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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**

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# Preface

Raspberry Pi Pico is a tiny, fast, and versatile board built using RP2040, a brand new microcontroller chip designed by Raspberry Pi in the UK. Supporting Python and C/C++ development, it is perfect for DIY projects. In this tutorial, we use Arduino to learn Pico. If you want to learn the Python version, please refer to another tutorial: [python\\_tutorial.pdf](#).

Using Arduino IDE as the development environment for Raspberry Pi Pico allows users to learn Pico better and more quickly, which is just like developing Arduino programs. In addition, resources such as Arduino's libraries can be directly used to greatly improve the efficiency of development.

If you have not downloaded the related material for Raspberry Pi Pico tutorial, you can download it from this link:

[https://github.com/Freenove/Freenove\\_Super\\_Starter\\_Kit\\_for\\_Raspberry\\_Pi\\_Pico](https://github.com/Freenove/Freenove_Super_Starter_Kit_for_Raspberry_Pi_Pico)

In this tutorial, we divide each project into 4 sections:

- 1, Component list: helps users to learn and find what components are needed in each project.
- 2, Component Knowledge: allows you to learn the features and usage of the components.
- 3, Circuit: assists to build circuit for each project.
- 4, Sketches and comments: makes it easier for users to learn to use Raspberry Pi Pico and make secondary development.

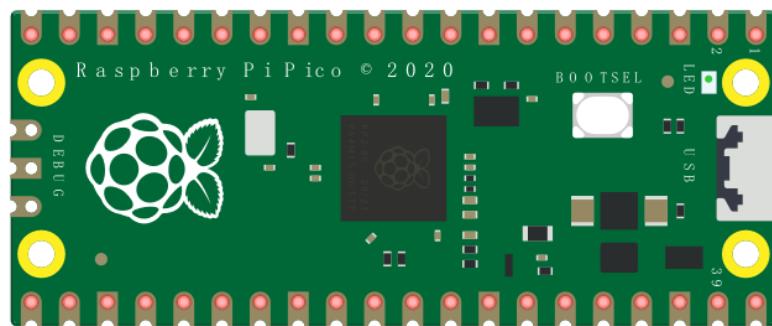
After completing the projects in this tutorial, you can also combine the components in different projects to make your own smart homes, smart car, robot, etc., bringing your imagination and creativity to life with Raspberry Pi Pico.

If you have any problems or difficulties using this product, please contact us for quick and free technical support: [support@freenove.com](mailto:support@freenove.com)

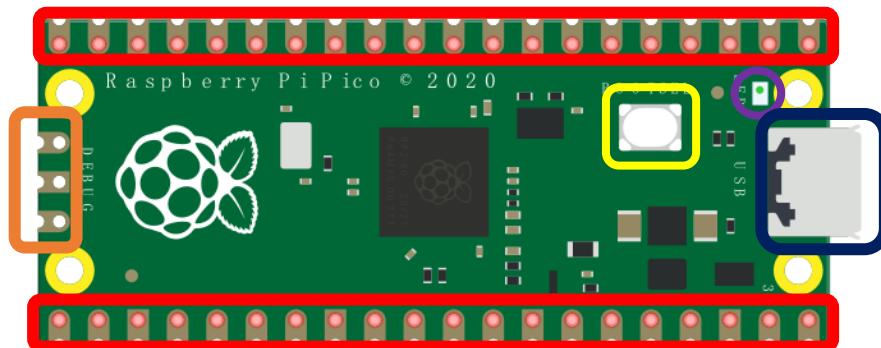
## Raspberry Pi Pico

Raspberry Pi Pico applies to all chapters except Wireless in this tutorial.

Before learning Pico, we need to know about it. Below is an imitated diagram of Pico, which looks very similar to the actual Pico.

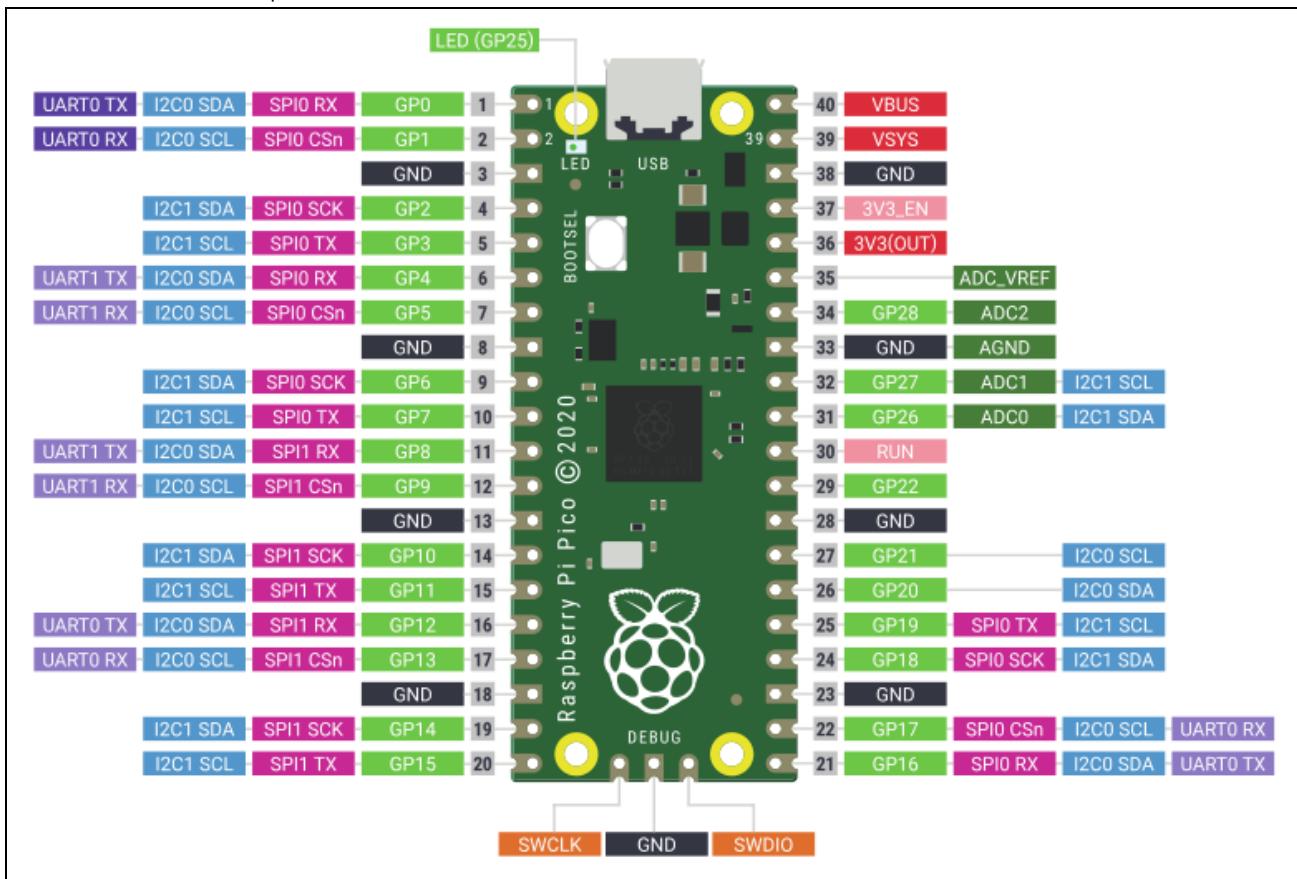


The hardware interfaces are distributed as follows:



Frame color	Description
	Pins
	BOOTSEL button
	USB port
	LED
	Debugging

Function definition of pins:



Color	Pins	Color	Pins
Black	GND	Red	Power
Green	GPIO	Dark Green	ADC
Magenta	UART(default)	Lavender	UART
Magenta	SPI	Light Blue	I2C
Pink	System Control	Orange	Debugging

For details: <https://datasheets.raspberrypi.org/pico/pico-datasheet.pdf>

## UART, I2C, SPI Default Pin

In Arduino IDE, the default pins of serial port are Pin0 and Pin1.

Note: Serial port is virtualized by RP2040. Therefore, when using the serial port, please enable the verification function of DTR. It can work under any baud rate.

### UART

Function	Default
UART_BAUDRATE	X
UART_BITS	8
UART_STOP	1
UART_TX	Pin 0
UART_RX	Pin 1

### I2C

Function	Default
I2C Frequency	400000
I2C_SDA	Pin 4
I2C_SCL	Pin 5

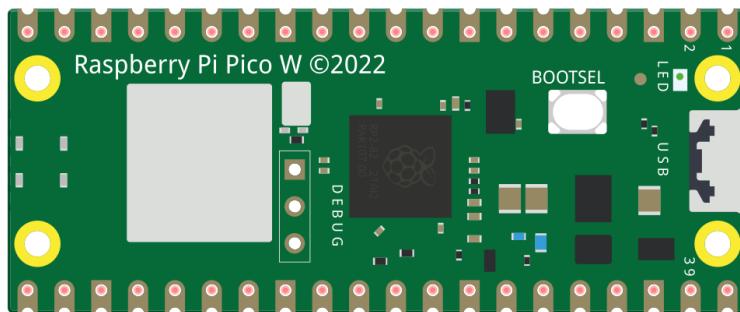
### SPI

Function	Default
SPI_BAUDRATE	1000000
SPI_POLARITY	0
SPI_PHASE	0
SPI_BITS	8
SPI_FIRSTBIT	MSB
SPI_SCK	Pin 18
SPI_MOSI	Pin 19
SPI_MISO	Pin 16
SPI_SS	Pin 17

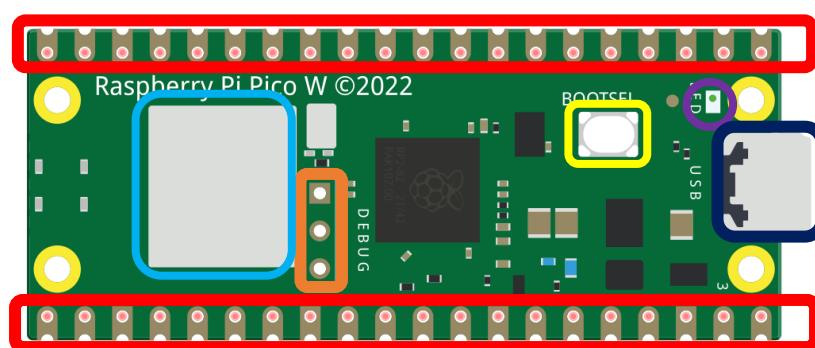
## Raspberry Pi Pico W

Raspberry Pi Pico W applies to all chapters in this tutorial.

Raspberry Pi Pico W adds CYW43439 as the WiFi function based on Raspberry Pi Pico. It is connected to RP2040 chip through SPI interface.

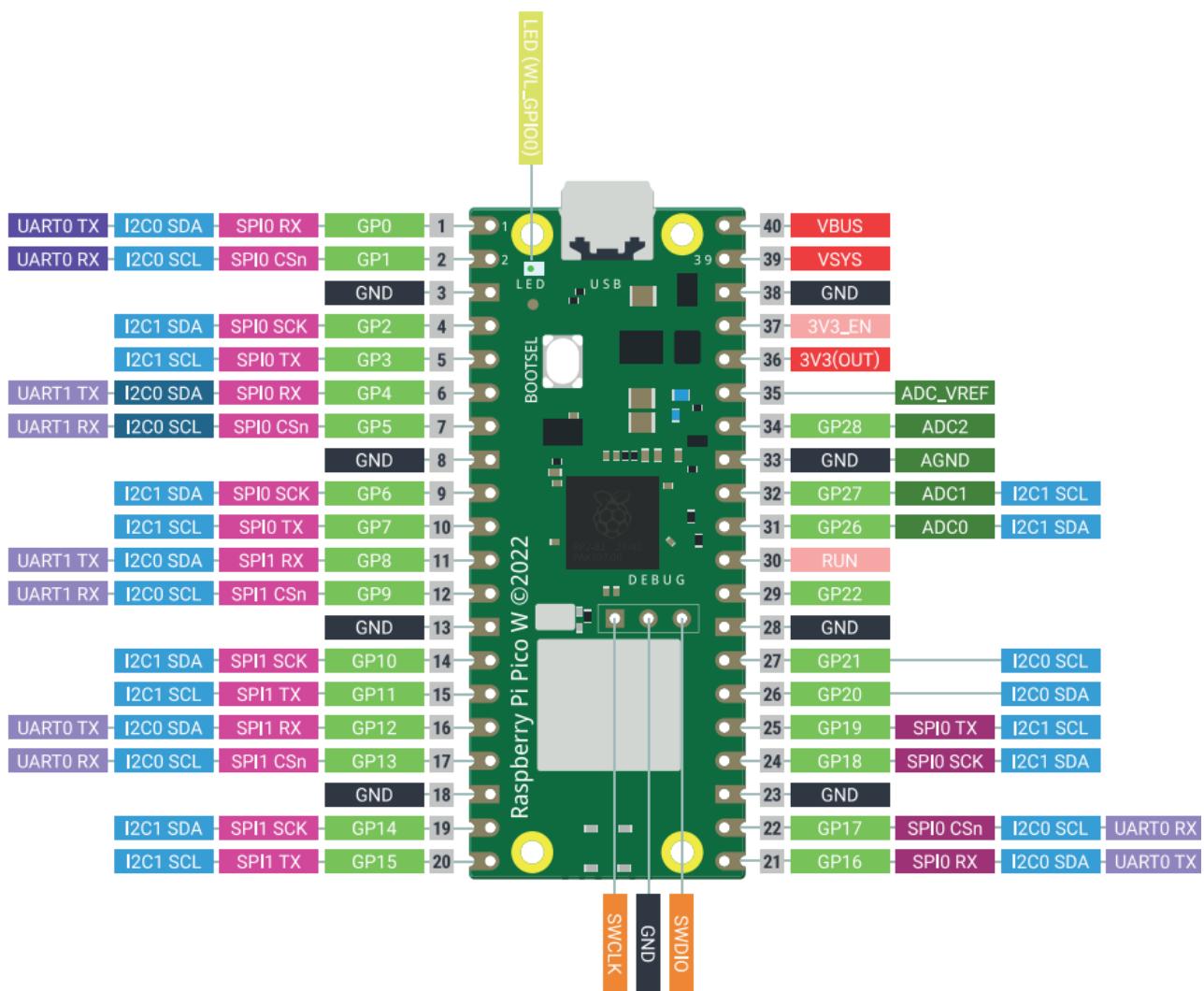


The hardware interfaces are distributed as follows:



Frame color	Description
	Pins
	BOOTSEL button
	USB port
	LED
	Debugging
	Wireless

Function definition of pins:



Color	Pins	Color	Pins
Black	GND	Red	Power
Green	GPIO	Dark Green	ADC
Purple	UART(default)	Purple	UART
Magenta	SPI	Blue	I2C
Orange	System Control	Grey	Debugging

For details: <https://datasheets.raspberrypi.com/picow/pico-w-datasheet.pdf>



## UART, I2C, SPI, Wireless Default Pin

In Arduino IDE, the default pins of serial port are Pin0 and Pin1.

Note: Serial port is virtualized by RP2040. Therefore, when using the serial port, please enable the verification function of DTR. It can work under any baud rate.

### UART

Function	Default
UART_BAUDRATE	X
UART_BITS	8
UART_STOP	1
UART_TX	Pin 0
UART_RX	Pin 1

### I2C

Function	Default
I2C Frequency	400000
I2C_SDA	Pin 4
I2C_SCL	Pin 5

### SPI

Function	Default
SPI_BAUDRATE	1000000
SPI_POLARITY	0
SPI_PHASE	0
SPI_BITS	8
SPI_FIRSTBIT	MSB
SPI_SCK	Pin 18
SPI_MOSI	Pin 19
SPI_MISO	Pin 16
SPI_SS	Pin 17

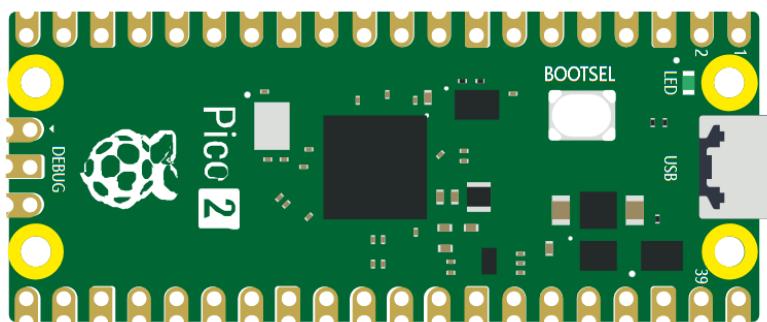
### Wireless

Function	Default
WL_ON	GPIO23
WL_D	GPIO24
WL_CLK	GPIO29_ADC
WL_CS	GPIO25

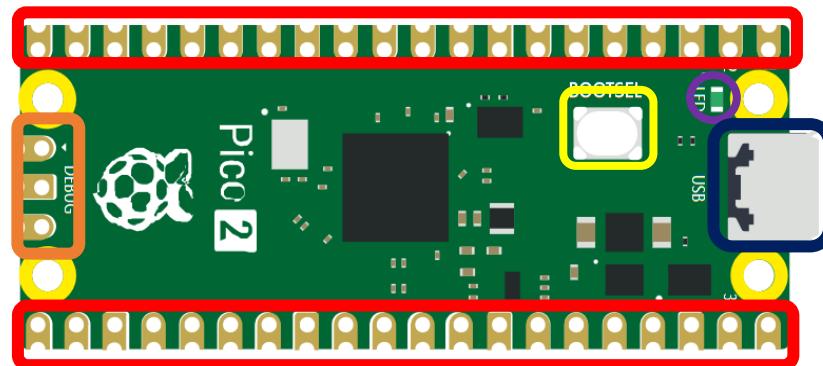
## Raspberry Pi Pico 2

Raspberry Pi Pico 2 is applicable to all chapters in this tutorial except RFID and those involving WiFi.

Raspberry Pi Pico 2 uses RP2350 chip as the main controller, which equipped with dual Cortex-M33 or Hazard3 processors, capable of running up to 150 MHz, providing a significant boost in processing power, compared with the original Pico. It also doubles the memory with 520KB of SRAM and 4MB of onboard flash memory, with the ADC sampling frequency increasing to up to 500ksps. In addition, it adds 8 more PWM channels, and features additional interfaces like 2× Timer with 4 alarms, 1× AON Timer and 4 x PIO.

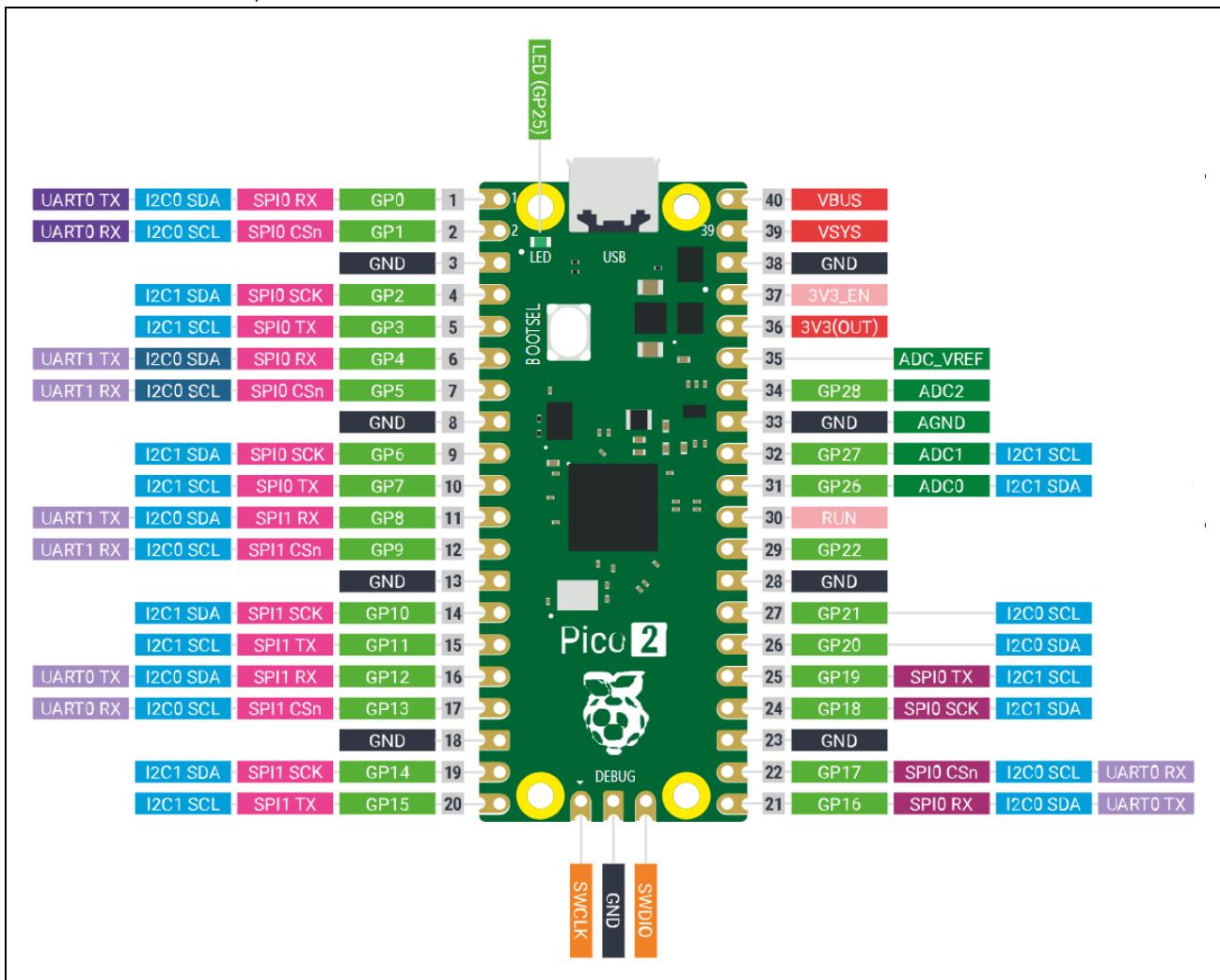


The hardware interfaces are distributed as follows:



Frame color	Description
	Pins
	BOOTSEL button
	USB port
	LED
	Debugging

Function definition of pins:



Color	Pins	Color	Pins
Black	GND	Red	Power
Green	GPIO	Dark Green	ADC
Purple	UART(default)	Lavender	UART
Magenta	SPI	Blue	I2C
Pink	System Control	Orange	Debugging

For details: <https://datasheets.raspberrypi.com/pico/pico-2-datasheet.pdf>

## UART, I2C, SPI Default Pin

In Arduino IDE, the default pins of serial port are Pin0 and Pin1.

Note: Serial port is virtualized by RP2350. Therefore, when using the serial port, please enable the verification function of DTR. It can work under any baud rate.

### UART

Function	Default
UART_BAUDRATE	X
UART_BITS	8
UART_STOP	1
UART_TX	Pin 0
UART_RX	Pin 1

### I2C

Function	Default
I2C Frequency	400000
I2C_SDA	Pin 4
I2C_SCL	Pin 5

### SPI

Function	Default
SPI_BAUDRATE	1000000
SPI_POLARITY	0
SPI_PHASE	0
SPI_BITS	8
SPI_FIRSTBIT	MSB
SPI_SCK	Pin 18
SPI_MOSI	Pin 19
SPI_MISO	Pin 16
SPI_SS	Pin 17

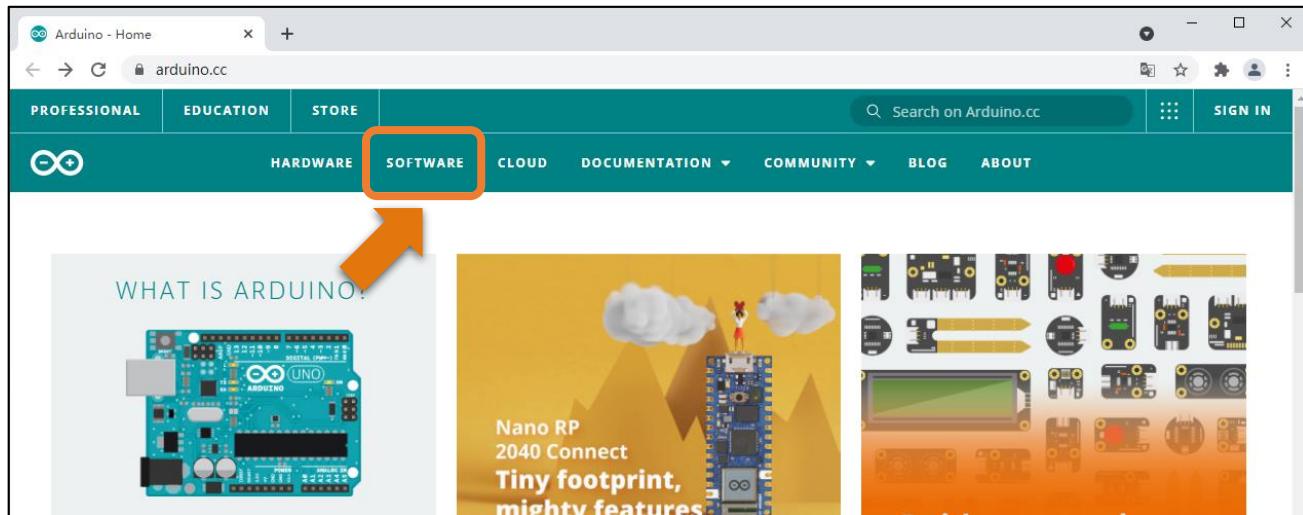
# Chapter 0 Getting Ready (Important)

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

## Programming Software

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

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



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

## Downloads

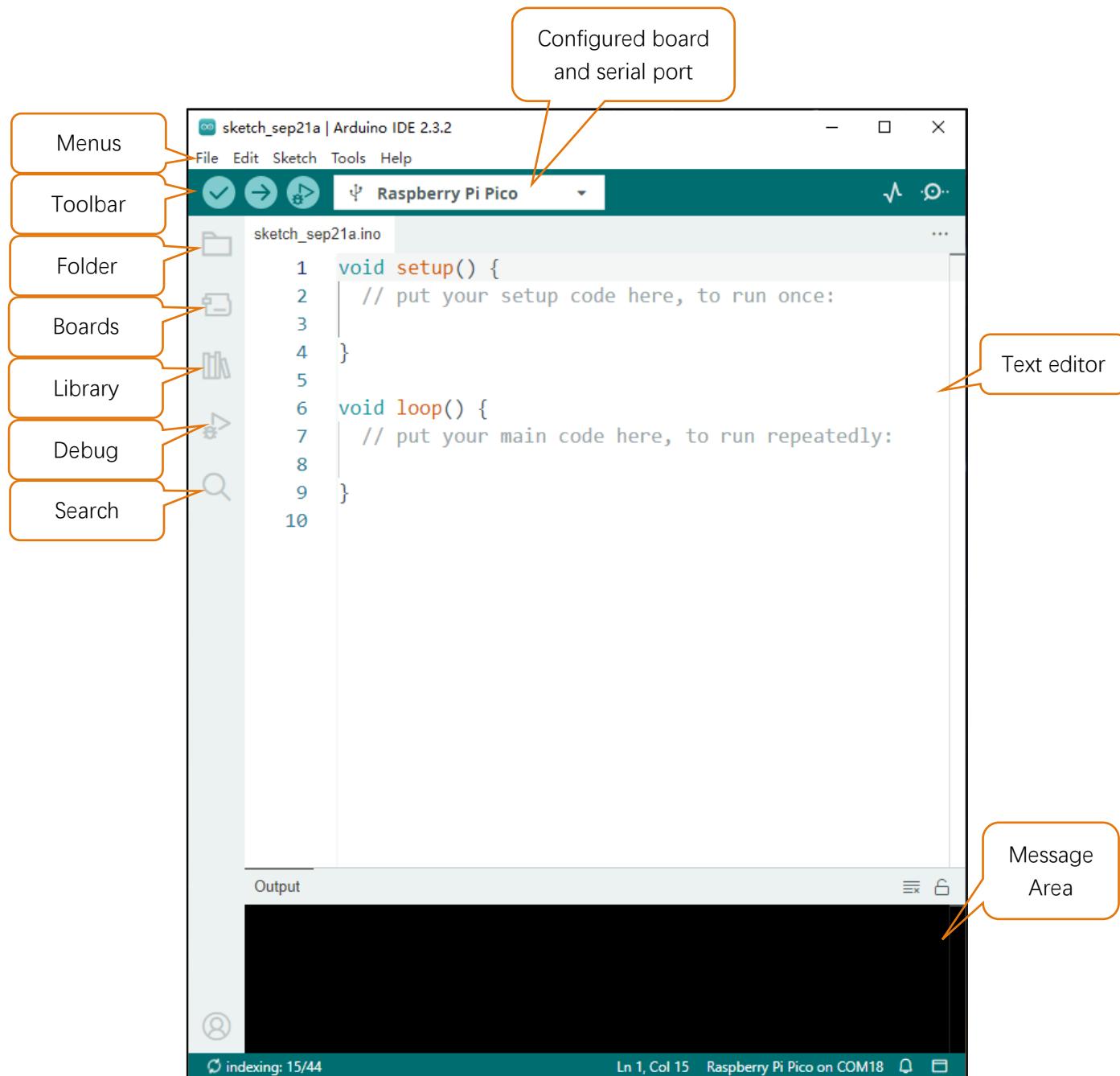
The screenshot shows the download page for Arduino IDE 2.3.2. On the left, there's a thumbnail of the Arduino logo and the text "Arduino IDE 2.3.2". Below that is a brief description: "The new major release of the Arduino IDE is faster and even more powerful! In addition to a more modern editor and a more responsive interface it features autocomplete, code navigation, and even a live debugger." It also mentions "Nightly builds with the latest bugfixes are available through the section below." At the bottom, there's a link to "SOURCE CODE" and a note about GitHub. On the right, under "DOWNLOAD OPTIONS", there are links for Windows (Win 10 and newer, 64 bits, MSI installer, ZIP file), Linux (AppImage 64 bits (X86-64), ZIP file 64 bits (X86-64)), and macOS (Intel, 10.15: "Catalina" or newer, 64 bits, Apple Silicon, 11: "Big Sur" or newer, 64 bits). A large orange arrow points from the text "Select and download corresponding installer according to your operating system" to the "Windows" download options.

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 comes up, please allow the installation.

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



The interface of Arduino Software is as follows:





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



### Verify

Check your code for compile errors.



### Upload

Compile your code and upload them to the configured board.



### Debug

Test and debug programs in real time.



### Select Board & Port

Detected Arduino boards automatically show up here, along with the port number.



### Serial Plotter

Open the serial plotter.



### Serial Monitor

Open the serial monitor.

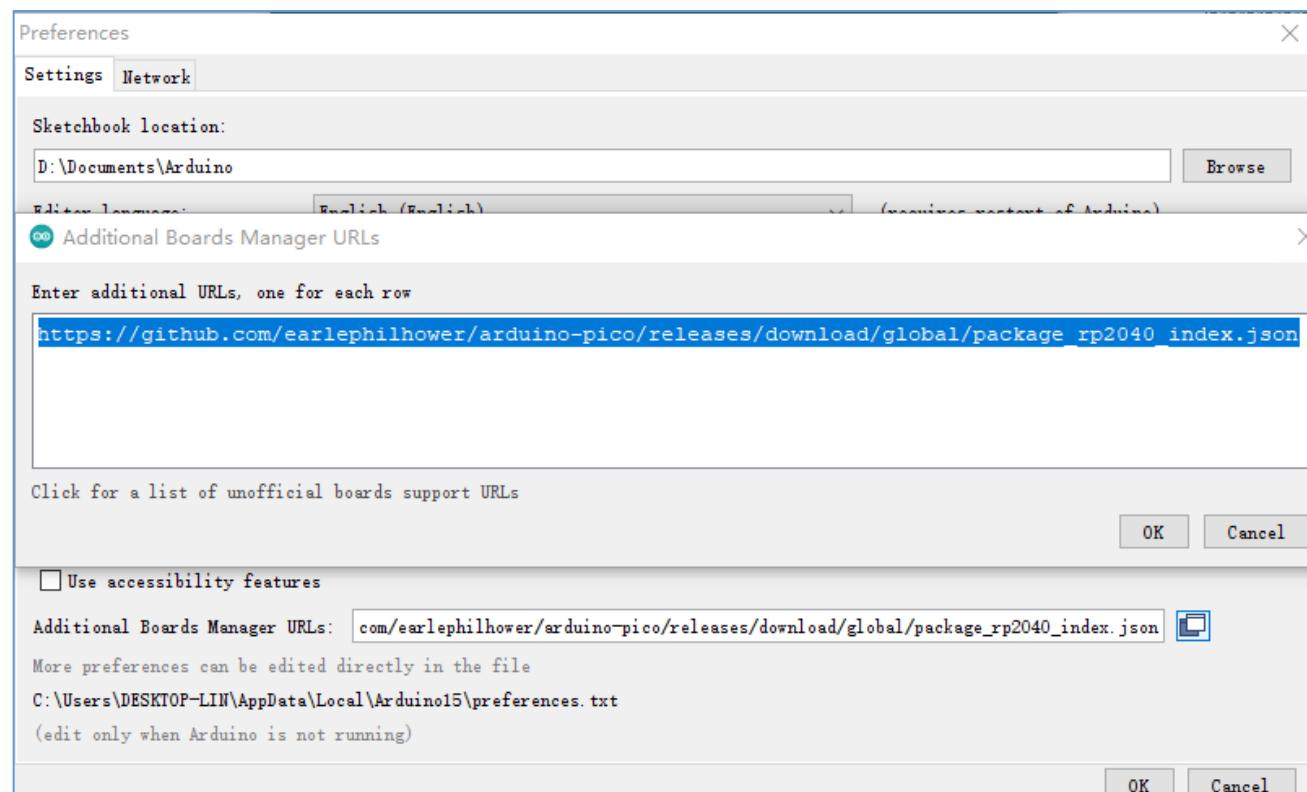
Additional commands are found within the five menus: File, Edit, Sketch, Tools, Help. The menus are context sensitive, which means only those items relevant to the work currently being carried out are available.

## Installation of Development Board Support Package

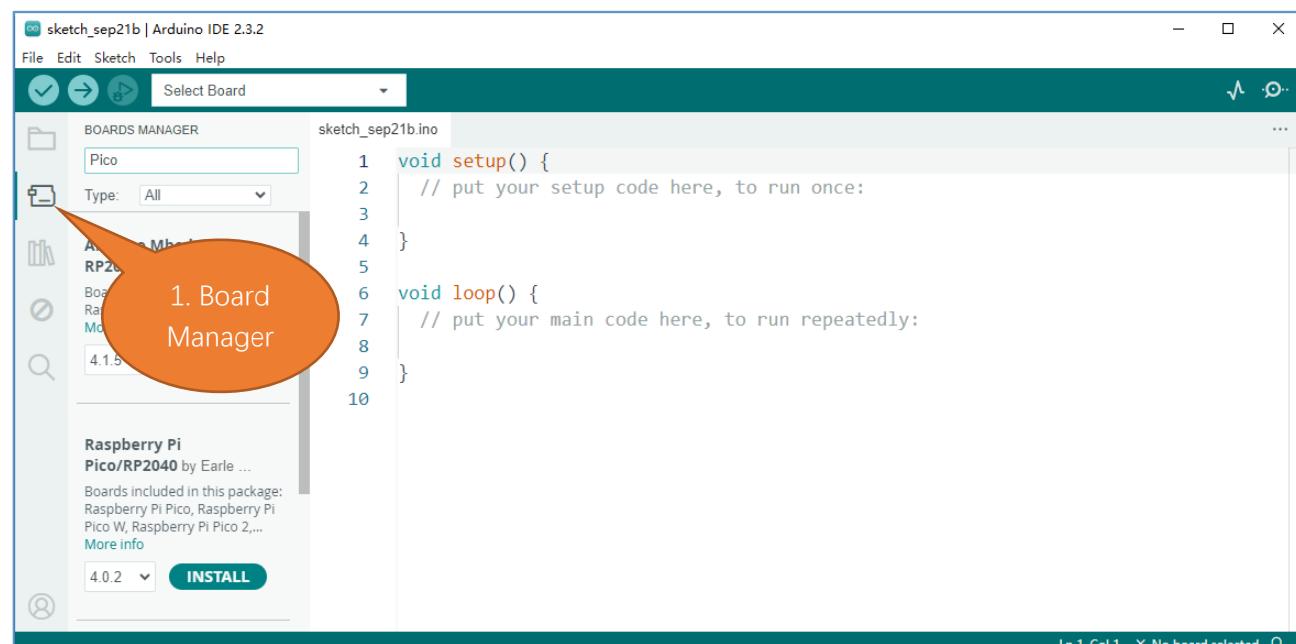
1. Make sure your network is of good connection.
2. Open Arduino IDE, and click File>Preference. In new pop-up window, find "Additional Boards Manager URLs", and replace with a new line:

[https://github.com/earlephilhower/arduino-pico/releases/download/global/package\\_rp2040\\_index.json](https://github.com/earlephilhower/arduino-pico/releases/download/global/package_rp2040_index.json)

As shown below:

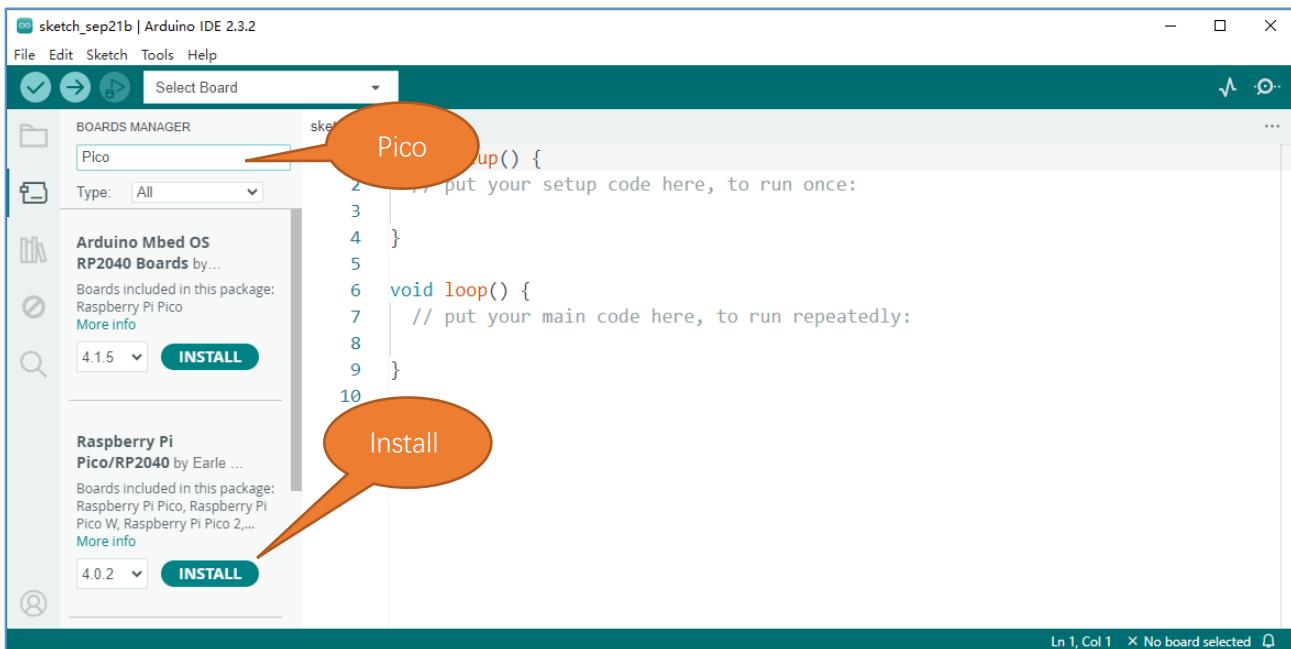


3. Open Arduino IDE; click Boards Manager on the left.



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

4. Enter Pico in the searching box, and select “Raspberry Pi Pico/RP2040” and click on Install.

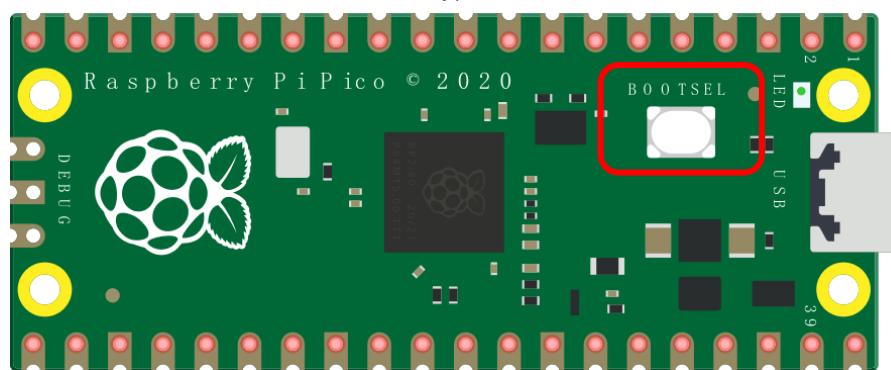


5. Click Yes in the pop-up “**dpinst-amd64.exe**” installation window. (Without it, you will fail to communicate with Arduino.) Thus far, we have finished installing the development support package.

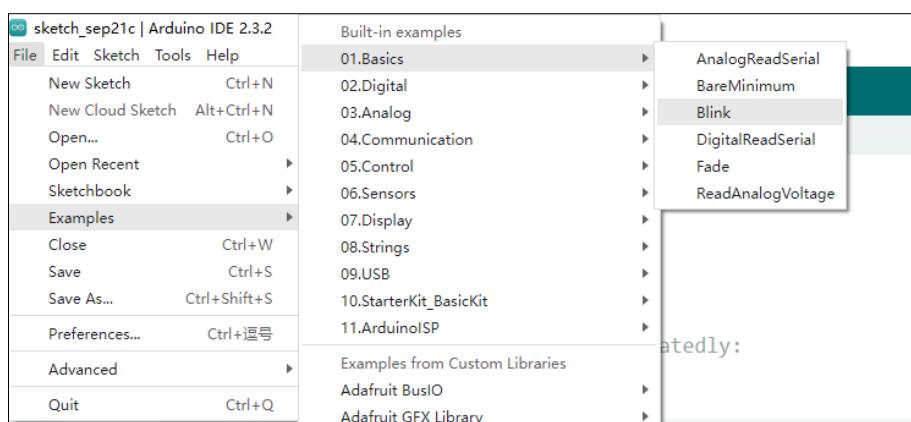
## Uploading Arduino-compatible Firmware for Pico

If your Pico is new and you want to use Arduino to learn and develop, you need to upload an Arduino-compatible Firmware for it. Please refer to the following steps to configure.

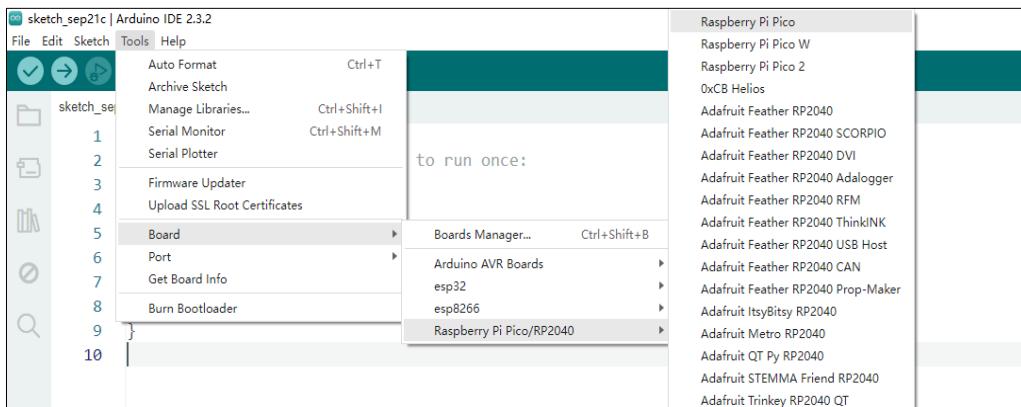
1. Disconnect Pico from computer. Keep pressing the white button (BOOTSEL) on Pico, and connect Pico to computer before releasing the button. (Note: Be sure to keep pressing the button before powering the Pico, otherwise the firmware will not download successfully)



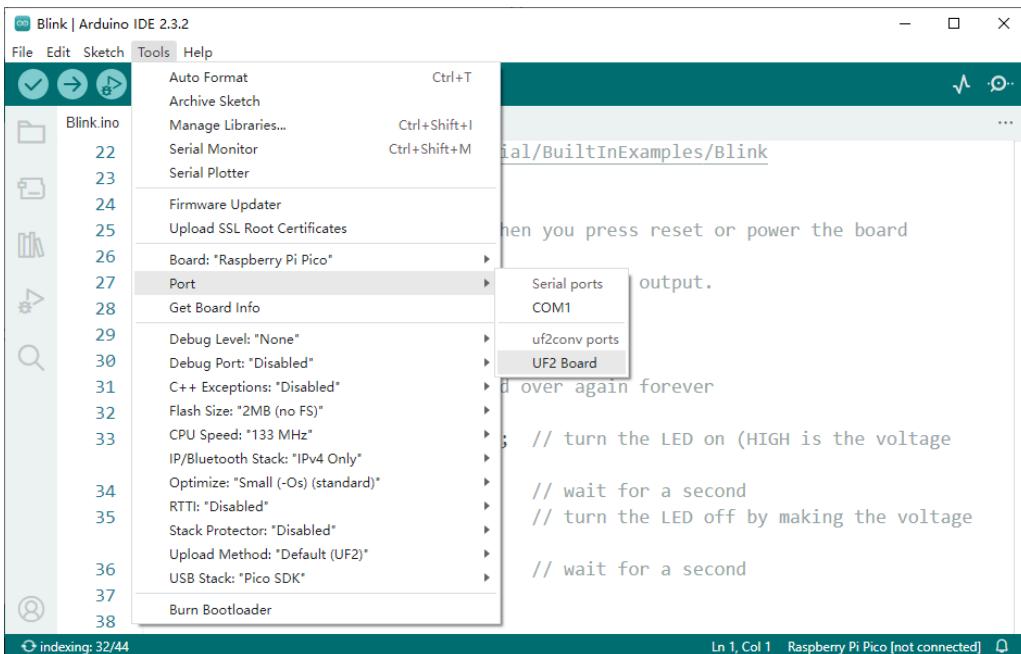
2. Open Arduino IDE. Click File>Examples>01.Basics>Blink.



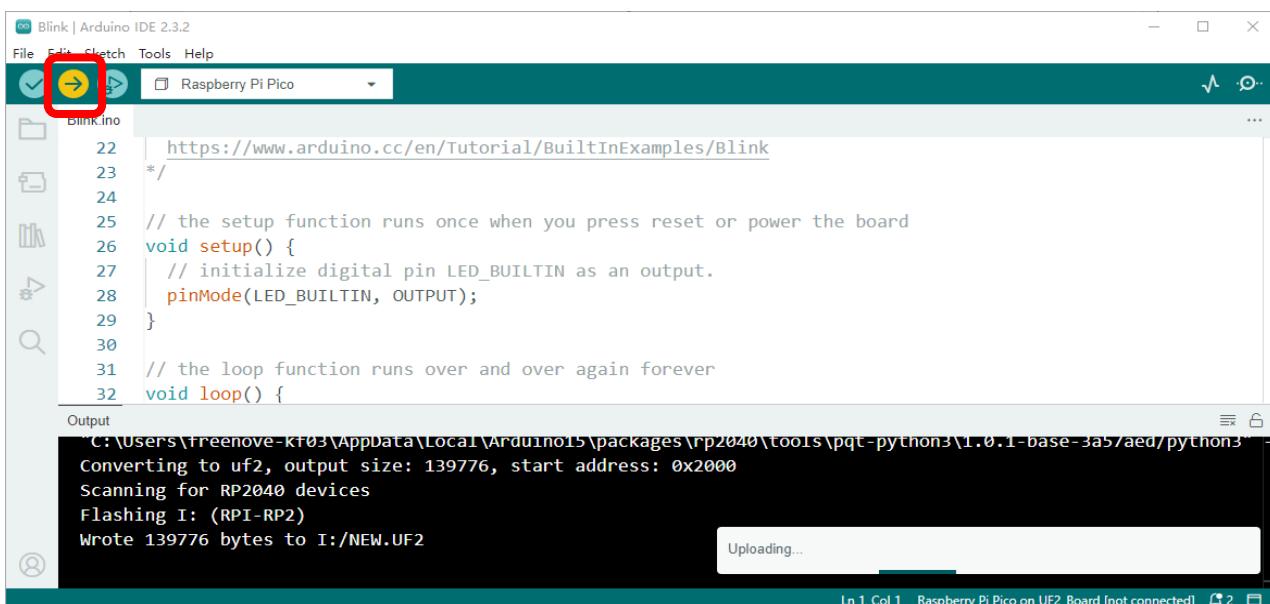
### 3. Click Tools>Board>Raspberry Pi RP2040 Boards>Raspberry Pi Pico.



### 4. Click Tools>Port>UF2 Board.

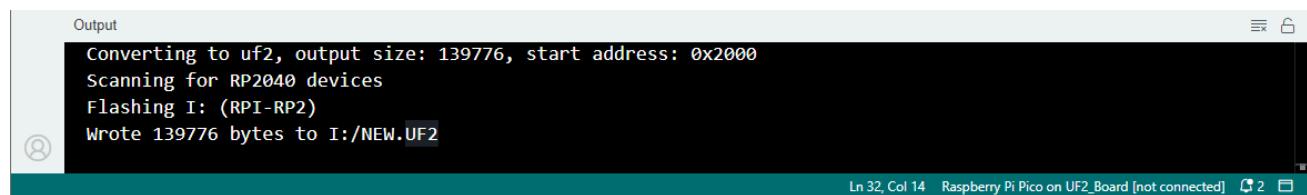


### 5. Upload sketch to Pico.



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

When the sketch finishes uploading, you can see the following prompt.

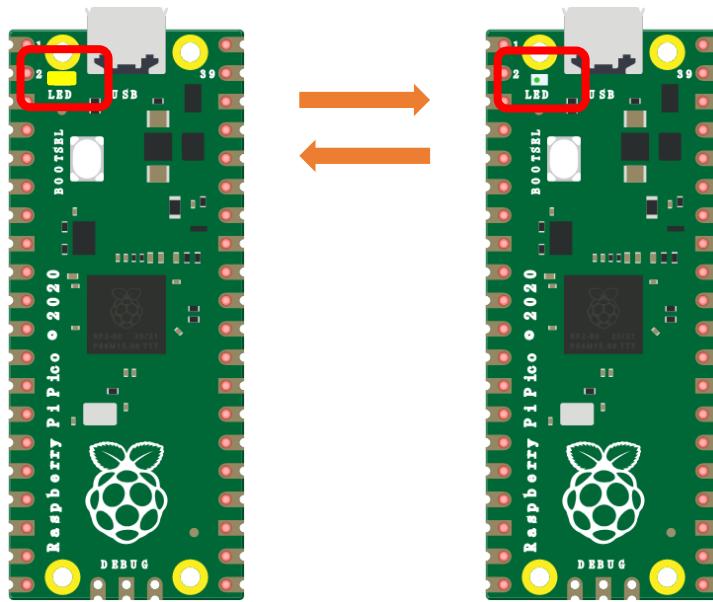


The screenshot shows the Arduino IDE's Output window. It displays the following text:

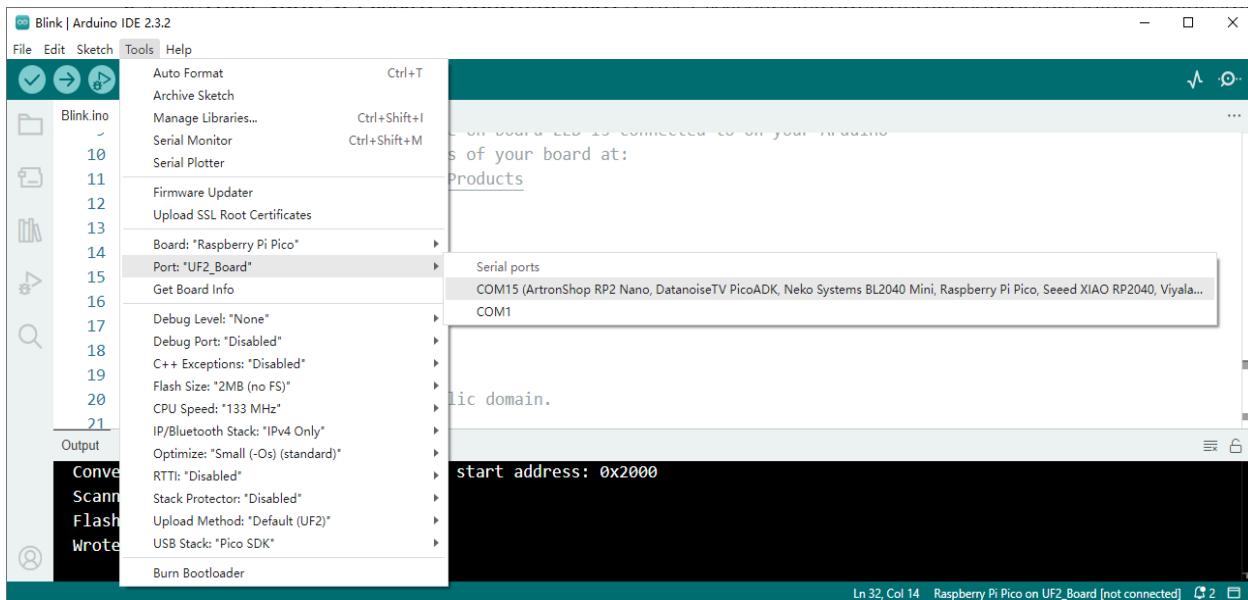
```
Output
Converting to uf2, output size: 139776, start address: 0x2000
Scanning for RP2040 devices
Flashing I: (RPI-RP2)
Wrote 139776 bytes to I:/NEW.UF2
```

At the bottom of the window, it says "Ln 32, Col 14 Raspberry Pi Pico on UF2\_Board [not connected] ⌂ 2 □".

And you can see the indicator on Pico starts to flash.



5. Click **Tools>Port>COMx(Raspberry Pi Pico)**. X of COMx varies from different computers. Please select the correct one on your computer. In our case, it is COM15.

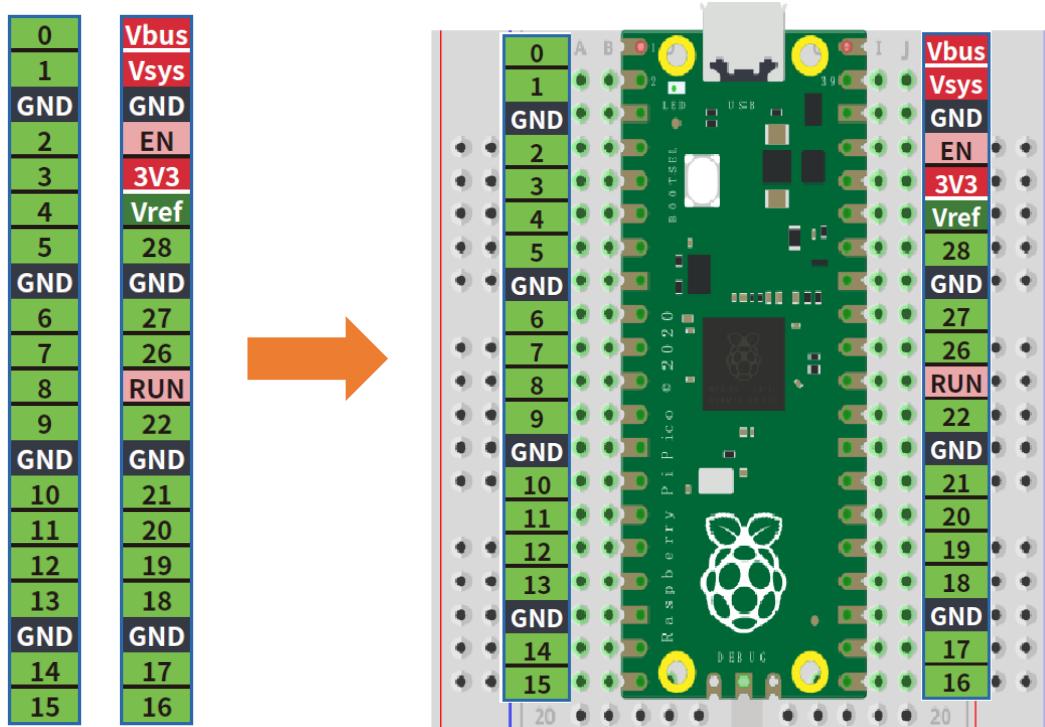


#### Note:

1. At the first time you use Arduino to upload sketch for Pico, you do not need to select port. After that, each time before uploading sketch, please check whether the port has been selected; otherwise, the downloading may fail.
2. Sometimes when using, Pico may lose firmware due to the code and fail to work. At this point, you can upload firmware for Pico as mentioned above.

## Paste the Sticker on the Breadboard

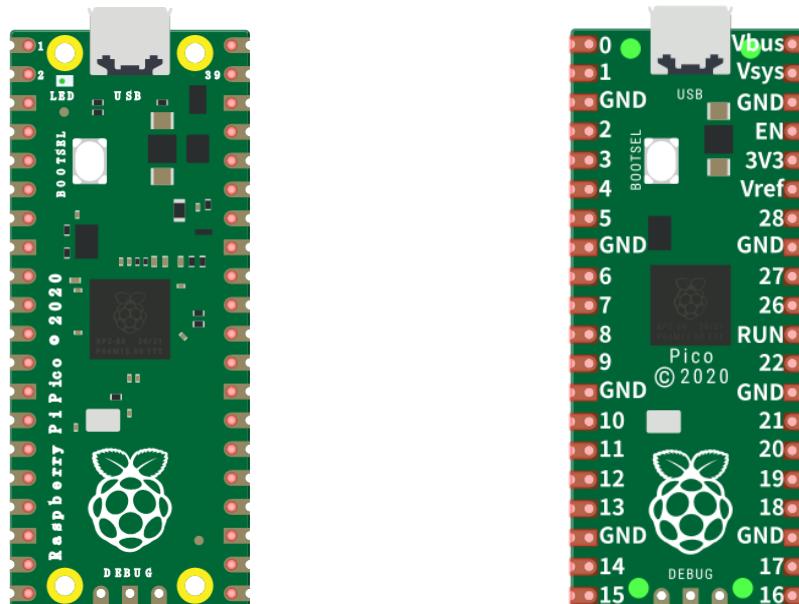
It is not difficult to use the Pico. However, officially, the pin functions are printed on the back of the board, which makes it inconvenient to use. To help users finish each project in the tutorial faster and easier, we provide stickers of the pin functions as follows:



You can paste the sticker on the blank area of the breadboard as above.

To make the tutorial more intuitive, we have made some changes to the simulation diagram as below. The left one is the actual Pico and the right one is its simulation diagram. Please note that to avoid misunderstanding.

In addition, the external pin interface functions of Pico, Pico W and Pico 2 are identical.





# Chapter 1 LED (Important)

Note:

Raspberry Pi Pico, Raspberry Pi Pico W and Raspberry Pi Pico 2 only differ by one wireless function, and are almost identical in other aspects. In this tutorial, except for the wireless function, other parts use Raspberry Pi Pico's map for tutorial demonstration.

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

## Project 1.1 Blink

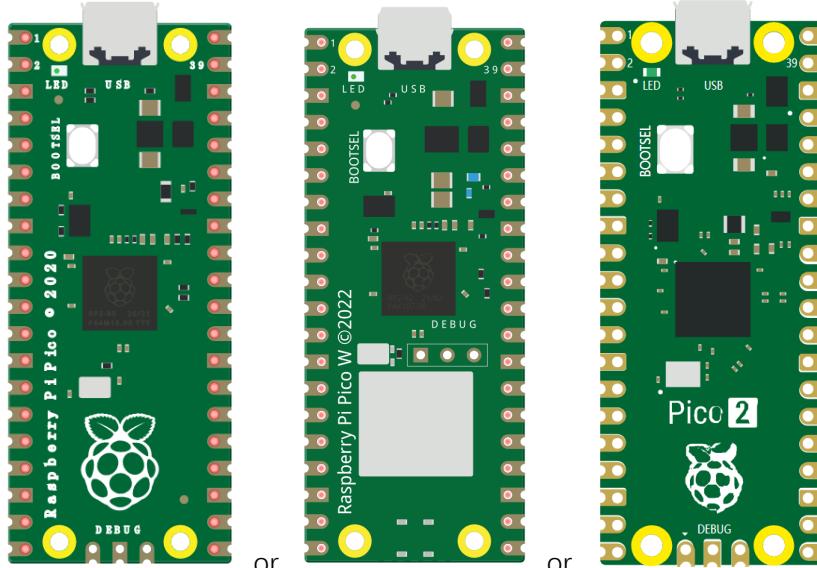
In this project, we will use Raspberry Pi Pico to control blinking a common LED.

If you have not installed Arduino IDE, you can click [Here](#).

If you have not uploaded firmware for Pico, you can click [Here](#) to upload.

## Component List

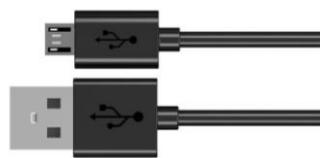
Raspberry Pi Pico (or Pico W or Pico 2) x1



or

or

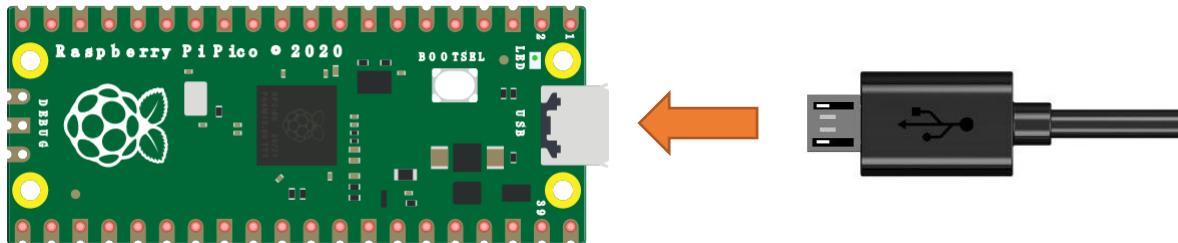
USB cable x1



## Power

Raspberry Pi Pico requires 5V power supply. You can either connect external 5V power supply to Vsys pin of Pico or connect a USB cable to the onboard USB base to power Pico.

In this tutorial, we use USB cable to power Pico and upload sketches.





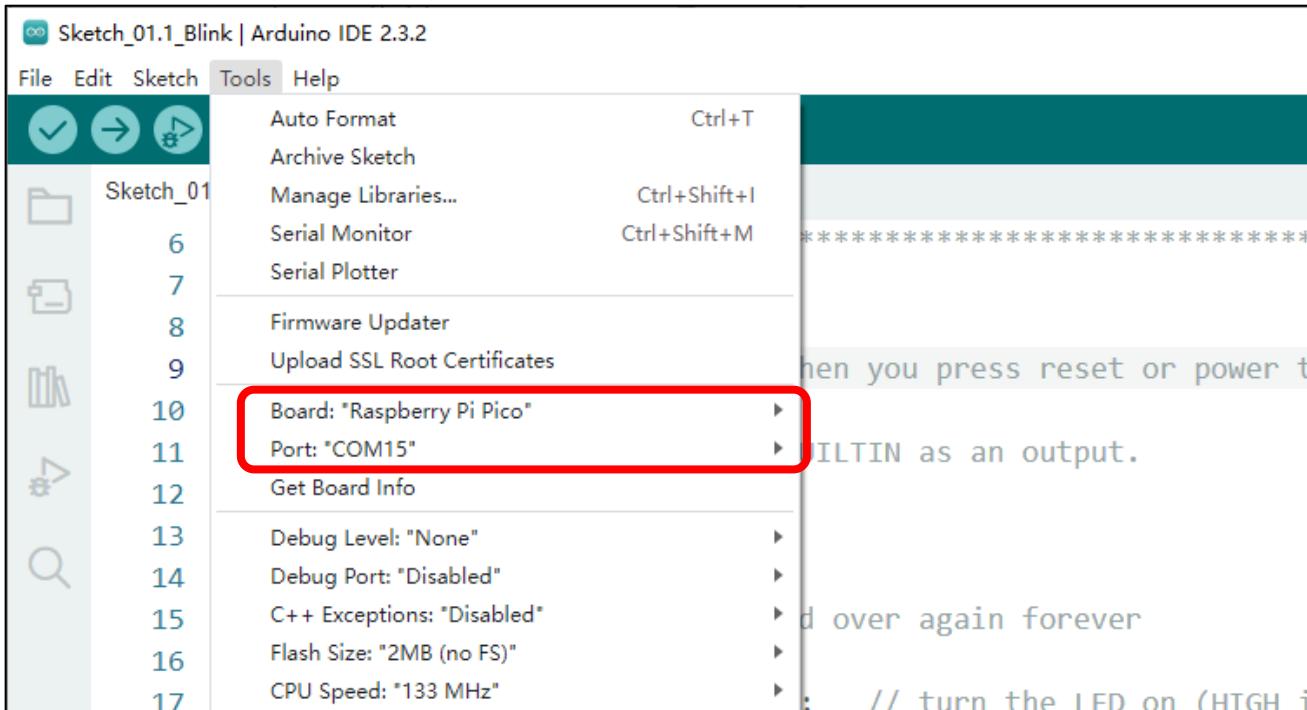
## Sketch

The onboard LED of Raspberry Pi Pico is controlled by GP25. When GP25 outputs high level, LED lights up; when it outputs low, LED lights off. You can open the provided code:

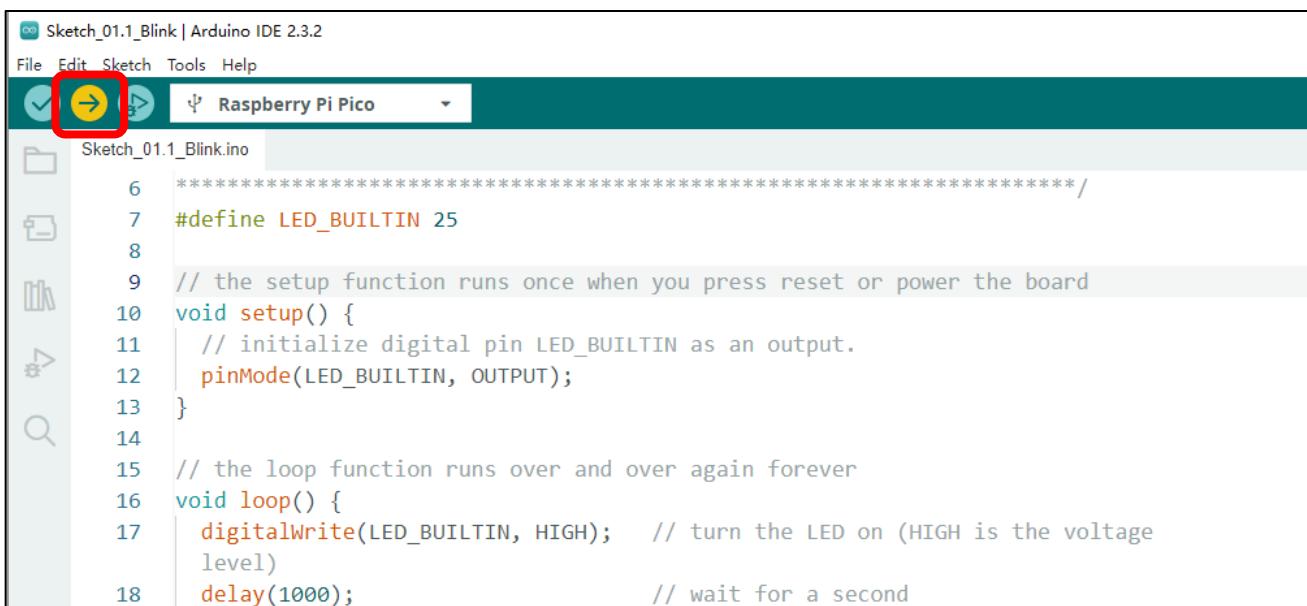
**Freenove\_Super\_Starter\_Kit\_for\_Raspberry\_Pi\_Pico\C\Sketches\Sketch\_01.1\_Blink.**

Before uploading code to Pico, please check the configuration of Arduino IDE.

Click Tools, make sure Board and Port are as follows:

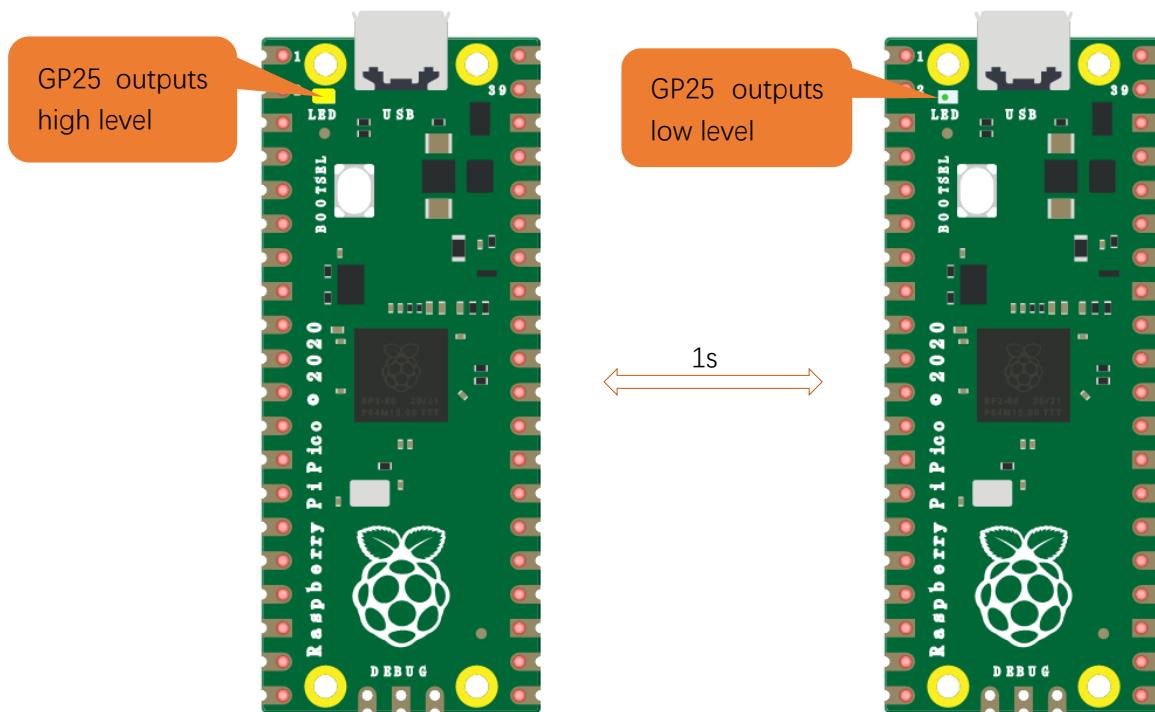


Click "Upload" to upload the sketch to Pico.



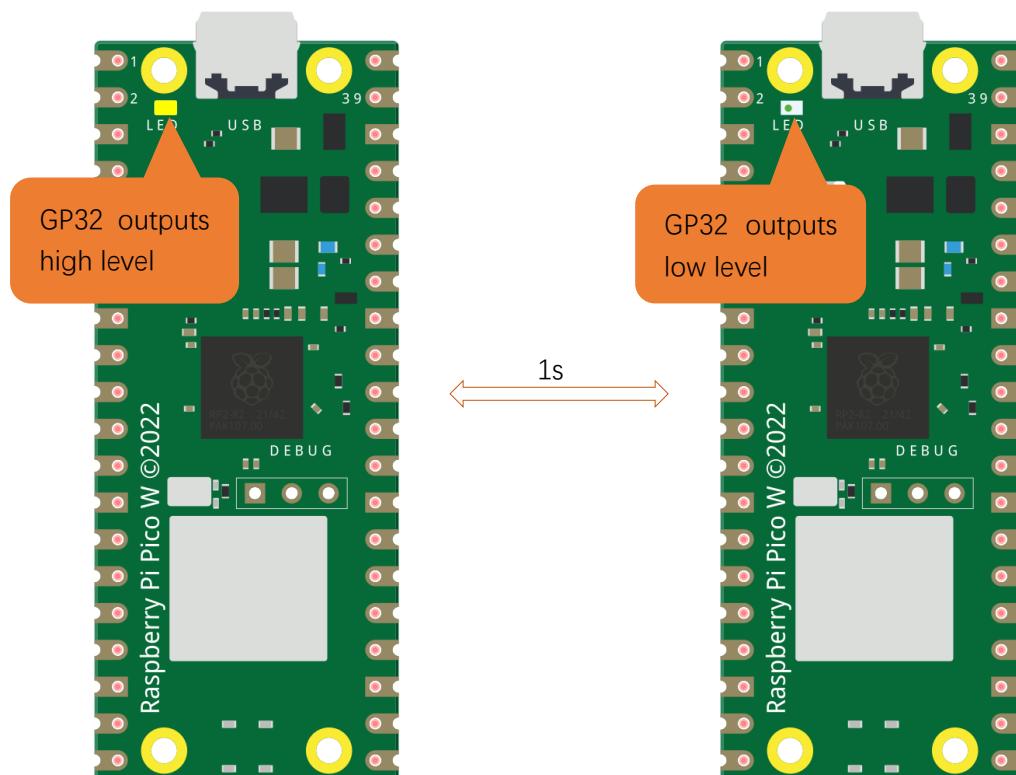
If you have any concerns, please contact us at [support@freenove.com](mailto:support@freenove.com)

Pico's on-board LED lights on and off every 1s, flashing cyclically.



Note: Pico's on-board LED is driven by GPIO25. Pico W's on-board LED uses WL\_GPIO0, which is defined as GPIO32 on Arduino.

If you use Pico W, please change "# define LED\_BUILTIN 25" to "# define LED\_BUILTIN 32" in the code.



The following is the program code:

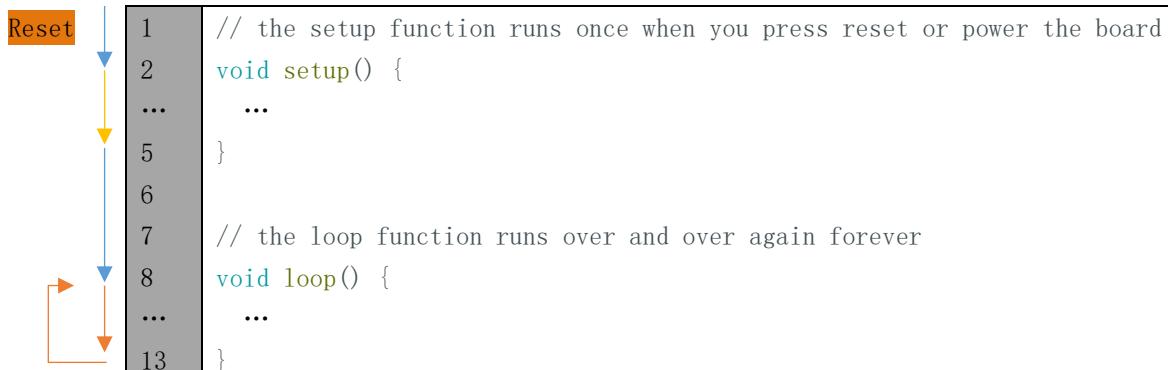
```

1 #define LED_BUILTIN 25
2
3 // the setup function runs once when you press reset or power the board
4 void setup() {
5     // initialize digital pin LED_BUILTIN as an output.
6     pinMode(LED_BUILTIN, OUTPUT);
7 }
8
9 // the loop function runs over and over again forever
10 void loop() {
11     digitalWrite(LED_BUILTIN, HIGH);    // turn the LED on (HIGH is the voltage level)
12     delay(1000);                      // wait for a second
13     digitalWrite(LED_BUILTIN, LOW);    // turn the LED off by making the voltage LOW
14     delay(1000);                      // wait for a second
15 }
```

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

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

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



In the circuit, GP25 of Pico is connected to the LED, so the LED pin is defined as 25.

```
1 #define LED_BUILTIN 25
```

This means that after this line of code, all LED\_BUILTIN will be regarded as 25.

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

```

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

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

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

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

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

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

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

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

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

## Reference

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

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

### Parameters

pin: the pin number to set the mode of LED.

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

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

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

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



## Project 1.2 Blink

In this project, we will use Raspberry Pi Pico to control blinking a common LED.

### Component List

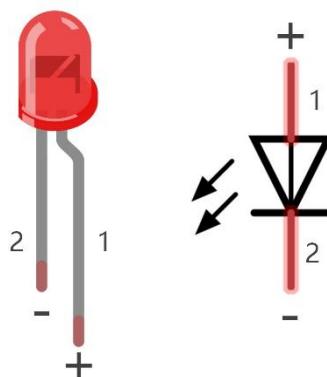
Raspberry Pi Pico x1	USB Cable x1
A green printed circuit board with a central Broadcom SoC, labeled "Raspberry Pi Pico • 2020". It has a 2x34 pin header at the bottom, four yellow circular pads on the top corners, and several surface-mount components like resistors and capacitors.	Two black USB cables, each with a standard A-type connector on one end and a smaller micro-B or Pico-specific connector on the other.
Breadboard x1	
A schematic diagram of a breadboard, showing its grid of 60 columns and 10 rows of 2mm spaced holes. Columns are labeled from A to J along both the top and bottom edges. Rows are numbered 1 through 30 across the middle.	
LED x1	Resistor 220Ω x1
A red light-emitting diode (LED) with two metal leads.	A cylindrical resistor with a grey band indicating a value of 220 ohms.
	Jumper
	A long, thin black wire with small black caps at each end, used for connecting components.

## Component Knowledge

### LED

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

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



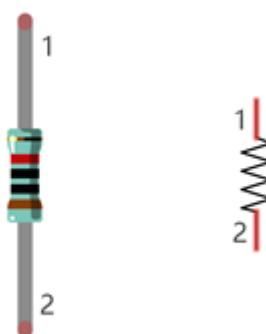
LED	Voltage	Maximum current	Recommended current
Red	1.9 - 2.2V	20mA	10mA
Green	2.9 - 3.4V	10mA	5mA
Blue	2.9 - 3.4V	10mA	5mA
Volt ampere characteristics conform to diode			

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

### Resistor

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

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

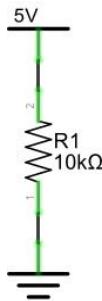


The bands of color on a resistor is a shorthand code used to identify its resistance value. For more details of resistor color codes, please refer to the appendix of this tutorial.

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



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



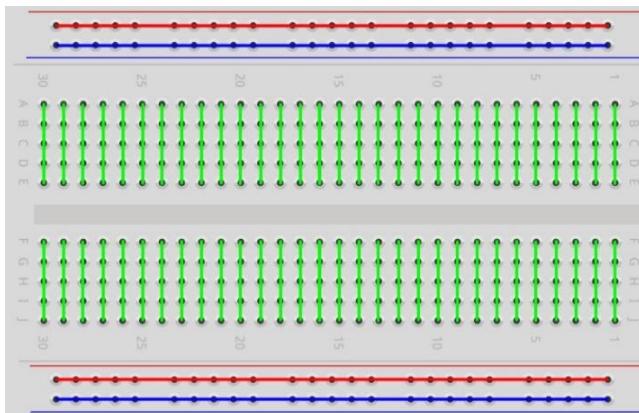
**WARNING:** Never connect the two poles of a power supply with anything of low resistance value (i.e. a metal object or bare wire) this is a Short and results in high current that may damage the power supply and electronic components.

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

### Breadboard

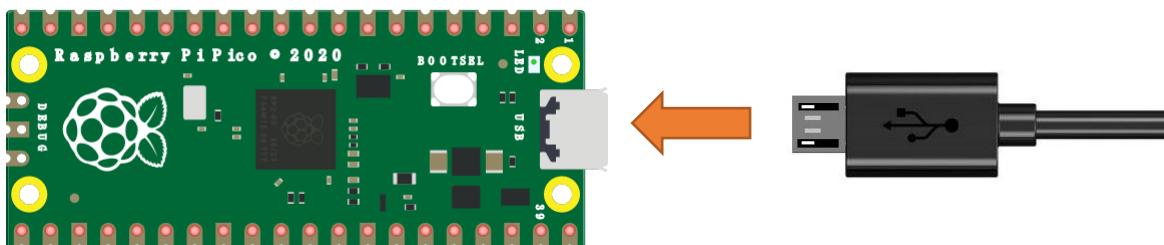
Here we have a small breadboard as an example of how the rows of holes (sockets) are electrically attached.

The left picture shows the way to connect pins. The right picture shows the practical internal structure.



### Power

In this tutorial, we connect Raspberry Pi Pico and computer with a USB cable.



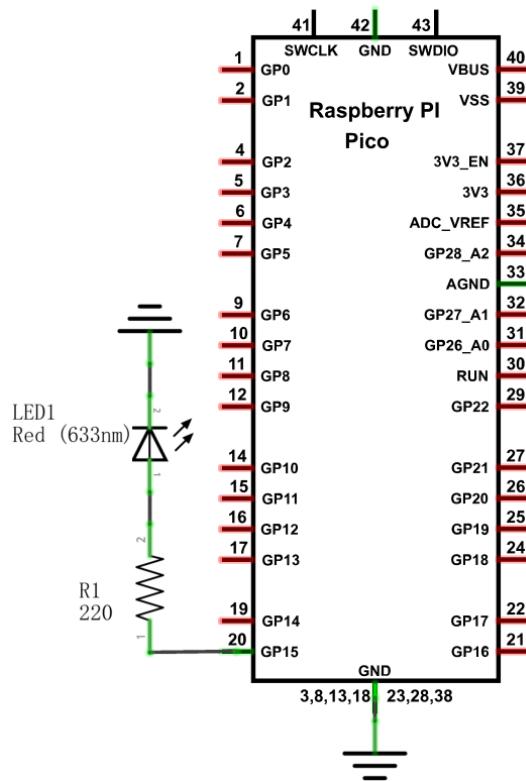
## Circuit

First, disconnect all power from the Raspberry Pi Pico. Then build the circuit according to the circuit and hardware diagrams. After the circuit is built and verified correct, connect the PC to Raspberry Pi Pico.

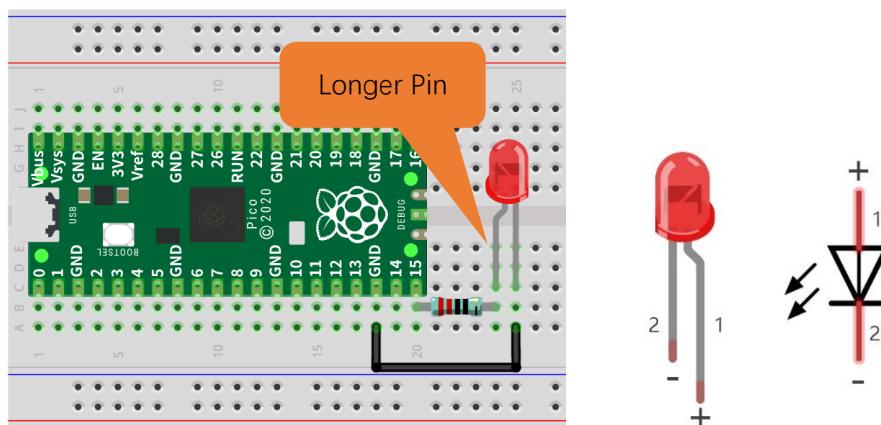
**CAUTION:** Avoid any possible short circuits (especially connecting 3.3V and GND)!

**WARNING:** A short circuit can cause high current in your circuit, create excessive component heat and cause permanent damage to your hardware!

## Schematic diagram



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



Note: To help users have a better experience when doing the projects, we have made some modifications to Pico's simulation diagram. Please note that there are certain differences between the simulation diagram and the actual board to avoid misunderstanding.



## Sketch

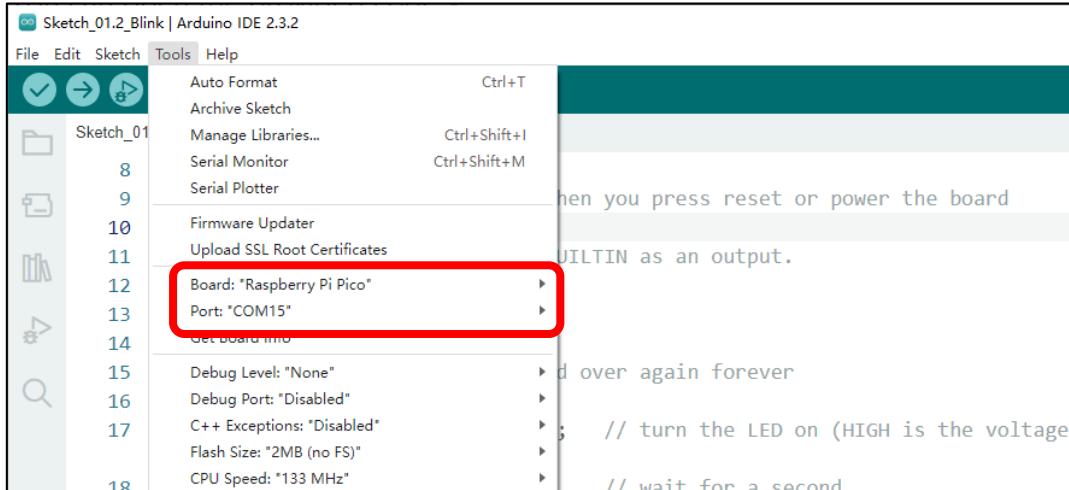
According to the circuit diagram, when GP15 of Pico outputs high level, LED lights up; when it outputs low, LED lights off. Therefore, we can make LED flash repeatedly by controlling GP15 to output high and low repeatedly.

You can open the provided code:

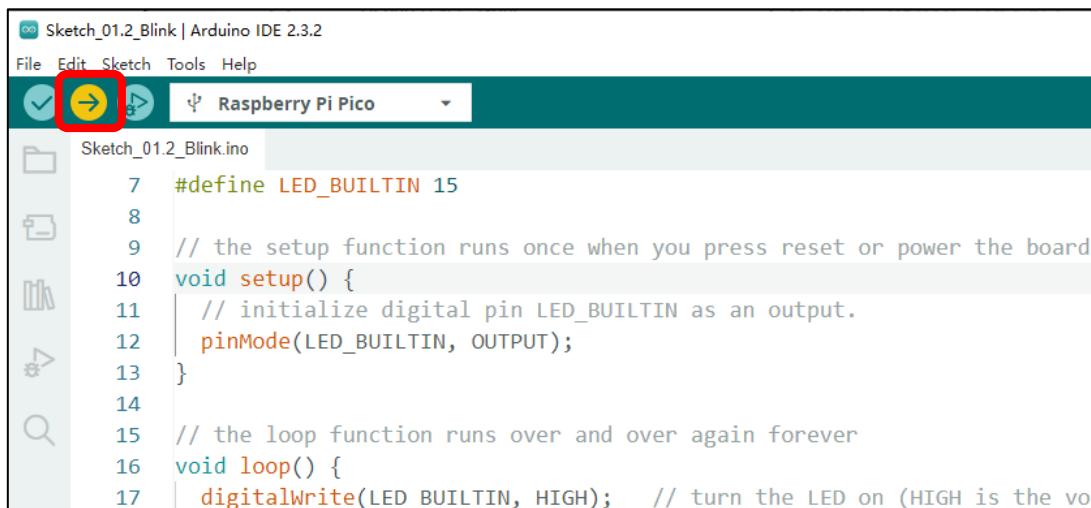
**Freenove\_Super\_Starter\_Kit\_for\_Raspberry\_Pi\_Pico\С\Sketches\Sketch\_01.2\_Blink.**

Before uploading code to Pico, please check the configuration of Arduino IDE.

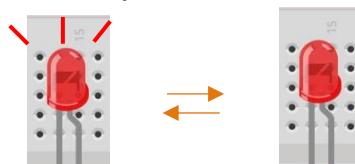
Click Tools, make sure Board and Port are as follows:



Click "Upload" to upload the sketch to Pico.



Click "Upload". Download the code to Pico and your LED in the circuit starts Blink.

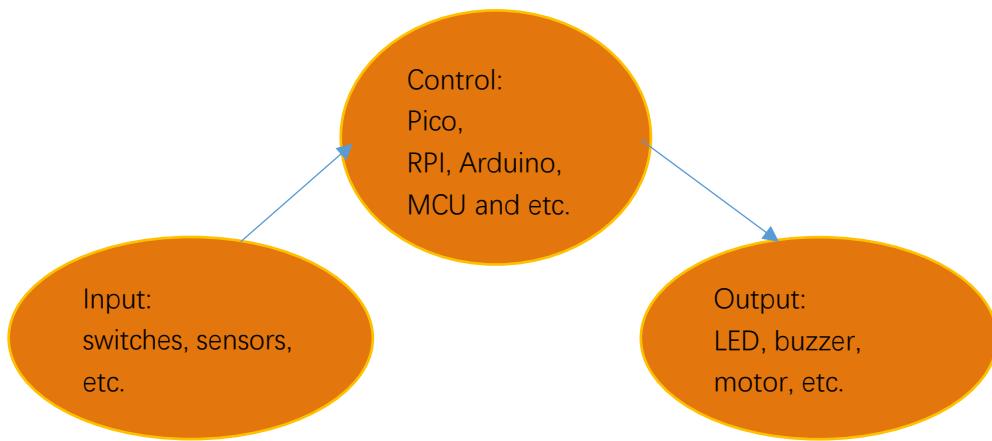


If you have any concerns, please contact us via: [support@freenove.com](mailto:support@freenove.com)

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

## Chapter 2 Button & LED

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



Next, we make a simple project: build a control system with button, LED and Raspberry Pi Pico.

Input: Button

Control: Raspberry Pi Pico

Output: LED

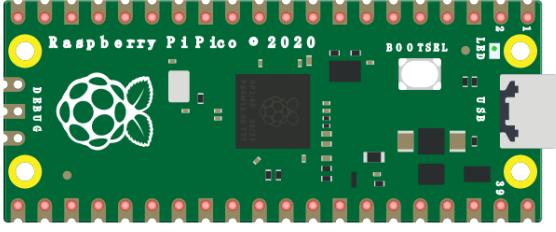
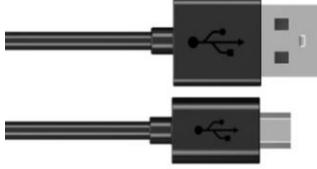
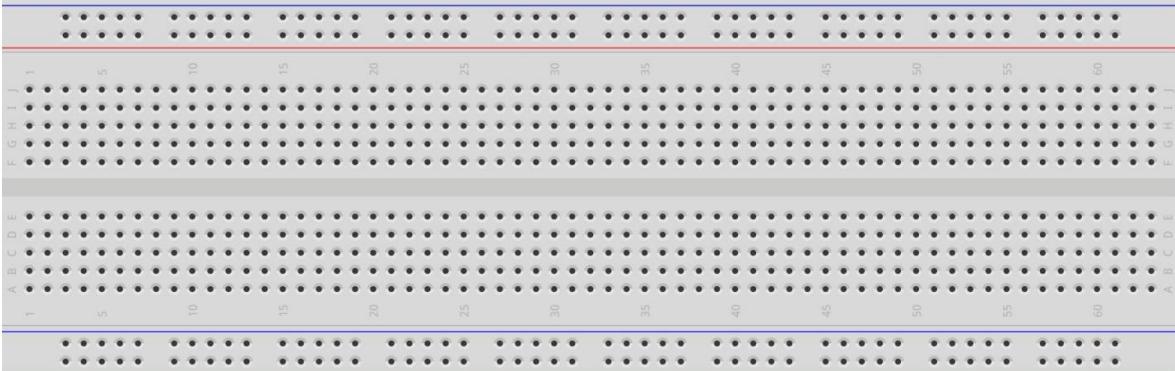


## Project 2.1 Button & LED

Note: Raspberry Pi Pico, Raspberry Pi Pico W and Raspberry Pi Pico 2 only differ by wireless function, and are almost identical in other aspects. In this tutorial, except for the wireless function, other parts use Raspberry Pi Pico's map for tutorial demonstration.

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

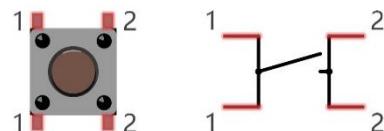
### Component List

Raspberry Pi Pico x1		USB cable x1		
Breadboard x1				
Jumper	LED x1	Resistor 220Ω x1	Resistor 10kΩ x2	Push button x1

## Component Knowledge

### Push button

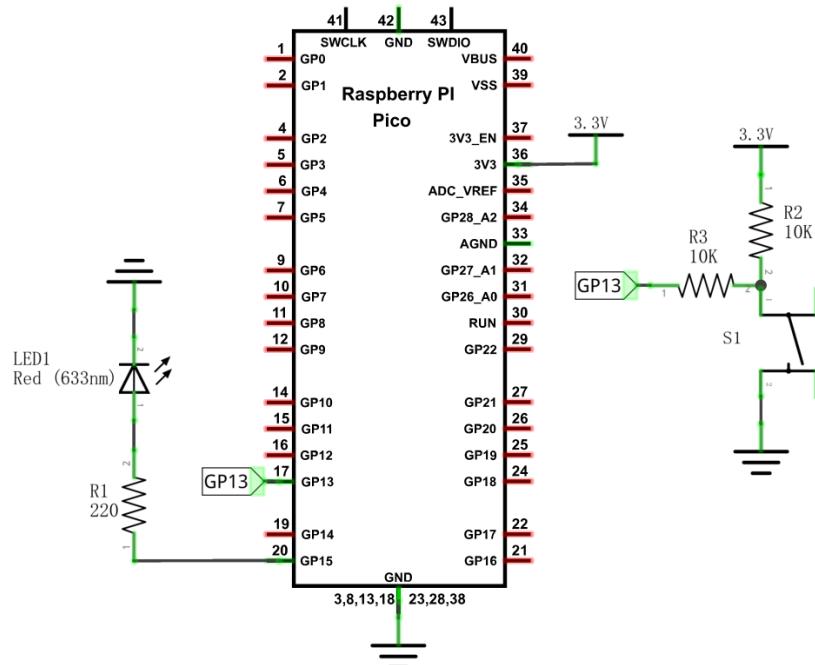
This type of Push Button Switch has four pins (2 Pole Switch). Two pins on the left are connected, and both left and right sides are the same per the illustration:



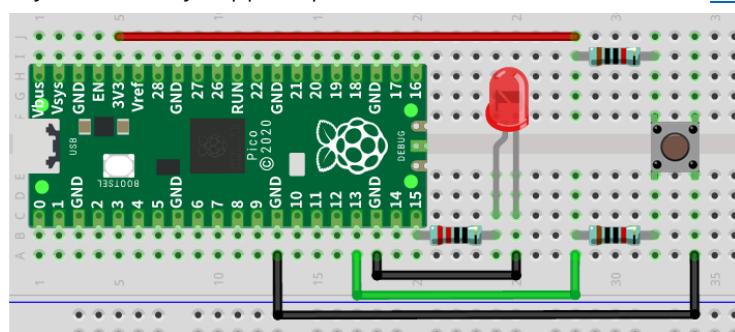
When the button on the switch is pressed, the circuit is completed (your project is Powered ON).

## Circuit

Schematic diagram



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



Note: To help users have a better experience when doing the projects, we have made some modifications to Pico's simulation diagram. Please note that there are certain differences between the simulation diagram and the actual board to avoid misunderstanding.

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



## Sketch

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

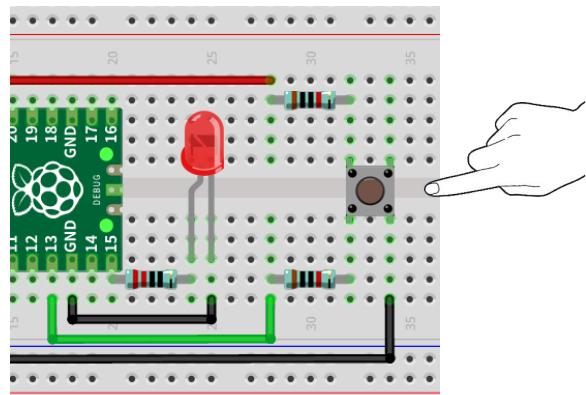
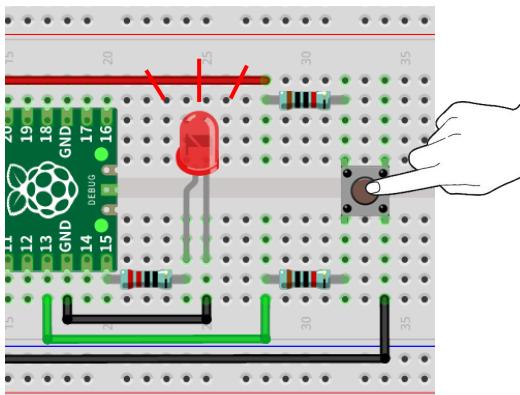
**Freenove\_Super\_Starter\_Kit\_for\_Raspberry\_Pi\_Pico\Sketches\Sketch\_02.1\_ButtonAndLed.**

**Sketch\_02.1\_ButtonAndLed**

```

Sketch_02.1_ButtonAndLed | Arduino IDE 2.3.2
File Edit Sketch Tools Help
Sketch_02.1_ButtonAndLed.ino
1 #define PIN_LED    15
2 #define PIN_BUTTON 13
3
4 void setup() {
5     // initialize digital pin PIN_LED as an output.
6     pinMode(PIN_LED, OUTPUT);
7     pinMode(PIN_BUTTON, INPUT);
8 }
9
10 // the loop function runs over and over again forever
11 void loop() {
12     if (digitalRead(PIN_BUTTON) == LOW) {
13         digitalWrite(PIN_LED,HIGH);
14     }else{
15         digitalWrite(PIN_LED,LOW);
16     }
17 }
```

Upload the sketch to Pico. When pressing the button, LED lights up; when releasing the button, LED lights OFF.



The following is the program code:

```

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

In the circuit connection, LED and button are connected with GP15 and GP13 respectively, so define ledPin and buttonPin as 15 and 13 respectively.

```

1 #define PIN_LED    15
2 #define PIN_BUTTON 13
```

In the while cycle of main function, use digitalRead(buttonPin) to determine the state of button. When the button is pressed, the function returns low level and the result of "if" is true, so LED lights up. Otherwise, LED lights OFF.

```

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

### Reference

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

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



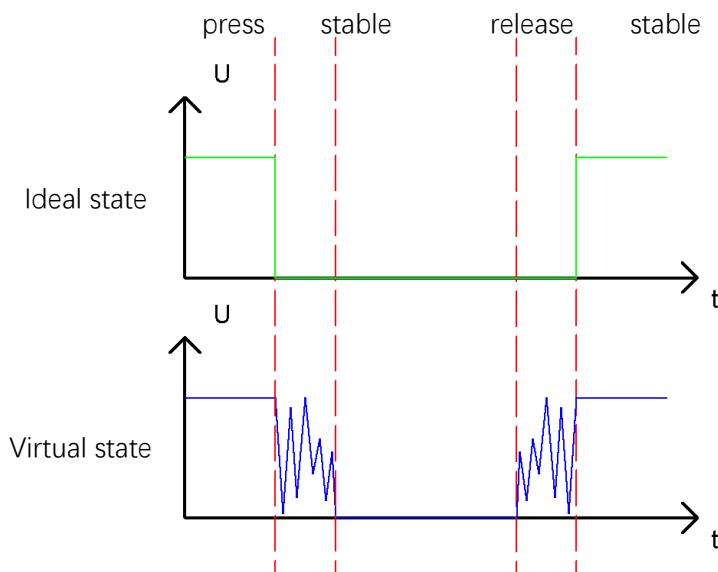
## Project 2.2 MINI table lamp

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

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

### Debounce for Push Button

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



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

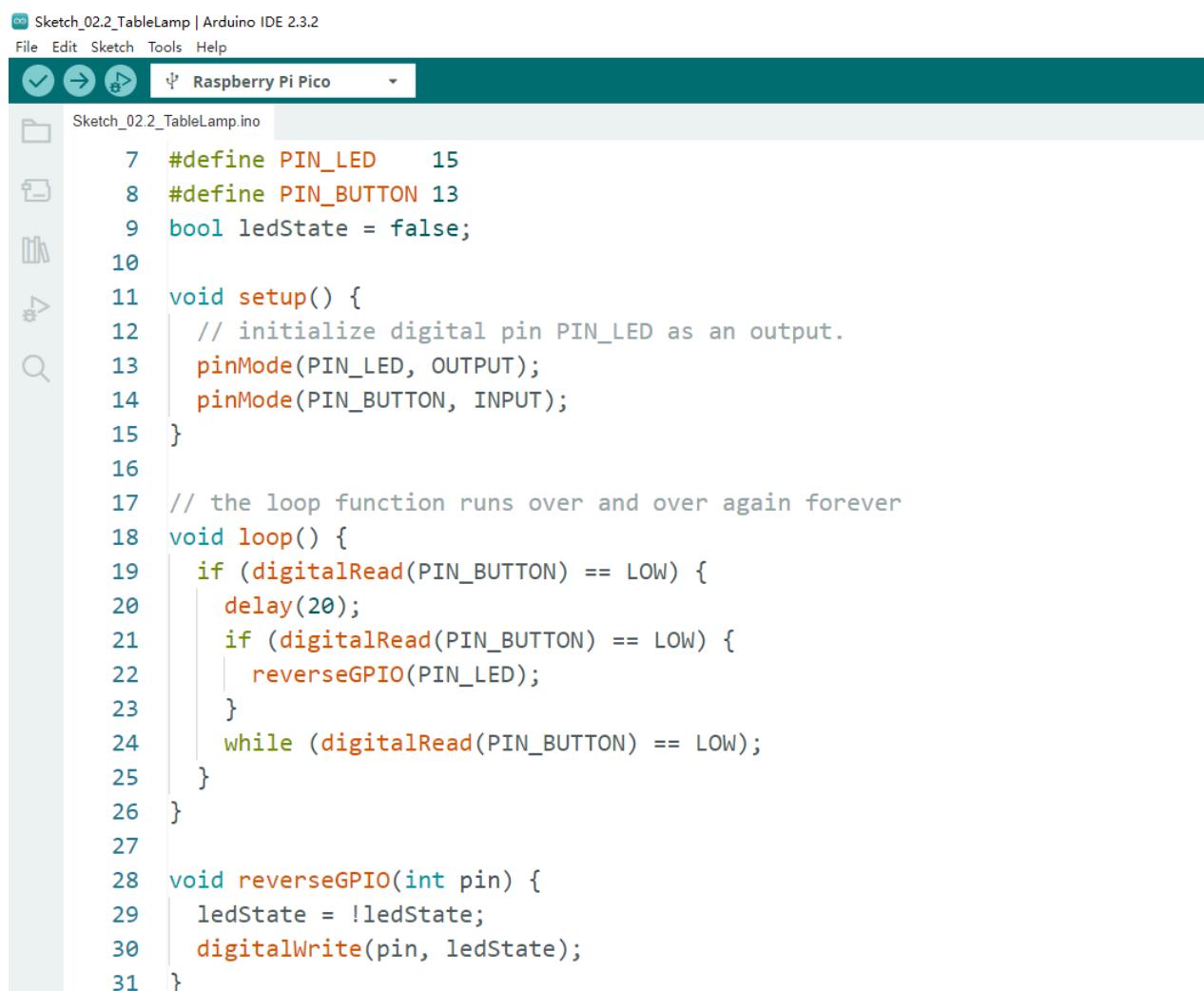
This project needs the same components and circuits as we used in the previous section.

## Sketch

Upload following sketch:

**Freenove\_Super\_Starter\_Kit\_for\_Raspberry\_Pi\_Pico\Sketches\Sketch\_02.2\_TableLamp.**

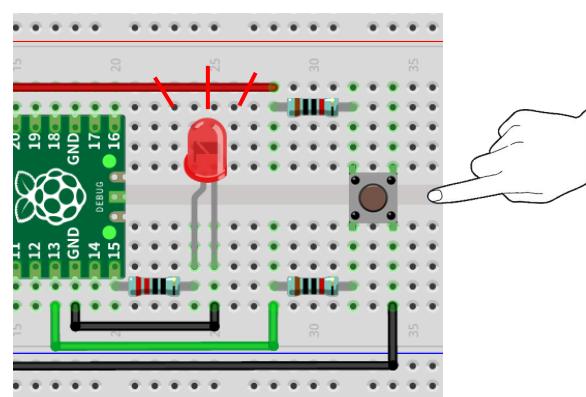
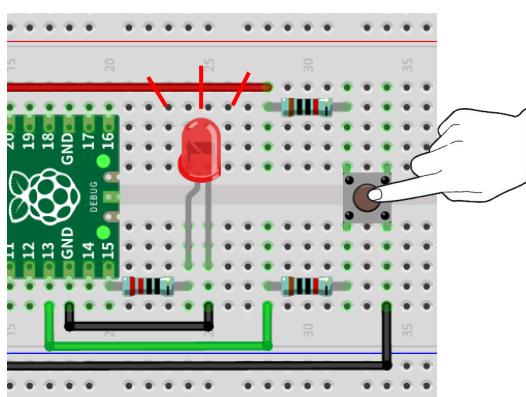
**Sketch\_02.2\_TableLamp**



```

Sketch_02.2_TableLamp | Arduino IDE 2.3.2
File Edit Sketch Tools Help
Sketch_02.2_TableLamp.ino
1 #define PIN_LED 15
2 #define PIN_BUTTON 13
3 bool ledState = false;
4
5 void setup() {
6     // initialize digital pin PIN_LED as an output.
7     pinMode(PIN_LED, OUTPUT);
8     pinMode(PIN_BUTTON, INPUT);
9 }
10
11 // the loop function runs over and over again forever
12 void loop() {
13     if (digitalRead(PIN_BUTTON) == LOW) {
14         delay(20);
15         if (digitalRead(PIN_BUTTON) == LOW) {
16             reverseGPIO(PIN_LED);
17         }
18         while (digitalRead(PIN_BUTTON) == LOW);
19     }
20 }
21
22 void reverseGPIO(int pin) {
23     ledState = !ledState;
24     digitalWrite(pin, ledState);
25 }
26
27
28
29
30
31 }
```

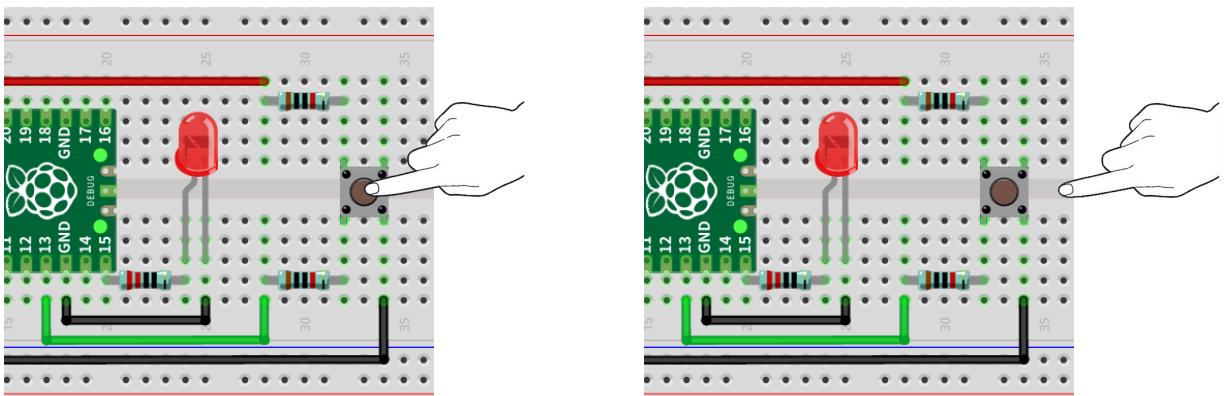
Upload the sketch to Pico. When the button is pressed, LED lights up; when the button is released, LED is still ON.



Any concerns? ✉ support@freenove.com



When the button is pressed again, LED turns OFF; when released, LED keeps OFF.



The following is the program code:

```

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

In the circuit connection, LED and button are connected with GP15 and GP13 respectively, so define ledPin and buttonPin as 15 and 13 respectively.

```

1 #define PIN_LED    15
2 #define PIN_BUTTON 13
```

Define a variable to store the status of LED.

```
3 bool ledState = false;
```

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

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

When the button is pressed, reverseGPIO function is called to change the variable that controls LED's statue, and write it to Pico to reverse the pin's output state.

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



# Chapter 3 LED Bar

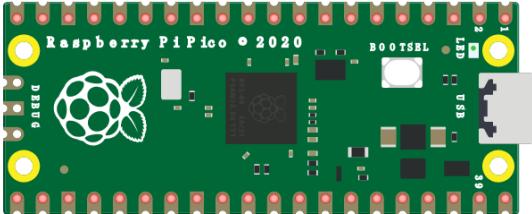
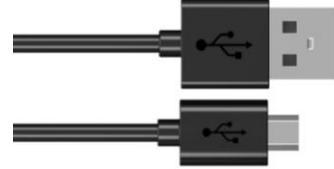
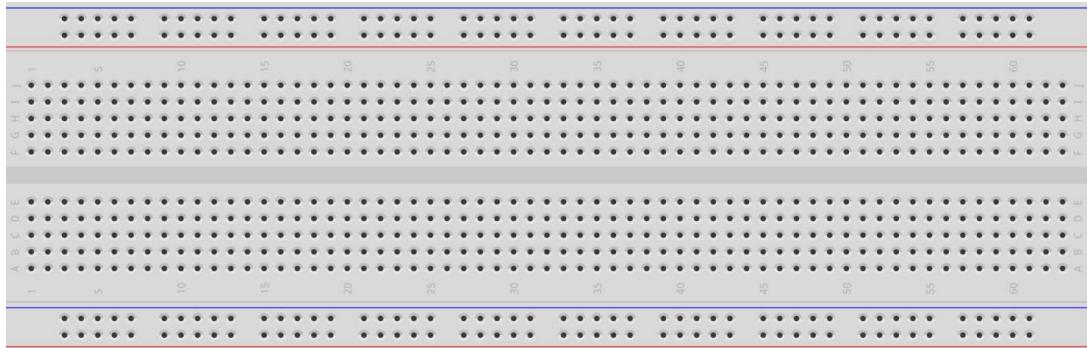
We have learned how to control an LED blinking, next we will learn how to control a number of LEDs.

## Project 3.1 Flowing Light

Note: Raspberry Pi Pico, Raspberry Pi Pico W and Raspberry Pi Pico 2 only differ by wireless function, and are almost identical in other aspects. In this tutorial, except for the wireless function, other parts use Raspberry Pi Pico's map for tutorial demonstration.

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

## Component List

Raspberry Pi Pico x1	USB cable x1	
		
Breadboard x1		
Jumper	LED bar graph x1	Resistor 220Ω x10

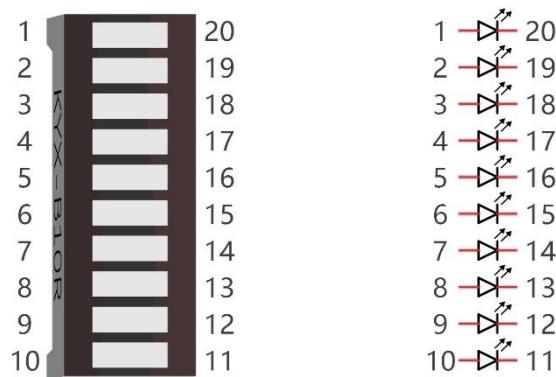
Any concerns? ✉ [support@freenove.com](mailto:support@freenove.com)

## Component Knowledge

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

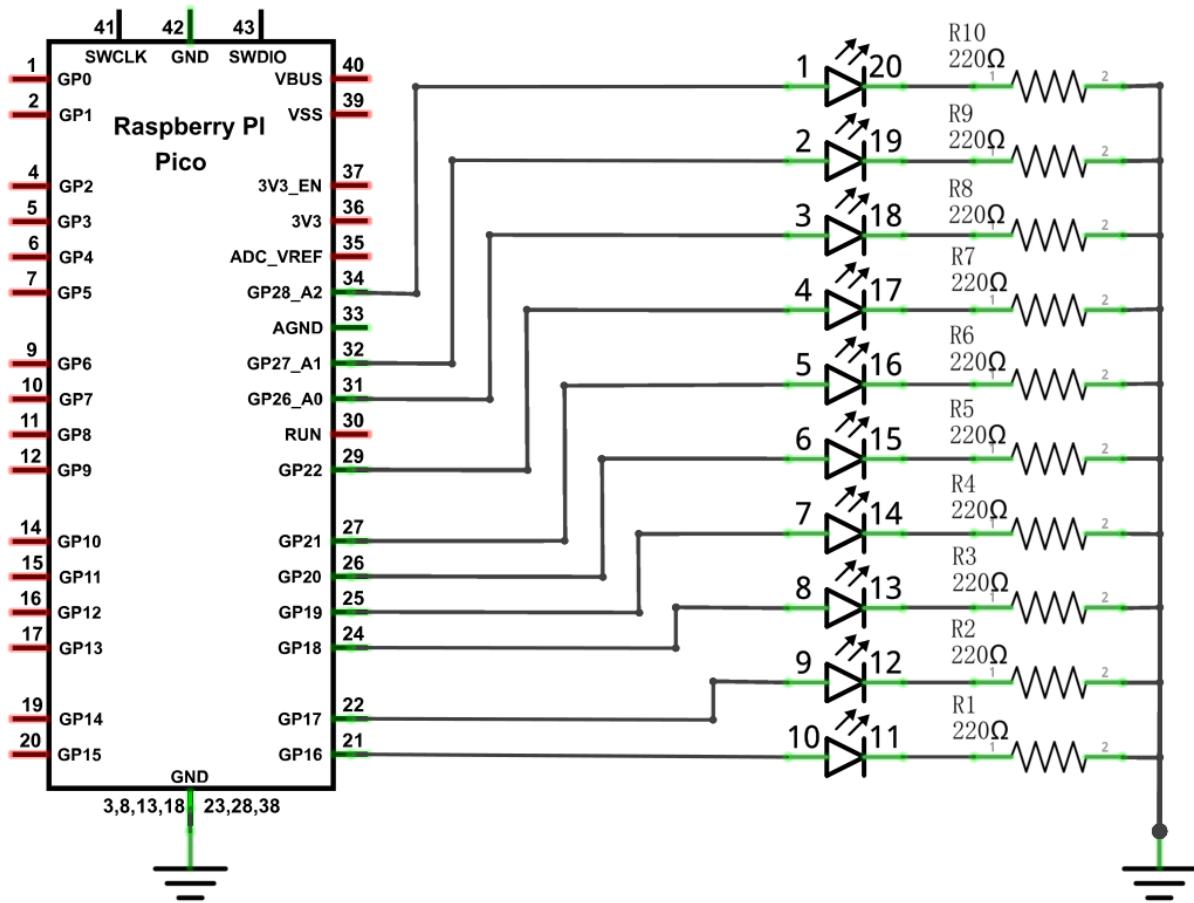
### LED bar

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

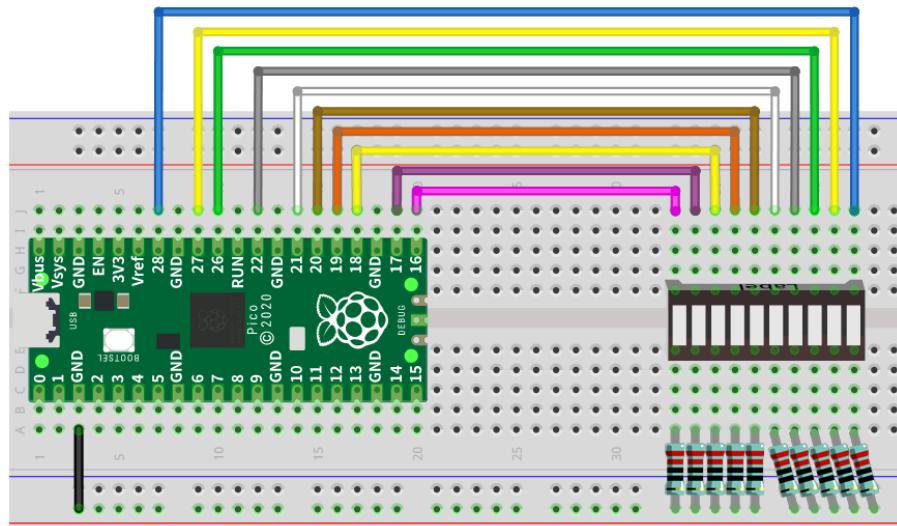


## Circuit

Schematic diagram



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



Note: To help users have a better experience when doing the projects, we have made some modifications to Pico's simulation diagram. Please note that there are certain differences between the simulation diagram and the actual board to avoid misunderstanding.

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

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

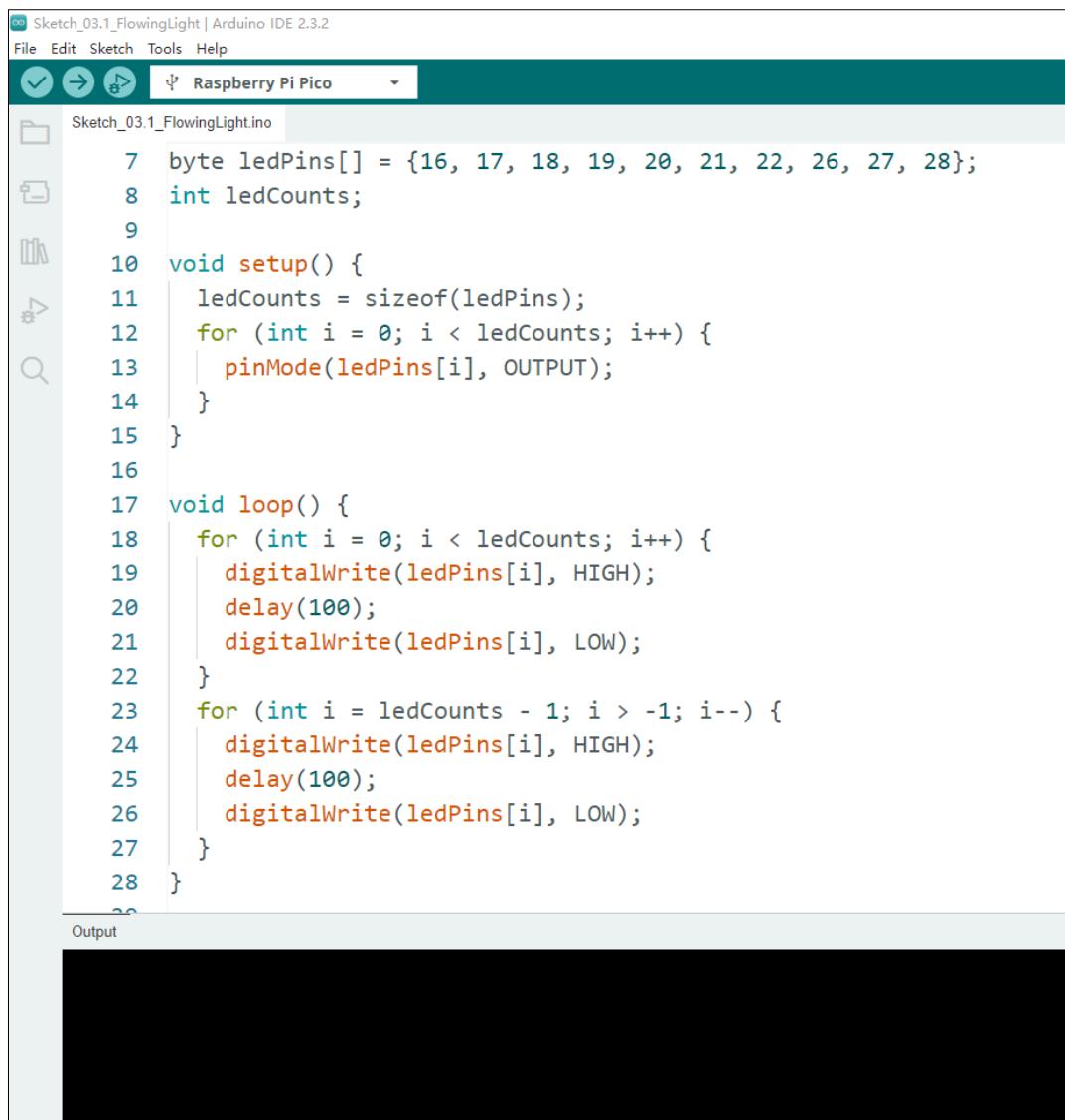
## Sketch

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

Upload following sketch:

**Freenove\_Super\_Starter\_Kit\_for\_Raspberry\_Pi\_Pico\С\Sketches\Sketch\_03.1\_FlowingLight.**

**Sketch\_03.1\_FlowingLight**



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

- Title Bar:** Sketch\_03.1\_FlowingLight | Arduino IDE 2.3.2
- File Menu:** File Edit Sketch Tools Help
- Board Selection:** Raspberry Pi Pico
- Code Area:** The code is named Sketch\_03.1\_FlowingLight.ino. It defines an array of pins (ledPins) and initializes them as outputs. The setup() function sets up the pins. The loop() function repeatedly turns each LED on and off in sequence from left to right and back from right to left, with a 100ms delay between each LED's on/off cycle.

```
byte ledPins[] = {16, 17, 18, 19, 20, 21, 22, 26, 27, 28};  
int ledCounts;  
  
void setup() {  
    ledCounts = sizeof(ledPins);  
    for (int i = 0; i < ledCounts; i++) {  
        pinMode(ledPins[i], OUTPUT);  
    }  
}  
  
void loop() {  
    for (int i = 0; i < ledCounts; i++) {  
        digitalWrite(ledPins[i], HIGH);  
        delay(100);  
        digitalWrite(ledPins[i], LOW);  
    }  
    for (int i = ledCounts - 1; i > -1; i--) {  
        digitalWrite(ledPins[i], HIGH);  
        delay(100);  
        digitalWrite(ledPins[i], LOW);  
    }  
}
```

- Output Area:** A large black box indicating no output.

Click Upload to upload the sketch to Pico. LEDs of LED bar graph lights up one by one from left to right and then back from right to left.



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

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



The following is the program code:

```

1 byte ledPins[] = {16, 17, 18, 19, 20, 21, 22, 26, 27, 28};
2 int ledCounts;
3
4 void setup() {
5     ledCounts = sizeof(ledPins);
6     for (int i = 0; i < ledCounts; i++) {
7         pinMode(ledPins[i], OUTPUT);
8     }
9 }
10
11 void loop() {
12     for (int i = 0; i < ledCounts; i++) {
13         digitalWrite(ledPins[i], HIGH);
14         delay(100);
15         digitalWrite(ledPins[i], LOW);
16     }
17     for (int i = ledCounts - 1; i > -1; i--) {
18         digitalWrite(ledPins[i], HIGH);
19         delay(100);
20         digitalWrite(ledPins[i], LOW);
21     }
22 }
```

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

```
1 byte ledPins[] = {16, 17, 18, 19, 20, 21, 22, 26, 27, 28};
```

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

```

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

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

```

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

# Chapter 4 Analog & PWM

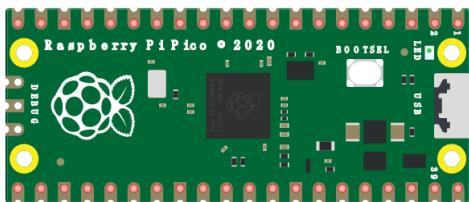
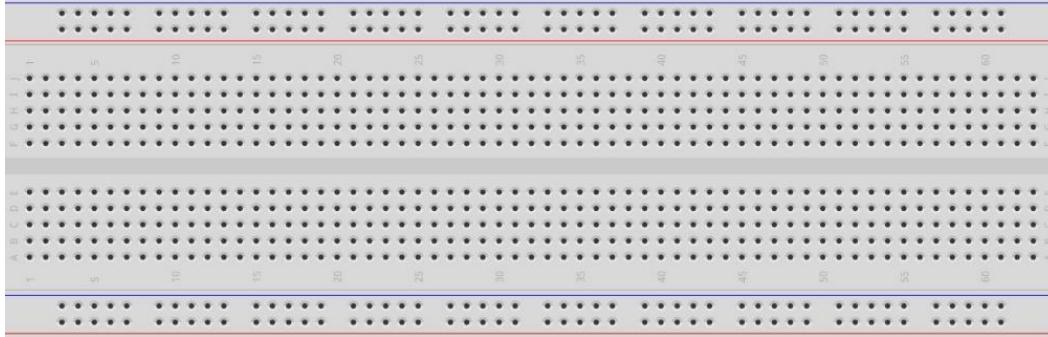
In previous study, we have known that one button has two states: pressed and released, and LED has light-on/off state, then how to enter a middle state? How to output an intermediate state to let LED "semi bright"? That is what we are going to learn.

First, let us learn how to control the brightness of an LED.

## Project 4.1 Breathing LED

Breathing light, that is, LED is turned from off to on gradually and gradually from on to off, just like "breathing". So, how to control the brightness of an LED? We will use PWM to achieve this target.

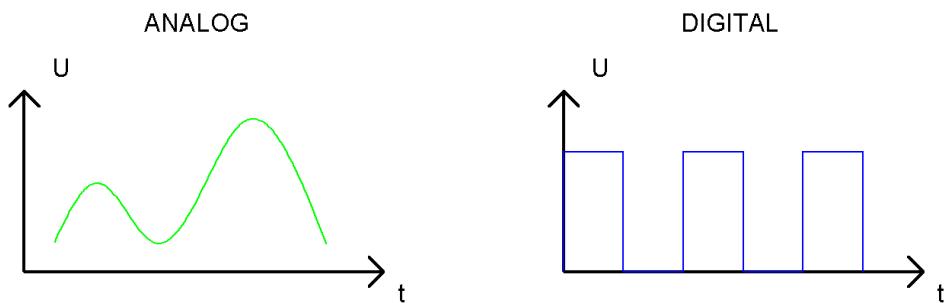
### Component List

Raspberry Pi Pico x1	USB cable x1	
		
		
Breadboard x1		
LED x1	Resistor 220Ω x1	Jumper
		

## Related Knowledge

### Analog & Digital

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



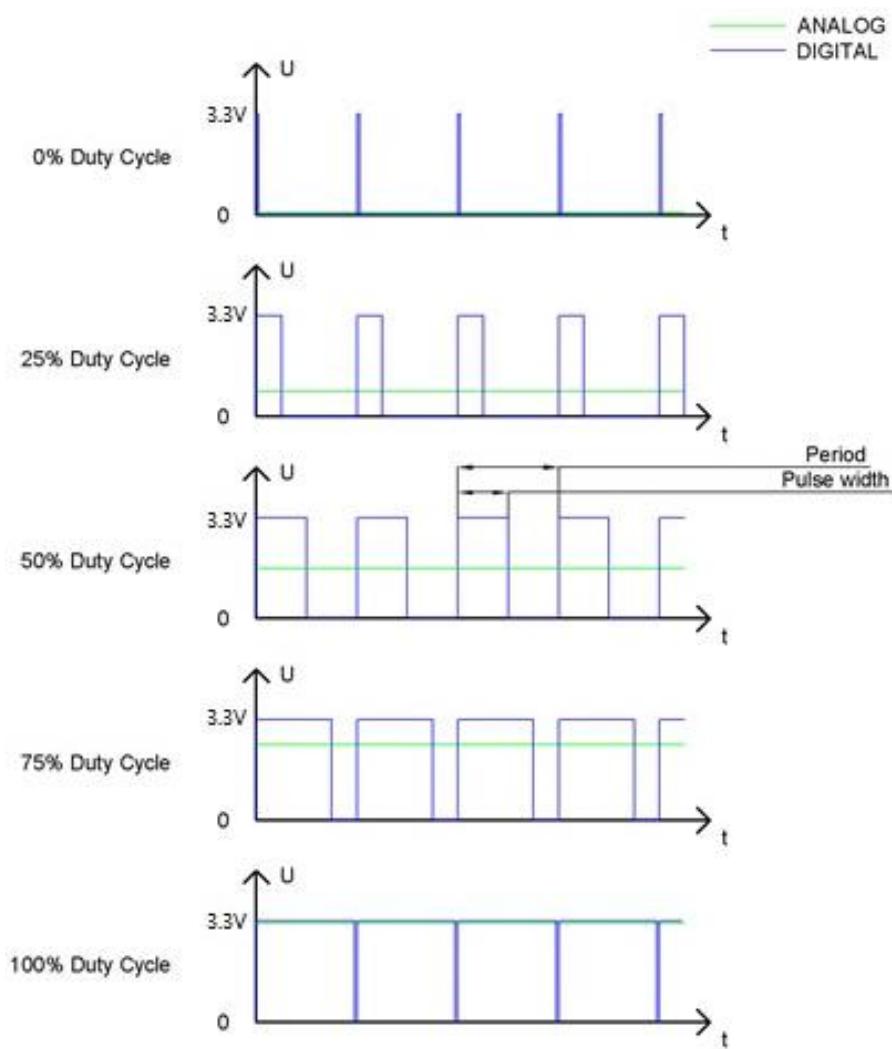
In practical application, we often use binary as the digital signal, that is a series of 0's and 1's. Since a binary signal only has two values (0 or 1), it has great stability and reliability. Lastly, both analog and digital signals can be converted into the other.

### PWM

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

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

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



The longer the PWM duty cycle is, the higher the output power will be. Now that we understand this relationship, we can use PWM to control the brightness of an LED or the speed of DC motor and so on. It is evident from the above that PWM is not real analog, and the effective value of the voltage is equivalent to the corresponding analog. Therefore, we can control the output power of the LED and other output modules to achieve different effects.

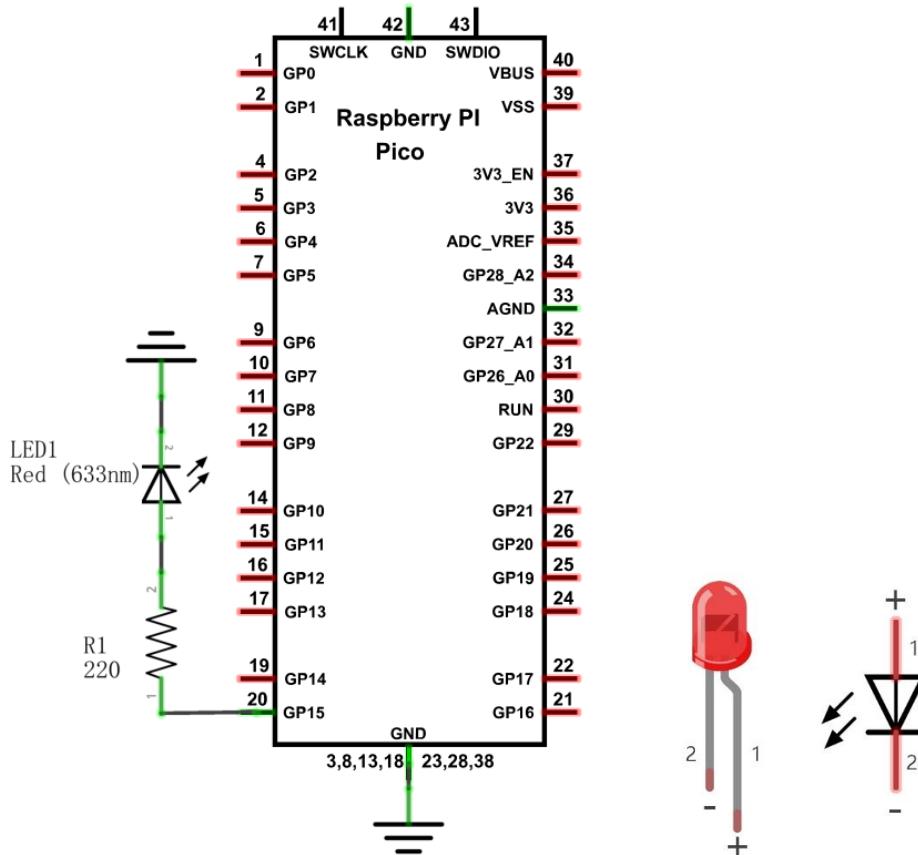
### Raspberry Pi Pico and PWM

Raspberry Pi Pico has 16 PWM channels, each of which can control frequency and duty cycle independently. Every pin on Raspberry Pi Pico can be configured as PWM output. In Arduino, PWM frequency is set to 500Hz. You can change the PWM output by changing duty cycle.

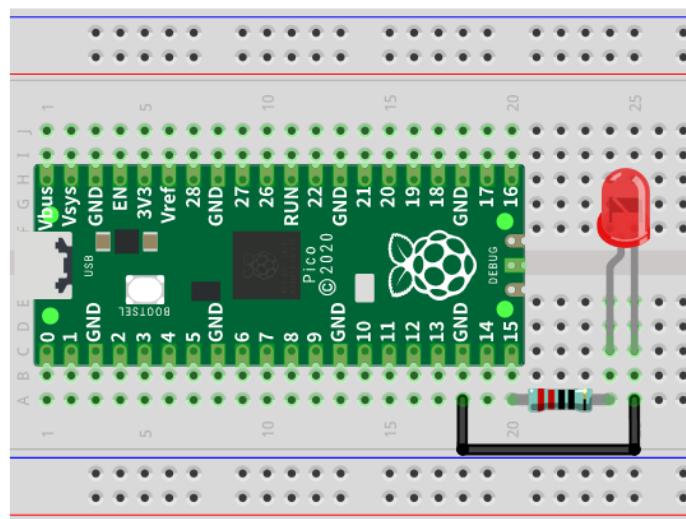
## Circuit

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

Schematic diagram



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



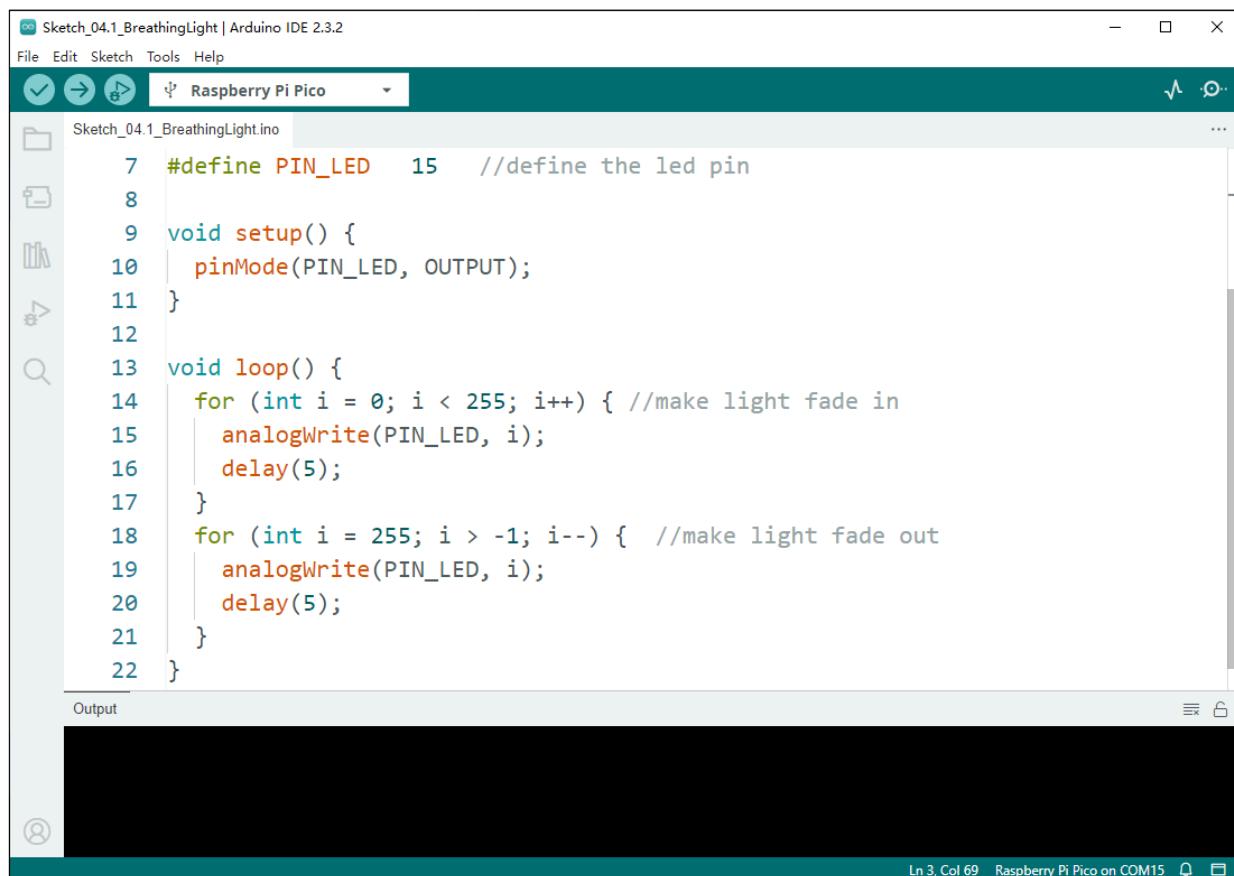
Note: To help users have a better experience when doing the projects, we have made some modifications to Pico's simulation diagram. Please note that there are certain differences between the simulation diagram and the actual board to avoid misunderstanding.

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

## Sketch

This project is designed to make PWM output GP15 with pulse width increasing from 0% to 100%, and then reducing from 100% to 0% gradually.

### Sketch\_04.1\_BreathingLight



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

- Title Bar:** Sketch\_04.1\_BreathingLight | Arduino IDE 2.3.2
- Toolbar:** File, Edit, Sketch, Tools, Help
- Sketch Selection:** Sketch\_04.1\_BreathingLight.ino
- Sketch Area:** Contains the following C++ code:

```
7 #define PIN_LED 15 //define the led pin
8
9 void setup() {
10     pinMode(PIN_LED, OUTPUT);
11 }
12
13 void loop() {
14     for (int i = 0; i < 255; i++) { //make light fade in
15         analogWrite(PIN_LED, i);
16         delay(5);
17     }
18     for (int i = 255; i > -1; i--) { //make light fade out
19         analogWrite(PIN_LED, i);
20         delay(5);
21     }
22 }
```
- Output Area:** A large black area indicating no output at the moment.
- Status Bar:** Ln 3, Col 69 Raspberry Pi Pico on COM15

Download the code to Pico, and you will see that LED is turned from on to off and then from off to on gradually like breathing.





The following is the program code:

```

1 #define PIN_LED 15 //define the led pin
2
3 void setup() {
4     pinMode(PIN_LED, OUTPUT);
5 }
6
7 void loop() {
8     for (int i = 0; i < 255; i++) { //make light fade in
9         analogWrite(PIN_LED, i);
10        delay(5);
11    }
12    for (int i = 255; i > -1; i--) { //make light fade out
13        analogWrite(PIN_LED, i);
14        delay(5);
15    }
16 }
```

Set the pin controlling LED to output mode.

7	pinMode(PIN_LED, OUTPUT);
---	---------------------------

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

```

11 for (int i = 0; i < 255; i++) { //make light fade in
12     analogWrite(PIN_LED, i);
13     delay(5);
14 }
15 for (int i = 255; i > -1; i--) { //make light fade out
16     analogWrite(PIN_LED, i);
17     delay(5);
18 }
```

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

analogWrite(pin, value)
-------------------------

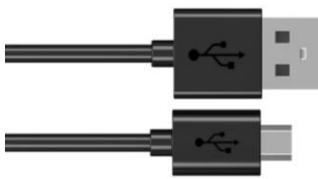
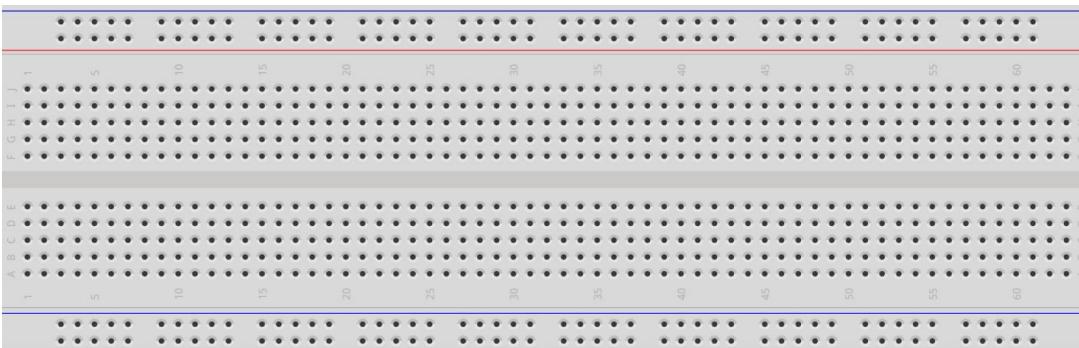
Arduino IDE provides the function, analogWrite(pin, value), which can make ports directly output PWM waves. Every pin on Pico board can be configured to output PWM. In the function called analogWrite(pin, value), the parameter "pin" specifies the port used to output PWM wave. The range of value is 0-255, which represents the duty cycle of 0%-100%.

In order to use this function, we need to set the port to output mode.

## Project 4.2 Meteor Flowing Light

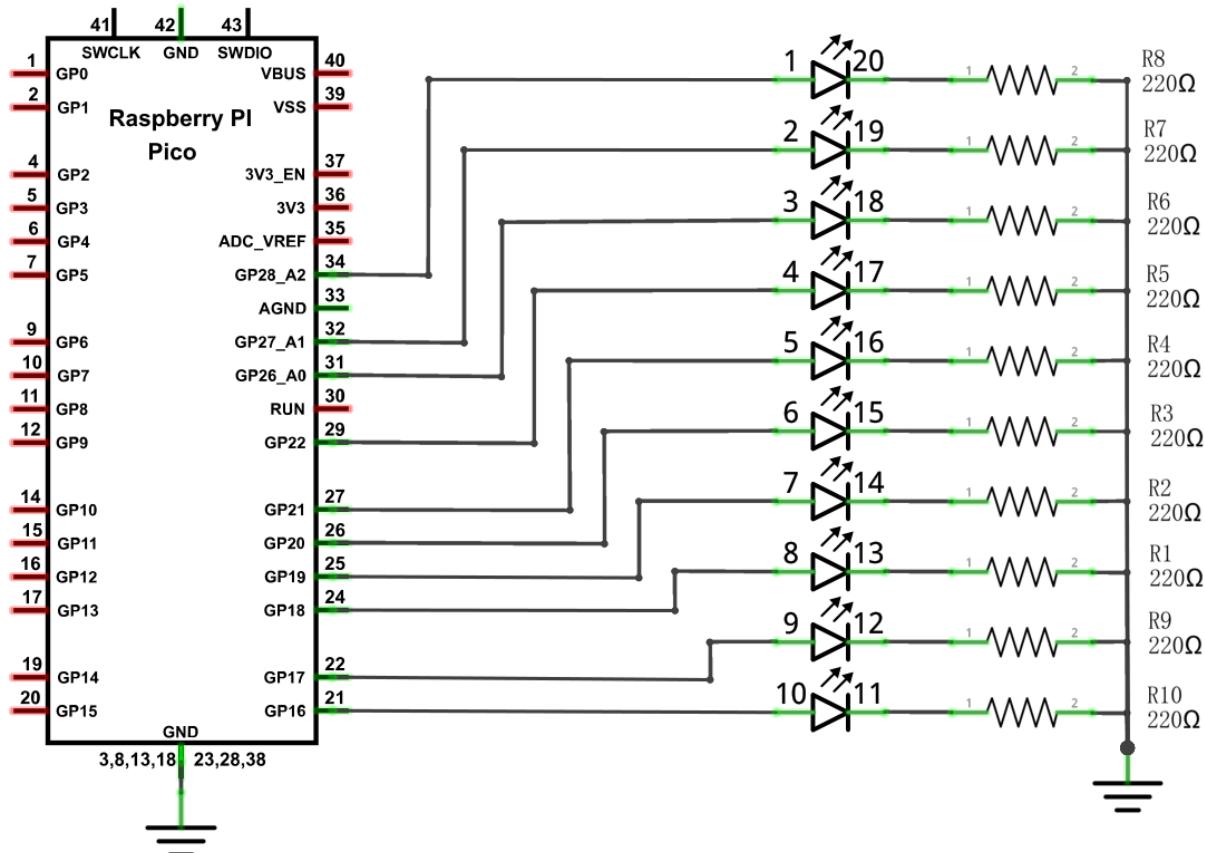
After learning about PWM, we can use it to control LED bar graph and realize a cooler flowing light. The component list, circuit, and hardware are exactly consistent with the project [Flowing Light](#).

### Component List

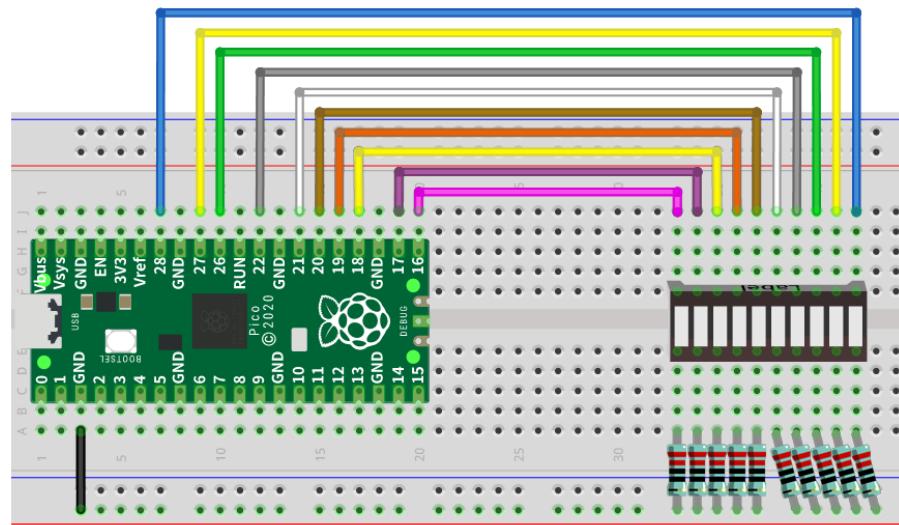
Raspberry Pi Pico x1	USB cable x1		
			
Breadboard x1			
	Jumper	LED bar graph x1	Resistor 220Ω x10

## Circuit

Schematic diagram



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



Note: To help users have a better experience when doing the projects, we have made some modifications to Pico's simulation diagram. Please note that there are certain differences between the simulation diagram and the actual board to avoid misunderstanding.

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

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

# Sketch

Meteor flowing light will be implemented with PWM.

Sketch\_04.2\_FlowingLight2

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

- Title Bar:** Sketch\_04.2\_FlowingLight2 | Arduino IDE 2.3.2
- Menu Bar:** File Edit Sketch Tools Help
- Toolbar:** Includes icons for Save, Run, Stop, and others.
- Sketch Name:** Sketch\_04.2\_FlowingLight2.ino
- Code Area:** Displays the C++ code for the sketch. The code defines 10 LED pins (pins 16-25) and their corresponding PWM duty cycles. It sets up the pins as outputs and then enters a loop where it alternates between flowing from left to right and right to left across all pins.

```
const byte ledPins[] = {16, 17, 18, 19, 20, 21, 22, 26, 27, 28}; //define led pins
const int dutys[] = {0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 4095, 2047, 1023, 512, 256, 128, 64, 32, 16, 8, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0}; //define the pwm dutys
int ledCounts; //the number of leds
int delayTimes = 50; //flowing speed ,the smaller, the faster
void setup() {
    ledCounts = sizeof(ledPins); //get the led counts
    for (int i = 0; i < ledCounts; i++) { //setup the pwm channels
        pinMode(ledPins[i], OUTPUT);
    }
}
void loop() {
    for (int i = 0; i < 20; i++) { //flowing one side to other side
        for (int j = 0; j < ledCounts; j++) {
            analogWrite(ledPins[j], map(dutys[i+j], 0, 4095, 0, 255));
        }
        delay(delayTimes);
    }
    for (int i = 0; i < 20; i++) { //flowing one side to other side
        for (int j = 0; j < ledCounts; j++) {
            analogWrite(ledPins[ledCounts - i - 1], map(dutys[i+j], 0, 4095, 0, 255));
        }
        delay(delayTimes);
    }
}
```

- Output Panel:** Shows the message "Ln 6, Col 72 Raspberry Pi Pico on COM15".

Download the code to Pico, and LED bar graph will gradually light up and out from left to right, then back from right to left.

The following is the program code:

```
1 const byte ledPins[] = {16, 17, 18, 19, 20, 21, 22, 26, 27, 28}; //define led pins
2
3 const int dutys[] = {0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
4 4095, 2047, 1023, 512, 256, 128, 64, 32, 16, 8,
5 0, 0, 0, 0, 0, 0, 0, 0, 0};//define the pwm dutys
6
7 int ledCounts; //the number of leds
```

```

8   int delayTimes = 50; //flowing speed , the smaller, the faster
9   void setup() {
10    ledCounts = sizeof(ledPins);           //get the led counts
11    for (int i = 0; i < ledCounts; i++) { //setup the pwm channels
12      pinMode(ledPins[i], OUTPUT);
13    }
14  }
15
16 void loop() {
17  for (int i = 0; i < 20; i++) {        //flowing one side to other side
18    for (int j = 0; j < ledCounts; j++) {
19      analogWrite(ledPins[j], map(dutys[i+j], 0, 4095, 0, 255));
20    }
21    delay(delayTimes);
22  }
23  for (int i = 0; i < 20; i++) {        //flowing one side to other side
24    for (int j = 0; j < ledCounts; j++) {
25      analogWrite(ledPins[ledCounts - j - 1], map(dutys[i+j], 0, 4095, 0, 255));
26    }
27    delay(delayTimes);
28  }
29}

```

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

```

1 const byte ledPins[] = {16, 17, 18, 19, 20, 21, 22, 26, 27, 28}; //define led pins
2
3 const int dutys[] = {0, 0, 0, 0, 0, 0, 0, 0, 0, 0,
4                      4095, 2047, 1023, 512, 256, 128, 64, 32, 16, 8,
5                      0, 0, 0, 0, 0, 0, 0, 0, 0};//define the pwm dutys

```

Define a variable to store the number of LEDs and another to control the flashing speed of the LED bar.

```

7 int ledCounts; //the number of leds
8 int delayTimes = 50; //flowing speed , the smaller, the faster

```

`Sizeof()` function is used to obtain the number of members of the array `ledPins` and assign it to `ledCount`. Use the 'for' loop to set all pins to output mode.

```

10 ledCounts = sizeof(ledPins);           //get the led counts
11 for (int i = 0; i < ledCounts; i++) { //setup the pwm channels
12   pinMode(ledPins[i], OUTPUT);
13 }

```

In loop(), a nested for loop is used to control the pulse width of the PWM, and LED bar graph moves one grid after each 1 is added in the first for loop, gradually changing according to the values in the array duties. As shown in the table below, the value of the second row is the value in the array duties, and the 10 green squares in each row below represent the 10 LEDs on the LED bar graph. Every 1 is added to  $I$ , the value of the LED bar graph will move to the right by one grid, and when it reaches the end, it will move from the end to the starting point, achieving the desired effect.

0	1	2	3	4	5	7	8	9	1	11	1	1	1	1	1	1	1	2	2	2	2	2	2	3
d	0	0	0	0	0	0	0	0	0	10	5	2	1	6	3	1	8	4	2	0	0	0	0	0
i										23	1	5	2	4	2	6								
0																								
1																								
2																								
3																								
...																								
1																								
8																								
1																								
9																								
2																								
0																								

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

```

17   for (int i = 0; i < 20; i++) {          //flowing one side to other side
18     for (int j = 0; j < ledCounts; j++) {
19       analogWrite(ledPins[j], map(dutys[i+j], 0, 4095, 0, 255));
20     }
21     delay(delayTimes);
22   }
23   for (int i = 0; i < 20; i++) {          //flowing one side to other side
24     for (int j = 0; j < ledCounts; j++) {
25       analogWrite(ledPins[ledCounts - j - 1], map(dutys[i+j], 0, 4095, 0, 255));
26     }
27     delay(delayTimes);
28   }

```

map(value, fromLow, fromHigh, toLow, toHigh)

This function is used to remap a value, which will return a new value whose percentage in the range of toLow-toHigh is equal to the percentage of "value" in the range of fromLow-fromHigh. For example, 1 is the maximum in the range of 0-1 and the maximum value in the scope of 0-2 is 2, that is, the result value of map (1, 0, 1, 0, 2) is 2.

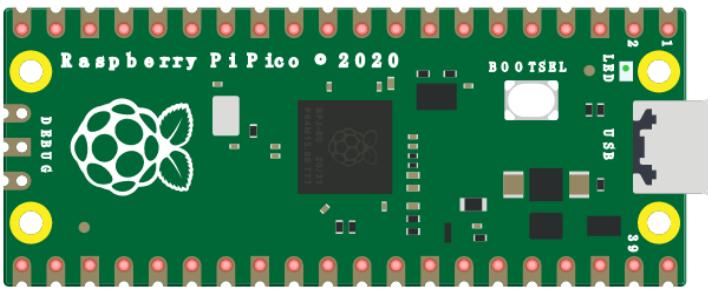
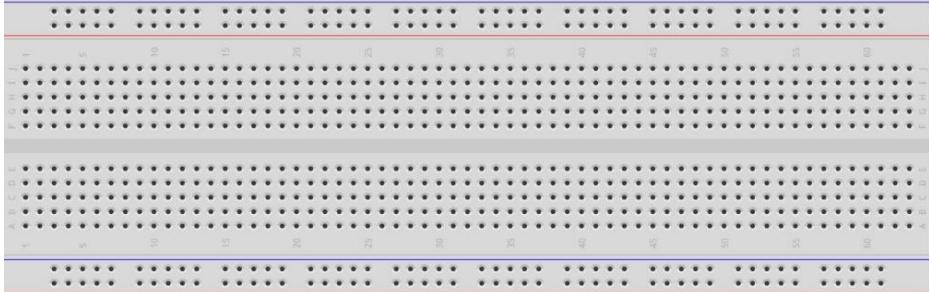
# Chapter 5 RGBLED

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

## Project 5.1 Random Color Light

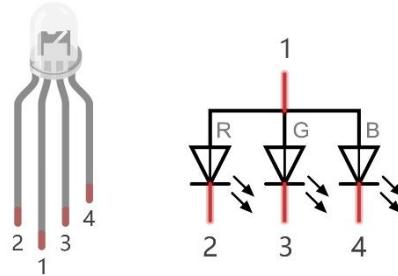
In this project, we will make a multicolored LED. And we can control RGBLED to switch different colors automatically.

### Component List

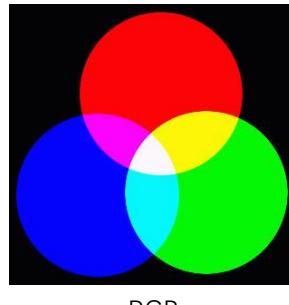
Raspberry Pi Pico x1	USB cable x1	
Breadboard x1		
RGBLED x1	Resistor 220Ω x3	Jumper
		

## Related Knowledge

RGB LED has integrated three LEDs that can respectively emit red, green and blue light. It has four pins. The long pin (1) is the common port, that is, 3 LED's positive or negative port. The RGB LED with common positive port and its symbol is shown below. We can make RGB LED emit various colors of light by controlling these three LEDs to emit light with different brightness.



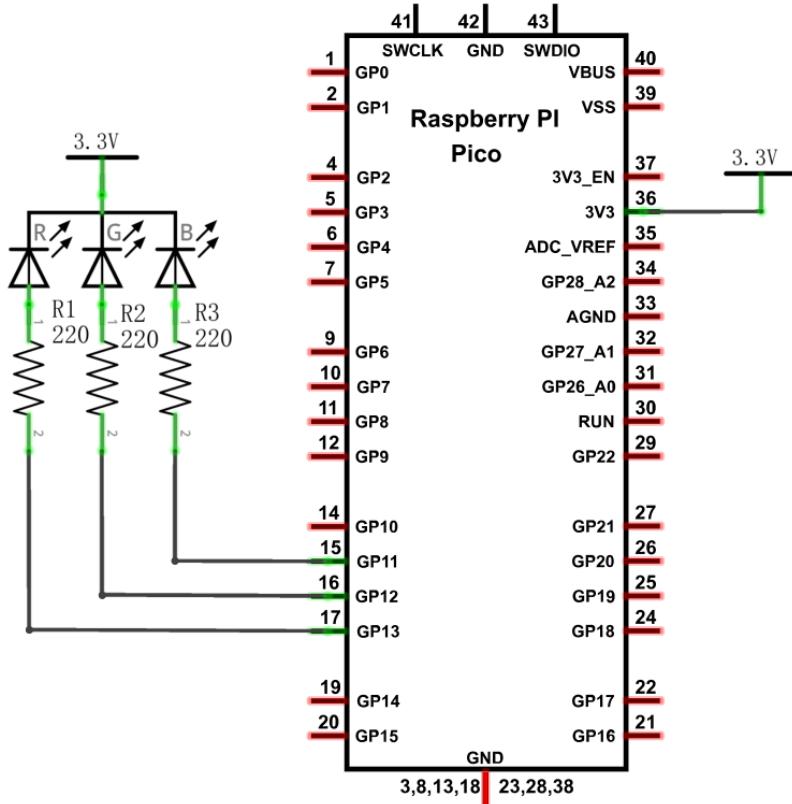
Red, green, and blue light are known as three primary colors. When you combine these three primary-color lights with different brightness, it can produce almost all kinds of visible lights. Computer screens, single pixel of cell phone screen, neon, etc. are working under this principle.



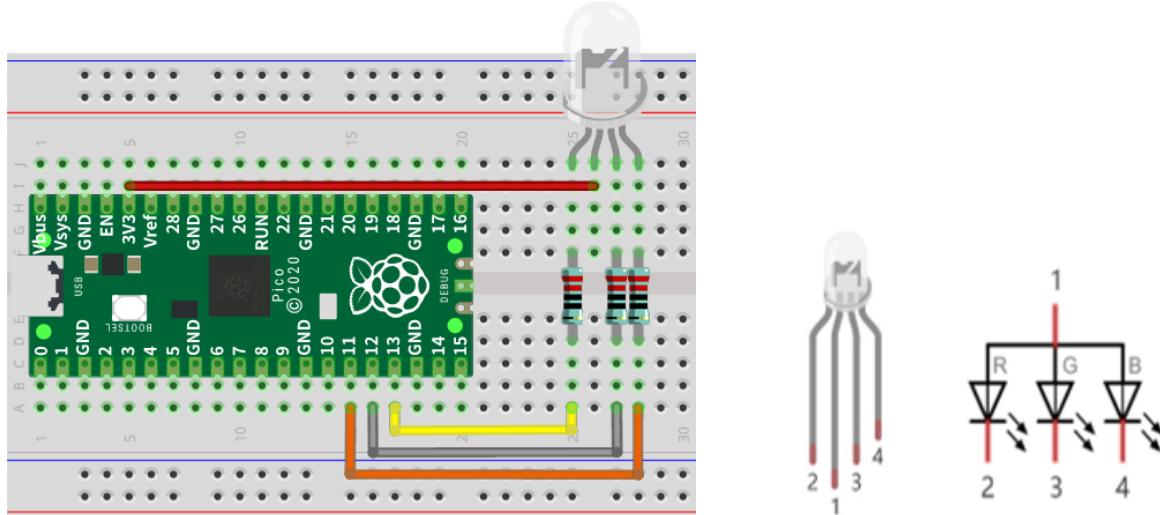
If we use three 8-bit PWMs to control the RGB LED, in theory, we can create  $2^8 \times 2^8 \times 2^8 = 16777216$  (16 million) colors through different combinations.

## Circuit

Schematic diagram



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

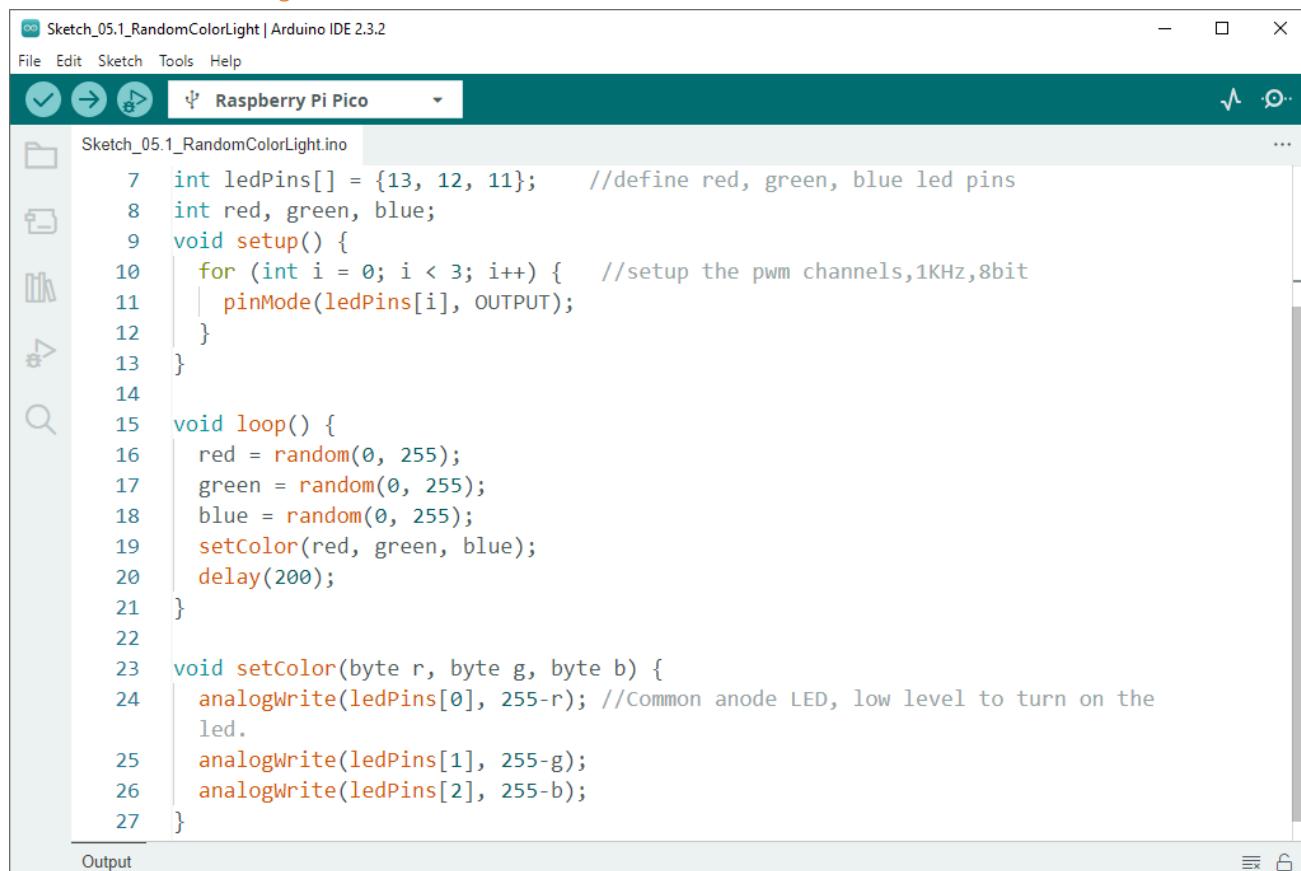


Note: To help users have a better experience when doing the projects, we have made some modifications to Pico's simulation diagram. Please note that there are certain differences between the simulation diagram and the actual board to avoid misunderstanding.

## Sketch

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

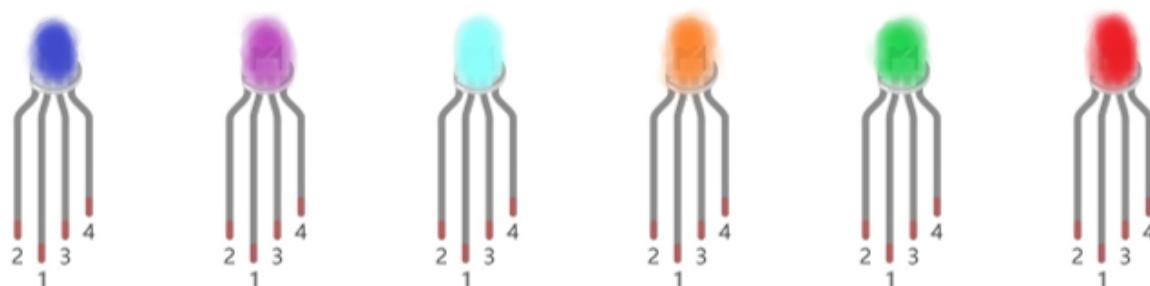
### Sketch\_05.1\_ColorfulLight



```

Sketch_05.1_RandomColorLight | Arduino IDE 2.3.2
File Edit Sketch Tools Help
Sketch_05.1_RandomColorLight.ino
1 int ledPins[] = {13, 12, 11};      //define red, green, blue led pins
2 int red, green, blue;
3 void setup() {
4     for (int i = 0; i < 3; i++) {    //setup the pwm channels,1KHz,8bit
5         pinMode(ledPins[i], OUTPUT);
6     }
7 }
8 void loop() {
9     red = random(0, 255);
10    green = random(0, 255);
11    blue = random(0, 255);
12    setColor(red, green, blue);
13    delay(200);
14 }
15 void setColor(byte r, byte g, byte b) {
16     analogWrite(ledPins[0], 255-r); //Common anode LED, low level to turn on the
17     //led.
18     analogWrite(ledPins[1], 255-g);
19     analogWrite(ledPins[2], 255-b);
20 }
21 }
22
23
24
25
26
27 }
```

With the code downloaded to Pico, RGB LED begins to display random colors.



The following is the program code:

1	<code>int ledPins[] = {13, 12, 11};      //define red, green, blue led pins</code>
2	<code>int red, green, blue;</code>
3	<code>void setup() {</code>
4	<code>    for (int i = 0; i &lt; 3; i++) {    //setup the pwm channels,1KHz,8bit</code>
5	<code>        pinMode(ledPins[i], OUTPUT);</code>
6	<code>    }</code>
7	<code>}</code>
8	

```

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

Define pins to control RGB LED, and configure them as output mode.

```

1 int ledPins[] = {13, 12, 11}; //define red, green, blue led pins
2 int red, green, blue;
3 void setup() {
4     for (int i = 0; i < 3; i++) { //setup the pwm channels, 1KHz, 8bit
5         pinMode(ledPins[i], OUTPUT);
6     }
7 }
```

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

```

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

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

```

12 red = random(0, 255);
13 green = random(0, 255);
14 blue = random(0, 255);
15 setColor(red, green, blue);
16 delay(200);
```

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

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

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

## Project 5.2 Gradient Color Light

In the previous project, we have mastered the usage of RGBLED, but the random color display is rather stiff.

This project will realize a fashionable Light with soft color changes.

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

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



## Sketch

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

### [Sketch\\_05.2\\_SoftColorfulLight](#)

The following is the program code:

```

1 const byte ledPins[] = {13, 12, 11};      //define led pins
2 void setup() {
3     for (int i = 0; i < 3; i++) {    //setup the pwm channels
4         pinMode(ledPins[i], OUTPUT);
5     }
6 }
7
8 void loop() {
9     for (int i = 0; i < 256; i++) {
10        setColor(wheel(i));
11        delay(100);
12    }
13 }
14
15 void setColor(long rgb) {
16     analogWrite(ledPins[0], 255 - (rgb >> 16) & 0xFF);
17     analogWrite(ledPins[1], 255 - (rgb >> 8) & 0xFF);
18     analogWrite(ledPins[2], 255 - (rgb >> 0) & 0xFF);
19 }
20
21 long wheel(int pos) {
22     long WheelPos = pos % 0xff;
23     if (WheelPos < 85) {
24         return ((255 - WheelPos * 3) << 16) | ((WheelPos * 3) << 8);
25     } else if (WheelPos < 170) {

```

```

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

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

```

15 void setColor(long rgb) {
16     ledcWrite(chns[0], 255 - (rgb >> 16) & 0xFF);
17     ledcWrite(chns[1], 255 - (rgb >> 8) & 0xFF);
18     ledcWrite(chns[2], 255 - (rgb >> 0) & 0xFF);
19 }
```

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

```

21 long wheel(int pos) {
22     long WheelPos = pos % 0xff;
23     if (WheelPos < 85) {
24         return (((255 - WheelPos * 3) << 16) | ((WheelPos * 3) << 8));
25     } else if (WheelPos < 170) {
26         WheelPos -= 85;
27         return (((255 - WheelPos * 3) << 8) | (WheelPos * 3));
28     } else {
29         WheelPos -= 170;
30         return ((WheelPos * 3) << 16 | (255 - WheelPos * 3));
31     }
32 }
```

# Chapter 6 NeoPixel

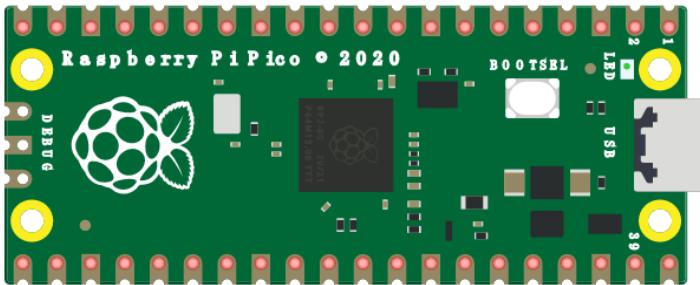
This chapter will help you learn to use a more convenient RGBLED lamp, which requires only one GPIO control and can be connected in infinite series in theory. Each LED can be controlled independently.

## Project 6.1 NeoPixel

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

### Component List

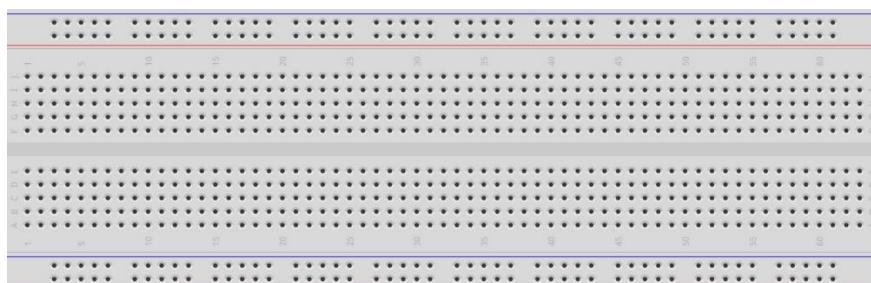
Raspberry Pi Pico x1



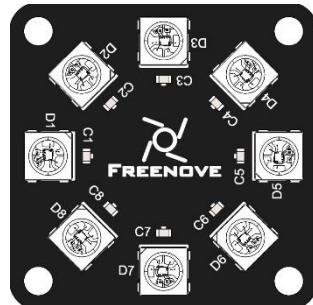
USB cable x1



Breadboard x1



Freenove 8 RGB LED Module x1



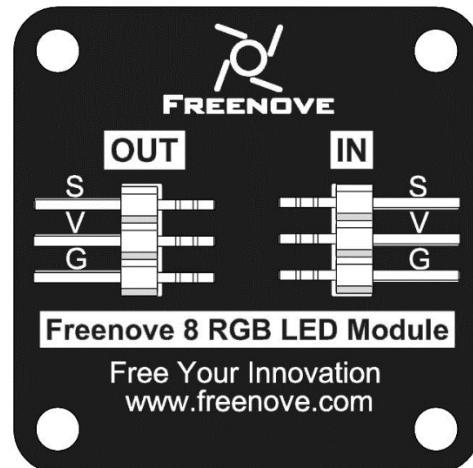
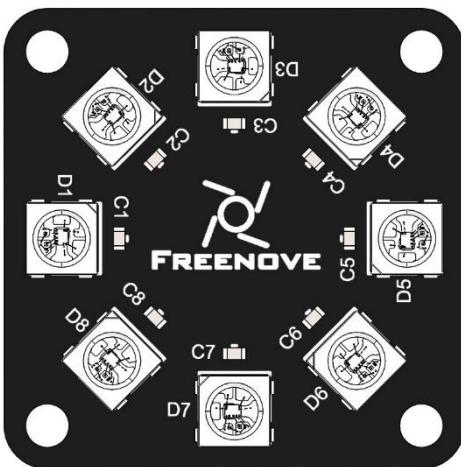
Jumper



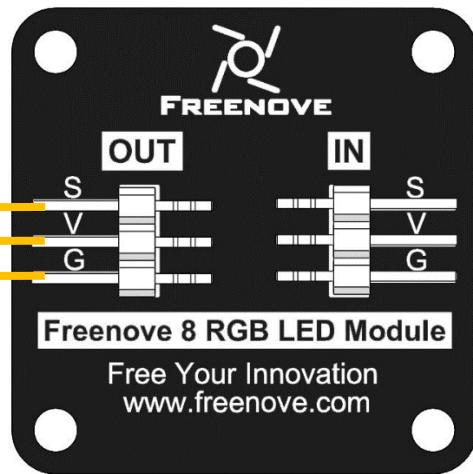
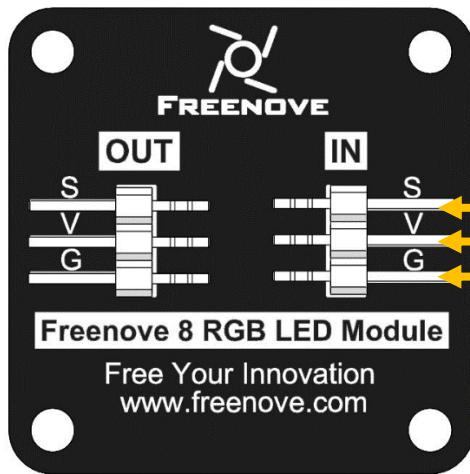
## Related Knowledge

### Freenove 8 RGB LED Module

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



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

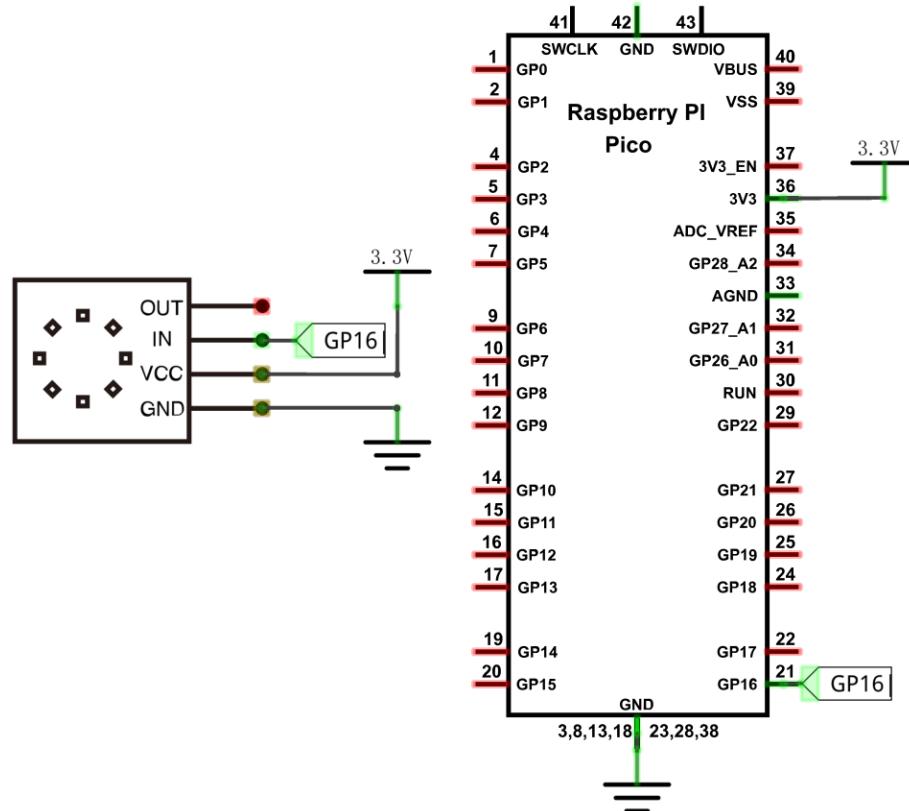


### Pin description:

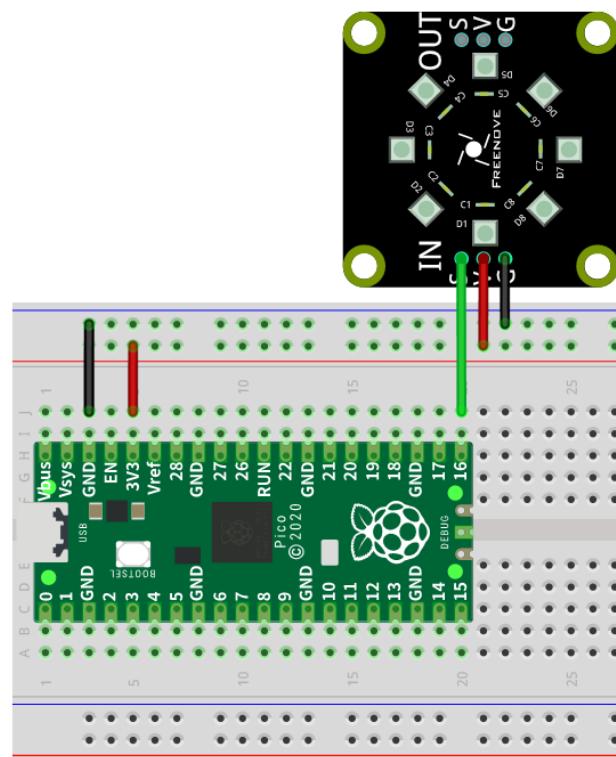
(IN)		(OUT)	
symbol	Function	symbol	Function
S	Input control signal	S	Output control signal
V	Power supply pin, +3.3V~5.5V	V	Power supply pin, +3.3V~5.5V
G	GND	G	GND

## Circuit

Schematic diagram



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



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



## Sketch

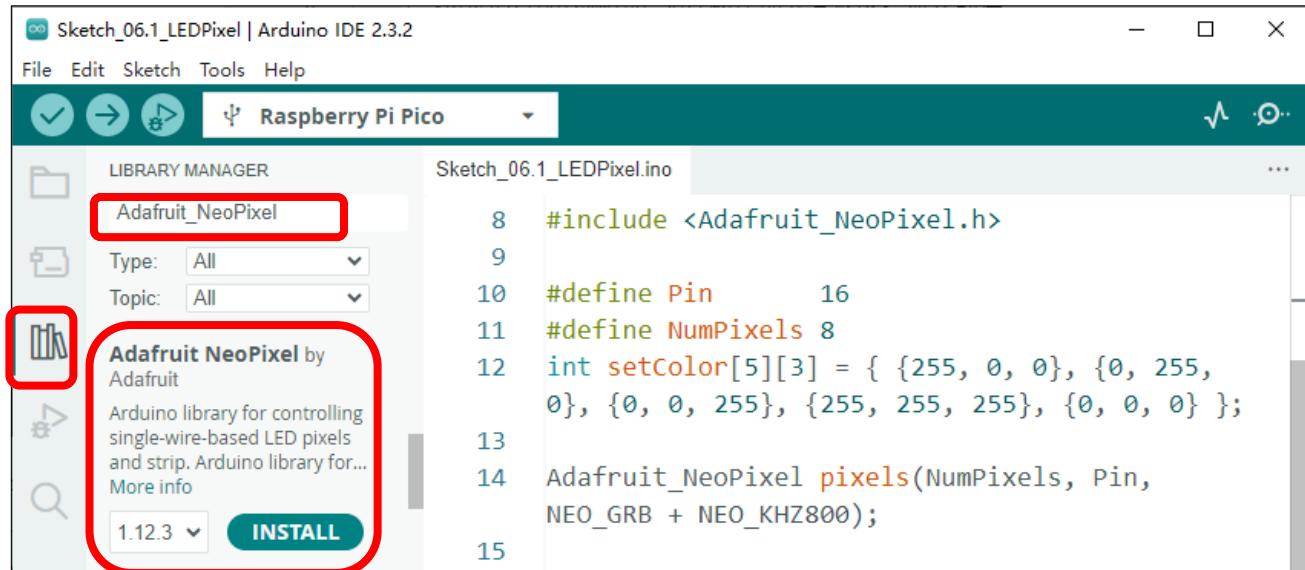
This code uses a library named "**Adafruit\_NeoPixel**". If you have not installed it, please do so first.

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

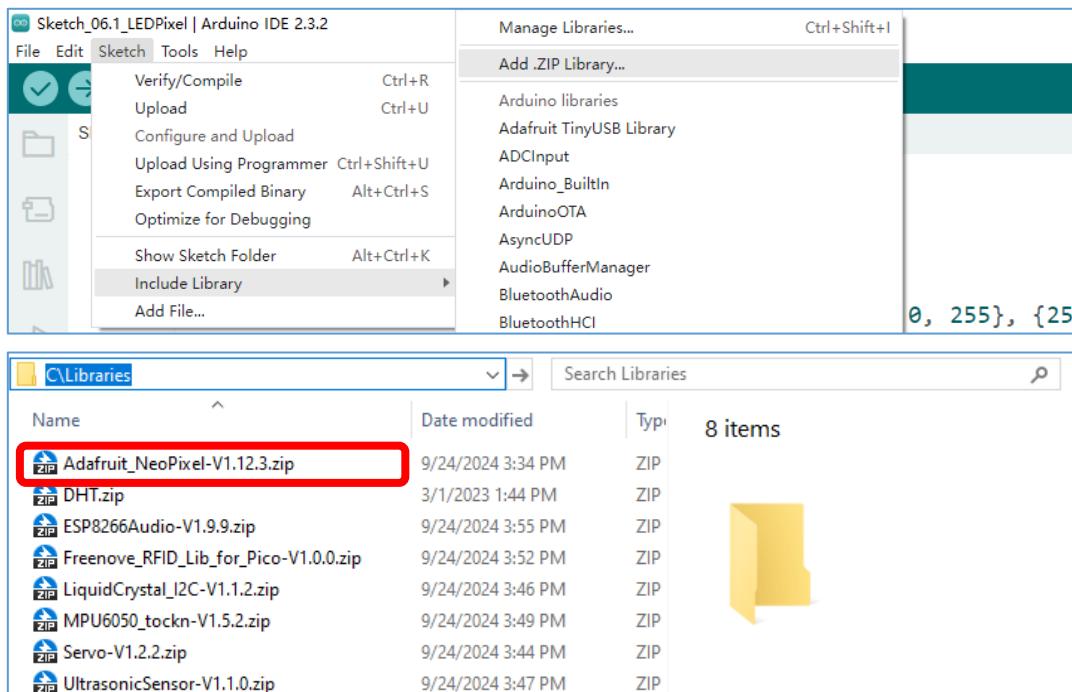
### How to install the library

There are two ways to add libraries.

The first way, open Arduino IDE, click **Library Manager** on the left, input "**Adafruit\_NeoPixel**" in the search bar and select "**Adafruit\_NeoPixel**" to install, as shown below.



The second way, open Arduino IDE, click Sketch→Include Library→Add .ZIP Library. In the pop-up window, find the file named ".Libraries/ **Adafruit\_NeoPixel-V1.12.3.Zip**" which locates in this directory, and click OPEN.



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

## Sketch\_06.1\_LEDPixel

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

- Title Bar:** Sketch\_06.1\_LEDPixel | Arduino IDE 2.3.2
- File Menu:** File Edit Sketch Tools Help
- Board Selection:** Raspberry Pi Pico
- Code Area:** Displays the `Sketch_06.1_LEDPixel.ino` file content.
- Code Content:**

```
10 #define Pin      16
11 #define NumPixels 8
12 int setColor[5][3] = { {255, 0, 0}, {0, 255, 0}, {0, 0, 255}, {255, 255, 255},
13   {0, 0, 0} };
14 Adafruit_NeoPixel pixels(NumPixels, Pin, NEO_GRB + NEO_KHZ800);
15
16 void setup() {
17   pixels.begin();
18   pixels.setBrightness(20);
19 }
20
21 void loop() {
22   for (int j = 0; j < 5; j++) {
23     for (int i = 0; i < NumPixels; i++) {
24       pixels.setPixelColor(i, setColor[j][0], setColor[j][1], setColor[j][2]);
25       pixels.show();
26       delay(100);
27     }
28     delay(500);
29   }
30 }
```
- Output Area:** Shows "Ln 5, Col 33" and "Raspberry Pi Pico on COM15".

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





The following is the program code:

```

1 #include <Adafruit_NeoPixel.h>
2
3 #define Pin      16
4 #define NumPixels 8
5 int setColor[5][3] = { {255, 0, 0}, {0, 255, 0}, {0, 0, 255}, {255, 255, 255}, {0, 0, 0} };
6
7 Adafruit_NeoPixel pixels(NumPixels, Pin, NEO_GRB + NEO_KHZ800);
8
9 void setup() {
10     pixels.begin();
11     pixels.setBrightness(20);
12 }
13
14 void loop() {
15     for (int j = 0; j < 5; j++) {
16         for (int i = 0; i < NumPixels; i++) {
17             pixels.setPixelColor(i, setColor[j][0], setColor[j][1], setColor[j][2]);
18             pixels.show();
19             delay(100);
20         }
21         delay(500);
22     }
23 }
```

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

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

Define the pins connected to the ring, the number of LEDs on the ring.

```

3 #define Pin      16
4 #define NumPixels 8
```

Apply for an object that controls the RGB LED ring, and assign the number of LEDs, the number of pins that control the LEDs, and the control mode of the LEDs to the object.

```
7 Adafruit_NeoPixel pixels(NumPixels, Pin, NEO_GRB + NEO_KHZ800);
```

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

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

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

```

10     pixels.begin();
11     pixels.setBrightness(20);
```

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

```

15     for (int j = 0; j < 5; j++) {
16         for (int i = 0; i < NumPixels; i++) {
17             pixels.setPixelColor(i, setColor[j][0], setColor[j][1], setColor[j][2]);
18             pixels.show();
```

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

```
19     delay(100);  
20 }  
21 delay(500);  
22 }
```

## Reference

**Adafruit\_NeoPixel**(uint16\_t n, int16\_t pin = 6, neoPixelType type = NEO\_GRB + NEO\_KHZ800)

Constructor to create a NeoPixel object.

Before each use of the constructor, please add “[Adafruit\\_NeoPixel.h](#)”

### Parameters

**n**: The number of led.

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

**type**: Types of LED.

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

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

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

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

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

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

**void begin(void)** ;

Initialize the NeoPixel object

**void setPixelColor (u8 index, u8 r, u8 g, u8 b);**

**void setPixelColor (u8 index, u32 rgb);**

**void setPixelColor (u8 index, u8 r, u8 g, u8 b, u8 w);**

Set the color of LED with order number n.

**void show(void)** ;

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

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

Set the brightness of the LED.

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

[https://github.com/adafruit/Adafruit\\_NeoPixel](https://github.com/adafruit/Adafruit_NeoPixel)



## Project 6.2 Rainbow Light

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

### Sketch

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



#### Sketch\_06.2\_RainbowLight

```
#include <Adafruit_NeoPixel.h>
#define Pin 16
#define NumPixels 8
int red = 0;
int green = 0;
int blue = 0;
Adafruit_NeoPixel strip(NumPixels, Pin, NEO_GRB + NEO_KHZ800);
void setup() {
    strip.begin();
    strip.setBrightness(20);
}
void loop() {
    for (int j = 0; j < 256 * 5; j++) {
        for (int i = 0; i < 8; i++) {
            Wheel(((i * 256 / 8) + j)%255);
            strip.setPixelColor(i, strip.Color(red, green, blue));
        }
        strip.show();
        delay(10);
    }
}
```

The screenshot shows the Arduino IDE interface with the sketch file "Sketch\_06.2\_RainbowLight.ino" open. The code implements a color wheel algorithm to cycle through all colors of an 8-pixel NeoPixel strip connected to pin 16. The sketch includes a setup function to initialize the strip and set its brightness to 20, and a loop function that iterates 256 times, each time cycling through the 8 pixels and setting their colors based on a color wheel formula. The Arduino IDE version shown is 2.3.2, and the board is set to "Raspberry Pi Pico".

Download the code to Pico, and the Freenove 8 RGB LED Strip displays different colors and the color changes gradually.



The following is the program code:

```
1 #include <Adafruit_NeoPixel.h>
2
3 #define Pin      16
4 #define NumPixels 8
5 int red = 0;
6 int green = 0;
7 int blue = 0;
8 Adafruit_NeoPixel strip(NumPixels, Pin, NEO_GRB + NEO_KHZ800);
9
10 void setup() {
11     strip.begin();
12     strip.setBrightness(20);
13 }
14
15 void loop() {
16     for (int j = 0; j < 256 * 5; j++) {
17         for (int i = 0; i < 8; i++) {
18             Wheel(((i * 256 / 8) + j)%255);
19             strip.setPixelColor(i, strip.Color(red, green, blue));
20         }
21         strip.show();
22         delay(10);
23     }
24 }
25
26 void Wheel(byte WheelPos) {
27     WheelPos = 255 - WheelPos;
28     if (WheelPos < 85) {
29         red = 255 - WheelPos * 3;
30         green = 0;
31         blue = WheelPos * 3;
32     }
33     else if (WheelPos < 170) {
34         WheelPos -= 85;
35         red = 0;
```

```
36     green = WheelPos * 3;
37     blue = 255 - WheelPos * 3;
38 }
39 else {
40     WheelPos -= 170;
41     red = WheelPos * 3;
42     green = 255 - WheelPos * 3;
43     blue = 0;
44 }
45 }
```

In the loop(), two “for” loops are used, the internal “for” loop(for-i) is used to set the color of each LED, and the external “for” loop(for-i) is used to change the color, in which the self-increment value in i+=1 can be changed to change the color step distance. Changing the delay parameter changes the speed of the color change. Wheel(((i \* 256 / 8) + j)%255) will take color from the color model at equal intervals starting from i.

```
16 for (int j = 0; j < 256 * 5; j++) {
17     for (int i = 0; i < 8; i++) {
18         Wheel(((i * 256 / 8) + j)%255);
19         strip.setPixelColor(i, strip.Color(red, green, blue));
20     }
21     strip.show();
22     delay(10);
23 }
```

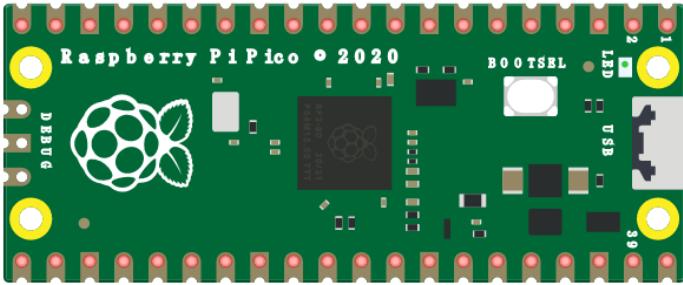
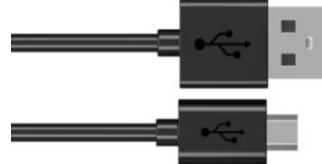
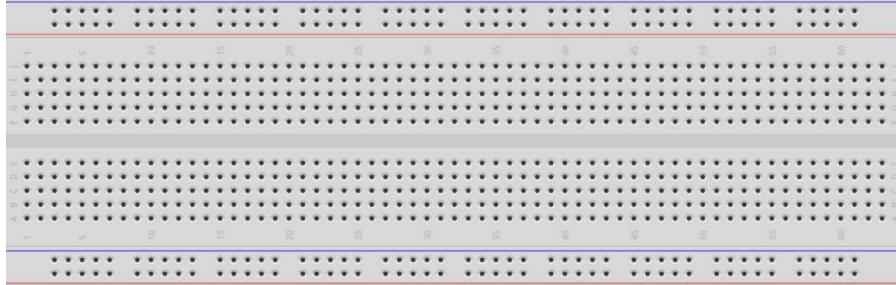
# Chapter 7 Buzzer

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

## Project 7.1 Doorbell

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

### Component List

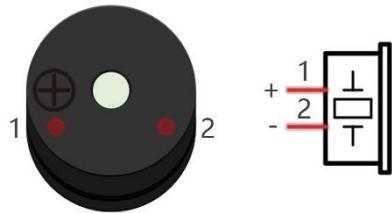
Raspberry Pi Pico x1		USB cable x1	
Breadboard x1			
Jumper			
NPN transistor x1 (S8050)		Active buzzer x1	
Push button x1		Resistor 1kΩ x1	
		Resistor 10kΩ x2	

## Component Knowledge

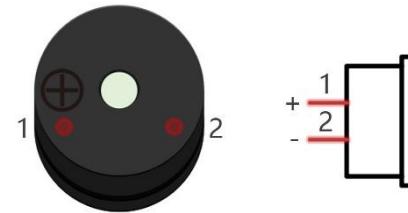
### Buzzer

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

Active buzzer



Passive buzzer



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

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

### How to identify active and passive buzzer?

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

Active buzzer



Passive buzzer



### Transistor

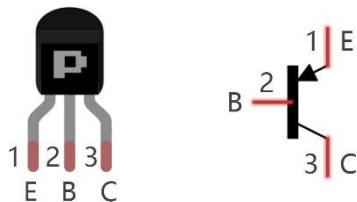
Because the buzzer requires such large current that GP of Raspberry Pi Pico output capability cannot meet the requirement, a transistor of NPN type is needed here to amplify the current.

Transistor, the full name: semiconductor transistor, is a semiconductor device that controls current. Transistor

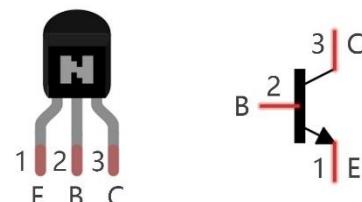
**Any concerns? ✉ support@freenove.com**

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

PNP transistor



NPN transistor

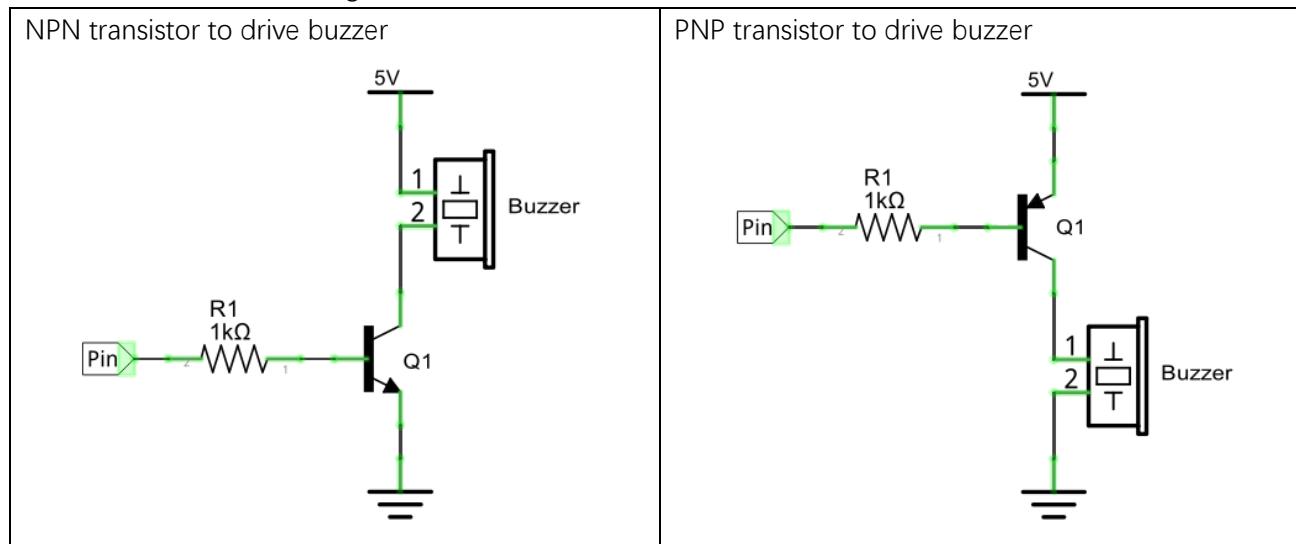


In our kit, the PNP transistor is marked with 8550, and the NPN transistor is marked with 8050.

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

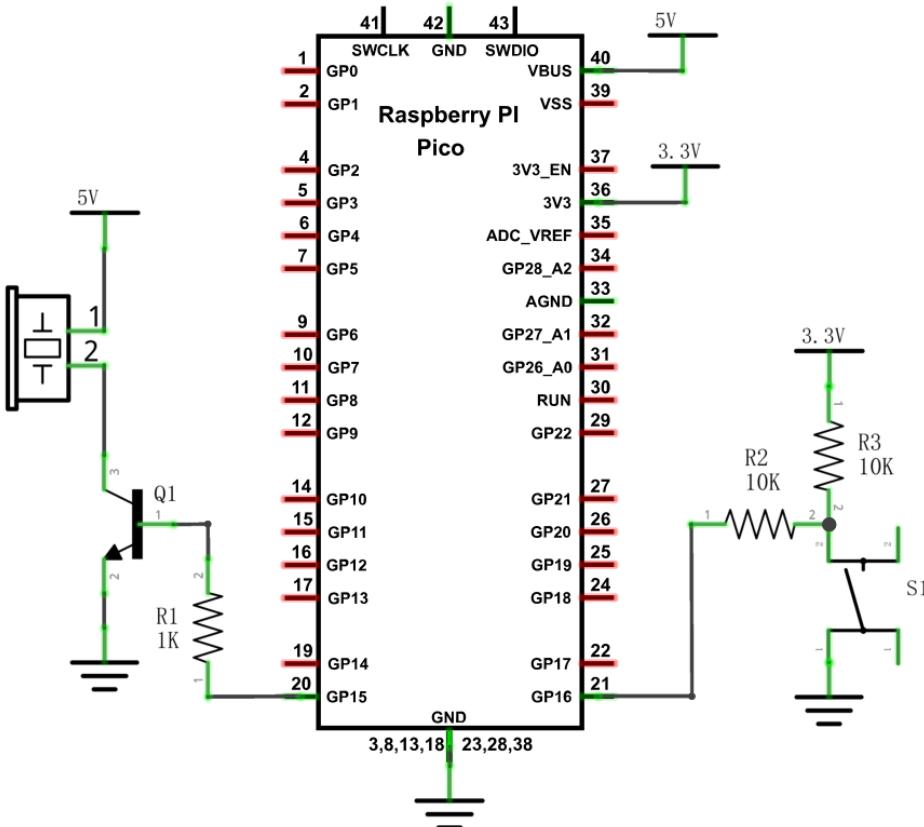
When using NPN transistor to drive buzzer, we often adopt the following method. If GP outputs high level, current will flow through R1, the transistor will be conducted, and the buzzer will sound. If GP outputs low level, no current flows through R1, the transistor will not be conducted, and buzzer will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

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

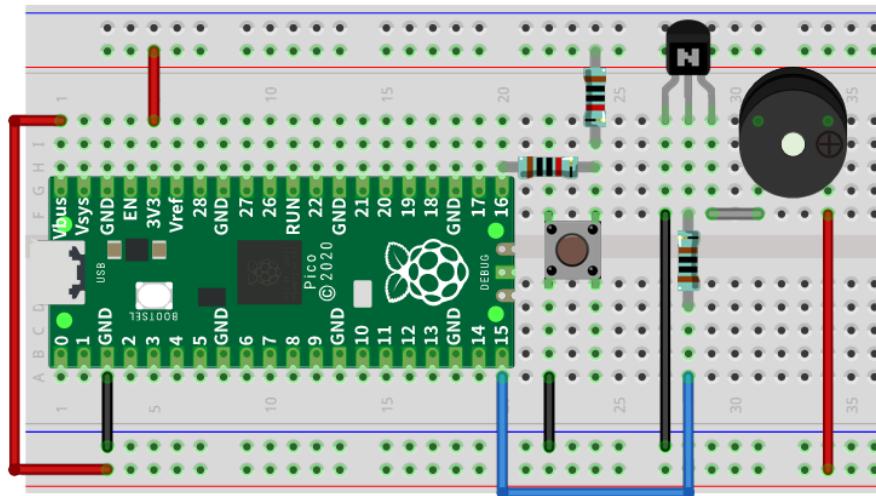


## Circuit

Schematic diagram



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



Note:

1. In this circuit, the power supply for buzzer is 5V, and pull-up resistor of the button connected to the power 3.3V. The buzzer can work when connected to power 3.3V, but it will reduce the loudness.
2. VBUS should be connect to the positive end of USB cable. If it connects to GND, it may burn the computer or Raspberry Pi Pico. Similarly, please be careful when wiring pins 36-40 of Pico to avoid short circuit.

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

# Sketch

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

## Sketch\_07.1\_Doorbell

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

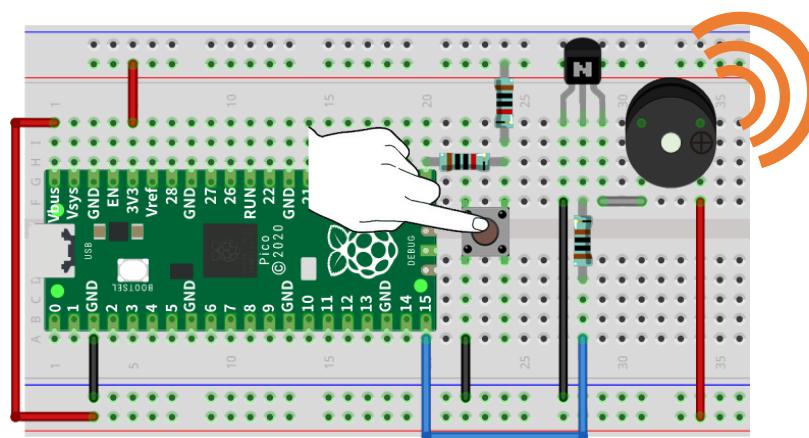
- Title Bar:** Sketch\_07.1\_Doorbell | Arduino IDE 2.3.2
- Toolbar:** File, Edit, Sketch, Tools, Help
- Sketch Selection:** Raspberry Pi Pico
- Sketch Content:** Sketch\_07.1\_Doorbell.ino (shown in the code editor)

```
7 #define PIN_BUZZER 15
8 #define PIN_BUTTON 16
9
10 void setup() {
11     pinMode(PIN_BUZZER, OUTPUT);
12     pinMode(PIN_BUTTON, INPUT);
13     digitalWrite(PIN_BUZZER,LOW);
14 }
15
16 void loop() {
17     if (digitalRead(PIN_BUTTON) == LOW) {
18         digitalWrite(PIN_BUZZER,HIGH);
19     }else{
20         digitalWrite(PIN_BUZZER,LOW);
21     }
22 }
```

- Output Panel:** Output (empty)
- Status Bar:** Ln 23, Col 1 Raspberry Pi Pico on COM15

---

Download the code to Pico, press the push button switch and the buzzer will sound. Release the push button switch and the buzzer will stop.





The following is the program code:

```
1 #define PIN_BUZZER 15
2 #define PIN_BUTTON 16
3
4 void setup() {
5     pinMode(PIN_BUZZER, OUTPUT);
6     pinMode(PIN_BUTTON, INPUT);
7     digitalWrite(PIN_BUZZER, LOW);
8 }
9
10 void loop() {
11     if (digitalRead(PIN_BUTTON) == LOW) {
12         digitalWrite(PIN_BUZZER, HIGH);
13     } else{
14         digitalWrite(PIN_BUZZER, LOW);
15     }
16 }
```

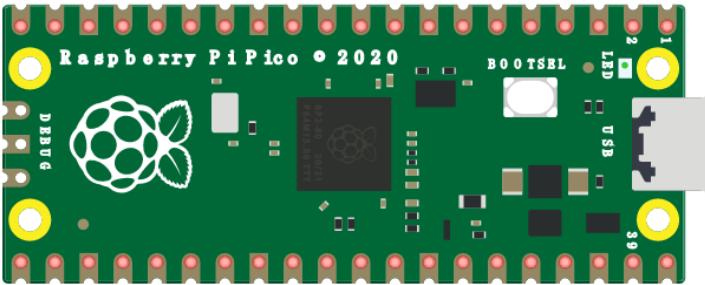
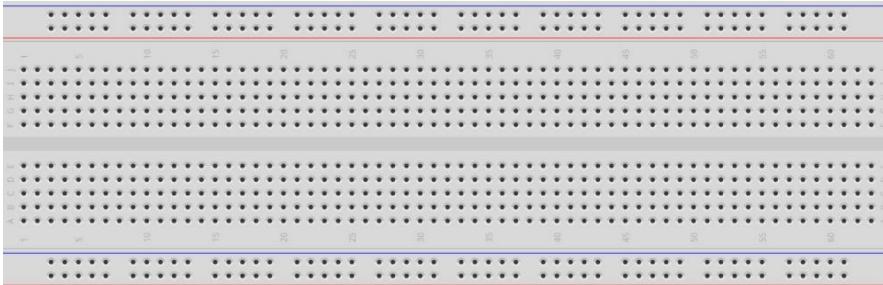
The code is logically the same as using button to control LED.

## Project 7.2 Alertor

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

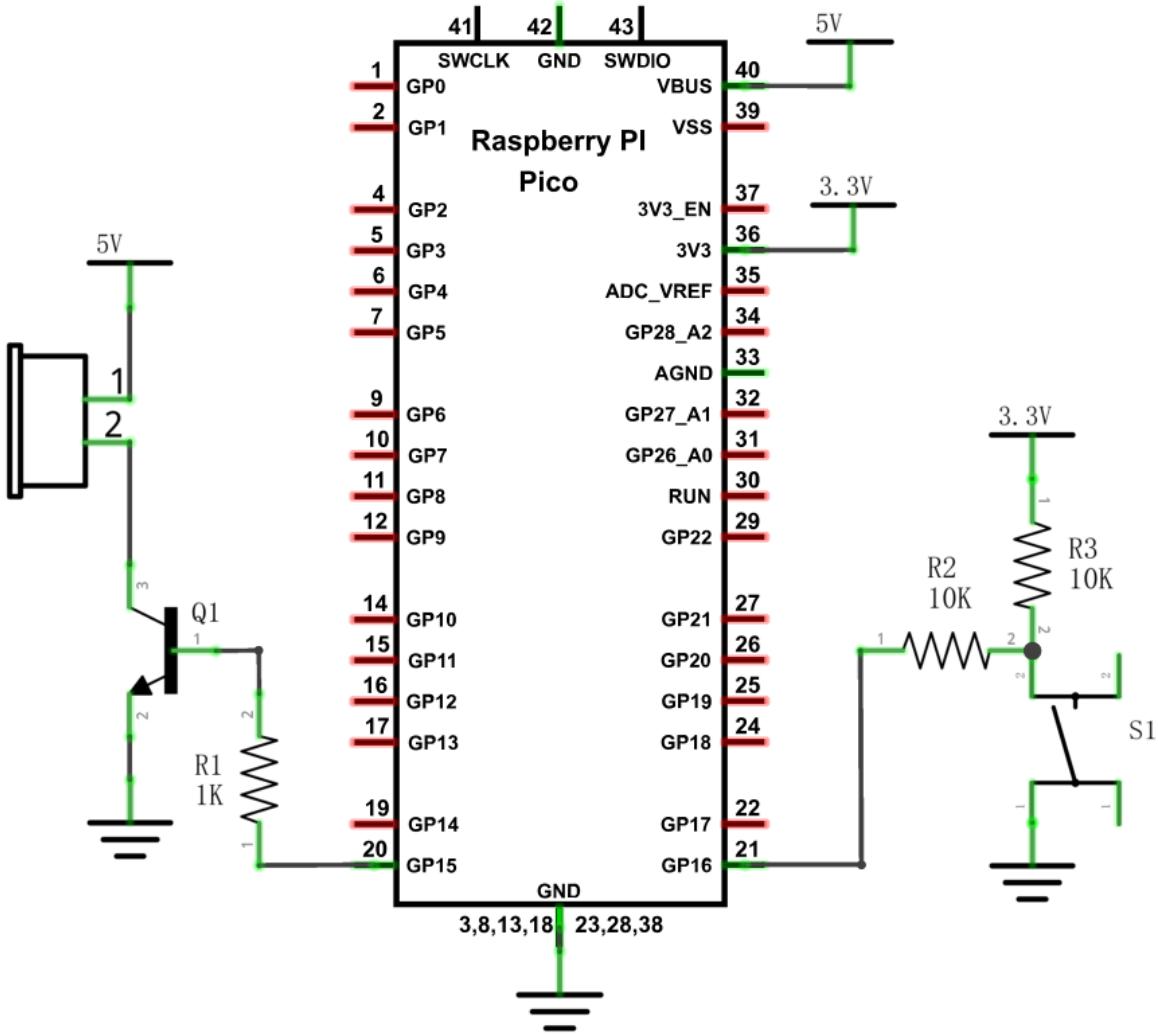
Component list and the circuit part is similar to last section, only the **active buzzer** needs to be **replaced** with a **passive buzzer** for this project.

### Component List

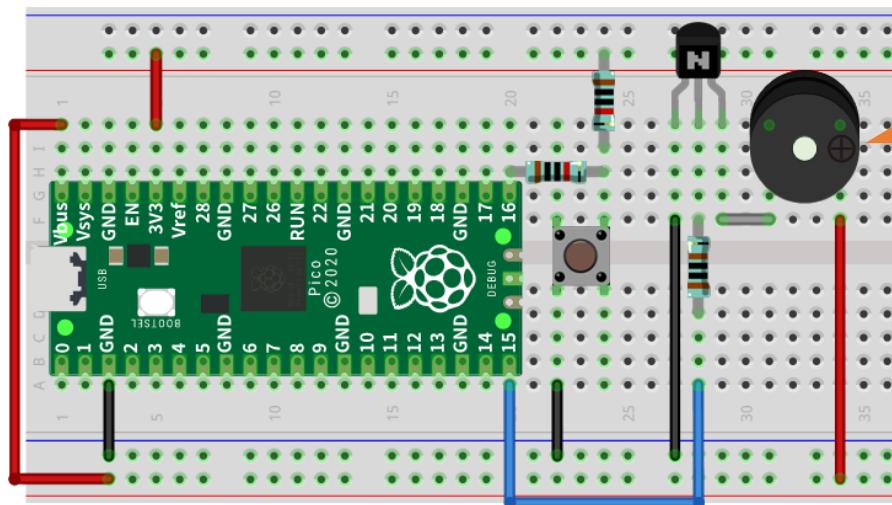
Raspberry Pi Pico x1	USB cable x1
	
Breadboard x1	
	
Jumper	
NPN transistorx1 (S8050)	Passive buzzer x1
	
Push button x1	Resistor 1kΩ x1
	
Resistor 10kΩ x2	

## Circuit

Schematic diagram



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

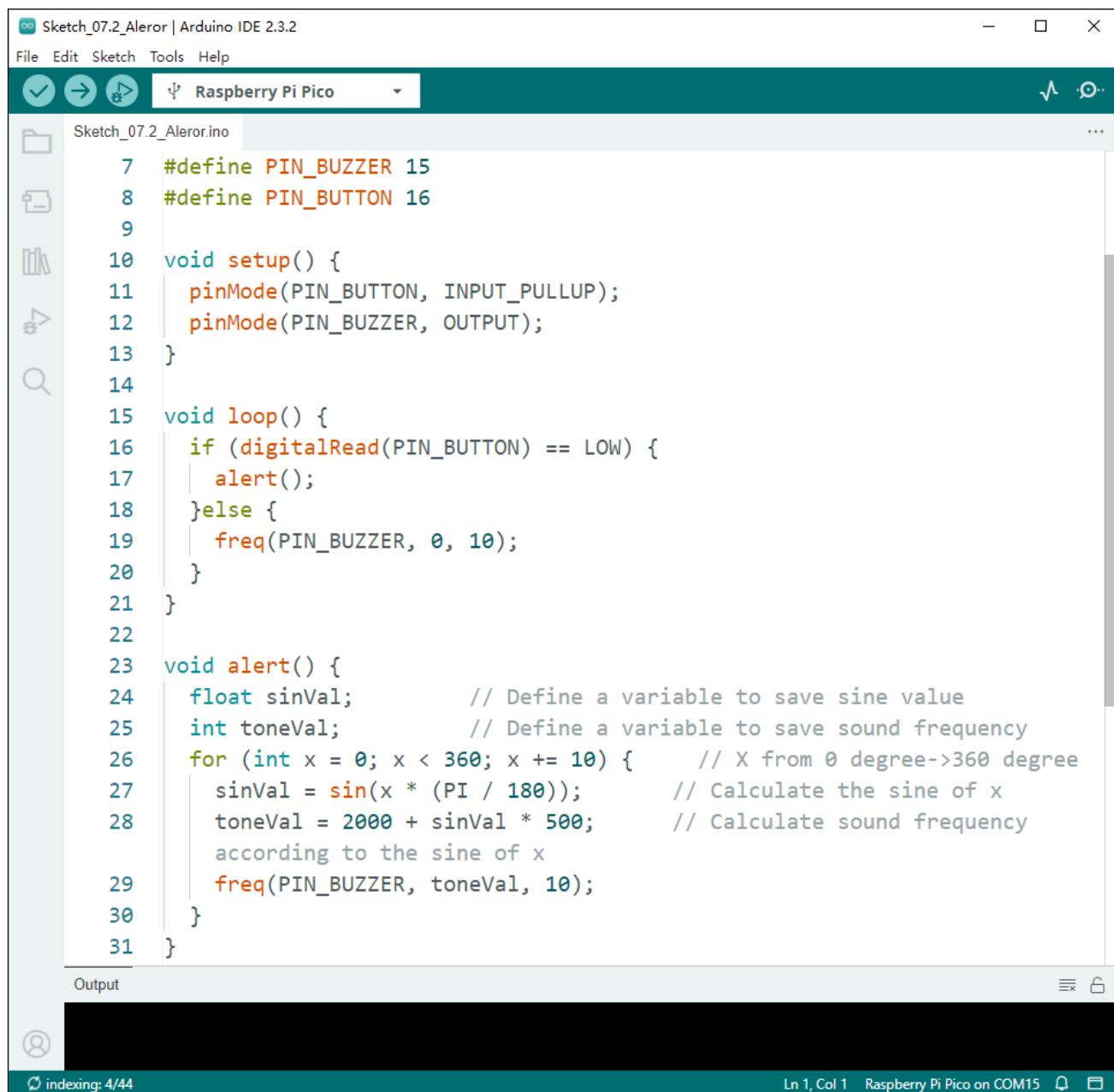


Any concerns? ✉ [support@freenove.com](mailto:support@freenove.com)

## Sketch

In this project, the buzzer alarm is controlled by the button. Press the button, then buzzer sounds. If you release the button, the buzzer will stop sounding. It is logically the same as using button to control LED, but in the control method, passive buzzer requires PWM of certain frequency to sound.

### Sketch\_07.2\_Alertor



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

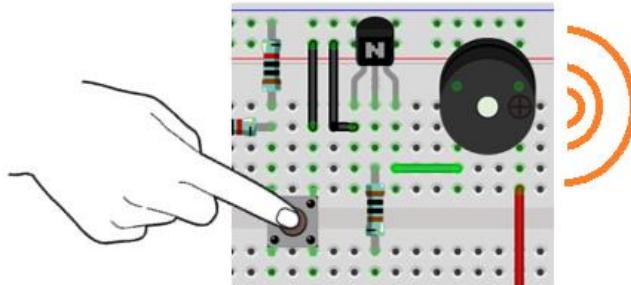
- Title Bar:** Sketch\_07.2\_Aleror | Arduino IDE 2.3.2
- Menu Bar:** File Edit Sketch Tools Help
- Toolbar:** Includes icons for Save, Run, Stop, and a dropdown for boards (set to Raspberry Pi Pico).
- Sketch Area:** Displays the C++ code for the sketch. The code defines pins for a buzzer and a button, sets up the button as an input and the buzzer as an output, and implements a loop where it reads the button state and either plays an alert tone or a sine wave based on the button's state.

```
Sketch_07.2_Aleror.ino
1 #define PIN_BUZZER 15
2 #define PIN_BUTTON 16
3
4 void setup() {
5     pinMode(PIN_BUTTON, INPUT_PULLUP);
6     pinMode(PIN_BUZZER, OUTPUT);
7 }
8
9 void loop() {
10    if (digitalRead(PIN_BUTTON) == LOW) {
11        alert();
12    }else {
13        freq(PIN_BUZZER, 0, 10);
14    }
15 }
16
17 void alert() {
18     float sinVal;          // Define a variable to save sine value
19     int toneVal;           // Define a variable to save sound frequency
20     for (int x = 0; x < 360; x += 10) {      // X from 0 degree->360 degree
21         sinVal = sin(x * (PI / 180));       // Calculate the sine of x
22         toneVal = 2000 + sinVal * 500;        // Calculate sound frequency
23         according to the sine of x
24         freq(PIN_BUZZER, toneVal, 10);
25     }
26 }
```

- Status Bar:** Shows "indexing: 4/44" and "Ln 1, Col 1 Raspberry Pi Pico on COM15".



Download the code to Pico, press the button, and then alarm sounds; when the button is released, the alarm will stop sounding.



The following is the program code:

```

1 #define PIN_BUZZER 15
2 #define PIN_BUTTON 16
3
4 void setup() {
5     pinMode(PIN_BUTTON, INPUT_PULLUP);
6     pinMode(PIN_BUZZER, OUTPUT);
7 }
8
9 void loop() {
10    if (digitalRead(PIN_BUTTON) == LOW) {
11        alert();
12    }else {
13        freq(PIN_BUZZER, 0, 10);
14    }
15 }
16
17 void alert() {
18     float sinVal;           // Define a variable to save sine value
19     int toneVal;            // Define a variable to save sound frequency
20     for (int x = 0; x < 360; x += 10) { // X from 0 degree->360 degree
21         sinVal = sin(x * (PI / 180));      // Calculate the sine of x
22         toneVal = 2000 + sinVal * 500;      // Calculate sound frequency according to the sine of x
23         freq(PIN_BUZZER, toneVal, 10);
24     }
25 }
26
27 void freq(int PIN, int freqs, int times) {
28     if (freqs == 0) {
29         digitalWrite(PIN, LOW);
30     } else {
31         for (int i = 0; i < times * freqs / 1000; i++) {
32             digitalWrite(PIN, HIGH);
33         }
34     }
35 }
```

```

34     delayMicroseconds(1000000 / freqs / 2);
35     digitalWrite(PIN, LOW);
36     delayMicroseconds(1000000 / freqs / 2);
37   }
38 }
39 }
```

Define the button and pin to control the passive buzzer.

```

1 #define PIN_BUZZER 15
2 #define PIN_BUTTON 16
```

Write a function to drive the passive buzzer with a duty cycle of 50%. The `delayMicroseconds()` function is in

1us.  $1\text{ s} = 1000000\text{ us}$ . By the formula  $T = \frac{1}{f}$ , when the frequency is fixed, the PWM period T is also fixed.

```

27 void freq(int PIN, int freqs, int times) {
28   if (freqs == 0) {
29     digitalWrite(PIN, LOW);
30   }
31   else {
32     for (int i = 0; i < times * freqs / 1000; i++) {
33       digitalWrite(PIN, HIGH);
34       delayMicroseconds(1000000 / freqs / 2);
35       digitalWrite(PIN, LOW);
36       delayMicroseconds(1000000 / freqs / 2);
37     }
38   }
39 }
```

The frequency curve of the alarm is based on the sine curve. We need to calculate the sine value from 0 to 360 degree and multiply a certain value (here it is 500) and plus the resonant frequency of buzzer.

```

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

In the `loop()` function, when the button is pressed, subfunction `alert()` will be called and the alertor will issue a warning sound; otherwise, it stops the buzzer.

```

10 if (digitalRead(PIN_BUTTON) == LOW) {
11   alert();
12 }else {
13   freq(PIN_BUZZER, 0, 10);
14 }
```

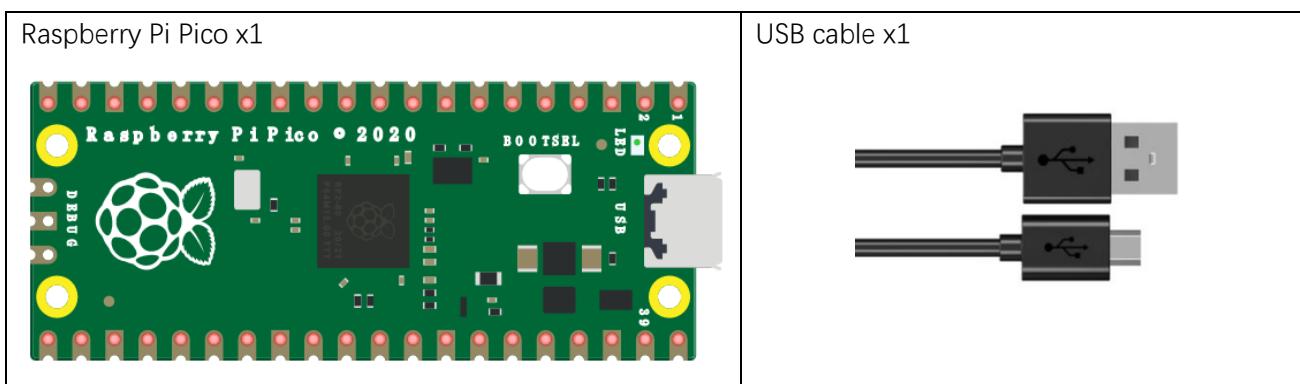
# Chapter 8 Serial Communication

Serial Communication is a means of Communication between different devices. This section describes Raspberry Pi Pico Serial Communication.

## Project 8.1 Serial Print

This project uses Raspberry Pi Pico serial communicator to send data to the computer and print it on the serial monitor.

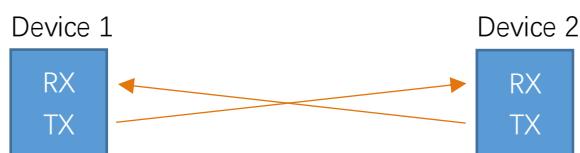
### Component List



### Related Knowledge

#### Serial communication

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



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

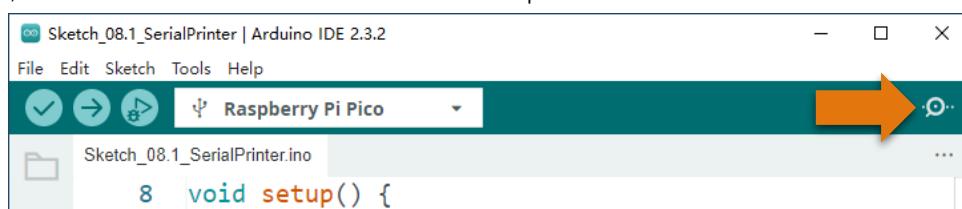
### Serial port on Raspberry Pi Pico

Raspberry Pi Pico has integrated USB to serial transfer, so it could communicate with computer connecting to USB cable.

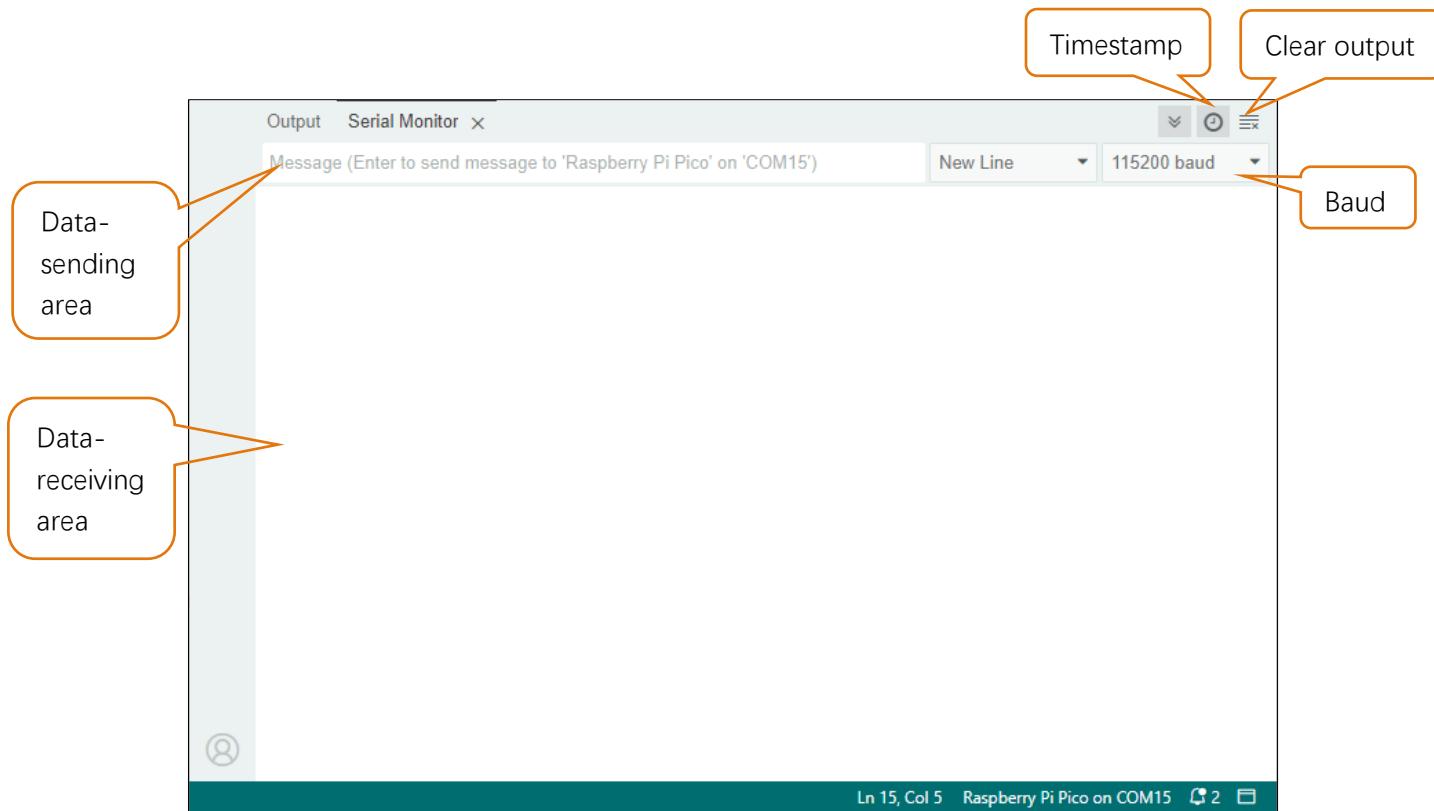


Arduino Software also uploads code to Pico through the serial connection.

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

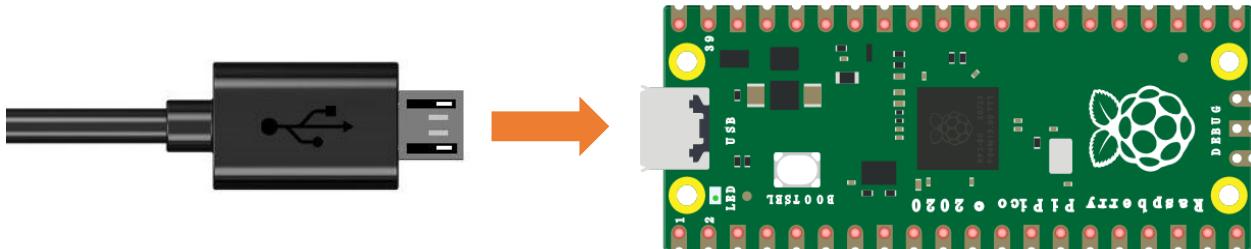


Interface of serial monitor window is as follows. If you cannot open it, make sure Pico has been connected to the computer, and choose the right serial port in the menu bar "Tools".



## Circuit

Connect Raspberry Pi Pico to the computer with USB cable.



## Sketch

### Sketch\_08.1\_SerialPrinter

A screenshot of the Arduino IDE version 2.3.2. The window title is "Sketch\_08.1\_SerialPrinter | Arduino IDE 2.3.2". The toolbar includes standard icons for file operations and sketch compilation. The dropdown menu shows "Raspberry Pi Pico" selected. The code editor contains the following C++ code:

```
Sketch_08.1_SerialPrinter.ino
1 //*****
2 // Filename   : SerialPrinter
3 // Description : Use UART send some data to PC, and show them on serial
4 // monitor.
5 // Author     : www.freenove.com
6 // Modification: 2021/10/13
7 //*****
8 void setup() {
9     Serial.begin(115200);
10    delay(2000);
11    Serial.println("Raspberry Pi Pico initialization completed!");
12 }
13
14 void loop() {
15     Serial.println( millis() / 1000 % 60);
16     delay(1000);
17 }
```

The status bar at the bottom indicates "Ln 18, Col 1 Raspberry Pi Pico on COM15 4 2".

Download the code to Pico, open the serial port monitor, set the baud rate to 115200. As shown in the following picture:

```

15 |     Serial.println( millis() / 1000 % 60 );
16 |     delay(1000);
17 |

```

Set the relevant information

Output Serial Monitor x

Message (Enter to send message to 'Raspberry Pi Pico' on 'COM15') New Line 115200 baud

13:59:58.860 -> Raspberry Pi Pico initialization completed!  
13:59:58.860 -> 1  
13:59:59.831 -> 2  
14:00:00.830 -> 3  
14:00:01.830 -> 4  
14:00:02.868 -> 5  
14:00:03.864 -> 6  
14:00:04.830 -> 7  
14:00:05.851 -> 8

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

Ln 10, Col 10 Raspberry Pi Pico on COM15

As shown above, when the code runs, the data is printed every one second.

#### Reference

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

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

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

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

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

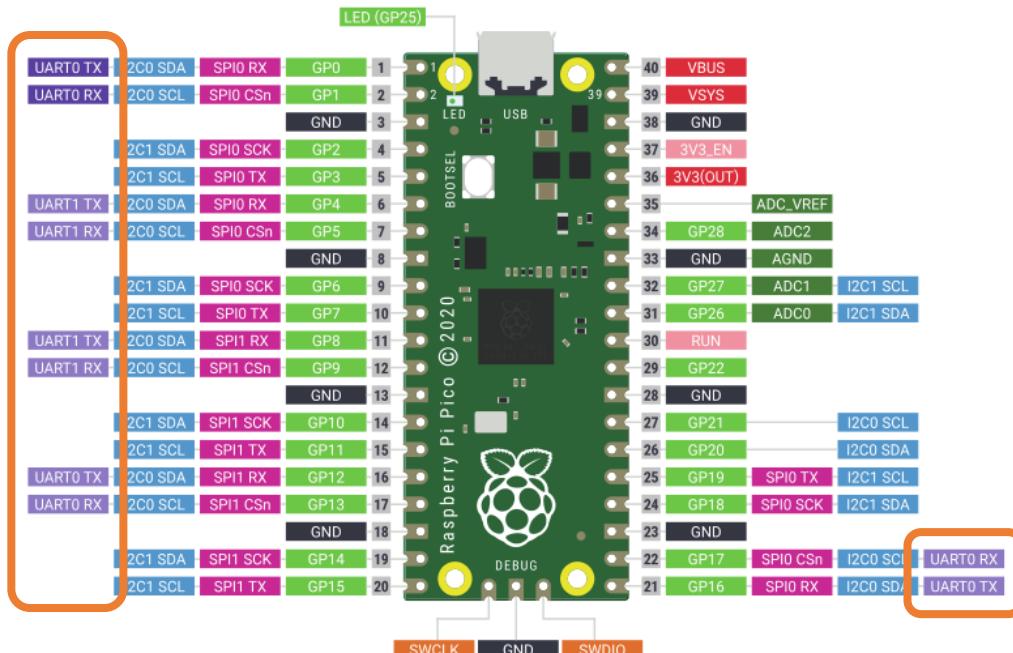
Print formatted content to the serial port in the same way as print in standard C.

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

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

For details, please refer to [UART, I2C, SPI default pin](#).

You can change settings according to the distribution of pins.



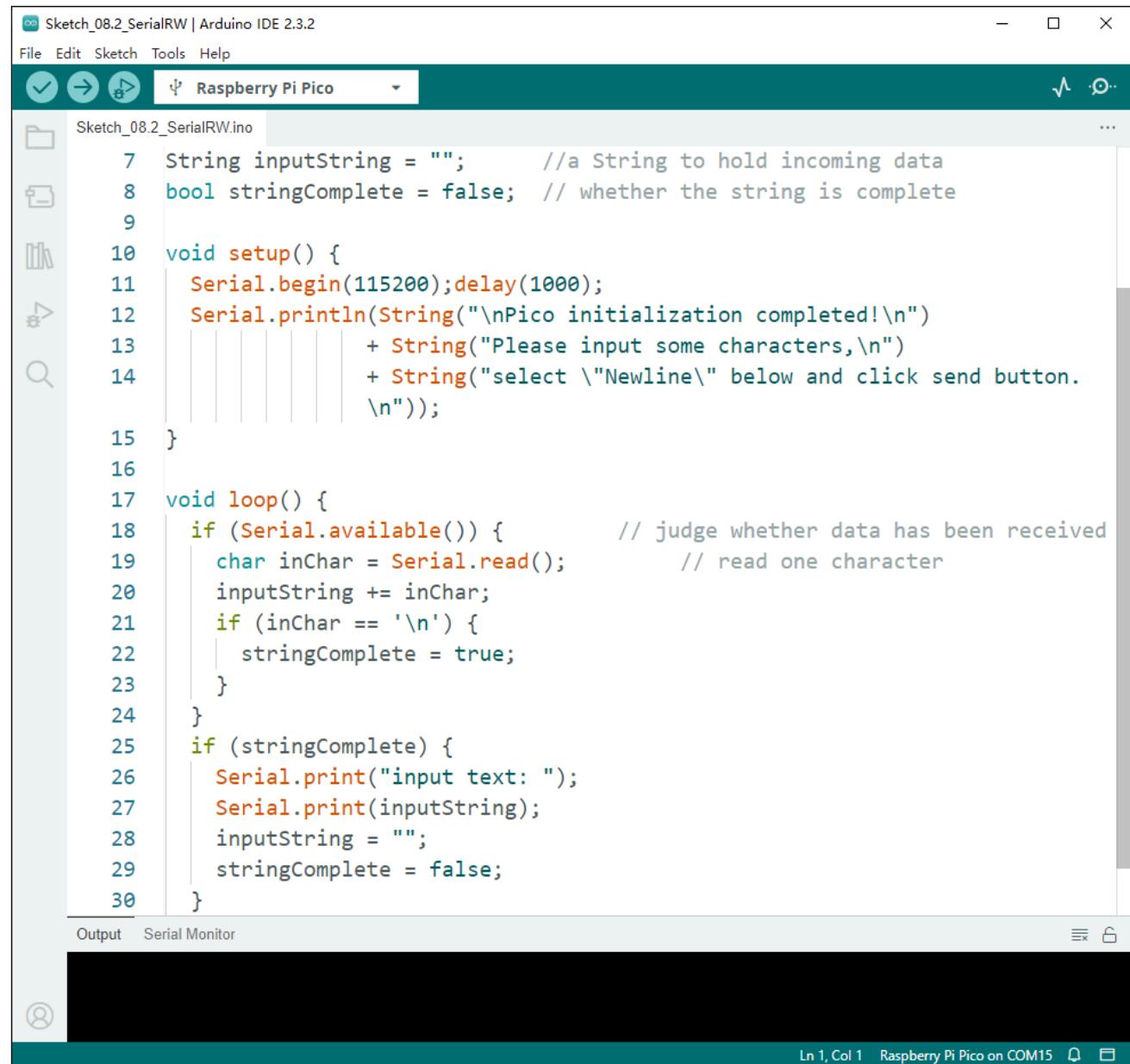
## Project 8.2 Serial Read and Write

From last section, we use serial port on Pico to send data to a computer, now we will use that to receive data from computer.

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

### Sketch

#### Sketch\_08.2\_SerialRW



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

- Title Bar:** Sketch\_08.2\_SerialRW | Arduino IDE 2.3.2
- Menu Bar:** File Edit Sketch Tools Help
- Toolbar:** Includes icons for Save, Run, Stop, and a dropdown menu set to "Raspberry Pi Pico".
- Code Editor:** Displays the `Sketch_08.2_SerialRW.ino` file content. The code initializes the serial port at 115200 baud, prints a welcome message, and then enters a loop to read incoming characters. It checks if a newline character (\n) has been received to determine if a complete string is available. If so, it prints the string and resets the inputString and stringComplete variables.

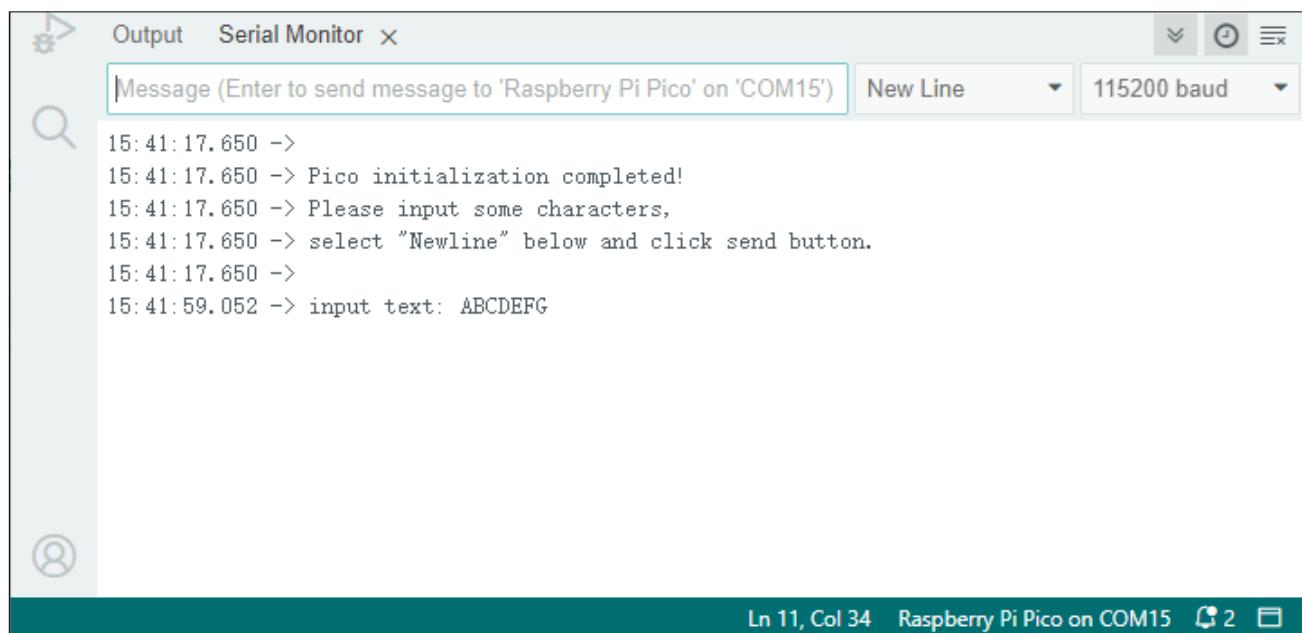
```
String inputString = "";      //a String to hold incoming data
bool stringComplete = false; // whether the string is complete
void setup() {
    Serial.begin(115200);delay(1000);
    Serial.println(String("\nPico initialization completed!\n")+
                  + String("Please input some characters,\n")+
                  + String("select \"Newline\" below and click send button.\n"));
}
void loop() {
    if (Serial.available()) {      // judge whether data has been received
        char inChar = Serial.read(); // read one character
        inputString += inChar;
        if (inChar == '\n') {
            stringComplete = true;
        }
    }
    if (stringComplete) {
        Serial.print("input text: ");
        Serial.print(inputString);
        inputString = "";
        stringComplete = false;
    }
}
```

- Status Bar:** Shows "Ln 1, Col 1" and "Raspberry Pi Pico on COM15".

Download the code to Pico, open the serial monitor, and set the bottom to Newline, 115200, as shown in the following picture:



Input texts like "ABCDEFG" in the Message Bar and press Enter to print the data received by Pico.



The following is the program code:

```

1  String inputString = "";      //a String to hold incoming data
2  bool stringComplete = false; // whether the string is complete
3
4  void setup() {
5      Serial.begin(115200);delay(1000);
6      Serial.println(String("\nPico initialization completed!\n")
7                      + String("Please input some characters, \n")
8                      + String("select \"Newline\" below and click send button. \n"));
9  }
10
11 void loop() {
12     if (Serial.available()) {      // judge whether data has been received
13         char inChar = Serial.read();      // read one character
14         inputString += inChar;
15         if (inChar == '\n') {
16             stringComplete = true;
17         }
18     }
19     if (stringComplete) {
20         Serial.print("input text: ");
21         Serial.print(inputString);
22         inputString = "";
23         stringComplete = false;
24     }
25 }
```

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

#### Reference

**String();**

Constructs an instance of the String class.

For more information, please visit

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

**int available(void);**

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

**Serial.read();**

Reads incoming serial data.

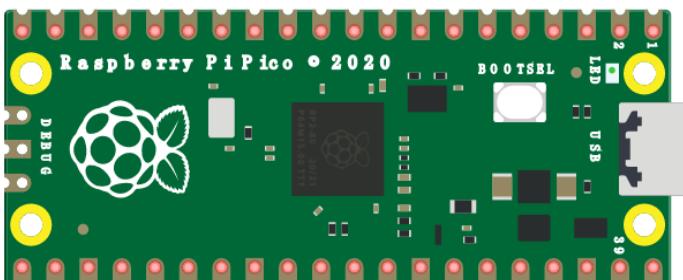
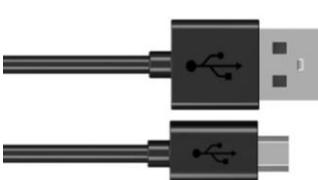
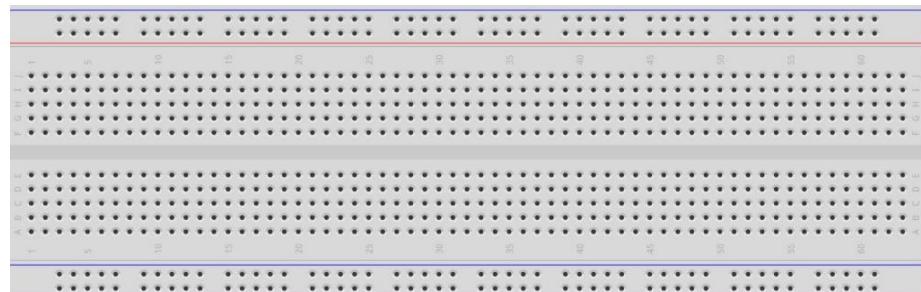
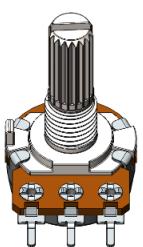
# Chapter 9 AD Converter

This chapter we learn to use the ADC function of Raspberry Pi Pico.

## Project 9.1 Read the Voltage of Potentiometer

In this chapter, we use ADC function of Pico to read the voltage output by potentiometer.

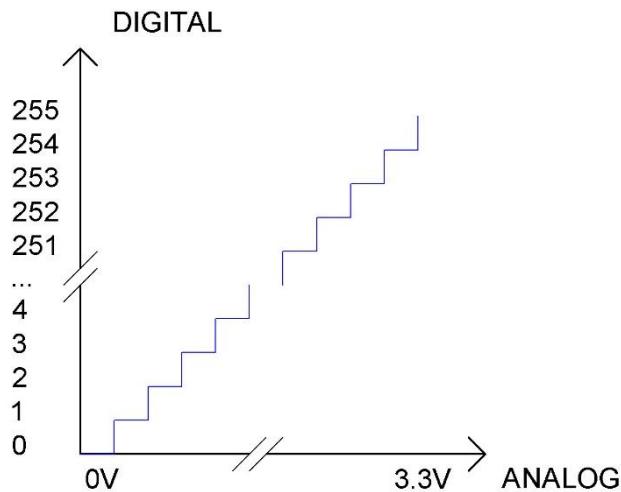
### Component List

Raspberry Pi Pico x1	 A photograph of a green Raspberry Pi Pico development board. It features a central Broadcom SoC, several pins along the edges, and various component markings like 'Raspberry Pi Pico • 2020' and 'BOOTSEL'.	USB cable x1	 A photograph of a standard black USB cable with two ends visible.
Breadboard x1		 A schematic diagram of a breadboard, showing its grid of holes and labeled pins 1 through 40 along the top and bottom edges.	
Rotary potentiometer x1	 A photograph of a standard three-terminal rotary potentiometer with a silver shaft and orange base.	Jumper	 A photograph of a long, thin black jumper wire with two small black caps at the ends.

## Related Knowledge

### ADC

An ADC is an electronic integrated circuit used to convert analog signals such as voltages to digital or binary form consisting of 1s and 0s. The range of our ADC on Pico 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 range of 0V---3.3/1023 V corresponds to digital 0;

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

...

The following analog will be divided accordingly.

The conversion formula is as follows:

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

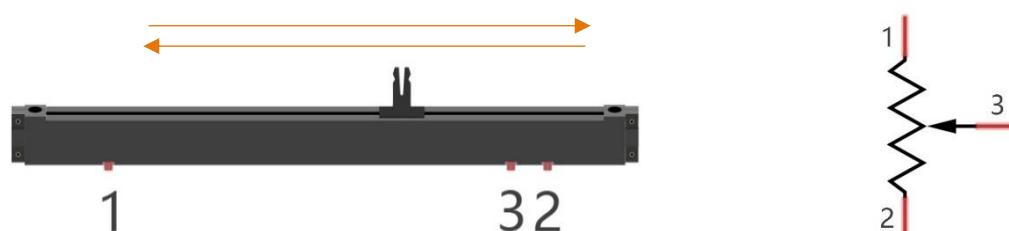
### ADC Channels Raspberry Pi Pico

Raspberry Pi Pico has four ADC channels, which are ADC0(GP26), ADC1(GP27), ADC2(GP28), ADC3(GP29). ADC3 used to measure VSYS on Pico board. Therefore, there are only three generic ADC channels that can be directly used, namely, ADC0, ADC1 and ADC2.

## Component Knowledge

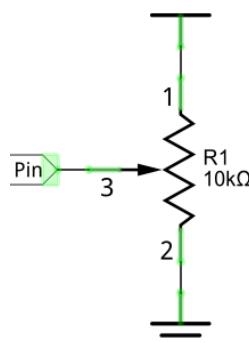
### Potentiometer

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



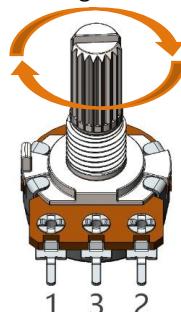
Between potentiometer pin 1 and pin 2 is the resistive element (a resistance wire or carbon) and pin 3 is connected to the brush that makes contact with the resistive element. In our illustration, when the brush moves from pin 1 to pin 2, the resistance value between pin 1 and pin 3 will increase linearly (until it reaches the highest value of the resistive element) and at the same time the resistance between pin 2 and pin 3 will decrease linearly and conversely down to zero. At the midpoint of the slider, the measured resistance values between pin 1 and 3 and between pin 2 and 3 will be the same.

In a circuit, both sides of resistive element are often connected to the positive and negative electrodes of power. When you slide the brush "pin 3", you can get variable voltage within the range of the power supply.



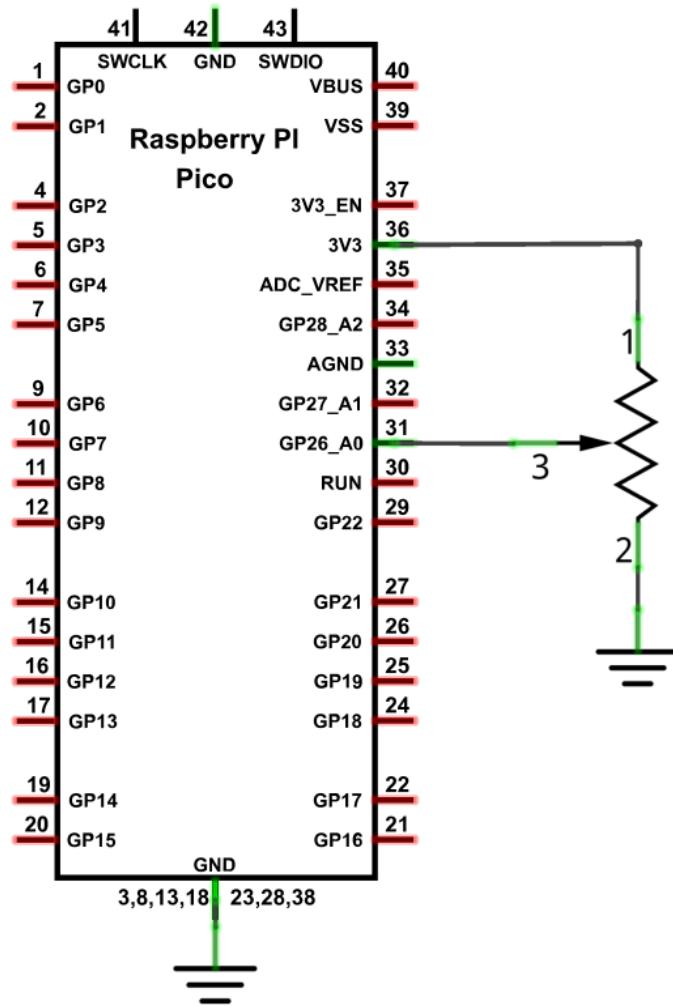
### Rotary potentiometer

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

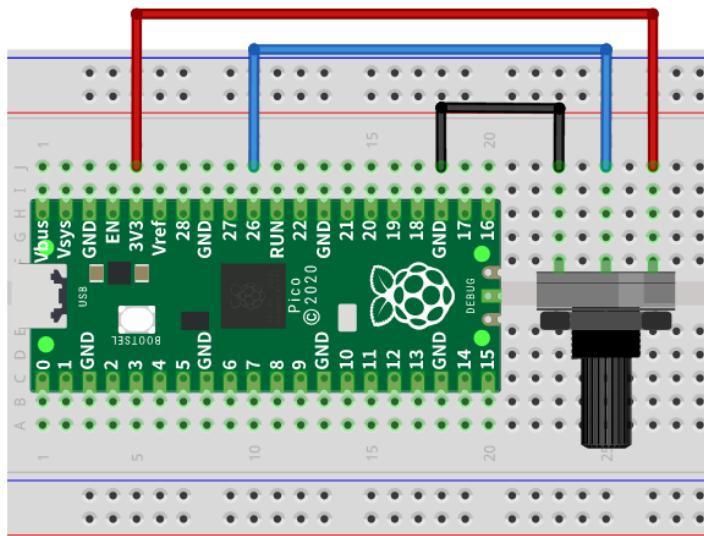


## Circuit

Schematic diagram



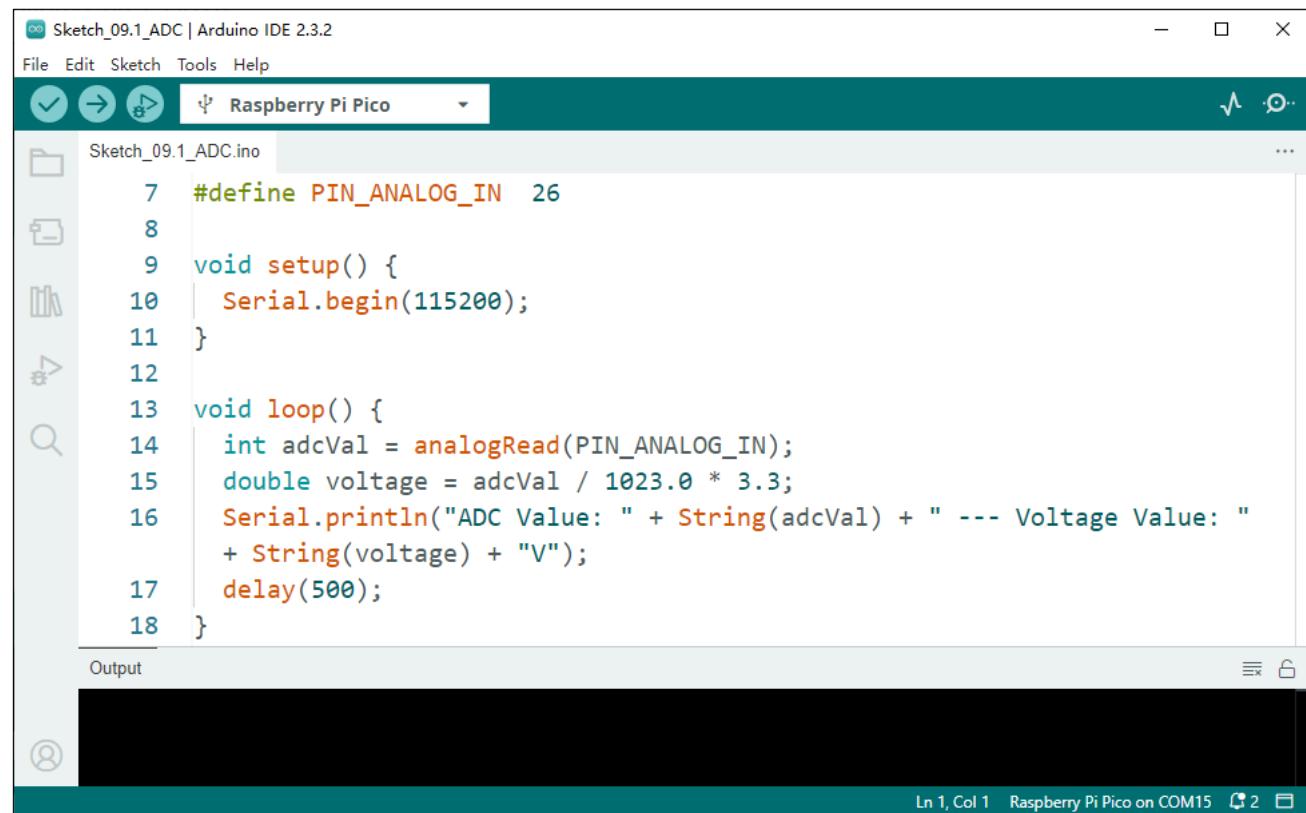
Hardware connection. If you need any support, please feel free to contact us via: [support@freenove.com](mailto:support@freenove.com)



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## Sketch

### Sketch\_09.1\_ADC



```

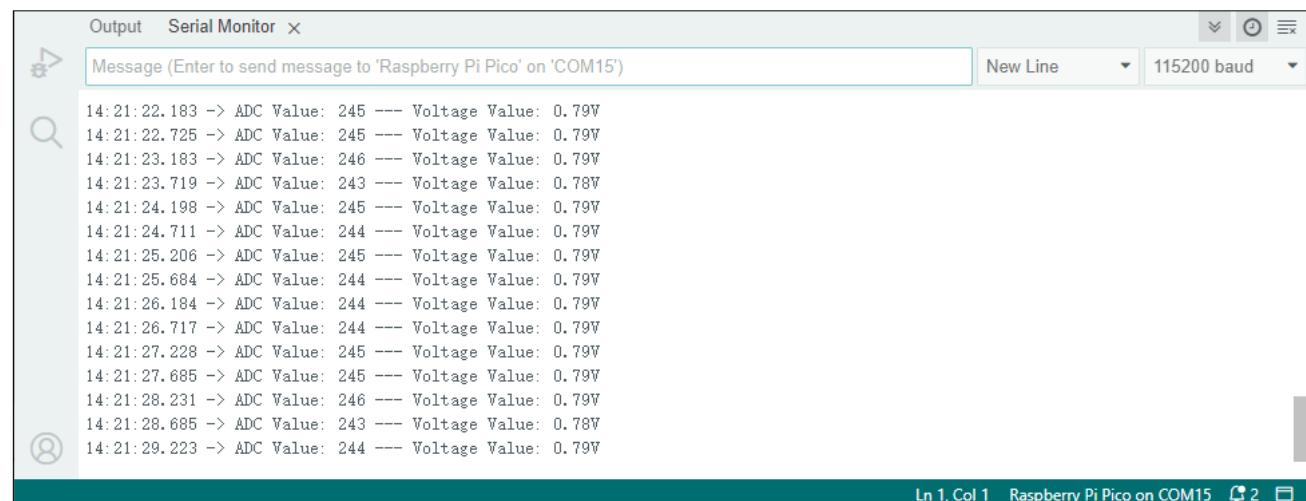
Sketch_09.1_ADC | Arduino IDE 2.3.2
File Edit Sketch Tools Help
Sketch_09.1_ADC.ino
 7 #define PIN_ANALOG_IN 26
 8
 9 void setup() {
10   Serial.begin(115200);
11 }
12
13 void loop() {
14   int adcVal = analogRead(PIN_ANALOG_IN);
15   double voltage = adcVal / 1023.0 * 3.3;
16   Serial.println("ADC Value: " + String(adcVal) + " --- Voltage Value: "
17     + String(voltage) + "V");
18   delay(500);
}

```

Output

Ln 1, Col 1 Raspberry Pi Pico on COM15 2 1

Download the code to Pico, open the serial monitor, and set the baud rate to 115200, as shown in the following picture,



Time	Message
14:21:22.183	ADC Value: 245 --- Voltage Value: 0.79V
14:21:22.725	ADC Value: 245 --- Voltage Value: 0.79V
14:21:23.183	ADC Value: 246 --- Voltage Value: 0.79V
14:21:23.719	ADC Value: 243 --- Voltage Value: 0.78V
14:21:24.198	ADC Value: 245 --- Voltage Value: 0.79V
14:21:24.711	ADC Value: 244 --- Voltage Value: 0.79V
14:21:25.206	ADC Value: 245 --- Voltage Value: 0.79V
14:21:25.684	ADC Value: 244 --- Voltage Value: 0.79V
14:21:26.184	ADC Value: 244 --- Voltage Value: 0.79V
14:21:26.717	ADC Value: 244 --- Voltage Value: 0.79V
14:21:27.228	ADC Value: 245 --- Voltage Value: 0.79V
14:21:27.685	ADC Value: 245 --- Voltage Value: 0.79V
14:21:28.231	ADC Value: 246 --- Voltage Value: 0.79V
14:21:28.685	ADC Value: 243 --- Voltage Value: 0.78V
14:21:29.223	ADC Value: 244 --- Voltage Value: 0.79V

Ln 1, Col 1 Raspberry Pi Pico on COM15 2 1

The following is the code:

```
1 #define PIN_ANALOG_IN 26
2
3 void setup() {
4     Serial.begin(115200);
5 }
6
7 void loop() {
8     int adcVal = analogRead(PIN_ANALOG_IN);
9     double voltage = adcVal / 1023.0 * 3.3;
10    Serial.println("ADC Value: " + String(adcVal) + " --- Voltage Value: " + String(voltage) +
11        "V");
12    delay(500);
13 }
```

In loop() function, analogRead is called to get the ADC value of ADC0 and assign it to adcVal. Calculate the measured voltage value through the formula, and print these data through the serial port monitor.

```
8 int adcVal = analogRead(PIN_ANALOG_IN);
9     double voltage = adcVal / 1023.0 * 3.3;
10    Serial.println("ADC Value: " + String(adcVal) + " --- Voltage Value: " + String(voltage) +
11        "V");
```

#### Reference

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

Reads the value from the specified analog pin. Return the analog reading on the pin. (0-1023 for 10 bits).

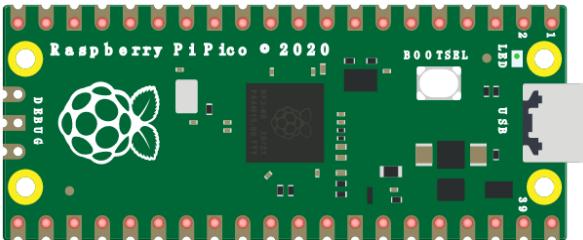
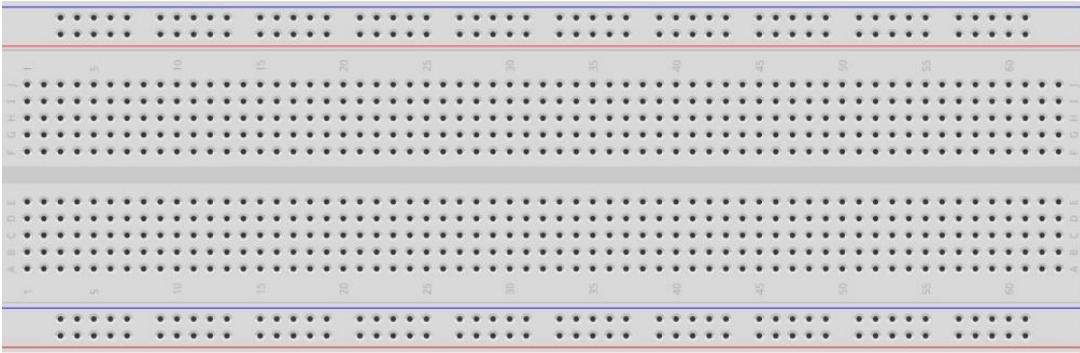
# Chapter 10 Potentiometer & LED

We have learnt to use ADC in the previous chapter. In this chapter, we will combine PWM and ADC to use potentiometer to control LED, RGBLED and Neopixel.

## Project 10.1 Soft Light

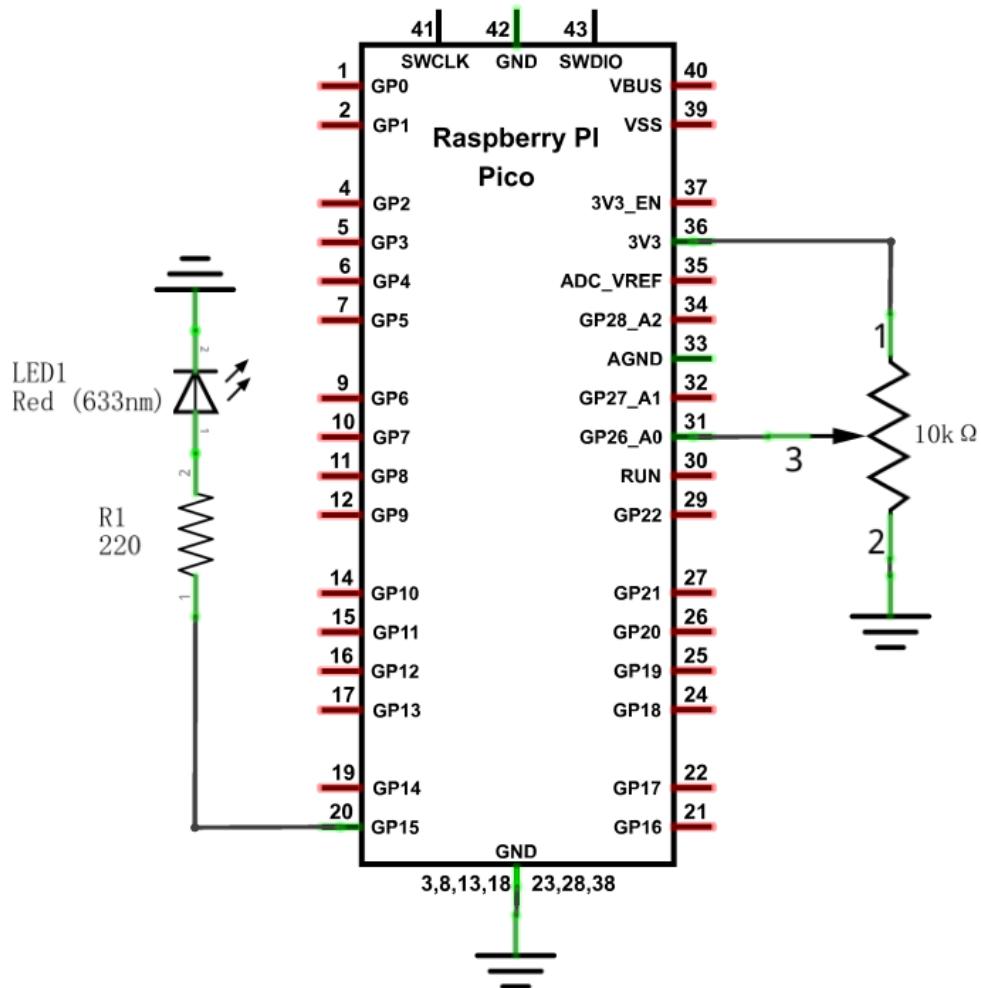
In this project, we will make a soft light. We will use an ADC Module to read ADC values of a potentiometer and map it to duty cycle of the PWM used to control the brightness of an LED. Then you can change the brightness of an LED by adjusting the potentiometer.

### Component List

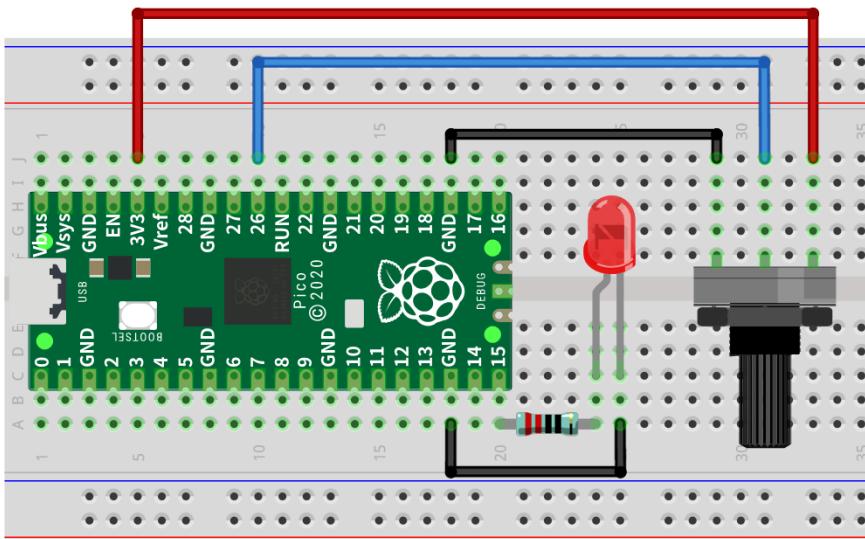
Raspberry Pi Pico x1	USB cable x1		
			
Breadboard x1			
Rotary potentiometer x1	Resistor 220Ω x1	LED x1	Jumper
			

## Circuit

Schematic diagram



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



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## Sketch

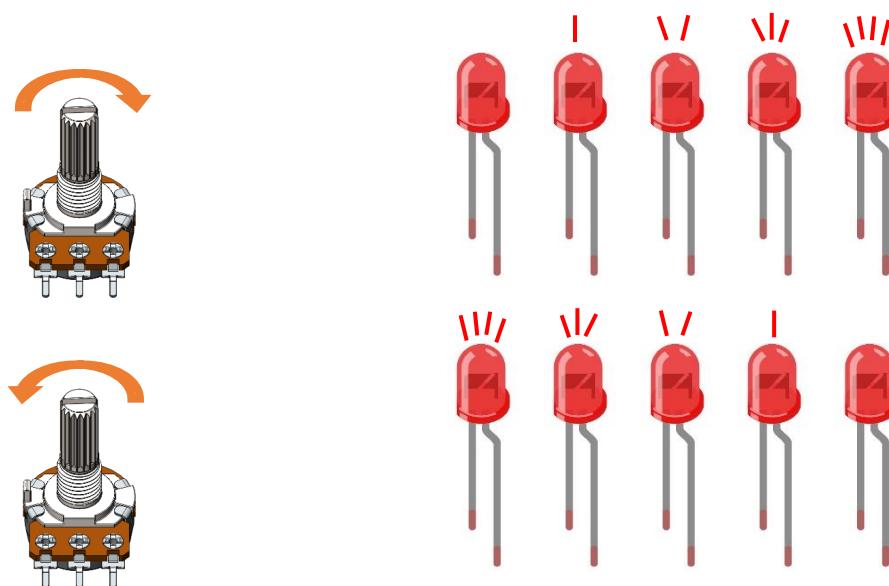
### Sketch\_10.1\_Softlight

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

- Title Bar:** Sketch\_10.1\_SoftLight | Arduino IDE 2.3.2
- Toolbar:** File, Edit, Sketch, Tools, Help
- Sketch Selection:** Raspberry Pi Pico
- Code Area:** Displays the `Sketch_10.1_SoftLight.ino` file content:

```
7 #define PIN_ADC0      26
8 #define PIN_LED       15
9
10 void setup() {
11     pinMode(PIN_LED, OUTPUT);
12 }
13
14 void loop() {
15     int adcVal = analogRead(PIN_ADC0); //read adc
16     analogWrite(PIN_LED, map(adcVal, 0, 1023, 0, 255));
17     delay(10);
18 }
```
- Output Area:** Empty, labeled "Output".
- Status Bar:** indexing: 2/44, Ln 1, Col 1, Raspberry Pi Pico on COM15

Download the code to Pico, by turning the adjustable resistor to change the input voltage of GP26, Pico changes the output voltage of GP15 according to this voltage value, thus changing the brightness of the LED.





The following is the code:

```
1 #define PIN_ADC0      26
2 #define PIN_LED       15
3
4 void setup() {
5     pinMode(PIN_LED, OUTPUT);
6 }
7
8 void loop() {
9     int adcVal = analogRead(PIN_ADC0); //read adc
10    analogWrite(PIN_LED, map(adcVal, 0, 1023, 0, 255));
11    delay(10);
12 }
```

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

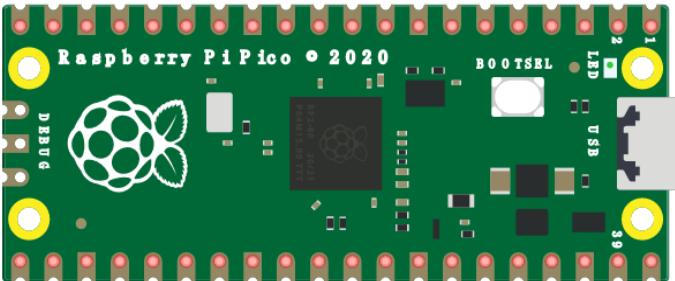
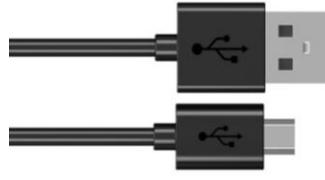
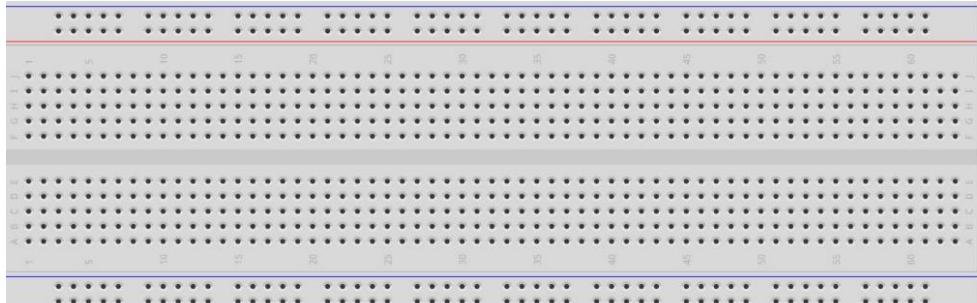
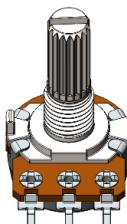
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## Project 10.2 Soft Colorful Light

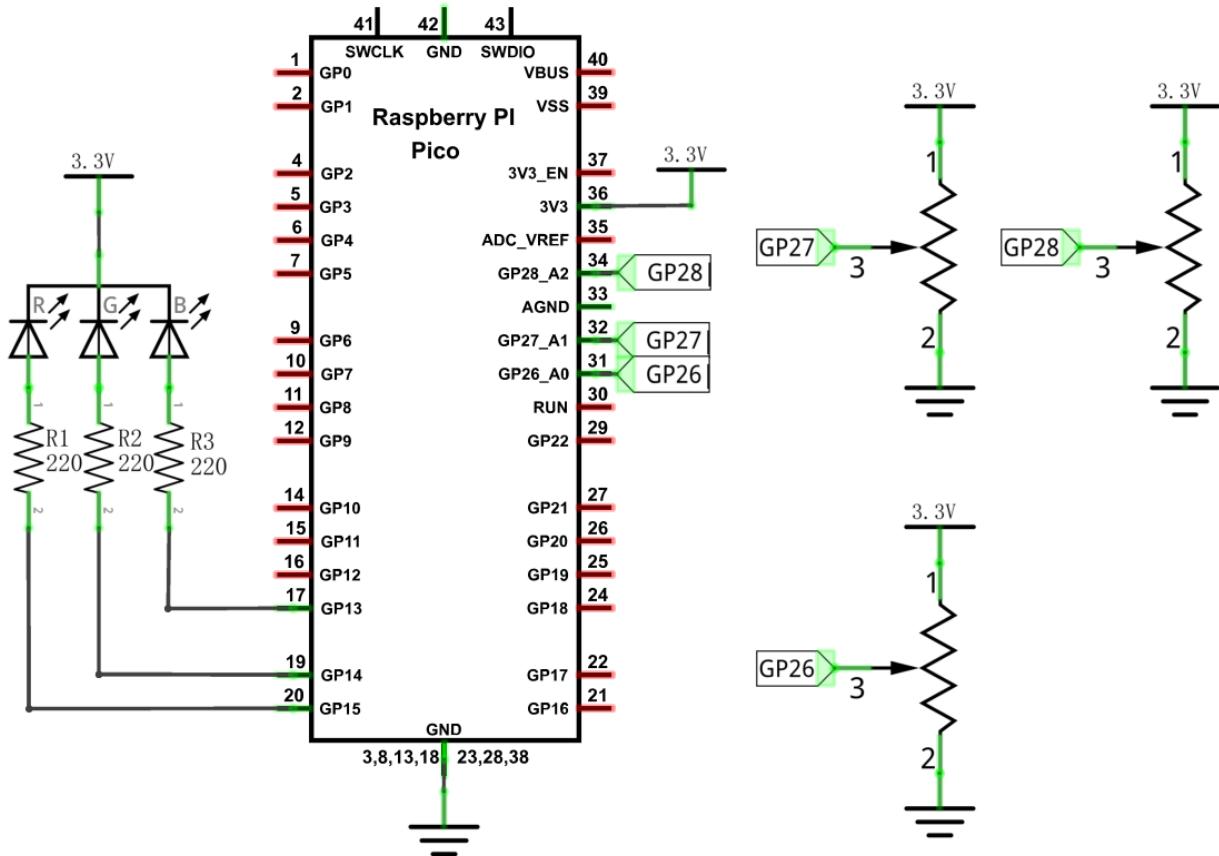
In this project, three potentiometers are used to control the RGB LED and in principle, it is the same as the Soft Light project. Namely, read the voltage value of the potentiometer and then convert it to PWM used to control LED brightness. Difference is that the original project only controlled one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

### Component List

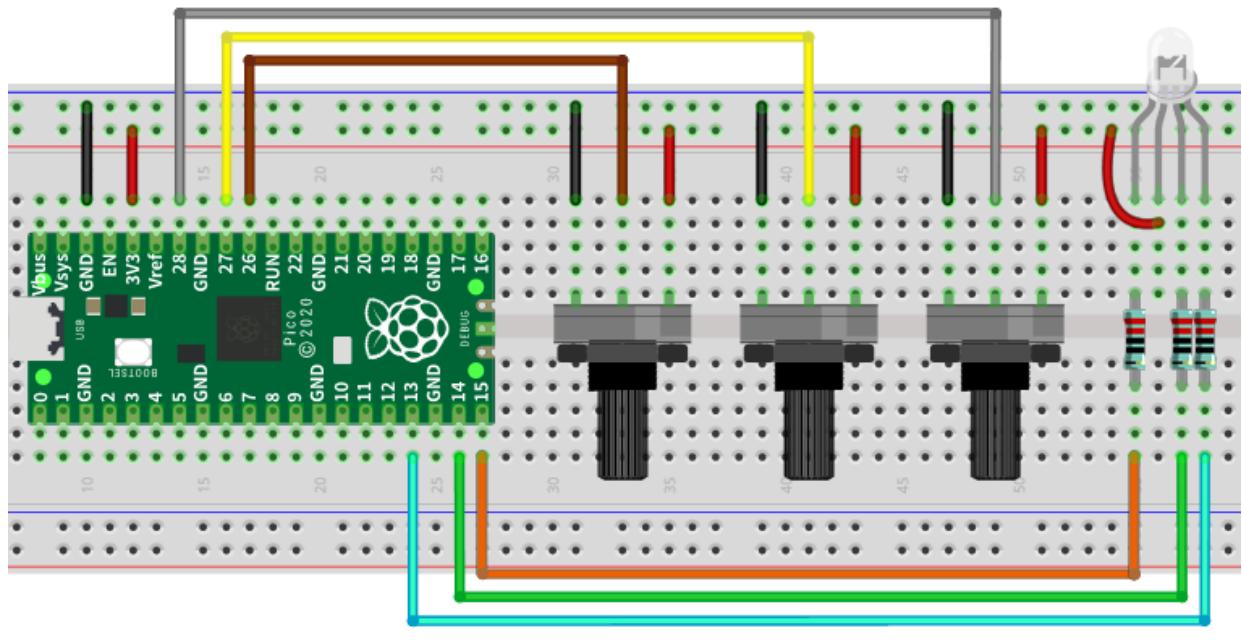
Raspberry Pi Pico x1		USB cable x1	
Breadboard x1			
Rotary potentiometer x3		Resistor 220Ω x3	
RGBLED x1		Jumper	

## Circuit

Schematic diagram



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



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## Sketch

### Sketch\_10.2\_SoftColorfullLight

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

- Title Bar:** Sketch\_10.2\_SoftColorfullLight | Arduino IDE 2.3.2
- File Menu:** File Edit Sketch Tools Help
- Sketch Selection:** Raspberry Pi Pico
- Code Area:** Displays the `Sketch_10.2_SoftColorfullLight.ino` file content.
- Code Content:**

```
7 const byte ledPins[] = {15, 14, 13};      //define led pins
8 const byte adcChns[] = {26, 27, 28};      // define the adc channels
9 int colors[] = {0, 0, 0};                  // red, green ,blue values of
color.
10 void setup() {
11     for (int i = 0; i < 3; i++) {    //setup the pwm channels
12         pinMode(ledPins[i], OUTPUT);
13     }
14 }
15
16 void loop() {
17     for (int i = 0; i < 3; i++) {
18         colors[i] = map(analogReadadcChns[i]), 0, 1023, 0, 255); //calculate
color value.
19         analogWrite(ledPins[i], colors[i]);
20     }
21     delay(10);
22 }
```
- Output Area:** Shows the message "Ln 1, Col 1 Raspberry Pi Pico on COM15".

Download the code to Pico, rotate one of the potentiometers, then the color of RGB LED will change.

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The following is the program code:

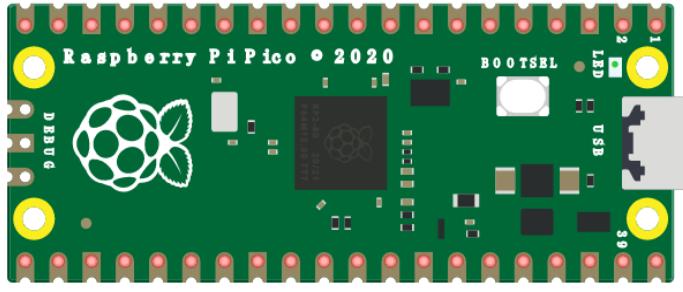
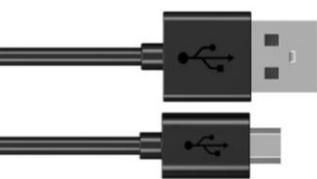
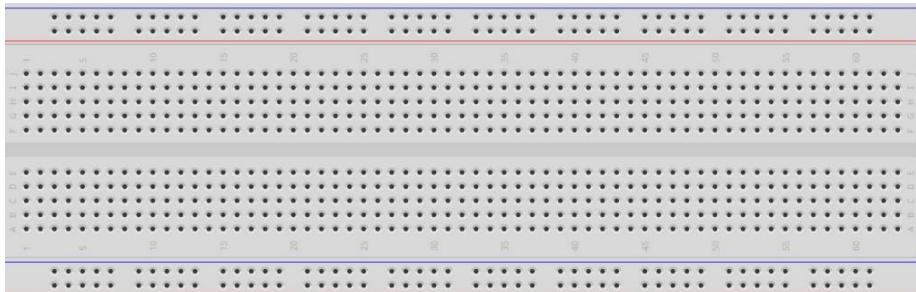
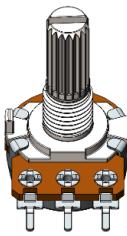
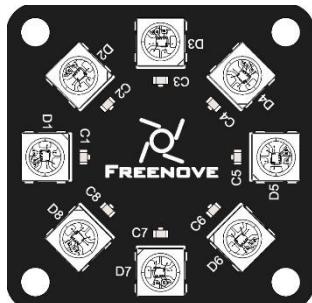
```
1 const byte ledPins[] = {15, 14, 13};      //define led pins
2 const byte adcChns[] = {26, 27, 28};      // define the adc channels
3 int colors[] = {0, 0, 0};                  // red, green, blue values of color.
4 void setup() {
5     for (int i = 0; i < 3; i++) {    //setup the pwm channels
6         pinMode(ledPins[i], OUTPUT);
7     }
8 }
9
10 void loop() {
11     for (int i = 0; i < 3; i++) {
12         colors[i] = map(analogRead(adcChns[i]), 0, 1023, 0, 255); //calculate color value.
13         analogWrite(ledPins[i], colors[i]);
14     }
15     delay(10);
16 }
```

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

## Project 10.3 Soft Rainbow Light

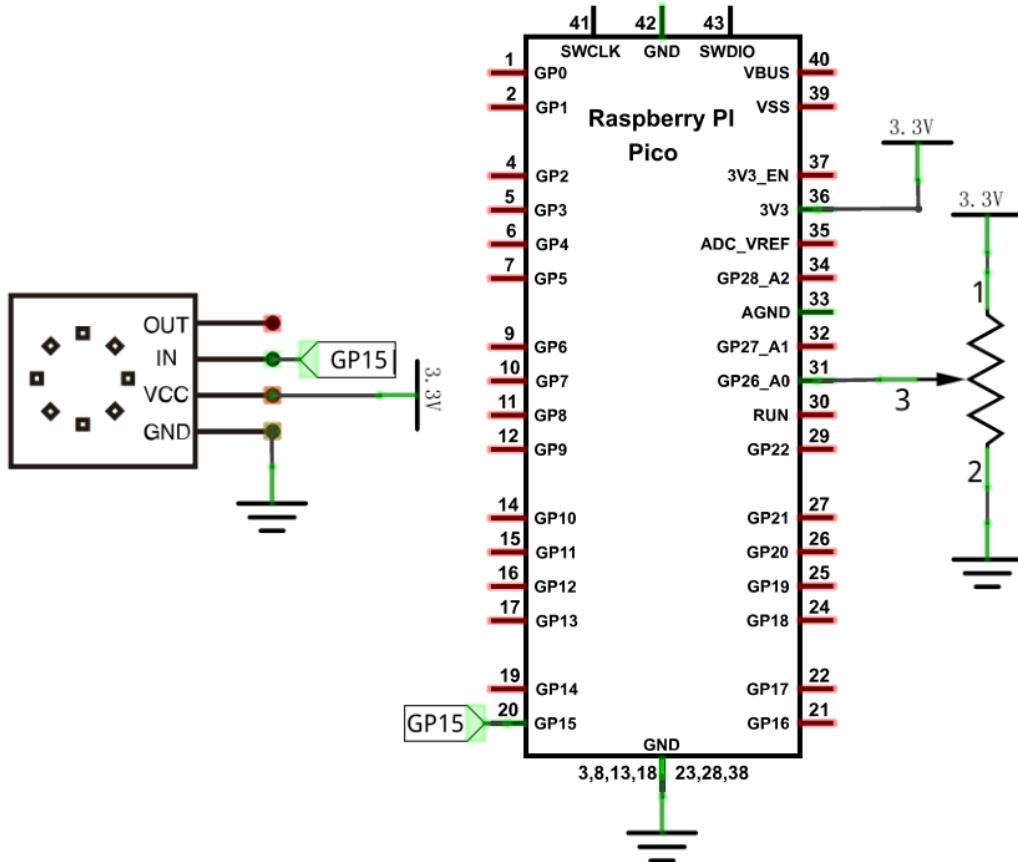
In this project, we use a potentiometer to control Freenove 8 RGBLED Module.

### Component List

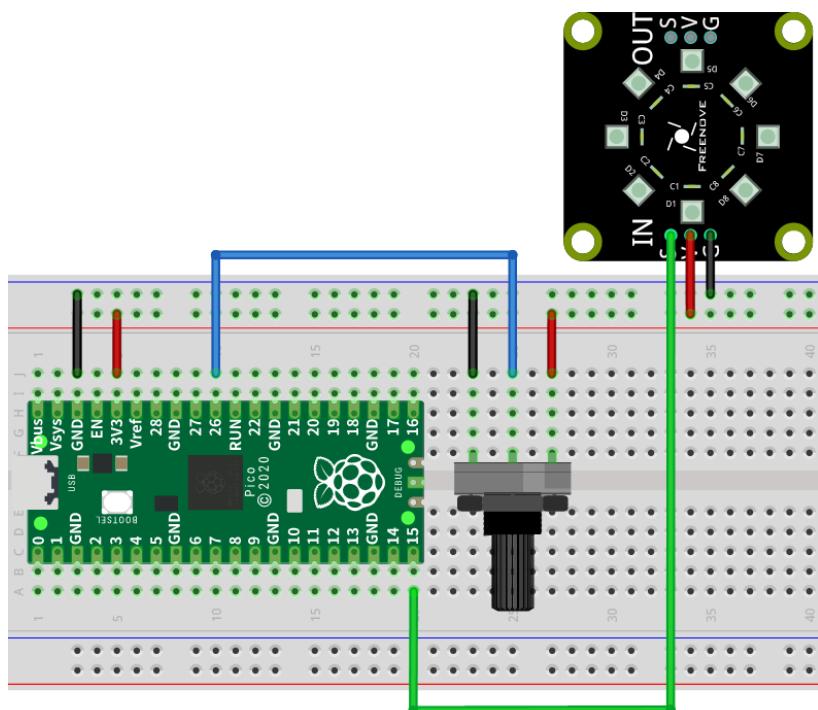
Raspberry Pi Pico x1	USB cable x1	
		
Breadboard x1		
Rotary potentiometer x1	Freenove 8 RGB LED Module x1	Jumper Jumper
		

## Circuit

Schematic diagram



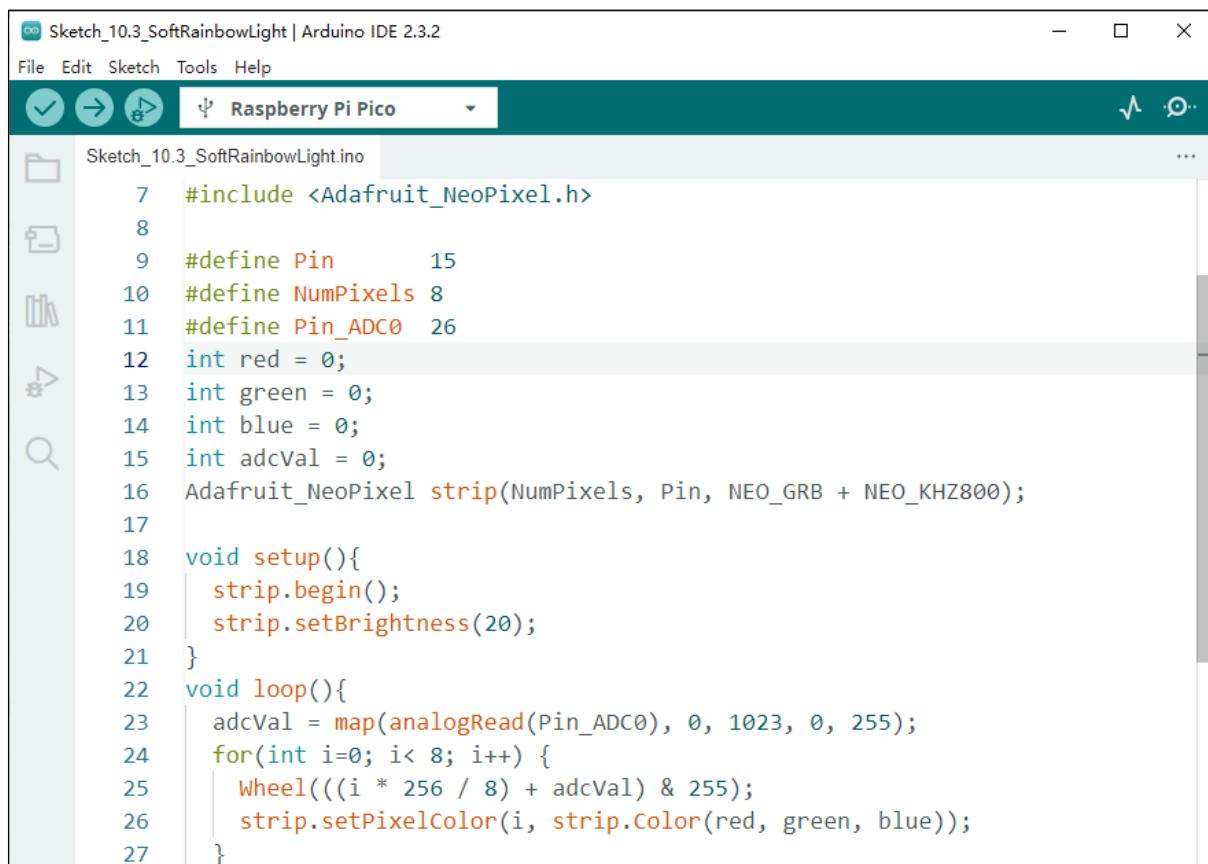
Hardware connection. If you need any support, please feel free to contact us via: [support@freenove.com](mailto:support@freenove.com)



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## Sketch

### Sketch\_10.3\_Soft\_Rainbow\_Light

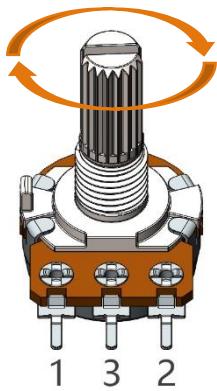


```

Sketch_10.3_SoftRainbowLight | Arduino IDE 2.3.2
File Edit Sketch Tools Help
Sketch_10.3_SoftRainbowLight.ino
 7 #include <Adafruit_NeoPixel.h>
 8
 9 #define Pin      15
10 #define NumPixels 8
11 #define Pin_ADC0 26
12 int red = 0;
13 int green = 0;
14 int blue = 0;
15 int adcVal = 0;
16 Adafruit_NeoPixel strip(NumPixels, Pin, NEO_GRB + NEO_KHZ800);
17
18 void setup(){
19     strip.begin();
20     strip.setBrightness(20);
21 }
22 void loop(){
23     adcVal = map(analogRead(Pin_ADC0), 0, 1023, 0, 255);
24     for(int i=0; i< 8; i++) {
25         wheel(((i * 256 / 8) + adcVal) & 255);
26         strip.setPixelColor(i, strip.Color(red, green, blue));
27     }
}

```

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



The following is the program code:

```

1 #include <Adafruit_NeoPixel.h>
2
3 #define Pin      16
4 #define NumPixels 8
5 #define Pin_ADC0 26
6 int red = 0;

```

```
7 int green = 0;
8 int blue = 0;
9 int adcVal = 0;
10 Adafruit_NeoPixel strip(NumPixels, Pin, NEO_GRB + NEO_KHZ800);
11
12 void setup() {
13     strip.begin();
14     strip.setBrightness(20);
15 }
16 void loop() {
17     adcVal = map(analogRead(Pin_ADC0), 0, 1023, 0, 255);
18     for(int i=0; i< 8; i++) {
19         Wheel(((i * 256 / 8) + adcVal) & 255);
20         strip.setPixelColor(i, strip.Color(red, green, blue));
21     }
22     strip.show();
23     delay(10);
24 }
25
26 void Wheel(byte WheelPos) {
27     WheelPos = 255 - WheelPos;
28     if(WheelPos < 85) {
29         red = 255 - WheelPos * 3;
30         green = 0;
31         blue = WheelPos * 3;
32     } else if(WheelPos < 170) {
33         WheelPos -= 85;
34         red = 0;
35         green = WheelPos * 3;
36         blue = 255 - WheelPos * 3;
37     } else{
38         WheelPos -= 170;
39         red = WheelPos * 3;
40         green = 255 - WheelPos * 3;
41         blue = 0;
42     }
43 }
```

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

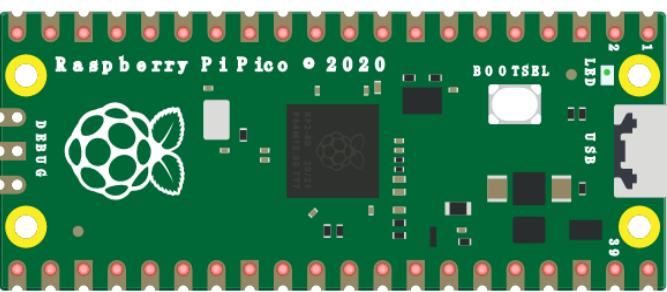
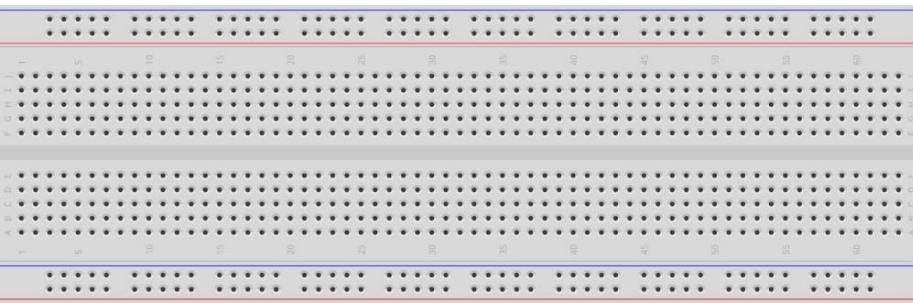
# Chapter 11 Photoresistor & LED

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

## Project 11.1 Control LED through Photoresistor

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

### Component List

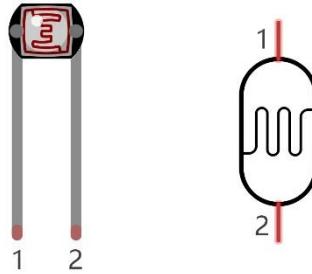
Raspberry Pi Pico x1		USB cable x1
Breadboard x1		
Photoresistor x1		
Photoresistor x1	Resistor 220Ω x1      10KΩ x1	LED x1  Jumper



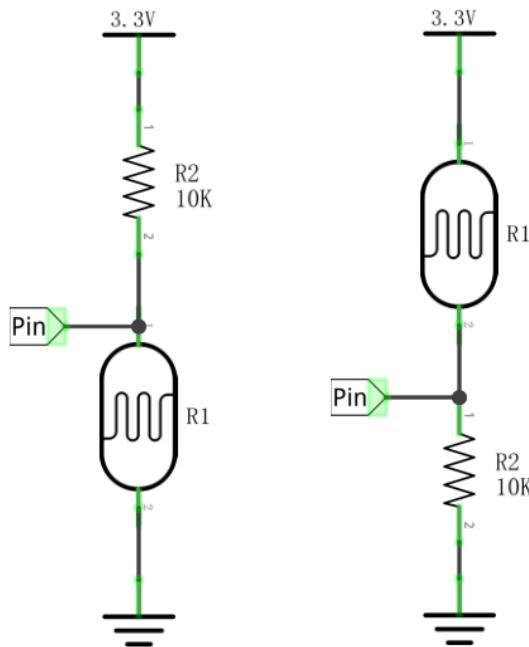
## Component Knowledge

### Photoresistor

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



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

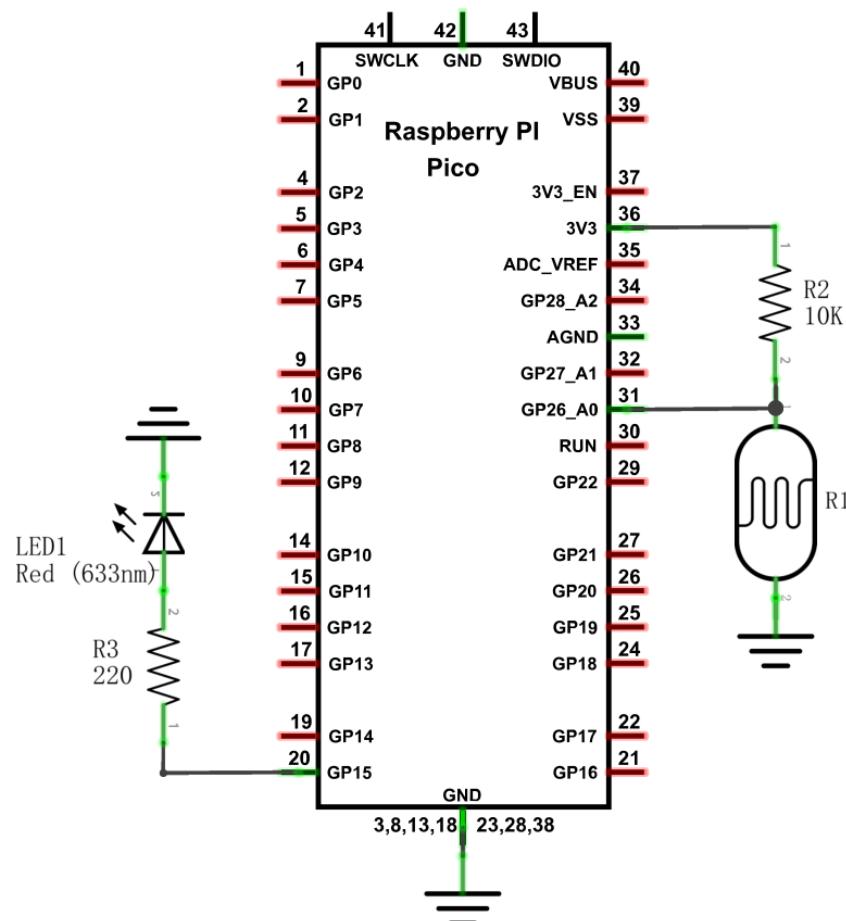


In the above circuit, when a Photoresistor's resistance value changes due to a change in light intensity, the voltage between the Photoresistor and Resistor R1 will also change. Therefore, the intensity of the light can be obtained by measuring this voltage.

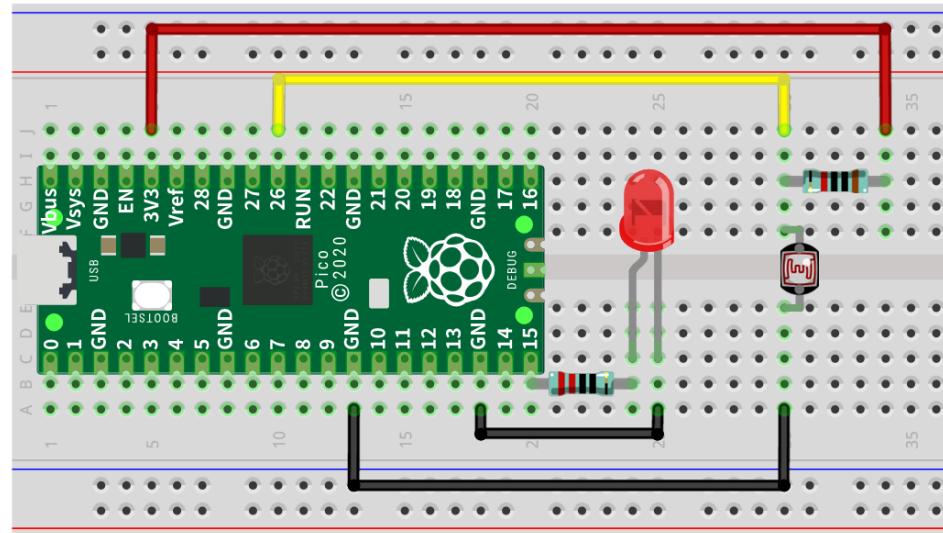
## Circuit

The circuit of this project is similar to SoftLight. The only difference is that the input signal is changed from a potentiometer to a combination of a photoresistor and a resistor.

Schematic diagram



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



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## Sketch

The circuit used is similar to the project Soft Light. The only difference is that the input signal of the ADC0 pin of ADC changes from a potentiometer to a combination of a photoresistor and a resistor.

### Sketch\_11.1\_Nightlamp

```

Sketch_11.1_Photosensitive | Arduino IDE 2.3.2
File Edit Sketch Tools Help
Sketch_11.1_Photosensitive.ino
7 #define PIN_ADC0      26
8 #define PIN_LED       15
9
10 void setup() {
11   pinMode(PIN_LED, OUTPUT);
12 }
13
14 void loop() {
15   int adcVal = analogRead(PIN_ADC0); //Read the voltage of the
                                         photoresistor
16   analogWrite(PIN_LED, map(adcVal, 0, 1023, 0, 255));
17   delay(10);
18 }

```

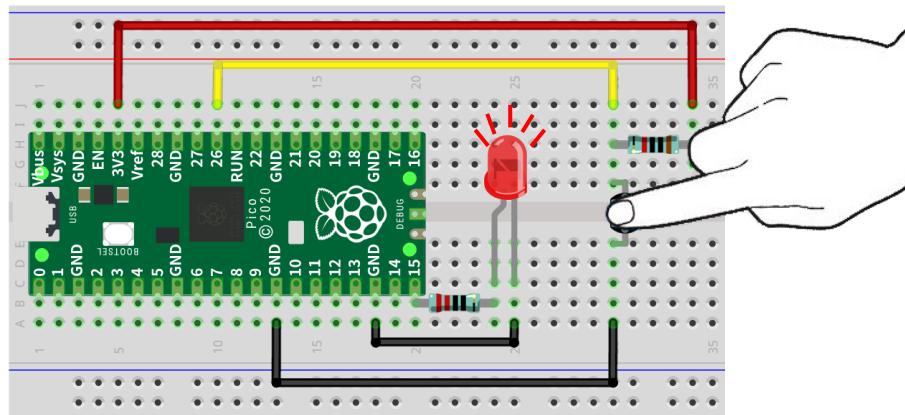
Output

Ln 1, Col 1 Raspberry Pi Pico on COM15

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

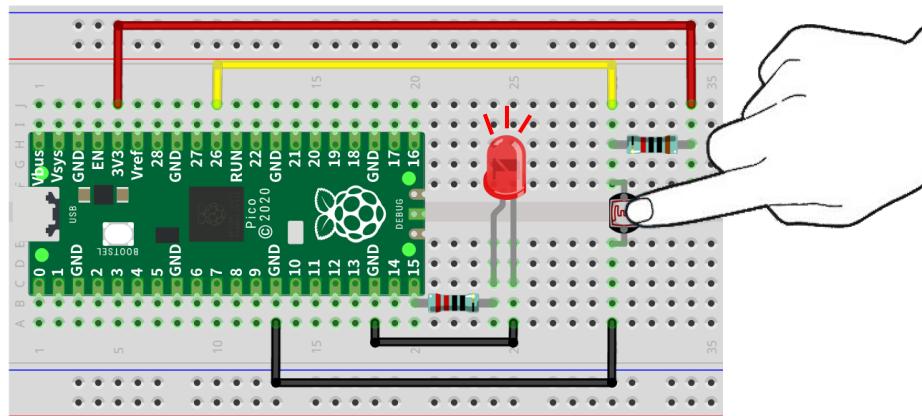
If you have any concerns, please contact us via: [support@freenove.com](mailto:support@freenove.com)

Fully cover the photoresistor:

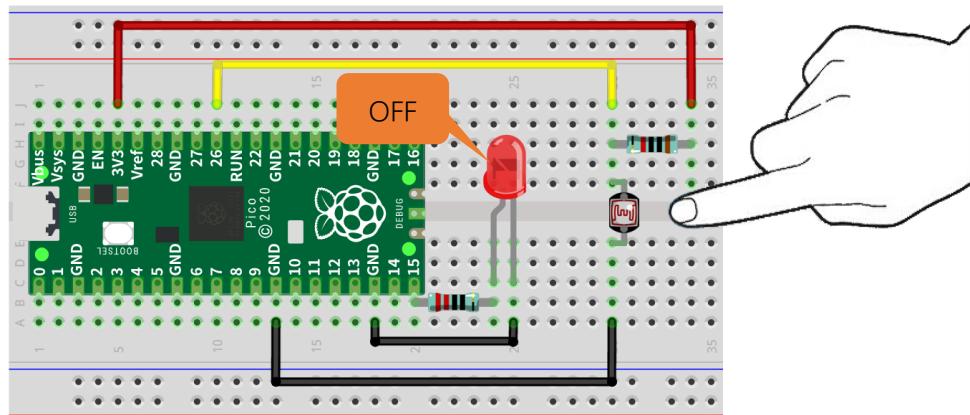


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Half cover the photoresistor:



Not cover the photoresistor:



The following is the program code:

```

1 #define PIN_ADC0      26
2 #define PIN_LED       15
3
4 void setup() {
5     pinMode(PIN_LED, OUTPUT);
6 }
7
8 void loop() {
9     int adcVal = analogRead(PIN_ADC0); //Read the voltage of the photoresistor
10    analogWrite(PIN_LED, map(adcVal, 0, 1023, 0, 255));
11    delay(10);
12 }
```



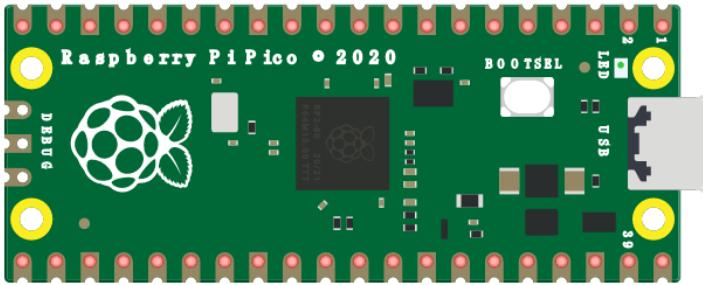
# Chapter 12 Thermistor

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

## Project 12.1 Thermometer

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

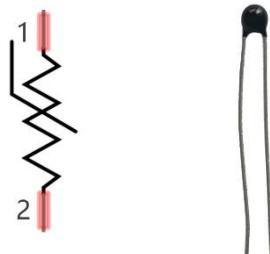
### Component List

Raspberry Pi Pico x1		USB cable x1
Breadboard x1		
Thermistor x1	Resistor 10kΩ x1	Jumper
		

## Component Knowledge

### Thermistor

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



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

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

**Where:**

Rt is the thermistor resistance under T2 temperature;

R is the nominal resistance of thermistor under T1 temperature;

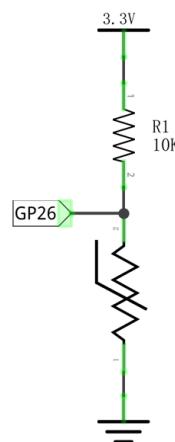
**EXP[n]** is nth power of e;

B is for thermal index;

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

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

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



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

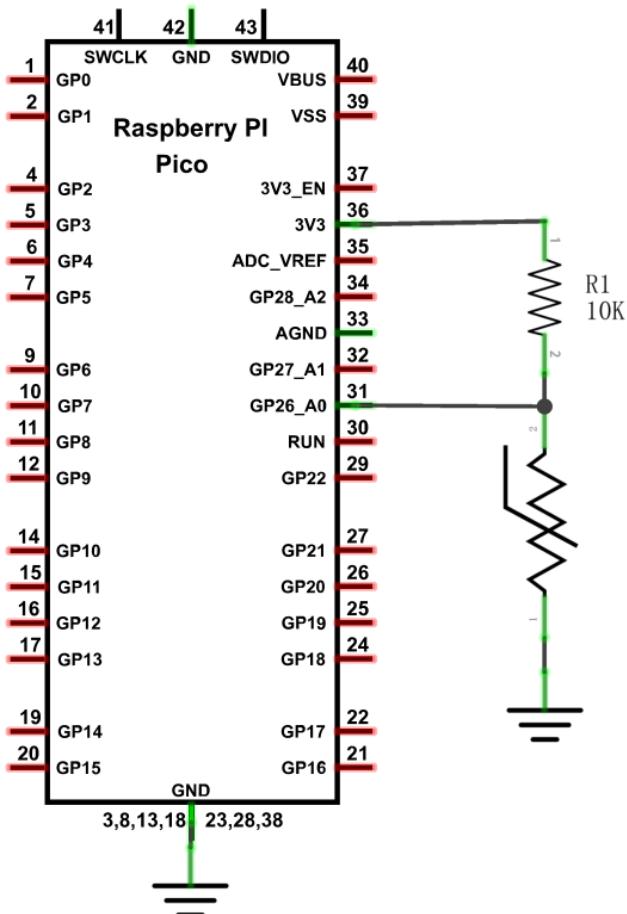
Therefore, the temperature formula can be derived as:

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

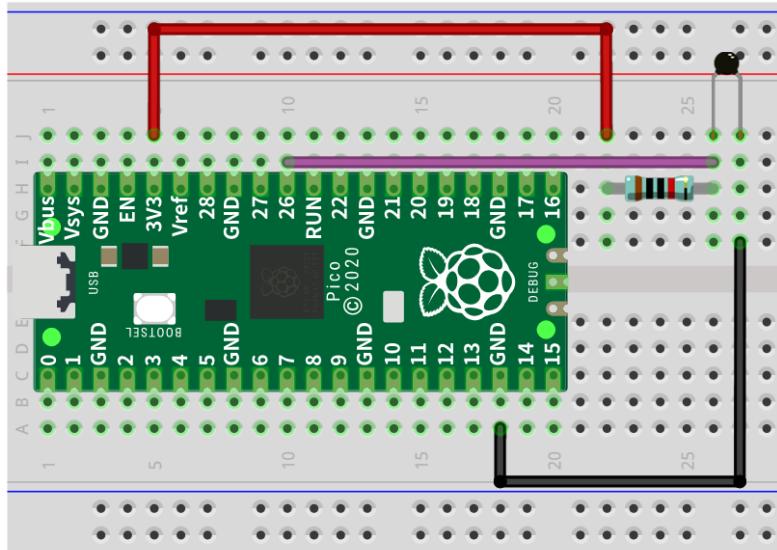
## Circuit

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

Schematic diagram



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



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## Sketch

### Sketch\_12.1\_Thermometer

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

- Title Bar:** Sketch\_12.1\_Thermometer | Arduino IDE 2.3.2
- File Menu:** File Edit Sketch Tools Help
- Sketch Name:** Sketch\_12.1\_Thermometer.ino
- Board:** Raspberry Pi Pico
- Code Content:**

```

7 #define PIN_ADC0 26
8 void setup() {
9     Serial.begin(115200);
10 }
11
12 void loop() {
13     int adcValue = analogRead(PIN_ADC0); //read ADC pin
14     double voltage = (float)adcValue / 1023.0 * 3.3; // calculate
15     voltage
16     double Rt = 10 * voltage / (3.3 - voltage); //calculate
17     resistance value of thermistor
18     double tempK = 1 / (1 / (273.15 + 25) + log(Rt / 10) / 3950.0); //calculate
19     temperature (Kelvin)
20     double tempC = tempK - 273.15; //calculate
21     temperature (Celsius)
22     Serial.println("Voltage: " + String(voltage) + "V,\t\t" + "Kelvins: " + String
23     (tempK) + "K,\t\t" + "Temperature: " + String(tempC) + "C");
24     delay(1000);
25 }
```
- Output Panel:** Shows a blacked-out message area.
- Status Bar:** Ln 14, Col 54 Raspberry Pi Pico on COM15 4 2

Upload the code to Pico and serial monitor will display the current ADC, voltage and temperature values. Try to “pinch” the thermistor (without touching the leads) with your index finger and thumb for a brief time, you should see that the temperature value increases.

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

- Header:** Output Serial Monitor
- Message Bar:** Message (Enter to send message to 'Raspberry Pi Pico' on 'COM15')
- Content:**

```

14:00:30.940 -> voltage: 1.04V, Kelvins: 301.51K, Temperature: 28.10C
14:00:36.952 -> Voltage: 1.52V, Kelvins: 301.86K, Temperature: 28.71C
14:00:37.959 -> Voltage: 1.53V, Kelvins: 301.58K, Temperature: 28.43C
14:00:38.935 -> Voltage: 1.52V, Kelvins: 301.86K, Temperature: 28.71C
14:00:39.958 -> Voltage: 1.54V, Kelvins: 301.31K, Temperature: 28.16C
14:00:40.953 -> Voltage: 1.52V, Kelvins: 301.67K, Temperature: 28.52C
14:00:41.961 -> Voltage: 1.52V, Kelvins: 301.67K, Temperature: 28.52C
14:00:42.917 -> Voltage: 1.52V, Kelvins: 301.67K, Temperature: 28.52C
14:00:43.940 -> Voltage: 1.53V, Kelvins: 301.49K, Temperature: 28.34C
14:00:44.946 -> Voltage: 1.54V, Kelvins: 301.22K, Temperature: 28.07C
14:00:45.918 -> Voltage: 1.52V, Kelvins: 301.67K, Temperature: 28.52C
14:00:46.919 -> Voltage: 1.54V, Kelvins: 301.31K, Temperature: 28.16C
14:00:47.942 -> Voltage: 1.53V, Kelvins: 301.49K, Temperature: 28.34C
14:00:48.947 -> Voltage: 1.53V, Kelvins: 301.58K, Temperature: 28.43C
14:00:49.960 -> Voltage: 1.52V, Kelvins: 301.67K, Temperature: 28.52C
14:00:50.920 -> Voltage: 1.53V, Kelvins: 301.58K, Temperature: 28.43C

```
- Bottom Status:** Ln 14, Col 54 Raspberry Pi Pico on COM15 4 2

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



The following is the code:

```
1 #define PIN_ADC0 26
2 void setup() {
3     Serial.begin(115200);
4 }
5
6 void loop() {
7     int adcValue = analogRead(PIN_ADC0); //read ADC pin
8     double voltage = (float)adcValue / 1023.0 * 3.3;// calculate voltage
9     double Rt = 10 * voltage / (3.3 - voltage);//calculate resistance value of thermistor
10    double tempK = 1 / (1 / (273.15 + 25) + log(Rt / 10) / 3950.0); //calculate temperature
11    (Kelvin)
12    double tempC = tempK - 273.15; //calculate temperature (Celsius)
13    Serial.println("Voltage: " + String(voltage) + "V, \t\t" + "Kelvins: " + String(tempK) +
14    "K, \t" + "Temperature: " + String(tempC) + "C");
15    delay(1000);
}
```

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

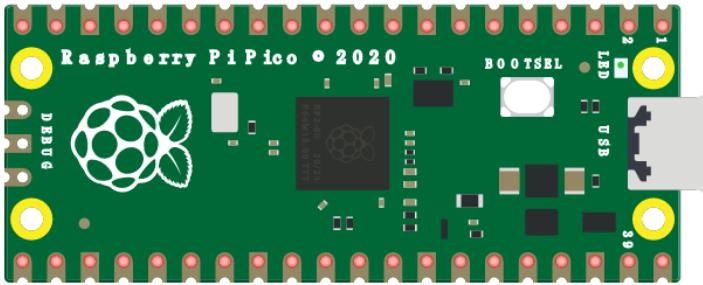
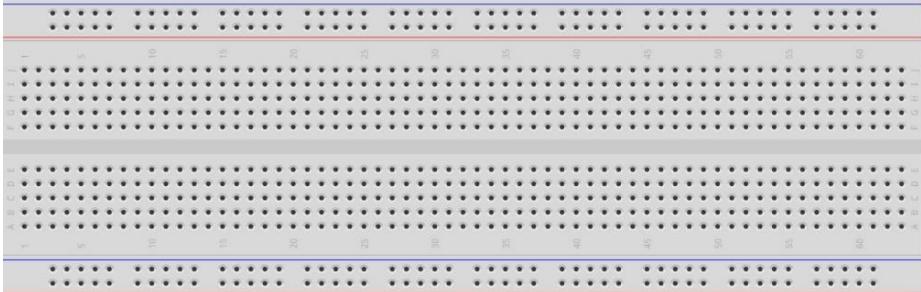
# Chapter 13 Joystick

In the previous chapter, we have learned how to use rotary potentiometer. Now, let us learn a new electronic module Joystick that works on the same principle as rotary potentiometer.

## Project 13.1 Joystick

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

### Component List

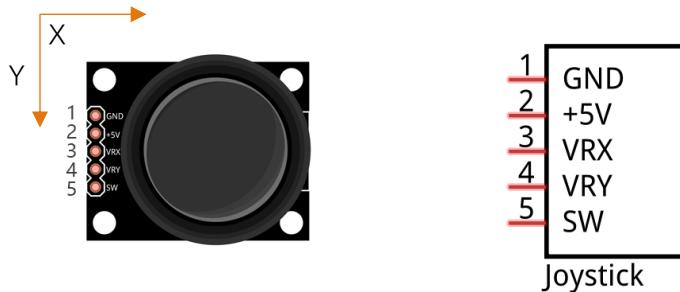
Raspberry Pi Pico x1	USB cable x1
	
Breadboard x1	
Joystick x1	Jumper



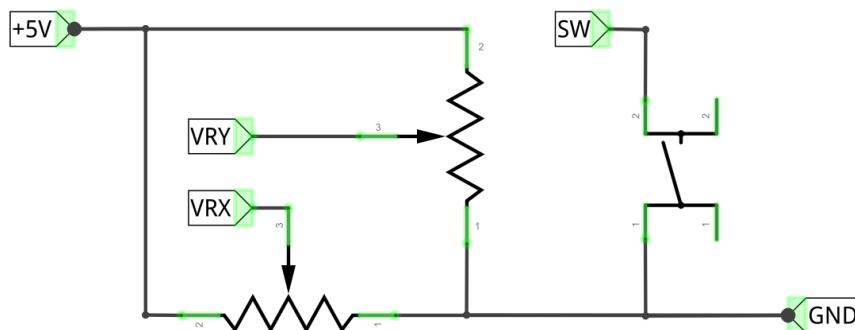
## Component Knowledge

### Joystick

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



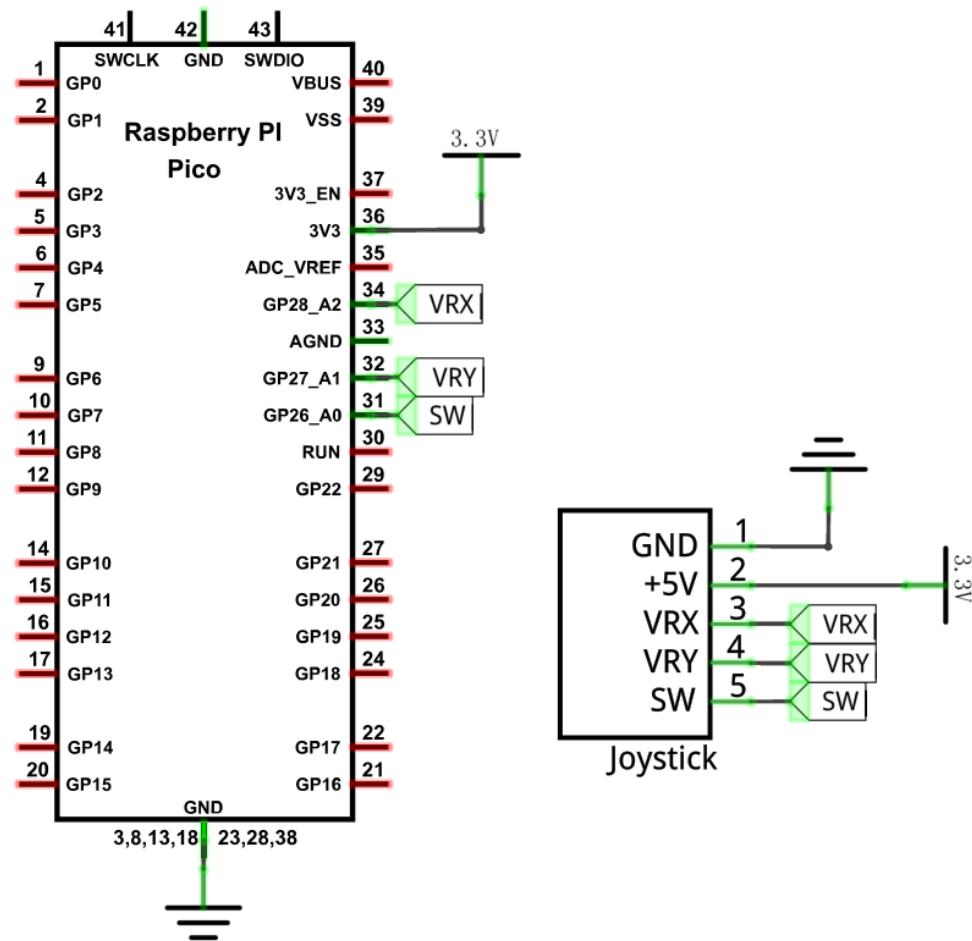
This is accomplished by incorporating two rotary potentiometers inside the Joystick Module at 90 degrees of each other, placed in such a manner as to detect shifts in direction in two directions simultaneously and with a Push Button Switch in the “vertical” axis, which can detect when a User presses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



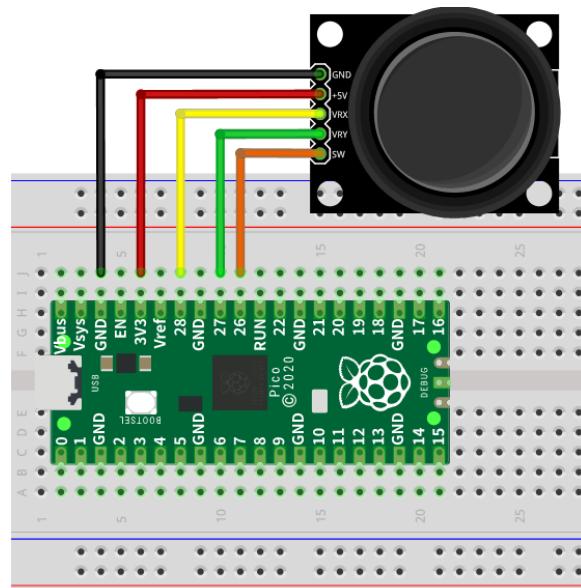
When the Joystick data is read, there are some differences between the axes: data of X and Y axes is analog, which needs to use the ADC. The data of the Z axis is digital, so you can directly use the GPIO to read this data or you have the option to use the ADC to read this.

## Circuit

Schematic diagram



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





## Sketch

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

### Sketch\_13.1\_Joystick

```

Sketch_13.1_Joystick | Arduino IDE 2.3.2
File Edit Sketch Tools Help
ψ Raspberry Pi Pico
Sketch_13.1_Joystick.ino ...
7 int xyzPins[] = {28, 27, 26}; //x,y,z pins
8 void setup() {
9   Serial.begin(115200);
10  pinMode(xyzPins[2], INPUT_PULLUP); //z axis is a button.
11 }
12
13 void loop() {
14   int xVal = analogRead(xyzPins[0]);
15   int yVal = analogRead(xyzPins[1]);
16   int zVal = digitalRead(xyzPins[2]);
17   Serial.println("X,Y,Z: " + String(xVal) + ", " + String(yVal) + ", " + String(zVal));
18   delay(500);
19 }

```

Output

Ln 1, Col 1 Raspberry Pi Pico on COM15

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

Output    Serial Monitor

Message (Enter to send message to 'Raspberry Pi Pico' on 'COM15')

New Line    115200 baud

```

14:57:15.701 -> X, Y, Z: 124, 1023, 1
14:57:16.156 -> X, Y, Z: 504, 519, 1
14:57:16.656 -> X, Y, Z: 502, 980, 1
14:57:17.188 -> X, Y, Z: 4, 521, 1
14:57:17.695 -> X, Y, Z: 506, 1023, 1
14:57:18.156 -> X, Y, Z: 5, 516, 0
14:57:18.657 -> X, Y, Z: 502, 517, 0
14:57:19.187 -> X, Y, Z: 1023, 1023, 1
14:57:19.699 -> X, Y, Z: 503, 518, 1
14:57:20.157 -> X, Y, Z: 501, 516, 1
14:57:20.680 -> X, Y, Z: 504, 519, 1
14:57:21.192 -> X, Y, Z: 504, 519, 1

```

Ln 1, Col 1 Raspberry Pi Pico on COM15

The following is the code:

```
1 int xyzPins[] = {28, 27, 26}; //x, y, z pins
2
3 void setup() {
4     Serial.begin(115200);
5     pinMode(xyzPins[2], INPUT_PULLUP); //z axis is a button.
6 }
7
8 void loop() {
9     int xVal = analogRead(xyzPins[0]);
10    int yVal = analogRead(xyzPins[1]);
11    int zVal = digitalRead(xyzPins[2]);
12    Serial.println("X,Y,Z: " + String(xVal) + ", " + String(yVal) + ", " + String(zVal));
13    delay(500);
14 }
```

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

```
5 pinMode(xyzPins[2], INPUT_PULLUP); //z axis is a button.
```

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

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



# Chapter 14 74HC595 & LED Bar Graph

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

## Project 14.1 Flowing Water Light

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

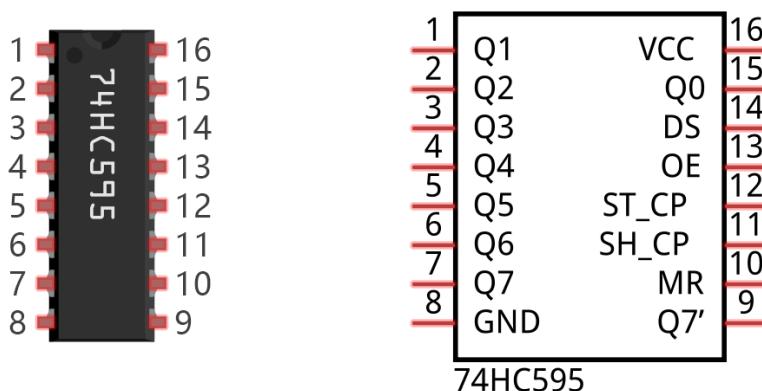
### Component List

Raspberry Pi Pico x1		USB cable x1	
Breadboard x1			
74HC595 x1	LED Bar Graph x1	Resistor 220Ω x8	Jumper

## Related Knowledge

### 74HC595

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



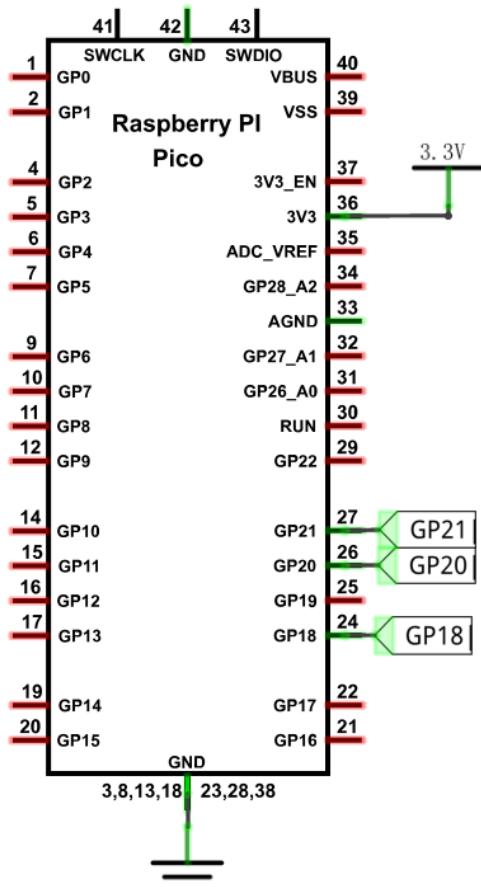
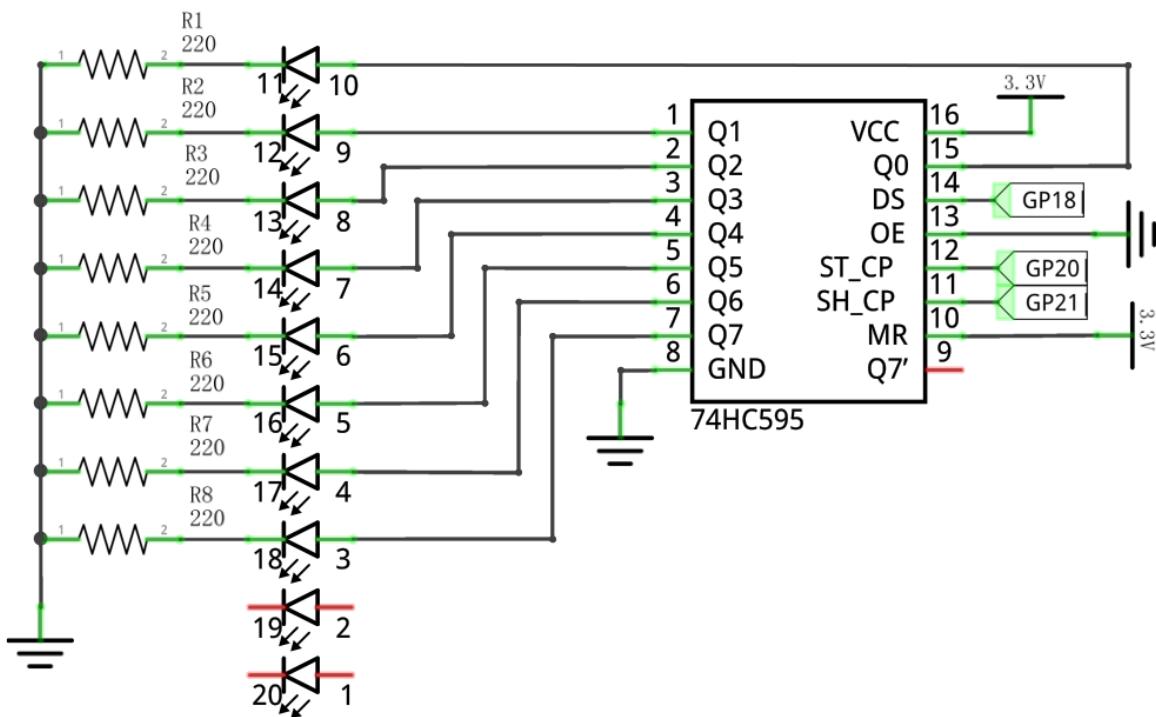
The ports of the 74HC595 chip are described as follows:

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

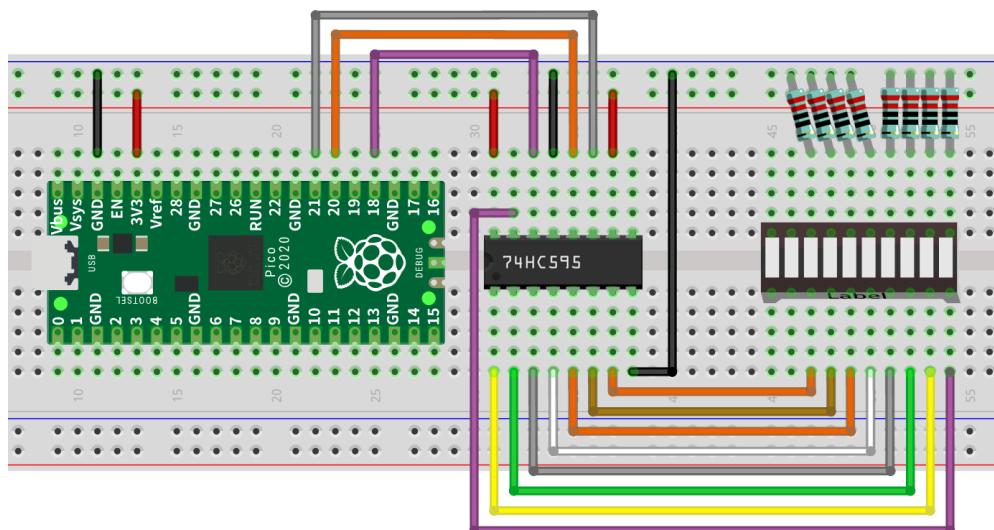
For more detail, please refer to the datasheet on the 74HC595 chip.

## Circuit

Schematic diagram



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



## Sketch

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

[Sketch\\_14.1\\_FlowingLight2](#)

```

Sketch_14.1_FlowingLight2 | Arduino IDE 2.3.2
File Edit Sketch Tools Help
Sketch_14.1_FlowingLight2.ino
1 int dataPin = 18; // Pin connected to DS of 74HC595(Pin14)
2 int latchPin = 20; // Pin connected to ST_CP of 74HC595(Pin12)
3 int clockPin = 21; // Pin connected to SH_CP of 74HC595(Pin11)
4
5 void setup() { // set pins to output
6     pinMode(latchPin, OUTPUT);
7     pinMode(clockPin, OUTPUT);
8     pinMode(dataPin, OUTPUT);
9 }
10
11 void loop() {
12     // Define a one-byte variable to use the 8 bits to represent the state of 8
13     // LEDs of LED bar graph.
14     // This variable is assigned to 0x01, that is binary 00000001, which
15     // indicates only one LED light on.
16     byte x = 0x01; // 0b 0000 0001
17     for (int j = 0; j < 8; j++) { // Let led light up from right to left
18         writeTo595(LSBFIRST, x);
19         x <<= 1; // make the variable move one bit to left once, then the bright
20
21
22
23
Output
Ln 1, Col 1 Raspberry Pi Pico on COM15

```

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

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The following is the program code:

```

1 int dataPin = 18; // Pin connected to DS of 74HC595(Pin14)
2 int latchPin = 20; // Pin connected to ST_CP of 74HC595(Pin12)
3 int clockPin = 21; // Pin connected to SH_CP of 74HC595(Pin11)
4
5 void setup() { // set pins to output
6     pinMode(latchPin, OUTPUT);
7     pinMode(clockPin, OUTPUT);
8     pinMode(dataPin, OUTPUT);
9 }
10
11 void loop() {
12     // Define a variable to use the 8 bits to represent the state of 8 LEDs of LED bar graph.
13     // This variable is assigned to 0x01, which indicates only one LED light on.
14     byte x = 0x01; // 0b 0000 0001
15     for (int j = 0; j < 8; j++) { // Let led light up from right to left
16         writeTo595(LSBFIRST, x);
17         x <= 1; // make the variable move one bit to left once, then the bright LED move one step
18         to the left once.
19         delay(100);
20     }
21     delay(100);
22     x = 0x80; //0b 1000 0000
23     for (int j = 0; j < 8; j++) { // Let led light up from left to right
24         writeTo595(LSBFIRST, x);
25         x >>= 1;
26         delay(100);
27     }
28 }
29 void writeTo595(BitOrder order, byte _data) {
30     // Output low level to latchPin
31     digitalWrite(latchPin, LOW);
32     // Send serial data to 74HC595
33     shiftOut(dataPin, clockPin, order, _data);
34     // Output high level to latchPin, and 74HC595 will update the data to the parallel output
35     // port.
36     digitalWrite(latchPin, HIGH);
37 }
```

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

14	byte x = 0x01; // 0b 0000 0001
----	--------------------------------

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

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

```

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

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

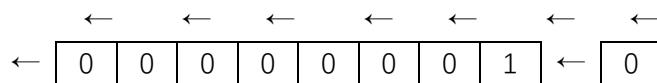
The subfunction writeTo595() is used to write data to 74HC595 and immediately output on the port of 74HC595.

#### Reference

##### << operator

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

byte x = 1 << 1;

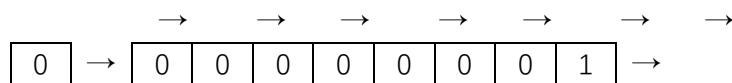


The result of x is 2 (binary 00000010) .



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

byte x = 1 >> 1;



The result of x is 0 (00000000) .



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

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

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

#### Parameters

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

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

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

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

For more details about shift function, please refer to:

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



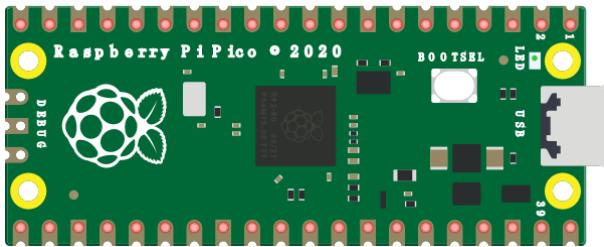
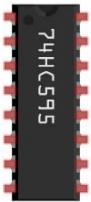
# Chapter 15 74HC595 & 7-Segment Display.

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

## Project 15.1 7-Segment Display.

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

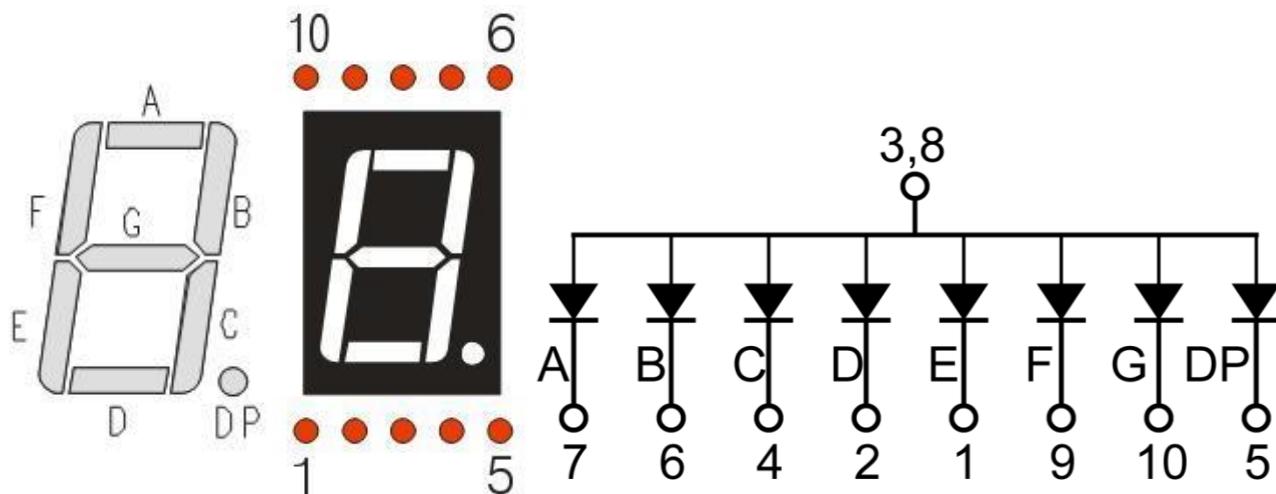
### Component List

Raspberry Pi Pico x1		USB cable x1
Breadboard x1		
74HC595 x1	7-segment display x1	Resistor 220Ω x8
		
Jumper		

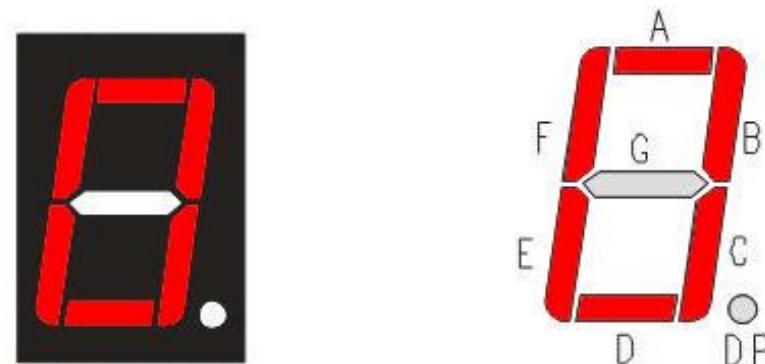
## Component Knowledge

### 7-segment display

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



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



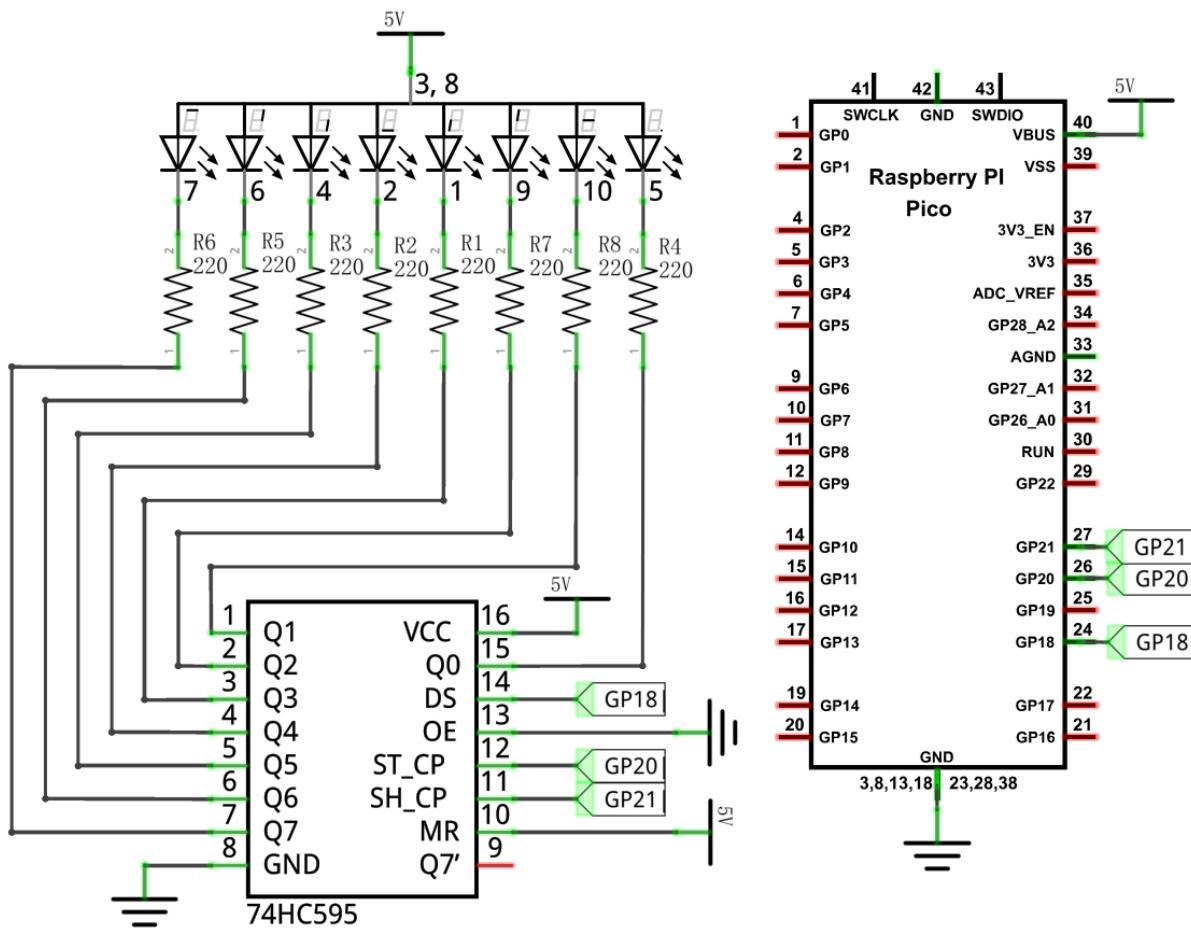
In this project, we will use a 7-Segment Display with a Common Anode. Therefore, when there is an input low level to an LED segment the LED will turn ON. Defining segment "A" as the lowest level and segment "DP" as the highest level, from high to low would look like this: "DP", "G", "F", "E", "D", "C",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

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

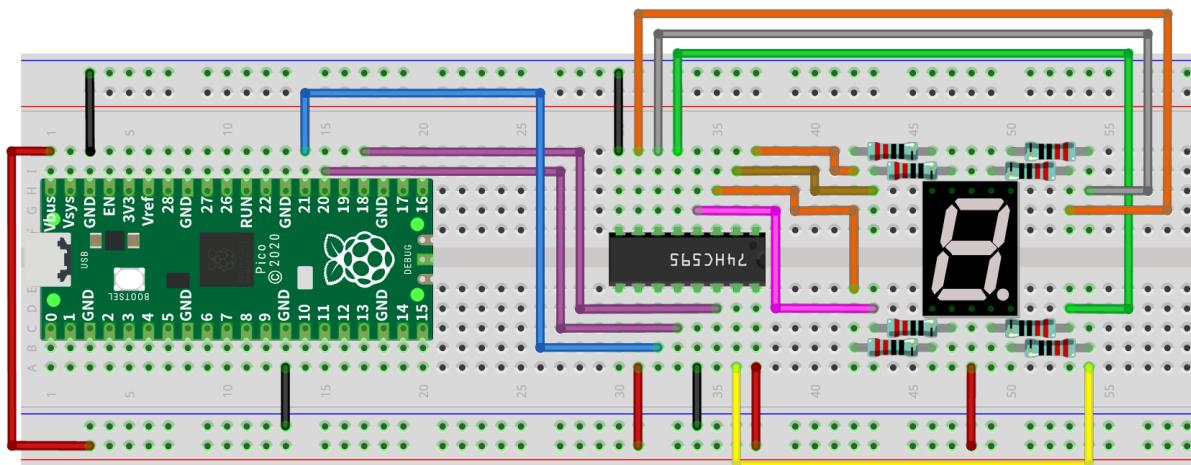
CHAR	DP	G	F	E	D	C	B	A	Hex	ASCII
0	1	1	0	0	0	0	0	0	0xc0	1100 0000
1	1	1	1	1	1	0	0	1	0xf9	1111 1001
2	1	0	1	0	0	1	0	0	0xa4	1010 0100
3	1	0	1	1	0	0	0	0	0xb0	1011 0000
4	1	0	0	1	1	0	0	1	0x99	1001 1001
5	1	0	0	1	0	0	1	0	0x92	1001 0010
6	1	0	0	0	0	0	1	0	0x82	1000 0010
7	1	1	1	1	1	0	0	0	0xf8	1111 1000
8	1	0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

## Circuit

Schematic diagram



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





## Sketch

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

### Sketch\_15.1\_7\_Segment\_Display

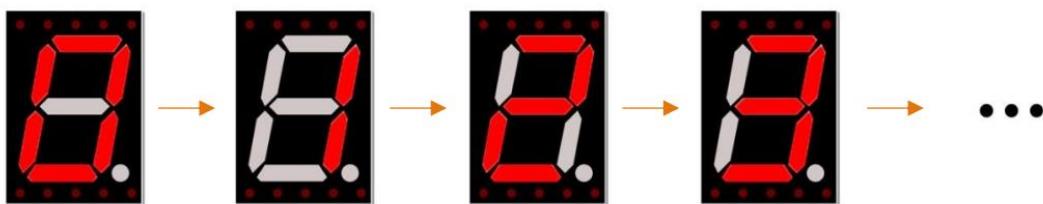
The screenshot shows the Arduino IDE interface with the following details:

- Title Bar:** Sketch\_15.1\_1\_Digit\_7-Segment\_Display | Arduino IDE 2.3.2
- Menu Bar:** File Edit Sketch Tools Help
- Toolbar:** Includes icons for Save, Run, Stop, and others.
- Sketch Area:** Displays the code for `Sketch_15.1_1_Digit_7-Segment_Display.ino`. The code initializes pins 18, 20, and 21, defines a byte array `num` for character encoding, and implements `setup()` and `loop()` functions to send data to the 74HC595 and clear the display.

```
Sketch_15.1_1_Digit_7-Segment_Display.ino
1 int dataPin = 18;
2 int latchPin = 20;
3 int clockPin = 21;
4
5 // Define the encoding of characters 0-F for the common-anode 7-Segment
6 // Display
7 byte num[] = {
8     0xc0, 0xf9, 0xa4, 0xb0, 0x99, 0x92, 0x82, 0xf8,
9     0x80, 0x90, 0x88, 0x83, 0xc6, 0xa1, 0x86, 0x8e
10 };
11
12 void setup() {
13     // set pins to output
14     pinMode(latchPin, OUTPUT);
15     pinMode(clockPin, OUTPUT);
16     pinMode(dataPin, OUTPUT);
17 }
18
19 void loop() {
20     // display 0-F on digital tube
21     for (int i = 0; i < 16; i++) {
22         writeData(num[i]); // Send data to 74HC595
23         delay(1000); // delay 1 second
24         writeData(0xff); // Clear the display content
25     }
26 }
```

- Output Area:** Shows the message "Ln 1, Col 1 Raspberry Pi Pico on COM15".

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



The following is the program code:

```

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

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

```

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

```

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

```

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

```

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

```

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

```

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

```

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

```

# Chapter 16 L293D & Motor

## Project 16.1 Control Motor with Potentiometer

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

### Component List

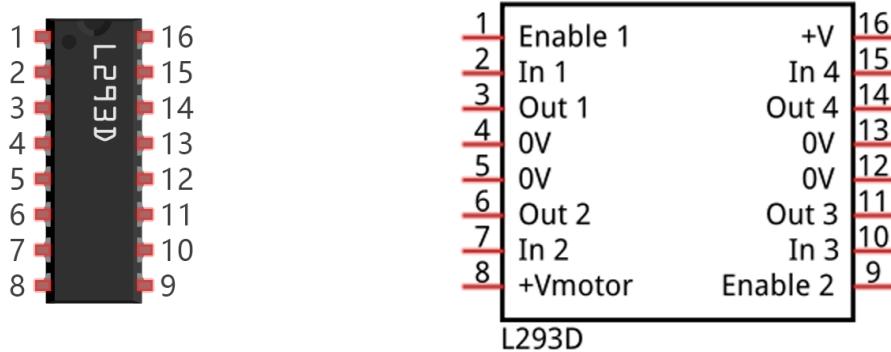
Raspberry Pi Pico x1	USB cable x1
Breadboard x1	
Rotary potentiometer x1	Motor x1
L293D x1	
Jumper	Battery box x1



## Component Knowledge

### L293D

L293D is an IC Chip (Integrated Circuit Chip) with a 4-channel motor drive. You can drive a Unidirectional DC Motor with 4 ports or a Bi-Directional DC Motor with 2 ports or a Stepper Motor (Stepper Motors are covered later in this Tutorial).



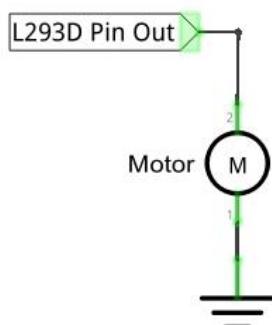
Port description of L293D module is as follows:

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

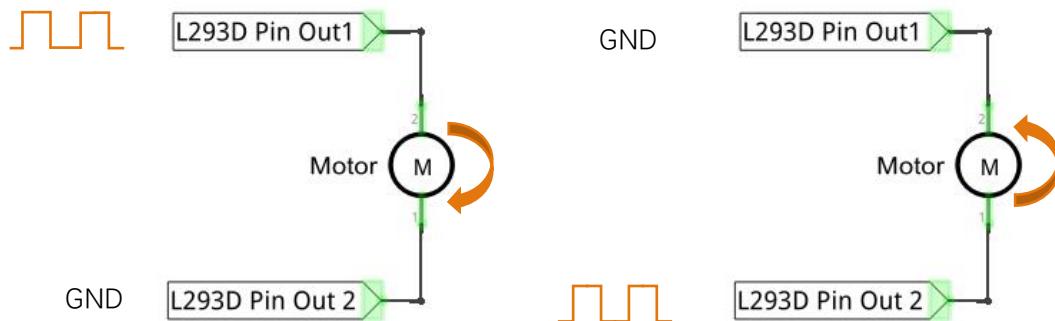
For more details, please refer to the datasheet for this IC Chip.

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

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

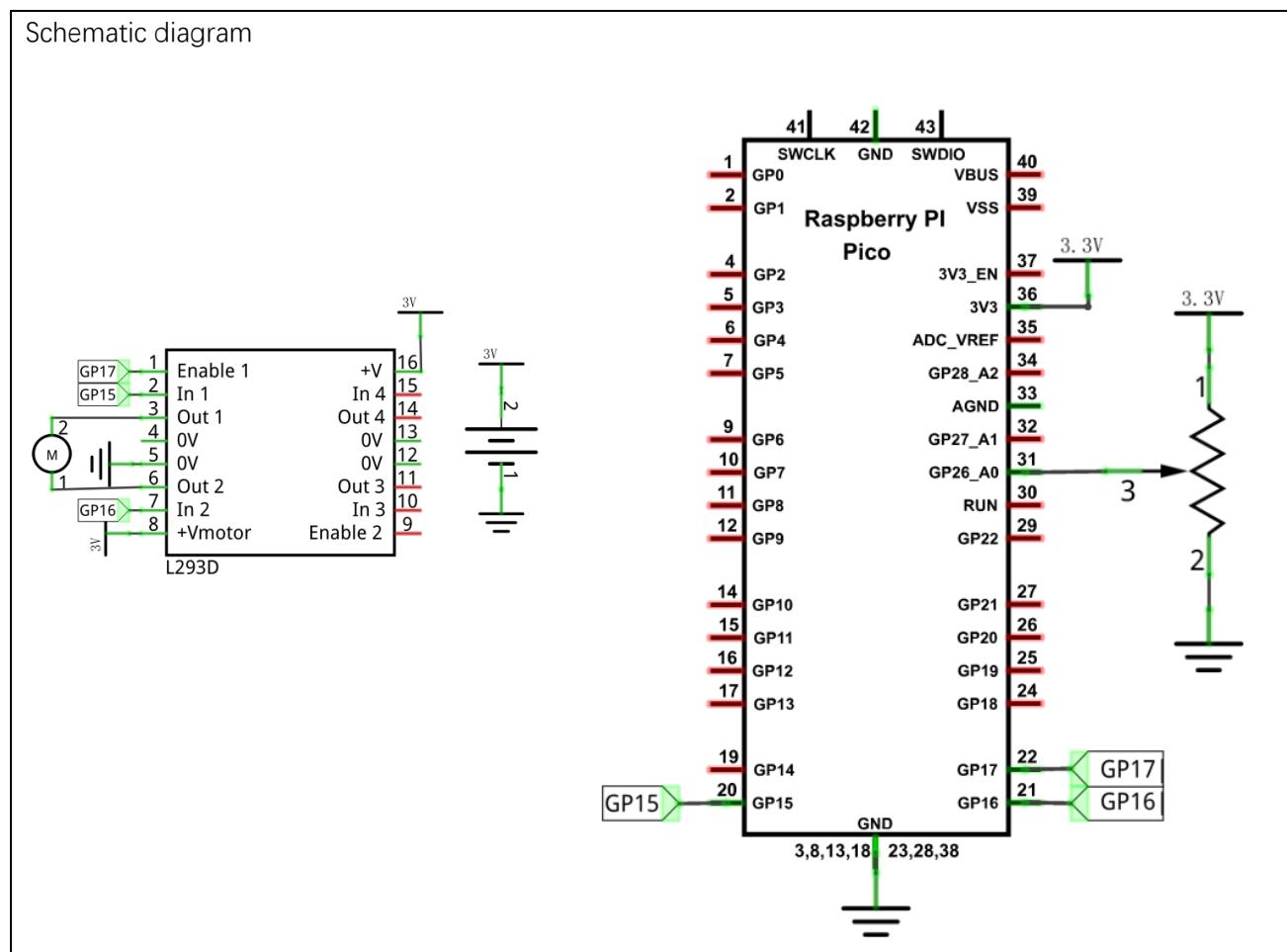


The following connection uses two channels of the L293D: one channel outputs the PWM wave, and the other channel connects to GND, therefore you can control the speed of the motor. When these two channel signals are exchanged, not only can they control the speed of motor, but also control the direction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

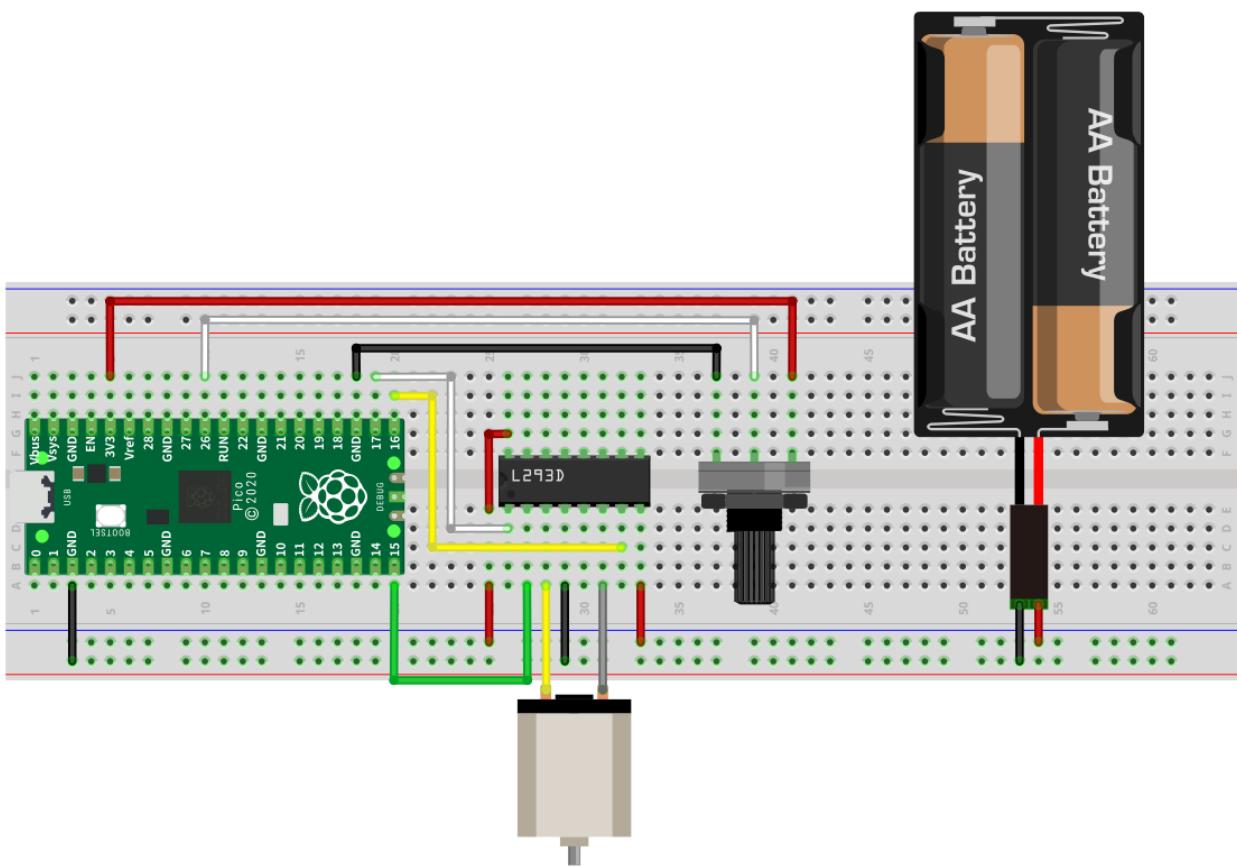


In practical use, the motor is usually connected to channels 1 and 2 by outputting different levels to in1 and in2 to control the rotational direction of the motor, and output to the PWM wave to Enable1 port to control the motor's rotational speed. If the motor is connected to channel 3 and 4 by outputting different levels to in3 and in4 to control the motor's rotation direction, and output to the PWM wave to Enable2 pin to control the motor's rotational speed.

## Circuit



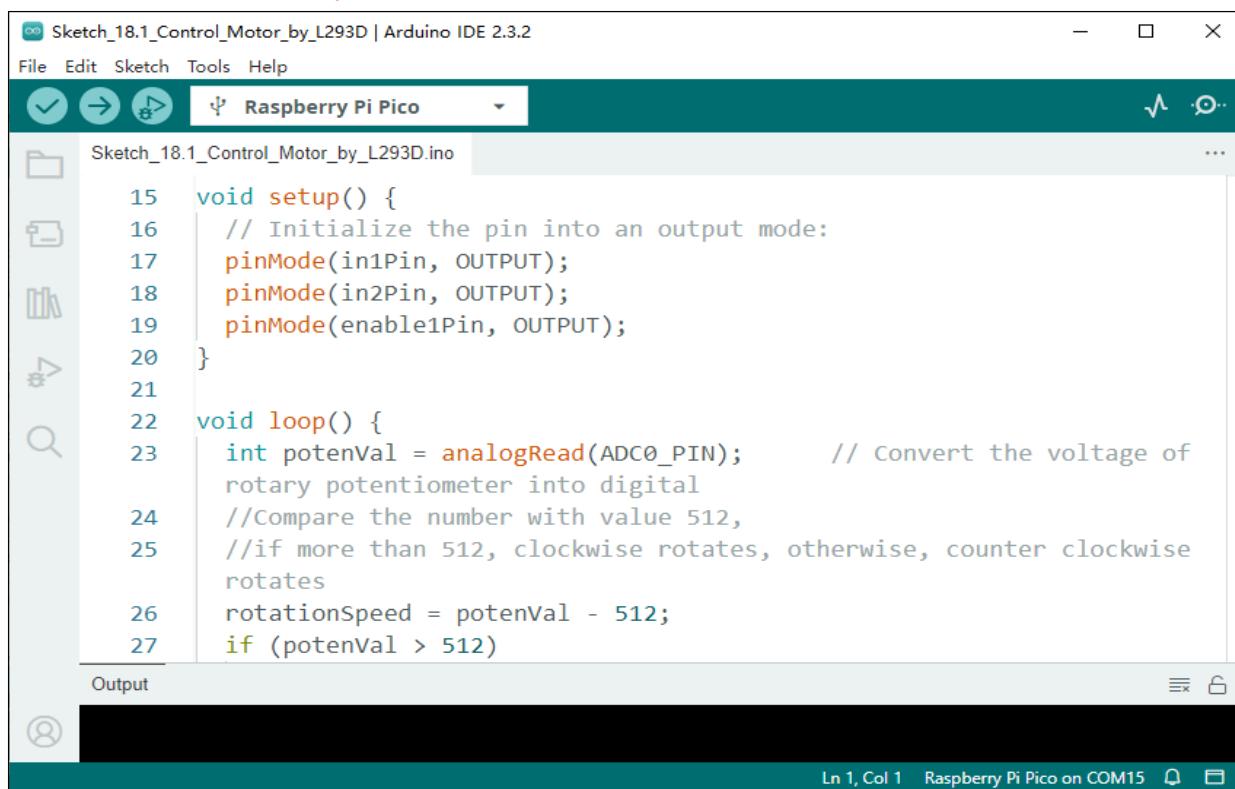
Hardware connection. If you need any support, please free to contact us via: [support@freenove.com](mailto:support@freenove.com)



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

## Sketch

### Sketch\_16.1\_Control\_Motor\_by\_L293D



The screenshot shows the Arduino IDE interface with the sketch `Sketch_16.1_Control_Motor_by_L293D.ino` open. The code is as follows:

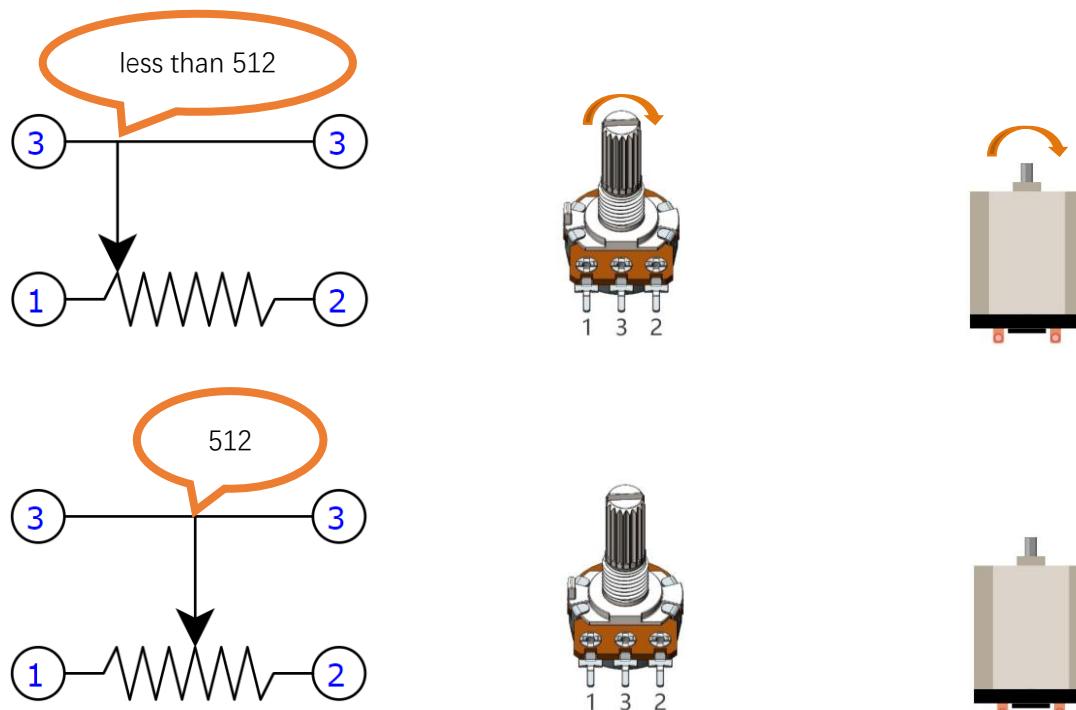
```

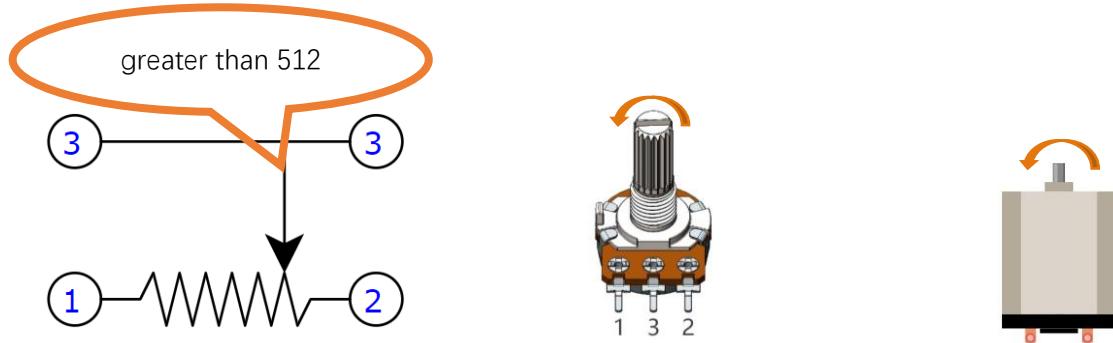
15 void setup() {
16     // Initialize the pin into an output mode:
17     pinMode(in1Pin, OUTPUT);
18     pinMode(in2Pin, OUTPUT);
19     pinMode(enable1Pin, OUTPUT);
20 }
21
22 void loop() {
23     int potenVal = analogRead(ADC0_PIN);      // Convert the voltage of
                                                 // rotary potentiometer into digital
24     //Compare the number with value 512,
25     //if more than 512, clockwise rotates, otherwise, counter clockwise
     //rotates
26     rotationSpeed = potenVal - 512;
27     if (potenVal > 512)

```

The code initializes three pins as outputs and reads the value from an analog pin (ADC0\_PIN). It then compares this value to 512 to determine the rotation direction of the motor.

Download code to Pico, rotate the potentiometer in one direction, and the motor speeds up slowly in one direction. Then rotate the potentiometer in the other direction and the motor will slow down to stop. Then rotate it in an inverse direction to accelerate the motor.





The following is the sketch:

```

1 int in1Pin = 15;           // Define L293D channel 1 pin
2 int in2Pin = 16;           // Define L293D channel 2 pin
3 int enable1Pin = 17;       // Define L293D enable 1 pin
4 int ADC0_PIN = 26;

5
6 boolean rotationDir;      // Define a variable to save the motor's rotation direction
7 int rotationSpeed;         // Define a variable to save the motor rotation speed
8
9 void setup() {
10    // Initialize the pin into an output mode:
11    pinMode(in1Pin, OUTPUT);
12    pinMode(in2Pin, OUTPUT);
13    pinMode(enable1Pin, OUTPUT);
14 }
15
16 void loop() {
17    int potenVal = analogRead(ADC0_PIN);      // Convert the voltage of rotary potentiometer
into digital
18    //Compare the number with value 512,
19    //if more than 512, clockwise rotates, otherwise, counter clockwise rotates
20    rotationSpeed = potenVal - 512;
21    if (potenVal > 512)
22        rotationDir = true;
23    else
24        rotationDir = false;
25    // Calculate the motor speed
26    rotationSpeed = abs(potenVal - 512);
27    //Control the steering and speed of the motor
28    driveMotor(rotationDir, constrain(rotationSpeed, 0, 512));
29 }
30
31 void driveMotor(boolean dir, int spd) {
32    // Control motor rotation direction

```

```

33   if (dir) {
34     digitalWrite(in1Pin, HIGH);
35     digitalWrite(in2Pin, LOW);
36   }
37   else {
38     digitalWrite(in1Pin, LOW);
39     digitalWrite(in2Pin, HIGH);
40   }
41   // Control motor rotation speed
42   analogWrite(enable1Pin, spd);
43 }
```

The ADC of Pico has a 10-bit accuracy, corresponding to a range from 0 to 1023. In this program, set the number 512 as the midpoint. If the value of ADC is less than 512, make the motor rotate in one direction. If the value of ADC is greater than 512, make the motor rotate in the other direction. Subtract 512 from the ADC value and take the absolute value and use this result as the speed of the motor.

```

17   int potenVal = analogRead(ADC0_PIN);      // Convert the voltage of rotary potentiometer
into digital
18   //Compare the number with value 512,
19   //if more than 512, clockwise rotates, otherwise, counter clockwise rotates
20   rotationSpeed = potenVal - 512;
21   if (potenVal > 512)
22     rotationDir = true;
23   else
24     rotationDir = false;
25   // Calculate the motor speed
26   rotationSpeed = abs(potenVal - 512);
27   //Control the steering and speed of the motor
28   driveMotor(rotationDir, constrain(rotationSpeed, 0, 512));
```

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

```

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

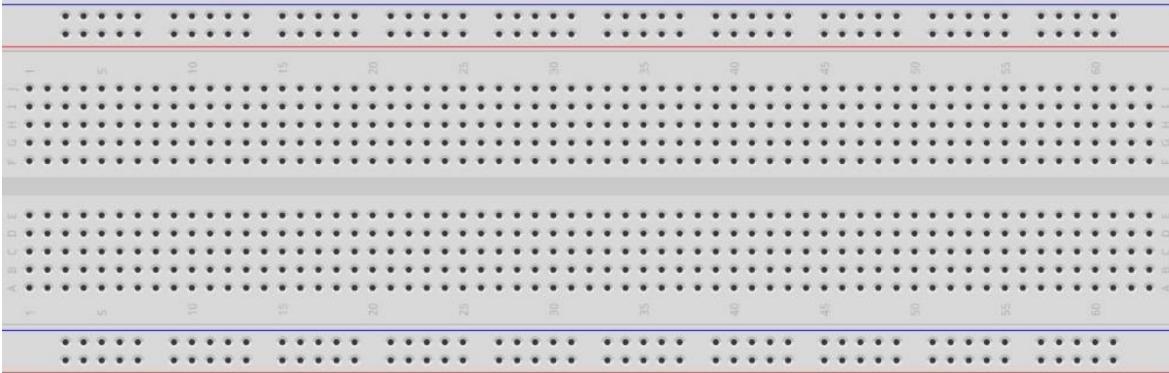
# Chapter 17 Servo

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

## Project 17.1 Servo Sweep

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

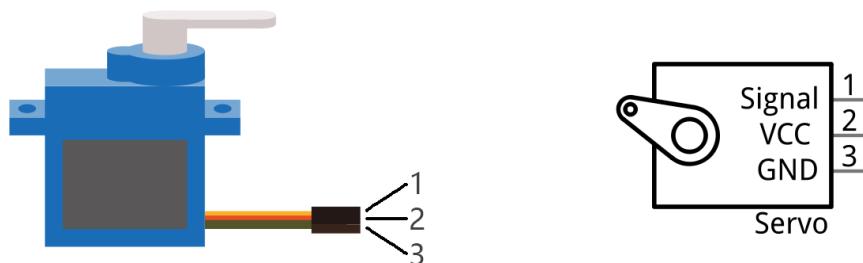
### Component List

Raspberry Pi Pico x1	USB cable x1
 A green printed circuit board (PCB) for the Raspberry Pi Pico. It features a central Broadcom SoC, a USB Type-C port, and several pins labeled with letters A through J and numbers 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, and 60.	 A standard black USB cable with two ends, each featuring a black plastic housing and a metal connector.
Breadboard x1	 A grey breadboard with four vertical columns of 40 numbered holes (5 to 60) and horizontal rows of 10 numbered holes (A to J). The central vertical column is labeled with numbers 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, and 60.
Servo x1	Jumper

## Component Knowledge

### Servo

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



We will use a 50Hz PWM signal with a duty cycle in a certain range to drive the Servo. The time interval of 0.5ms-2.5ms of PWM single cycle high level corresponds to the Servo angle 0 degrees - 180 degrees linearly. Part of the corresponding values are as follows:

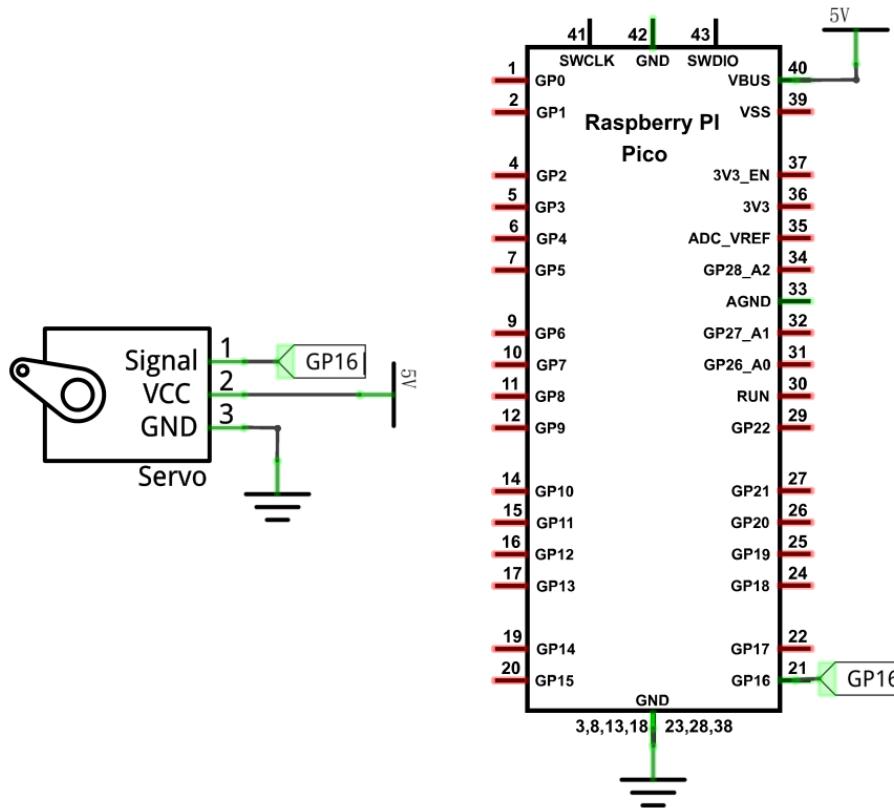
High level time	Servo angle
0.5ms	0 degree
1ms	45 degree
1.5ms	0 degree
2ms	45 degree
2.5ms	180 degree

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

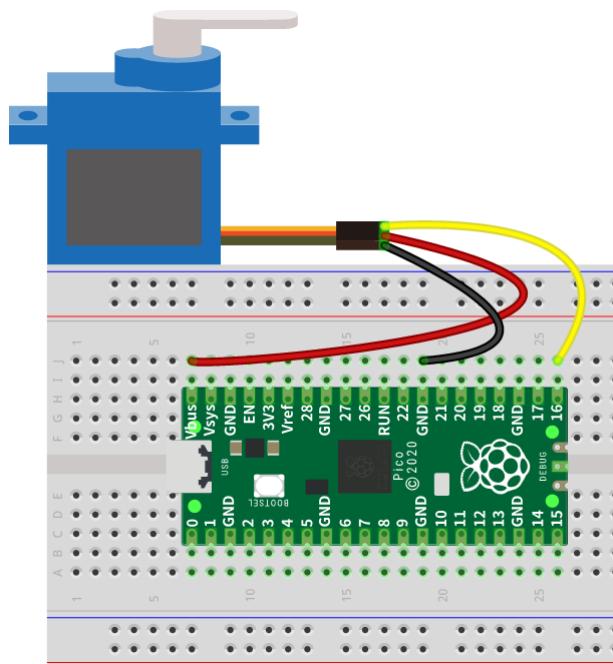
## Circuit

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

Schematic diagram



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



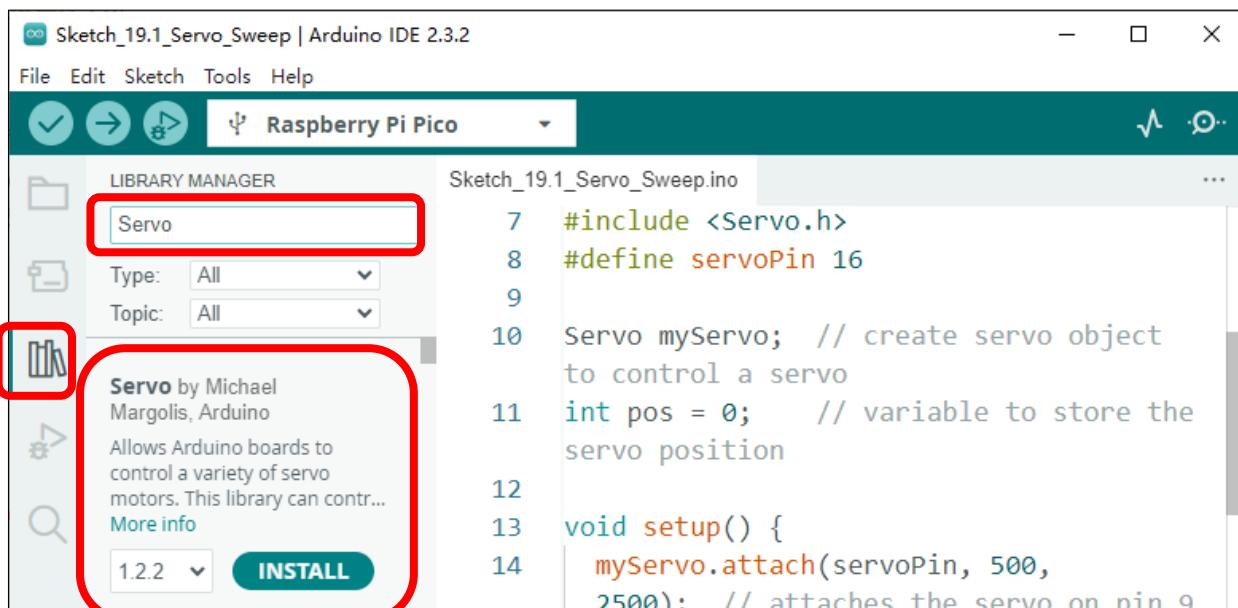
Any concerns? ✉ [support@freenove.com](mailto:support@freenove.com)

## Sketch

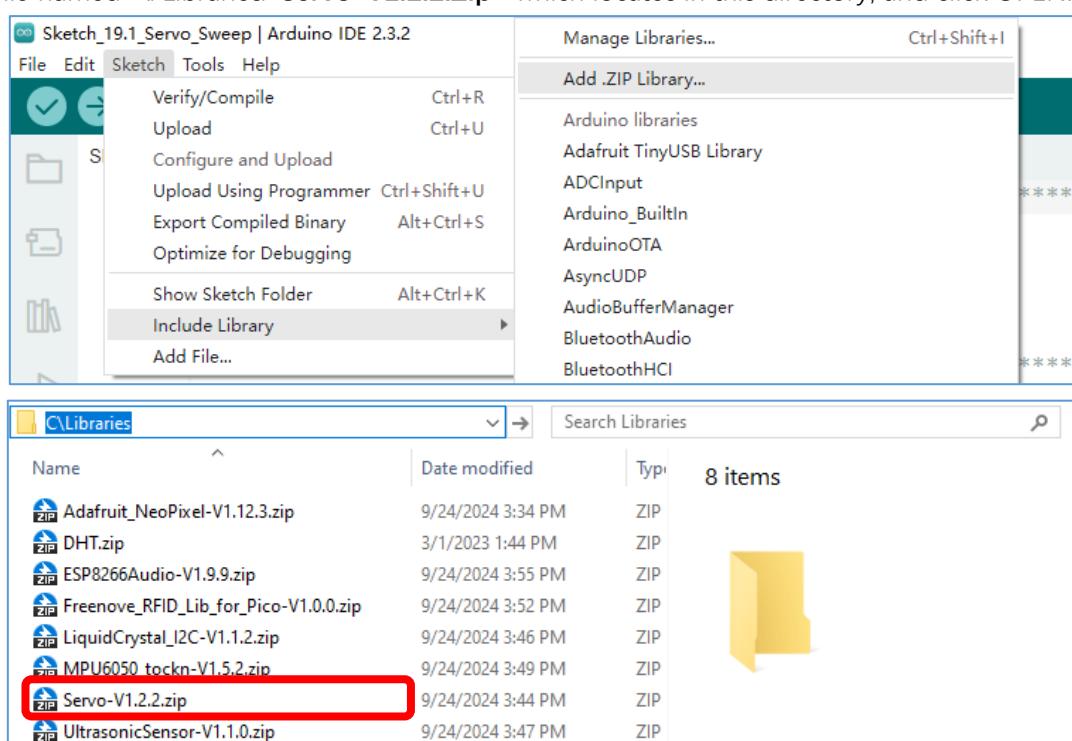
### How to install the library

If you have not installed the Servo library, please do so first.

The first one: Open Arduino IDE, click **Library Manager** on the left, input “Servo” in the search bar, select it to install.



The second way, open Arduino IDE, click Sketch→Include Library→Add .ZIP Library. In the pop-up window, find the file named “./Libraries/ **Servo-V1.2.2.Zip**” which locates in this directory, and click OPEN.



Use the Servo library to control the servomotor and let the servomotor rotate back and forth.

### Sketch\_17.1\_Servo\_Sweep



The screenshot shows the Arduino IDE interface with the sketch `Sketch_17.1_Servo_Sweep.ino` open. The code defines a servo object and sets it to rotate from 0 to 180 degrees in 1-degree steps, then reverse direction. The code is as follows:

```

1 #include <Servo.h>
2 #define servoPin 16
3
4 Servo myServo; // create servo object to control a servo
5 int pos = 0; // variable to store the servo position
6
7 void setup() {
8     myServo.attach(servoPin, 500, 2500); // attaches the servo on pin 9 to the
9         servo object
10 }
11
12 void loop() {
13     for (pos = 0; pos <= 180; pos += 1) { // goes from 0 degrees to 180 degrees
14         // in steps of 1 degree
15         myServo.write(pos); // tell servo to go to position in
16 }
17 }
```

Compile and upload the code to Pico, the servo will rotate from 0 degrees to 180 degrees and then reverse the direction to make it rotate from 180 degrees to 0 degrees and repeat these actions in an endless loop.



The following is the program code:

```

1 #include <Servo.h>
2 #define servoPin 16
3
4 Servo myServo; // create servo object to control a servo
5 int pos = 0; // variable to store the servo position
6
7 void setup() {
8     myServo.attach(servoPin); // attaches the servo on pin 9 to the servo object
9 }
10
11 void loop() {
12     for (pos = 0; pos <= 180; pos += 1) { // goes from 0 degrees to 180 degrees
13         // in steps of 1 degree
14         myServo.write(pos); // tell servo to go to position in variable 'pos'
15 }
```

```
15    delay(15);           // waits 15 ms for the servo to reach the position
16 }
17 for (pos = 180; pos >= 0; pos -= 1) { // goes from 180 degrees to 0 degrees
18     myServo.write(pos);           // tell servo to go to position in variable 'pos'
19     delay(15);                 // waits 15 ms for the servo to reach the position
20 }
21 }
```

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

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

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

```
4 Servo myServo; // create servo object to control a servo
```

Set the control servo motor pin.

```
8 myServo.attach(servоСPin); // attaches the servo on pin 9 to the servo object
```

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

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

## Reference

### Servo Class

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

**Servo myservo;**

Most other boards can define 12 objects of Servo type, namely, they can control up to 12 servos.

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

**myservo.attach(pin):** Initialize the servo, the parameter is the port connected to servo signal line;

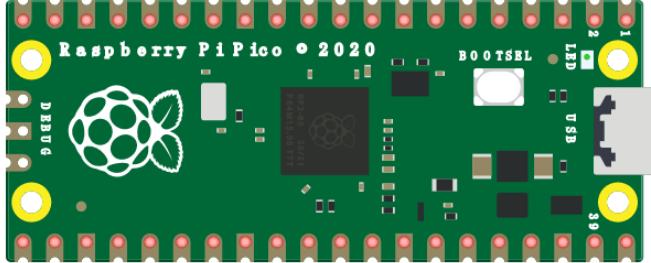
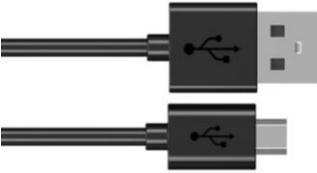
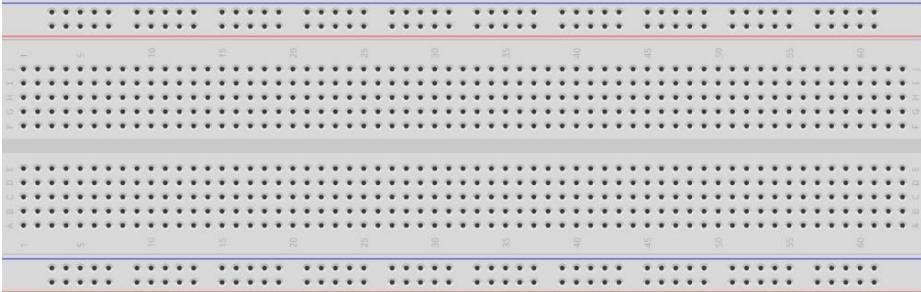
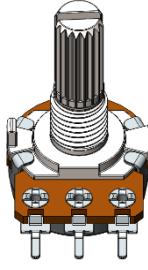
**myservo.write(angle):** Control servo to rotate to the specified angle; parameter here is to specify the angle.



## Project 17.2 Servo Knob

Use a potentiometer to control the servomotor to rotate at any angle.

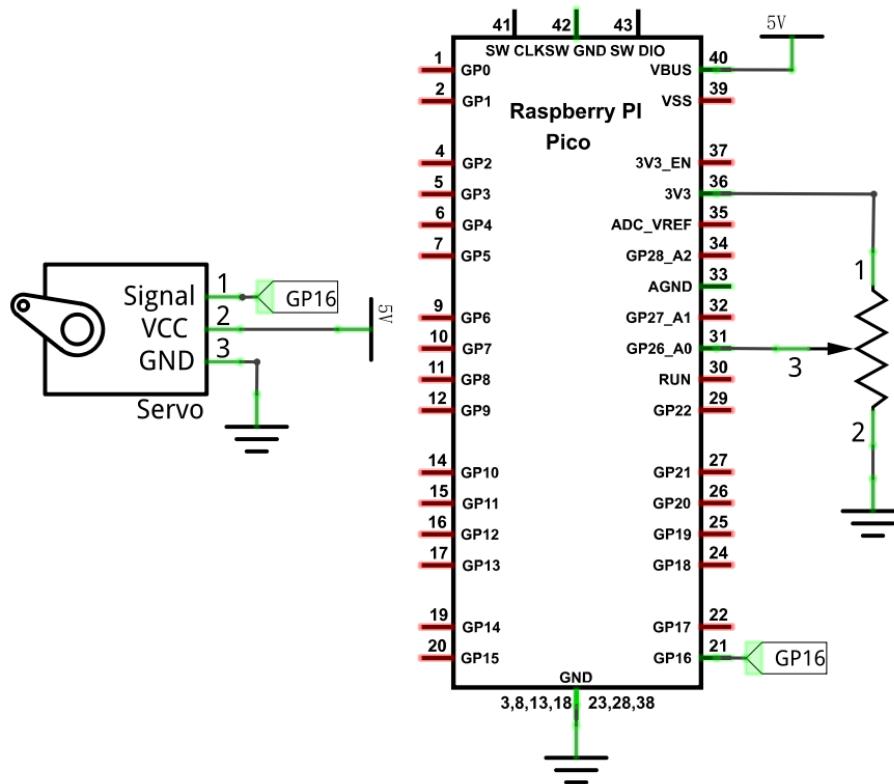
### Component List

Raspberry Pi Pico x1	USB cable x1	
Breadboard x1		
Servo x1	Jumper	Rotary potentiometer x1
		
		

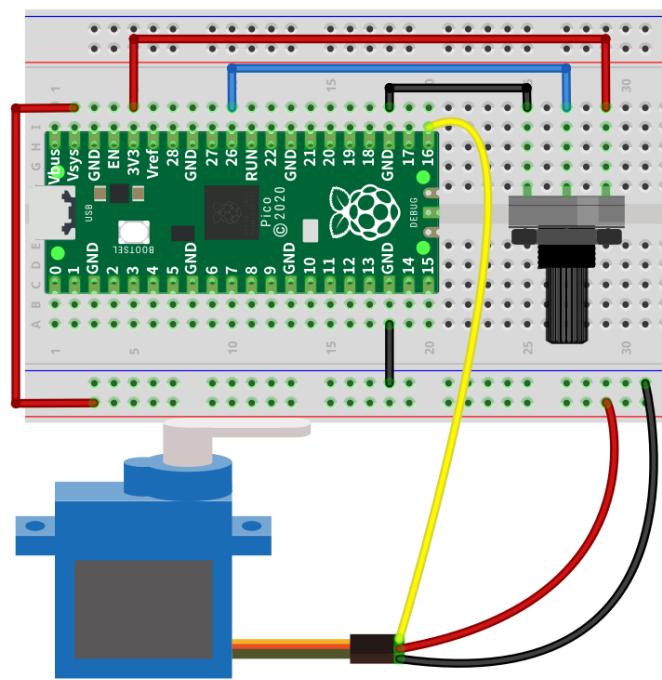
## Circuit

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

Schematic diagram



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



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



## Sketch

### Sketch\_17.2\_Control\_Servo\_by\_Potentiometer

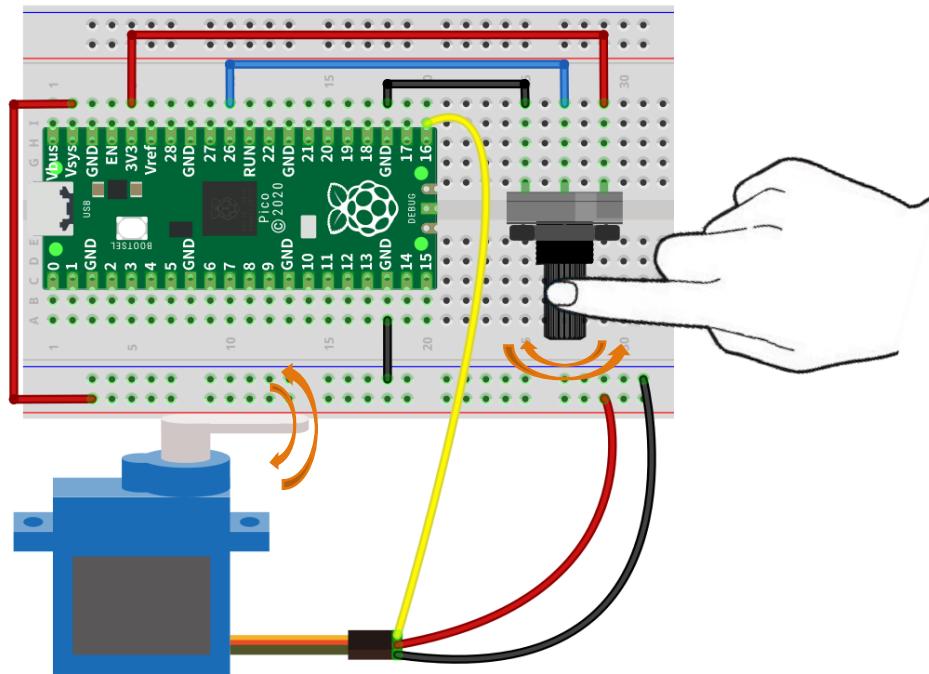
Now, write the code to detect the voltage of rotary potentiometer, and control servo to rotate to a different angle according to that.

```

1 #include <Servo.h>
2
3 #define servoPin 16          // define the pin of servo signal line
4 #define adcPin   26          // analog pin used to connect the potentiometer
5
6 Servo myservo;           // create servo object to control a servo
7 int potVal;              // variable to read the potValue from the analog pin
8
9 void setup() {
10     myservo.attach(servoPin); // attaches the servo on servoPin to the servo object
11 }
12
13 void loop() {
14     potVal = analogRead(adcPin);      // reads the potValue of the potentiometer
15     potVal = map(potVal, 0, 1023, 0, 180); // scale it to use it with the servo
16     myservo.write(potVal);           // sets the servo position
17     delay(15);                   // waits for the servo to get there
18 }
```

In the code, we obtain the ADC value of GP26, and map it to the servo angle.

Verify and upload the code, turn the potentiometer shaft, and then the servo will rotate to a corresponding angle.



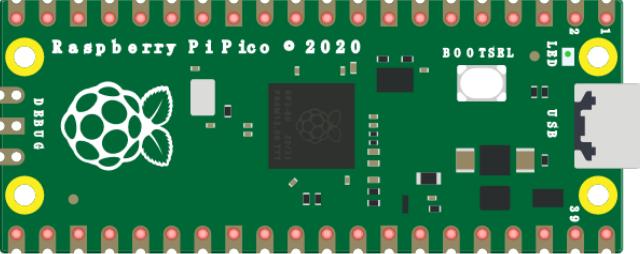
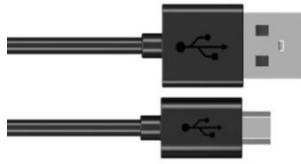
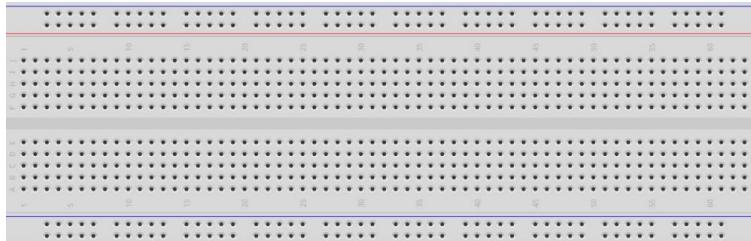
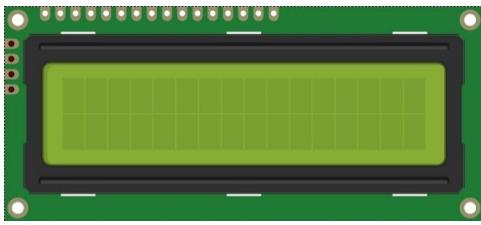
# Chapter 18 LCD1602

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

## Project 18.1 LCD1602

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

### Component List

Raspberry Pi Pico x1		USB cable x1	
Breadboard x1			
LCD1602 Module x1		Jumper	



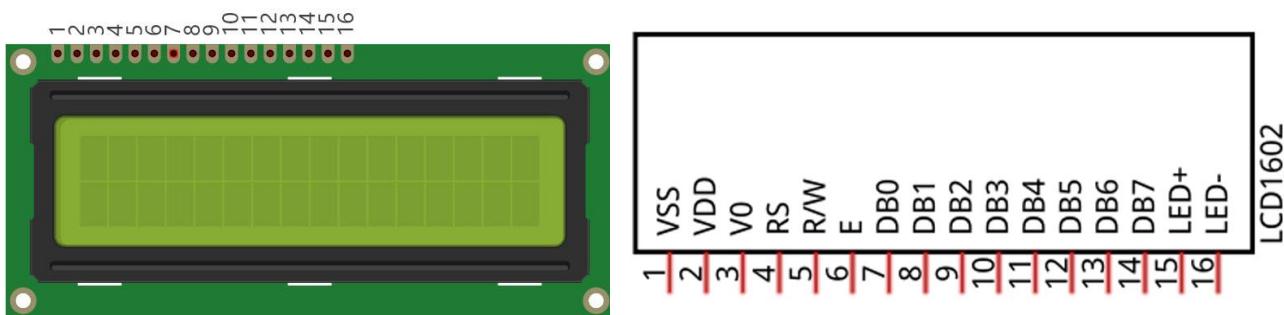
## Component Knowledge

### I2C communication

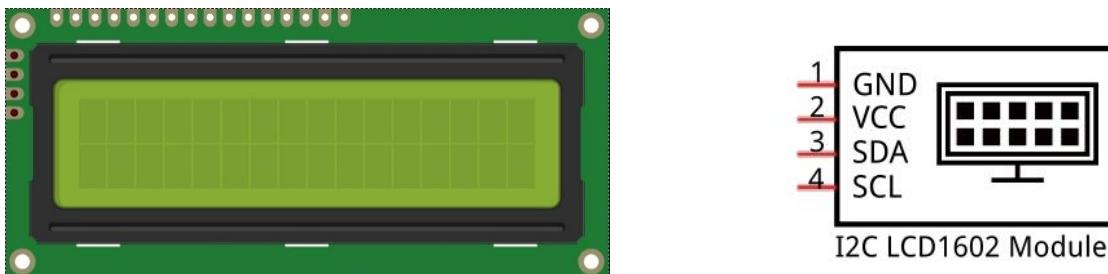
I2C (Inter-Integrated Circuit) is a two-wire serial communication mode, which can be used for the connection of micro controllers and their peripheral equipment. Devices using I2C communication must be connected to the serial data (SDA) line, and serial clock (SCL) line (called I2C bus). Each device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

### LCD1602 communication<sup>\*</sup>

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

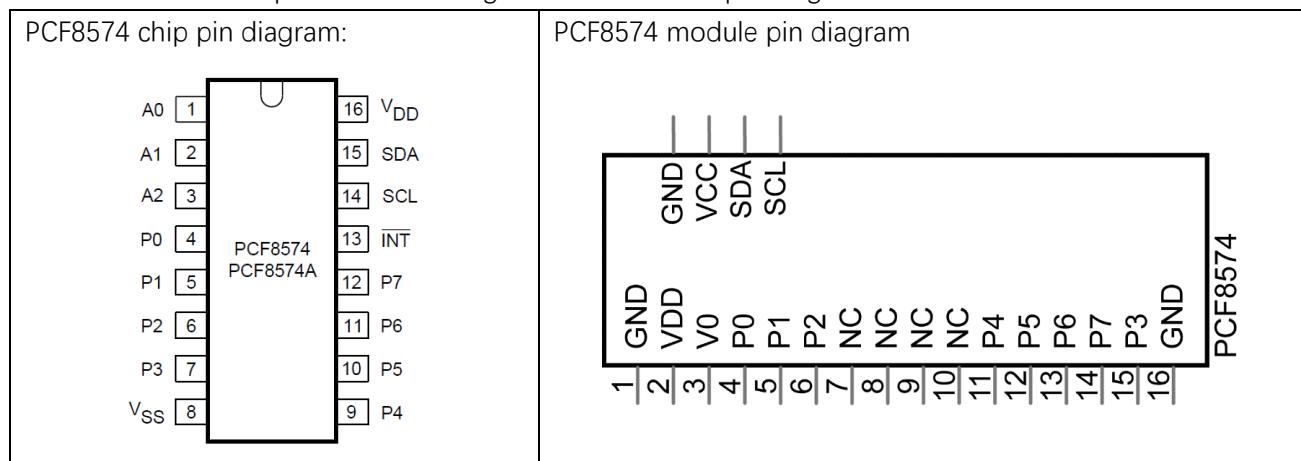


I2C LCD1602 Display Screen integrates an I2C interface, which connects the serial-input & parallel-output module to the LCD1602 Display Screen. This allows us to use only four lines to operate the LCD1602.

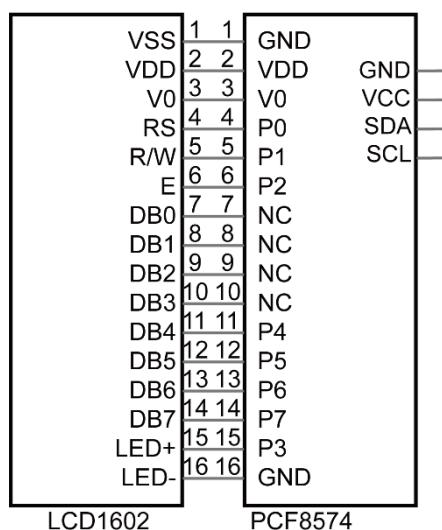


The serial-to-parallel IC chip used in this module is PCF8574T (PCF8574AT), and its default I2C address is 0x27(0x3F).

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



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

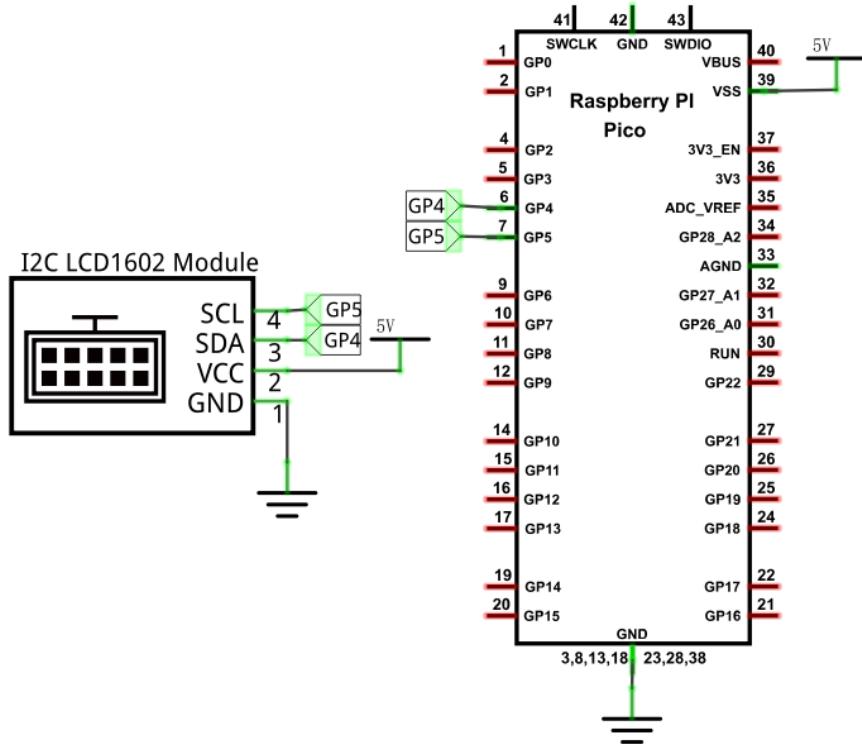


Therefore, we only need four pins to control the 16 pins of the LCD1602 Display Screen through the I2C interface.

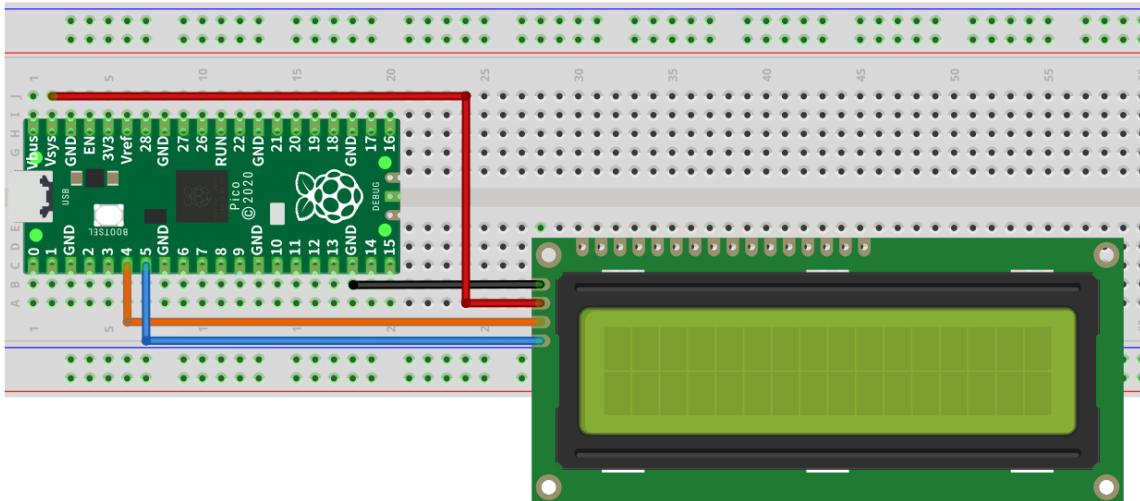
In this project, we will use the I2C LCD1602 to display some static characters and dynamic variables.

## Circuit

Schematic diagram



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

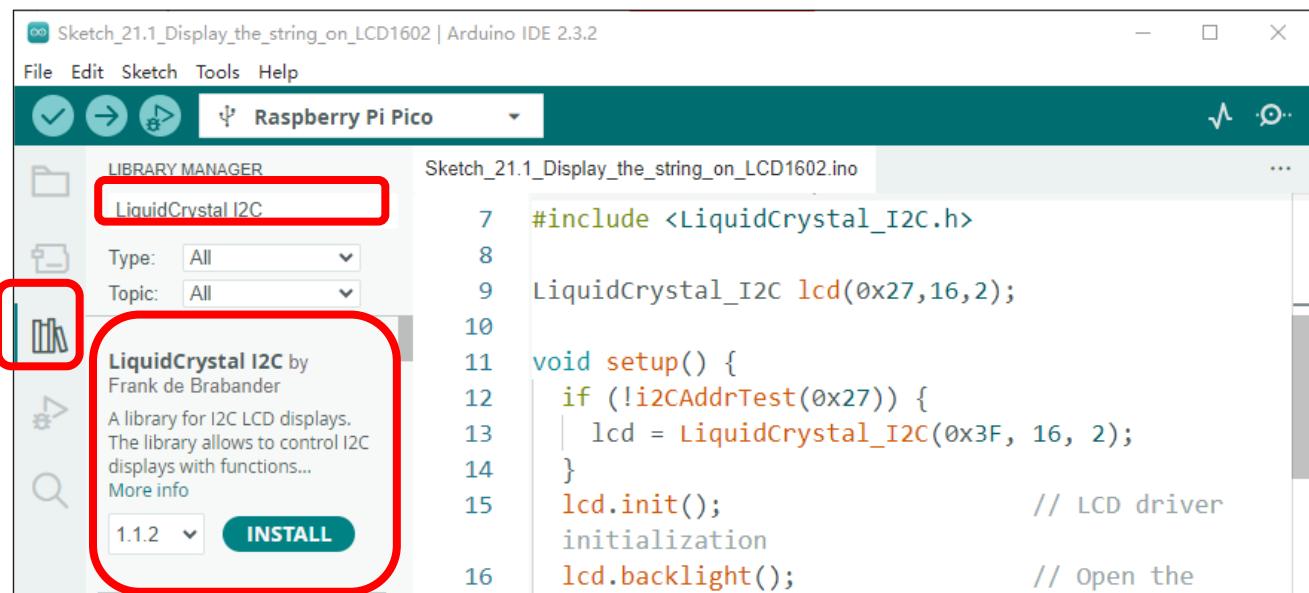


## Sketch

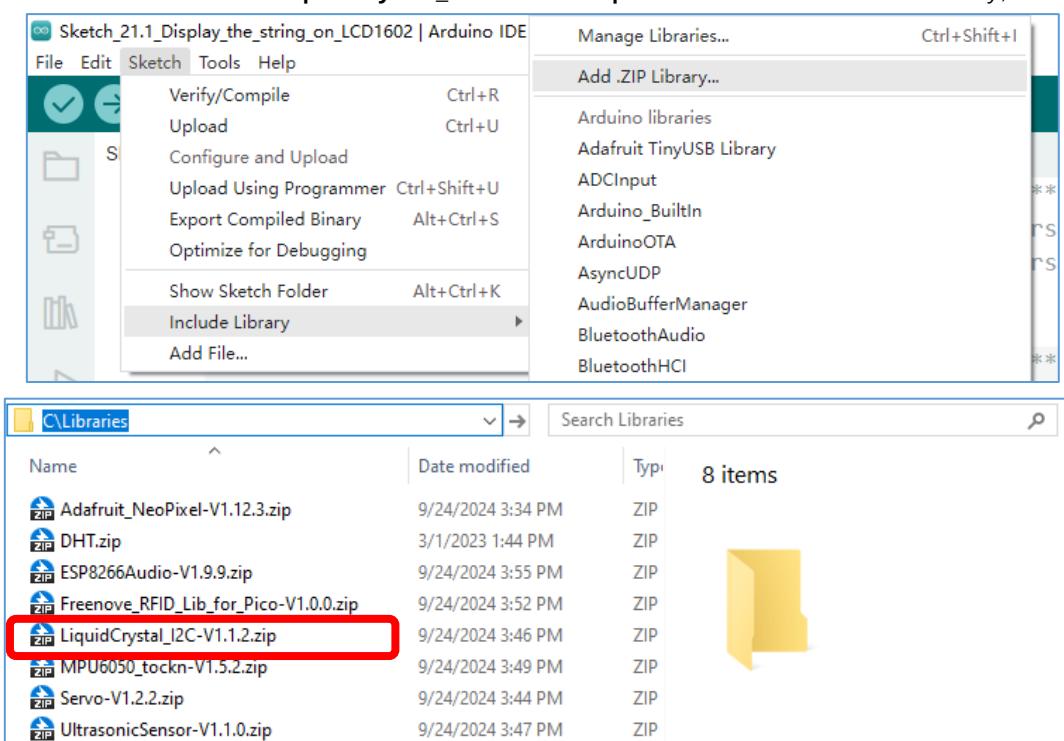
### How to install the library

In this project, we use a third-party library named **LiquidCrystal I2C**. Here are two ways to install the library for your reference.

The first one: Open Arduino IDE; click **Library Manager** on the left, search "LiquidCrystal I2C" to install.

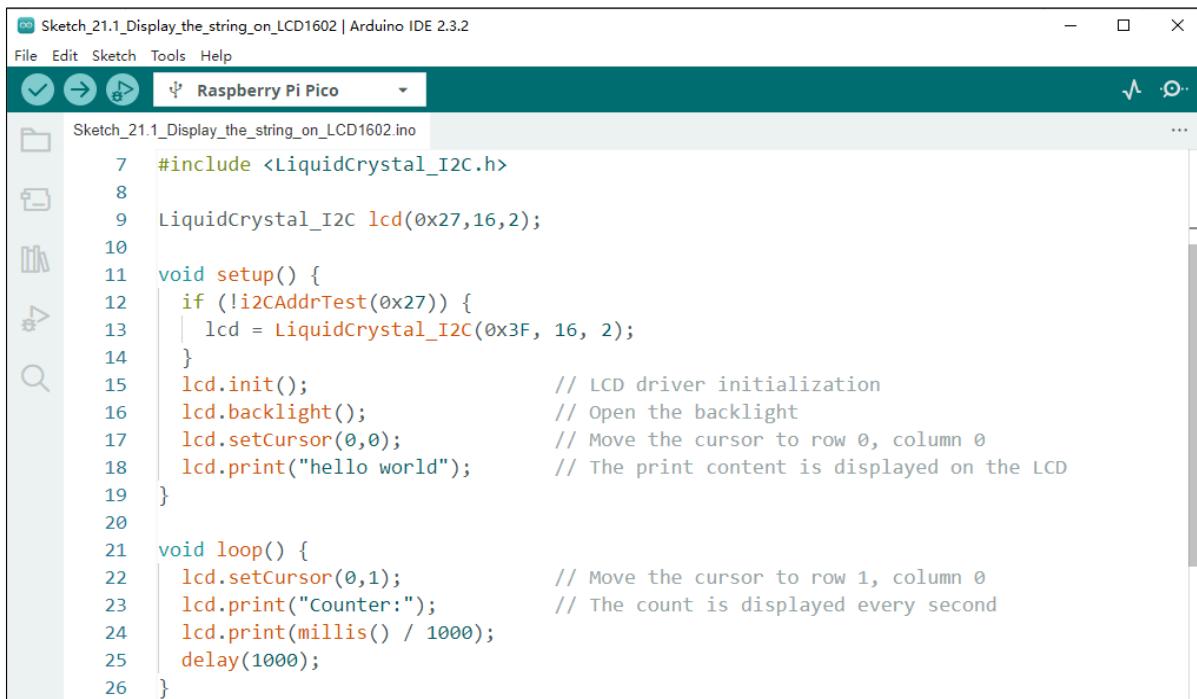


The second way, open Arduino IDE, click Sketch → Include Library → Add .ZIP Library. In the pop-up window, find the file named "../Libraries/ **LiquidCrystal\_I2C-V1.1.2.Zip**" which locates in this directory, and click OPEN.



Use I2C LCD 1602 to display characters and variables.

### Sketch\_18.1\_Display\_the\_string\_on\_LCD1602



```

Sketch_21.1_Display_the_string_on_LCD1602 | Arduino IDE 2.3.2
File Edit Sketch Tools Help
Sketch_21.1_Display_the_string_on_LCD1602.ino
7 #include <LiquidCrystal_I2C.h>
8
9 LiquidCrystal_I2C lcd(0x27, 16, 2);
10
11 void setup() {
12     if (!i2cAddrTest(0x27)) {
13         lcd = LiquidCrystal_I2C(0x3F, 16, 2);
14     }
15     lcd.init(); // LCD driver initialization
16     lcd.backlight(); // Open the backlight
17     lcd.setCursor(0,0); // Move the cursor to row 0, column 0
18     lcd.print("Hello world!"); // The print content is displayed on the LCD
19 }
20
21 void loop() {
22     lcd.setCursor(0,1); // Move the cursor to row 1, column 0
23     lcd.print("Counter:");
24     lcd.print(millis() / 1000);
25     delay(1000);
26 }

```

Compile and upload the code to Pico and the LCD1602 displays characters.

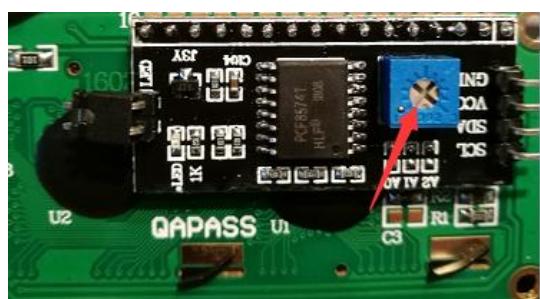


So far, at this writing, we have two types of LCD1602 on sale. One needs to adjust the backlight, and the other does not.

The LCD1602 that does not need to adjust the backlight is shown in the figure below.



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



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

The following is the program code:

```

1 #include <LiquidCrystal_I2C.h>
2
3 LiquidCrystal_I2C lcd(0x27, 16, 2);
4
5 void setup() {
6     if (!i2CAddrTest(0x27)) {
7         lcd = LiquidCrystal_I2C(0x3F, 16, 2);
8     }
9     lcd.init(); // LCD driver initialization
10    lcd.backlight(); // Open the backlight
11    lcd.setCursor(0,0); // Move the cursor to row 0, column 0
12    lcd.print("hello world"); // The print content is displayed on the LCD
13 }
14
15 void loop() {
16     lcd.setCursor(0,1); // Move the cursor to row 1, column 0
17     lcd.print("Counter:");
18     lcd.print(millis() / 1000);
19     delay(1000);
20 }
21
22 bool i2CAddrTest(uint8_t addr) {
23     Wire.begin();
24     Wire.beginTransmission(addr);
25     if (Wire.endTransmission() == 0) {
26         return true;
27     }
28     return false;
29 }
```

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

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

Instantiate the I2C LCD1602 screen. It should be noted here that if your LCD driver chip uses PCF8574T, set the I2C address to 0x27, and if uses PCF8574AT, set the I2C address to 0x3F.

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

Initialize LCD1602 and turn on the backlight of LCD.

```

6     if (!i2CAddrTest(0x27)) {
7         lcd = LiquidCrystal_I2C(0x3F, 16, 2);
8     }
9     lcd.init(); // LCD driver initialization
10    lcd.backlight(); // Turn on the backlight
```

Check whether the I2C address is responded by a device.

```

22 bool i2CAddrTest(uint8_t addr) {
23     Wire.begin();
```

```

24   Wire.beginTransmission(addr);
25   if (Wire.endTransmission() == 0) {
26     return true;
27   }
28   return false;
29 }
```

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

```

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

Print the number on the second line of LCD1602.

```

16 void loop() {
17   lcd.setCursor(0, 1);           // Move the cursor to row 1, column 0
18   lcd.print("Counter:");        // The count is displayed every second
19   lcd.print(millis() / 1000);
20   delay(1000);
21 }
```

#### Reference

##### class LiquidCrystal

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

**LiquidCrystal\_I2C lcd(0x27, 16, 2);**

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

**init();**

Initializes the Lcd1602's device

**backlight();**

Turn on Lcd1602's backlight.

**setCursor(column, row);**

Sets the screen's column and row.

**Column:** The range is 0 to 15.

**Row:** The range is 0 to 1.

**print(String);**

Print the character string on Lcd1602

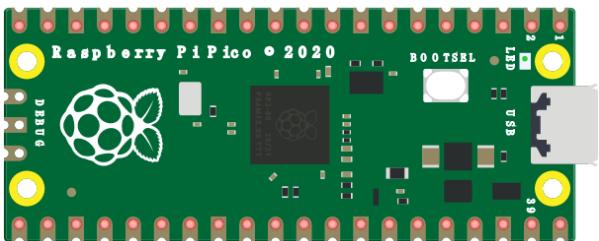
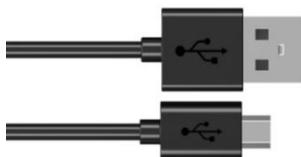
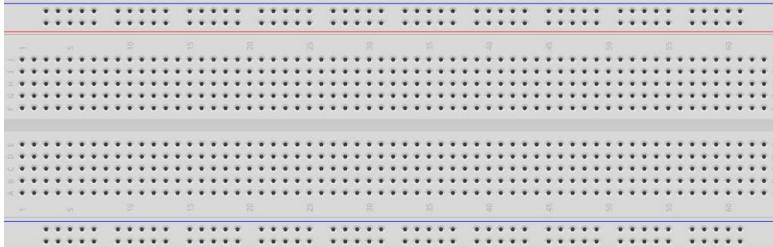
# Chapter 19 Ultrasonic Ranging

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

## Project 19.1 Ultrasonic Ranging

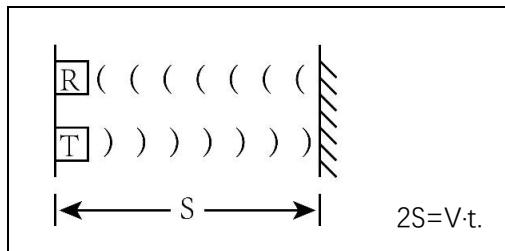
In this project, we use ultrasonic ranging module to measure distance, and print out the data in the terminal.

### Component List

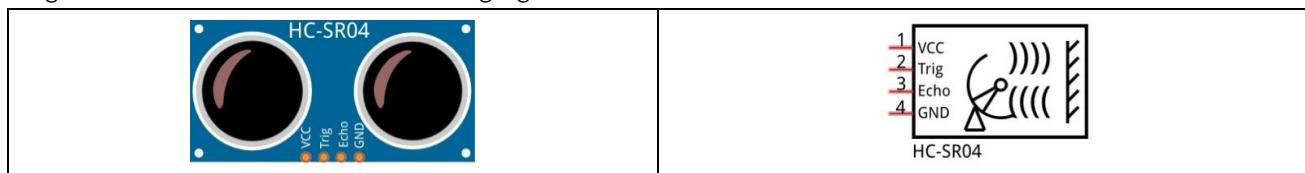
Raspberry Pi Pico x1	USB cable x1
	
Breadboard x1	
Jumper	HC SR04 x1

## Component Knowledge

The Ultrasonic Ranging Module uses the principle that ultrasonic waves will reflect when they encounter any obstacles. This is possible by counting the time interval between when the ultrasonic wave is transmitted to when the ultrasonic wave reflects back after encountering an obstacle. Time interval counting will end after an ultrasonic wave is received, and the time difference (delta) is the total time of the ultrasonic wave's journey from being transmitted to being received. Because the speed of sound in air is a constant, and is about  $v=340\text{m/s}$ , we can calculate the distance between the Ultrasonic Ranging Module and the obstacle:  $s=vt/2$ .



The HC-SR04 Ultrasonic Ranging Module integrates both an ultrasonic transmitter and a receiver. The transmitter is used to convert electrical signals (electrical energy) into high frequency (beyond human hearing) sound waves (mechanical energy) and the function of the receiver is opposite of this. The picture and the diagram of the HC SR04 Ultrasonic Ranging Module are shown below:



Pin description:

Pin	Description
VCC	power supply pin
Trig	trigger pin
Echo	Echo pin
GND	GND

### Technical specs:

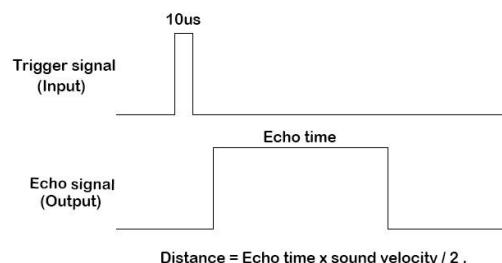
Working voltage: 5V

Working current: 12mA

Minimum measured distance: 2cm

Maximum measured distance: 200cm

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

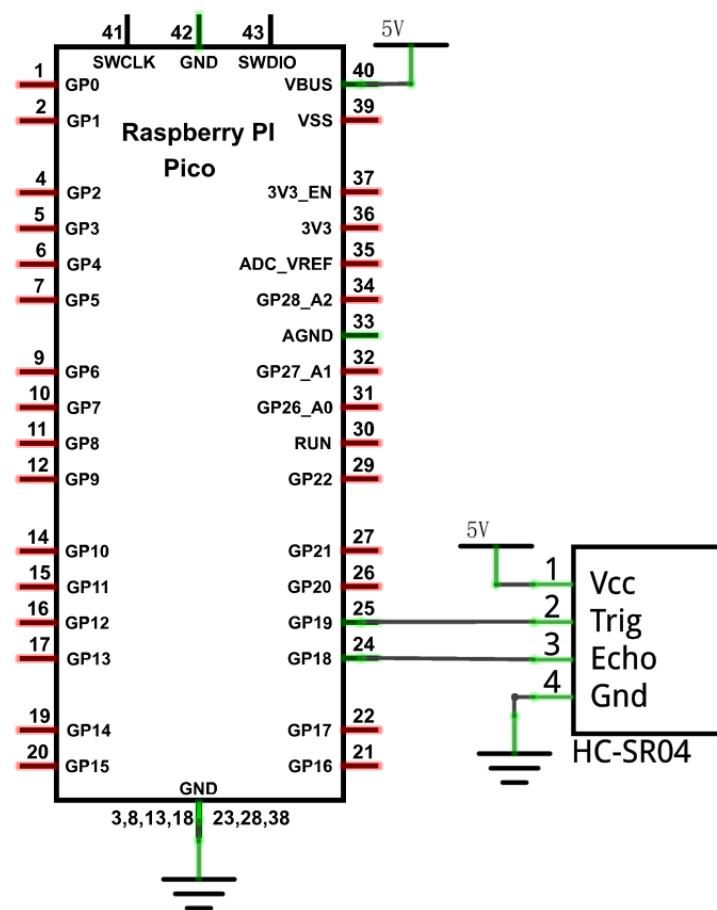


Any concerns? ✉ support@freenove.com

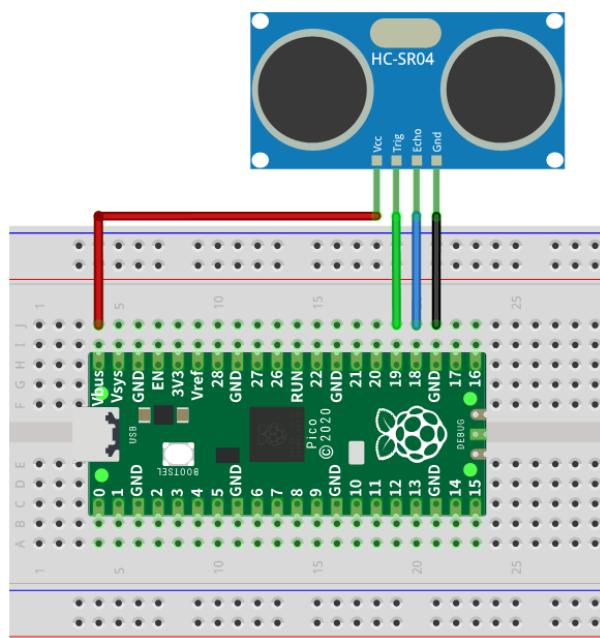
## Circuit

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

Schematic diagram



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



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



## Sketch

### Sketch\_19.1\_Ultrasonic\_Ranging

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

- Title Bar:** Sketch\_22.1\_Ultrasonic\_Ranging | Arduino IDE 2.3.2
- Menu Bar:** File Edit Sketch Tools Help
- Toolbar:** Includes icons for Save, Run, Stop, and others.
- Sketch Selection:** Raspberry Pi Pico
- Code Area:** Displays the following C++ code for ultrasonic ranging:

```

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

```

Download the code to Pico, open the serial monitor, set the baud rate to 115200, and you can use it to measure the distance between the ultrasonic module and the object, as shown in the following picture:



The following is the program code:

```

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

```

32     return distance; // return the distance value
33 }
```

First, define the pins and the maximum measurement distance.

```

1 #define trigPin 19 // define trigPin
2 #define echoPin 18 // define echoPin.
3 #define MAX_DISTANCE 700      //define the maximum measured distance
```

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

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

Subfunction getSonar () function is used to start the ultrasonic module to begin measuring, and return the measured distance in cm units. In this function, first let trigPin send 10us high level to start the ultrasonic module. Then use pulseIn () to read the ultrasonic module and return the duration time of high level. Finally, the measured distance according to the time is calculated.

```

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

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

```

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

About function `pulseIn()`:

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

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

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

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

Project 19.2 Ultrasonic Ranging

## Component List and Circuit

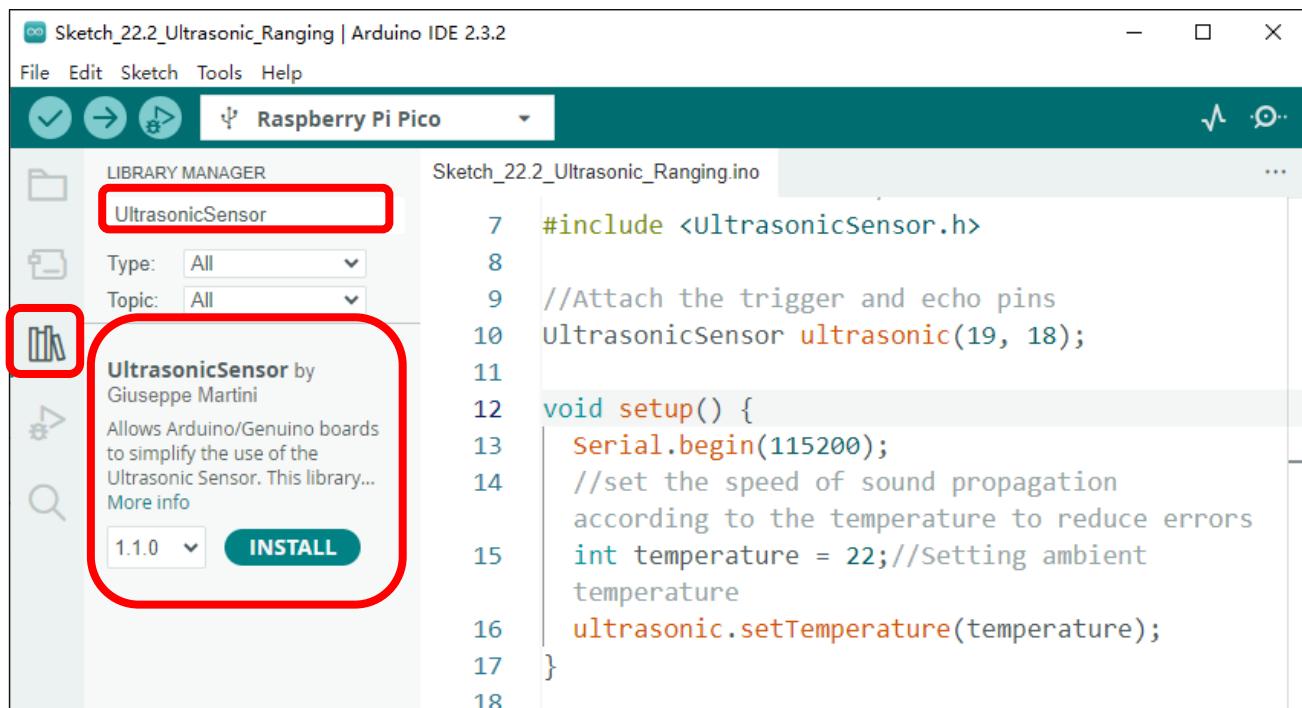
Component List and Circuit are the same as the previous section.

# Sketch

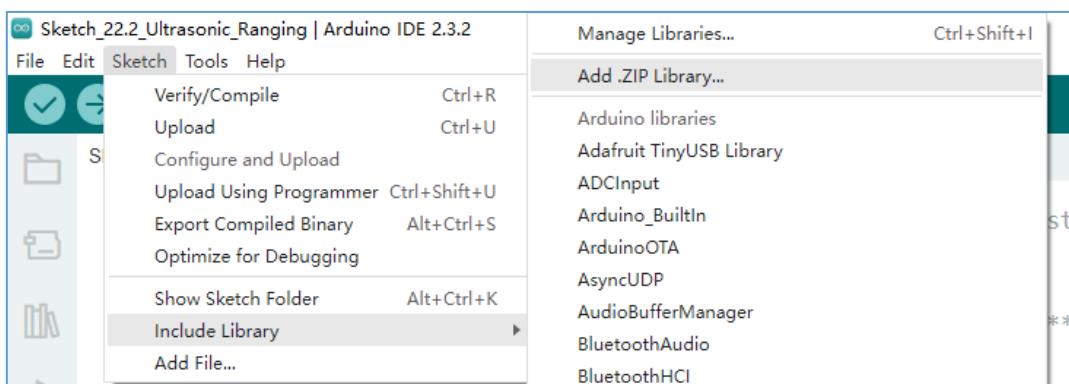
## How to install the library

In this project, we use a third-party library named **UltrasonicSensor**. Here are two ways to install the library for your reference.

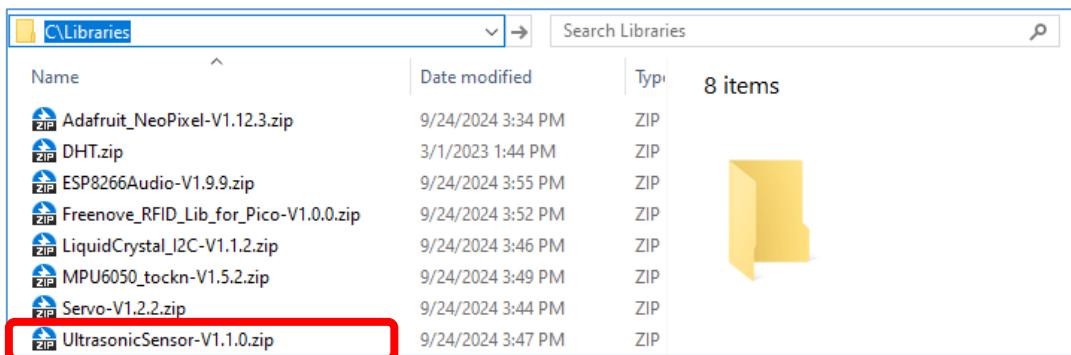
The first one: Open Arduino IDE, click **Library Manage** on the left, and search "**UltrasonicSensor**" to install.



The second way, open Arduino IDE, click Sketch→Include Library→Add .ZIP Library. In the pop-up window, find the file named “./Libraries/ **UltrasonicSensor-V1.1.0.Zip**” which locates in this directory, and click OPEN.



Any concerns?  support@freenove.com



## Sketch\_19.2\_Ultrasonic\_Ranging

The screenshot shows the Arduino IDE interface with the title bar "Sketch\_22.2\_Ultrasonic\_Ranging | Arduino IDE 2.3.2". The central code editor window displays the following C++ code:

```

7 #include <UltrasonicSensor.h>
8
9 //Attach the trigger and echo pins
10 ultrasonicSensor ultrasonic(19, 18);
11
12 void setup() {
13     Serial.begin(115200);
14     //set the speed of sound propagation according to the temperature to
15     //reduce errors
16     int temperature = 22;//Setting ambient temperature
17     ultrasonic.setTemperature(temperature);
18 }
19
20 void loop() {
21     int distance = ultrasonic.distanceInCentimeters();
22     Serial.println(String("Distance: ")+distance+String("cm"));
23     delay(300);
}

```

Upload the sketch to Pico, open the serial monitor and set the baud rate to 115200. Use the ultrasonic module to measure distance, as shown in the following picture:

The screenshot shows the Serial Monitor window with the title bar "Output Serial Monitor". The message area displays a series of distance measurements:

```

08:41:36.524 -> Distance: 34cm
08:41:36.813 -> Distance: 34cm
08:41:37.122 -> Distance: 34cm
08:41:37.421 -> Distance: 34cm
08:41:37.716 -> Distance: 35cm
08:41:38.003 -> Distance: 36cm
08:41:38.308 -> Distance: 38cm
08:41:38.630 -> Distance: 34cm
08:41:38.950 -> Distance: 35cm
08:41:39.238 -> Distance: 34cm
08:41:39.543 -> Distance: 34cm
08:41:39.830 -> Distance: 34cm
08:41:40.151 -> Distance: 33cm
08:41:40.456 -> Distance: 34cm

```

The status bar at the bottom shows "indexing: 9/44", "Ln 12, Col 15", "Raspberry Pi Pico on COM15", and "4 3".



The following is the program code:

```

1 #include <UltrasonicSensor.h>
2
3 //Attach the trigger and echo pins
4 UltrasonicSensor ultrasonic(19, 18);
5
6 void setup() {
7     Serial.begin(115200);
8     //set the speed of sound propagation according to the temperature to reduce errors
9     int temperature = 22; //Setting ambient temperature
10    ultrasonic.setTemperature(temperature);
11 }
12
13 void loop() {
14     int distance = ultrasonic.distanceInCentimeters();
15     Serial.print(String("Distance: ")+distance+String("cm\n"));
16     delay(300);
17 }
```

First, add UltrasonicSensor library.

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

Define an ultrasonic object and associate it with the pins.

```
4 UltrasonicSensor ultrasonic(19, 18);
```

Set the ambient temperature to make the module measure more accurately.

```
10 ultrasonic.setTemperature(temperature);
```

Use the distanceInCentimeters function to get the distance measured by the ultrasound and print it out through the serial port.

```

13 void loop() {
14     int distance = ultrasonic.distanceInCentimeters();
15     Serial.print(String("Distance: ")+distance+String("cm\n"));
16     delay(300);
17 }
```

#### Reference

##### **class UltrasonicSensor**

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

**UltrasonicSensor ultrasonic(19, 18);**

**setTemperature(value):** The speed of sound propagation is different at different temperatures. In order to get more accurate data, this function needs to be called. **value** is the temperature value of the current environment.

**distanceInCentimeters():** The ultrasonic distance acquisition function returns the value in centimeters.

**distanceInMillimeters():** The ultrasonic distance acquisition function returns the value in millimeter.

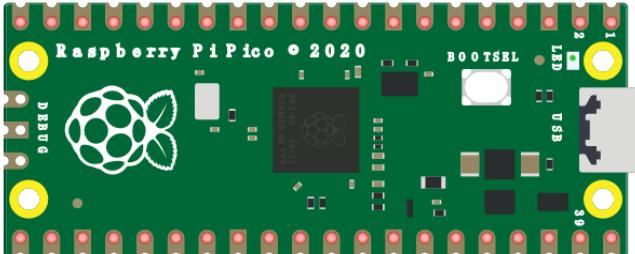
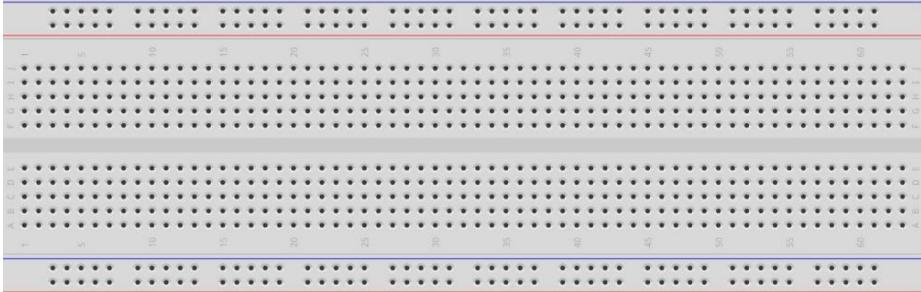
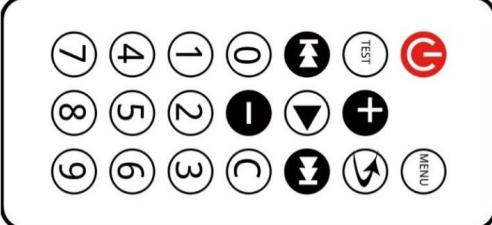
# Chapter 20 Infrared Remote

In this chapter, we will learn how to use an infrared remote control, and control an LED.

## Project 20.1 Infrared Remote Control

First, we need to understand how infrared remote control works, then get the command sent from infrared remote control.

### Component List

Raspberry Pi Pico x1		USB cable x1
Breadboard x1		
Jumper		Infrared Remote x1 (May need CR2025 battery x1, please check the holder)
Infrared Remote x1		Resistor 10kΩ x1
		



## Component Knowledge

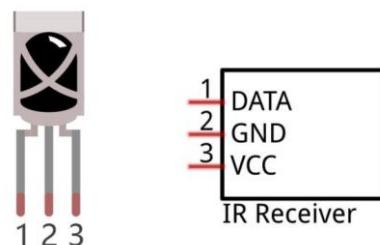
### Infrared Remote

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



### Infrared receiver

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



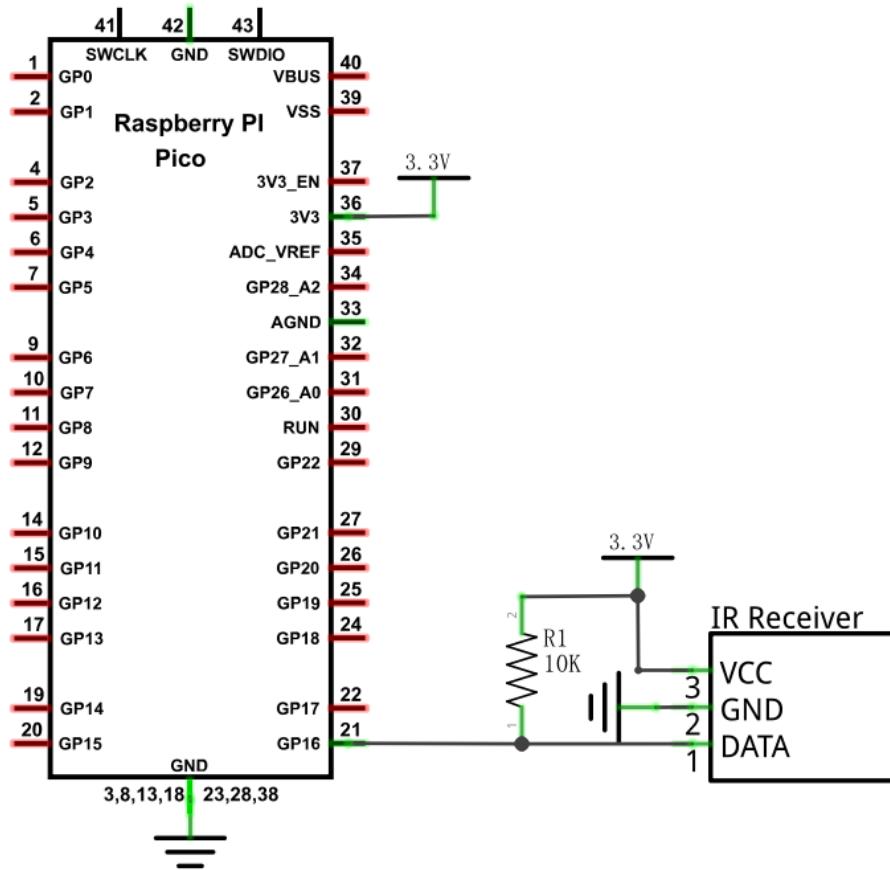
When you use the infrared remote control, it sends a key value to the receiving circuit according to the pressed key. We can program the Raspberry Pi Pico to do things like lighting, when a key value is received.

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

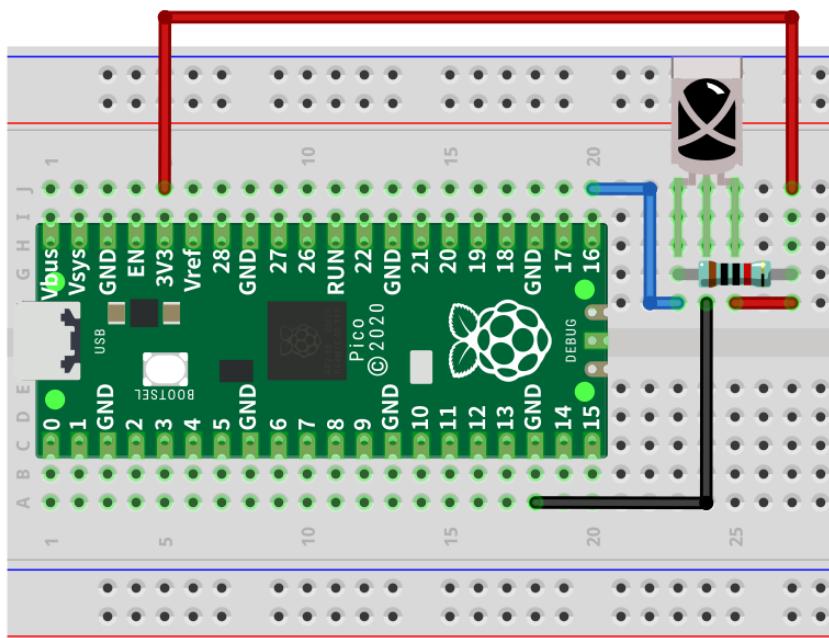
ICON	KEY Value	ICON	KEY Value
	FFA25D		FFB04F
	FFE21D		FF30CF
	FF22DD		FF18E7
	FF02FD		FF7A85
	FFC23D		FF10EF
	FFE01F		FF38C7
	FFA857		FF5AA5
	FF906F		FF42BD
	FF6897		FF4AB5
	FF9867		FF52AD

## Circuit

Schematic diagram



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

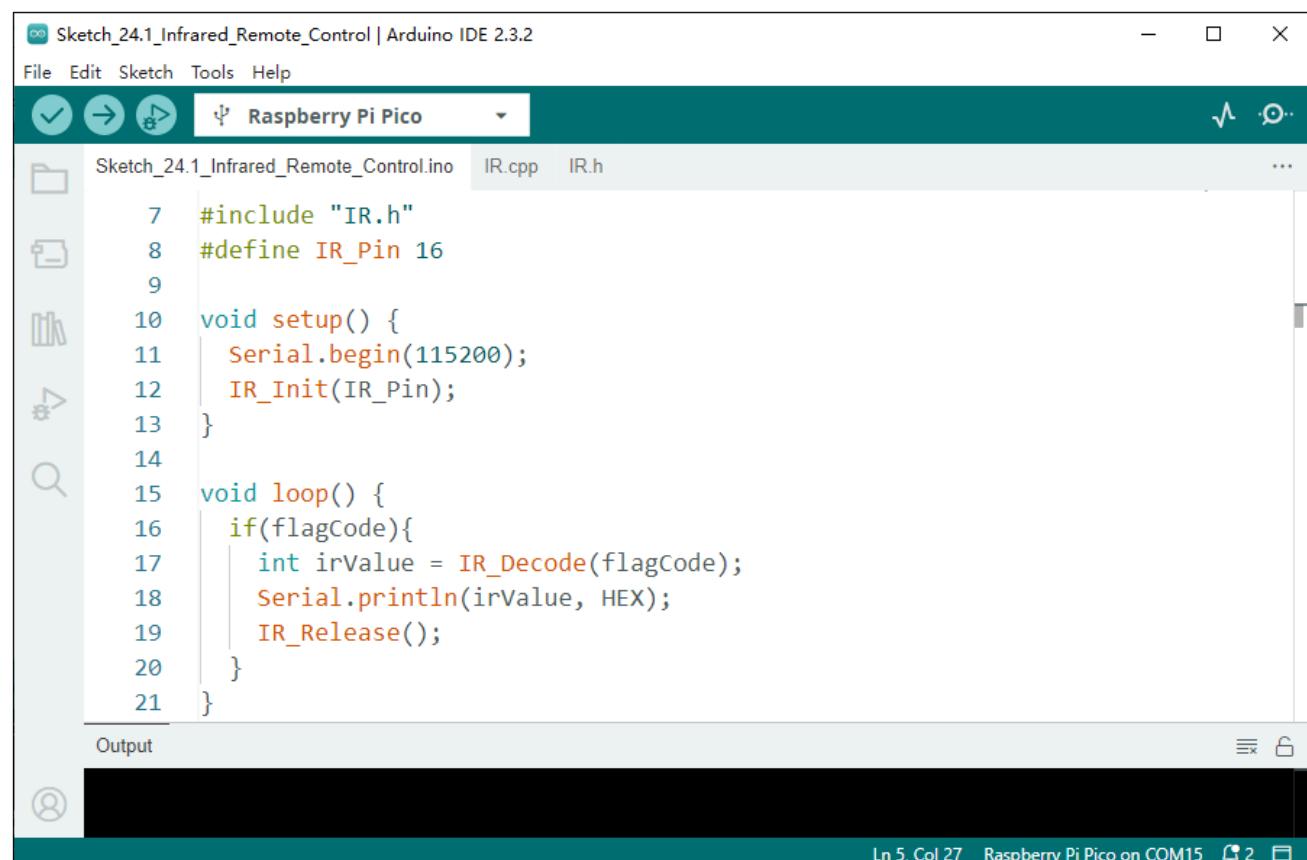


Any concerns? ✉ [support@freenove.com](mailto:support@freenove.com)

## Sketch

This sketch uses the infrared receiving tube to receive the value sent from the infrared remote control, and print it out via the serial port.

### Sketch\_20.1\_Infrared\_Remote\_Control

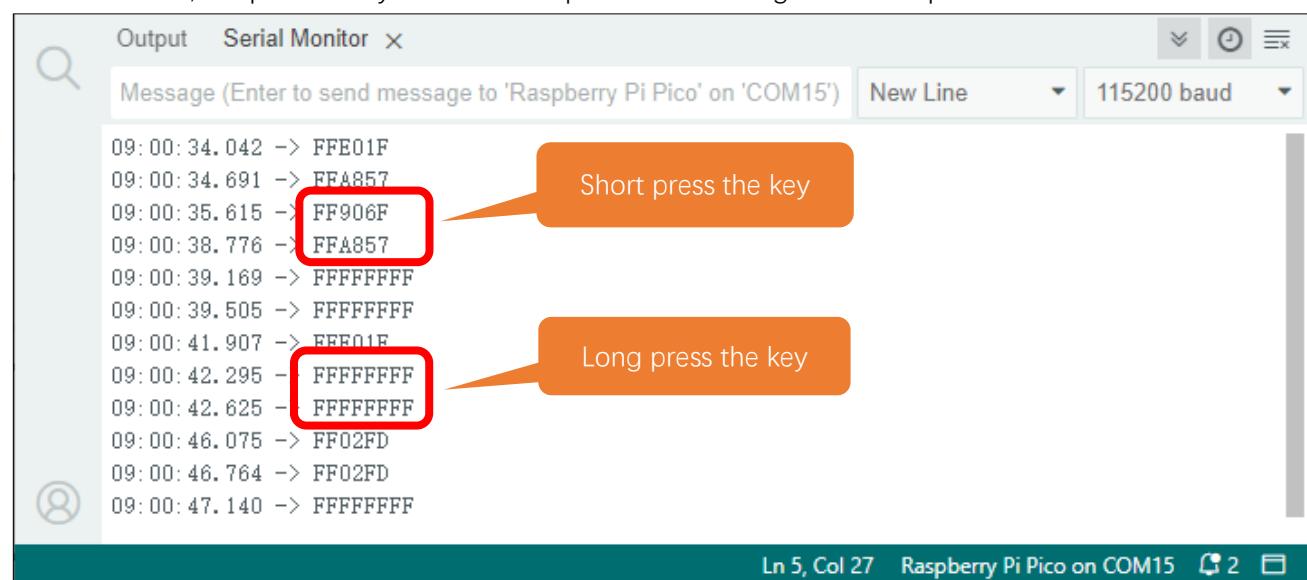


```
#include "IR.h"
#define IR_Pin 16

void setup() {
    Serial.begin(115200);
    IR_Init(IR_Pin);
}

void loop() {
    if(flagCode){
        int irValue = IR_Decode(flagCode);
        Serial.println(irValue, HEX);
        IR_Release();
    }
}
```

Download the code to Pico, open the serial port monitor, set the baud rate to 115200, and press the IR remote control, the pressed keys value will be printed out through the serial port.



Time	Value
09:00:34.042	-> FFE01F
09:00:34.691	-> FFA857
09:00:35.615	-> FF906F
09:00:38.776	-> FFA857
09:00:39.169	-> FFFFFFFF
09:00:39.505	-> FFFFFFFF
09:00:41.907	-> FFE01F
09:00:42.295	-> FFFFFFFF
09:00:42.625	-> FFFFFFFF
09:00:46.075	-> FF02FD
09:00:46.764	-> FF02FD
09:00:47.140	-> FFFFFFFF

## IR.cpp

```
1 #include "IR.h"
2
3 int logList[32];
4 unsigned long startTime;
5 int endTime, end2Time;
6 int flagCode = 0;
7 int irPin;
8 bool irState = true;
9
10 void IR_Init(int pin) {
11     irPin = pin;
12     pinMode(irPin, INPUT_PULLUP);
13     attachInterrupt(digitalPinToInterrupt(irPin), IR_Read, CHANGE);
14 }
15
16 void IR_Read() {
17     if (irState == true) {
18         unsigned long lowTime, highTime, intervalTime;
19         int num = 0;
20         while (digitalRead(irPin) == LOW) {
21             startTime = micros();
22             while (digitalRead(irPin) == LOW) {
23                 lowTime = micros();
24             }
25             intervalTime = lowTime - startTime;
26             while (digitalRead(irPin) == HIGH) {
27                 highTime = micros();
28                 intervalTime = highTime - lowTime;
29                 if (intervalTime > 10000) {
30                     end2Time = millis();
31                     if (num == 32) {
32                         flagCode = 1;
33                         endTime = millis();
34                     }
35                     else if (num == 0 && end2Time - endTime > 300 && end2Time - endTime < 400) {
36                         flagCode = 2;
37                         endTime = millis();
38                     }
39                     return;
40                 }
41             }
42             if (intervalTime < 2000) {
43                 if (intervalTime < 700) {
```

```
44         logList[num ++] = 0;
45     }
46     else {
47         logList[num ++] = 1;
48     }
49 }
50 }
51 }
52 }

53

54 unsigned long IR_Decode(int &code) {
55     unsigned long irData = 0;
56     irState=false;
57     if (code == 1) {
58         code = 0;
59         for (int i = 0; i < 32; i++) {
60             if (logList[i] == 0) {
61                 irData <<= 1;
62             }
63             else {
64                 irData <<= 1;
65                 irData++;
66             }
67             logList[i] = 0;
68         }
69     }
70     if (code == 2) {
71         code = 0;
72         irData = 0xffffffff;
73     }
74     return irData;
75 }
76 }

77

78 void IR_Release() {
79     irState=true;
80 }
```

When the IR\_Init() function is called, Pico initializes the infrared received pin and sets the external interrupt, associating it with the IR\_Read() function. Every time the infrared receives data, external interrupt calls IR\_Read() function to receive data, and resets the bit flag.

```
extern int flagCode;
void IR_Init(int pin);
void IR_Read();
```

You can check whether flagCode has been reset, If it is reset, call IR\_Decode() to decode the infrared data.

Note: once IR\_Decode() is called, infrared receiver will not receive data until IR\_Release() is called.

```
unsigned long IR_Decode(int &code);
void IR_Release();
```

The following is the program code:

```
1 #include "IR.h"
2 #define IR_Pin 16
3
4 void setup() {
5     Serial.begin(115200);
6     IR_Init(IR_Pin);
7 }
8
9 void loop() {
10    if(flagCode) {
11        int irValue = IR_Decode(flagCode);
12        Serial.println(irValue, HEX);
13        IR_Release();
14    }
15 }
```

IR\_Init() is called to initialize infrared receiving pin GP16, enable external interrupt and associate it with GP16.

```
6     IR_Init(IR_Pin);
```

In loop(), determines whether infrared bit flag is reset. If it is, IR\_Decode() is called to decode the data and print them out via serial monitor.

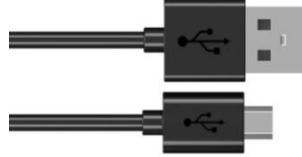
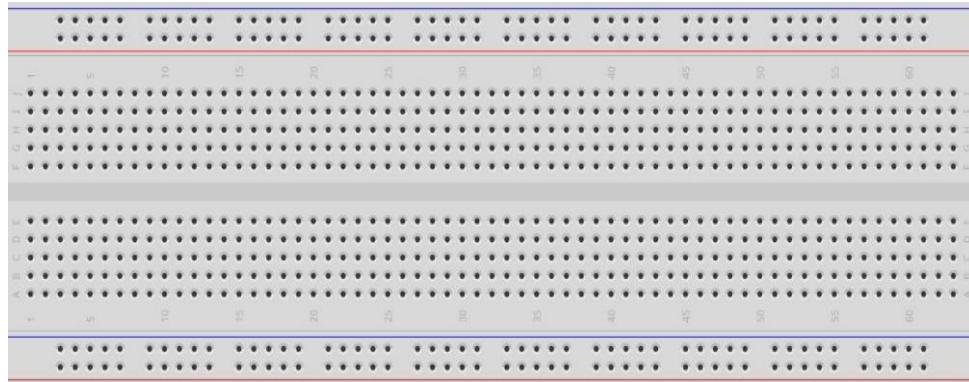
After using the infrared decoding function IR\_Decode(), you need to call IR\_Release() to release the infrared data receiving function. Otherwise, it will not receiver new infrared data again.

```
10 if(flagCode) {
11     int irValue = IR_Decode(flagCode);
12     Serial.println(irValue, HEX);
13     IR_Release();
14 }
```

## Project 20.2 Control LED through Infrared Remote

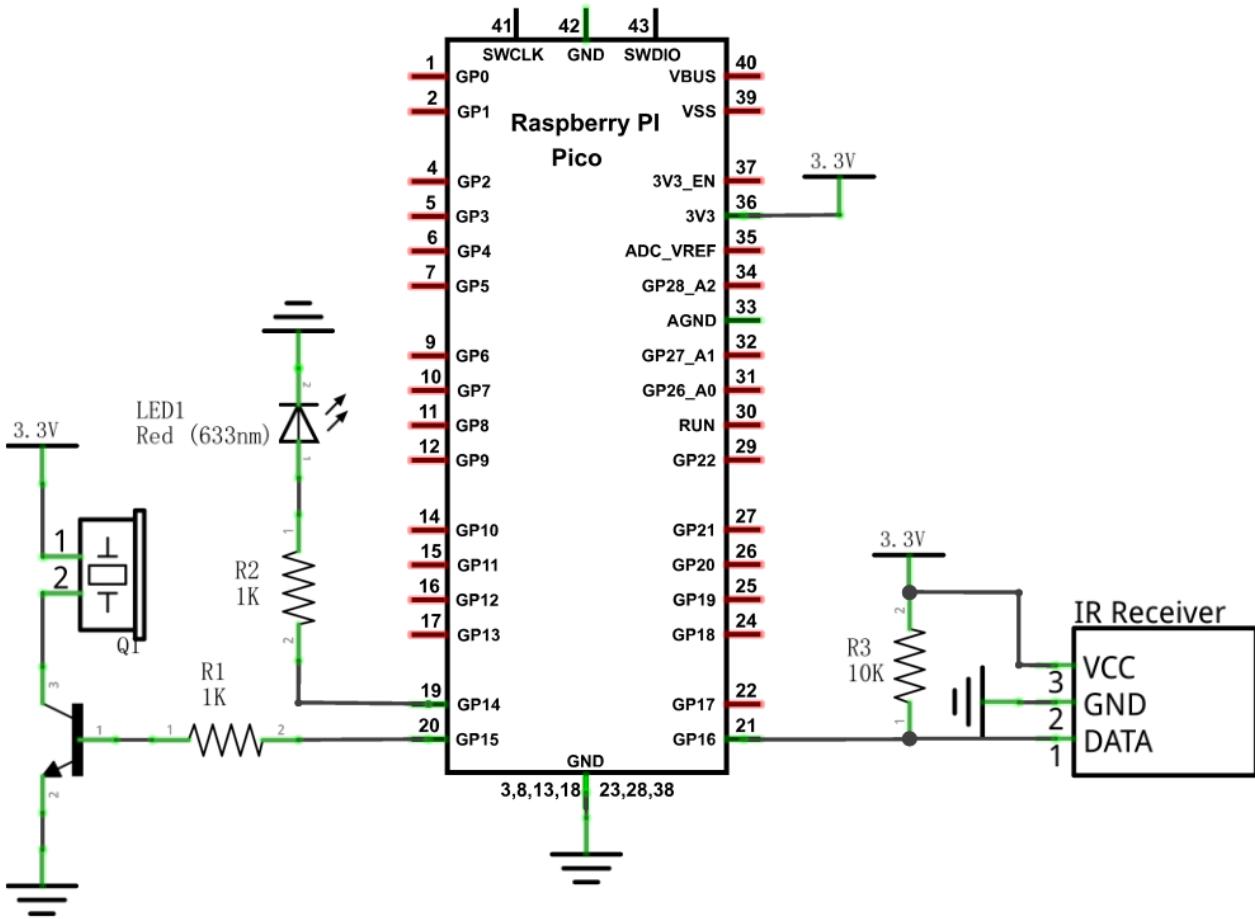
In this project, we will control the brightness of LED lights through an infrared remote control.

### Component List

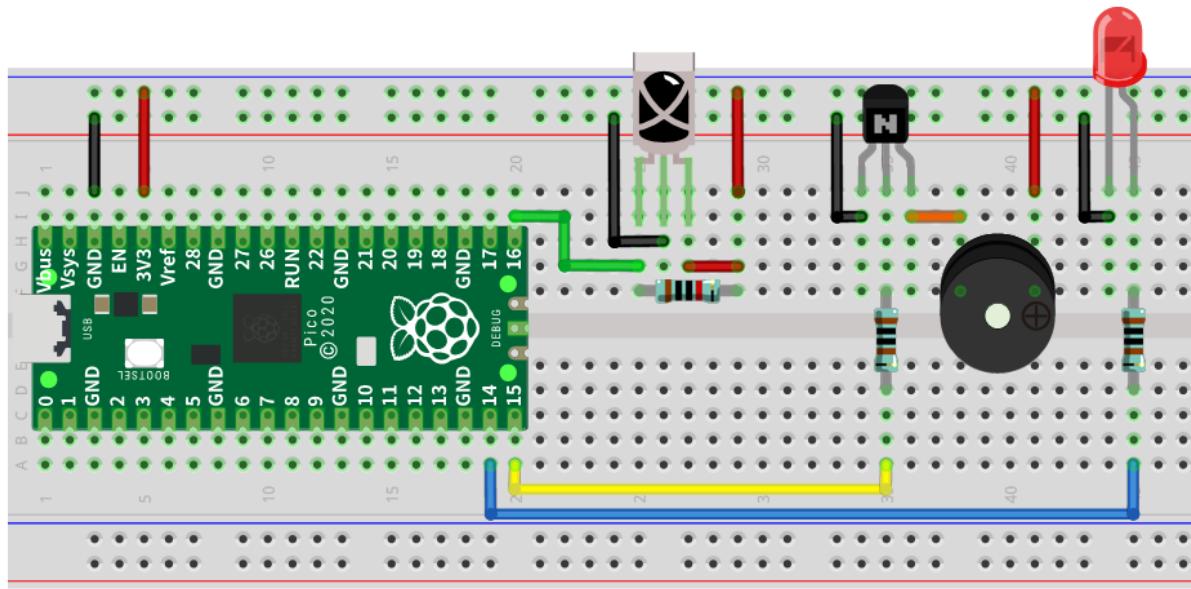
Raspberry Pi Pico x1	USB cable x1
	
Breadboard x1	
Jumper	Infrared Remote x1 (May need CR2025 battery x1, please check the battery holder)
LED x1	Active buzzer x1
	
Resistor 1kΩ x2	
Infrared receiver x1	NPN transistor x1 (S8050)
	
Resistor 10kΩ x1	

## Circuit

Schematic diagram



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

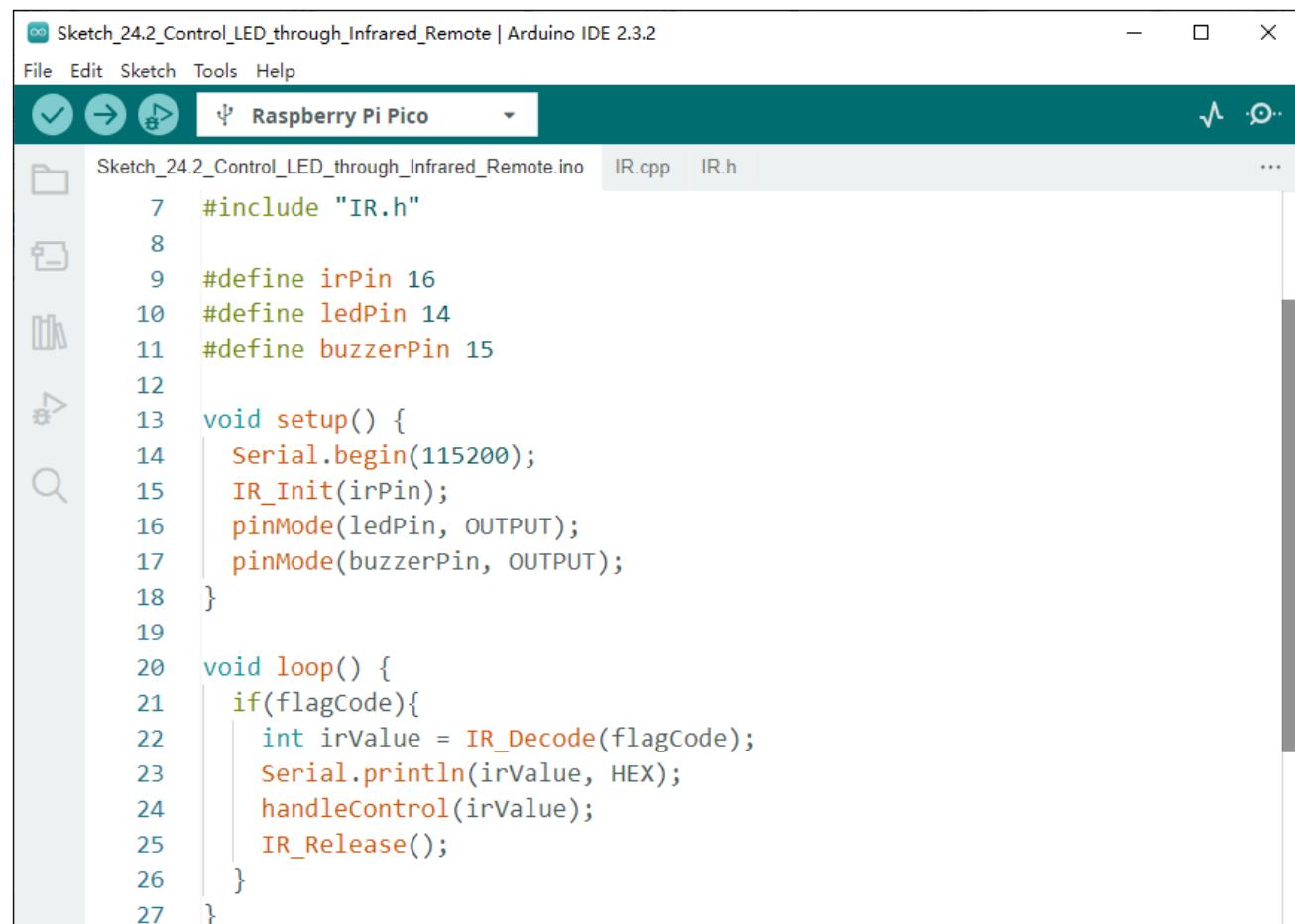


Any concerns? ✉ [support@freenove.com](mailto:support@freenove.com)

## Sketch

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

[Sketch\\_20.2\\_Control\\_LED\\_through\\_Infrared\\_Remote](#)



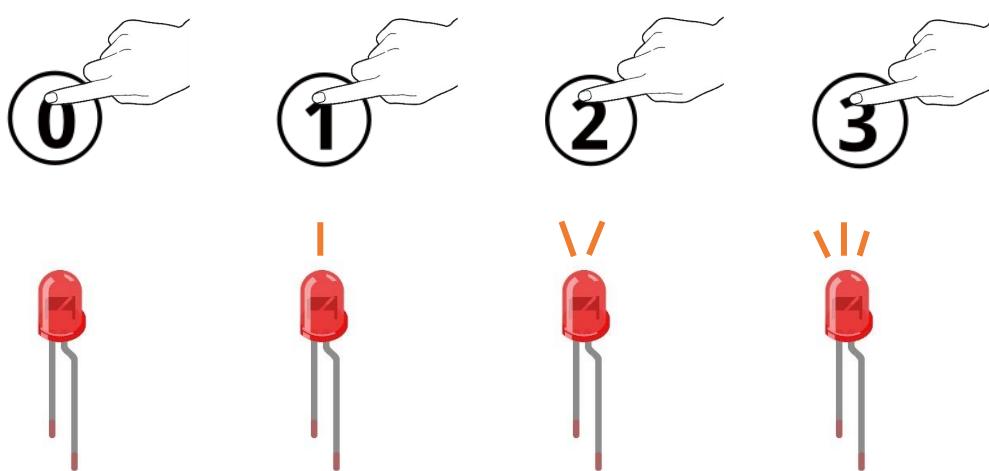
```

Sketch_24.2_Control_LED_through_Infrared_Remote | Arduino IDE 2.3.2
File Edit Sketch Tools Help
Sketch_24.2_Control_LED_through_Infrared_Remote.ino IR.cpp IR.h ...
7 #include "IR.h"
8
9 #define irPin 16
10 #define ledPin 14
11 #define buzzerPin 15
12
13 void setup() {
14     Serial.begin(115200);
15     IR_Init(irPin);
16     pinMode(ledPin, OUTPUT);
17     pinMode(buzzerPin, OUTPUT);
18 }
19
20 void loop() {
21     if(flagCode){
22         int irValue = IR_Decode(flagCode);
23         Serial.println(irValue, HEX);
24         handleControl(irValue);
25         IR_Release();
26     }
27 }

```

Compile and upload the code to the Pico. When pressing "0", "1", "2", "3" of the infrared remote control, the buzzer will sound once, and the brightness of the LED light will change correspondingly.

Rendering:



The following is the program code:

```
1 #include "IR.h"
2
3 #define irPin 16
4 #define ledPin 14
5 #define buzzerPin 15
6
7 void setup() {
8     Serial.begin(115200);
9     IR_Init(irPin);
10    pinMode(ledPin, OUTPUT);
11    pinMode(buzzerPin, OUTPUT);
12 }
13
14 void loop() {
15     if(flagCode) {
16         int irValue = IR_Decode(flagCode);
17         Serial.println(irValue, HEX);
18         handleControl(irValue);
19         IR_Release();
20     }
21 }
22
23 void handleControl(unsigned long value) {
24     digitalWrite(buzzerPin, HIGH);
25     delay(100);
26     digitalWrite(buzzerPin, LOW);
27     // Handle the commands
28     switch (value) {
29         case 0xFF6897:           // Receive the number '0'
30             analogWrite(ledPin, 0); // Turn off LED
31             break;
32         case 0xFF30CF:           // Receive the number '1'
33             analogWrite(ledPin, 50); // Dimmest brightness
34             break;
35         case 0xFF18E7:           // Receive the number '2'
36             analogWrite(ledPin, 100); // Medium brightness
37             break;
38         case 0xFF7A85:           // Receive the number '3'
39             analogWrite(ledPin, 255); // Strongest brightness
40             break;
41     }
42 }
```

The handleControl() function is used to execute events corresponding to infrared code values. Every time when the function is called, the buzzer sounds once and determine the brightness of the LED based on the infrared key value. If the key value is not "0", "1", "2", "3", the buzzer sounds once, but the brightness of LED will not change.

```
23 void handleControl(unsigned long value) {  
24     digitalWrite(buzzerPin, HIGH);  
25     delay(100);  
26     digitalWrite(buzzerPin, LOW);  
27     // Handle the commands  
28     switch (value) {  
29         case 0xFF6897:           // Receive the number '0'  
30             analogWrite(ledPin, 0); // Turn off LED  
31             break;  
32         case 0xFF30CF:           // Receive the number '1'  
33             analogWrite(ledPin, 50); // Dimmest brightness  
34             break;  
35         case 0xFF18E7:           // Receive the number '2'  
36             analogWrite(ledPin, 100); // Medium brightness  
37             break;  
38         case 0xFF7A85:           // Receive the number '3'  
39             analogWrite(ledPin, 255); // Strongest brightnss  
40             break;  
41     }  
42 }
```

In the loop() function, each time the infrared data is received, it is decoded and printed out through the serial monitor, and the handleControl() function is called to control the LED and buzzer to execute the corresponding code.

```
14 void loop() {  
15     if(flagCode){  
16         int irValue = IR_Decode(flagCode);  
17         Serial.println(irValue, HEX);  
18         handleControl(irValue);  
19         IR_Release();  
20     }  
21 }
```



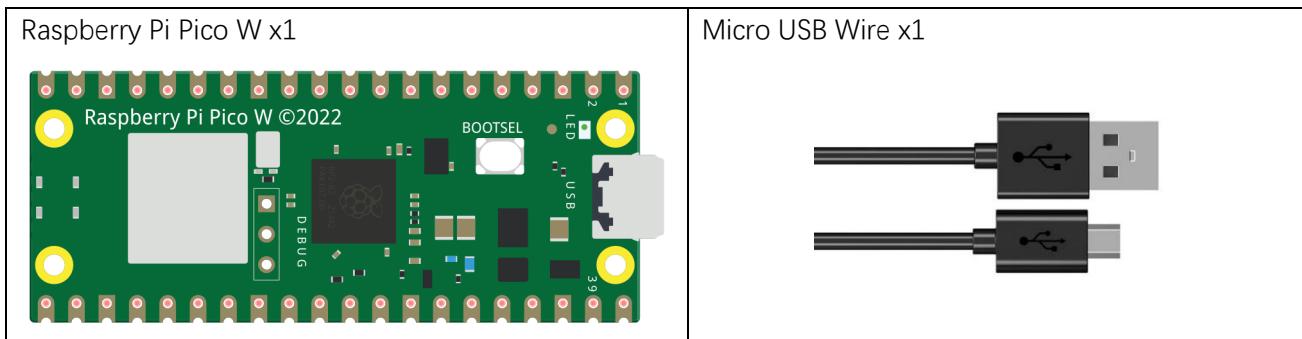
# Chapter 21 WiFi Working Modes (Only for Pico W)

The biggest difference between the raspberry pi pico and the raspberry pi Pico W is that the raspberry pi pico W is equipped with a WiFi function module. At the beginning of this chapter, we will learn about the WiFi function of Pico W of Raspberry Pi.

If you have Pico in your hand, please change it to Pico W before continuing to learn.

## Project 21.1 Station mode

### Component List



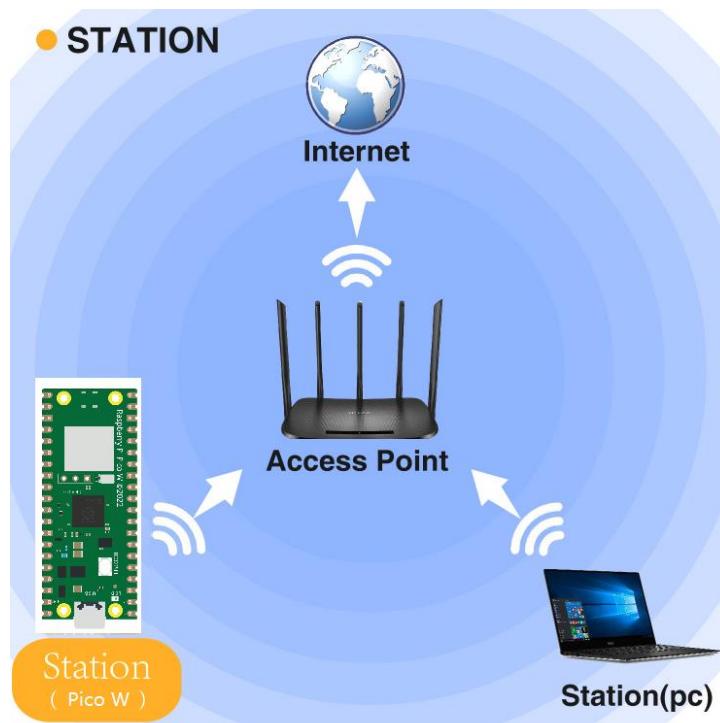
### Component knowledge

#### Wireless

Pico W has an on-board 2.4GHz wireless interface using an Infineon CYW43439. The antenna is an onboard antenna licensed from ABRACON (formerly ProAnt). The wireless interface is connected via SPI to the RP2040.

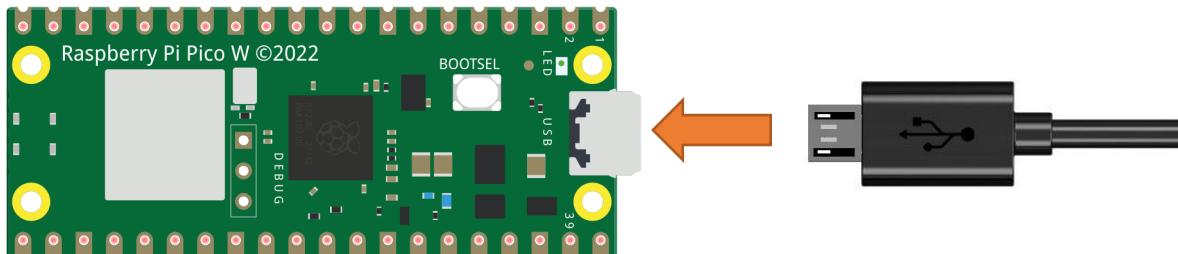
#### Station mode

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



## Circuit

Connect Pico W to the computer using the USB cable.





## Sketch

### Sketch\_21.1\_Station\_mode

```
Sketch_30.1_WiFi_Station | Arduino IDE 2.3.2
File Edit Sketch Tools Help
ψ Raspberry Pi Pico W
Sketch_30.1_WiFi_Station.ino
7 #include <WiFi.h>
8
9 const char *ssid_Router      = "*****"; //Enter the router name
10 const char *password_Router = "*****"; //Enter the router password
11
12 void setup(){
13     Serial.begin(115200);
14     delay(2000);
15     Serial.println("Setup start");
16     WiFi.begin(ssid_Router, password_Router);
17     Serial.println(String("Connecting to ") + ssid_Router);
18     while (WiFi.status() != WL_CONNECTED){
19         delay(500);
20         Serial.print(".");
21     }
--
```

Output

Ln 9, Col 31 Raspberry Pi Pico W on COM9 2

Enter the correct Router name and password.

Because the names and passwords of routers are different, before the Sketch runs, users need to enter the correct router's name and password in the box as shown in the illustration above.

After making sure the router name and password are entered correctly, compile and upload codes to Pico W, open serial monitor and set baud rate to 115200. Then it will display as follows:



When PICO W successfully connects to “ssid\_Router”, serial monitor will print out the IP address assigned to PICO W by the router.

The following is the program code:

```

1 #include <WiFi.h>
2
3 const char *ssid_Router      = "*****"; //Enter the router name
4 const char *password_Router = "*****"; //Enter the router password
5
6 void setup() {
7     Serial.begin(115200);
8     delay(2000);
9     Serial.println("Setup start");
10    WiFi.begin(ssid_Router, password_Router);
11    Serial.println(String("Connecting to ") + ssid_Router);
12    while (WiFi.status() != WL_CONNECTED) {
13        delay(500);
14        Serial.print(".");
15    }
16    Serial.println("\nConnected, IP address: ");
17    Serial.println(WiFi.localIP());
18    Serial.println("Setup End");
19 }
20 void loop() {
21 }
```

Include the WiFi Library header file of Pico W.

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

Enter correct router name and password.

```

3   const char *ssid_Router      = "*****"; //Enter the router name
4   const char *password_Router = "*****"; //Enter the router password

```

Set Pico W in Station mode and connect it to your router.

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

Check whether Pico W has connected to router successfully every 0.5s.

```

12  while (WiFi.status() != WL_CONNECTED) {
13      delay(500);
14      Serial.print(".");
15  }

```

Serial monitor prints out the IP address assigned to Pico W.

```
17  Serial.println(WiFi.localIP());
```

Reference

### Class Station

Every time when using WiFi, you need to include header file "WiFi.h".

**begin(ssid, password,channel, bssid, connect):** PICO W is used as Station to connect hotspot.

**ssid:** WiFi hotspot name

**password:** WiFi hotspot password

**channel:** WiFi hotspot channel number; communicating through specified channel; optional parameter

**bssid:** mac address of WiFi hotspot, optional parameter

**connect:** boolean optional parameter, defaulting to true. If set as false, then PICO W won't connect WiFi.

**config(local\_ip, gateway, subnet, dns1, dns2):** set static local IP address.

**local\_ip:** station fixed IP address.

**subnet:** subnet mask

**dns1,dns2:** optional parameter. define IP address of domain name server

**status:** obtain the connection status of WiFi

**local IP():** obtain IP address in Station mode

**disconnect():** disconnect wifi

## Project 21.2 AP mode

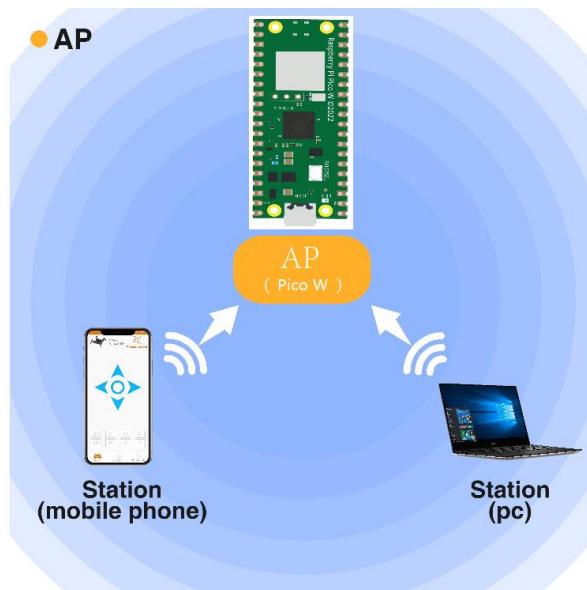
### Component List & Circuit

Component List & Circuit are the same as in Section 30.1.

### Component knowledge

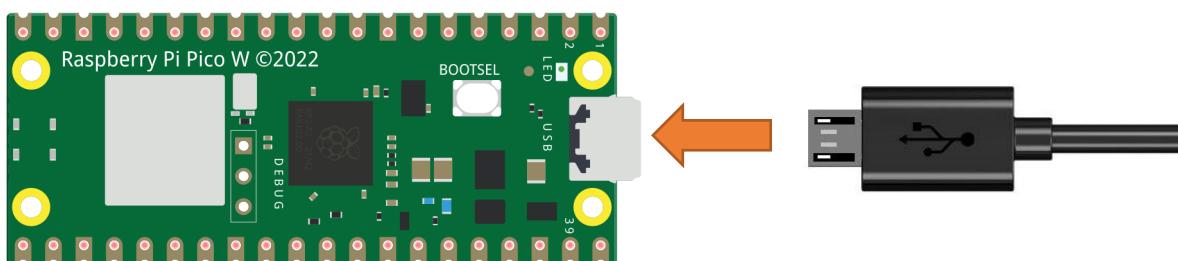
#### AP mode

When PICO W selects AP mode, it creates a hotspot network that is separate from the Internet and waits for other WiFi devices to connect. As shown in the figure below, PICO W is used as a hotspot. If a mobile phone or PC wants to communicate with PICO W, it must be connected to the hotspot of PICO W. Only after a connection is established with PICO W can they communicate.



### Circuit

Connect Pico W to the computer using the USB cable.





## Sketch

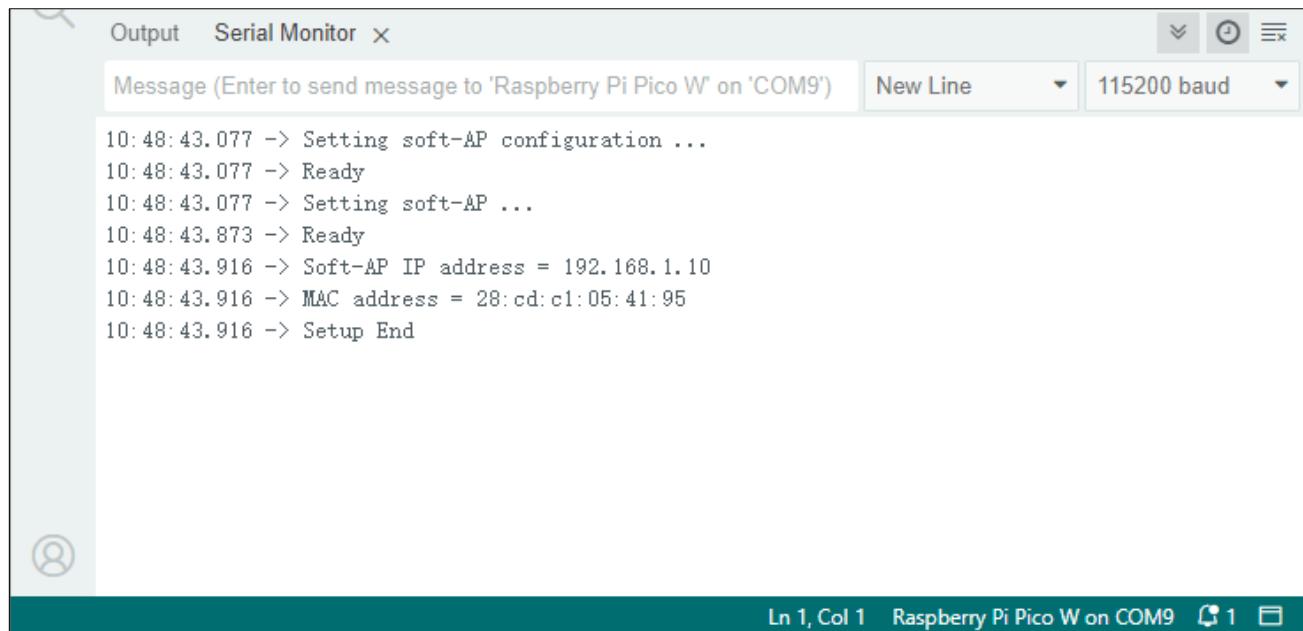
### Sketch\_21.2\_AP\_mode

```
Sketch_30.2_WiFi_AP | Arduino IDE 2.3.2
File Edit Sketch Tools Help
Sketch_30.2_WiFi_AP.ino
7 #include <WiFi.h>
8
9 const char *ssid_AP      = "WiFi_Name"; //Enter the router name
10 const char *password_AP = "12345678"; //Enter the router password
11
12 IPAddress local_IP(192,168,1,100); //Set the IP address of ESP8266 itself
13 IPAddress gateway(192,168,1,10); //Set the gateway of ESP8266 itself
14 IPAddress subnet(255,255,255,0); //Set the subnet mask for itself
15
16 void setup(){
17     Serial.begin(115200);
18     delay(2000);
19     Serial.println("Setting soft-AP configuration ... ");
20     WiFi.disconnect();
```

Set a name and a password for PICO W AP mode.

Before the Sketch runs, you can make any changes to the AP name and password for PICO W in the box as shown in the illustration above. Of course, you can leave it alone by default.

Compile and upload codes to PICO W, open the serial monitor and set the baud rate to 115200. Then it will display as follows.



The screenshot shows the 'Serial Monitor' window with the title 'Output Serial Monitor'. The message area displays the following log entries:

```

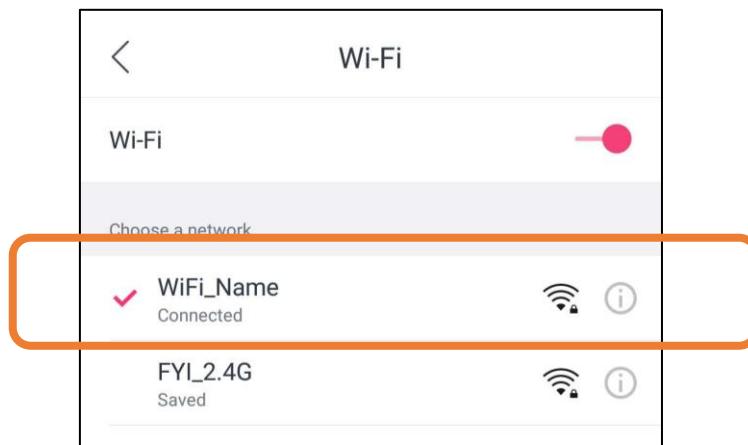
Message (Enter to send message to 'Raspberry Pi Pico W' on 'COM9')
New Line 115200 baud

10:48:43.077 -> Setting soft-AP configuration ...
10:48:43.077 -> Ready
10:48:43.077 -> Setting soft-AP ...
10:48:43.873 -> Ready
10:48:43.916 -> Soft-AP IP address = 192.168.1.10
10:48:43.916 -> MAC address = 28:cd:c1:05:41:95
10:48:43.916 -> Setup End

```

The status bar at the bottom indicates 'Ln 1, Col 1 Raspberry Pi Pico W on COM9'.

When observing the print information of the serial monitor, turn on the WiFi scanning function of your phone, and you can see the ssid\_AP on PICO W, which is called "WiFi\_Name" in this Sketch. You can enter the password "12345678" to connect it or change its AP name and password by modifying Sketch.



Note:

1. Every time you change the WiFi name and password in the code, please power off and then on again, and then upload the code. It is possible that the WiFi name and password have not actually changed due to the direct uploading of code without power. This is because Pico W WiFi module and RP2040 chip are separated. Only when the power is cut off can the WiFi name and password be flashed to the WiFi module again.
2. Pico W executes this code only to open a WiFi hotspot, and does not configure the code related to online data transmission, so the mobile phone will display no data after connection.



The following is the program code:

```

1 #include <WiFi.h>
2
3 const char *ssid_AP      = "WiFi_Name"; //Enter the router name
4 const char *password_AP = "12345678"; //Enter the router password
5
6 IPAddress local_IP(192, 168, 1, 100); //Set the IP address of PICO W itself
7 IPAddress gateway(192, 168, 1, 10); //Set the gateway of PICO W itself
8 IPAddress subnet(255, 255, 255, 0); //Set the subnet mask for PICO W itself
9
10 void setup() {
11     Serial.begin(115200);
12     delay(2000);
13     Serial.println("Setting soft-AP configuration ... ");
14     WiFi.disconnect();
15     WiFi.mode(WIFI_AP);
16     Serial.println(WiFi.softAPConfig(local_IP, gateway, subnet) ? "Ready" : "Failed!");
17     Serial.println("Setting soft-AP ... ");
18     boolean result = WiFi.softAP(ssid_AP, password_AP);
19     if(result) {
20         Serial.println("Ready");
21         Serial.println(String("Soft-AP IP address = ") + WiFi.softAPIP().toString());
22         Serial.println(String("MAC address = ") + WiFi.softAPmacAddress().c_str());
23     } else {
24         Serial.println("Failed!");
25     }
26     Serial.println("Setup End");
27 }
28
29 void loop() {
30 }
```

Include WiFi Library header file of PICO W.

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

Enter correct AP name and password.

```
3 const char *ssid_AP      = "WiFi_Name"; //Enter the router name
4 const char *password_AP = "12345678"; //Enter the router password
```

Set PICO W in AP mode.

```
15 WiFi.mode(WIFI_AP);
```

Configure IP address, gateway and subnet mask for PICO W.

```
16 WiFi.softAPConfig(local_IP, gateway, subnet)
```

Turn on an AP in PICO W, whose name is set by ssid\_AP and password is set by password\_AP.

```
18 WiFi.softAP(ssid_AP, password_AP);
```

Check whether the AP is turned on successfully. If yes, print out IP and MAC address of AP established by PICO W. If no, print out the failure prompt.

```
19 if(result) {  
20     Serial.println("Ready");  
21     Serial.println(String("Soft-AP IP address = ") + WiFi.softAPIP().toString());  
22     Serial.println(String("MAC address = ") + WiFi.softAPmacAddress().c_str());  
23 } else {  
24     Serial.println("Failed!");  
25 }  
26 Serial.println("Setup End");
```

Reference

### Class AP

Every time when using WiFi, you need to include header file "WiFi.h".

**softAP(ssid, password, channel, ssid\_hidden, max\_connection):**

**ssid:** WiFi hotspot name

**password:** WiFi hotspot password

**channel:** Number of WiFi connection channels, range 1-13. The default is 1.

**ssid\_hidden:** Whether to hide WiFi name from scanning by other devices. The default is not hide.

**max\_connection:** Maximum number of WiFi connected devices. The range is 1-4. The default is 4.

**softAPConfig(local\_ip, gateway, subnet):** set static local IP address.

**local\_ip:** station fixed IP address.

**Gateway:** gateway IP address

**subnet:** subnet mask

**softAP():** obtain IP address in AP mode

**softAPdisconnect ():** disconnect AP mode.



## Project 21.3 AP+Station mode

### Component List & Circuit

Component List & Circuit are the same as in Section 30.1.

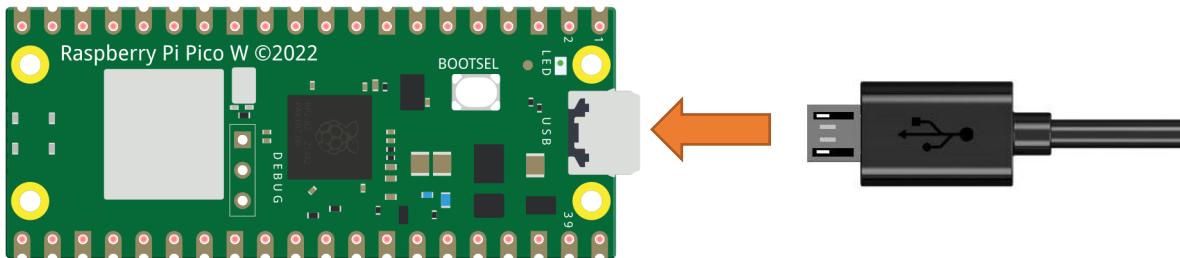
### Component knowledge

#### AP+Station mode

PICO W currently does not support simultaneous use of AP mode and Station mode, so this section can be skipped. In the actual mode configuration, the last configured mode shall prevail.

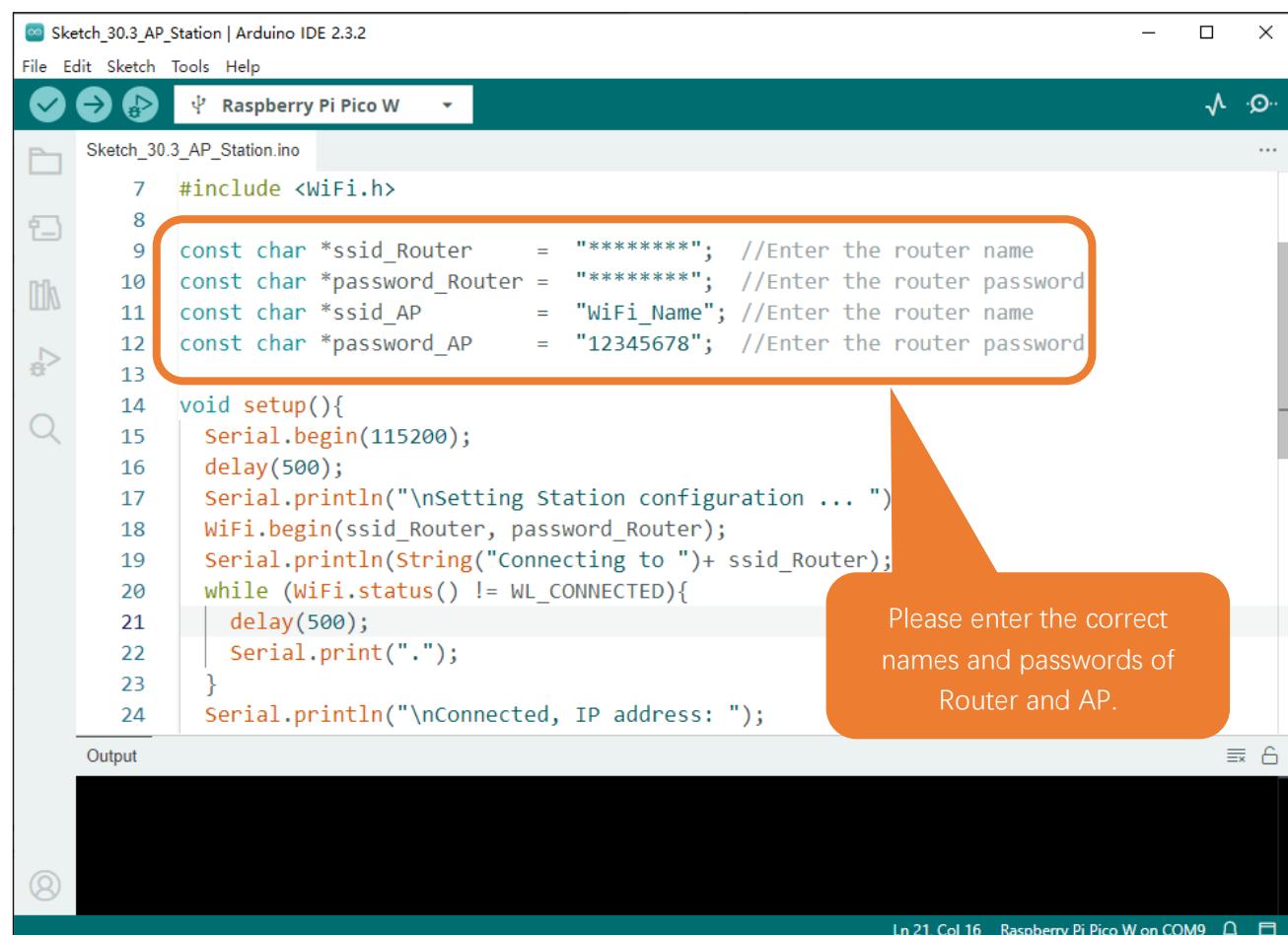
### Circuit

Connect Pico W to the computer using the USB cable.



## Sketch

### Sketch\_21.3\_AP\_Station\_mode



The screenshot shows the Arduino IDE interface with the sketch file "Sketch\_21.3\_AP\_Station\_mode" open. The code is as follows:

```
#include <WiFi.h>
const char *ssid_Router      = "*****"; //Enter the router name
const char *password_Router = "*****"; //Enter the router password
const char *ssid_AP          = "WiFi_Name"; //Enter the router name
const char *password_AP      = "12345678"; //Enter the router password

void setup(){
  Serial.begin(115200);
  delay(500);
  Serial.println("\nSetting Station configuration ... ")
  WiFi.begin(ssid_Router, password_Router);
  Serial.println(String("Connecting to ")+ ssid_Router);
  while (WiFi.status() != WL_CONNECTED){
    delay(500);
    Serial.print(".");
  }
  Serial.println("\nConnected, IP address: ");
}
```

A callout bubble with an orange border points to the configuration parameters (ssid\_Router, password\_Router, ssid\_AP, password\_AP) which are highlighted with a red rectangle. The text inside the callout bubble reads:

Please enter the correct names and passwords of Router and AP.

It is analogous to Project 21.1 and Project 21.2. Before running the Sketch, you need to modify ssid\_Router, password\_Router, ssid\_AP and password\_AP shown in the box of the illustration above.



After making sure that Sketch is modified correctly, compile and upload codes to PICO W, open serial monitor and set baud rate to 115200. Then it will display as follows:

The screenshot shows the Arduino Serial Monitor window. The title bar says "Output Serial Monitor". The message area contains the following text:

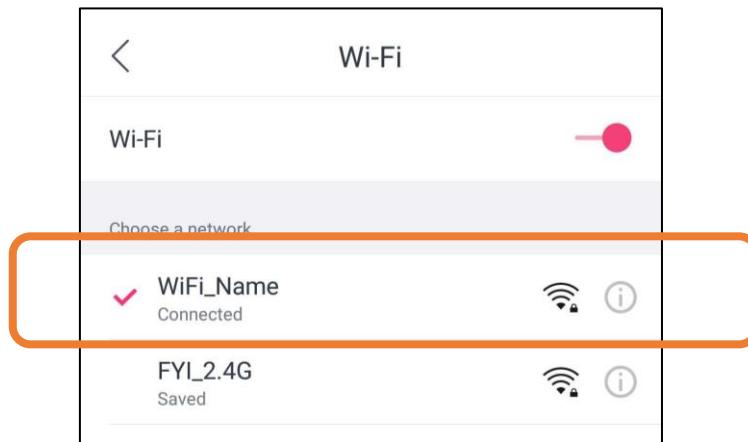
```

Message (Enter to send message to 'Raspberry Pi Pico W' on 'COM9')
10:53:45.024 -> Connecting to FYI_2.4G
10:53:45.024 ->
10:53:45.024 -> Connected, IP address:
10:53:45.024 -> 192.168.1.23
10:53:45.518 -> Setting soft-AP configuration ...
10:53:45.518 -> Setting soft-AP ...
10:53:46.357 -> Ready
10:53:46.357 -> Soft-AP IP address = 192.168.1.1
10:53:46.357 -> MAC address = 28:cd:c1:05:41:95
10:53:46.357 -> Setup End

```

The status bar at the bottom right shows "Ln 15, Col 24 Raspberry Pi Pico W on COM9" and icons for a bell and a refresh.

When observing the print information of the serial monitor, turn on the WiFi scanning function of your phone, and you can see the ssid\_AP on PICO W.



The following is the program code:

```

1 #include <WiFi.h>
2
3 const char *ssid_Router      = "*****"; //Enter the router name
4 const char *password_Router = "*****"; //Enter the router password
5 const char *ssid_AP         = "WiFi_Name"; //Enter the AP name
6 const char *password_AP     = "12345678"; //Enter the AP password
7
8 void setup() {
9   Serial.begin(115200);

```

```
10 Serial.println("Setting soft-AP configuration ... ");
11 WiFi.disconnect();
12 WiFi.mode(WIFI_AP);
13 Serial.println("Setting soft-AP ... ");
14 boolean result = WiFi.softAP(ssid_AP, password_AP);
15 if(result){
16     Serial.println("Ready");
17     Serial.println(String("Soft-AP IP address = ") + WiFi.softAPIP().toString());
18     Serial.println(String("MAC address = ") + WiFi.softAPmacAddress().c_str());
19 }else{
20     Serial.println("Failed!");
21 }
22
23 Serial.println("\nSetting Station configuration ... ");
24 WiFi.begin(ssid_Router, password_Router);
25 Serial.println(String("Connecting to ") + ssid_Router);
26 while (WiFi.status() != WL_CONNECTED) {
27     delay(500);
28     Serial.print(".");
29 }
30 Serial.println("\nConnected, IP address: ");
31 Serial.println(WiFi.localIP());
32 Serial.println("Setup End");
33 }
34
35 void loop() {
36 }
```



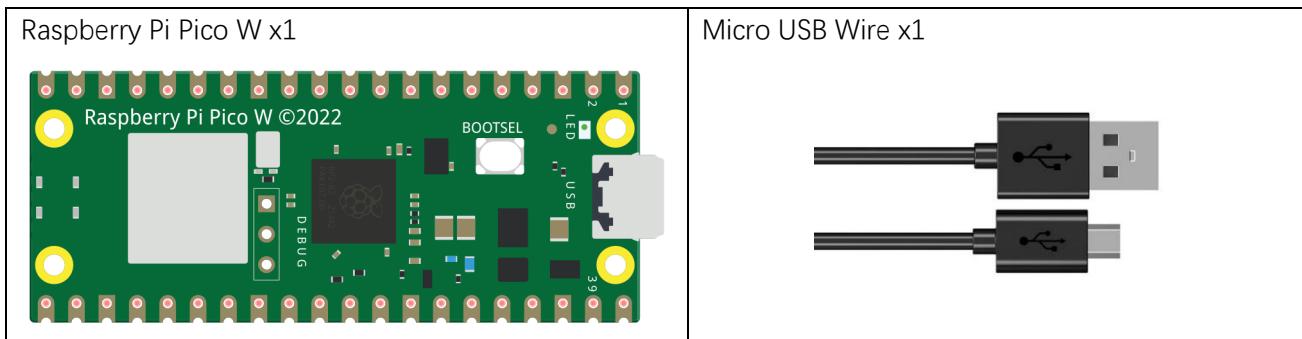
# Chapter 22 TCP/IP (Only for Pico W)

In this chapter, we will introduce how PICO W implements network communications based on TCP/IP protocol. There are two roles in TCP/IP communication, namely Server and Client, which will be implemented respectively with two projects in this chapter.

## Project 22.1 as Client

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

### Component List



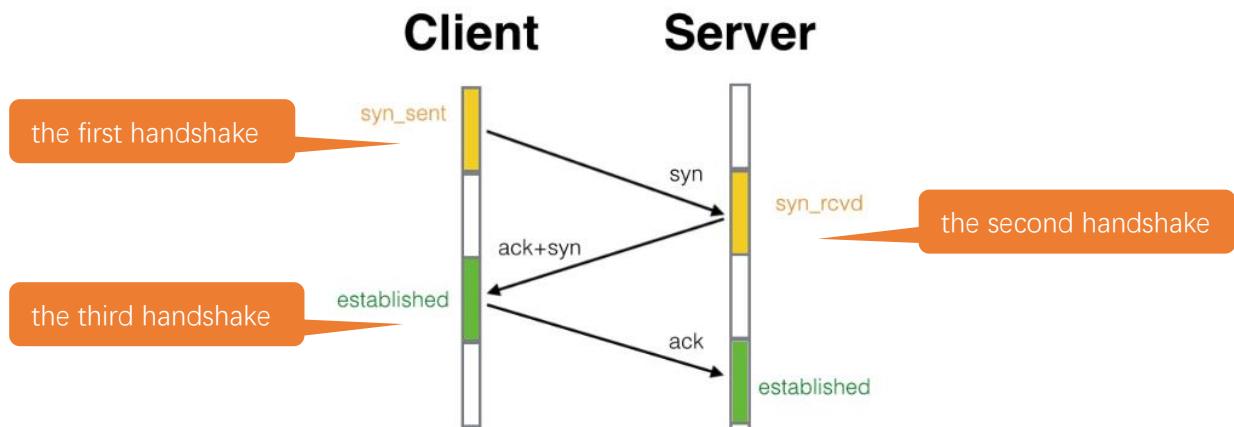
### Component knowledge

#### TCP connection

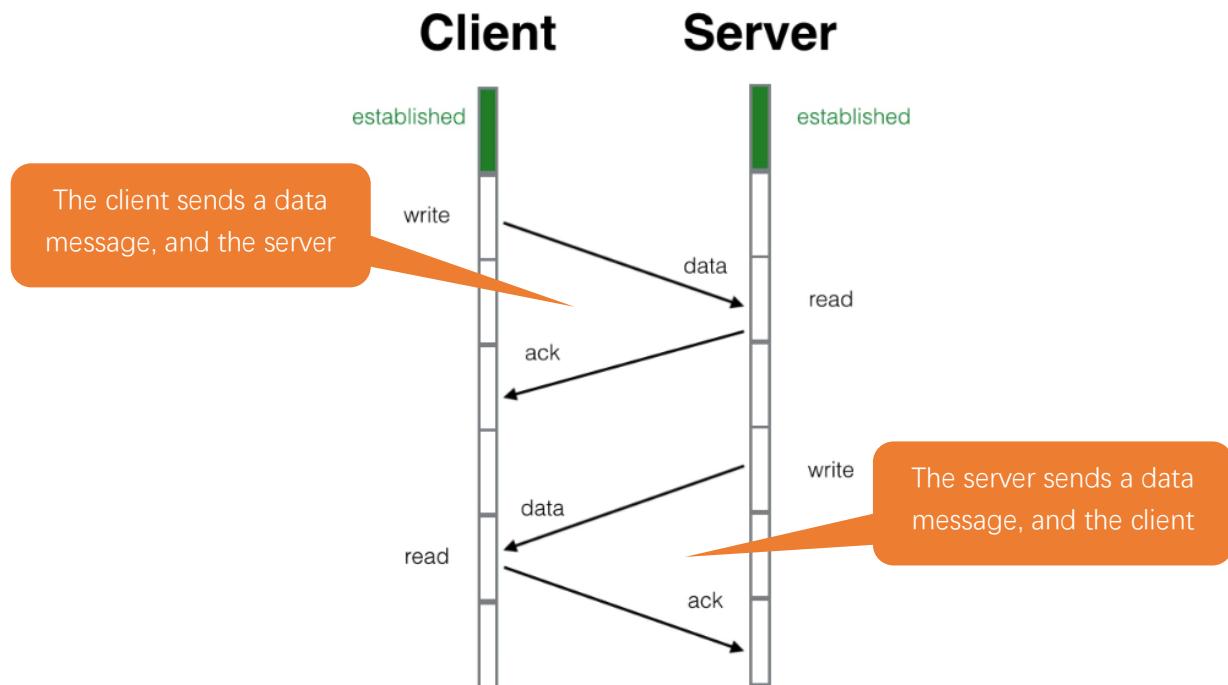
Before transmitting data, TCP needs to establish a logical connection between the sending end and the receiving end. It provides reliable and error-free data transmission between the two computers. In the TCP connection, the client and the server must be clarified. The client sends a connection request to the server, and each time such a request is proposed, a "three-time handshake" is required.

Three-time handshake: In the TCP protocol, during the preparation phase of sending data, the client and the server interact three times, to ensure the reliability of the connection, which is called "three-times handshake". The first handshake, the client sends a connection request to the server and waits for the server to confirm. The second handshake, the server sends a response back to the client informing that it has received the connection request.

The third handshake, the client sends a confirmation message to the server again to confirm the connection.



TCP is a connection-oriented, low-level transmission control protocol. After TCP establishes a connection, the client and server can send and receive messages to each other, and the connection will always exist as long as the client or server does not initiate disconnection. Each time one party sends a message, the other party will reply with an ack signal.





## Install Processing

In this tutorial, we use Processing to build a simple TCP/IP communication platform.

If you have not installed Processing, you can download it by clicking <https://processing.org/download/>. You can choose an appropriate version to download according to your PC system.

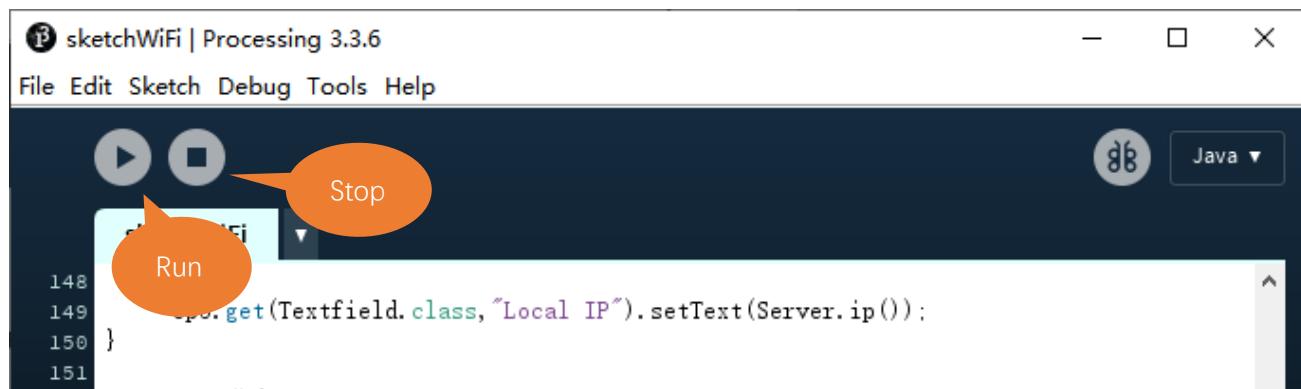
The screenshot shows the official Processing website. At the top, there's a navigation bar with links for "Processing", "p5.js", "Processing.py", "Processing for Android", "Processing for Pi", and "Processing Foundation". Below the navigation bar is a large banner featuring the word "Processing" in a bold, sans-serif font, overlaid on a dark background with a geometric, wireframe-like pattern. To the right of the banner is a search bar with a magnifying glass icon. On the left side of the main content area, there's a sidebar with links: "Cover", "Download", "Donate", "Exhibition", "Reference", "Libraries", "Tools", "Environment", "Tutorials", "Examples", "Books", "Overview", and "People". In the center, under the heading "Download Processing", it says "Processing is available for Linux, Mac OS X, and Windows. Select your choice to download the software below." Below this text is a large circular logo with a stylized "P" inside. To the right of the logo, it says "3.5.4 (17 January 2020)". Underneath, there are download links for "Windows 64-bit", "Windows 32-bit", "Linux 64-bit", and "Mac OS X". At the bottom of the sidebar, there are links for "» Github", "» Report Bugs", "» Wiki", "» Supported Platforms", and a note: "Read about the [changes in 3.0](#). The list of revisions covers the differences between releases in detail."

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

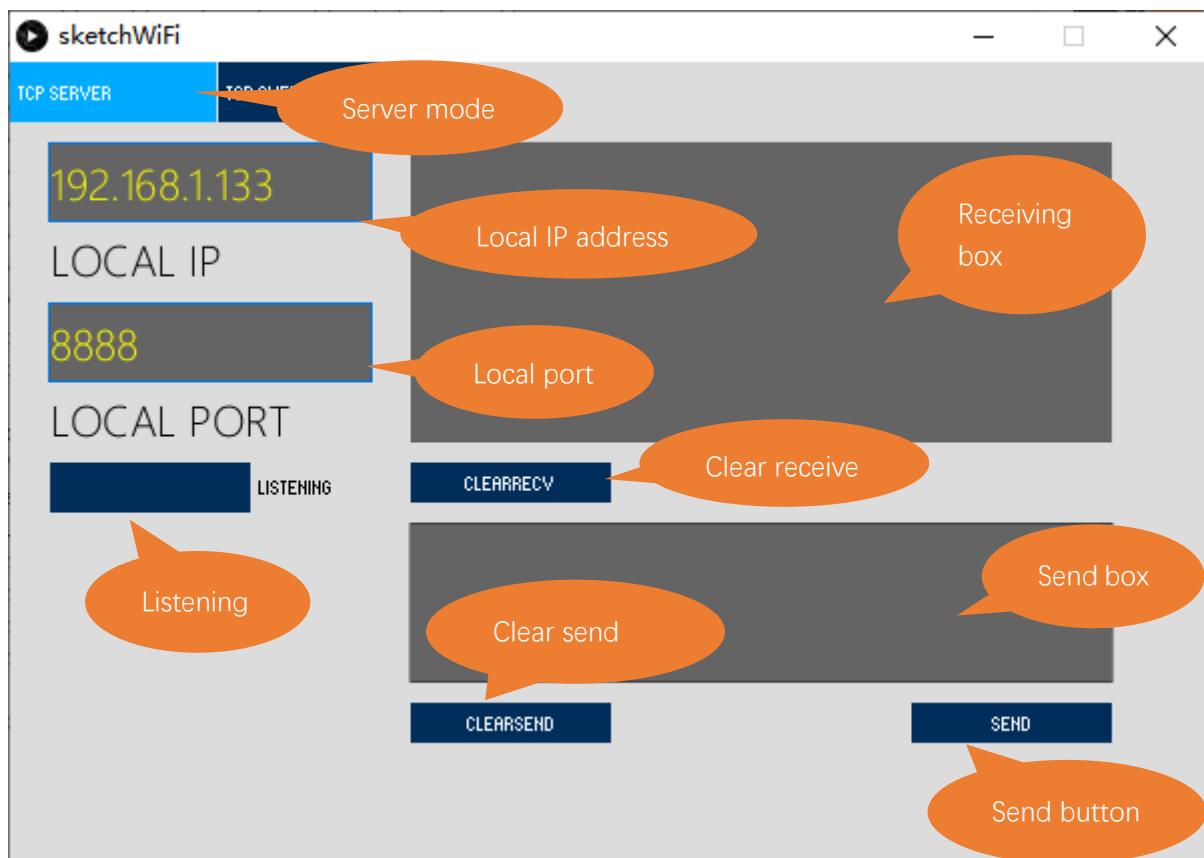
core	2020/1/17 12:16
java	2020/1/17 12:17
lib	2020/1/17 12:16
modes	2020/1/17 12:16
tools	2020/1/17 12:16
processing.exe	2020/1/17 12:16
processing-java.exe	2020/1/17 12:16
revisions.txt	2020/1/17 12:16

Use Server mode for communication

Open the “**Freenove\_Super\_Starter\_Kit\_for\_Raspberry\_Pi\_Pico\Sketches\Sketch\_22.1\_WiFiClient\sketchWiFi\sketchWiFi.pde**”, and click “Run”.

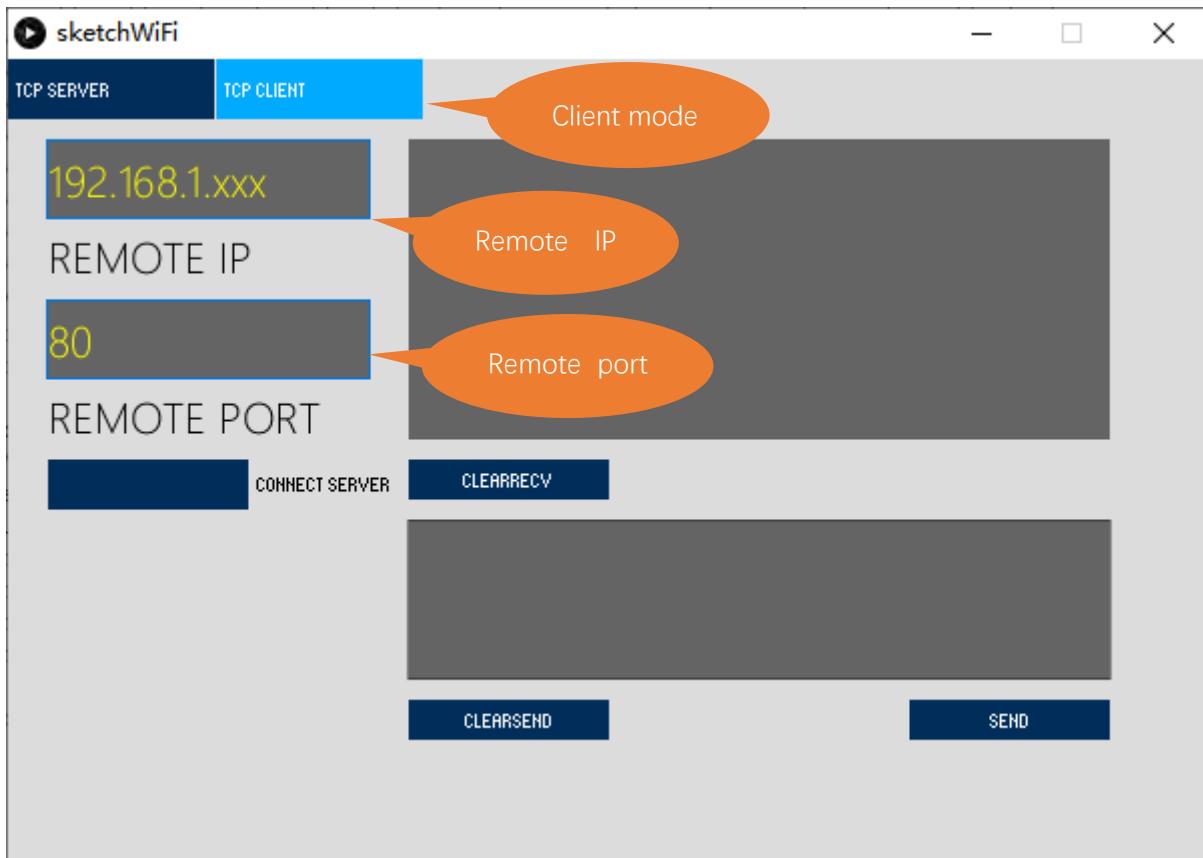


The new pop-up interface is as follows. If PICO W is used as client, select TCP SERVER mode for sketchWiFi.



When sketchWiFi selects TCP SERVER mode, Pico W Sketch needs to be changed according to sketchWiFi's displaying of LOCAL IP or LOCAL PORT.

If PICO W serves as server, select TCP CLIENT mode for sketchWiFi.



When sketchWiFi selects TCP CLIENT mode, the LOCAL IP and LOCAL PORT of sketchWiFi need to be changed according to the IP address and port number printed by the serial monitor.

#### **Mode selection: select Server mode/Client mode.**

**IP address:** In server mode, this option does not need to be filled in, and the computer will automatically obtain the IP address.

In client mode, fill in the remote IP address to be connected.

**Port number:** In server mode, fill in a port number for client devices to make an access connection.

In client mode, fill in port number given by the Server devices to make an access connection.

**Start button:** In server mode, push the button, then the computer will serve as server and open a port number for client to make access connection. During this period, the computer will keep monitoring.

In client mode, before pushing the button, please make sure the server is on, remote IP address and remote port number is correct; push the button, and the computer will make access connection to the remote port number of the remote IP as a client.

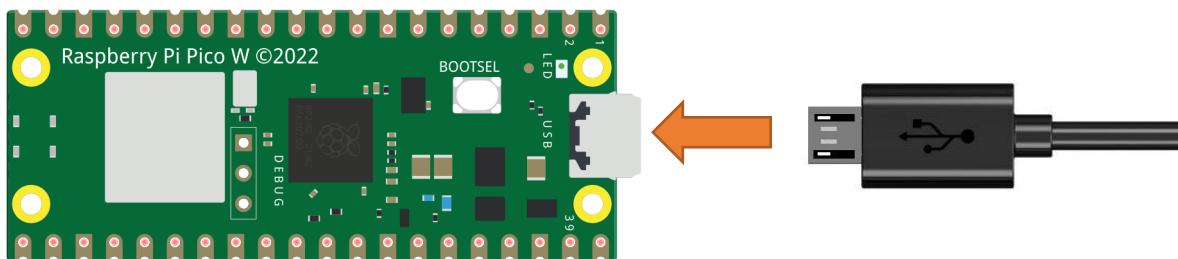
**clear receive:** clear out the content in the receiving text box

**clear send:** clear out the content in the sending text box

**Sending button:** push the sending button, the computer will send the content in the text box to others.

## Circuit

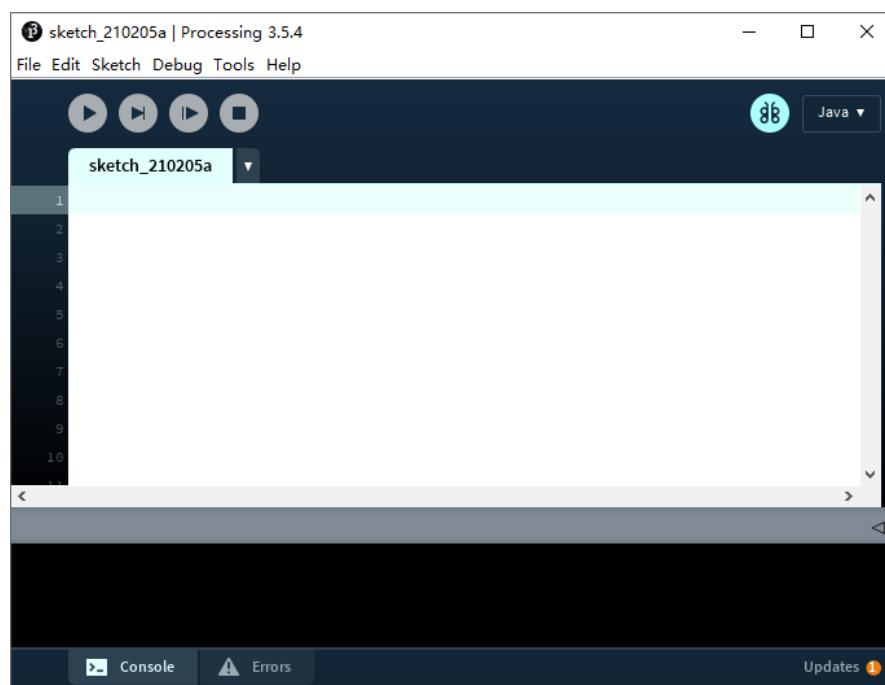
Connect Pico W to the computer using the USB cable.



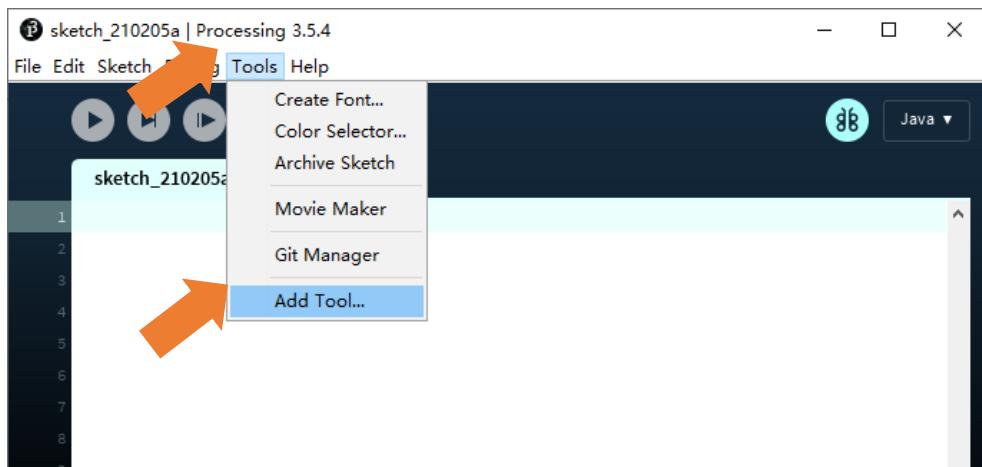
## Sketch

If you have not installed “ControlIP5”, please follow the following steps to continue the installation, if you have installed, please skip this section.

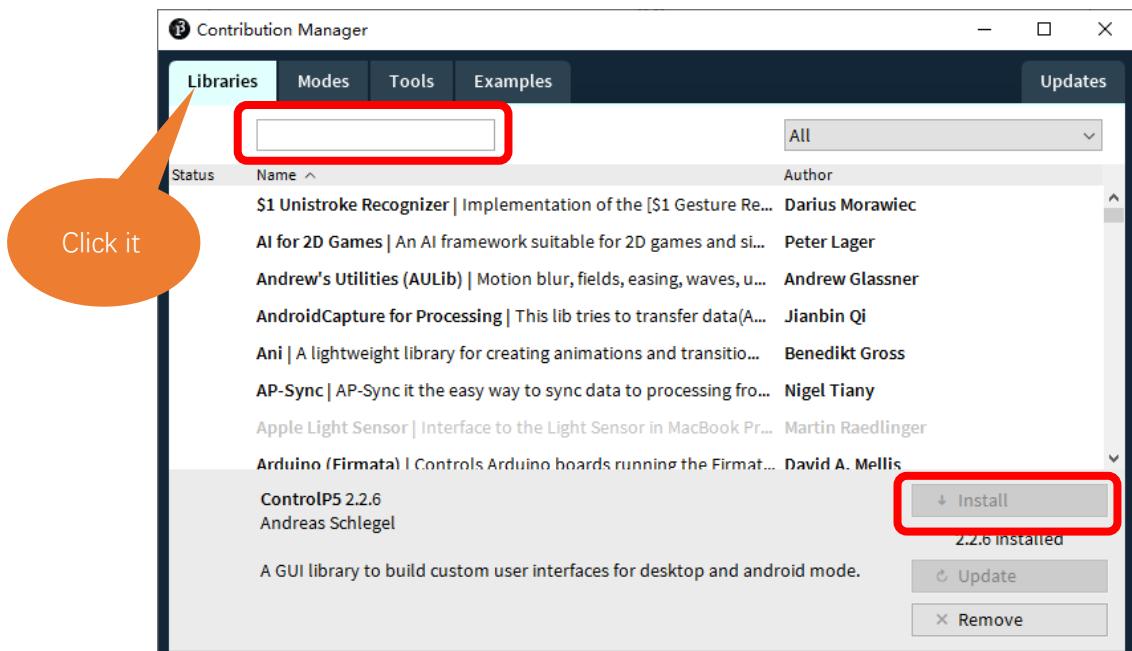
Open Processing.



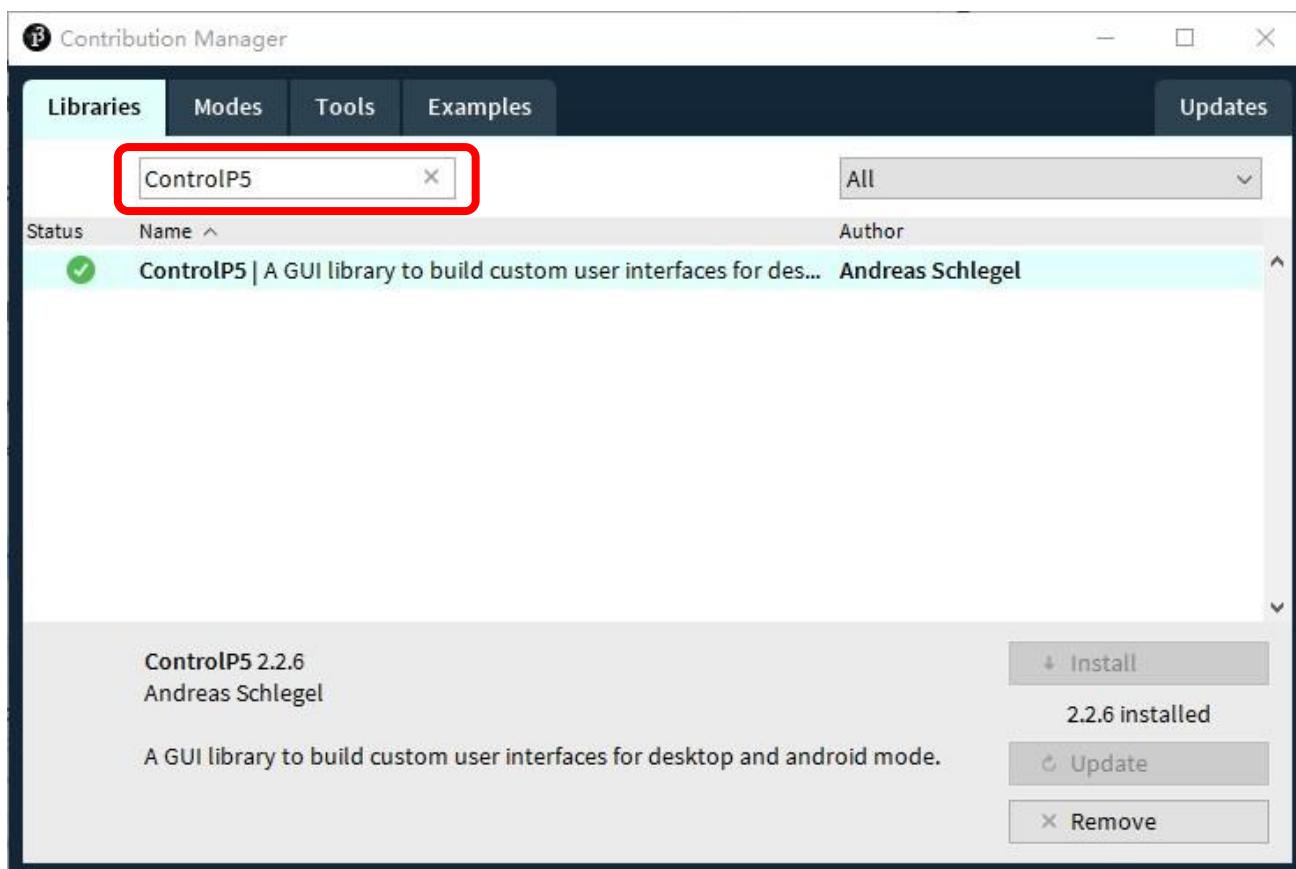
Click Add Tool under Tools.



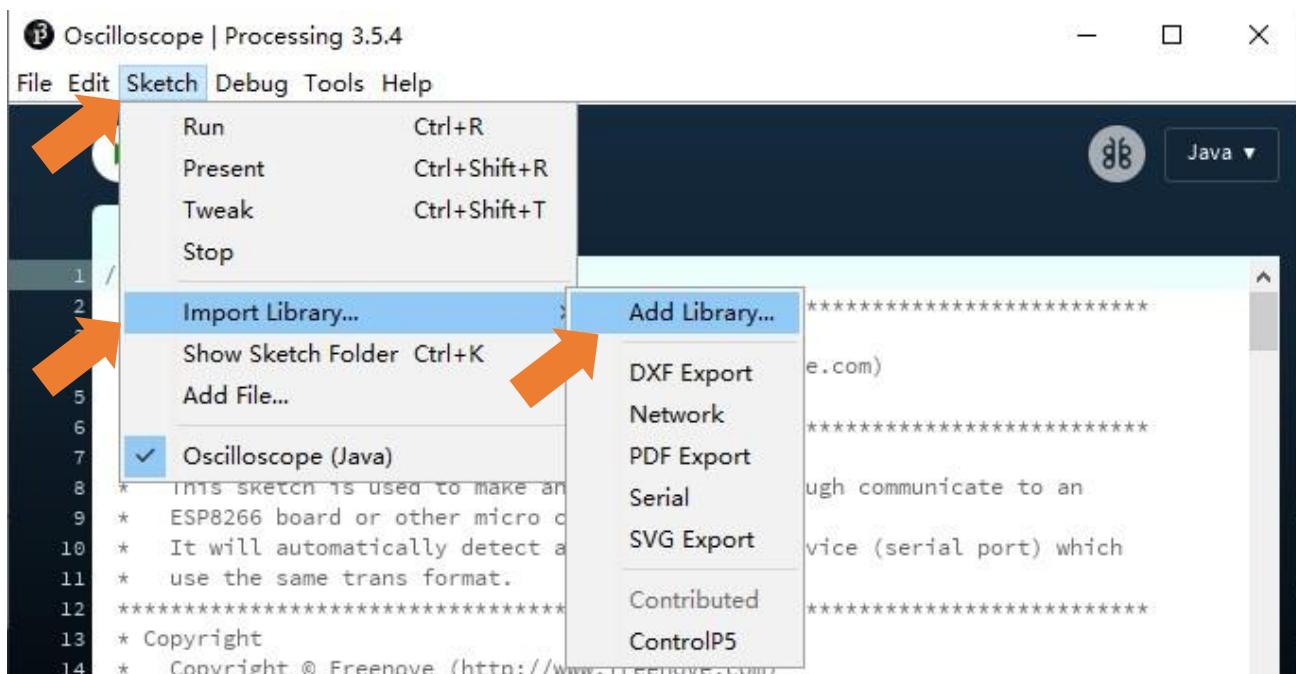
Select Libraries in the pop-up window.



Input "ControlP5" in the searching box, and then select the option as below. Click "Install" and wait for the installation to finish.

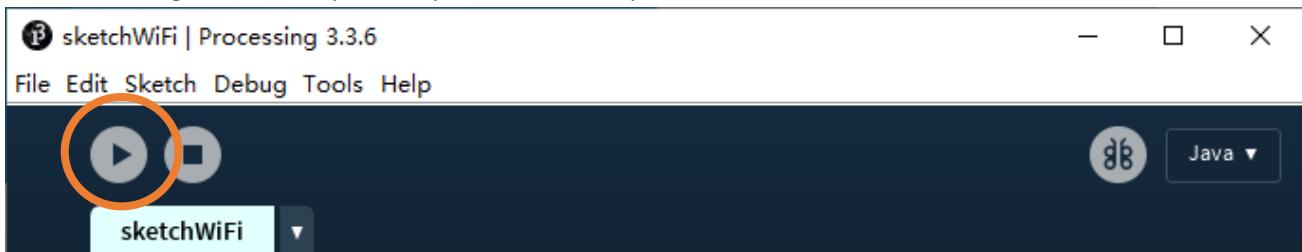


You can also click Add Library under 'Import Library' under 'Sketch'.

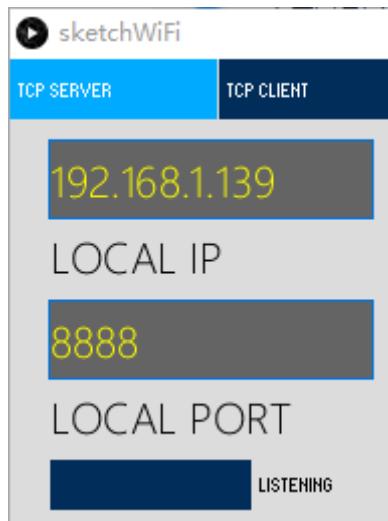


### Sketch\_22.1\_As Client

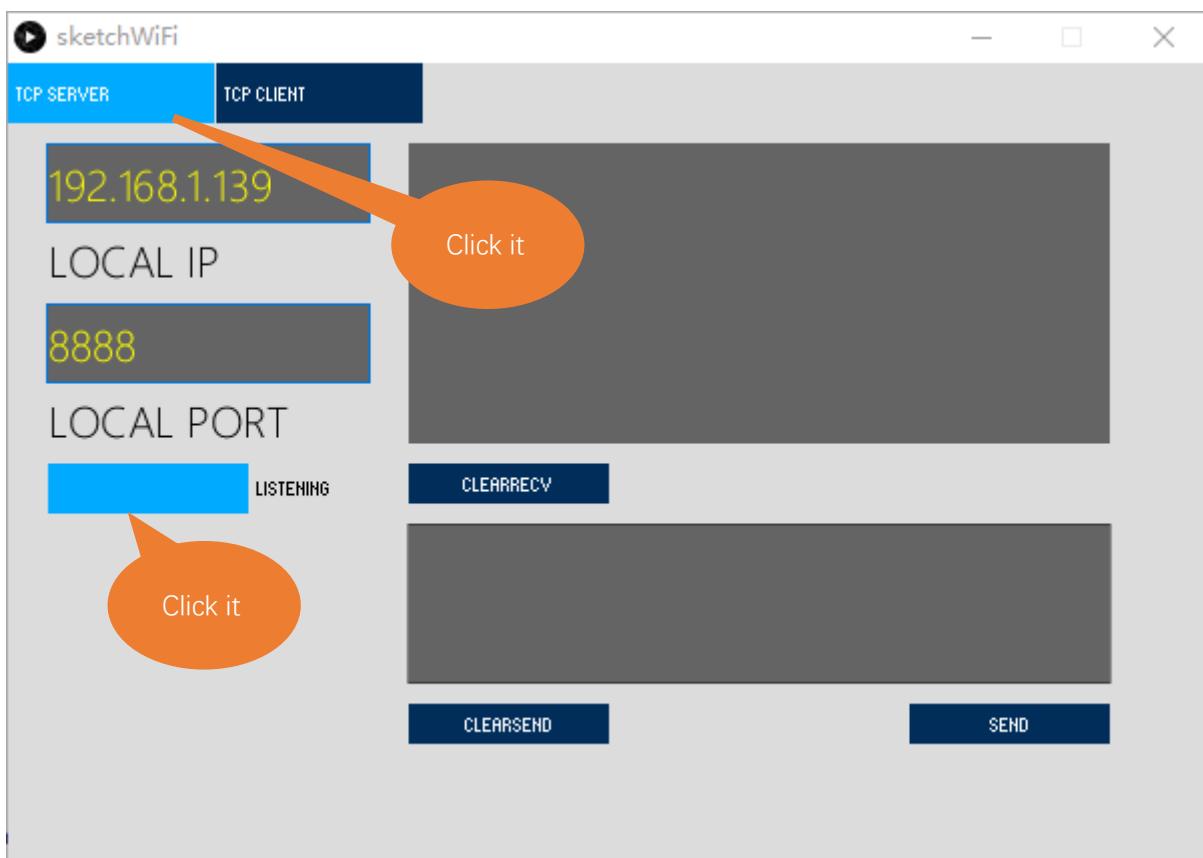
Before running the Sketch, please open “sketchWiFi.pde.” first, and click “Run”.



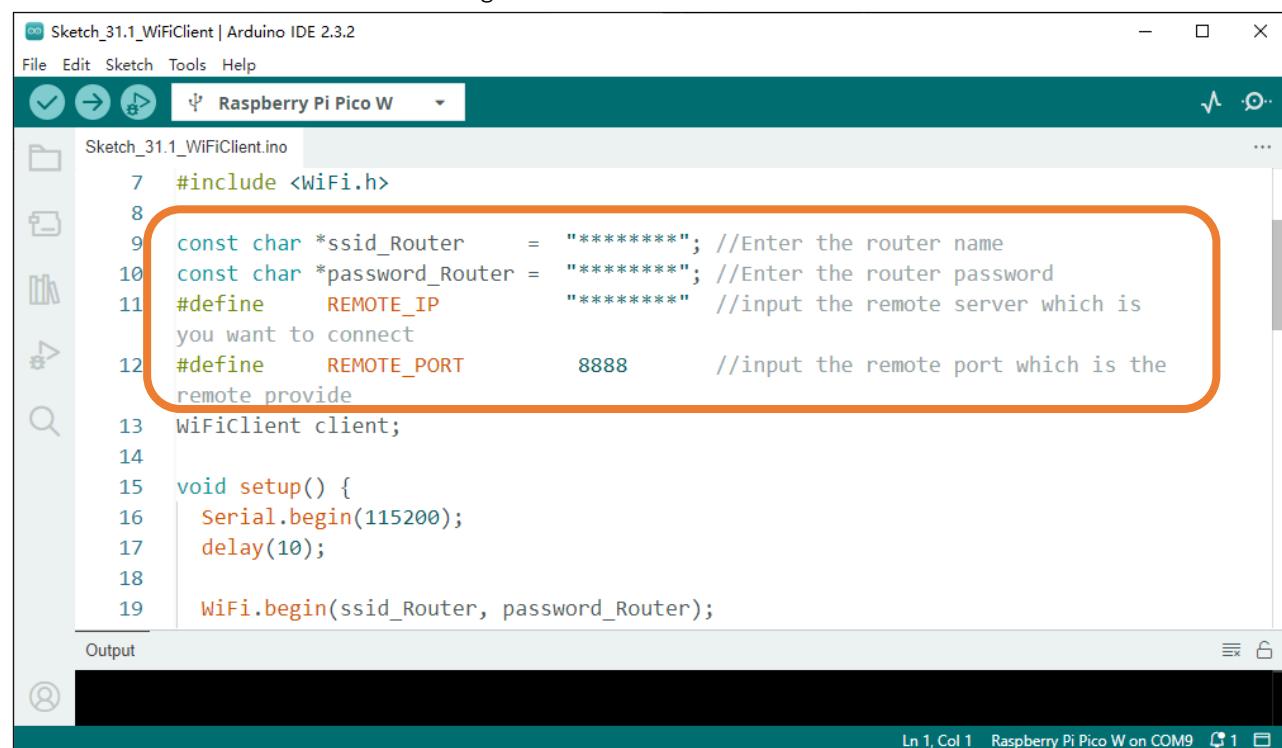
The newly pop up window will use the computer's IP address by default and open a data monitor port.



Click LISTENING, turn on TCP SERVER's data listening function and wait for PICO W to connect.



Next, open Sketch\_22.1\_WiFiClient.ino. Before running it, please change the following information based on "LOCAL IP" and "LOCAL PORT" in the figure above.



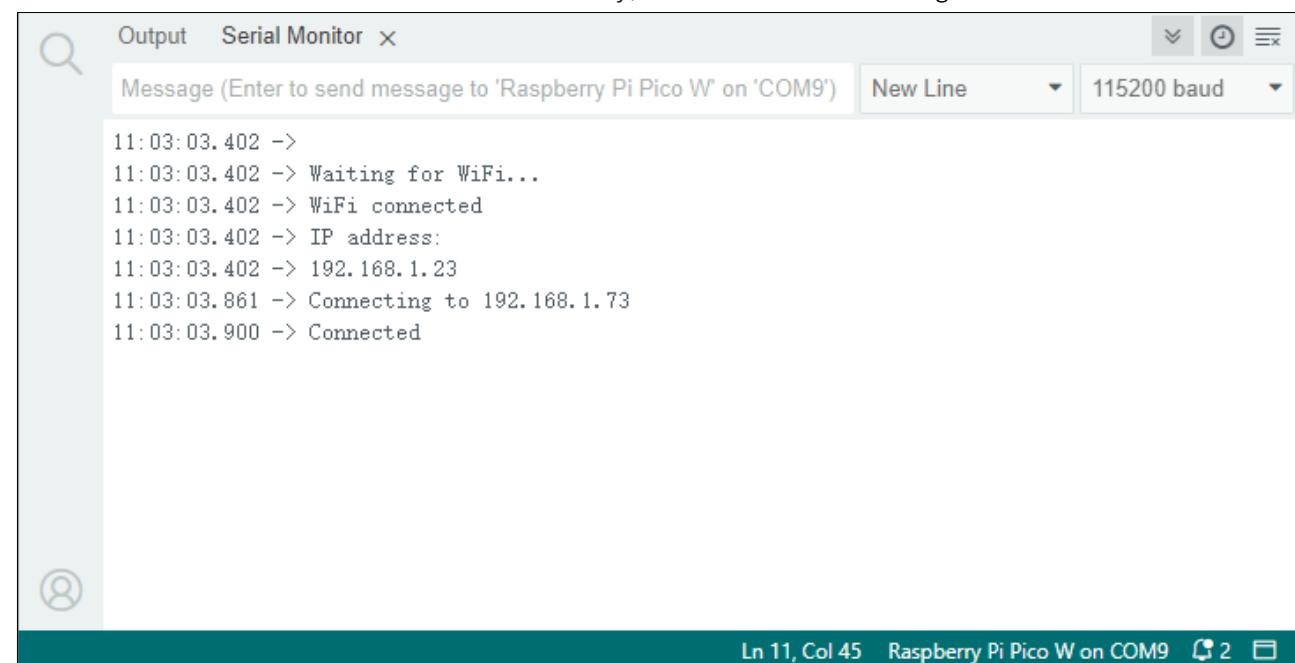
```

Sketch_31.1_WiFiClient | Arduino IDE 2.3.2
File Edit Sketch Tools Help
Raspberry Pi Pico W
Sketch_31.1_WiFiClient.ino
7 #include <WiFi.h>
8
9 const char *ssid_Router      = "*****"; //Enter the router name
10 const char *password_Router = "*****"; //Enter the router password
11 #define    REMOTE_IP          "*****" //input the remote server which is
you want to connect
12 #define    REMOTE_PORT        8888     //input the remote port which is the
remote provide
13 WiFiClient client;
14
15 void setup() {
16   Serial.begin(115200);
17   delay(10);
18
19   WiFi.begin(ssid_Router, password_Router);

```

REMOTE\_IP needs to be filled in according to the interface of sketchWiFi.pde. Taking this tutorial as an example, its REMOTE\_IP is "192.168.1.73". Generally, by default, the ports do not need to change its value.

Compile and upload code to PICO W, open the serial monitor and set the baud rate to 115200. PICO W connects router, obtains IP address and sends access request to server IP address on the same LAN till the connection is successful. When connect successfully, PICO W can send messages to server.



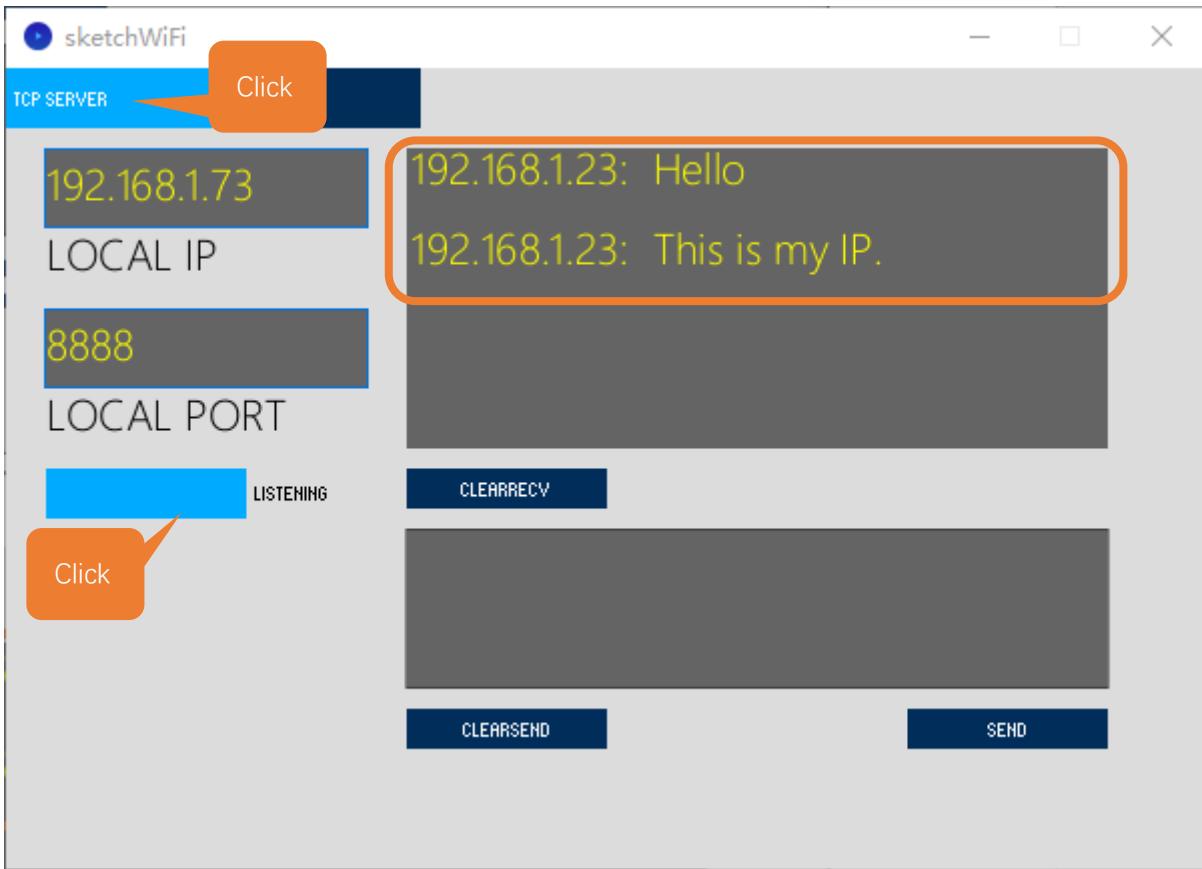
```

Output Serial Monitor ×
Message (Enter to send message to 'Raspberry Pi Pico W' on 'COM9') New Line 115200 baud
11:03:03.402 ->
11:03:03.402 -> Waiting for WiFi...
11:03:03.402 -> WiFi connected
11:03:03.402 -> IP address:
11:03:03.402 -> 192.168.1.23
11:03:03.861 -> Connecting to 192.168.1.73
11:03:03.900 -> Connected

```



PICO W connects with TCP SERVER, and TCP SERVER receives messages from PICO W, as shown in the figure below.



At this point, you can send data to Pico W through sketchWiFi. Pico W will send the received data back to sketchWiFi after receiving it.

The following is the program code:

```
1 #include <WiFi.h>
2
3 const char *ssid_Router      = "*****"; //Enter the router name
4 const char *password_Router = "*****"; //Enter the router password
5 #define    REMOTE_IP        "*****"   //input the remote server which is you want to connect
6 #define    REMOTE_PORT       8888      //input the remote port which is the remote provide
7 WiFiClient client;
8
9 void setup() {
10   Serial.begin(115200);
11   delay(10);
12
13   WiFi.begin(ssid_Router, password_Router);
14   Serial.print("\nWaiting for WiFi... ");
15   while (WiFi.status() != WL_CONNECTED) {
16     Serial.print(".");
17     delay(500);
18   }
19   Serial.println("");
20   Serial.println("WiFi connected");
21   Serial.println("IP address: ");
22   Serial.println(WiFi.localIP());
23   delay(500);
24
25   Serial.print("Connecting to ");
26   Serial.println(REMOTE_IP);
27
28   while (!client.connect(REMOTE_IP, REMOTE_PORT)) {
29     Serial.println("Connection failed.");
30     Serial.println("Waiting a moment before retrying... ");
31   }
32   Serial.println("Connected");
33   client.print("Hello\n");
34   client.print("This is my IP.\n");
35
36 void loop() {
37   if (client.available() > 0) {
38     delay(20);
39     //read back one line from the server
40     String line = client.readString();
41     Serial.println(REMOTE_IP + String(":") + line);
42   }
}
```

```

43   if (Serial.available() > 0) {
44     delay(20);
45     String line = Serial.readString();
46     client.print(line);
47   }
48   if (client.connected () == 0) {
49     client.stop();
50     WiFi.disconnect();
51   }
52 }
```

Add WiFi function header file.

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

Enter the actual router name, password, remote server IP address, and port number.

```

3 const char *ssid_Router      = "*****"; //Enter the router name
4 const char *password_Router = "*****"; //Enter the router password
5 #define    REMOTE_IP        "*****"  //input the remote server which is you want to connect
6 #define    REMOTE_PORT       8888     //input the remote port which is the remote provide
```

Apply for the method class of WiFiClient.

```
7 WiFiClient client;
```

Connect specified WiFi until it is successful. If the name and password of WiFi are correct but it still fails to connect. Please disconnect the power supply and try again several times.

```

13 WiFi.begin(ssid_Router, password_Router);
14 Serial.print("\nWaiting for WiFi... ");
15 while (WiFi.status() != WL_CONNECTED) {
16   Serial.print(".");
17   delay(500);
18 }
```

Send connection request to remote server until connect successfully. When connect successfully, print out the connecting prompt on the serial monitor and send messages to remote server.

```

28 while (!client.connect(REMOTE_IP, REMOTE_PORT)) {//Connect to Server
29   Serial.println("Connection failed.");
30   Serial.println("Waiting a moment before retrying... ");
31 }
32 Serial.println("Connected");
33 client.print("Hello\n");
```

When PICO W receive messages from servers, it will print them out via serial port; Users can also send messages to servers from serial port.

```

37 if (client.available() > 0) {
38   delay(20);
39   //read back one line from the server
40   String line = client.readString();
41   Serial.println(REMOTE_IP + String(":") + line);
42 }
43 if (Serial.available() > 0) {
```

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

```
44     delay(20);  
45     String line = Serial.readString();  
46     client.print(line);  
47 }
```

If the server is disconnected, turn off WiFi of PICO W.

```
48 if (client.connected () == false) {  
49     client.stop();  
50     WiFi.disconnect();  
51 }
```

## Reference

### Class Client

Every time when using Client, you need to include header file "WiFi.h"

**connect(ip, port, timeout)/connect(\*host, port, timeout)**: establish a TCP connection.

**ip, \*host**: ip address of target server

**port**: port number of target server

**timeout**: connection timeout

**connected()**: judge whether client is connecting. If return value is 1, then connect successfully; If return value is 0, then fail to connect.

**stop()**: stop tcp connection

**print()**: send data to server connecting to client

**available()**: return to the number of bytes readable in receive buffer, if no, return to 0 or -1.

**read()**: read one byte of data in receive buffer

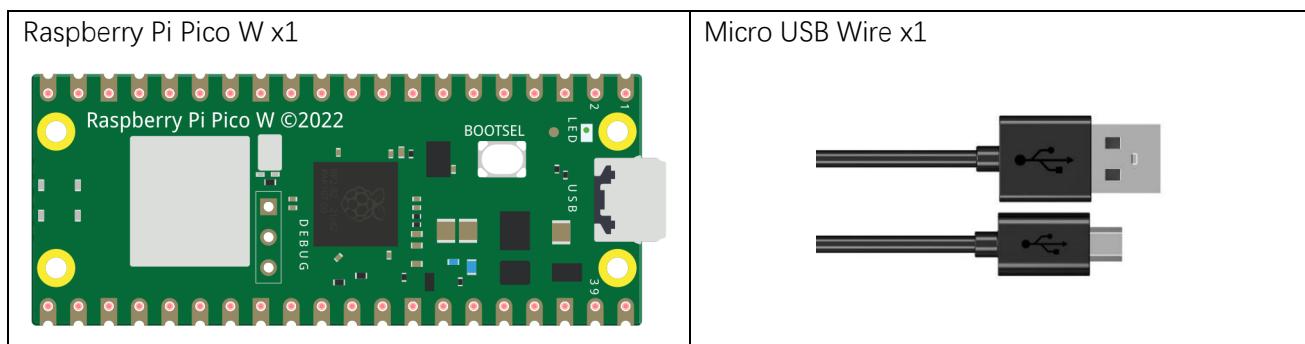
**readString()**: read string in receive buffer



## Project 22.2 as Server

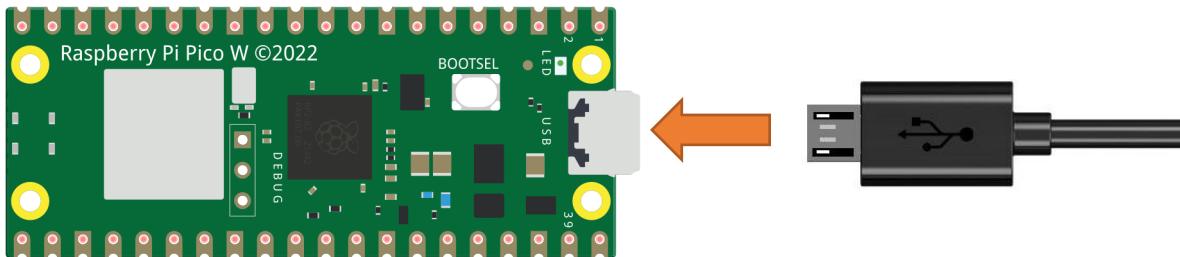
In this section, PICO W is used as a server to wait for the connection and communication of client on the same LAN.

### Component List



### Circuit

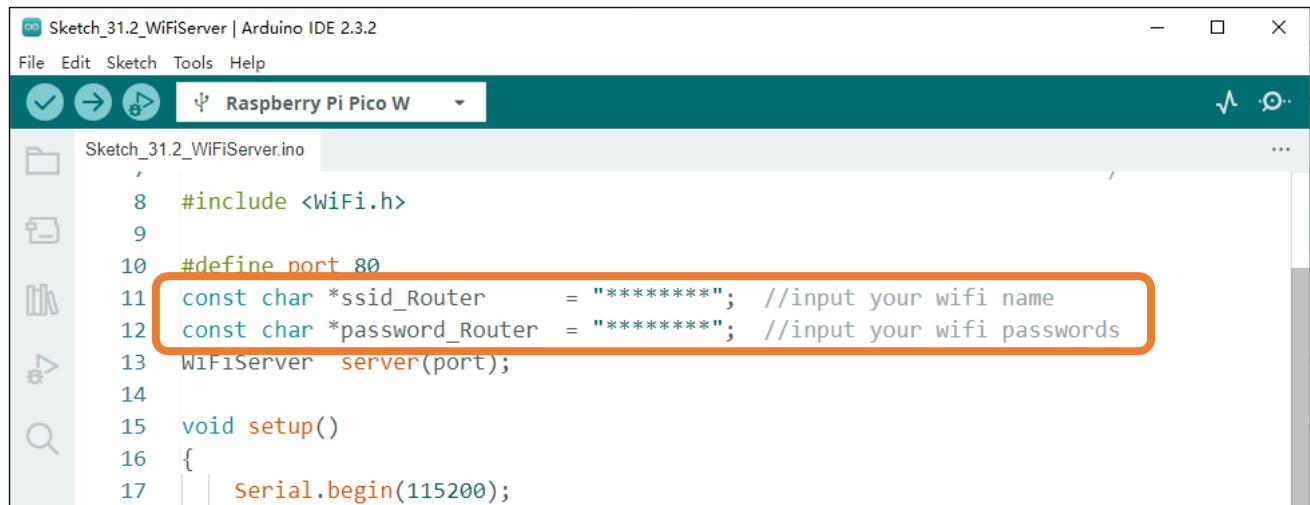
Connect Pico W to the computer using the USB cable.



## Sketch

Before running Sketch, please modify the contents of the box below first.

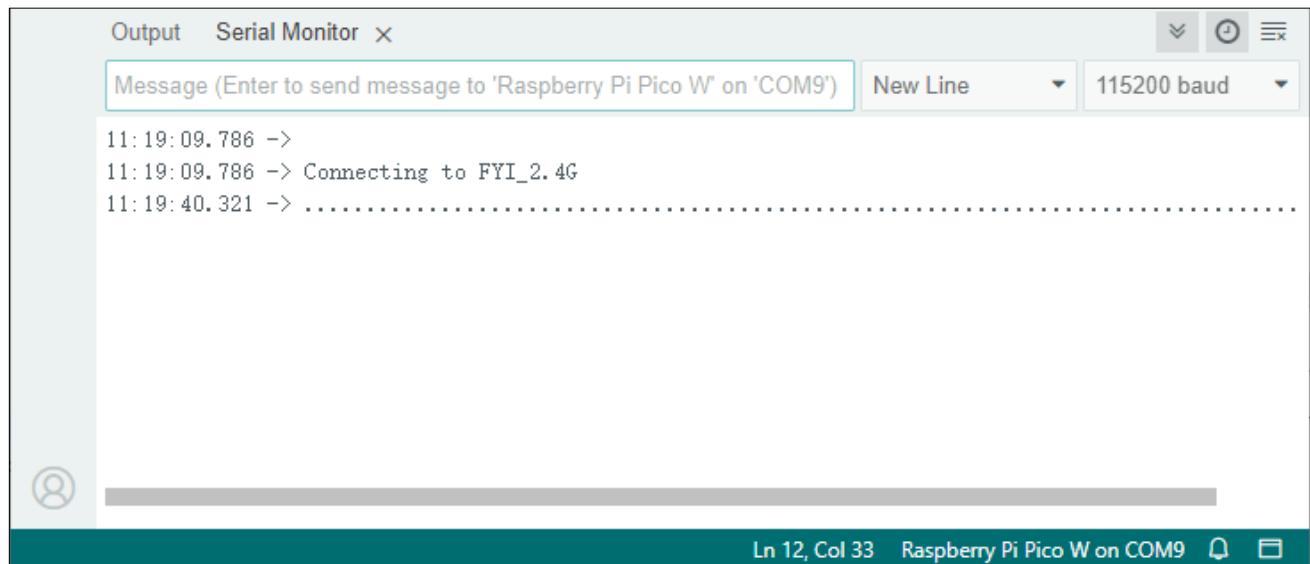
Sketch\_22.2\_As\_Server



```
Sketch_31.2_WiFiServer | Arduino IDE 2.3.2
File Edit Sketch Tools Help
Sketch_31.2_WiFiServer.ino
1
2   #include <WiFi.h>
3
4
5 #define port 80
6 const char *ssid_Router      = "*****"; //input your wifi name
7 const char *password_Router = "*****"; //input your wifi passwords
8 WiFiServer server(port);
9
10 void setup()
11 {
12     Serial.begin(115200);
```

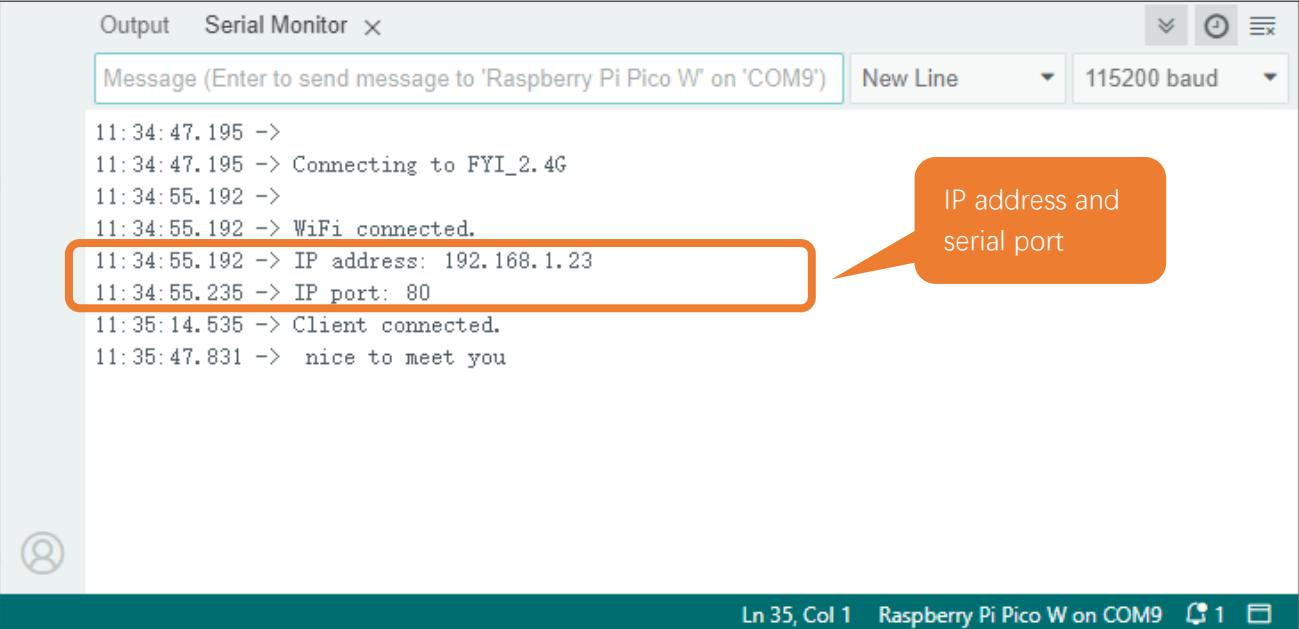
Compile and upload code to PICO W board, open the serial monitor and set the baud rate to 115200. Turn on server mode for PICO W, waiting for the connection of other devices on the same LAN. Once a device connects to server successfully, they can send messages to each other.

If the Pico W fails to connect to router, please disconnect the power supply and try again several times.



Output	Serial Monitor
Message (Enter to send message to 'Raspberry Pi Pico W' on 'COM9')	New Line
11:19:09.786 ->	115200 baud
11:19:09.786 -> Connecting to FYI_2.4G	
11:19:40.321 -> .....	

## Serial Monitor



Output   Serial Monitor ×

Message (Enter to send message to 'Raspberry Pi Pico W' on 'COM9')   New Line   115200 baud

```

11:34:47.195 ->
11:34:47.195 -> Connecting to FYI_2.4G
11:34:55.192 ->
11:34:55.192 -> WiFi connected.
11:34:55.192 -> IP address: 192.168.1.23
11:34:55.235 -> IP port: 80
11:35:14.535 -> Client connected.
11:35:47.831 -> nice to meet you

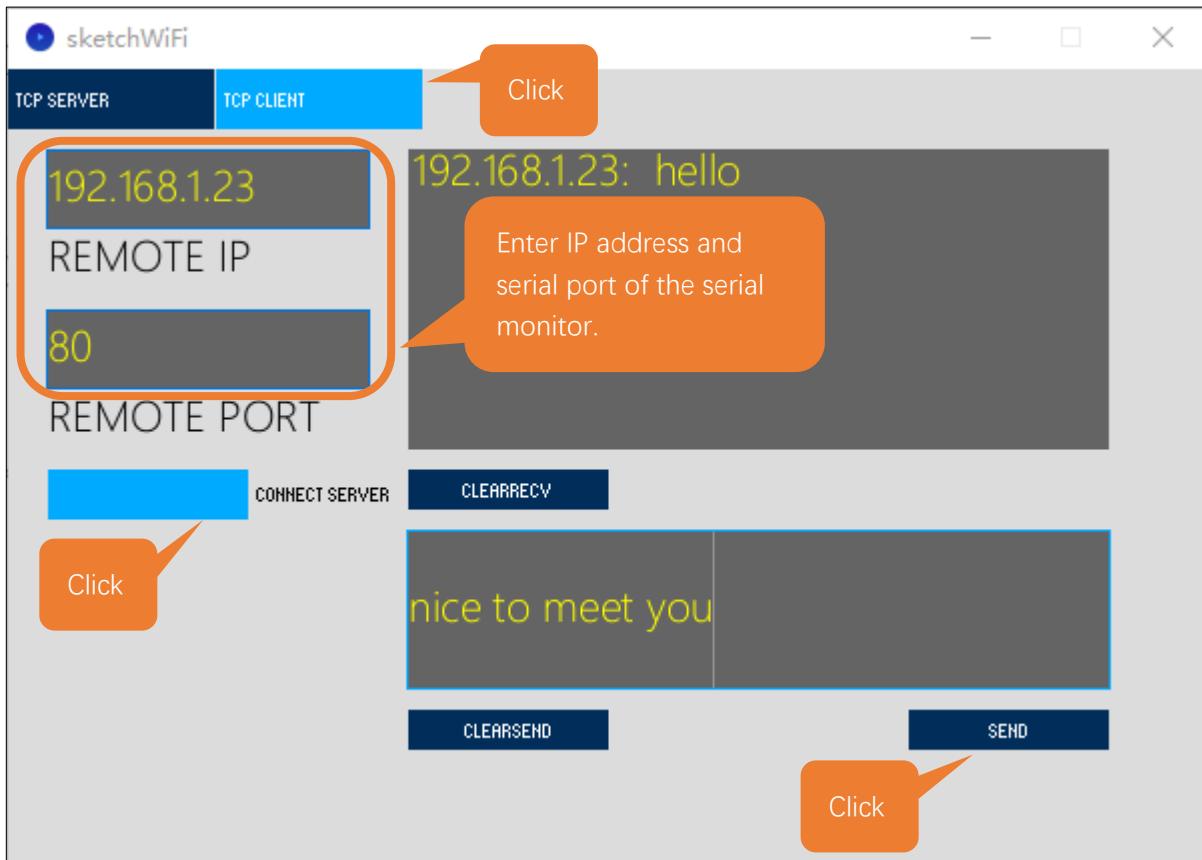
```

Ln 35, Col 1   Raspberry Pi Pico W on COM9   1

Processing:

Open the “**Freenove\_Super\_Starter\_Kit\_for\_Raspberry\_Pi\_Pico\Sketches\Sketch\_22.2\_WiFiServer\sketchWiFi\sketchWiFi.pde**”.

Based on the messages printed by the serial monitor, enter correct IP address and serial port in Processing to establish connection and make communication.



The following is the program code:

```
1 #include <WiFi.h>
2
3 #define port 80
4 const char *ssid_Router      = "*****"; //input your wifi name
5 const char *password_Router  = "*****"; //input your wifi passwords
6 WiFiServer server(port);
7
8 void setup()
9 {
10    Serial.begin(115200);
11    Serial.printf("\nConnecting to ");
12    Serial.println(ssid_Router);
13    WiFi.disconnect();
14    WiFi.begin(ssid_Router, password_Router);
15    delay(1000);
16    while (WiFi.status() != WL_CONNECTED) {
17        delay(500);
18        Serial.print(".");
19    }
20    Serial.println("");
21    Serial.println("WiFi connected.");
22    Serial.print("IP address: ");
23    Serial.println(WiFi.localIP());
24    Serial.printf("IP port: %d\n", port);
25    server.begin(port);
26 }
27
28 void loop() {
29    WiFiClient client = server.available();           // listen for incoming clients
30    if (client) {                                     // if you get a client
31        Serial.println("Client connected.");
32        while (client.connected()) {                  // loop while the client's connected
33            if (client.available()) {                  // if there's bytes to read from the
34                Serial.println(client.readStringUntil('\n'));// print it out the serial monitor
35                while (client.read() > 0);               // clear the wifi receive area cache
36            }
37            if (Serial.available()) {                  // if there's bytes to read from the
38                client.print(Serial.readStringUntil('\n'));// print it out the client.
39                while (Serial.read() > 0);              // clear the wifi receive area cache
40            }
41        }
42    }
43 }
```

```

42     client.stop();                                // stop the client connecting.
43     Serial.println("Client Disconnected.");
44 }
45 }
```

Apply for method class of WiFiServer.

```

6 WiFiServer server(port);           //Apply for a Server object whose port number is 80
```

Connect specified WiFi until it is successful. If the name and password of WiFi are correct but it still fails to connect, please disconnect the power supply and try again several times.

```

13 WiFi.disconnect();
14 WiFi.begin(ssid_Router, password_Router);
15 delay(1000);
16 while (WiFi.status() != WL_CONNECTED) {
17     delay(500);
18     Serial.print(".");
19 }
20 Serial.println("");
21 Serial.println("WiFi connected.");
```

Print out the IP address and port number of PICO W.

```

22 Serial.print("IP address: ");
23 Serial.println(WiFi.localIP());          //print out IP address of PICO W
24 Serial.printf("IP port: %d\n", port);    //Print out PICO W's port number
```

Turn on server mode of PICO W.

```

25 server.begin();                         //Turn ON PICO W as Server mode
```

When PICO W receive messages from servers, it will print them out via serial port; Users can also send messages to servers from serial port.

```

33     if (client.available()) {                // if there's bytes to read from the
client
34         Serial.println(client.readStringUntil('\n'));// print it out the serial monitor
35         while(client.read()>0);                  // clear the wifi receive area cache
36     }
37     if(Serial.available()){                  // if there's bytes to read from the
serial monitor
38         client.print(Serial.readStringUntil('\n'));// print it out the client.
39         while(Serial.read()>0);                  // clear the wifi receive area cache
40     }
```

## Reference

### Class Server

Every time use Server functionality, we need to include header file "WiFi.h".

**WiFiServer(uint16\_t port=80, uint8\_t max\_clients=4)**: create a TCP Server.

**Port**: ports of Server; range from 0 to 65535 with the default number as 80.

**max\_clients**: maximum number of clients with default number as 4.

**begin(port)**: start the TCP Server.

**Port**: port of Server; range from 0 to 65535 with the default number as 0.

**setNoDelay(bool nodelay)**: whether to turn off the delay sending functionality.

**nodelay**: true stands for forbidden Nagle algorithm.

**close()**: close tcp connection.

**stop()**: stop tcp connection.



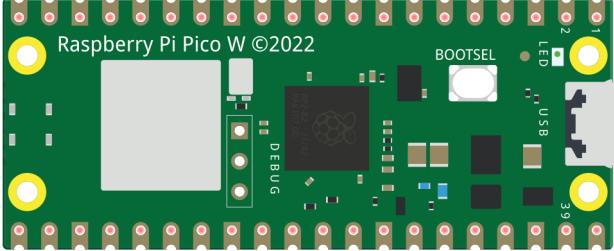
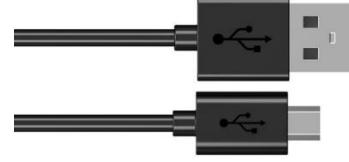
# Chapter 23 Control LED with Web (Only for Pico W)

In this chapter, we will use PICO W to make a simple smart home. We will learn how to control LED lights through web pages.

## Project 23.1 Control the LED with Web

In this project, we need to build a Web Service and then use PICO W to control the LED through the Web browser of the phone or PC. Through this example, you can remotely control the appliances in your home to achieve smart home.

### Component List

Raspberry Pi Pico W x1	Micro USB Wire x1
	

## Component knowledge

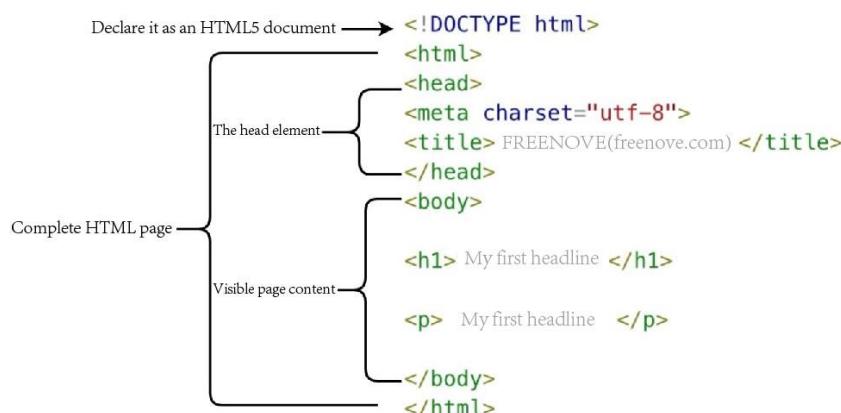
### HTML

Hypertext Markup Language (HTML) is a standard Markup Language for creating web pages. It includes a set of tags that unify documents on the network and connect disparate Internet resources into a logical whole. HTML text is descriptive text composed of HTML commands that describe text, graphics, animations, sounds, tables, links, etc. The extension of the HTML file is HTM or HTML. Hypertext is a way to organize information. It uses hyperlinks to associate words and charts in Text with other information media. These related information media may be in the same Text, other files, or files located on a remote computer. This way of organizing information connects the information resources distributed in different places, which is convenient for people to search and retrieve information.

The nature of the Web is hypertext Markup Language (HTML), which can be combined with other Web technologies (e.g., scripting languages, common gateway interfaces, components, etc.) to create powerful Web pages. Thus, Hypertext Markup Language (HTML) is the foundation of World Wide Web (Web) programming, that is, the World Wide Web is based on hypertext. Hypertext Markup Language is called hypertext Markup language because the text contains so-called "hyperlink" points.

You can build your own WEB site using HTML, which runs on the browser and is parsed by the browser.

Example analysis is shown in the figure below:



**<!DOCTYPE html>**: Declare it as an HTML5 document

**<html>**: Is the root element of an HTML page

**<head>**: Contains meta data for the document, such as `<meta charset="utf-8">`; Define the web page encoding format to UTF-8.

**<title>**: Notes the title of the document

**<body>**: Contains visible page content

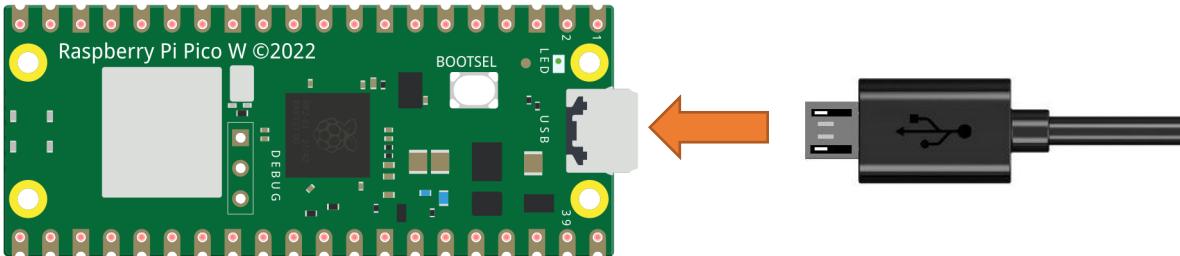
**<h1>**: Define a big heading

**<p>**: Define a paragraph

For more information, please visit: <https://developer.mozilla.org/en-US/docs/Web/HTML>

## Circuit

Connect Pico W to the computer using the USB cable.



## Sketch

### Sketch\_23.1\_Control\_the\_LED\_with\_Web

The screenshot shows the Arduino IDE interface with the sketch `Sketch_23.1_Control_the_LED_with_Web.ino` open. The code is written in C++ and uses the WiFi library to connect to a Wi-Fi network and serve a web page. It includes variables for SSID and password, which are highlighted with a red rectangle and a callout bubble. The callout bubble contains the text: "Enter the correct Router name and password."

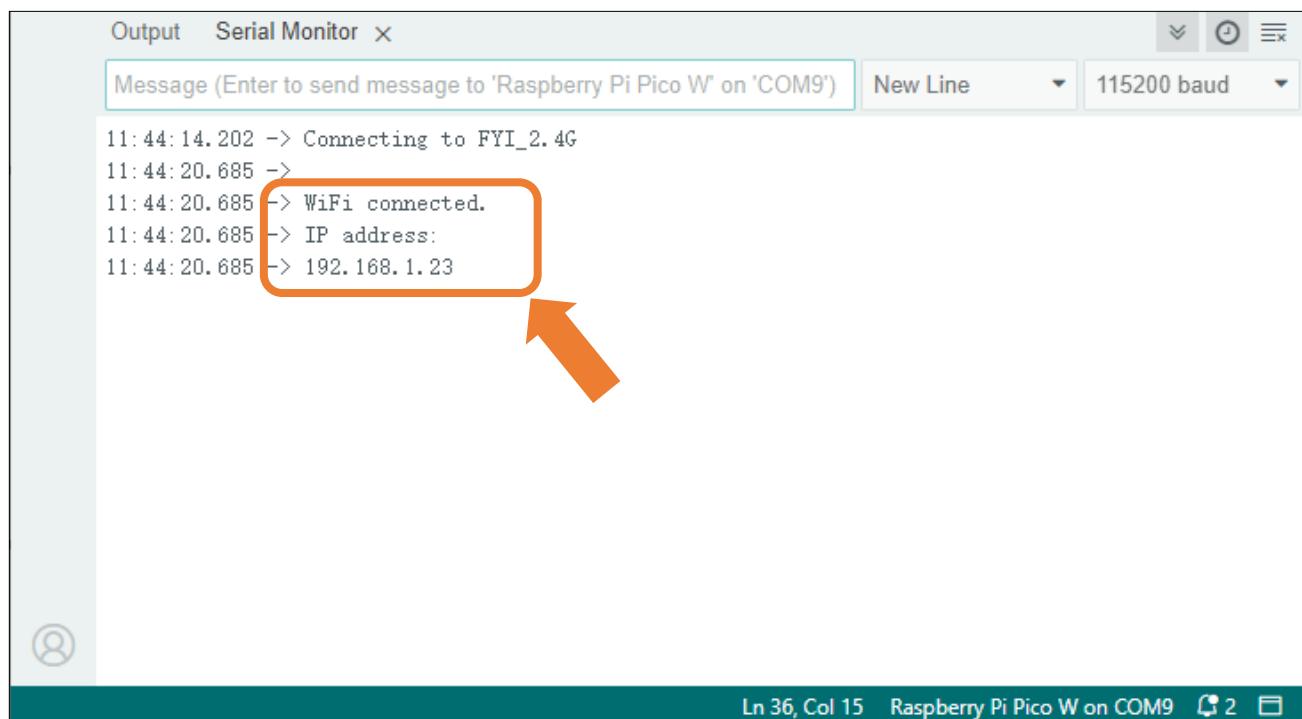
```

11 #include <WiFi.h>
12
13 // Replace with your network credentials
14 const char* ssid      = "*****";
15 const char* password = "*****";
16
17 // Set web server port number to 80
18 WiFiServer server(80);
19 // Variable to store the HTTP request
20 String header;
21 // Auxiliar variables to store the current output state
22 String PIN_LEDstate = "OFF";
23
24 // Current time
25 unsigned long currentTime = millis();
26 // Previous time
27 unsigned long previousTime = 0;
28 // Define timeout time in milliseconds (example: 2000ms = 2s)
29 const long timeoutTime = 2000;
30
31 void setup() {
32   Serial.begin(115200);
33   // Initialize the output variables as outputs
34   pinMode(LED_BUILTIN, OUTPUT);
35   digitalWrite(LED_BUILTIN, LOW);
36
37   // Connect to Wi-Fi network with SSID and password
38   Serial.print("Connecting to ");

```

Ln 1, Col 1   X No board selected

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



The screenshot shows the 'Serial Monitor' window with the title 'Output' and 'Serial Monitor'. The message area contains the following text:

```
11:44:14.202 -> Connecting to FYI_2.4G  
11:44:20.685 ->  
11:44:20.685 -> WiFi connected.  
11:44:20.685 -> IP address:  
11:44:20.685 -> 192.168.1.23
```

An orange arrow points from the text 'As shown in the following figure:' to the line '11:44:20.685 -> WiFi connected.'.

When PICO W successfully connects to "ssid\_Router", serial monitor will print out the IP address assigned to PICO W by the router. Access <http://192.168.1.23> in a computer browser on the LAN. [As shown in the following figure:](#)



You can click the corresponding button to control the LED on and off.



The following is the program code:

```
1 #include <WiFi.h>
2
3 // Replace with your network credentials
4 const char* ssid      = "*****";
5 const char* password = "*****";
6
7 // Set web server port number to 80
8 WiFiServer server(80);
9 // Variable to store the HTTP request
10 String header;
11 // Auxiliar variables to store the current output state
12 String PIN_LEDState = "OFF";
13
14 // Current time
15 unsigned long currentTime = millis();
16 // Previous time
17 unsigned long previousTime = 0;
18 // Define timeout time in milliseconds (example: 2000ms = 2s)
19 const long timeoutTime = 2000;
20
21 void setup() {
22     Serial.begin(115200);
23     // Initialize the output variables as outputs
24     pinMode(LED_BUILTIN, OUTPUT);
25     digitalWrite(LED_BUILTIN, LOW);
26
27     // Connect to Wi-Fi network with SSID and password
28     Serial.print("Connecting to ");
29     Serial.println(ssid);
30     WiFi.begin(ssid, password);
31     while (WiFi.status() != WL_CONNECTED) {
32         delay(500);
33         Serial.print(".");
34     }
35     // Print local IP address and start web server
36     Serial.println("");
37     Serial.println("WiFi connected.");
38     Serial.println("IP address: ");
39     Serial.println(WiFi.localIP());
40     server.begin();
41 }
42 void loop() {
43     WiFiClient client = server.available(); // Listen for incoming clients
```

Any concerns? ✉ support@freenove.com

```
44  if (client) {                                // If a new client connects,
45      Serial.println("New Client.");           // print a message out in the serial port
46      String currentLine = "";                 // make a String to hold incoming data from the
47      client
48      currentTime = millis();
49      previousTime = currentTime;
50      while (client.connected() && currentTime - previousTime <= timeoutTime) { // loop while
the client's connected
51          currentTime = millis();
52          if (client.available()) { // if there's bytes to read from the client,
53              char c = client.read(); // read a byte, then
54              Serial.write(c);       // print it out the serial monitor
55              header += c;
56              if (c == '\n') { // if the byte is a newline character
57                  // if the current line is blank, you got two newline characters in a row.
58                  // that's the end of the client HTTP request, so send a response:
59                  if (currentLine.length() == 0) {
60                      // HTTP headers always start with a response code (e.g. HTTP/1.1 200 OK)
61                      // and a content-type so the client knows what's coming, then a blank line:
62                      client.println("HTTP/1.1 200 OK");
63                      client.println("Content-type:text/html");
64                      client.println("Connection: close");
65                      client.println();
66                      // turns the GPIOs on and off
67                      if (header.indexOf("GET /LED_BUILTIN/ON") >= 0) {
68                          Serial.println("LED_BUILTIN ON");
69                          PIN_LEDState = "ON";
70                          digitalWrite(LED_BUILTIN, HIGH);
71                      } else if (header.indexOf("GET /LED_BUILTIN/OFF") >= 0) {
72                          Serial.println("LED_BUILTIN OFF");
73                          PIN_LEDState = "OFF";
74                          digitalWrite(LED_BUILTIN, LOW);
75                      }
76                      // Display the HTML web page
77                      client.println("<!DOCTYPE html><html>");
78                      client.println("<head> <title>Pico W Web Server</title> <meta name=\"viewport\""
content="width=device-width, initial-scale=1">");
79                      client.println("<link rel=\"icon\" href=\"data:, \">");
80                      // CSS to style the on/off buttons
81                      // Feel free to change the background-color and font-size attributes to fit your
preferences
82                      client.println("<style>html {font-family: Helvetica; display:inline-block; margin:
0px auto; text-align: center;}</style>");
```



```

83         client.println(".button{background-color: #4286f4; display: inline-block; border:
84             none; border-radius: 4px; color: white; padding: 16px 40px;text-decoration: none; font-size:
85             30px; margin: 2px; cursor: pointer;}");
86         client.println(".button2{background-color: #4286f4;display: inline-block; border:
87             none; border-radius: 4px; color: white; padding: 16px 40px;text-decoration: none; font-size:
88             30px; margin: 2px; cursor: pointer;}</style></head>");
89         // Web Page Heading
90         client.println("<body><h1>Pico W Web Server</h1>");
91         client.println("<p>GPIO state: " + PIN_LEDState + "</p>"); 
92         client.println("<p><a href=\"/LED_BUILTIN/ON\"><button class=\"button
button2\">ON</button></a></p>"); 
93         client.println("<p><a href=\"/LED_BUILTIN/OFF\"><button class=\"button
button2\">OFF</button></a></p>"); 
94         client.println("</body></html>"); 
95         // The HTTP response ends with another blank line
96         client.println(); 
97         // Break out of the while loop
98         break;
99     } else { // if you got a newline, then clear currentLine
100        currentLine = "";
101    }
102  }
103  // Clear the header variable
104  header = "";
105  // Close the connection
106  client.stop();
107  Serial.println("Client disconnected.");
108  Serial.println("");
109 }
110 }
```

Include the WiFi Library header file of PICO W.

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

Enter correct router name and password.

```
3 const char* ssid      = "*****"; //Enter the router name
4 const char* password = "*****"; //Enter the router password
```

Set PICO W in Station mode and connect it to your router.

```
30 WiFi.begin(ssid, password);
```

Check whether PICO W has connected to router successfully every 0.5s.

```
31 while (WiFi.status() != WL_CONNECTED) {
32     delay(500);
```

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

```
33     Serial.print(".");
34 }
```

Serial monitor prints out the IP address assigned to PICO W.

```
39 Serial.println(WiFi.localIP());
```

Click the button on the web page to control the LED light on and off.

```
65 // turns the GPIOs on and off
66 if (header.indexOf("GET /LED_BUILTIN/ON") >= 0) {
67     Serial.println("LED_BUILTIN ON");
68     PIN_LEDState = "ON";
69     digitalWrite(LED_BUILTIN, HIGH);
70 } else if (header.indexOf("GET /LED_BUILTIN/OFF") >= 0) {
71     Serial.println("LED_BUILTIN OFF");
72     PIN_LEDState = "OFF";
73     digitalWrite(LED_BUILTIN, LOW);
74 }
```

# Chapter 24 Bluetooth (Only for Pico W)

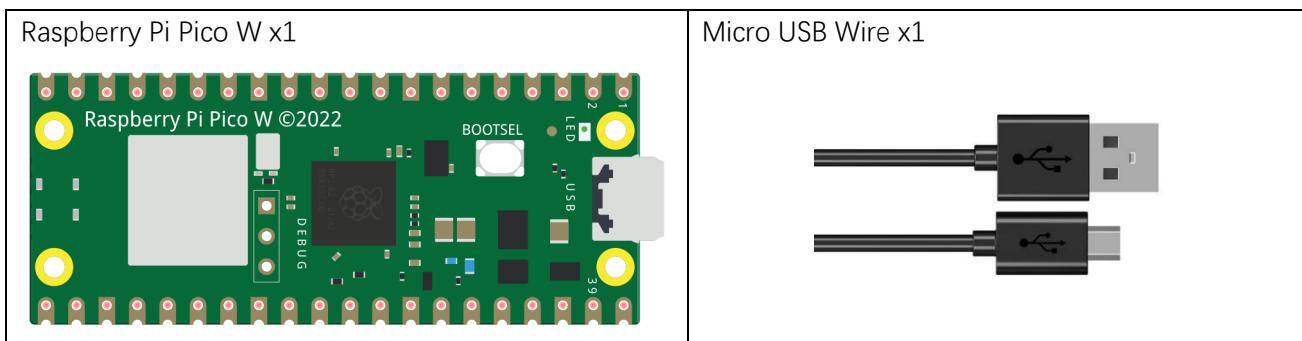
In June 2023, Raspberry Pi Official has updated to add Bluetooth support to the Pico W.

Pico W's Bluetooth 5.2 supports Bluetooth Classic and Bluetooth Low Energy (BLE) functionality. At the beginning of this chapter, we will learn the Pico W's Bluetooth function.

If you have Pico in your hand, please change it to Pico W before continuing to learn.

## Project 24.1 Bluetooth Passthrough

### Component List



### Component knowledge

Pico W's wireless functionality is provided by the Infineon CYW43439 device, which contains a 2.4 GHz radio providing both 802.11n Wi-Fi and Bluetooth 5.2, supporting Bluetooth Classic and Bluetooth Low Energy (BLE) functionality.

For simple data transfer, there are two modes:

#### Master mode

A device works in master mode can connect to one or more slave devices.

We can search and select the slave devices nearby to connect.

When a device initiates a connection request in master mode, it requires information about other Bluetooth devices, including their addresses and pairing keys.

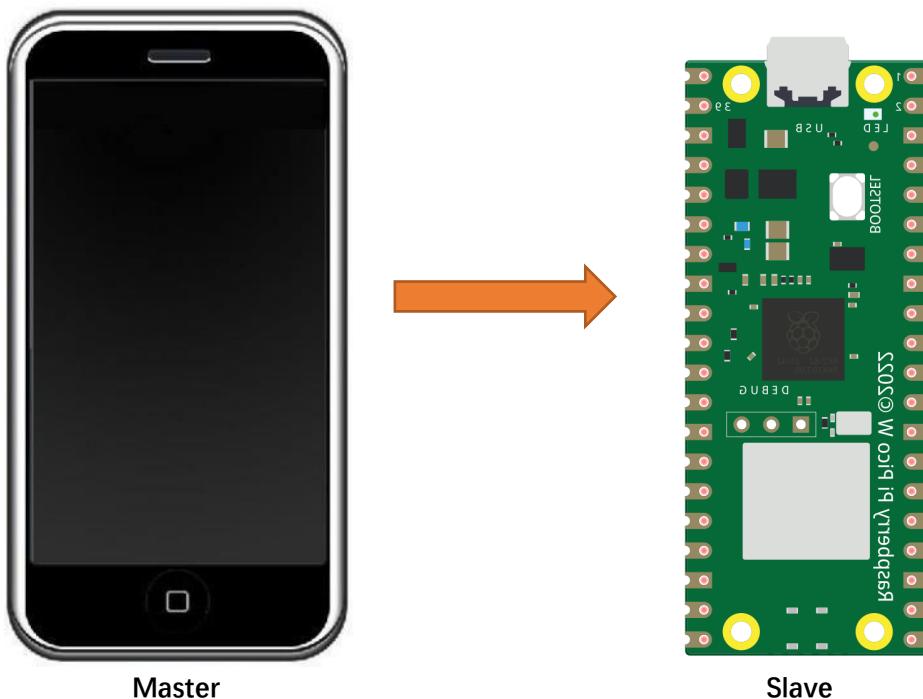
Once the devices are paired, a direct connection can be established.

#### Slave mode

A Bluetooth module operating in slave mode can only receive connection requests from a master device and cannot actively initiate connections.

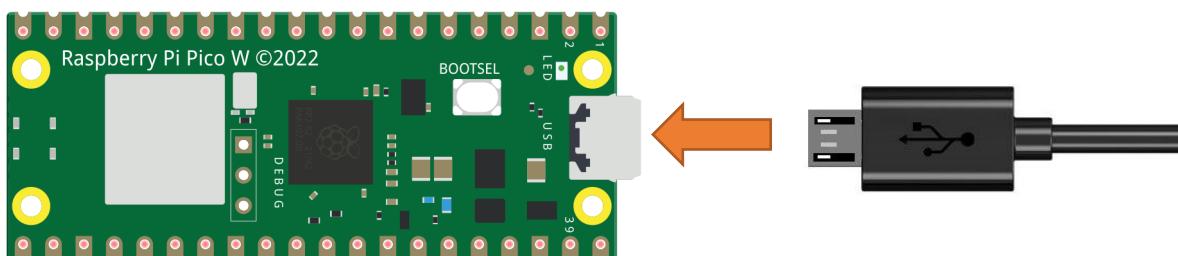
After establishing a connection with a master device, it can either send or receive data.

Bluetooth devices can interact with each other, with one in master mode and the other in slave mode. During data communication, the master device searches for and selects nearby devices to connect with. Once a connection is made, data can be exchanged between the devices. In the case of data exchange between a smartphone and a Raspberry Pi Pico W, the smartphone typically operates in master mode, while the Raspberry Pi Pico W functions in slave mode.



## Circuit

Connect Pico W to the computer using the USB cable.

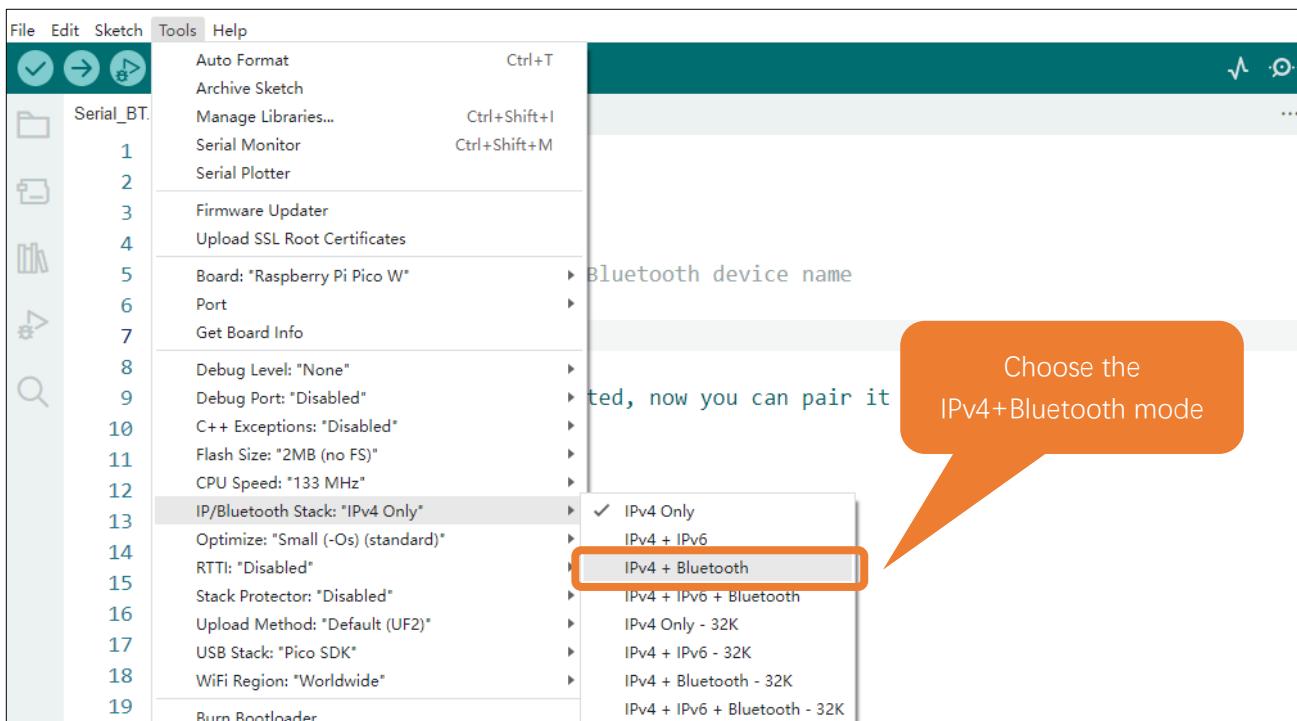
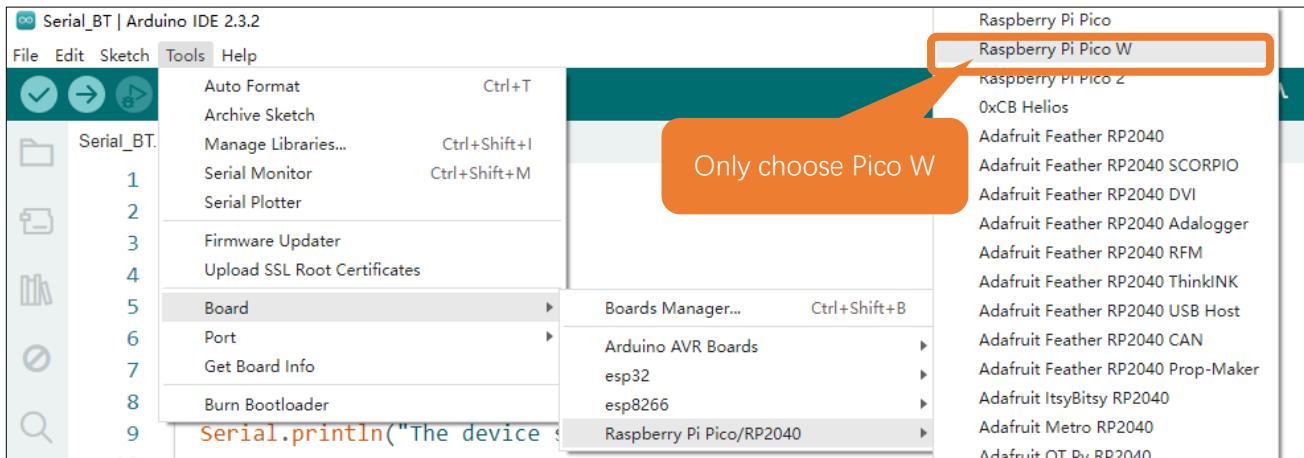




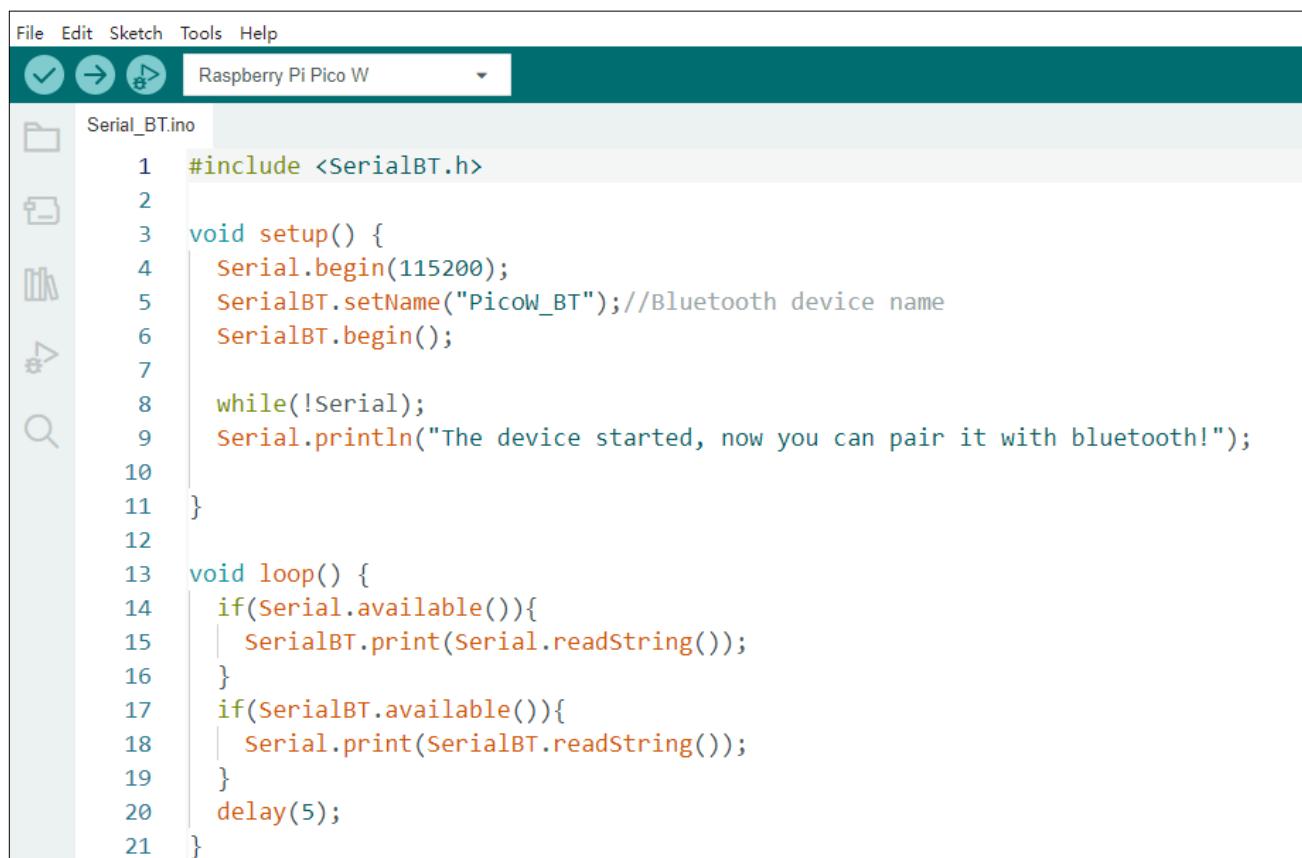
## Sketch

### How to enable Pico W's Bluetooth

In default setting, Pico W only enables the ipv4 function of its WiFi. To enable Bluetooth, please refer to the following steps:

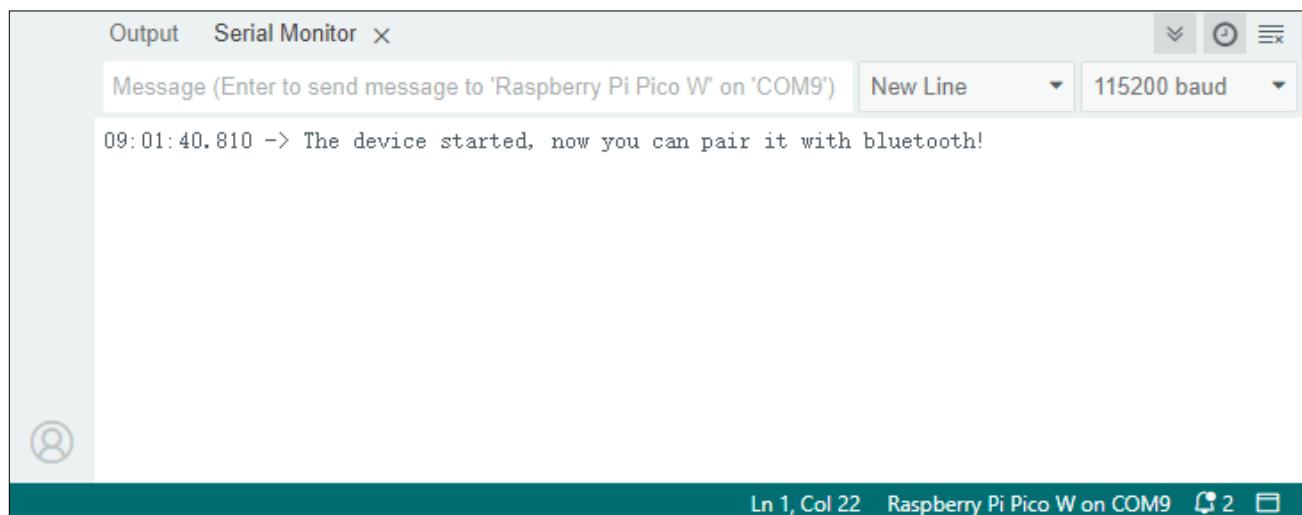


### Sketch\_24.1\_Serial\_BT



```
File Edit Sketch Tools Help
Serial_BT.ino
1 #include <SerialBT.h>
2
3 void setup() {
4     Serial.begin(115200);
5     SerialBT.setName("PicoW_BT"); //Bluetooth device name
6     SerialBT.begin();
7
8     while(!Serial);
9     Serial.println("The device started, now you can pair it with bluetooth!");
10 }
11
12 void loop() {
13     if(Serial.available()){
14         SerialBT.print(Serial.readString());
15     }
16     if(SerialBT.available()){
17         Serial.print(SerialBT.readString());
18     }
19     delay(5);
20 }
```

Upload the sketch to Pico W and open the serial monitor, set the baud rate to 115200. When you see the message as shown below, it indicates that, the Bluetooth of Pico W is ready.



Output Serial Monitor X

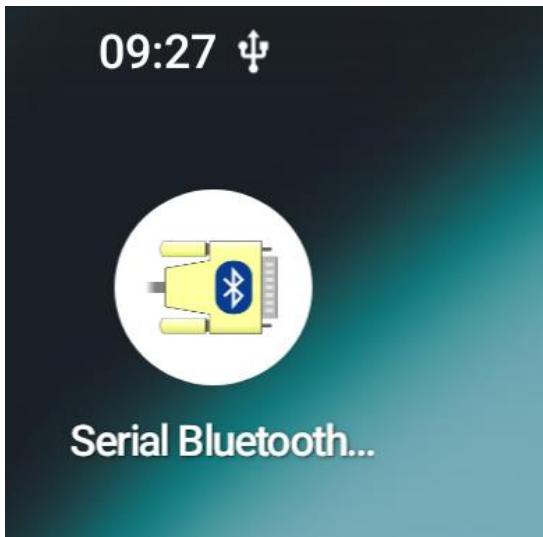
Message (Enter to send message to 'Raspberry Pi Pico W' on 'COM9') New Line 115200 baud

09:01:40.810 -> The device started, now you can pair it with bluetooth!

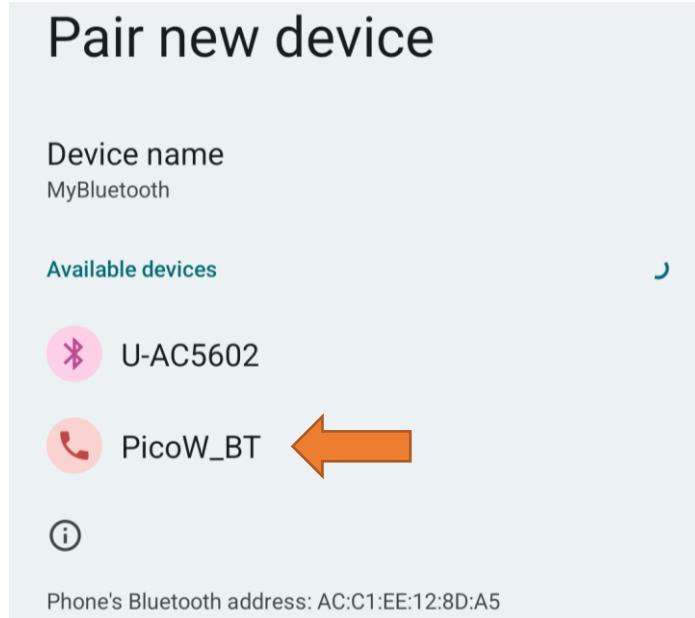
Ln 1, Col 22 Raspberry Pi Pico W on COM9 2



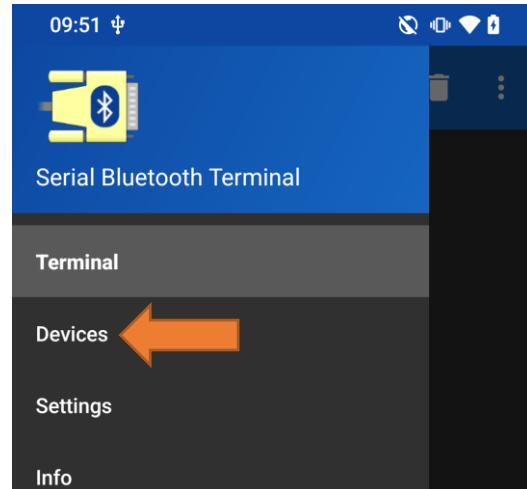
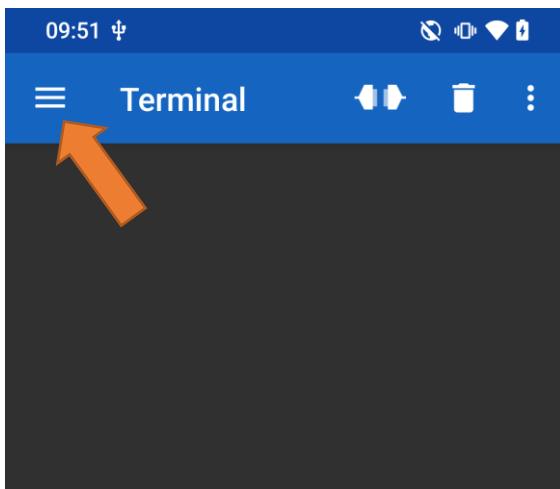
Please make sure the Bluetooth of your phone is turn ON and the App Serial Bluetooth Terminal has installed on your phone.



Click Pair new device and select "PicoW\_BT" to connect.

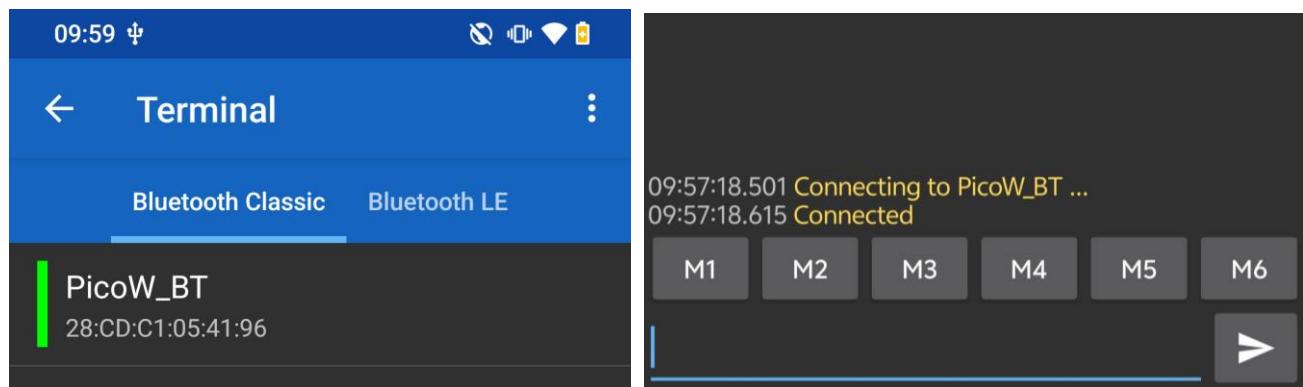


Open the App "Serial Bluetooth Terminal", expand the menu and select "Devices".



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

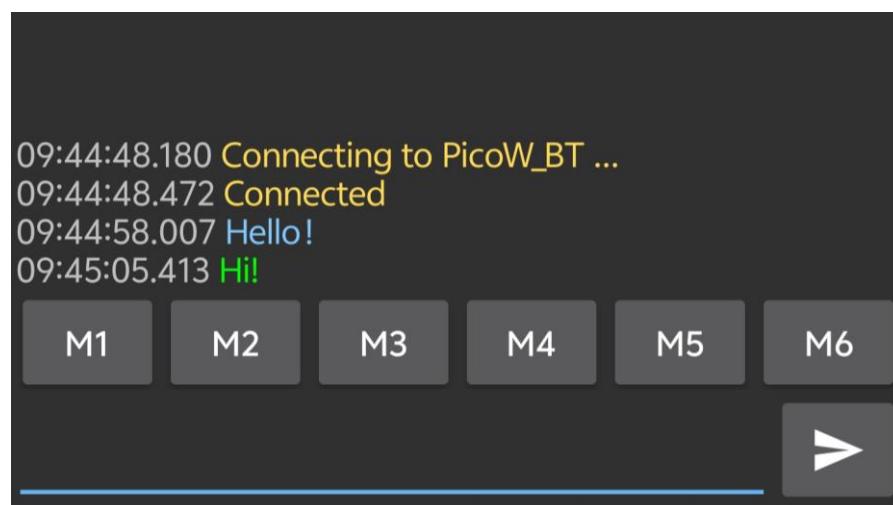
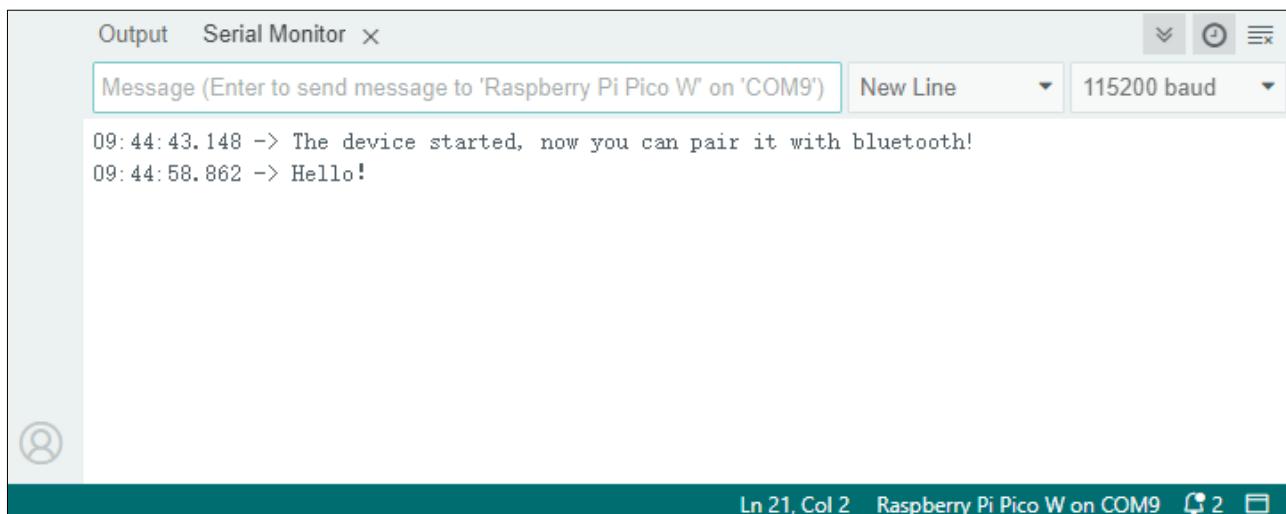
In Bluetooth Classic mode, select PicoW\_BT, and you will see "Connected", which indicates a successful connection.



Now, the data can be transferred between your phone and computer (Pico W).

Input Hello at the sending bar on the phone app and tap the send icon to send message to pico W.

When the computer receives it, input "Hi" at the Message bar and hit Enter key to send message to your phone.



The following is the program code:

```
1 #include <SerialBT.h>
2
3 void setup() {
4     Serial.begin(115200);
5     SerialBT.setName("PicoW_BT"); //Bluetooth device name
6     SerialBT.begin();
7     while(!Serial);
8     Serial.println("The device started, now you can pair it with bluetooth!");
9 }
10
11 void loop() {
12     if(Serial.available()) {
13         SerialBT.print(Serial.readString());
14     }
15     if(SerialBT.available()) {
16         Serial.print(SerialBT.readString());
17     }
18     delay(5);
19 }
20 }
```

## Reference

### Class SerialBT

This is a class library used to operate SerialBT, which can directly read and set SerialBT. Here are some member functions:

**SetName(const char \*name)**: Sets the Bluetooth module name.

**begin()**: Initializes the Bluetooth functionality.

**available()**: Retrieves data sent from the buffer; if none, returns 0.

**read()**: Reads data from Bluetooth, returns data as an int type.

**readString()**: Reads data from Bluetooth, returns data as a String type.

**write(uint8\_t c)**: Sends a single uint8\_t type of data to Bluetooth.

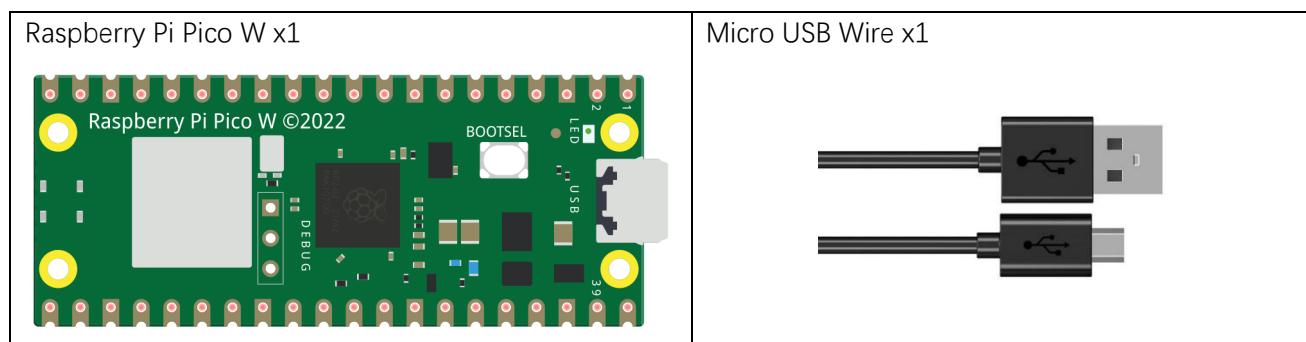
**write(const uint8\_t \*p, size\_t len)**: Sends the first len bytes of data stored at pointer address p to Bluetooth.

**print()**: Sends all types of data to Bluetooth for printing.

**end()**: Disconnects all Bluetooth devices and turns off Bluetooth, freeing up all occupied space.

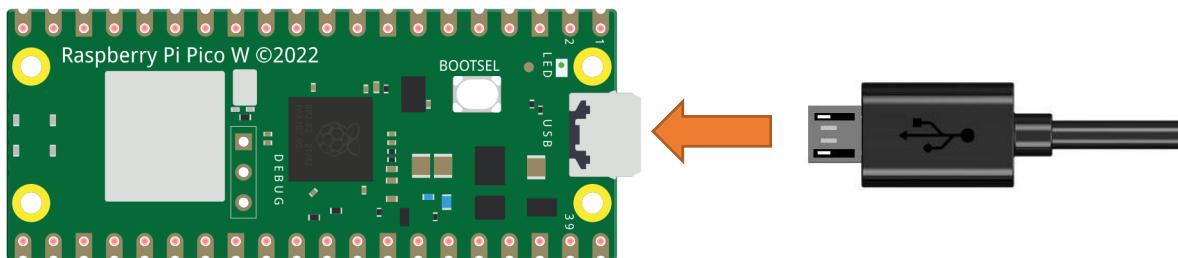
## Project 24.2 Bluetooth Low Energy Data Passthrough

### Component List

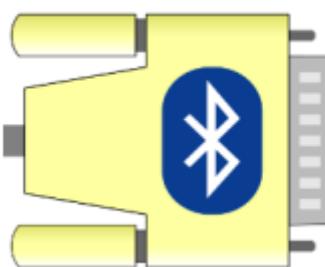


### Circuit

Connect Pico W to the computer using the USB cable.



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





## Sketch

### Sketch\_24.2\_Serial\_BT

```

File Edit Sketch Tools Help
Serial_BLE.ino
42 void setup(void) {
43   Serial.begin(115200);
44   while(!Serial);
45
46   setupBLE("PicoW_BLE");
47 }
48
49 void loop(void) {
50   BTstack.loop();
51
52   if (Serial.available() > 0) {           // Check if there is serial
53     String input = Serial.readStringUntil('\n'); // Read until '\n'
54     input.trim();                         // Remove front and back blanks
55
56     size_t input_length = input.length();    // Get String length
57
58     // Copy input to characteristic_data and add line breaks
59     memcpy(characteristic_data, input.c_str(), input_length);
60     characteristic_data[input_length] = '\n'; // add linefeeds
61     characteristic_data[input_length + 1] = '\0'; // End of string
62
63     Serial.print("input data: ");
64     Serial.print(characteristic_data);

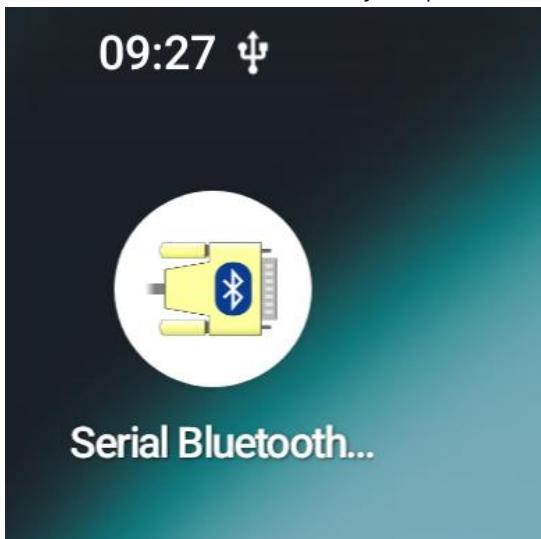
```

Before uploading the sketch, please make sure the Bluetooth of Pico W is enabled.

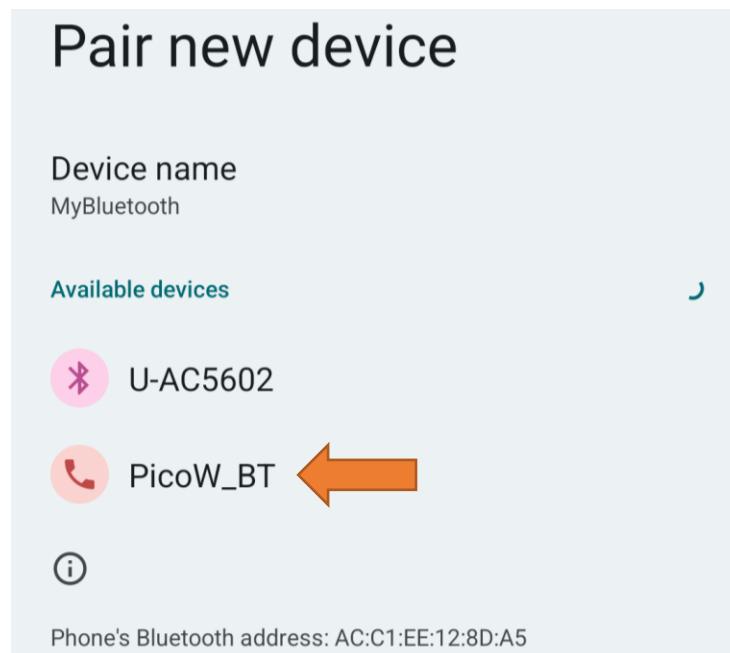
#### Serial Bluetooth

Compile and upload sketch th Pico W. The opration is similar to that in the previous section.

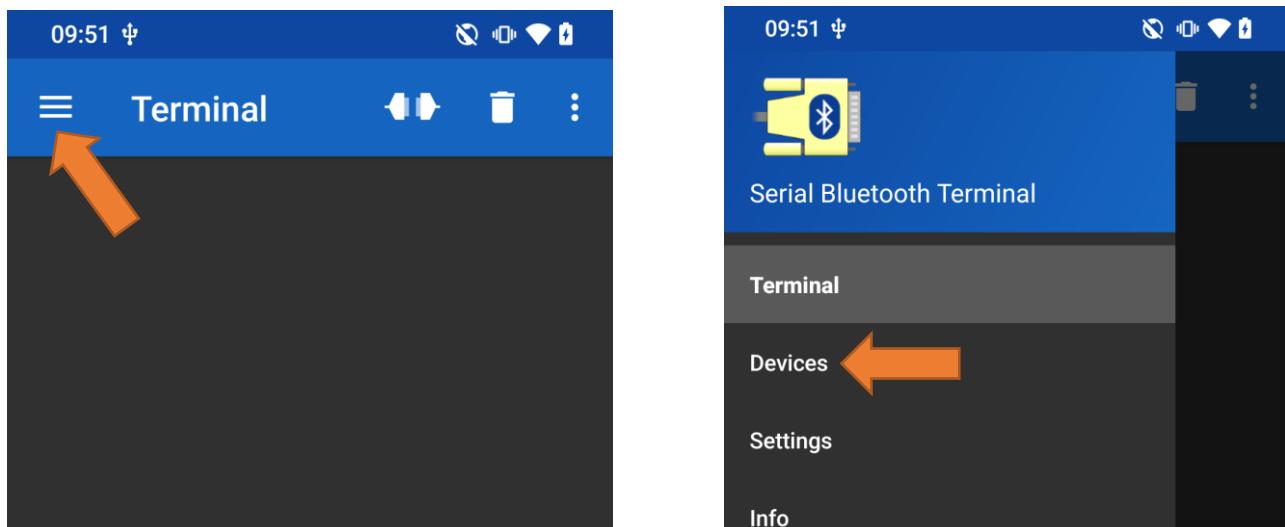
First, make sure Bluetooth on your phone is turned ON, and open Serial Bluetooth Terminal.



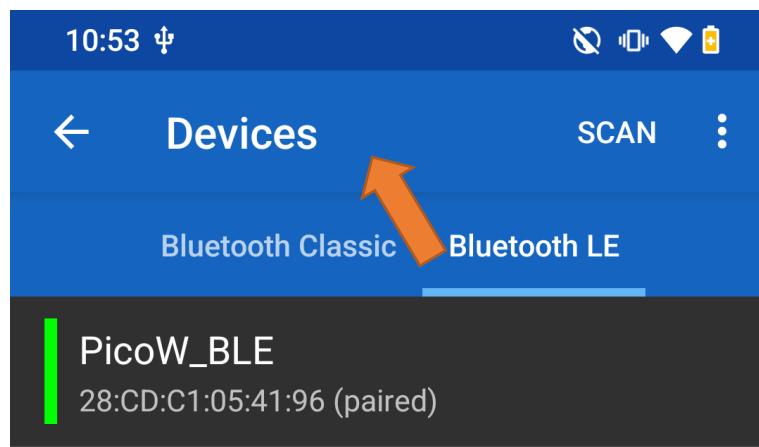
Click Pair new device, select "PicoW\_BT" to connect.



Expand the menu at the left of the app, and select "Devices".

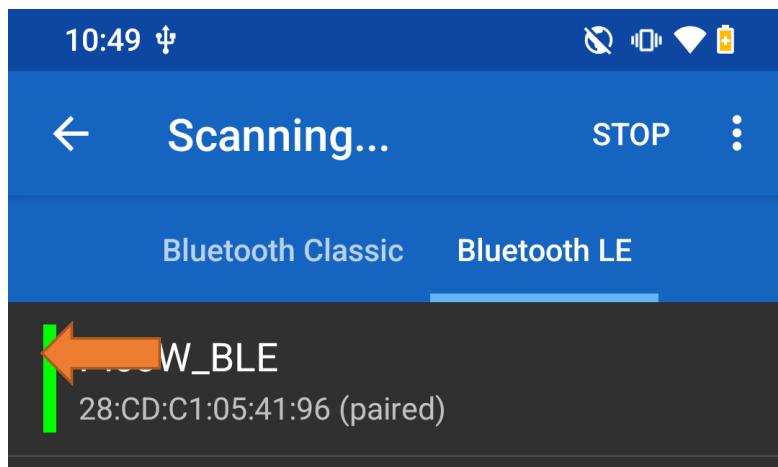


Select BLUETOOTH LE and click scan to search for BLE devices nearby.





Select “PicoW\_BLE”.



### LightBlue

If Serial Bluetooth cannot be installed on your phone, try LightBlue. If you do not have this software installed on your phone, you can refer to this link:

iPhone: <https://apps.apple.com/us/app/lightblue/id557428110?platform=iphone>



**LightBlue®** 4+

The go-to BLE development tool  
Punch Through

★★★★★ 4.0 • 4 Ratings

Free

### Screenshots Mac iPhone iPad

The screenshots demonstrate the LightBlue app's functionality across different platforms (Mac, iPhone, iPad).  
 1. \*\*Peripheral List (iPhone):\*\* Shows a list of nearby Bluetooth peripherals, including "Health Monitor", "Matt's Mug", "Thed's Arduino Uno", "Gretchen's Fitbit Blaze", "Heart Rate Monitor", "Colin's iPhone Xs", "Sous Vide Bean", "Mike's MacBook Pro", "PT DevKit", and "Health Monitor".  
 2. \*\*Health Monitor (iPhone):\*\* Details for a connected "Health Monitor" peripheral. It shows ADVERTISEMENT DATA, Device Information (Hardware Revision String: "IE", Manufacturer Name String: "Punch Through"), and Health Thermometer services with properties like Intermediate Temperature, Temperature Measurement, Temperature Type, and Measurement Interval.  
 3. \*\*Temperature Measurement (iPhone):\*\* Details for a "Temperature Measurement" service. It shows INDICATED VALUES, DESCRIPTORS, and PROPERTIES. A "Cloud Connect" feature is also present.  
 4. \*\*Characteristic Format (iPad):\*\* A detailed view of the "Temperature Measurement" service's characteristics. It shows binary values (e.g., 123456, 04432126), their types (Hex, Octal, Binary), and descriptions ("4V", "UTF-8 String"). It includes controls for Byte Count (+/-) and Endianness (Big, Little).

Step 1. Upload sketch 33.1 to Pico W.

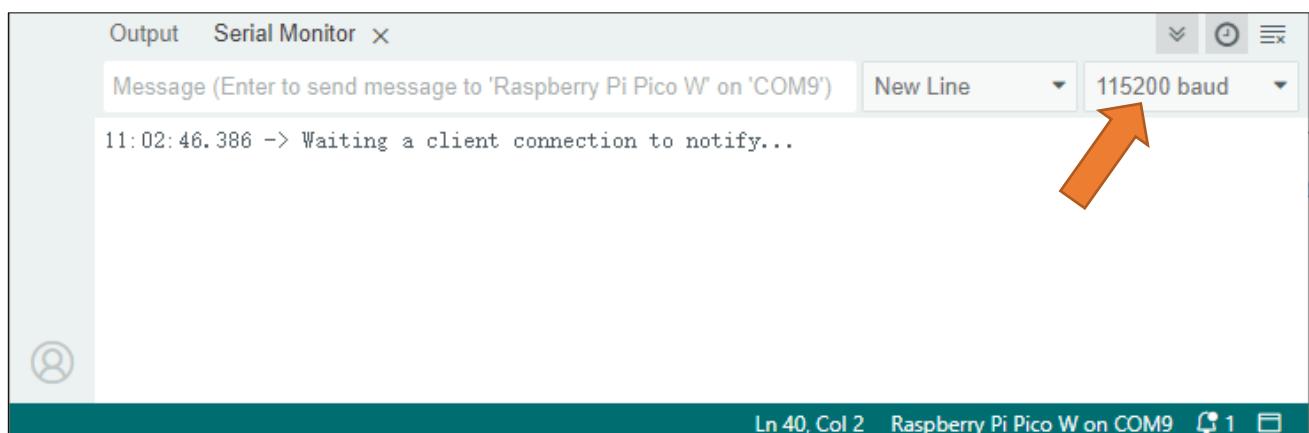
Step 2. Open Serial Monitor.

```

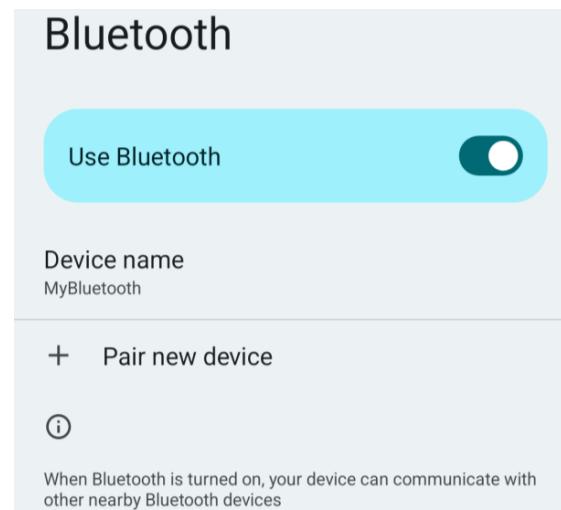
File Edit Sketch Tools Help
Raspberry Pi Pico W
Sketch 33.1 BLE.ino
41 void setup(void) {
42   Serial.begin(115200);
43   while(!Serial);
44
45
46   setupBLE("PicoW_BLE");
47 }
48
49 void loop(void) {
50   BTstack.loop();
51
52   if (Serial.available() > 0) { // Check if there is serial
53     String input = Serial.readStringUntil('\n');
54     input.trim(); // Remove front and back bla
55
56     size_t input_length = input.length(); // Get String length
57

```

Step 3. Set the baud rate to 115200.

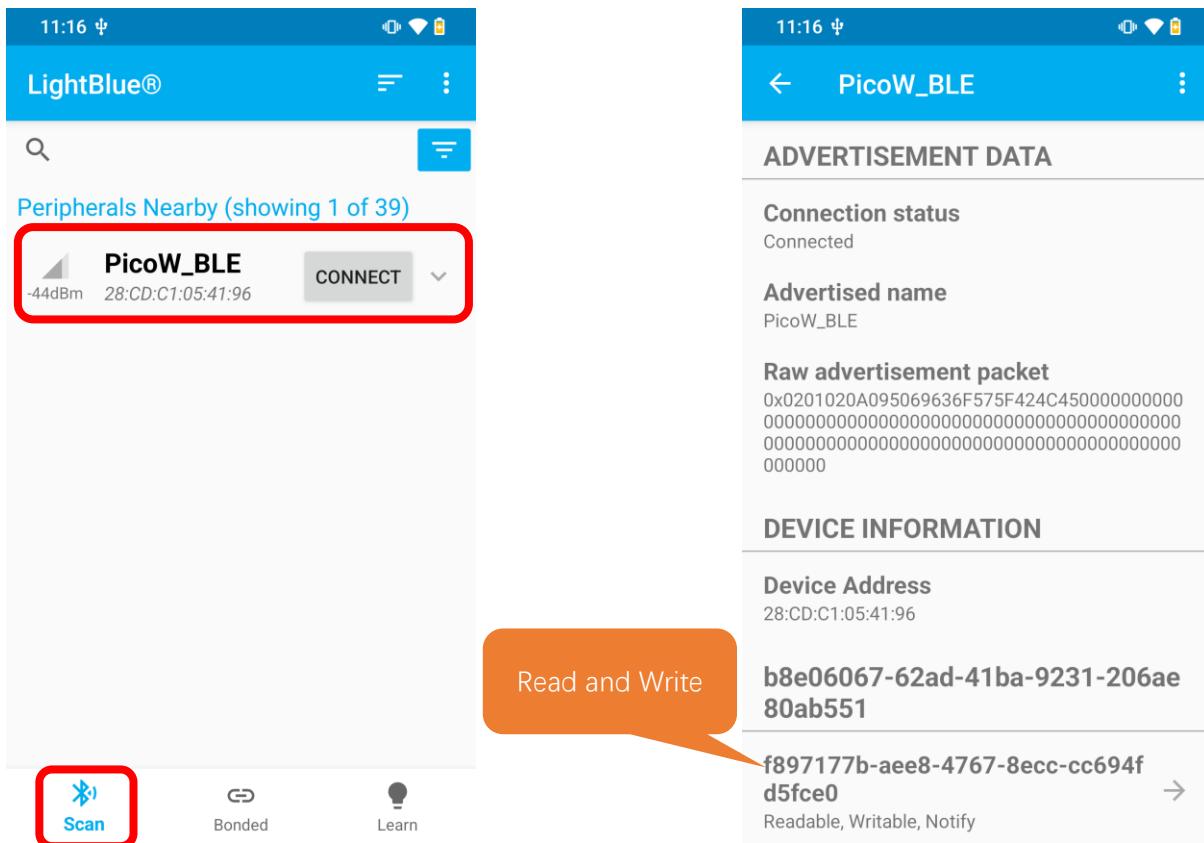


Turn ON Bluetooth on your phone and open LightBlue App.

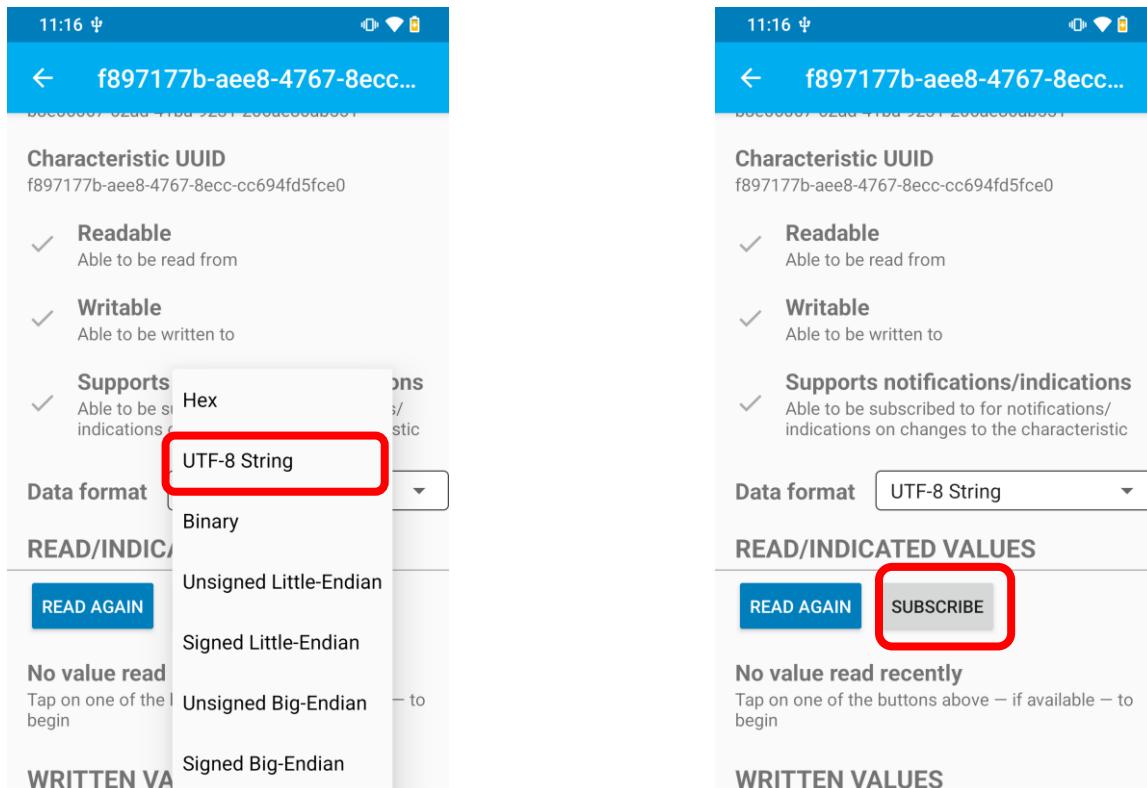


Any concerns? [✉ support@freenove.com](mailto:support@freenove.com)

At the device scan page, scroll down to refresh the devices nearby. Select PicoW\_BLE to connect.



Click "Read and Write". Click on "Read and Write". Select the corresponding data format in the box on the right side of the data format, such as HEX hexadecimal, utf-string string, Binary binary, etc. Then click SUBSCRIBE.



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

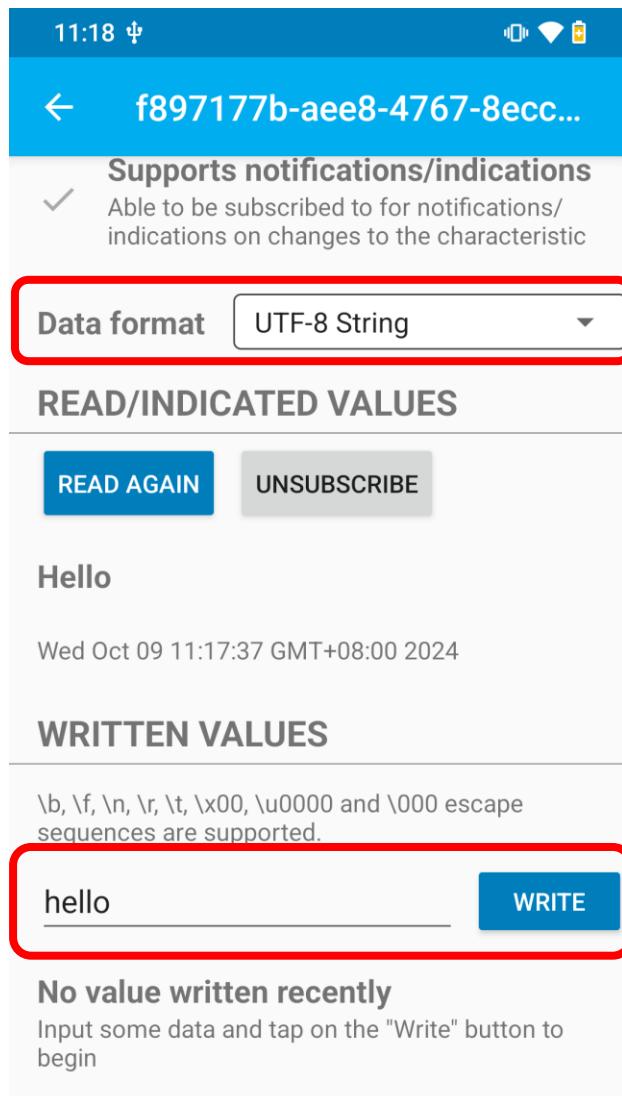
Return to the serial monitor on Arduino IDE, you can input any message and hit the Enter key to send.



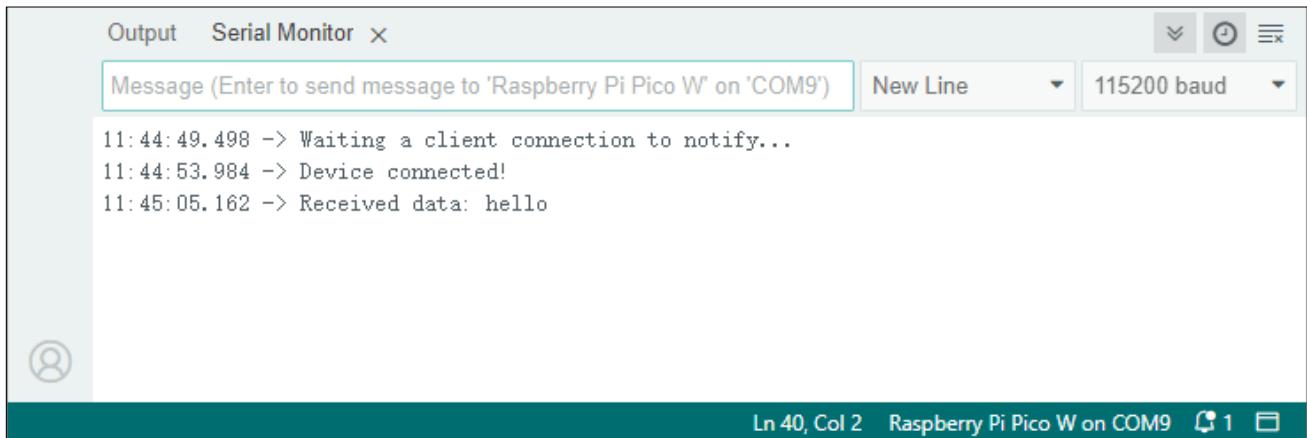
Then you can see LightBlue on your phone receive the data.

The screenshot shows the LightBlue app interface. At the top, it displays the device address "f897177b-aee8-4767-8ecc...". Below this, three characteristics are listed with checkmarks: "Readable" (Able to be read from), "Writable" (Able to be written to), and "Supports notifications/indications" (Able to be subscribed to for notifications/indications on changes to the characteristic). A red box highlights the "Data format" dropdown set to "UTF-8 String". The "READ/INDICATED VALUES" section shows the message "Hello" in a red-bordered box, with the timestamp "Wed Oct 09 11:17:37 GMT+08:00 2024". The "WRITTEN VALUES" section contains the text "\b, \f, \n, \r, \t, \x00, \u0000 and \000 escape sequences are supported."

Similarly, you can send data from your phone to computer. Input any content and click WRITE to send the data.



You can see the data received.



Now the data can be transferred between your phone and pico W.

The following is the program code:

```
1 #include <BTstackLib.h>
2 #include <SPI.h>
3 #include <btstack.h>
4
5 #define MAX_LENGTH 256
6 static char characteristic_data[MAX_LENGTH] = "Pico W Bluetooth";
7
8 // Track subscription status
9 bool isSubscribed = false;
10
11 // The handle of the connection
12 hci_con_handle_t connection_handle = HCI_CON_HANDLE_INVALID;
13
14 // characteristic handle
15 uint16_t characteristic_handle = 0;
16
17 // Assuming the handle of CCCD is a characteristic handle+1
18 #define CCCD_HANDLE (characteristic_handle + 1)
19
20 void setupBLE(const char *BLEName) {
21     //Set callback function
22     BTstack.setBLEDeviceConnectedCallback(deviceConnectedCallback);
23     BTstack.setBLEDeviceDisconnectedCallback(deviceDisconnectedCallback);
24     BTstack.setGATTCharacteristicRead(gattReadCallback);
25     BTstack.setGATTCharacteristicWrite(gattWriteCallback);
26
27     //Set GATT database
28     BTstack.addGATTService(new UUID("B8E06067-62AD-41BA-9231-206AE80AB551"));
29     characteristic_handle = BTstack.addGATTCharacteristicDynamic(
30         new UUID("f897177b-ae8-4767-8ecc-cc694fd5fce0"),
31         ATT_PROPERTY_READ | ATT_PROPERTY_WRITE | ATT_PROPERTY_NOTIFY,
32         0
33     );
34
35     //Activate Bluetooth and broadcast
36     BTstack.setup(BLEName);
37     BTstack.startAdvertising();
38
39     Serial.println("Waiting a client connection to notify... ");
40 }
41
42 void setup() {
43     Serial.begin(115200);
```

```
44     while(!Serial);
45
46     setupBLE("PicoW_BLE");
47 }
48
49 void loop() {
50     BTstack.loop();
51
52     if (Serial.available() > 0) {           // Check if there is serial data
53         String input = Serial.readStringUntil('\n');
54         input.trim();                      // Remove front and back blank spaces
55
56         size_t input_length = input.length(); // Get String length
57
58         // Copy input to characteristic_data and add line breaks
59         memcpy(characteristic_data, input.c_str(), input_length);
60         characteristic_data[input_length] = '\n'; // add linefeeds
61         characteristic_data[input_length + 1] = '\0'; // End of string
62
63         Serial.print("input data: ");
64         Serial.print(characteristic_data);
65
66         sendNotificationToSubscribers();        //Send notifications to subscribed devices
67     }
68     //Delay by 5ms to prevent data loss due to receiving too quickly
69     delay(5);
70 }
71
72 void deviceConnectedCallback(BLEStatus status, BLEDevice *device) {
73     if(status == BLE_STATUS_OK) {
74         Serial.println("Device connected!");
75         connection_handle = device->getHandle(); // Get connection handle
76     }
77 }
78
79 void deviceDisconnectedCallback(BLEDevice * device) {
80     (void) device;
81     Serial.println("Disconnected.");
82     connection_handle = HCI_CON_HANDLE_INVALID;
83     isSubscribed = false;                  // Reset subscription status
84 }
85
86 // Callback function for reading data
87 uint16_t gattReadCallback(uint16_t value_handle, uint8_t * buffer, uint16_t buffer_size) {
```

```
88     (void) value_handle;
89     if (buffer && buffer_size > 0) {
90         Serial.print("Read data: ");
91         Serial.println(characteristic_data);
92
93         size_t data_length = strlen(characteristic_data); // Get characteristic_data length
94         if (data_length > buffer_size) // Limit length
95             data_length = buffer_size;
96         }
97
98         memcpy(buffer, characteristic_data, data_length); // Copy String
99         return data_length;
100    }
101    return 0;
102 }
103
104 // Callback function for writing data
105 int gattWriteCallback(uint16_t value_handle, uint8_t *buffer, uint16_t size) {
106     if (value_handle == CCCD_HANDLE) { // Processing CCCD writing
107         if (size >= 2) {
108             uint16_t cccd_value = buffer[0] | (buffer[1] << 8);
109             isSubscribed = true; //Subscription status is true
110         }
111     } else { // Writing of processing feature data
112         size_t copy_size = (size < (MAX_LENGTH - 1)) ? size : (MAX_LENGTH - 1);
113         memcpy(characteristic_data, buffer, copy_size); // Copy String
114         characteristic_data[copy_size] = '\0'; // Ensure that the string ends
115
116         Serial.print("Received data: ");
117         Serial.println(characteristic_data);
118     }
119
120     return 0;
121 }
122
123 void sendNotificationToSubscribers() {
124     if (isSubscribed && connection_handle != HCI_CON_HANDLE_INVALID) {
125         // Send notifications
126         att_server_notify(connection_handle, characteristic_handle,
127                           (uint8_t*)characteristic_data, strlen(characteristic_data));
128     }
129 }
130 }
```



Define the specified UUID number for BLE vendor.

```

28  BTstack.addGATTService(new UUID("B8E06067-62AD-41BA-9231-206AE80AB551"));
29  characteristic_handle = BTstack.addGATTCharacteristicDynamic(
30      new UUID("f897177b-aee8-4767-8ecc-cc694fd5fce0"),
31      ATT_PROPERTY_READ | ATT_PROPERTY_WRITE | ATT_PROPERTY_NOTIFY,
32      0
33  );

```

Write a Callback function for the BLE server to manage BLE connections.

```

72  void deviceConnectedCallback(BLEStatus status, BLEDevice *device) {
73      if(status == BLE_STATUS_OK) {
74          Serial.println("Device connected!");
75          connection_handle = device->getHandle();           // Get connection handle
76      }
77  }

```

Write a Callback function for the BLE server to handle BLE disconnections.

```

79  void deviceDisconnectedCallback(BLEDevice * device) {
80      (void) device;
81      Serial.println("Disconnected.");
82      connection_handle = HCI_CON_HANDLE_INVALID;
83      isSubscribed = false;                                // Reset subscription status
84  }

```

Write a Callback function to read data. When BLE needs to read data, print the read data on the phone.

```

86  // Callback function for reading data
87  uint16_t gattReadCallback(uint16_t value_handle, uint8_t * buffer, uint16_t buffer_size) {
88      (void) value_handle;
89      if (buffer && buffer_size > 0) {
90          Serial.print("Read data: ");
91          Serial.println(characteristic_data);
92
93          size_t data_length = strlen(characteristic_data); // Get characteristic_data length
94          if (data_length > buffer_size) {                  // Limit length
95              data_length = buffer_size;
96          }
97
98          memcpy(buffer, characteristic_data, data_length); // Copy String
99          return data_length;
100     }
101
102 }

```

Create a Callback function for writing data. When data is written to BLE, check if it is the CCCD characteristic handle or a write characteristic handle. If it is the CCCD, it indicates a subscription state; otherwise, print the written data to the serial console.

```

104 // Callback function for writing data
105 int gattWriteCallback(uint16_t value_handle, uint8_t *buffer, uint16_t size) {

```

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

```

106 if (value_handle == CCCD_HANDLE) {           // Processing CCCD writing
107     if (size >= 2) {
108         uint16_t cccd_value = buffer[0] | (buffer[1] << 8);
109         isSubscribed = true;           //Subscription status is true
110     }
111 } else { // Writing of processing feature data
112     size_t copy_size = (size < (MAX_LENGTH - 1)) ? size : (MAX_LENGTH - 1);
113     memcpy(characteristic_data, buffer, copy_size); // Copy String
114     characteristic_data[copy_size] = '\0';           // Ensure that the string ends
115
116     Serial.print("Received data: ");
117     Serial.println(characteristic_data);
118 }
119
120 return 0;
121 }
```

Write a function to send subscription notifications. When data is received through the serial port, send a notification to let BLE receive the data.

```

123 void sendNotificationToSubscribers() {
124     if (isSubscribed && connection_handle != HCI_CON_HANDLE_INVALID) {
125         // Send notifications
126         att_server_notify(connection_handle, characteristic_handle,
127                            (uint8_t*)characteristic_data, strlen(characteristic_data));
128     }
129 }
```

Process serial port data: Upon receiving data from the serial port, remove any leading and trailing whitespace, append a newline character to the end of the string, and then use the notification function to transmit the data to the mobile device via BLE.

```

52     if (Serial.available() > 0) {           // Check if there is serial data
53         String input = Serial.readStringUntil('\n');
54         input.trim();                      // Remove front and back blank spaces
55
56         size_t input_length = input.length(); // Get String length
57
58         // Copy input to characteristic_data and add line breaks
59         memcpy(characteristic_data, input.c_str(), input_length);
60         characteristic_data[input_length] = '\n'; // add linefeeds
61         characteristic_data[input_length + 1] = '\0'; // End of string
62
63         Serial.print("input data: ");
64         Serial.print(characteristic_data);
65
66         sendNotificationToSubscribers();        //Send notifications to subscribed devices
67     }
```



The design for creating the BLE server is:

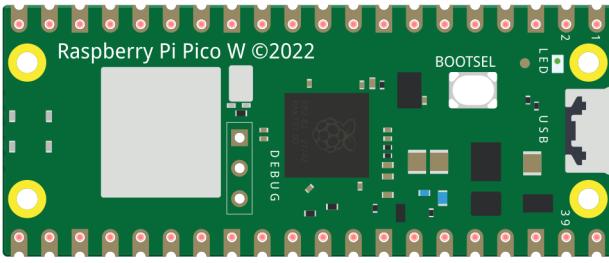
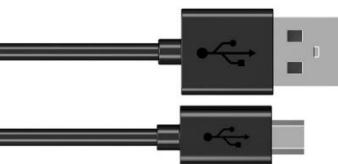
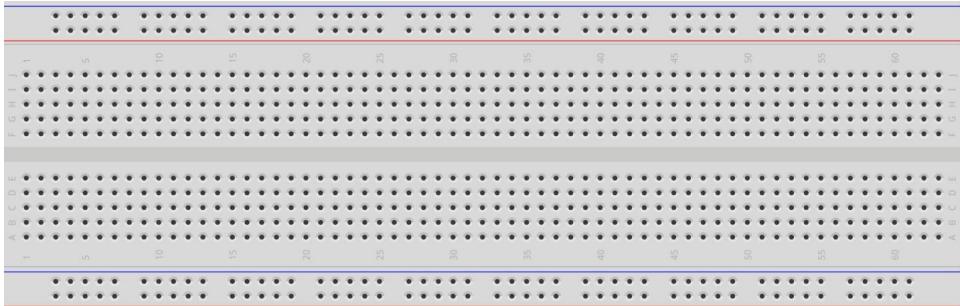
1. Set up a connection Callback function.
2. Set up a Callback function for disconnection.
3. Set up GATT read characteristic.
4. Set up GATT write characteristic.
5. Add GATT service.
6. Add GATT dynamic characteristic (read, write, notify).
7. Initialize BLE.
8. Start advertising.

```
20 void setupBLE(const char *BLEName) {  
21     //Set callback function  
22     BTstack.setBLEDeviceConnectedCallback(deviceConnectedCallback);  
23     BTstack.setBLEDeviceDisconnectedCallback(deviceDisconnectedCallback);  
24     BTstack.setGATTCharacteristicRead(gattReadCallback);  
25     BTstack.setGATTCharacteristicWrite(gattWriteCallback);  
26  
27     //Set GATT database  
28     BTstack.addGATTService(new UUID("B8E06067-62AD-41BA-9231-206AE80AB551"));  
29     characteristic_handle = BTstack.addGATTCharacteristicDynamic(  
30         new UUID("f897177b-aee8-4767-8ecc-cc694fd5fce0"),  
31         ATT_PROPERTY_READ | ATT_PROPERTY_WRITE | ATT_PROPERTY_NOTIFY,  
32         0  
33     );  
34  
35     //Activate Bluetooth and broadcast  
36     BTstack.setup(BLEName);  
37     BTstack.startAdvertising();  
38  
39     Serial.println("Waiting a client connection to notify...");  
40 }
```

## Project 24.3 Bluetooth Control LED

In this project, we will control an LED via Pico W's Bluetooth function.

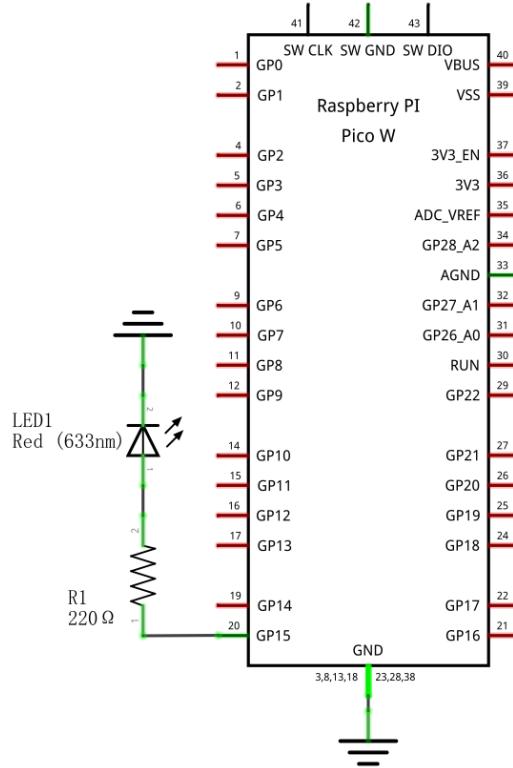
### Component List

Raspberry Pi Pico W x1	Micro USB Wire x1
	
Breadboard x1	
	  

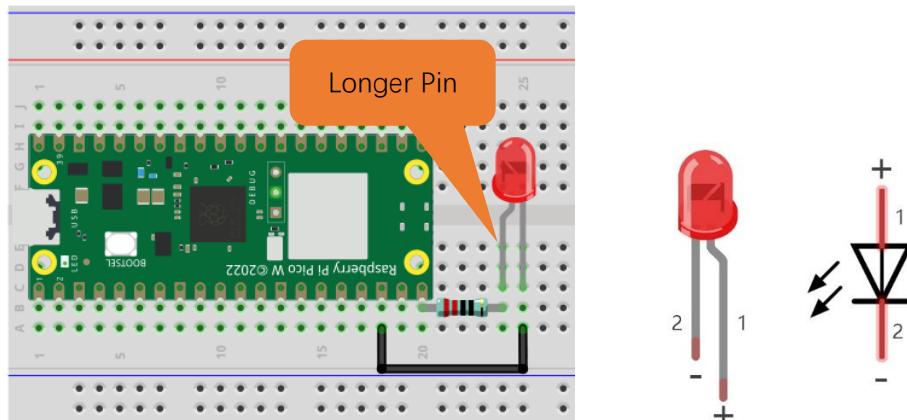
## Circuit

Connect Pico W to your phone with the USB cable.

Schematic diagram



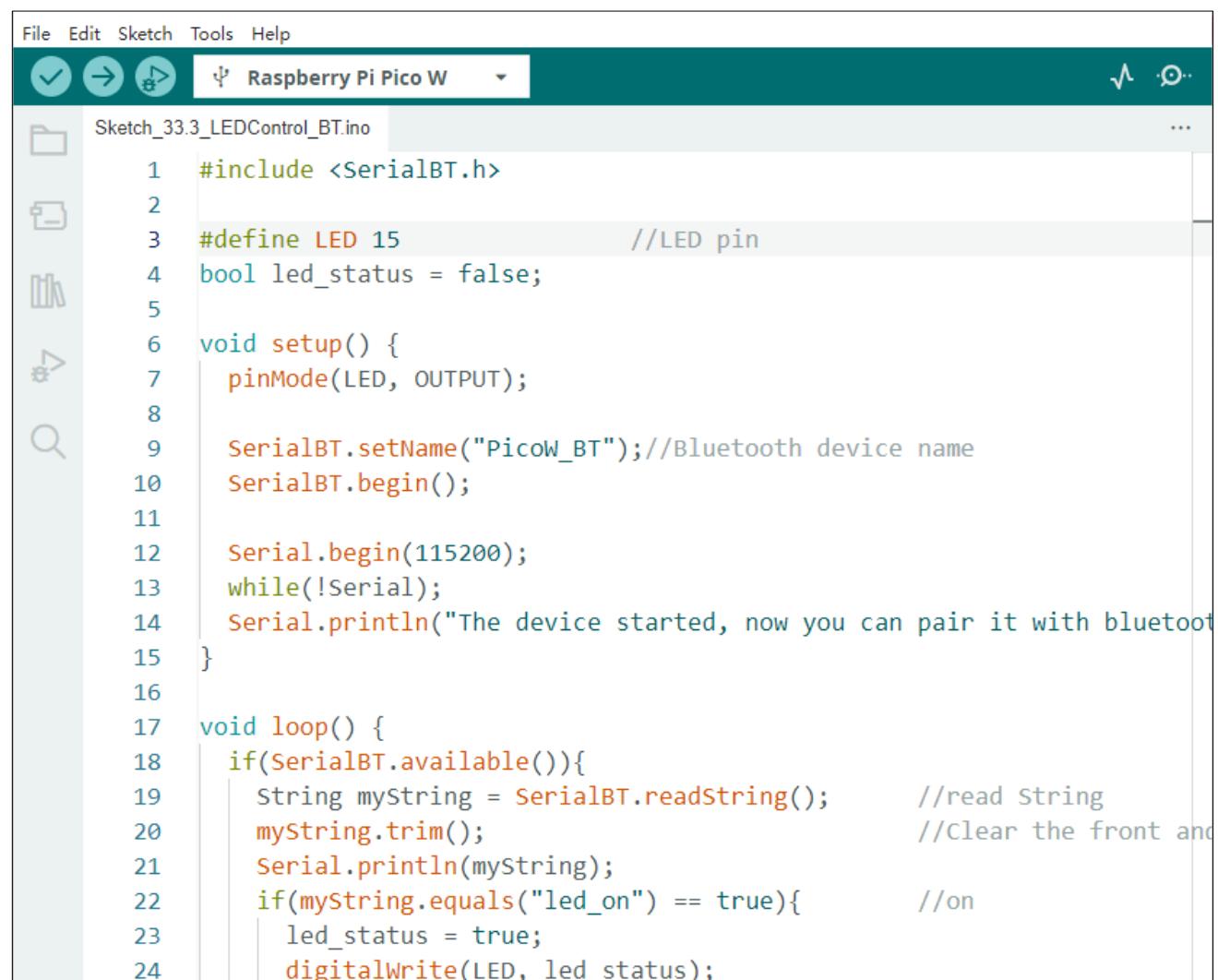
Hardware connection. If you need any support, please feel free to contact us via: [support@freenove.com](mailto:support@freenove.com)



Note: To help users have a better experience when doing the projects, we have made some modifications to Pico's simulation diagram. Please note that there are certain differences between the simulation diagram and the actual board to avoid misunderstanding.

## Sketch

### Sketch\_24.3\_LEDControl\_BT



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

- File Menu:** File, Edit, Sketch, Tools, Help.
- Sketch Menu:** Sketch, Tools, Help.
- Board Selection:** Raspberry Pi Pico W.
- Sketch Name:** Sketch\_33.3\_LEDControl\_BT.ino
- Code Content:** The code is for controlling an LED via Bluetooth. It includes setup and loop functions using the SerialBT library to handle incoming messages and control the LED state.

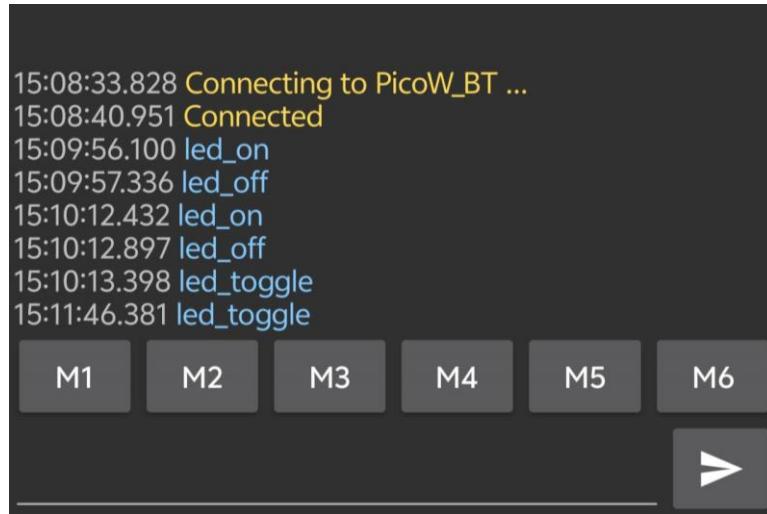
```
#include <SerialBT.h>
#define LED 15 //LED pin
bool led_status = false;

void setup() {
    pinMode(LED, OUTPUT);
    SerialBT.setName("PicoW_BT"); //Bluetooth device name
    SerialBT.begin();
    Serial.begin(115200);
    while(!Serial);
    Serial.println("The device started, now you can pair it with bluetooth");
}

void loop() {
    if(SerialBT.available()){
        String myString = SerialBT.readString(); //read String
        myString.trim(); //Clear the front and back spaces
        Serial.println(myString);
        if(myString.equals("led_on") == true){ //on
            led_status = true;
            digitalWrite(LED, led_status);
        }
    }
}
```

Upload the sketch to Pico W.

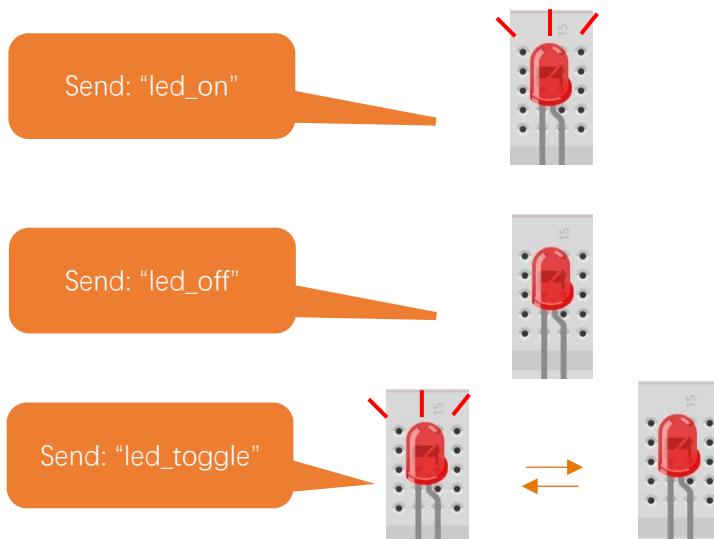
The operation on the phone app is similar to that in Project 24.1. You just need to change the sending messages to "led\_on", "led\_off" and "led\_toggle" to control the status of the LED.



Displays on the serial monitor.



LED status.



Note: If the messages you send are not "led\_on", "led\_off", or "led toggle", the status of the LED won't change. For example, when the LED is already ON, it will remain ON unless the message "led\_off", or "led toggle" is received.

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

The following is the program code:

```

1 #include <SerialBT.h>
2
3 #define LED 15           //LED pin
4 bool led_status = false;
5
6 void setup() {
7     pinMode(LED, OUTPUT);
8
9     SerialBT.setName("PicoW_BT"); //Bluetooth device name
10    SerialBT.begin();
11
12    Serial.begin(115200);
13    while(!Serial);
14    Serial.println("The device started, now you can pair it with bluetooth!");
15 }
16
17 void loop() {
18     if(SerialBT.available()) {
19         String myString = SerialBT.readString(); //read String
20         myString.trim(); //Clear the front and back blank spaces
21         Serial.println(myString);
22         if(myString.equals("led_on") == true){ //on
23             led_status = true;
24             digitalWrite(LED, led_status);
25         }
26         if(myString.equals("led_off") == true){ //off
27             led_status = false;
28             digitalWrite(LED, led_status);
29         }
30         if(myString.equals("led_toggle") == true){ //toggle
31             led_status = !led_status;
32             digitalWrite(LED, led_status);
33         }
34     }
35 }
```

Define the pin of LED and set its default status as false.

```

3 #define LED 15           //LED pin
4 bool led_status = false;
```

Set the LED pin to output mode.

```

3 pinMode(LED, OUTPUT);
```

Process the received Bluetooth data, determine the status of the LED light. If it is "led\_on", the LED light is on; if it is "led\_off", the LED light is off; if it is "led\_toggle", the LED status is opposite to the current status.

```

18 if(SerialBT.available()) {
```

```
19  String myString = SerialBT.readString();      //read String
20  myString.trim();                            //Clear the front and back blank spaces
21  Serial.println(myString);
22  if(myString.equals("led_on") == true){        //on
23      led_status = true;
24      digitalWrite(LED, led_status);
25  }
26  if(myString.equals("led_off") == true){        //off
27      led_status = false;
28      digitalWrite(LED, led_status);
29  }
30  if(myString.equals("led_toggle") == true){    //toggle
31      led_status = !led_status;
32      digitalWrite(LED, led_status);
33  }
34 }
```

## Reference

The 'trim()' function is used to remove whitespace from both sides of a string, converting "led\_on\n" to "led\_on" for easier subsequent judgment.

### **void String: :trim(void)**

removes whitespace from both sides of a string.

The 'equals()' function is used to compare if two strings are identical, providing a simple and fast way to compare strings.

### **unsigned char String: :equals(const String &s2)**

s2: The other string to be compared.

Return value: If s2 is not equal to the current string, the return value is 0.

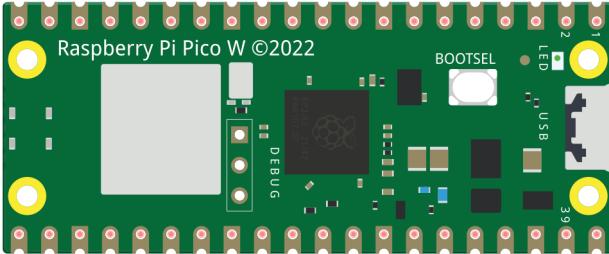
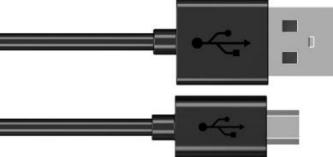
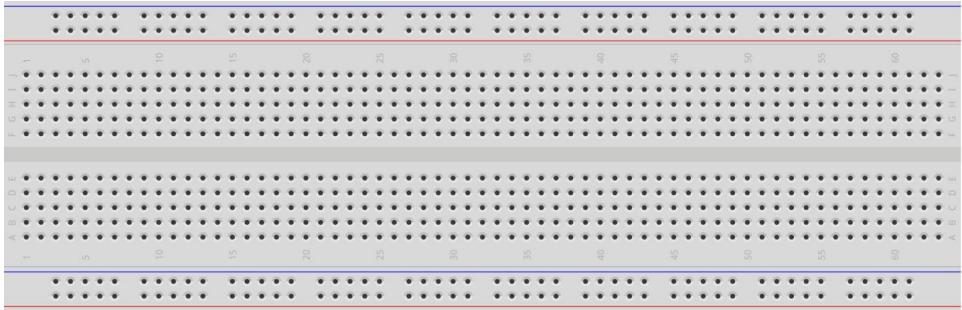
If s2 is equal to the current string, the return value is 1.

Note: Both data being compared must be of string type.

## Project 24.4 Bluetooth Low Energy Control LED

This project is basically the same as the previous one. You do not need to change the circuit wiring. Just upload the corresponding sketch.

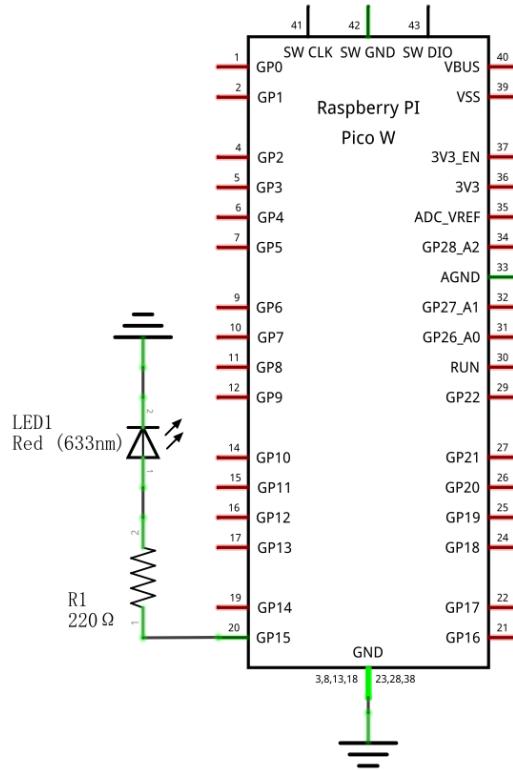
### Component List

Raspberry Pi Pico W x1	Micro USB Wire x1	
		
Breadboard x1		
LED x1	Resistor 220Ω x1	Jumper

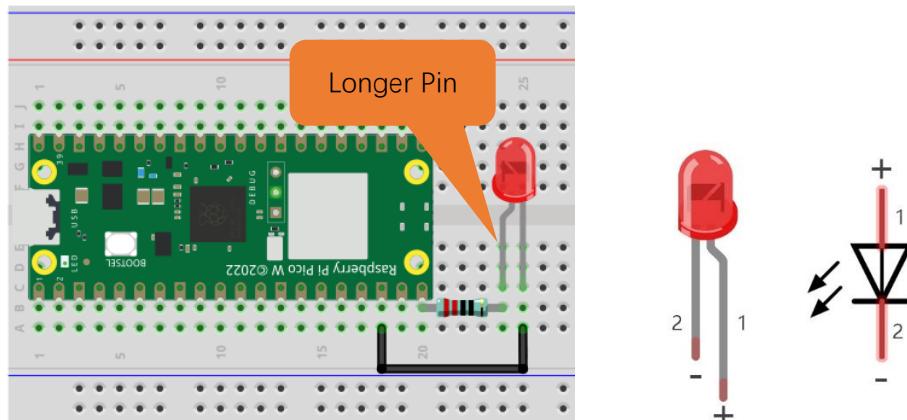
## Circuit

Connect the Pico W to your computer with a USB cable.

Schematic diagram



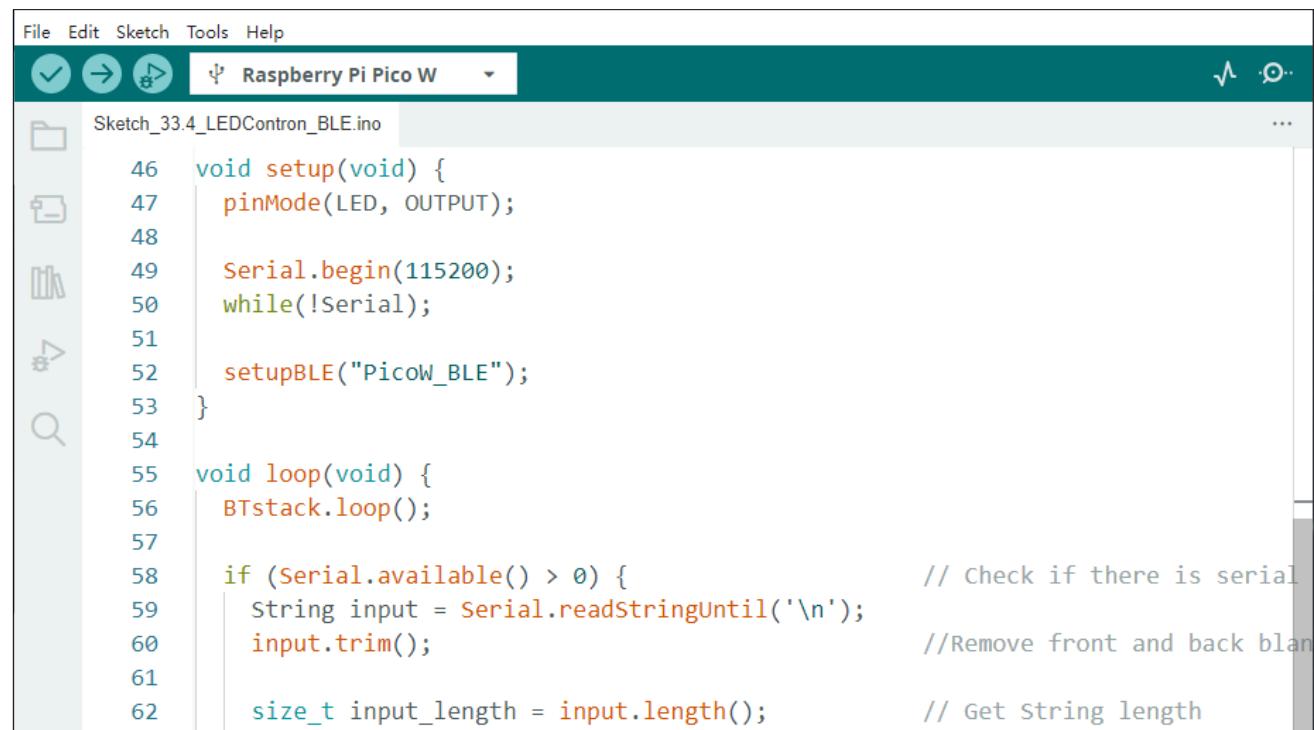
Hardware connection. If you need any support, please feel free to contact us via: [support@freenove.com](mailto:support@freenove.com)



Note: To help users have a better experience when doing the projects, we have made some modifications to Pico's simulation diagram. Please note that there are certain differences between the simulation diagram and the actual board to avoid misunderstanding.

## Sketch

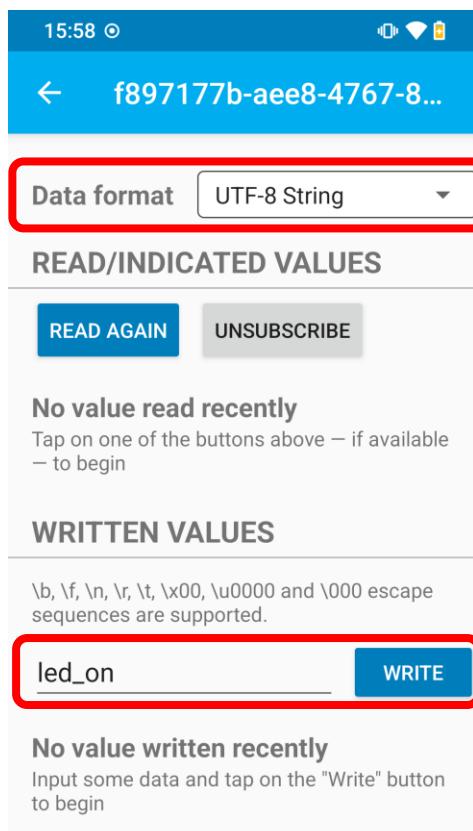
### Sketch\_24.4\_LEDControl\_BLE



```

File Edit Sketch Tools Help
Sketch_24.4_LEDControl_BLE.ino
Sketch_33.4_LEDControl_BLE.ino ...
46 void setup(void) {
47     pinMode(LED, OUTPUT);
48
49     Serial.begin(115200);
50     while(!Serial);
51
52     setupBLE("PicoW_BLE");
53 }
54
55 void loop(void) {
56     BTstack.loop();
57
58     if (Serial.available() > 0) { // Check if there is serial
59         String input = Serial.readStringUntil('\n');
60         input.trim(); //Remove front and back blank
61
62         size_t input_length = input.length(); // Get String length
    
```

Upload the sketch to Pico W. As previously mentioned, you can input “led\_on”, “led\_off”, or “led\_toggle” to change the status of the LED.





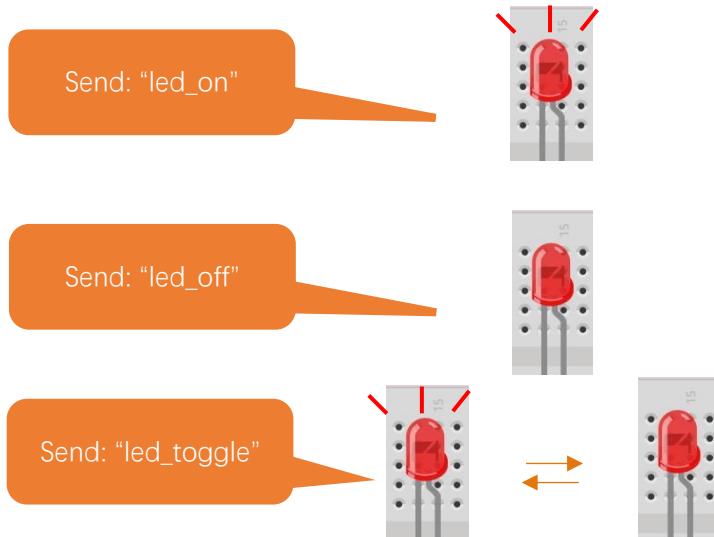
Displays on the serial monitor.

The screenshot shows the 'Serial Monitor' window with the title 'Output' and 'Serial Monitor'. The message area displays the following log:

```
Message (Enter to send message to 'Raspberry Pi Pico W' on 'COM9')  
15:59:27.800 -> Waiting a client connection to notify...  
15:59:28.952 -> Device connected!  
15:59:49.320 -> Received data: led_on  
15:59:54.347 -> Received data: led_off  
15:59:58.369 -> Received data: led_on  
16:00:01.319 -> Received data: led_off  
16:00:06.918 -> Received data: led_toggle  
16:00:07.991 -> Received data: led_toggle
```

At the bottom right of the window, it says 'Ln 47, Col 18 Raspberry Pi Pico W on COM9' with a speech bubble icon and a '2'.

LED Status.



Note: If the messages you send are not "led\_on", "led\_off", or "led toggle", the status of the LED will not change.

For example, when the LED is already ON, it will remain ON unless the message "led\_off", or "led toggle" is received.

The following is the program code:

```
1 #include <BTstackLib.h>
2 #include <SPI.h>
3 #include <btstack.h>
4
5 #define LED 15           // LED pin
6 bool led_status = false;
7
8 #define MAX_LENGTH 256
9 static char characteristic_data[MAX_LENGTH] = "Pico W Bluetooth";
10
11 // Track subscription status
12 bool isSubscribed = false;
13
14 // The handle of the connection
15 hci_con_handle_t connection_handle = HCI_CON_HANDLE_INVALID;
16
17 // characteristic handle
18 uint16_t characteristic_handle = 0;
19
20 // Assuming the handle of CCCD is a characteristic handle+1
21 #define CCCD_HANDLE (characteristic_handle + 1)
22
23 void setupBLE(const char *BLEName) {
24     //Set callback function
25     BTstack.setBLEDeviceConnectedCallback(deviceConnectedCallback);
26     BTstack.setBLEDeviceDisconnectedCallback(deviceDisconnectedCallback);
27     BTstack.setGATTCharacteristicRead(gattReadCallback);
28     BTstack.setGATTCharacteristicWrite(gattWriteCallback);
29
30     //Set GATT database
31     BTstack.addGATTService(new UUID("B8E06067-62AD-41BA-9231-206AE80AB551"));
32     characteristic_handle = BTstack.addGATTCharacteristicDynamic(
33         new UUID("f897177b-aee8-4767-8ecc-cc694fd5fce0"),
34         ATT_PROPERTY_READ | ATT_PROPERTY_WRITE | ATT_PROPERTY_NOTIFY,
35         0
36     );
37
38     //Activate Bluetooth and broadcast
39     BTstack.setup(BLEName);
40     BTstack.startAdvertising();
41
42     Serial.println("Waiting a client connection to notify...");
43 }
```

```
44
45 void setup() {
46     pinMode(LED, OUTPUT);
47
48     Serial.begin(115200);
49     while(!Serial);
50
51     setupBLE("PicoW_BLE");
52 }
53
54 void loop() {
55     BTstack.loop();
56
57     if (Serial.available() > 0) { // Check if there is serial data
58         String input = Serial.readStringUntil('\n');
59         input.trim(); // Remove front and back blank spaces
60
61         size_t input_length = input.length(); // Get String length
62
63         // Copy input to characteristic_data and add line breaks
64         memcpy(characteristic_data, input.c_str(), input_length);
65         characteristic_data[input_length] = '\n'; // add linefeeds
66         characteristic_data[input_length + 1] = '\0'; // End of string
67
68         Serial.print("input data: ");
69         Serial.print(characteristic_data);
70
71         sendNotificationToSubscribers(); //Send notifications to subscribed devices
72     }
73     //Delay by 5ms to prevent data loss due to receiving too quickly
74     delay(5);
75 }
76
77 void deviceConnectedCallback(BLEStatus status, BLEDevice *device) {
78     if(status == BLE_STATUS_OK) {
79         Serial.println("Device connected!");
80         connection_handle = device->getHandle(); // Get connection handle
81     }
82 }
83
84 void deviceDisconnectedCallback(BLEDevice * device) {
85     (void) device;
86     Serial.println("Disconnected.");
87     connection_handle = HCI_CON_HANDLE_INVALID;
```

```
88     isSubscribed = false;           // Reset subscription status
89 }
90
91 // Callback function for reading data
92 uint16_t gattReadCallback(uint16_t value_handle, uint8_t * buffer, uint16_t buffer_size) {
93     (void) value_handle;
94     if (buffer && buffer_size > 0) {
95         Serial.print("Read data: ");
96         Serial.println(characteristic_data);
97
98         size_t data_length = strlen(characteristic_data); // Get characteristic_data length
99         if (data_length > buffer_size) {                  // Limit length
100             data_length = buffer_size;
101         }
102
103         memcpy(buffer, characteristic_data, data_length); // Copy String
104         return data_length;
105     }
106     return 0;
107 }

108
109 // Callback function for writing data
110 int gattWriteCallback(uint16_t value_handle, uint8_t *buffer, uint16_t size) {
111     if (value_handle == CCCD_HANDLE) {                // Processing CCCD writing
112         if (size >= 2) {
113             uint16_t cccd_value = buffer[0] | (buffer[1] << 8);
114             isSubscribed = true;                      //Subscription status is true
115         }
116     } else {                                         // Writing of processing feature data
117         size_t copy_size = (size < (MAX_LENGTH - 1)) ? size : (MAX_LENGTH - 1);
118         memcpy(characteristic_data, buffer, copy_size); // Copy String
119         characteristic_data[copy_size] = '\0';          // Ensure that the string ends
120
121         String myString = String(characteristic_data)    // Convert to String
122         myString.trim();                                // Remove front and back blank spaces
123         if(myString.equals("1led_on") == true){          // led on
124             led_status = true;
125             digitalWrite(LED, led_status);
126         }
127         if(myString.equals("1led_off") == true){          // led off
128             led_status = false;
129             digitalWrite(LED, led_status);
130         }
131         if(myString.equals("1led_toggle") == true){        // led toggle
```

```
132     led_status = !led_status;
133     digitalWrite(LED, led_status);
134 }
135
136 Serial.print("Received data: ");
137 Serial.println(characteristic_data);
138 }
139
140 return 0;
141 }
142
143 void sendNotificationToSubscribers() {
144 if (isSubscribed && connection_handle != HCI_CON_HANDLE_INVALID) {
145 // Send notifications
146 att_server_notify(connection_handle, characteristic_handle,
147                     (uint8_t*)characteristic_data, strlen(characteristic_data));
148 }
149 }
```

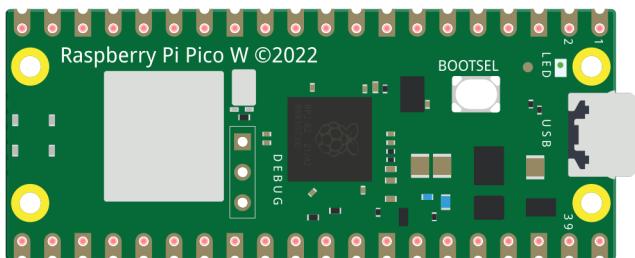
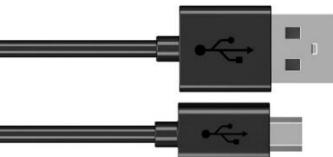
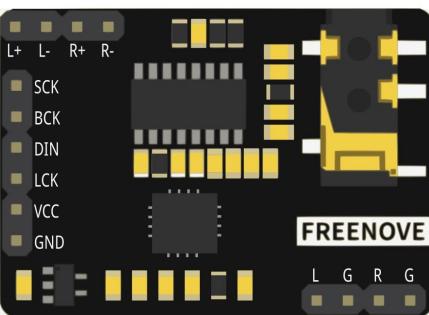
# Chapter 25 Bluetooth Audio (Only for Pico W)

Raspberry Pi Pico W integrates both Classic Bluetooth and Bluetooth Low Energy (BLE), enabling it to transmit not only simple data and commands but also files including text and audio. In this section, we will use the Bluetooth reception function to receive music from a smartphone and play it.

## Project 24.1 Bluetooth Passthrough

Utilizing the Bluetooth audio reception capability of the Raspberry Pi Pico W, we can decode audio data from a smartphone using the A2DP protocol, allowing the Raspberry Pi Pico W to receive high-quality audio. In this project, we will employ an audio converter and amplifier to transform the audio data into stereo and output it.

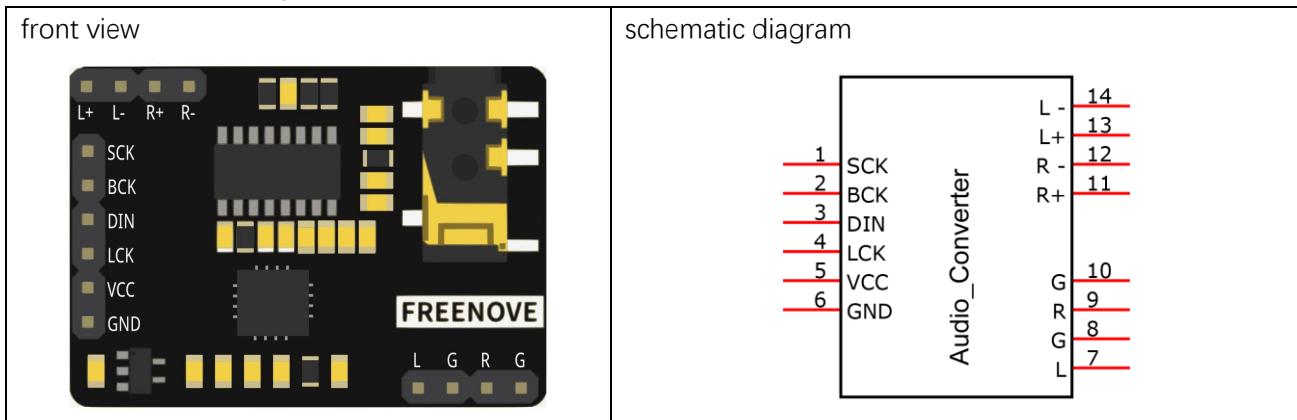
### Component List

Raspberry Pi Pico W x1	 A photograph of the Raspberry Pi Pico W development board. It is a green PCB with a central Broadcom chip, various capacitors, resistors, and connectors. Two yellow circular pads are visible on the left side. Labels include "Raspberry Pi Pico W ©2022", "DEBUG", "BOOTSEL", "LED", and "USB".	Micro USB Wire x1	 A photograph of a standard black Micro USB cable with two ends, each featuring a black plastic housing and a metal connector.
Audio Converter & Amplifier	 A photograph of the Freenove Audio Converter & Amplifier module. It is a black PCB with a central chip and several gold-plated pins for connection. A legend on the left lists pins: L+, L-, R+, R-, SCK, BCK, DIN, LCK, VCC, GND, and GND. The word "FREENOVE" is printed on the module.	Speaker*1	 A photograph of a black speaker with a circular grille and a central driver. Two wires, one red and one black, extend from the back of the speaker.
Jumper wire F/M*4			 A photograph of a long, thin black jumper wire with four pins at each end, designed for connecting between the Pico W and the audio converter module.



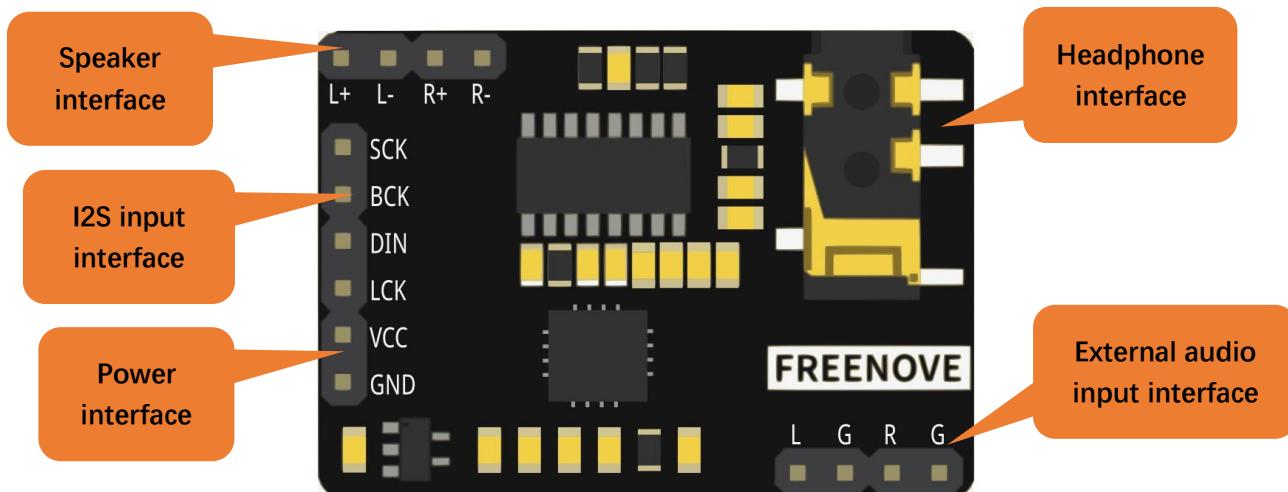
## Component knowledge

### Audio Converter & Amplifier module



### Interface description for Audio Converter & Amplifier module

Pin	Name	Introductions
1	SCK	System clock input
2	BCK	Audio data bit clock input
3	DIN	Audio data input
4	LCK	Audio data word clock input
5	VCC	Power input, 3.3V~5.0V
6	GND	Power Ground
7	L	External audio left channel input
8	G	Power Ground
9	R	External audio right channel input
10	G	Power Ground
11	R+	Positive pole of right channel horn
12	R-	Negative pole of right channel horn
13	L+	Positive pole of left channel horn
14	L-	Negative pole of left channel horn



Any concerns? ✉ support@freenove.com

**Speaker interface:** Connect left channel speaker and right channel speaker. Group L: L+ & L-; Group R: R+ & R-. The two interfaces of the speaker can be connected to the interfaces of group L or group R. However, when one interface is connected to group L, the other cannot be connected to group R. Doing so may cause the module to malfunction.

**Headphone interface:** the interface to connect the headphones.

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

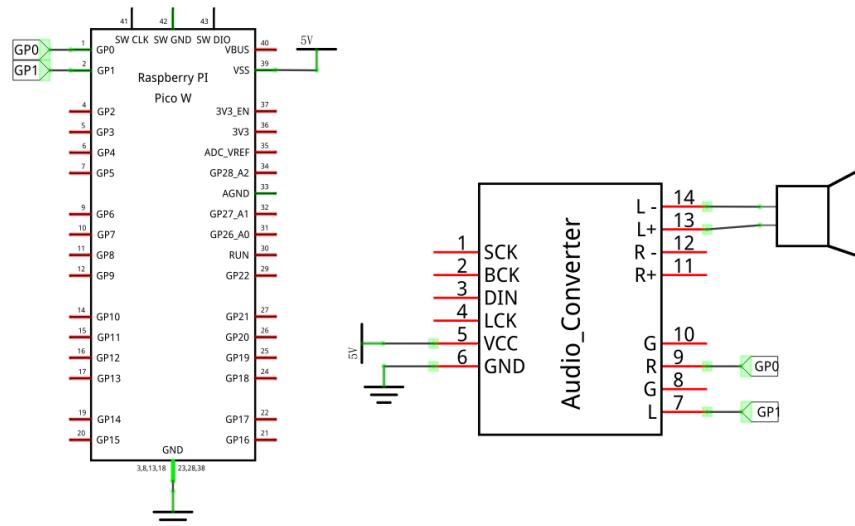
**External audio input interface:** connect to external audio equipment. Used to amplify externally input audio signals.

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

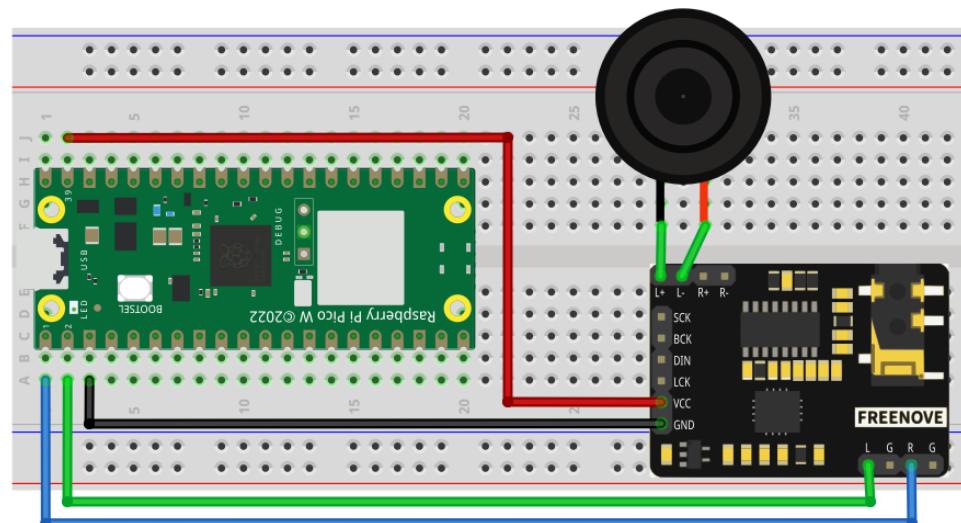
## Circuit

The connection between the control board and the audio module is shown in the figure below.

Schematic diagram



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





## Sketch

### Sketch\_24.4\_Bluetooth\_By\_PCM5102A

```

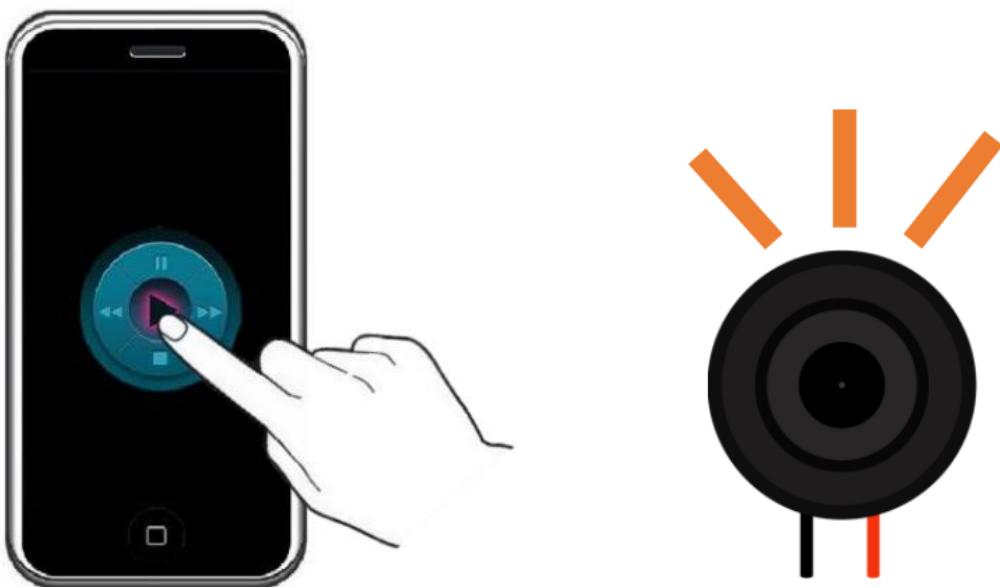
File Edit Sketch Tools Help
Sketch_24.4_Bluetooth_By_PCM5102A.ino
1 #include <BluetoothAudio.h>
2 #include <PWMAudio.h>
3
4 PWMAudio pwm;
5 A2DPSink a2dp;
6
7 // Define a playback state
8 volatile A2DPSink::PlaybackStatus status = A2DPSink::STOPPED;
9
10 // Volume callback function
11 void volumeCB(void *param, int pct) {
12     (void) param;
13     Serial.printf("Speaker volume changed to %d%\n", pct);
14 }
15
16 // Connect callback function
17 void connectCB(void *param, bool connected) {
18     (void) param;
19     if (connected) {
20         //Print the address of the connected device
21         Serial.printf("A2DP connection started to %s\n", bd_addr_to_str(a2dp.getSourceAddress()));
22     } else {
23         Serial.printf("A2DP connection stopped\n");
24     }
25 }
26
27 // Play status callback function
28 void playbackCB(void *param, A2DPSink::PlaybackStatus state) {
29     (void) param;
30     status = state;
31 }

```

When you see the messages as shown below, it indicates that the Pico W's Bluetooth is ready for connection and playing music.

Message
17:38:41.169 -> Starting, connect to the PicoW and start playing music
17:38:41.169 -> Use BOOTSEL to pause/resume playback
17:38:41.918 -> NOW PLAYING:

Search “Pico W Boom” on your phone to connect. Upon successful connection, you can display audio via Pico W.



The following is the program code:

```
1 #include <BluetoothAudio.h>
2 #include <PWMAudio.h>
3
4 PWMAudio pwm;
5 A2DPSink a2dp;
6
7 // Define a playback state
8 volatile A2DPSink::PlaybackStatus status = A2DPSink::STOPPED;
9
10 // Volume callback function
11 void volumeCB(void *param, int pct) {
12     (void) param;
13     Serial.printf("Speaker volume changed to %d%%\n", pct);
14 }
15
16 // Connect callback function
17 void connectCB(void *param, bool connected) {
18     (void) param;
19     if (connected) {
20         //Print the address of the connected device
21         Serial.printf("A2DP connection started to %s\n", bd_addr_to_str(a2dp.getSourceAddress()));
22     } else {
23         Serial.printf("A2DP connection stopped\n");
24     }
25 }
```

```

27 // Play status callback function
28 void playbackCB(void *param, A2DPSink::PlaybackStatus state) {
29     (void) param;
30     status = state;
31 }
32
33 void setup() {
34     Serial.begin(115200);
35     while(!Serial);
36
37     Serial.printf("Starting, connect to the PicoW and start playing music\n");
38     Serial.printf("Use BOOTSEL to pause/resume playback\n");
39
40     a2dp.setName("PicoW Boom 00:00:00:00:00:00");
41     // Set the audio consumer to PWM audio output
42     a2dp.setConsumer(new BluetoothAudioConsumerPWM(pwm));
43     a2dp.onVolume(volumeCB);
44     a2dp.onConnect(connectCB);
45     a2dp.onPlaybackStatus(playbackCB);
46     a2dp.begin();
47 }
48
49 char *nowPlaying = nullptr; //Store the name of the currently playing track
50
51 void loop() {
52     if (BOOTSEL) {
53         if (status == A2DPSink::PAUSED) {           // if the playback status is paused
54             a2dp.play();                            // play
55             Serial.printf("Resuming\n");
56         } else if (status == A2DPSink::PLAYING) { // if the playback status is playing
57             a2dp.pause();                          // pause
58             Serial.printf("Pausing\n");
59         }
60         while (BOOTSEL);
61     }
62     if (!nowPlaying || strcmp(nowPlaying, a2dp.trackTitle())) {
63         free(nowPlaying);
64         nowPlaying = strdup(a2dp.trackTitle());
65         Serial.printf("NOW PLAYING: %s\n", nowPlaying);
66     }
67 }
```

Include two libraries: "BluetoothAudio.h" and "PWMAudio.h".

1	#include <BluetoothAudio.h>
2	#include <PWMAudio.h>

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

Before using the functions in these two libraries, it is necessary to construct objects of the PWMAudio class and the A2DPSink class.

```
4  PWMAudio pwm;
5  A2DPSink a2dp;
```

Define the playback status of Bluetooth audio, the default is stop status.

```
8  volatile A2DPSink::PlaybackStatus status = A2DPSink::STOPPED;
```

Write a volume callback function that is called when the volume changes and prints the volume percentage.

```
11 void volumeCB(void *param, int pct) {
12     (void) param;
13     Serial.printf("Speaker volume changed to %d%%\n", pct);
14 }
```

Write a connection callback function to print the Bluetooth device address when connected to Pico W Bluetooth.

```
17 void connectCB(void *param, bool connected) {
18     (void) param;
19     if (connected) {
20         //Print the address of the connected device
21         Serial.printf("A2DP connection started to %s\n", bd_addr_to_str(a2dp.getSourceAddress()));
22     } else {
23         Serial.printf("A2DP connection stopped\n");
24     }
25 }
```

Write a playback status Callback function to control the playback status of Bluetooth audio.

```
28 void playbackCB(void *param, A2DPSink::PlaybackStatus state) {
29     (void) param;
30     status = state;
31 }
```

The steps for creating A2DP Bluetooth audio are:

1. Set the Bluetooth name and MAC address.
2. Set the audio consumer to PWM audio output.
3. Enable callbacks for volume, connection, and playback status.
4. Initialize A2DP.

```
40 a2dp.setName("PicoW Boom 00:00:00:00:00:00");
41 // Set the audio consumer to PWM audio output
42 a2dp.setConsumer(new BluetoothAudioConsumerPWM(pwm));
43 a2dp.onVolume(volumeCB);
44 a2dp.onConnect(connectCB);
45 a2dp.onPlaybackStatus(playbackCB);
46 a2dp.begin();
```



## Reference

## Class A2DPSink

**SetName(const char \*name)**: Sets the Bluetooth module name and MAC address.

**SetConsumer(BluetoothAudioConsumer\_ \*c)**: Sets the audio consumer as an A2DP receiver.

**onVolume(void ( \*cb)(void \*, int), void \*cbData = nullptr)**: Enables the Bluetooth audio volume Callback.

**onConnect(void ( \*cb)(void \*, bool), void \*cbData = nullptr)**: Enables the Bluetooth audio connection Callback.

**onPlaybackStatus(void ( \*cb)(void \*, PlaybackStatus), void \*cbData = nullptr)**: Enables the Bluetooth audio playback status Callback.

**begin()**: Initializes A2DP.

**play()**: Changes the Bluetooth audio playback status to playing.

**pause()**: Changes the Bluetooth audio playback status to paused.

**trackTitle()**: Obtains the title of the current Bluetooth audio track.

## What's Next?

THANK YOU for participating in this learning experience!

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

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, 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.

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