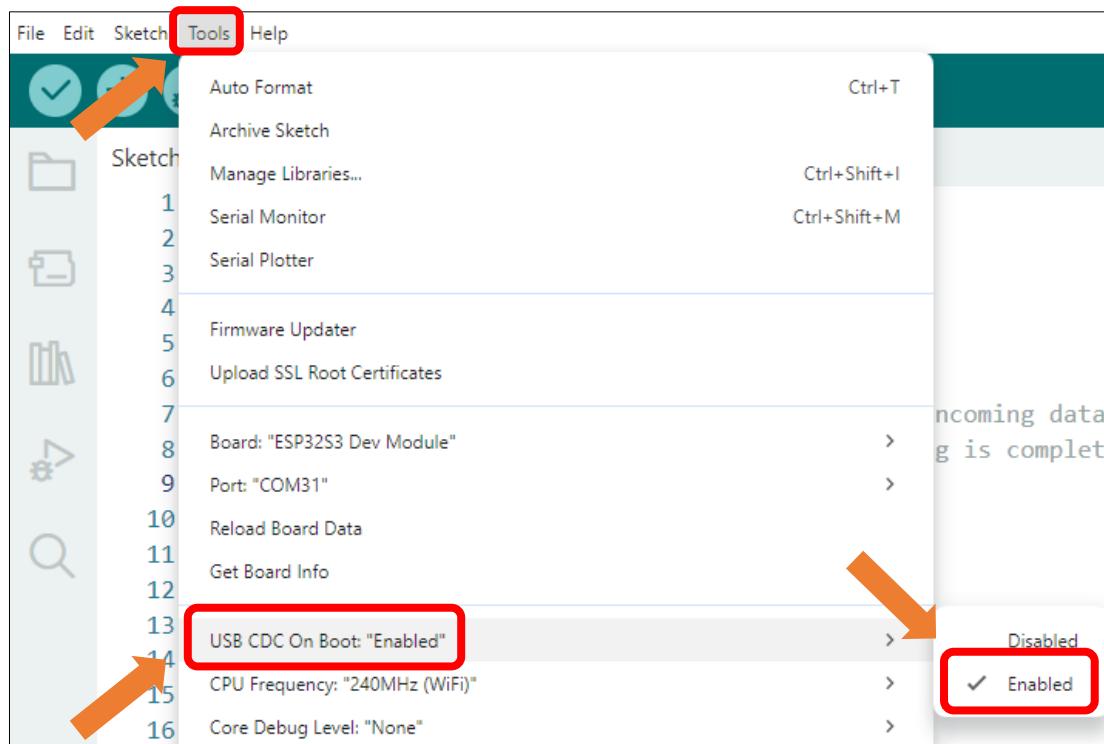
```
63 setupBLE("ESP32S3_BLE");
```

The Loop function check the connection status and serial data every 100 milliseconds.

```

66 void loop() {
67     long now = millis();
68     if (now - lastMsg > 100) {
69         if (deviceConnected&&rxload.length()>0) {
70             Serial.println(rxload);
71             rxload="";
72         }
73         if(Serial.available()>0) {
74             String str=Serial.readString();
75             const char *newValue=str.c_str();
76             pCharacteristic->setValue(newValue);
77             pCharacteristic->notify();
78         }
79         lastMsg = now;
80     }
81 }
```

Enable the "USB CDC On Boot" feature.

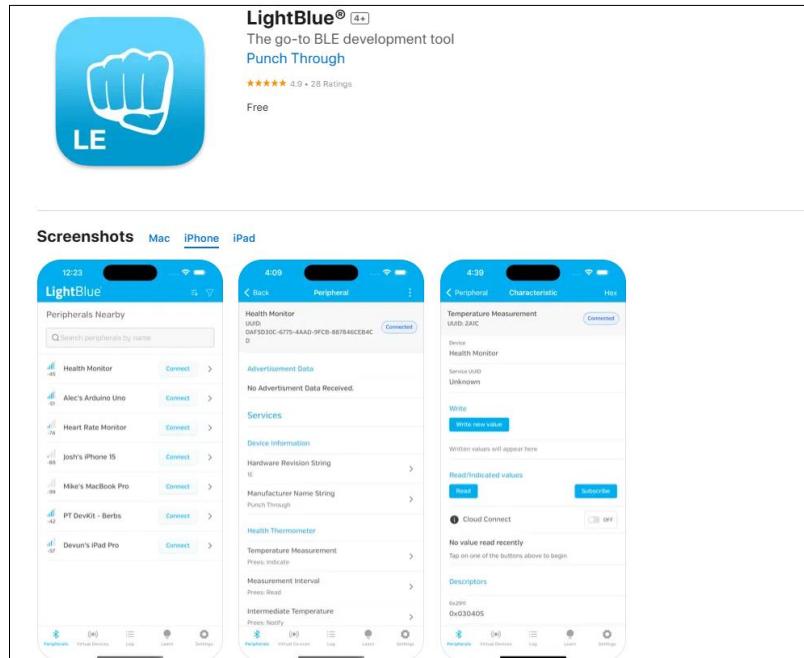




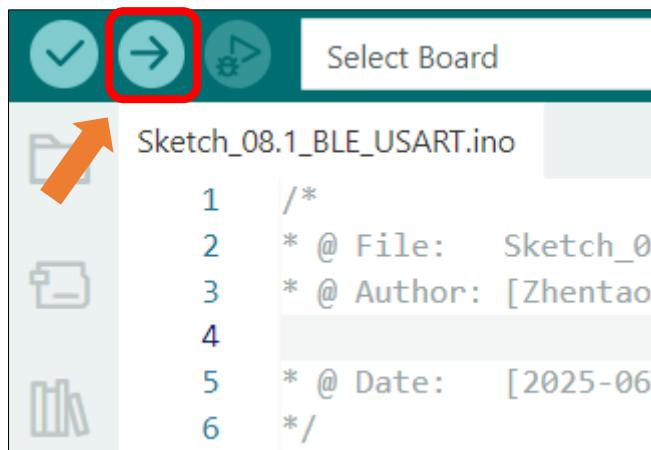
LightBlue

If you do not have this software installed on your phone, you can refer to this link:

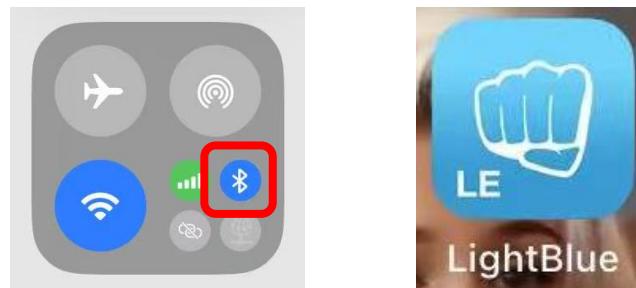
<https://apps.apple.com/us/app/lightblue/id557428110>



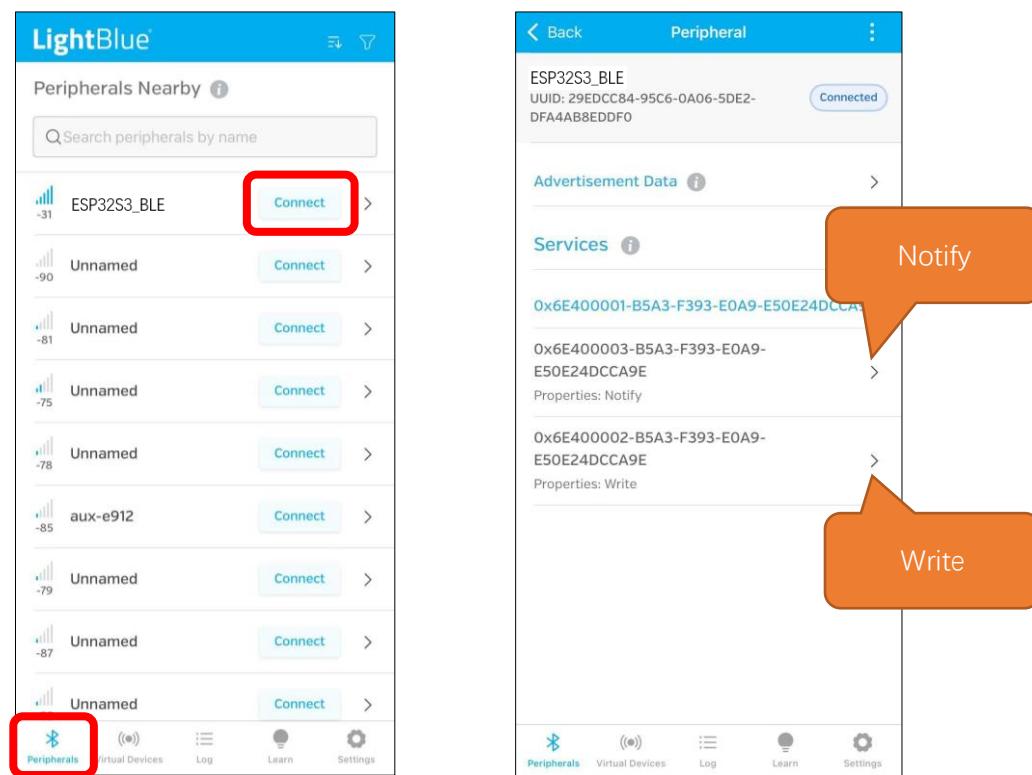
Click “Upload” to upload the code to Freenove ESP32 S3 Display.



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

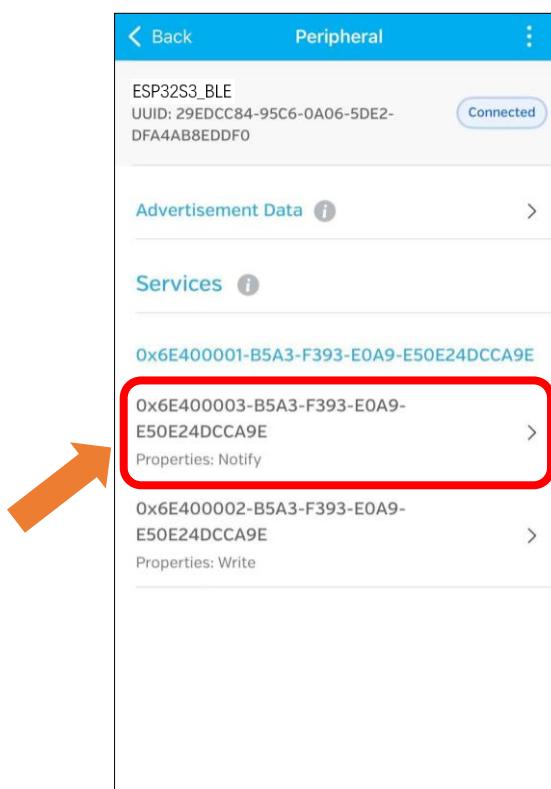


In the Scan page, swipe down to refresh the name of Bluetooth that the phone searches for. Click the Connection button of ESP32S3_BLE

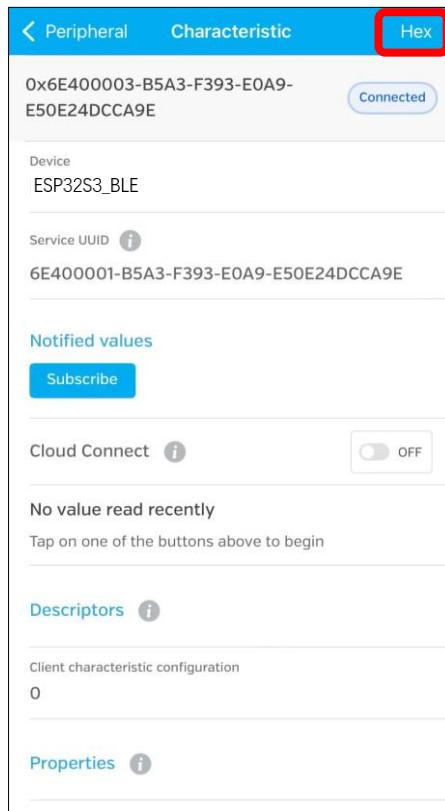


Receiving Data

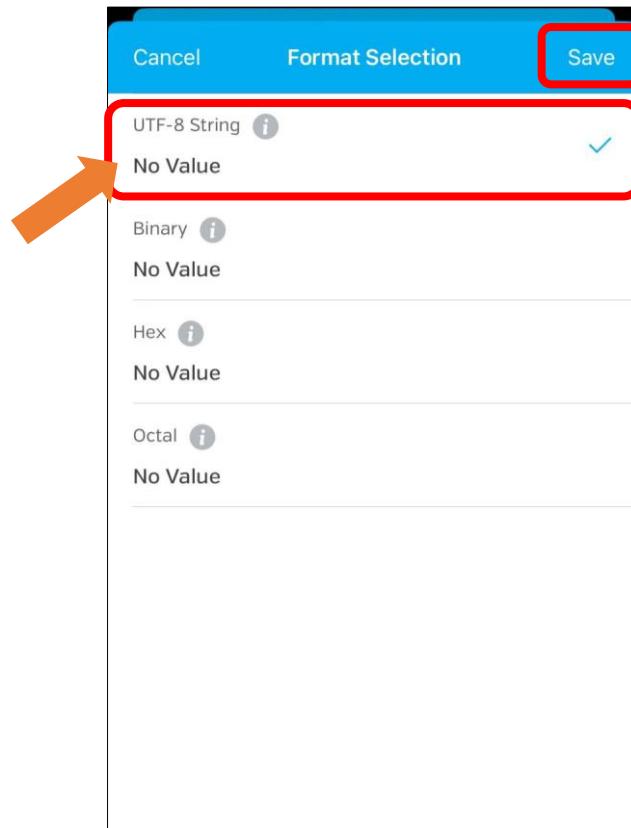
Click Notify



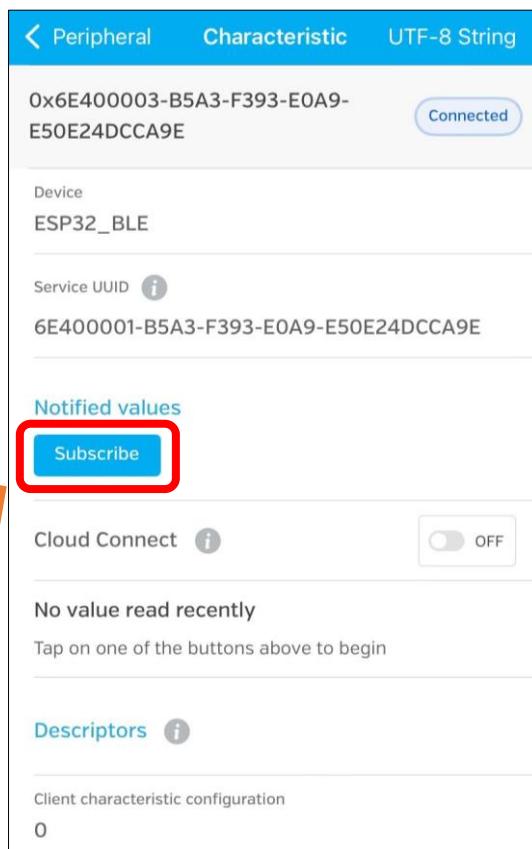
click the top right corner to change the string type.



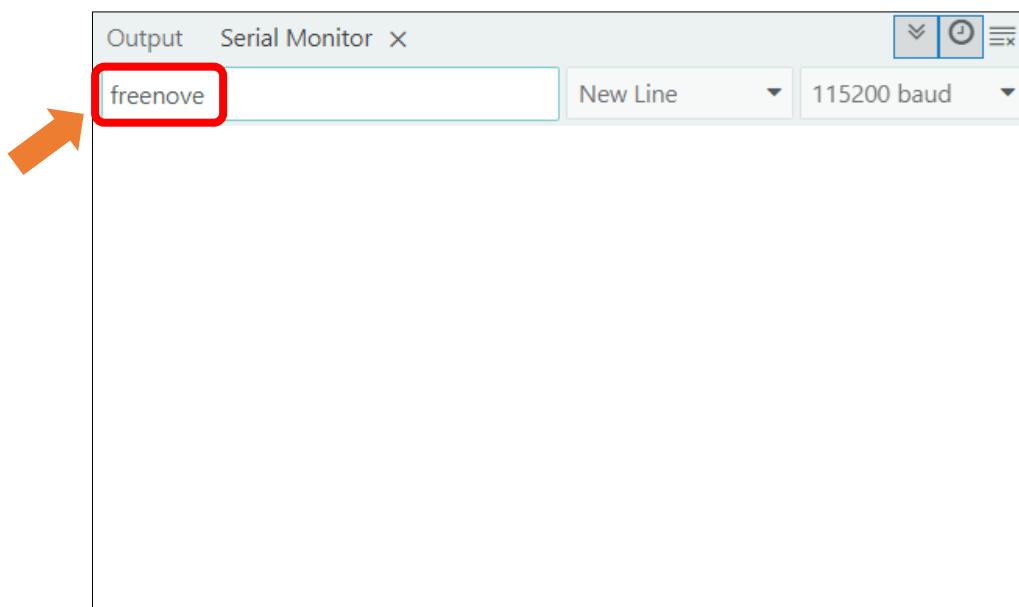
Select UTF-8 String, and click "Save".



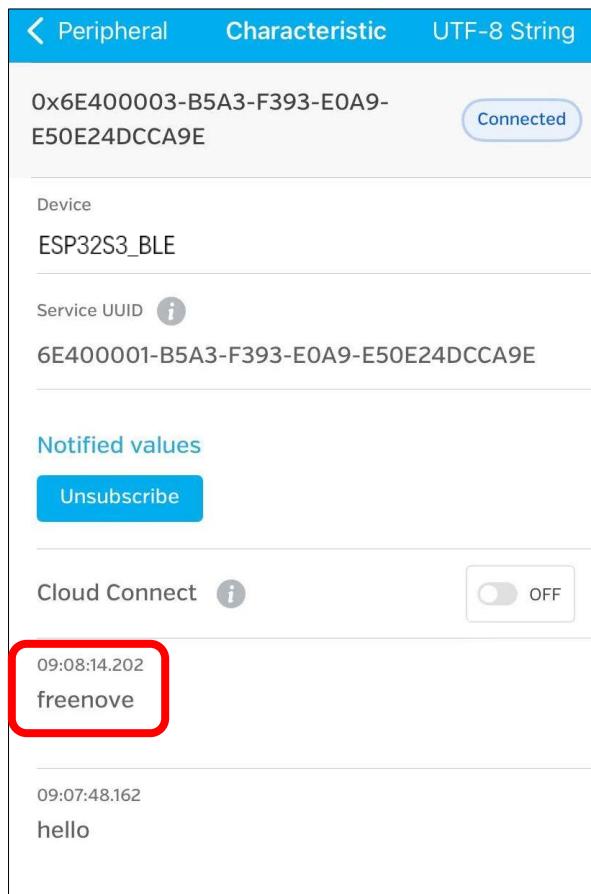
Click Subscribe



Send data on the serial monitor.

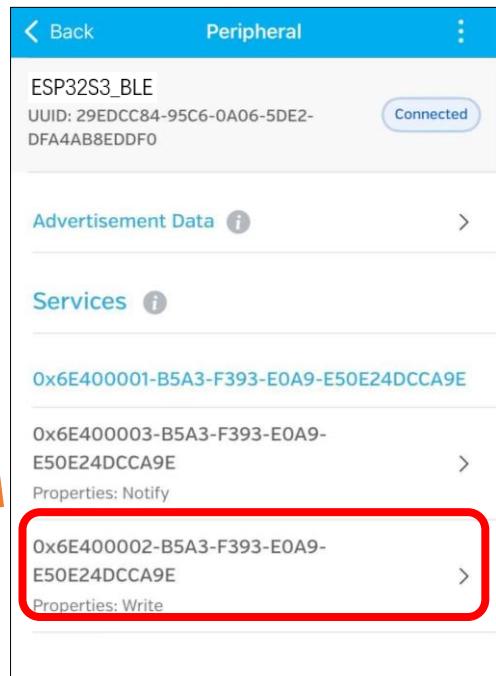


Data will be received on the LightBlue app.

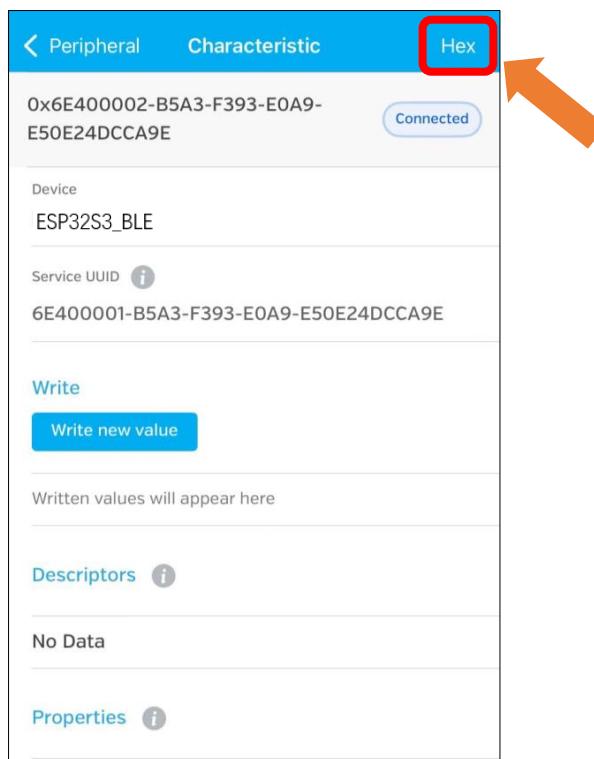


Sending Data

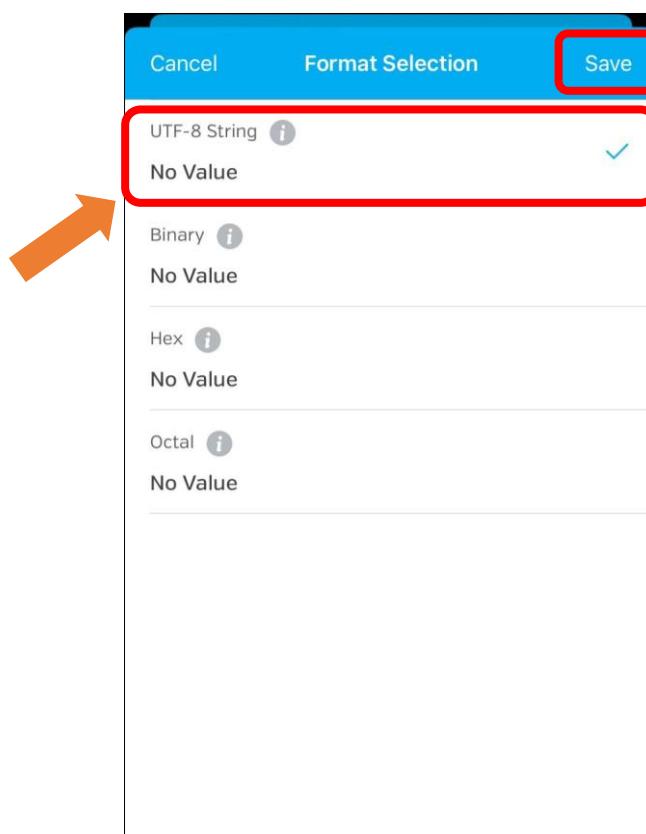
Click Write



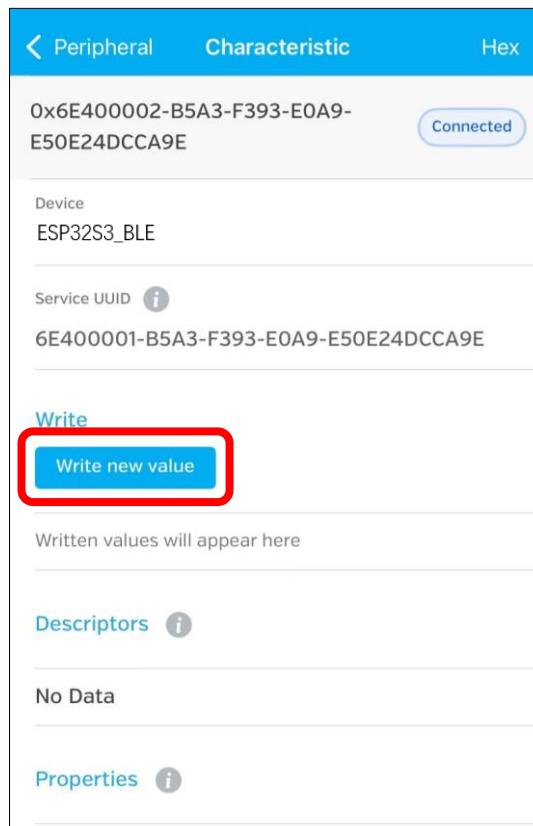
Click the top right corner to change the string type.



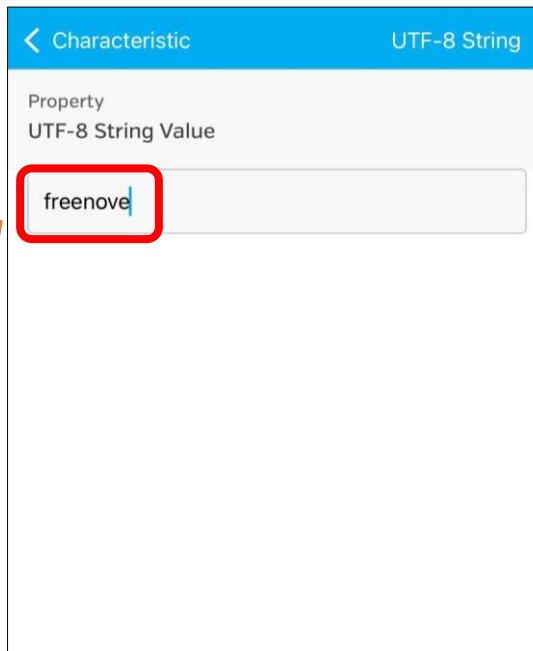
Select UTF-8 String and click "Save".



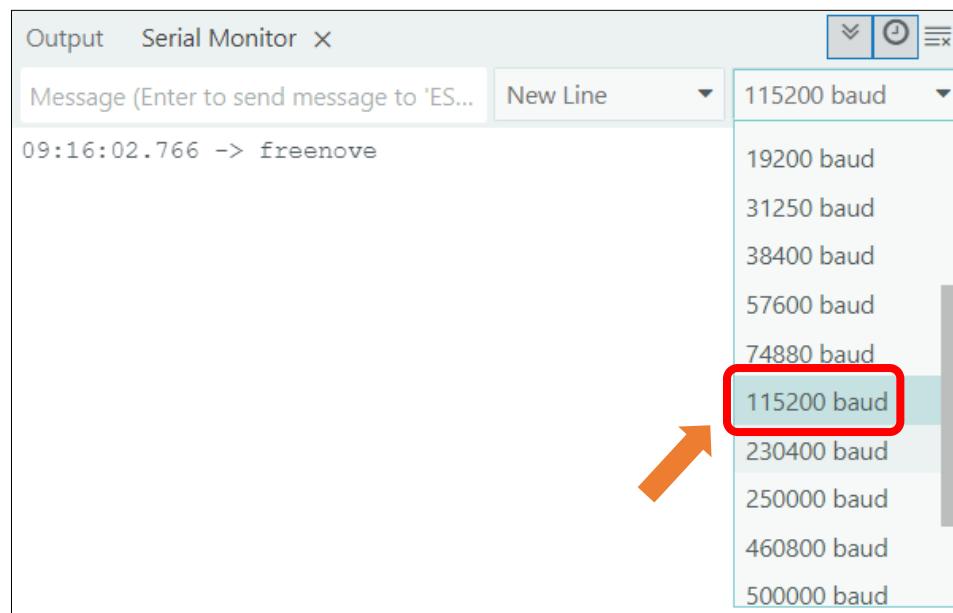
Click "Write new value"



Enter the messages to send.



Set the baud rate to **115200**, and the serial monitor will print the data received.



Project 8.2 BLE RGB

In this section we will control the RGB LED via BLE.

Component List

Freenove ESP32 S3 Display x 1

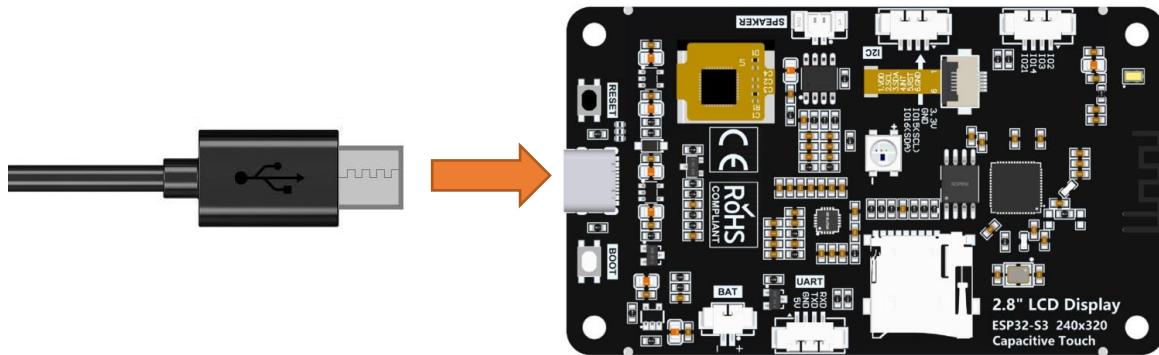


USB cable x1



Circuit

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



Sketch

Next, we download the code to Freenove_ESP32_S3_Display to test. Open “**Sketch_08.2_BLE_RGB**” folder under “**Freenove_ESP32_S3_Display\Sketches**” and double-click “**Sketch_08.2_BLE_RGB.ino**”.

Sketch_08.2_BLE_RGB

The following is the program code:

```

1  /*
2   * @ File: Sketch_08.2_BLE_RGB.ino
3   * @ Author: [Zhentao Lin]
4   * @ Date: [2025-06-14]
5   */
6
7 #include "BLEDevice.h"
8 #include "BLEServer.h"
9 #include "BLEUtils.h"
10 #include "BLE2902.h"
11 #include "String.h"
12 #include "Freenove_WS2812_Lib_for_ESP32.h"
13
14 BLECharacteristic *pCharacteristic;
15 bool deviceConnected = false;
16 uint8_t txValue = 0;
17 long lastMsg = 0;
18 String rxload = "Test\n";
19
20 #define SERVICE_UUID "6E400001-B5A3-F393-E0A9-E50E24DCCA9E"
21 #define CHARACTERISTIC_UUID_RX "6E400002-B5A3-F393-E0A9-E50E24DCCA9E"
22 #define CHARACTERISTIC_UUID_TX "6E400003-B5A3-F393-E0A9-E50E24DCCA9E"
23

```

```
24 #define KEY_PIN 0
25 #define LEDS_COUNT 1
26 #define LEDS_PIN 42
27 #define CHANNEL 0
28
29 Freenove_ESP32_WS2812 strip = Freenove_ESP32_WS2812(LEDS_COUNT, LEDS_PIN, CHANNEL, TYPE_GRB);
30
31 uint8_t m_color[5][3] = { { 255, 0, 0 }, { 0, 255, 0 }, { 0, 0, 255 }, { 255, 255, 255 }, { 0,
32 0, 0 } };
33
34 void stripInit(void) {
35     strip.begin();
36     strip.setBrightness(10);
37 }
38
39 void switchRGB(int value) {
40     int colorIndex = value % 4;
41     switch (colorIndex) {
42         case 1:
43             strip.setLedColorData(0, m_color[0][0], m_color[0][1], m_color[0][2]);
44             strip.show();
45             break;
46         case 2:
47             strip.setLedColorData(0, m_color[1][0], m_color[1][1], m_color[1][2]);
48             strip.show();
49             break;
50         case 3:
51             strip.setLedColorData(0, m_color[2][0], m_color[2][1], m_color[2][2]);
52             strip.show();
53             break;
54         default:
55             strip.setLedColorData(0, m_color[4][0], m_color[4][1], m_color[4][2]);
56             strip.show();
57             break;
58     }
59 }
60
61 class MyServerCallbacks : public BLEServerCallbacks {
62     void onConnect(BLEServer *pServer) {
63         deviceConnected = true;
64     };
65     void onDisconnect(BLEServer *pServer) {
66         deviceConnected = false;
67     }
}
```

```
68 } ;
69
70 class MyCallbacks : public BLECharacteristicCallbacks {
71     void onWrite(BLECharacteristic *pCharacteristic) {
72         String rxValue = pCharacteristic->getValue();
73         if (rxValue.length() > 0) {
74             rxload = "";
75             for (int i = 0; i < rxValue.length(); i++) {
76                 rxload += (char)rxValue[i];
77             }
78         }
79     }
80 };
81
82 void setupBLE(String BLEName) {
83     const char *ble_name = BLEName.c_str();
84     BLEDevice::init(ble_name);
85     BLEServer *pServer = BLEDevice::createServer();
86     pServer->setCallbacks(new MyServerCallbacks());
87     BLEService *pService = pServer->createService(SERVICE_UUID);
88     pCharacteristic = pService->createCharacteristic(CHARACTERISTIC_UUID_TX,
89     BLECharacteristic::PROPERTY_NOTIFY);
90     pCharacteristic->addDescriptor(new BLE2902());
91     BLECharacteristic *pCharacteristic = pService->createCharacteristic(CHARACTERISTIC_UUID_RX,
92     BLECharacteristic::PROPERTY_WRITE);
93     pCharacteristic->setCallbacks(new MyCallbacks());
94     pService->start();
95     pServer->getAdvertising()->start();
96     Serial.println("Waiting a client connection to notify...");
97 }
98
99 void setup() {
100     Serial.begin(115200);
101     stripInit();
102     switchRGB(0);
103     setupBLE("ESP32S3_BLE");
104 }
105
106 void loop() {
107     long now = millis();
108     if (now - lastMsg > 100) {
109         if (deviceConnected && rxload.length() > 0) {
110             Serial.println(rxload);
111             if (strncmp(rxload.c_str(), "red_on", 6) == 0) {
```

```

112     switchRGB(1);
113 } else if (strcmp(rxload.c_str(), "red_off", 7) == 0) {
114     switchRGB(0);
115 } else if (strcmp(rxload.c_str(), "green_on", 8) == 0) {
116     switchRGB(2);
117 } else if (strcmp(rxload.c_str(), "green_off", 9) == 0) {
118     switchRGB(0);
119 } else if (strcmp(rxload.c_str(), "blue_on", 7) == 0) {
120     switchRGB(3);
121 } else if (strcmp(rxload.c_str(), "blue_off", 8) == 0) {
122     switchRGB(0);
123 }
124 rxload = "";
125 }
126 if (Serial.available() > 0) {
127     String str = Serial.readString();
128     const char *newValue = str.c_str();
129     pCharacteristic->setValue(newValue);
130     pCharacteristic->notify();
131 }
132 lastMsg = now;
133 }
134 }
```

Code Explanation

Include the necessary header files.

```

7 #include "BLEDevice.h"
8 #include "BLEServer.h"
9 #include "BLEUtils.h"
10 #include "BLE2902.h"
11 #include "String.h"
12 #include "Freenove_WS2812_Lib_for_ESP32.h"
```

Define Service UUID and Characteristic UUID.

```

20 #define SERVICE_UUID "6E400001-B5A3-F393-E0A9-E50E24DCCA9E"
21 #define CHARACTERISTIC_UUID_RX "6E400002-B5A3-F393-E0A9-E50E24DCCA9E"
22 #define CHARACTERISTIC_UUID_TX "6E400003-B5A3-F393-E0A9-E50E24DCCA9E"
```

Define pins for the RGB LED.

```

24 #define KEY_PIN 0
25 #define LEDS_COUNT 1
26 #define LEDS_PIN 42
27 #define CHANNEL 0
```

The MyServerCallbacks class handles device connection and disconnection events and updates the deviceConnected status.

```

61 class MyServerCallbacks: public BLEServerCallbacks {
62     void onConnect(BLEServer* pServer) {
```

```

63     deviceConnected = true;
64   };
65   void onDisconnect(BLEServer* pServer) {
66     deviceConnected = false;
67   }
68 };

```

The MyCallbacks class handles the receiving data and save them to the rxload string.

```

70   class MyCallbacks: public BLECharacteristicCallbacks {
71     void onWrite(BLECharacteristic *pCharacteristic) {
72       String rxValue = pCharacteristic->getValue();
73       if (rxValue.length() > 0) {
74         rxload="";
75         for (int i = 0; i < rxValue.length(); i++) {
76           rxload +=(char)rxValue[i];
77         }
78       }
79     }
80   };

```

Set the baud rate to 115200

```
97   Serial.begin(115200);
```

Initialize RGB LED setting, initialize the BLE device, create services, and set up characteristics.

```

101  stripInit();
102  switchRGB(0);
103  setupBLE("ESP32S3_BLE");

```

The Loop function checks the sending command every 100 milliseconds.

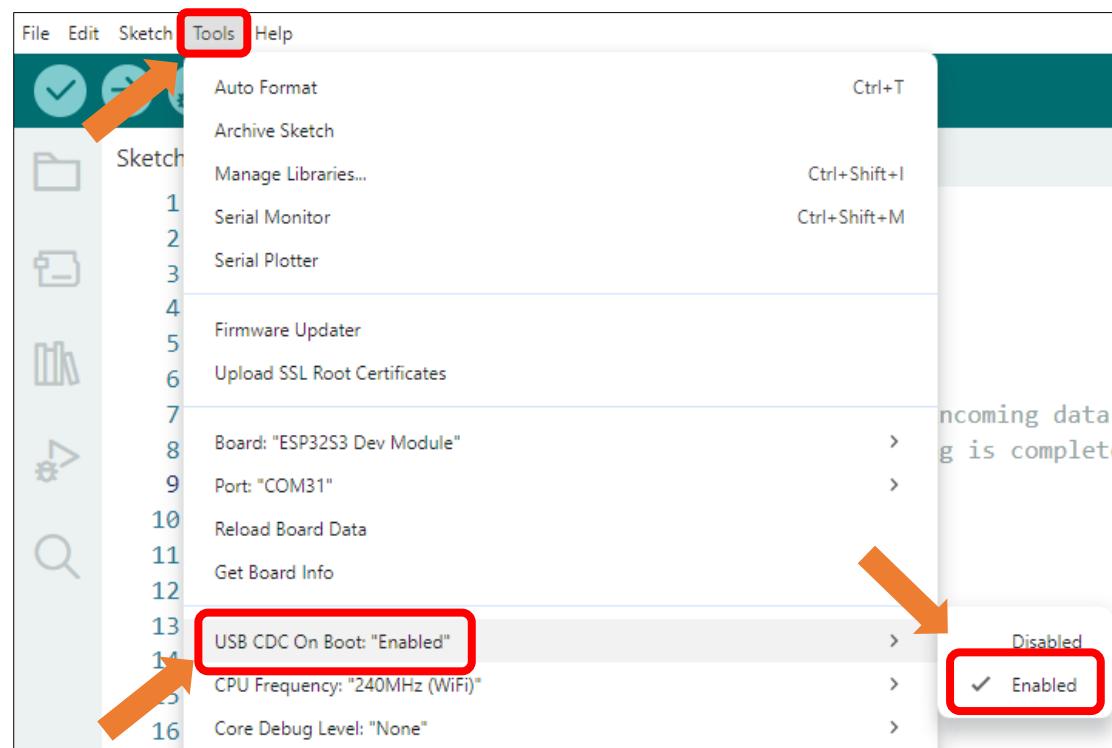
```

106  void loop() {
107    long now = millis();
108    if (now - lastMsg > 100) {
109      if (deviceConnected && rxload.length() > 0) {
110        Serial.println(rxload);
111        if (strncmp(rxload.c_str(), "red_on", 6) == 0) {
112          setRGB(1, 0, 0);
113        } else if (strncmp(rxload.c_str(), "red_off", 7) == 0) {
114          setRGB(0, 0, 0);
115        } else if (strncmp(rxload.c_str(), "green_on", 8) == 0) {
116          setRGB(0, 1, 0);
117        } else if (strncmp(rxload.c_str(), "green_off", 9) == 0) {
118          setRGB(0, 0, 0);
119        } else if (strncmp(rxload.c_str(), "blue_on", 7) == 0) {
120          setRGB(0, 0, 1);
121        } else if (strncmp(rxload.c_str(), "blue_off", 8) == 0) {
122          setRGB(0, 0, 0);
123        }
124        rxload = "";

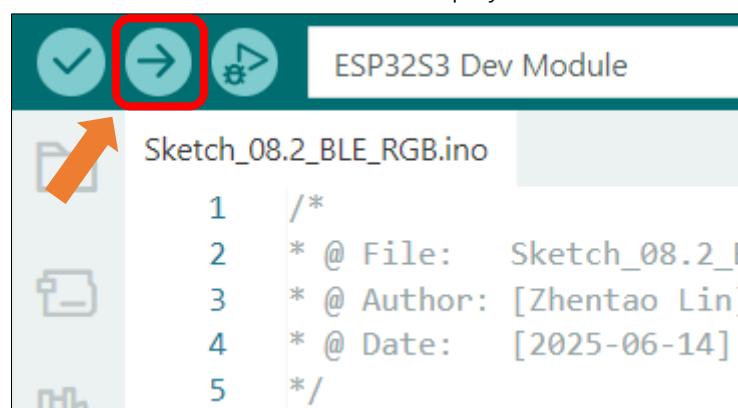
```

```
125 }
126     if (Serial.available() > 0) {
127         String str = Serial.readString();
128         const char *newValue = str.c_str();
129         pCharacteristic->setValue(newValue);
130         pCharacteristic->notify();
131     }
132     lastMsg = now;
133 }
134 }
```

Enable the "USB CDC On Boot" feature.

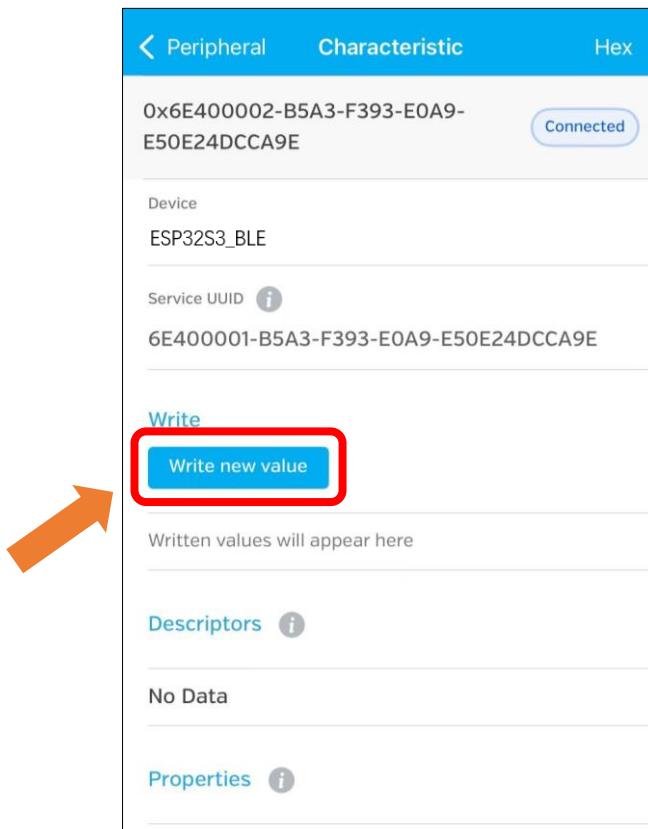


Click "Upload" to upload the code to Freenove ESP32 S3 Display.

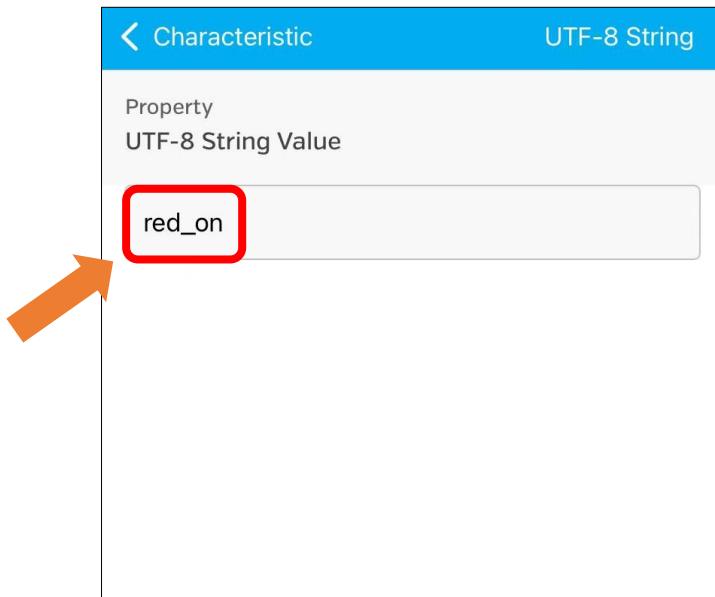




Click "Write new value"



Enter the messages to send. Here we take "red_on" as an example.



The RGB LED on the Freenove ESP32 S3 Display emits red light.



You can also use the following instructions to control the RGB LED:

red_off: red light off

green_on: green light on

green_off: green light off

blue_on: blue light on

blue_off: blue light off

Chapter 9 WIFI Web Server

Project 9.1 WIFI Web Servers LED

Component List

Freenove ESP32 S3 Display x 1



USB cable x1



Component Knowledge

Wi-Fi

Wi-Fi is a wireless LAN (WLAN) technology compliant with the IEEE 802.11 standard, enabling devices to transmit data or connect to the internet via radio waves within short-range coverage (typically up to tens of meters). In embedded systems, Wi-Fi modules provide wireless communication capabilities, allowing devices to connect to routers, access cloud services, or interact with other devices.

Its core features include:

- Wireless connectivity (eliminating the need for physical cabling)
- Moderate to high-speed data transfer (depending on protocol versions such as 802.11n/ac)
- Secure communication (ensured by encryption protocols like WPA2/WPA3)

In embedded development, Wi-Fi is one of the key technologies for enabling IoT (Internet of Things) device connectivity.

Web

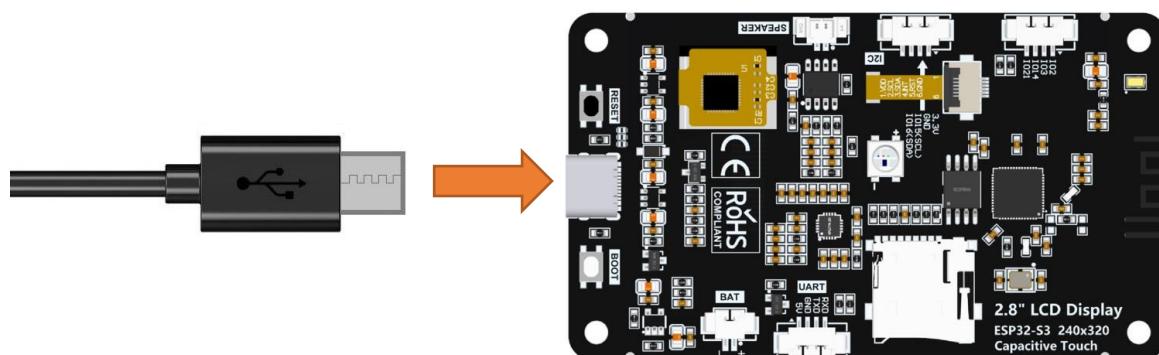
The Web (World Wide Web) is an internet-based information system that integrates global resources through hypertext links. In the embedded field, Web technology refers to devices equipped with lightweight built-in web servers, allowing users to remotely access the device interface via browsers (such as Chrome or Edge). By entering the device's IP address, users can open an interactive page to perform functions like status monitoring, parameter configuration, or firmware upgrades. Its core value lies in cross-platform compatibility (no need for dedicated software installation) and standardized protocols (HTTP/HTTPS), making it a mainstream solution for remote management of embedded devices.

HTML & CSS & JavaScript

- **HTML (HyperText Markup Language)** is the standard language for structuring web pages. It uses tags to define page elements, forming the foundational framework. In embedded web interfaces, HTML describes the layout of components such as device status displays and configuration forms.
- **CSS (Cascading Style Sheets)** controls the visual presentation of web pages, including colors, fonts, spacing, and responsive layouts. Through CSS rules, developers style HTML elements into intuitive interactive interfaces. The combination of HTML and CSS enables the creation of lightweight device control pages without complex graphics libraries, reducing resource overhead in embedded systems.
- **JavaScript (a scripting language)** adds dynamic behavior and interaction logic to web pages. In embedded web interfaces, JavaScript plays a crucial role: it responds to user actions and enables asynchronous communication with the device backend through technologies like **AJAX** or **WebSocket**. This allows the webpage to fetch real-time device status data, update displays without refreshing, and send control commands or configuration parameters—delivering a smooth and efficient remote management experience.

Circuit

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



Sketch

Next, we download the code to Freenove_ESP32_S3_Display to test. Open “**Sketch_09.1_WiFi_Web_Servers_LED**” folder under “**Freenove_ESP32_S3_Display\Sketches**” and double-click “**Sketch_09.1_WiFi_Web_Servers_LED.ino**”.

Important Note: Before upload the code, please ensure that the Wi-Fi SSID and Password are correctly configured in the code, and that the Wi-Fi network to connect is 2.4GHz.

```

10 const char* ssid      = "*****";
11 const char* password = "*****";
  
```

Sketch_09.1_WiFi_Web_Servers_LED

The following is the program code:

```

1 /*
2 * @ File: Sketch_09.1_WiFi_Web_Servers_LED.ino (modified to use WS2812 strip with color
3 names)
4 * @ Author: [Zhentao Lin]
  
```



```
5  * @ Date: [2025-08-23]
6  */
7
8 #include <WiFi.h>
9 #include "Freenove_WS2812_Lib_for_ESP32.h"
10
11 // WiFi credentials
12 const char* ssid      = "*****";
13 const char* password = "*****";
14
15 // Web server on port 80
16 WiFiServer server(80);
17
18 // HTTP request buffer
19 String request;
20
21 // WS2812 LED strip configuration
22 #define LEDS_COUNT 1
23 #define LEDS_PIN    42
24 #define CHANNEL     0
25
26 Freenove_ESP32_WS2812 strip = Freenove_ESP32_WS2812(LEDS_COUNT, LEDS_PIN, CHANNEL, TYPE_GRB);
27
28 // LED state tracking (0=Red, 1=Green, 2=Blue)
29 bool ledStates[3] = {false, false, false}; // All OFF initially
30 String redLedState = "OFF";
31 String greenLedState = "OFF";
32 String blueLedState = "OFF";
33
34 // Timeout settings
35 unsigned long currentTime = millis();
36 unsigned long previousTime = 0;
37 const long timeoutTime = 2000; // 2 seconds
38
39 void setupStrip(void) {
40     strip.begin();
41     strip.setBrightness(10);
42     strip.setLedColorData(0, 0, 0, 0); // Turn off all LEDs
43     strip.show();
44 }
45
46 void updateLedStrip(void) {
47     uint8_t r = ledStates[0] ? 255 : 0;
48     uint8_t g = ledStates[1] ? 255 : 0;
```

```
49     uint8_t b = ledStates[2] ? 255 : 0;
50
51     strip.setLedColorData(0, r, g, b);
52     strip.show();
53 }
54
55 void setup() {
56     Serial.begin(115200);
57
58     // Initialize LED strip
59     setupStrip();
60
61     // Connect to WiFi
62     Serial.print("Connecting to ");
63     Serial.println(ssid);
64     WiFi.begin(ssid, password);
65     while (WiFi.status() != WL_CONNECTED) {
66         delay(500);
67         Serial.print(".");
68     }
69
70     Serial.println("");
71     Serial.println("WiFi connected.");
72     Serial.println("IP address: ");
73     Serial.println(WiFi.localIP());
74
75     server.begin();
76 }
77
78 void loop() {
79     WiFiClient client = server.available();
80
81     if (client) {
82         currentTime = millis();
83         previousTime = currentTime;
84         Serial.println("New Client.");
85         String currentLine = "";
86
87         while (client.connected() && currentTime - previousTime <= timeoutTime) {
88             currentTime = millis();
89             if (client.available()) {
90                 char c = client.read();
91                 Serial.write(c);
92                 request += c;
```

```
93
94     if (c == '\n') {
95         if (currentLine.length() == 0) {
96             // HTTP response headers
97             // Handle incoming commands first. These are AJAX requests.
98             if (request.indexOf("GET /red/ON") >= 0) {
99                 Serial.println("Red LED ON");
100                redLedState = "ON";
101                ledStates[0] = true;
102            } else if (request.indexOf("GET /red/OFF") >= 0) {
103                Serial.println("Red LED OFF");
104                redLedState = "OFF";
105                ledStates[0] = false;
106            } else if (request.indexOf("GET /green/ON") >= 0) {
107                Serial.println("Green LED ON");
108                greenLedState = "ON";
109                ledStates[1] = true;
110            } else if (request.indexOf("GET /green/OFF") >= 0) {
111                Serial.println("Green LED OFF");
112                greenLedState = "OFF";
113                ledStates[1] = false;
114            } else if (request.indexOf("GET /blue/ON") >= 0) {
115                Serial.println("Blue LED ON");
116                blueLedState = "ON";
117                ledStates[2] = true;
118            } else if (request.indexOf("GET /blue/OFF") >= 0) {
119                Serial.println("Blue LED OFF");
120                blueLedState = "OFF";
121                ledStates[2] = false;
122            }
123
124         // Update LED strip based on states
125         updateLedStrip();
126
127         // Send HTML page for non-AJAX requests
128         if (request.indexOf("/red/") < 0 && request.indexOf("/green/") < 0 &&
129             request.indexOf("/blue/") < 0) {
130             // Send the Complete HTML page
131             client.println("HTTP/1.1 200 OK");
132             client.println("Content-type:text/html");
133             client.println("Connection: close");
134             client.println();
135
136             // Generate HTML response
```

```
137     client.println("<!DOCTYPE html><html>");  
138     client.println("<head><meta charset=\"UTF-8\">");  
139     client.println("<meta name=\"viewport\" content=\"width=device-width, initial-  
140 scale=1.0\">");  
141     client.println("<title>ESP32 Web Server LED</title>");  
142     client.println("<style>");  
143         client.println("html {font-family: 'Segoe UI', Roboto, sans-  
144 serif; background:#f5f5f5; height:100vh; display:flex; justify-content:center; align-  
145 items:center;}");  
146         client.println("body {margin:0; padding:20px; background:white; border-  
147 radius:15px; box-shadow:0 10px 30px rgba(0,0,0,0.1); max-width:800px; width:90vw;}");  
148         client.println(".container {display:grid; grid-template-columns:repeat(3,  
149 1fr); gap:20px; margin-top:20px;}");  
150         client.println(".card {border-radius:15px; padding:25px; text-align:center; min-  
151 width:180px; transition:all 0.3s; cursor:pointer; border:2px  
solid; position:relative; overflow:hidden;}");  
152             client.println(".card:hover {transform:translateY(-5px); box-shadow:0 15px 35px  
153 rgba(0,0,0,0.15);}");  
154             client.println(".card:active {transform:translateY(0) scale(0.98);}");  
155             client.println("#red-card {background:linear-  
156 gradient(145deg, #ffccdd2, #ef9a9a); border-color:#f44336;}");  
157             client.println("#green-card {background:linear-  
158 gradient(145deg, #c8e6c9, #a5d6a7); border-color:#4caf50;}");  
159             client.println("#blue-card {background:linear-  
160 gradient(145deg, #bbdefb, #90caf9); border-color:#2196f3;}");  
161             client.println(".card.off-state {filter:grayscale(70%) brightness(0.85);}");  
162             client.println("h1 {color:#333; text-align:center; font-size:2.4rem; margin-  
163 bottom:10px; border-bottom:2px solid #eee; padding-bottom:15px;}");  
164             client.println(".status {font-size:1.4rem; font-weight:600; margin:25px  
165 0; color:#333; position:relative; z-index:2;}");  
166             client.println(".device-info {text-align:center; margin-top:25px; color:#777; font-  
167 size:0.9rem; padding-top:15px; border-top:1px solid #eee;}");  
168             client.println("@media (max-width:768px) { .container {grid-template-columns:1fr;}  
169 body {padding:15px;} h1 {font-size:2rem;} }");  
170             client.println("</style></head>");  
171             client.println("<body>");  
172                 client.println("<h1>ESP32 Web Server LED</h1>");  
173                 client.println("<div class=\"container\">");  
174  
175                     // Red LED control  
176                     client.println("<div class=\"card " + String(redLedState == \"OFF\" ? \"off-  
177 state\" : "") + "\\" id=\"red-card\" onclick=\"toggleLED('red', this)\\>");  
178                     client.println("<h2>Red LED</h2>");  
179  
180             
```

```
181     client.println("<p class=\"status\" id=\"status-red\">" + redLedState +
182     "</p>");  
183     client.println("</div>");  
184  
185     // Green LED control  
186     client.println("<div class=\"card " + String(greenLedState == "OFF" ? "off-  
187 state" : "") + "\\" id=\"green-card\" onclick=\"toggleLED('green', this)\\>");  
188     client.println("<h2>Green LED</h2>");  
189     client.println("<p class=\"status\" id=\"status-green\">" + greenLedState +  
190     "</p>");  
191     client.println("</div>");  
192  
193     // Blue LED control  
194     client.println("<div class=\"card " + String(blueLedState == "OFF" ? "off-  
195 state" : "") + "\\" id=\"blue-card\" onclick=\"toggleLED('blue', this)\\>");  
196     client.println("<h2>Blue LED</h2>");  
197     client.println("<p class=\"status\" id=\"status-blue\">" + blueLedState +  
198     "</p>");  
199     client.println("</div>");  
200  
201     client.println("</div>");  
202     client.println("<div class=\"device-info\\>Device IP: " +  
203 WiFi.localIP().toString() + " | ESP32 Web Server LED</div>");  
204     client.println("<script>");  
205     client.println("function toggleLED(color, element) {");  
206     client.println("  const statusElement = document.getElementById('status-' +  
207 color);");  
208     client.println("  const currentState = statusElement.innerText;");  
209     client.println("  const newState = currentState === 'ON' ? 'OFF' : 'ON';");  
210     client.println("  fetch('/" + color + '/' + newState);");  
211     client.println("  statusElement.innerText = newState;");  
212     client.println("  if (newState === 'ON') { element.classList.remove('off-  
213 state'); } else { element.classList.add('off-state'); }");  
214     client.println("}");  
215     client.println("</script>");  
216     client.println("</body></html>");  
217     }  
218     break;  
219   } else {  
220     currentLine = "";  
221   }  
222 } else if (c != '\r') {  
223   currentLine += c;  
224 }
```

```

225     }
226 }
227
228     request = "";
229     client.stop();
230     Serial.println("Client disconnected.");
231     Serial.println("");
232 }
233 }
```

Code Explanation

Include necessary header files.

```
7 #include <WiFi.h>
```

Configure WiFi SSID and password.

```

12 const char* ssid      = "*****";
13 const char* password = "*****";
```

Define pins for the RGB LED.

```

21 // WS2812 LED strip configuration
22 #define LEDS_COUNT 1
23 #define LEDS_PIN    42
24 #define CHANNEL     0
```

Initialize the configuration related to RGB LED.

```

40 strip.begin();
41 strip.setBrightness(10);
42 strip.setLedColorData(0, 0, 0, 0); // Turn off all LEDs
43 strip.show();
```

Connect to WIFI.

```

61 // Connect to WiFi
62 Serial.print("Connecting to ");
63 Serial.println(ssid);
64 WiFi.begin(ssid, password);
65 while (WiFi.status() != WL_CONNECTED) {
66     delay(500);
67     Serial.print(".");
68 }
69
70 Serial.println("");
71 Serial.println("WiFi connected.");
72 Serial.println("IP address: ");
73 Serial.println(WiFi.localIP());
74
75 server.begin();
```

Check if there are any new clients connected to the server.

```
78 WiFiClient client = server.available();
```

Parse the URL command and control the corresponding LED on and off.

```

87 // Handle incoming commands
88 if (request.indexOf("GET /red/ON") >= 0) {
89     Serial.println("Red LED ON");
90     redLedState = "ON";
91     ledStates[0] = true;
92 } else if (request.indexOf("GET /red/OFF") >= 0) {
93     Serial.println("Red LED OFF");
94     redLedState = "OFF";
95     ledStates[0] = false;
96 } else if (request.indexOf("GET /green/ON") >= 0) {
97     Serial.println("Green LED ON");
98     greenLedState = "ON";
99     ledStates[1] = true;
100 } else if (request.indexOf("GET /green/OFF") >= 0) {
101     Serial.println("Green LED OFF");
102     greenLedState = "OFF";
103     ledStates[1] = false;
104 } else if (request.indexOf("GET /blue/ON") >= 0) {
105     Serial.println("Blue LED ON");
106     blueLedState = "ON";
107     ledStates[2] = true;
108 } else if (request.indexOf("GET /blue/OFF") >= 0) {
109     Serial.println("Blue LED OFF");
110     blueLedState = "OFF";
111     ledStates[2] = false;
112 }

```

Use CSS styles to enhance the visual appeal of web interfaces.

```

121 client.println("html{font-family:'Segoe UI',Roboto,sans-
122 serif;background:#f5f5f5;height:100vh;display:flex;justify-content:center;align-
123 items:center;}");
124 client.println("body{margin:0;padding:20px;background:white;border-radius:15px;box-shadow:0
125 10px 30px rgba(0,0,0,0.1);max-width:800px;width:90vw;}");
126 client.println(".container{display:grid;grid-template-columns:repeat(3, 1fr);gap:20px;margin-
127 top:20px;}");
128 client.println(".card{border-radius:15px;padding:25px;text-align:center;min-
129 width:180px;transition:all 0.3s;cursor:pointer;border:2px
130 solid;position:relative;overflow:hidden;}");
131 client.println(".card:hover{transform:translateY(-5px);box-shadow:0 15px 35px
132 rgba(0,0,0,0.15);}");
133 client.println(".card:active{transform:translateY(0) scale(0.98);}");
134 client.println("#red-card{background:linear-gradient(145deg, #ffcdd2, #ef9a9a);border-
135 color:#f44336;}");
136 client.println("#green-card{background:linear-gradient(145deg, #c8e6c9, #a5d6a7);border-
137 color:#4caf50;}");

```

```

138 client.println("#blue-card{background:linear-gradient(145deg,#bbdefb,#90caf9);border-
139 color:#2196f3;}");
140 client.println(".card.off-state{filter:grayscale(70%) brightness(0.85);}");
141 client.println("h1{color:#333;text-align:center;font-size:2.4rem;margin-bottom:10px;border-
142 bottom:2px solid #eee;padding-bottom:15px;}");
143 client.println(".status{font-size:1.4rem;font-weight:600;margin:25px
144 0;color:#333;position:relative;z-index:2;}");
145 client.println(".device-info{text-align:center;margin-top:25px;color:#777;font-
146 size:0.9rem;padding-top:15px;border-top:1px solid #eee;}");
147 client.println("@media (max-width:768px) {.container{grid-template-columns:1fr;}}
148 body{padding:15px;} h1{font-size:2rem;}}");

```

Generate the HTML contents to control the LED.

```

154 // Red LED control
155 client.println("<div class=\"card " + String(redLedState == "OFF" ? "off-state" : "") + "\"
156 id=\"red-card\" onclick=\"toggleLED('22', this)\">");
157 client.println("<h2>Red LED</h2>");
158 client.println("<p class=\"status\" id=\"status-22\">" + redLedState + "</p>"); 
159 client.println("</div>");

160

161 // Green LED control
162 client.println("<div class=\"card " + String(greenLedState == "OFF" ? "off-state" : "") + "\"
163 id=\"green-card\" onclick=\"toggleLED('16', this)\">");
164 client.println("<h2>Green LED</h2>");
165 client.println("<p class=\"status\" id=\"status-16\">" + greenLedState + "</p>"); 
166 client.println("</div>");

167

168 // Blue LED control
169 client.println("<div class=\"card " + String(blueLedState == "OFF" ? "off-state" : "") + "\"
170 id=\"blue-card\" onclick=\"toggleLED('17', this)\">");
171 client.println("<h2>Blue LED</h2>");
172 client.println("<p class=\"status\" id=\"status-17\">" + blueLedState + "</p>"); 
173 client.println("</div>"); 

```

Disconnect from the client and print the disconnection information in the serial monitor

```

172 client.stop();
173 Serial.println("Client disconnected.");
174 Serial.println("");

```

Input correct WiFi(2.4GHz) SSID and password.

```

9 // WiFi credentials
10 const char* ssid      = "*****";
11 const char* password = "*****";

```

Click “Upload” to upload the code to Freenove ESP32 Display.



When the serial monitor prints the following information, it means the network connection is successful. Use a mobile phone or computer browser to open the IP address printed by the serial monitor.

Please note: If it keeps printing dots, please confirm whether the WiFi is in the 2.4G band.

```

14:31:24.553 -> Connecting to FYI_2.4G
14:31:25.115 -> ....
14:31:27.088 -> WiFi connected.
14:31:27.088 -> IP address:
14:31:27.122 -> 192.168.1.29

```

The following screen will be displayed in the computer's browser, where you can control the color of the RGB light by clicking on the three cards.



On the phone web browser, you'll see the following contents. The color of the RGB light can be controlled by clicking on the three cards.



Chapter 10 TFT Display

Project 10.1 TFT_Rainbow

Component List

Freenove ESP32 S3 Display x 1



USB cable x1



Component Knowledge

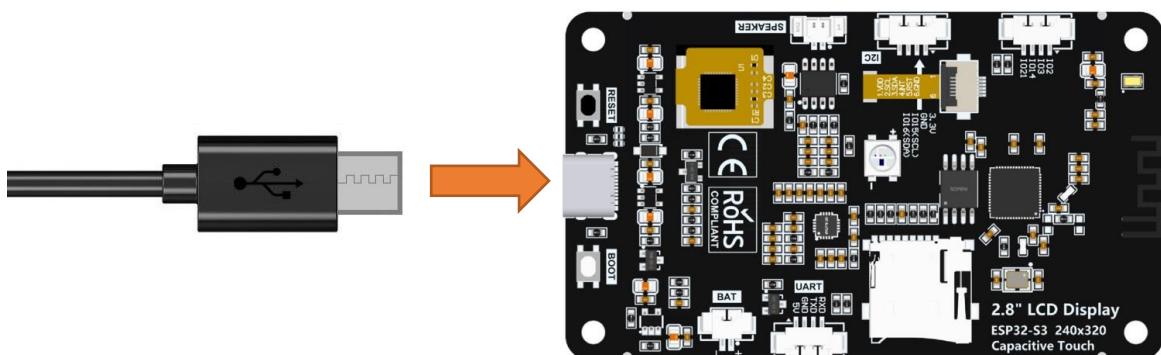
TFT Display

TFT (Thin Film Transistor) is an electronic component that serves as the foundation for TFT displays, the mainstream display technology in modern laptops and desktop computers. In these displays, each individual liquid crystal pixel is controlled by its own dedicated thin-film transistor embedded directly behind it. This architecture classifies TFT screens as a form of active-matrix LCD (AMLCD) technology.

As one of the finest LCD color displays available, TFT screens offer superior performance characteristics including rapid response times, exceptional brightness levels, and outstanding contrast ratios.

Circuit

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

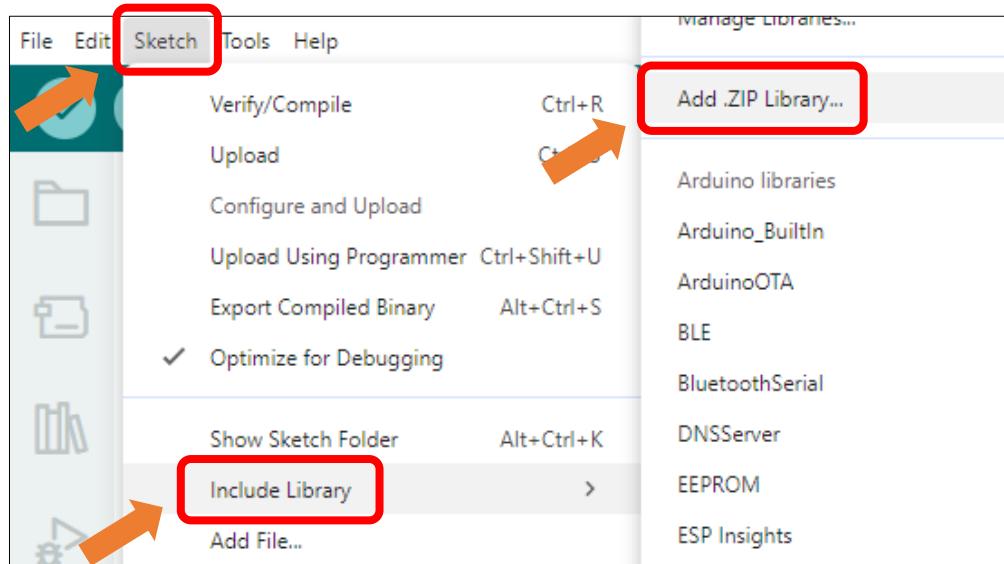


Sketch

Open “**Sketch_10.1_TFT_Rainbow.ino**” folder under “**Freenove_ESP32_S3_Display\Sketches**” and double-click “**Sketch_10.1_TFT_Rainbow.ino**”.

Install Libraries

Click **Sketch -> Include Library -> Add .ZIP Library...**

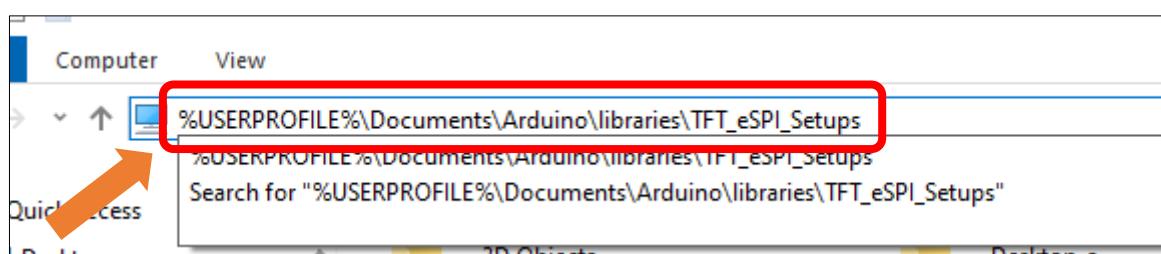


Install **TFT_eSPI_v2.5.43.zip** and **TFT_eSPI_Setups_v1.2.zip**

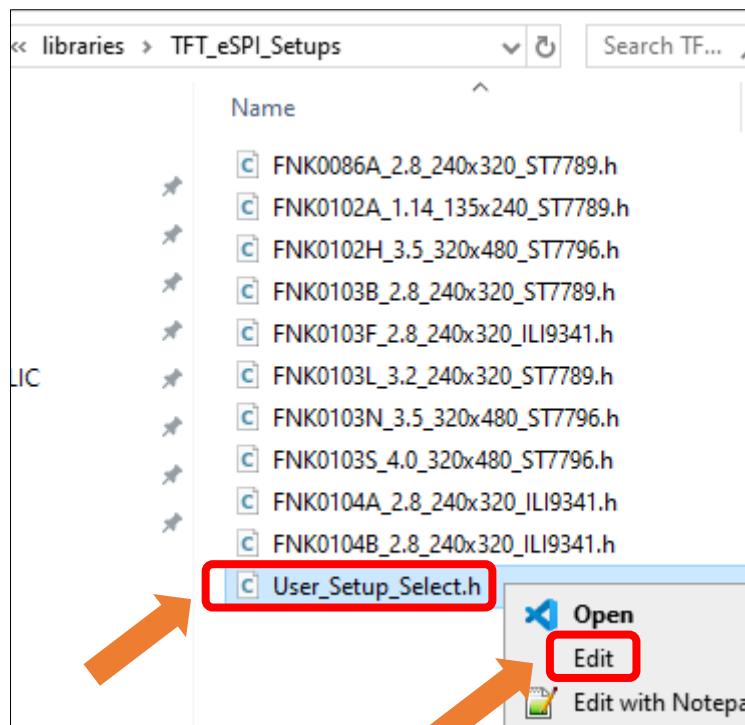
ESP32-audiol2S_v3.0.13.zip	2025/8/26 9:09
Freenove_WS2812_Lib_for_ESP32_v2.0.1.zip	2025/9/2 13:34
FT6336U_v1.0.2.zip	2025/8/26 9:10
lval_v8.4.0.zip	2025/9/2 10:11
TFT_eSPI_Setups_v1.2.zip	2025/9/11 17:12
TFT_eSPI_v2.5.43.zip	2025/8/28 17:16

How to configure (Important)

Open This PC, input **%USERPROFILE%\Documents\Arduino\libraries\TFT_eSPI_Setups** and press the **Enter** key.



Right click **User_Setup_Select.h**, click **Edit**.



Uncomment the corresponding macro definition based on the model purchased.

If the screen **does not have touch functionality**, configure as below:

```

#define FNK0086A_2P8_240x320_ST7789
#define FNK0102A_1P14_135x240_ST7789
#define FNK0102H_3P5_320x480_ST7796
#define FNK0103B_2P8_240x320_ST7789
#define FNK0103F_2P8_240x320_ILI9341
#define FNK0103L_3P2_240x320_ST7789
#define FNK0103N_3P5_320x480_ST7796
#define FNK0103S_4P0_320x480_ST7796
#define FNK0104A_2P8_240x320_ILI9341
#define FNK0104B_2P8_240x320_ILI9341

```

If the screen **has touch functionality**, configure as below:

```

#define FNK0086A_2P8_240x320_ST7789
#define FNK0102A_1P14_135x240_ST7789
#define FNK0102H_3P5_320x480_ST7796
#define FNK0103B_2P8_240x320_ST7789
#define FNK0103F_2P8_240x320_ILI9341
#define FNK0103L_3P2_240x320_ST7789
#define FNK0103N_3P5_320x480_ST7796
#define FNK0103S_4P0_320x480_ST7796
#define FNK0104A_2P8_240x320_ILI9341
#define FNK0104B_2P8_240x320_ILI9341

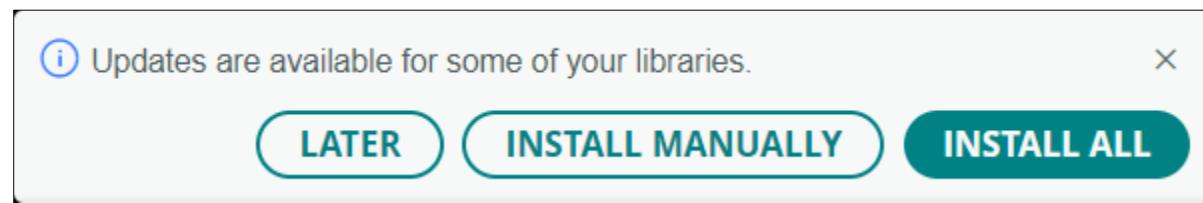
```

Important Note: Only one macro definition should be uncommented.

Save the change and exit the file.

Warning:

If the following update prompt appears, click "LATER". Updating the TFT_eSPI library will reset all related configurations. If you click "INSTALL", please reinstall the TFT_eSPI library to ensure proper project operation.

**Sketch_10.1_TFT_Rainbow**

The following is the program code:

```
1  /*
2  * @ File: Sketch_10.1_TFT_Rainbow.ino
3  * @ Author: [Zhentao Lin]
4  * @ Date: [2025-08-23]
5  */
6
7 #include <TFT_eSPI.h> // TFT display library
8
9 TFT_eSPI tft = TFT_eSPI(); // Create TFT object instance
10
11 unsigned long targetTime = 0; // Timing variable to control animation intervals
12 byte red = 31; // Start with full red
13 byte green = 0; // No green
14 byte blue = 0; // No blue
15 byte state = 0; // State machine variable
16 unsigned int colour = red << 11; // Initial color value: Red only
17
18 void setup(void) {
19     tft.init(); // Initialize the TFT screen
20     tft.setRotation(1); // Set screen rotation (landscape mode)
21     targetTime = millis() + 100; // Set initial target time for rainbow effect
22     tft.fillScreen(TFT_RED); // Fill screen with solid red
23     delay(1000);
24     tft.fillScreen(TFT_GREEN); // Fill screen with solid green
25     delay(1000);
26     tft.fillScreen(TFT_BLUE); // Fill screen with solid blue
27     delay(1000);
28     tft.fillScreen(TFT_BLACK); // Fill screen with solid black
29     delay(1000);
30     tft.fillScreen(TFT_WHITE); // Fill screen with solid white
31     delay(1000);
32 }
```

```
34 void loop() {  
35     if (targetTime < millis()) {      // Check if it's time to start the rainbow animation  
36         targetTime = millis() + 10000; // Set next trigger after 10 seconds  
37     }  
38     for (int i = 0; i < 320; i++) {           // Generate horizontal rainbow using  
39         vertical lines  
40         tft.drawFastVLine(i, 0, tft.height(), colour); // Draw one vertical line  
41         switch (state) {  
42             case 0:  
43                 green += 2; // Transition from red to yellow (increase green)  
44                 if (green == 64) {  
45                     green = 63; // Cap at max green value  
46                     state = 1;  
47                 }  
48                 break;  
49             case 1:  
50                 red--; // Transition from yellow to green (decrease red)  
51                 if (red == 255) {  
52                     red = 0;  
53                     state = 2;  
54                 }  
55                 break;  
56             case 2:  
57                 blue++; // Transition from green to cyan (increase blue)  
58                 if (blue == 32) {  
59                     blue = 31; // Cap at max blue value  
60                     state = 3;  
61                 }  
62                 break;  
63             case 3:  
64                 green -= 2; // Transition from cyan to blue (decrease green)  
65                 if (green == 255) {  
66                     green = 0;  
67                     state = 4;  
68                 }  
69                 break;  
70             case 4:  
71                 red++; // Transition from blue to magenta (increase red)  
72                 if (red == 32) {  
73                     red = 31; // Cap at max red value  
74                     state = 5;  
75                 }  
76                 break;  
77             case 5:
```

```

78     blue--; // Transition from magenta to red (decrease blue)
79     if (blue == 255) {
80         blue = 0;
81         state = 0;
82     }
83     break;
84 }
85 colour = red << 11 | green << 5 | blue; // Combine RGB values into 16-bit color
86 }
87 tft.setTextColor(TFT_BLACK); // Set text color to black
88 tft.setCursor(12, 5); // Set cursor position
89 tft.print("Original Adafruit font!"); // Print simple string
90 tft.setTextColor(TFT_BLACK, TFT_BLACK); // Transparent background
91 tft.drawCentreString("Font size 2", 80, 14, 2); // Font 2
92 tft.drawCentreString("Font size 4", 80, 30, 4); // Font 4
93 tft.drawCentreString("12.34", 80, 54, 6); // Font 6
94 tft.drawCentreString("12.34 is in font size 6", 80, 92, 2); // Font 2
95 float pi = 3.14159; // Value to print
96 int precision = 3; // Number of decimal digits
97 int xpos = 50; // X position
98 int ypos = 110; // Y position
99 int font = 2; // Font type
100 xpos += tft.drawFloat(pi, precision, xpos, ypos, font); // Draw float and update x-
101 position
102 tft.drawString(" is pi", xpos, ypos, font); // Continue drawing string from
103 updated x position
104 delay(6000); // Wait before next cycle
105 }
106 }

```

Code Explanation

Include the necessary header file.

```
7 #include <TFT_eSPI.h> // TFT display library
```

Define TFT display object.

```
9 TFT_eSPI tft = TFT_eSPI(); // Create TFT object instance
```

Initialize the TFT display.

```
19 tft.init(); // Initialize the TFT screen
20 tft.setRotation(1); // Set screen rotation (landscape mode)
```

Change the color of the screen in the sequence of red -> green -> blue -> black -> white.

```
22 tft.fillScreen(TFT_RED); // Fill screen with solid red
23 delay(1000);
24 tft.fillScreen(TFT_GREEN); // Fill screen with solid green
25 delay(1000);
26 tft.fillScreen(TFT_BLUE); // Fill screen with solid blue
27 delay(1000);
```

```

28 tft.fillScreen(TFT_BLACK); // Fill screen with solid black
29 delay(1000);
30 tft.fillScreen(TFT_WHITE); // Fill screen with solid white
31 delay(1000);

```

Implement the rainbow animation effect.

```

38 for (int i = 0; i < 320; i++) {           // Generate horizontal rainbow using vertical lines
39     tft.drawFastVLine(i, 0, tft.height(), colour); // Draw one vertical line
40     switch (state) {
41         case 0:
42             green += 2; // Transition from red to yellow (increase green)
43             if (green == 64) {
44                 green = 63; // Cap at max green value
45                 state = 1;
46             }
47             break;
48         case 1:
49             red--; // Transition from yellow to green (decrease red)
50             if (red == 255) {
51                 red = 0;
52                 state = 2;
53             }
54             break;
55         case 2:
56             blue++; // Transition from green to cyan (increase blue)
57             if (blue == 32) {
58                 blue = 31; // Cap at max blue value
59                 state = 3;
60             }
61             break;
62         case 3:
63             green -= 2; // Transition from cyan to blue (decrease green)
64             if (green == 255) {
65                 green = 0;
66                 state = 4;
67             }
68             break;
69         case 4:
70             red++; // Transition from blue to magenta (increase red)
71             if (red == 32) {
72                 red = 31; // Cap at max red value
73                 state = 5;
74             }
75             break;
76         case 5:

```

```

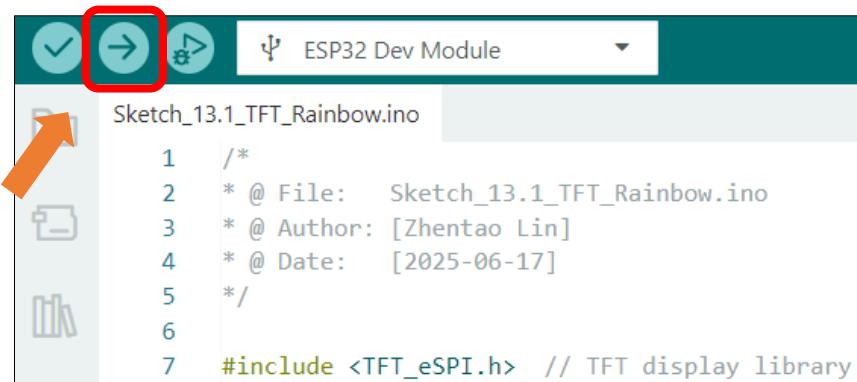
77     blue--; // Transition from magenta to red (decrease blue)
78     if (blue == 255) {
79         blue = 0;
80         state = 0;
81     }
82     break;
83 }
84 colour = red << 11 | green << 5 | blue; // Combine RGB values into 16-bit color
85 }
```

Text display.

```

87 tft.setTextColor(TFT_BLACK);           // Set text color to black
88 tft.setCursor(12, 5);                // Set cursor position
89 tft.print("Original Adafruit font!"); // Print simple string
90 tft.setTextColor(TFT_BLACK, TFT_BLACK); // Transparent background
91 tft.drawCentreString("Font size 2", 80, 14, 2);           // Font 2
92 tft.drawCentreString("Font size 4", 80, 30, 4);           // Font 4
93 tft.drawCentreString("12.34", 80, 54, 6);               // Font 6
94 tft.drawCentreString("12.34 is in font size 6", 80, 92, 2); // Font 2
```

Click “Upload” to upload the code to Freenove_ESP32_S3_Display.



The TFT screen will change colors in the order of red -> green -> blue -> black -> white before displaying text and rainbow effects.





Project 10.2 Flash JPG DMA

Component List

Freenove ESP32 S3 Display x 1



USB cable x1



Component Knowledge

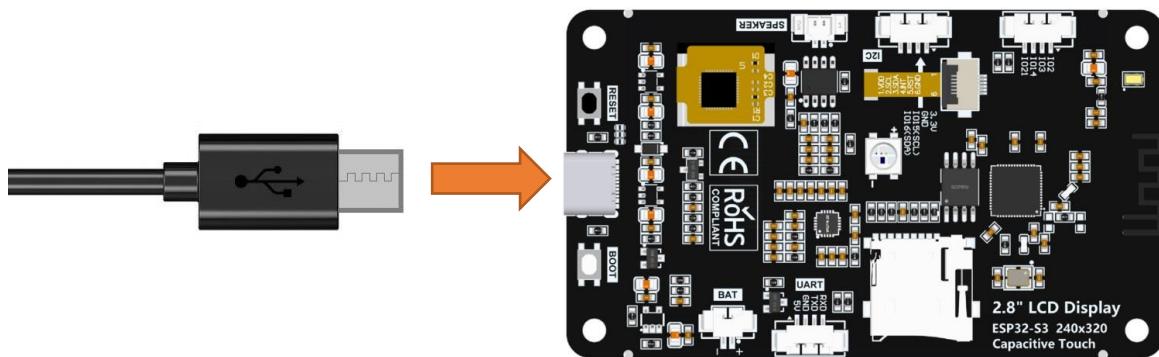
DMA

DMA, or Direct Memory Access, is a hardware feature that allows peripherals to transfer data to and from memory without needing the CPU to be directly involved, dramatically improving overall system efficiency while minimizing processor workload.

The core mechanism of DMA relies on a dedicated DMA controller taking over data transfer tasks. The CPU only needs to initialize the transfer parameters before offloading the operation, allowing computation and I/O operations to proceed in parallel.

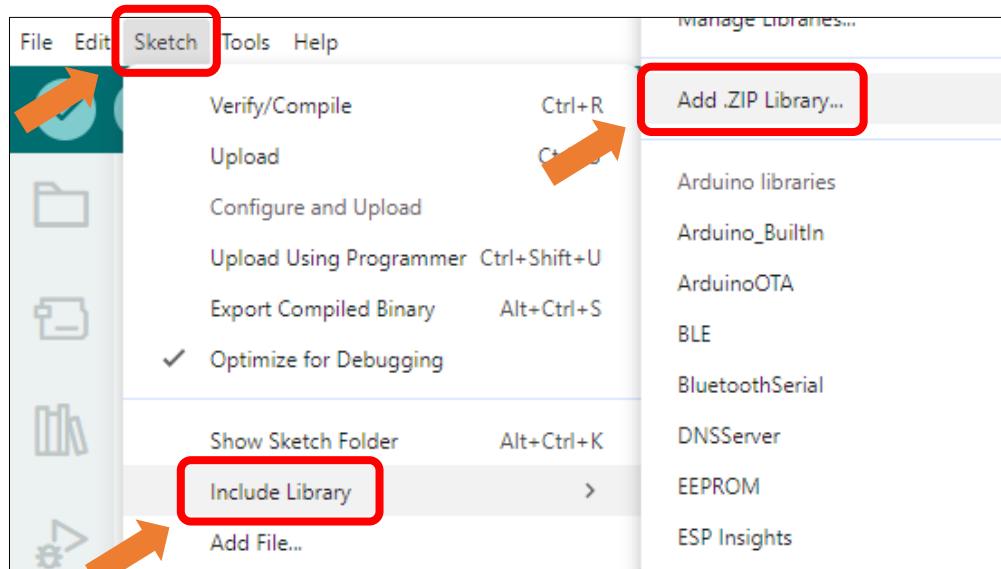
Circuit

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



Sketch

Click Sketch -> Include Library -> Add .ZIP Library...



Install TJpg_Decoder_v1.1.0.zip

Name	Date modified	Type	Size
ESP8266Audio_v2.0.0.zip	2025/5/30 14:06	WinRAR ZIP...	7,821 KB
lvgl_v8.4.0.zip	2025/5/30 13:52	WinRAR ZIP...	26,083 KB
TFT_eSPI_Setups_v1.0.zip	2025/6/11 15:45	WinRAR ZIP...	45 KB
TFT_eSPI_v2.5.43.zip	2025/6/11 15:45	WinRAR ZIP...	5,975 KB
TFT_Touch_v0.3.zip	2025/5/30 13:51	WinRAR ZIP...	14 KB
TJpg_Decoder_v1.1.0.zip	2025/5/30 14:08	WinRAR ZIP...	313 KB

Open "Sketch_10.2_Flash_Jpg_DMA" folder under "Freenove_ESP32_S3_Display\Sketches" and double-click "Sketch_10.2_Flash_Jpg_DMA.ino".

Sketch_10.2_Flash_Jpg_DMA

The following is the program code:

```

1 // Example for library: https://github.com/Bodmer/TJpg_Decoder
2
3 // This example renders a JPEG file stored in Flash memory (see panda.h)
4
5 #include <TFT_eSPI.h> // TFT display library
6 #include "panda.h"      // Include raw JPEG image data array
7 #include <TJpg_Decoder.h> // Include JPEG decoder library
8
9 TFT_eSPI tft = TFT_eSPI(); // Create TFT object instance
10
11 // Callback function to draw decoded JPEG blocks on screen
12 bool tft_output(int16_t x, int16_t y, uint16_t w, uint16_t h, uint16_t* bitmap) {
13     if (y >= tft.height()) return 0; // Stop decoding if off-screen
14     tft.pushImage(x, y, w, h, bitmap); // Draw without DMA

```

```

15     return 1; // Continue decoding next block
16 }
17
18 void setup() {
19     Serial.begin(115200);
20     Serial.println("\n\n Testing TJpg_Decoder library");
21
22     tft.begin(); // Initialize TFT display
23     tft.setTextColor(TFT_WHITE, TFT_BLACK);
24     tft.fillScreen(TFT_BLACK); // Clear screen with black background
25     tft.setRotation(0);
26
27     TJpgDec.setJpgScale(1); // Set scale factor (1=full size)
28     tft.setSwapBytes(true); // Match color byte order
29     TJpgDec.setCallback(tft_output); // Register drawing callback
30 }
31
32 void loop() {
33     uint16_t w = 0, h = 0;
34     TJpgDec.getJpgSize(&w, &h, img_asset, sizeof(img_asset)); // Get image dimensions
35     Serial.print("Width = ");
36     Serial.print(w);
37     Serial.print(", height = ");
38     Serial.print(h);
39
40     uint32_t dt = millis();
41     tft.startWrite();
42     TJpgDec.drawJpg(0, 0, img_asset, sizeof(img_asset)); // Draw the JPEG image
43     tft.endWrite();
44
45     dt = millis() - dt;
46     Serial.print(", dt = ");
47     Serial.print(dt);
48     Serial.println(" ms");
49
50     delay(2000); // Wait before redraw
51 }

```

Code Explanation

Include necessary header files.

```

1 #include <TFT_eSPI.h> // TFT display library
2 #include "panda.h"      // Include raw JPEG image data array
3 #include <TJpg_Decoder.h> // Include JPEG decoder library

```

Create TFT object instance.

```
19 TFT_eSPI tft = TFT_eSPI(); // Create TFT object instance
```

JPEG decoding callback function

```
12  bool tft_output(int16_t x, int16_t y, uint16_t w, uint16_t h, uint16_t* bitmap) {  
13      if (y >= tft.height()) return 0; // Stop decoding if off-screen  
14      tft.pushImage(x, y, w, h, bitmap); // Draw without DMA  
15      return 1; // Continue decoding next block  
16  }
```

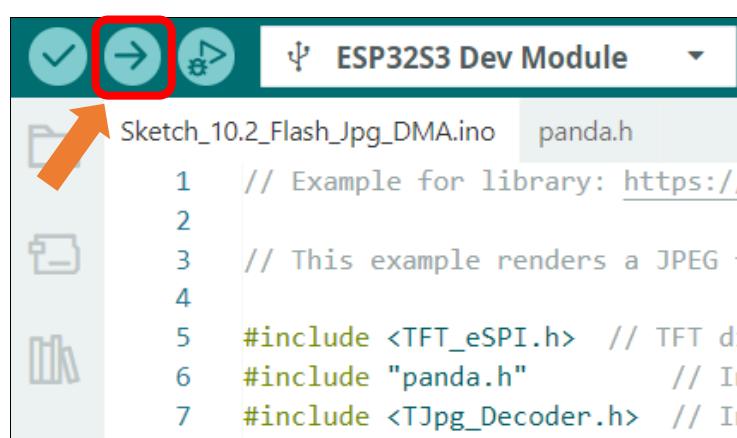
Get JPG size.

```
46  TJpgDec.getJpgSize(&w, &h, img_asset, sizeof(img_asset)); // Get image dimensions
```

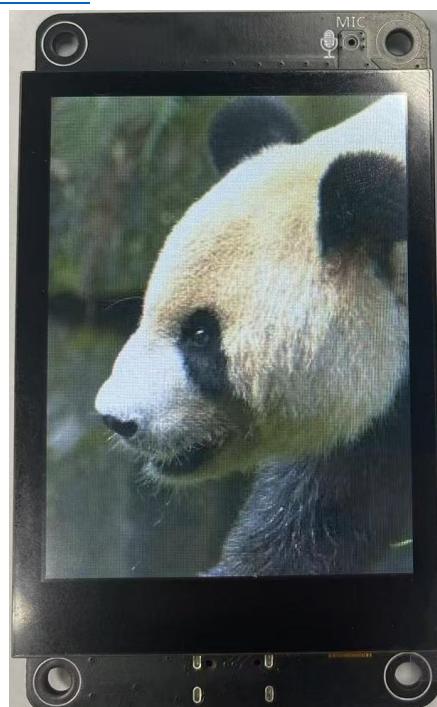
Draw images on the TFT screen.

```
57  tft.startWrite();  
58  TJpgDec.drawJpg(0, 0, img_asset, sizeof(img_asset)); // Draw the JPEG image  
59  tft.endWrite();
```

Click “Upload” to upload the code to Freenove ESP32 Display



After the code is uploaded, an image will be displayed on the TFT screen. The image is from https://github.com/Bodmer/TJpg_Decoder





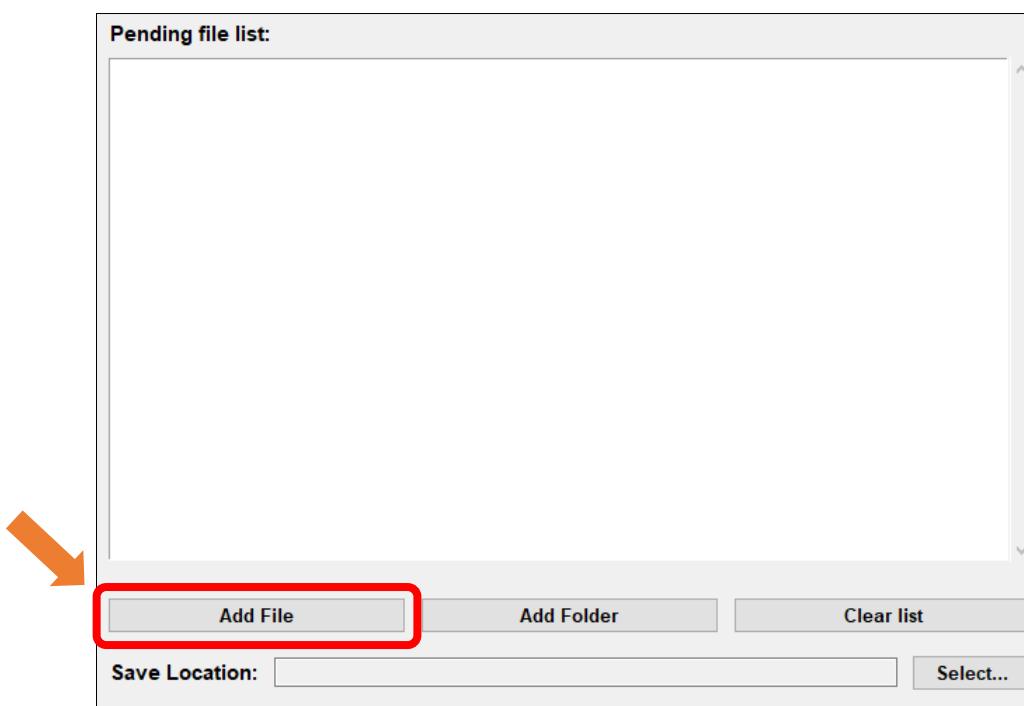
Custom image display

You can customize the image displayed on the display according to your personal preferences.

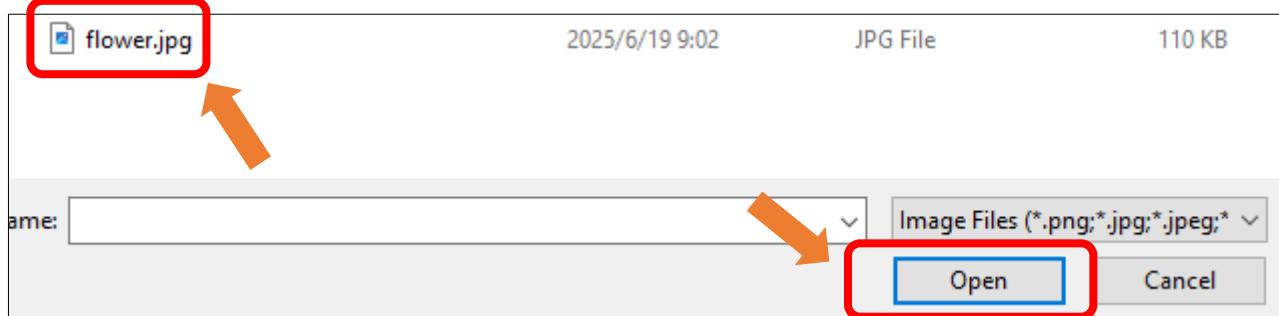
First, open **Freenove_ESP32_S3_Display\Sketches\Sketch_10.2_Flash_Jpg_DMA\Freenove Image Tool.exe**

Name	Date modified
Picture	2025/6/19 14:36
Freenove Image Tool.exe	2025/6/23 8:36
panda.h	2025/6/19 15:31
Sketch_10.2_Flash_Jpg_DMA.ino	2025/6/19 15:39

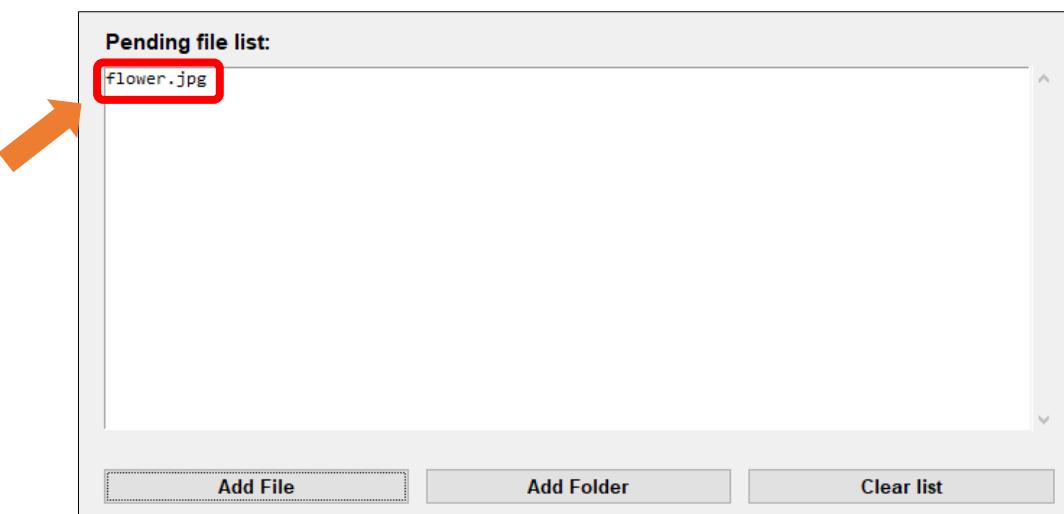
Click “Add File”



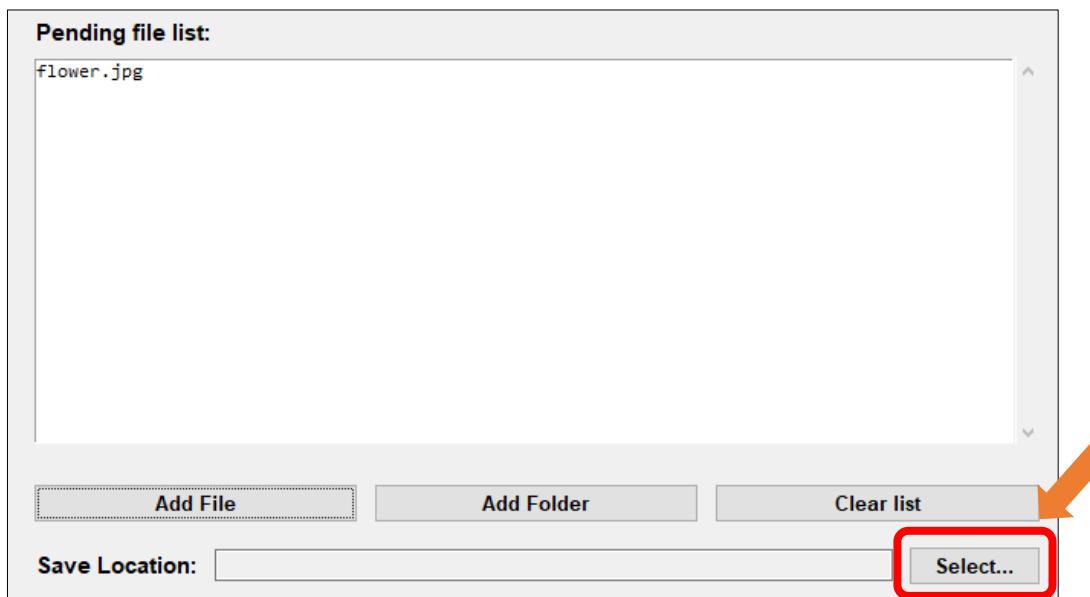
Select any image you like



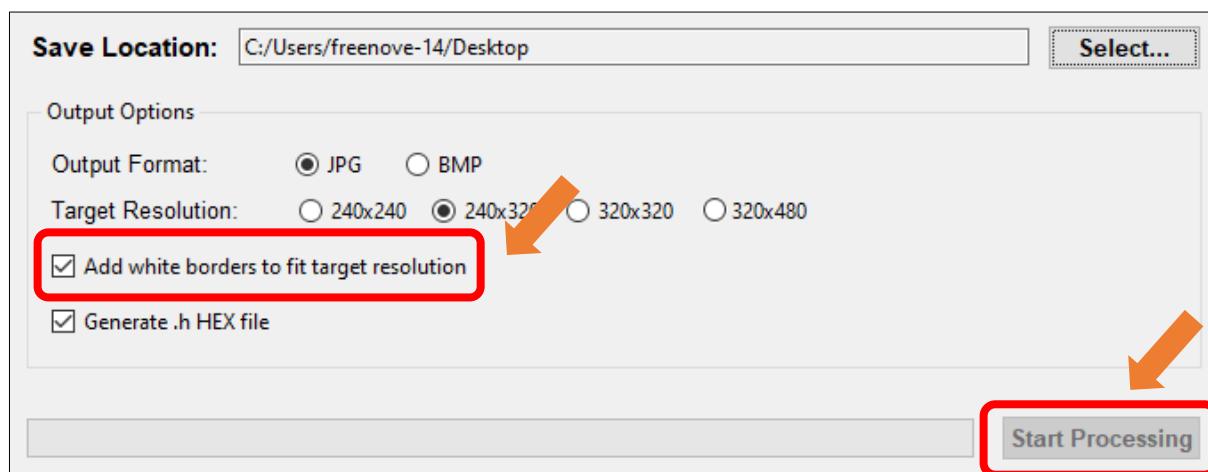
The image files from your folder will now appear in the **Pending File List**.



Click "Select..." to change the save location.

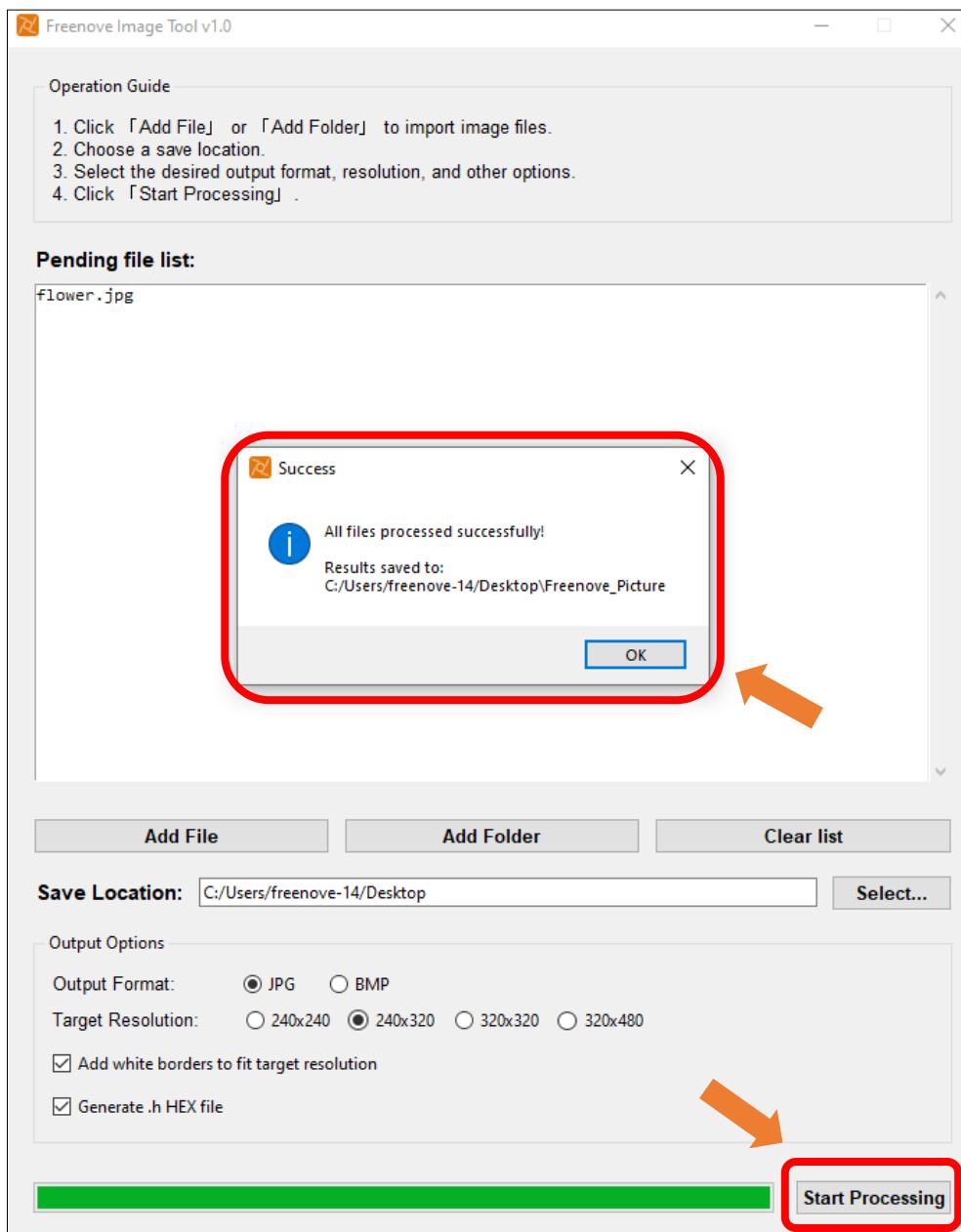


The resolution size is selected according to the [screen resolution](#). Check the "**Add white borders to fit target resolution**" and "**Generate .h HEX file**" options.





Click **Start Processing**. Wait for the progress bar to complete and the target folder will be generated.



There will be three folders in the generated folder

original_images: backup of images before processing

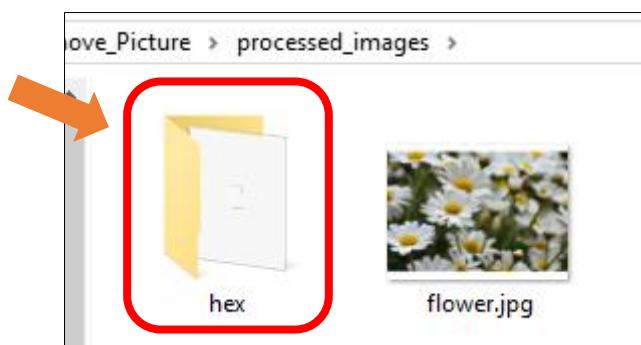
processed_images: processed images

processed_images\hex: generated .h files corresponding to the images

Double click to open **processed_images**

Name	Date modified
original_images	2025/6/19 15:13
processed_images	2025/6/19 15:13

Double click to open **hex**



Replace the entire content of `panda.h` with the copied data from the `.h file`, then upload the sketch again.

```
Sketch_10.2_Flash_Jpg_DMA.ino  panda.h

1  /*
2   * If you need to customize the displayed image, first use the Freenove Image Tool
3   * to crop it to the appropriate width and height for your display.
4
5   * The tool will automatically adjust the image quality to ensure proper display.
6
7   * Paste the generated array into this file, ensuring the correct array format:
8
9   const uint8_t name[] PROGMEM = {
10
11  to start and end with:
12
13 };
14 */
15
16 const unsigned char img_asset[] PROGMEM = {
17  0xFF, 0xD8, 0xFF, 0xE0, 0x00, 0x10, 0x4A, 0x46, 0x49, 0x46, 0x00, 0x01,
18  0x01, 0x00, 0x00, 0x01, 0x00, 0x01, 0x00, 0x00, 0xFF, 0xDB, 0x00, 0x43,
19  0x00, 0x05, 0x03, 0x04, 0x04, 0x04, 0x03, 0x05, 0x04, 0x04, 0x04, 0x05,
20  0x05, 0x05, 0x06, 0x07, 0x0C, 0x08, 0x07, 0x07, 0x07, 0x07, 0x0F, 0x0B,
21  0x0B, 0x09, 0x0C, 0x11, 0x0F, 0x12, 0x12, 0x11, 0x0F, 0x11, 0x11, 0x13,
22  0x16, 0x1C, 0x17, 0x13, 0x14, 0x1A, 0x15, 0x11, 0x11, 0x18, 0x21, 0x18,
23  0x1A, 0x1D, 0x1D, 0x1F, 0x1F, 0x13, 0x17, 0x22, 0x24, 0x22, 0x1E,
24  0x24, 0x1C, 0x1E, 0x1F, 0x1E, 0xFF, 0xDB, 0x00, 0x43, 0x01, 0x05, 0x05,
25  0x05, 0x07, 0x06, 0x07, 0x0E, 0x08, 0x08, 0x0E, 0x1E, 0x14, 0x11, 0x14,
26  0x1E, 0x1E,
27  0x1E, 0x1E,
28  0x1E, 0x1E,
29  0x1E, 0x1E,
30  0x1E, 0x1E, 0xFF, 0xC0, 0x00, 0x11, 0x08, 0x01, 0x40, 0x01, 0xE0, 0x03,
31  0x01, 0x22, 0x00, 0x02, 0x11, 0x01, 0x03, 0x11, 0x01, 0xFF, 0xC4, 0x00,
32  0x1C, 0x00, 0x00, 0x02, 0x02, 0x03, 0x01, 0x01, 0x01, 0x00, 0x00, 0x00,
33  0x00, 0x00,
```



The image will display on the screen.



Note:

To adjust the image display orientation, modify the following code in Sketch_10.2_Flash_Jpg_DMA.ino:

```
42  tft.setRotation(uint8_t rotation);
```

Value	Rotation Angle	Description
0	0°	Default orientation (no rotation)
1	90°	Clockwise 90-degree rotation
2	180°	Clockwise 180-degree rotation
3	270°	Clockwise 270-degree rotation

Chapter 11 LVGL

Project 11.1 LVGL

Component List

Freenove ESP32 S3 Display x 1	 A black Freenove ESP32 S3 Display module. It features a central TFT screen with a resolution of 240x240 pixels, surrounded by various pins and connectors. The word "FREENOVE" is printed vertically on the left side.	USB cable x1	 A standard black USB cable with a Type-A connector on one end and a Type-B connector on the other, coiled on a light-colored surface.
-------------------------------	--	--------------	--

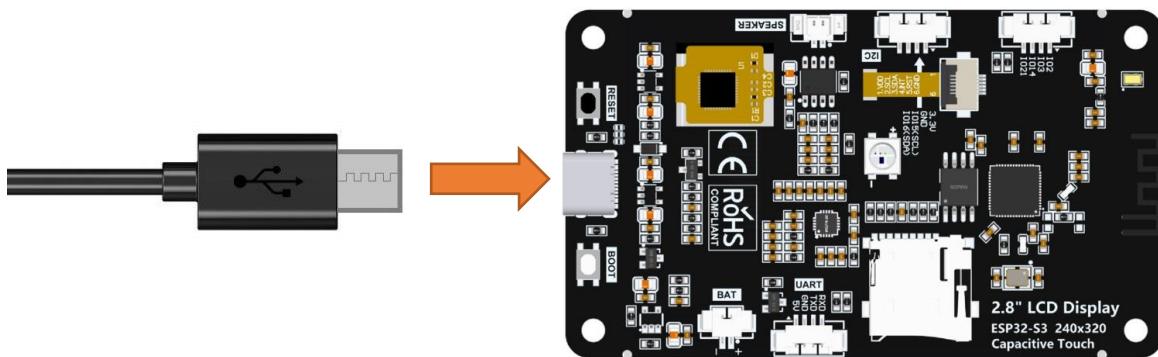
Component Knowledge

LVGL is a widely-used embedded GUI library that is implemented in pure C, making it highly portable and performant. It offers rich features and content, supporting both display and input devices such as touchscreens and keyboards.

	Features supported by LVGL
1	Powerful building blocks such as buttons, charts, lists, sliders, images, and more.
2	Advanced graphics with animation, anti-aliasing, opacity, and smooth scrolling.
3	Various input devices, such as touchpads, mice, keyboards, encoders, and more.
4	Multiple languages with UTF-8 encoding.
5	Multiple display types, including TFT and monochrome displays.
6	Fully customizable graphical elements.
7	LVGL can be used independently of any microcontroller or display hardware.
8	Highly extensible and can be configured to use very little memory (e.g. 64 kB of flash and 16 kB of RAM)
9	It can be used with or without an operating system, and supports external memory and GPUs as optional features.
10	Single-frame buffer operation, even with advanced graphics effects.
11	Written in C language to achieve maximum compatibility (compatible with C++ as well).
12	LVGL has a simulator that allows for embedded GUI design on a PC without any embedded hardware.
13	Resources to help developers quickly get started with the library, including tutorials, examples, and themes.
14	A wide range of resources.

Circuit

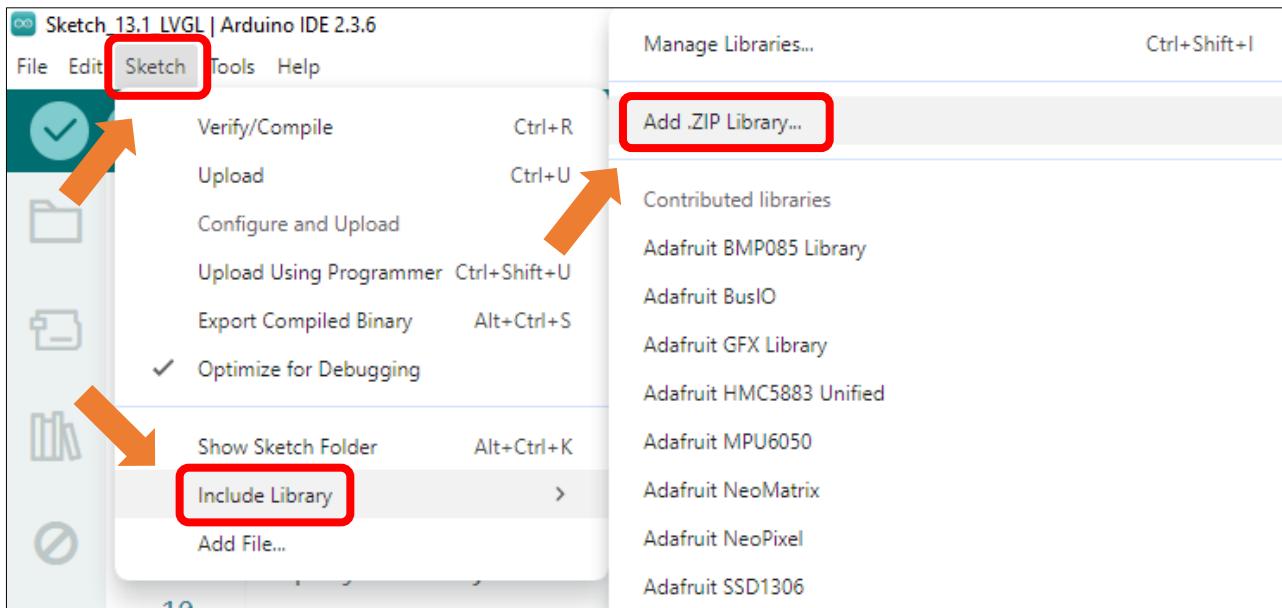
Connect Freenove ESP32 -S3 to the computer using the USB cable.



Sketch

Install Libraries

Click Sketch -> Include Library -> Add .ZIP Library...



Install lvgl_v8.4.0.zip

Name	Date modified	Type	Size
ESP8266Audio_v2.0.0.zip	2025/5/30 14:06	WinRAR ZIP...	7,821 KB
lvgl_v8.4.0.zip	2025/5/30 13:52	WinRAR ZIP...	26,083 KB
TFT_eSPI_Setups_v1.0.zip	2025/6/11 15:45	WinRAR ZIP...	45 KB
TFT_eSPI_v2.5.43.zip	2025/6/11 15:45	WinRAR ZIP...	5,975 KB
TFT_Touch_v0.3.zip	2025/5/30 13:51	WinRAR ZIP...	14 KB
Tjpg_Decoder_v1.1.0.zip	2025/5/30 14:08	WinRAR ZIP...	313 KB

Open "Sketch_11.1_LVGL" folder under "Freenove_ESP32_S3_Display\Sketches" and double-click "Sketch_11.1_LVGL.ino".

Sketch_11.1_LVGL

The following is the program code:

```
1  /*
2   * @ File: Sketch_11.1_LVGL.ino
3   * @ Author: [Zhentao Lin]
4   * @ Date: [2025-06-20]
5   */
6
7 #include "display.h"
8
9 Display screen;
10
11 void setup()
12 {
13     /* prepare for possible serial debug */
14     Serial.begin( 115200 );
15
16     /*** Init screen ***/
17     screen.init();
18
19     String LVGL_Arduino = "Hello Arduino! ";
20     LVGL_Arduino += String('V') + lv_version_major() + "." + lv_version_minor() + "." +
21     lv_version_patch();
22
23     Serial.println( LVGL_Arduino );
24     Serial.println( "I am LVGL_Arduino" );
25
26     /* Create simple label */
27     lv_obj_t *label = lv_label_create( lv_scr_act() );
28     lv_label_set_text( label, LVGL_Arduino.c_str() );
29     lv_obj_align( label, LV_ALIGN_CENTER, 0, 0 );
30
31     Serial.println( "Setup done" );
32 }
33
34 void loop()
35 {
36     screen.routine(); /* let the GUI do its work */
37     delay( 5 );
38 }
```

Code Explanation

Include the header file.

```
7 #include "display.h"
```

Set the baud rate to 115200

```
19 Serial.begin( 115200 );
```

Initialize the screen.

```
11 screen.init();
```

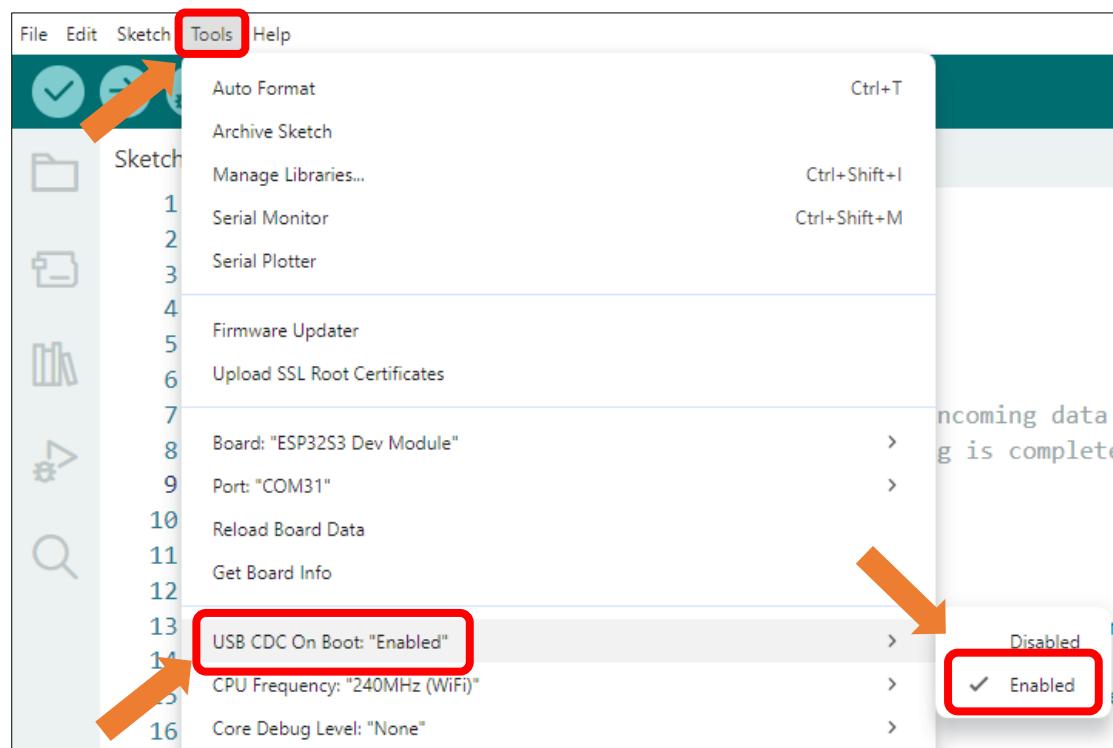
Configure the screen interface.

```
15 String LVGL_Arduino = "Hello Arduino! ";
16 LVGL_Arduino += String('V') + lv_version_major() + "." + lv_version_minor() + "." +
17 lv_version_patch();
18
19 Serial.println( LVGL_Arduino );
20 Serial.println( "I am LVGL_Arduino" );
21
22 /* Create simple label */
23 lv_obj_t *label = lv_label_create( lv_scr_act() );
24 lv_label_set_text( label, LVGL_Arduino.c_str() );
25 lv_obj_align( label, LV_ALIGN_CENTER, 0, 0 );
```

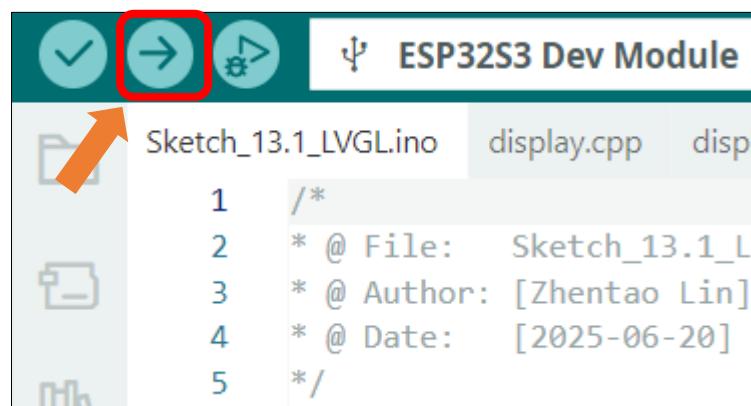
Let the LVGL handle the tasks.

```
46 screen.routine(); /* let the GUI do its work */
```

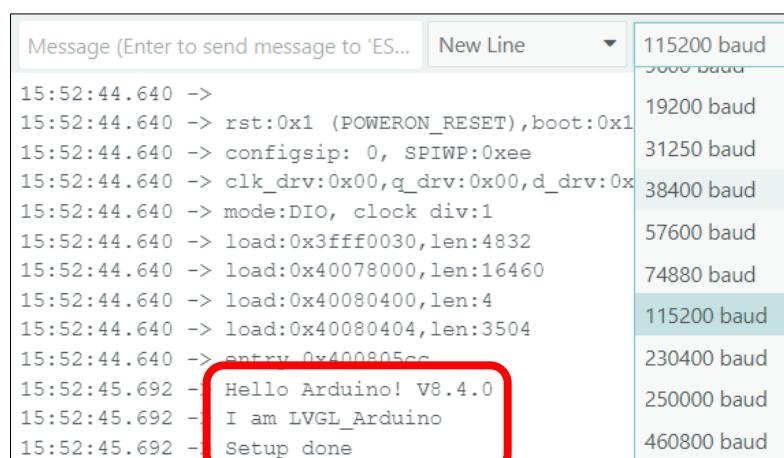
Enable the "USB CDC On Boot" feature.



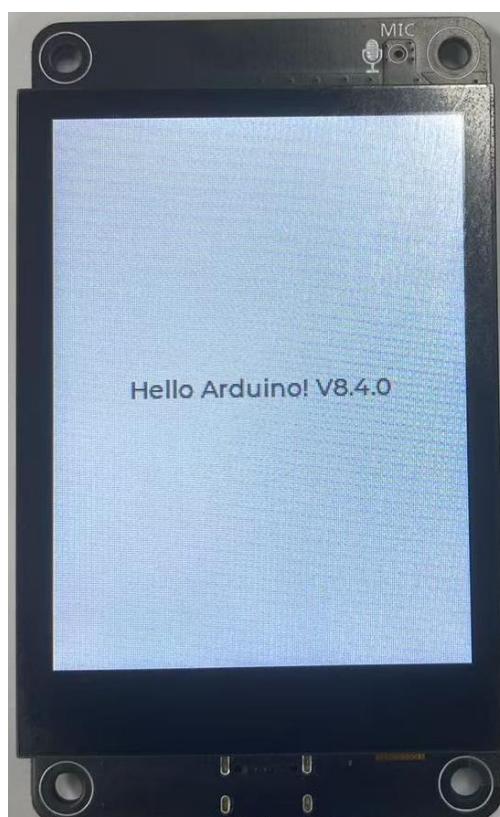
Click “Upload” to upload the code to Freenove ESP32 Display. Set the baud rate to 115200.



Data will be printed on the serial monitor.



The text “Hello Arduino! V8.4.0” will be displayed on the screen.



Chapter 12 LVGL Arduino

Project 12.1 LVGL Arduino

Component List

Freenove ESP32 S3 Display x 1

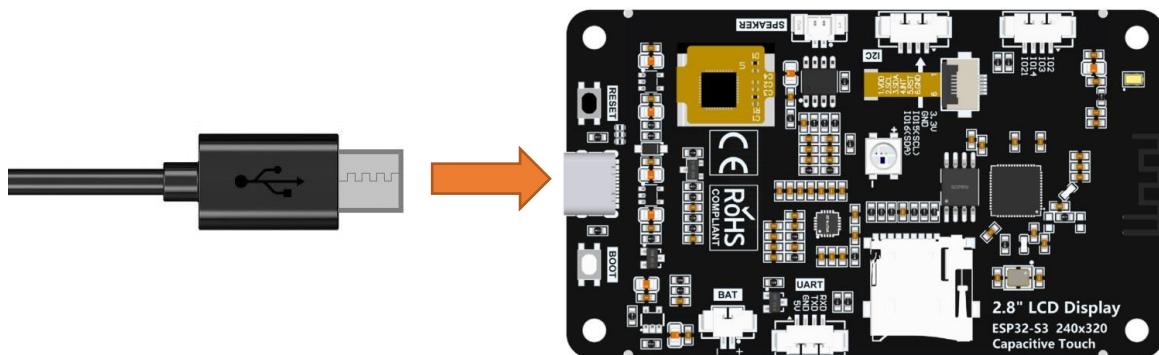


USB cable x1



Circuit

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



Sketch

Open “**Sketch_12.1_Lvgl_Arduino**” folder under “**Freenove_ESP32_S3_Display\Sketches**” and double-click “**Sketch_12.1_Lvgl_Arduino.ino**”.

Sketch_12.1_Lvgl_Arduino

The following is the program code:

```

1  /*Using LVGL with Arduino requires some extra steps:
2   *Be sure to read the docs here: https://docs.lvgl.io/master/get-
3   *started/platforms/arduino.html */
4

```

```
5 #include <lvgl.h>
6 #include "demos/lv_demos.h"
7 #include <TFT_eSPI.h>
8
9 #ifdef FNK0104B_2P8_240x320_ILI9341
10     #include "FT6336U.h"
11 #endif
12
13 /*To use the built-in examples and demos of LVGL uncomment the includes below respectively.
14 *You also need to copy `lvgl/examples` to `lvgl/src/examples`. Similarly for the demos
15 `lvgl/demos` to `lvgl/src/demos`.
16 Note that the `lv_examples` library is for LVGL v7 and you shouldn't install it for this
17 version (since LVGL v8)
18 as the examples and demos are now part of the main LVGL library. */
19
20 /*Change to your screen resolution*/
21 #define TFT_DIRECTION 0 //Select TFT Direction (0 - 3)
22
23 #ifdef FNK0104B_2P8_240x320_ILI9341
24     #define I2C_SCL 15
25     #define I2C_SDA 16
26     #define INT_N_PIN 17
27     #define RST_N_PIN 18
28 #endif
29
30 #define TFT_SCREEN_WIDTH 240
31 #define TFT_SCREEN_HEIGHT 320
32
33 static const uint16_t screenWidth = TFT_SCREEN_WIDTH;
34 static const uint16_t screenHeight = TFT_SCREEN_HEIGHT;
35 static const uint16_t screenHeightBuf = TFT_SCREEN_HEIGHT / 10;
36 static lv_disp_draw_buf_t draw_buf;
37 static lv_color_t draw_buf1[screenWidth * screenHeightBuf];
38
39 TFT_eSPI tft = TFT_eSPI(screenWidth, screenHeight); /* TFT instance */
40
41 #ifdef FNK0104B_2P8_240x320_ILI9341
42     FT6336U_ft6336u(I2C_SDA, I2C_SCL, RST_N_PIN, INT_N_PIN);
43     FT6336U_TouchPointType tp;
44 #endif
45
46 #if LV_USE_LOG != 0
47 /* Serial debugging */
48 void my_print(const char * buf)
```

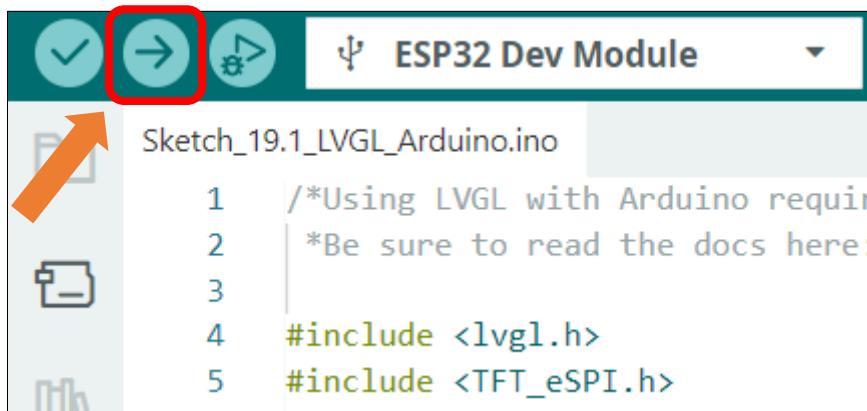


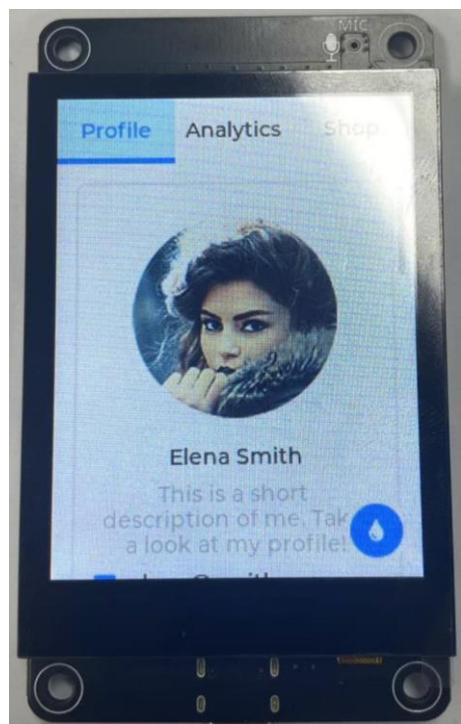
```
49     {
50         Serial.printf(buf);
51         Serial.flush();
52     }
53 #endif
54
55 /* Display flushing */
56 void my_disp_flush( lv_disp_drv_t *disp_drv, const lv_area_t *area, lv_color_t *color_p )
57 {
58     uint32_t w = ( area->x2 - area->x1 + 1 );
59     uint32_t h = ( area->y2 - area->y1 + 1 );
60
61     tft.startWrite();
62     tft.setAddrWindow( area->x1, area->y1, w, h );
63     tft.pushColors( ( uint16_t * )&color_p->full, w * h, true );
64     tft.endWrite();
65
66     lv_disp_flush_ready( disp_drv );
67 }
68
69 #ifdef FNK0104B_2P8_240x320_ILI9341
70 void my_touchpad_read( lv_indev_drv_t * indev_driver, lv_indev_data_t * data )
71 {
72     uint16_t touchX, touchY;
73
74     //bool touched = tft.getTouch( &touchX, &touchY, 600 );
75     tp = ft6336u.scan();
76     int touched = tp.touch_count;
77
78     if( !touched )
79     {
80         data->state = LV_INDEV_STATE_REL;
81     }
82     else
83     {
84         int x = tp.tp[0].x;
85         int y = tp.tp[0].y;
86         if(x >= 0 && x < screenWidth && y >= 0 && y < screenHeight)
87         {
88             data->state = LV_INDEV_STATE_PR;
89             data->point.x = tp.tp[0].x;
90             data->point.y = tp.tp[0].y;
91         }
92     }
93 }
```

```
93 }
94 #endif
95
96 void setup()
97 {
98     Serial.begin( 115200 ); /* prepare for possible serial debug */
99
100    String LVGL_Arduino = "Hello Arduino! ";
101    LVGL_Arduino += String('V') + lv_version_major() + "." + lv_version_minor() + "." +
102    lv_version_patch();
103
104    Serial.println( LVGL_Arduino );
105    Serial.println( "I am LVGL_Arduino" );
106
107    tft.begin(); /* TFT init */
108    tft.setRotation(TFT_DIRECTION);
109 #ifdef FNK0104B_2P8_240x320_ILI9341
110     ft6336u.begin();
111 #endif
112    lv_init();
113
114 #if LV_USE_LOG != 0
115     lv_log_register_print_cb( my_print ); /* register print function for debugging */
116 #endif
117
118    lv_disp_draw_buf_init(&draw_buf, draw_buf1, NULL, screenWidth * screenHeightBuf);
119
120    /*Initialize the display*/
121    static lv_disp_drv_t disp_drv;
122    lv_disp_drv_init( &disp_drv );
123    /*Change the following line to your display resolution*/
124    disp_drv.hor_res = screenWidth;
125    disp_drv.ver_res = screenHeight;
126    disp_drv.flush_cb = my_disp_flush;
127    disp_drv.draw_buf = &draw_buf;
128    lv_disp_drv_register( &disp_drv );
129
130 #ifdef FNK0104B_2P8_240x320_ILI9341
131     /*Initialize the (dummy) input device driver*/
132     static lv_indev_drv_t indev_drv;
133     lv_indev_drv_init( &indev_drv );
134     indev_drv.type = LV_INDEV_TYPE_POINTER;
135     indev_drv.read_cb = my_touchpad_read;
136     lv_indev_drv_register( &indev_drv );
```

```
137 #endif
138
139 /* Create simple label */
140 // lv_obj_t *label = lv_label_create( lv_scr_act() );
141 // lv_label_set_text( label, "Hello Ardino and LVGL!" );
142 // lv_obj_align( label, LV_ALIGN_CENTER, 0, 0 );
143
144 /* Try an example. See all the examples
145 * online: https://docs.lvgl.io/master/examples.html
146 * source codes:
147 https://github.com/lvgl/lvgl/tree/e7f88efa5853128bf871dde335c0ca8da9eb7731/examples */
148 //lv_example_btn_1();
149
150 /*Or try out a demo. Don't forget to enable the demos in lv_conf.h. E.g.
151 LV_USE_DEMOS_WIDGETS*/
152 lv_demo_widgets();
153 // lv_demo_benchmark();
154 // lv_demo_keypad_encoder();
155 // lv_demo_music();
156 // lv_demo_printer();
157 // lv_demo_stress();
158
159 Serial.println( "Setup done" );
160 }
161
162 void loop()
163 {
164 lv_timer_handler(); /* let the GUI do its work */
165 delay( 5 );
166 }
```

Click “Upload” to upload the code to Freenove ESP32 Display







What's next?

Thank you again for choosing Freenove products.

THANK YOU for participating in this learning experience!

We have reached the end of this Tutorial. If you find errors, omissions, or you have suggestions and/or questions about the Tutorial or component contents of this Kit, please feel free to contact us:
support@freenove.com

We will make every effort to make changes and correct errors as soon as feasibly possible and publish a revised version.

If you want to learn more about Arduino, ESP32, Raspberry Pi Pico W, Raspberry Pi, Smart Cars, Robotics and other interesting products in science and technology, please continue to visit our website. We will continue to launch fun, cost effective, innovative and exciting products.

Thank you again for choosing Freenove products.