# Welcome

Thank you for choosing Freenove products!

## Getting Started

When reading this, you should have downloaded the ZIP file for this product.
Unzip it and you will get a folder containing tutorials and related files. Please start with this PDF tutorial.

! Unzip the ZIP file instead of opening the file in the ZIP file directly.
! Do not move, delete or rename files in the folder just unzipped.

## Get Support

Encounter problems? Don't worry! Refer to "TroubleShooting.pdf" or contact us.

When there are packaging damage, quality problems, questions encountering in use, etc., just send us an email. We will reply to you within one working day and provide a solution.

support@freenove.com

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

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

# About Freenove

Freenove provides open source electronic products and services worldwide.

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

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

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

http://www.freenove.com

# Copyright



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# Contents

# 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_Basic_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.

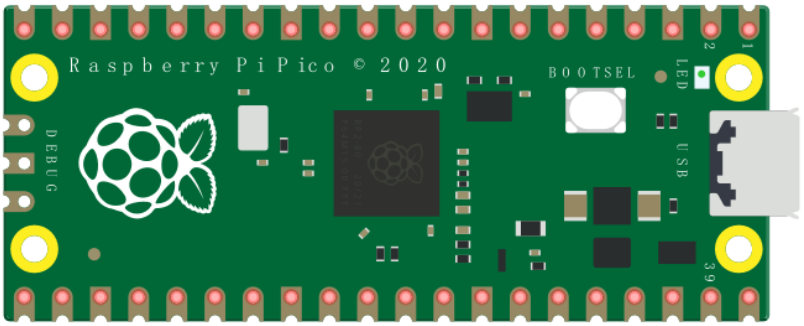
After completing the projects in this tutorial, you can also combine the components in different projects to make your own smart homes, smart car, robot, etc., bringing your imagination and creativity to life with Raspberry Pi Pico.

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

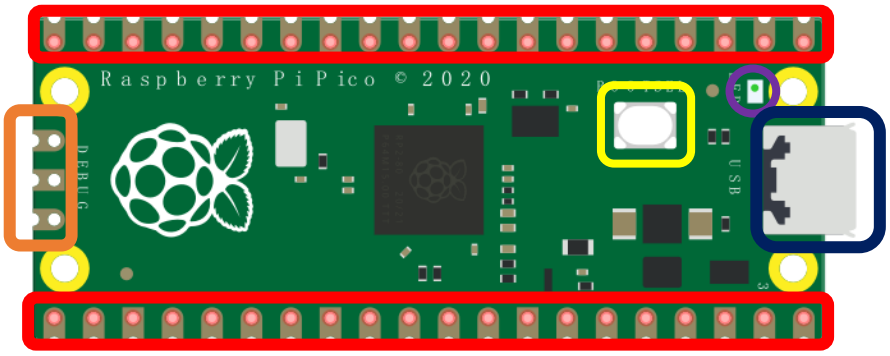
# Raspberry Pi Pico

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.

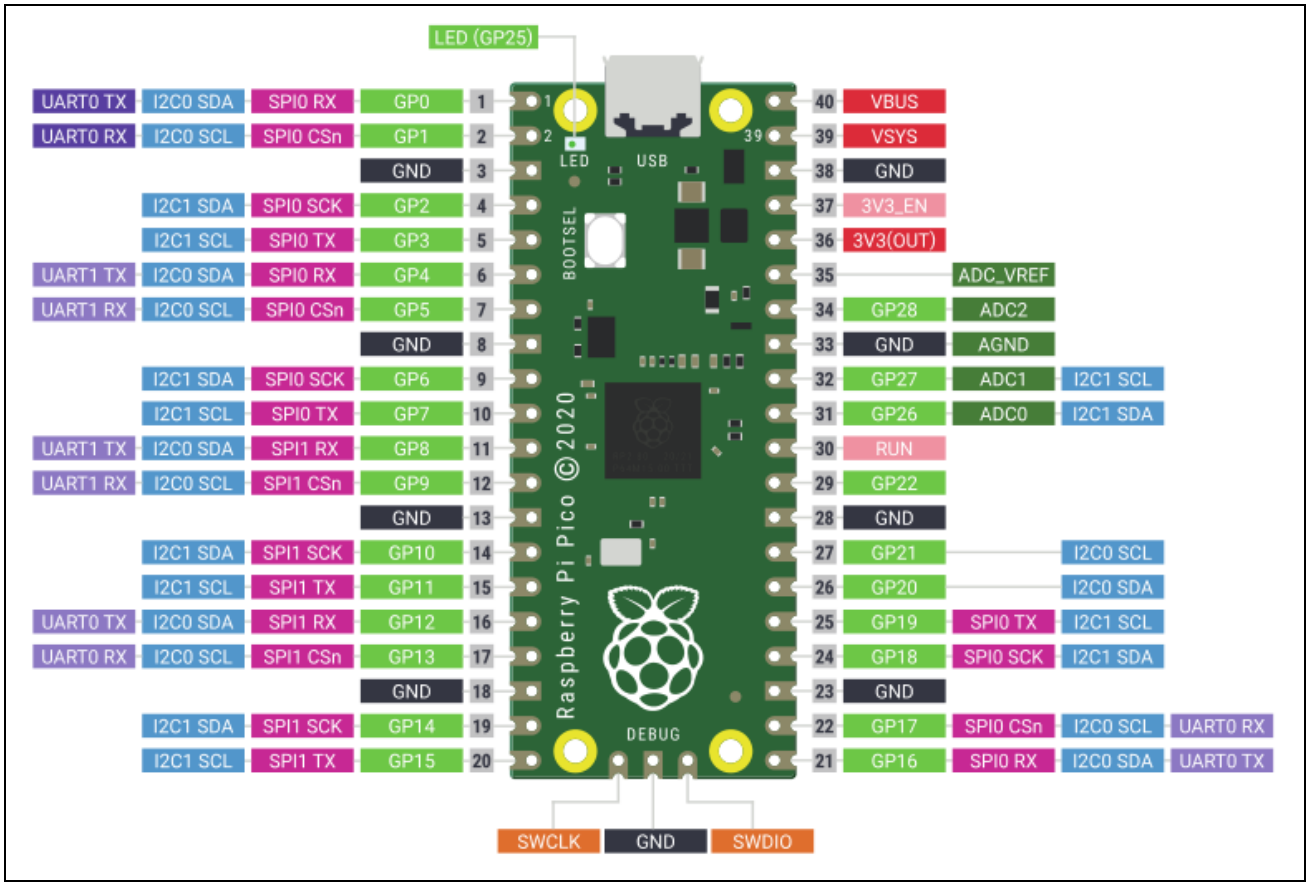



The hardware interfaces are distributed as follows:




| Frame color | Description |
|---|---|
| | Pins |
| | BOOTSE button |
| | USB port |
| | LED |
| | Debugging |

Function definition of pins:




| Color | Pins | Color | Pins |
|---|---|---|---|
| | GND | | Power |
| | GPIO | | ADC |
| | UART(default) | | UART |
| | SPI | | I2C |
| | System Control | | 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 |

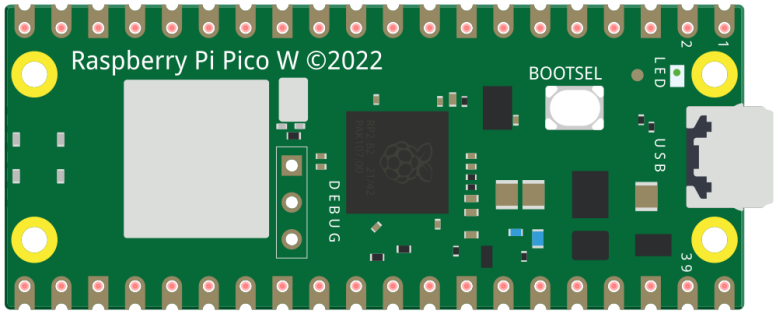
### SPI

| 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 |

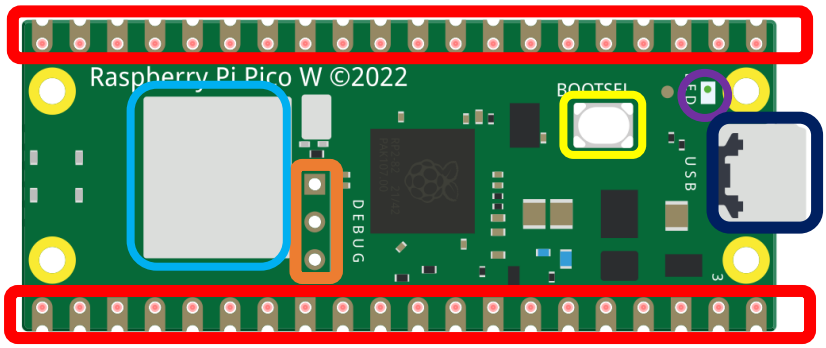
# Raspberry Pi Pico W

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.

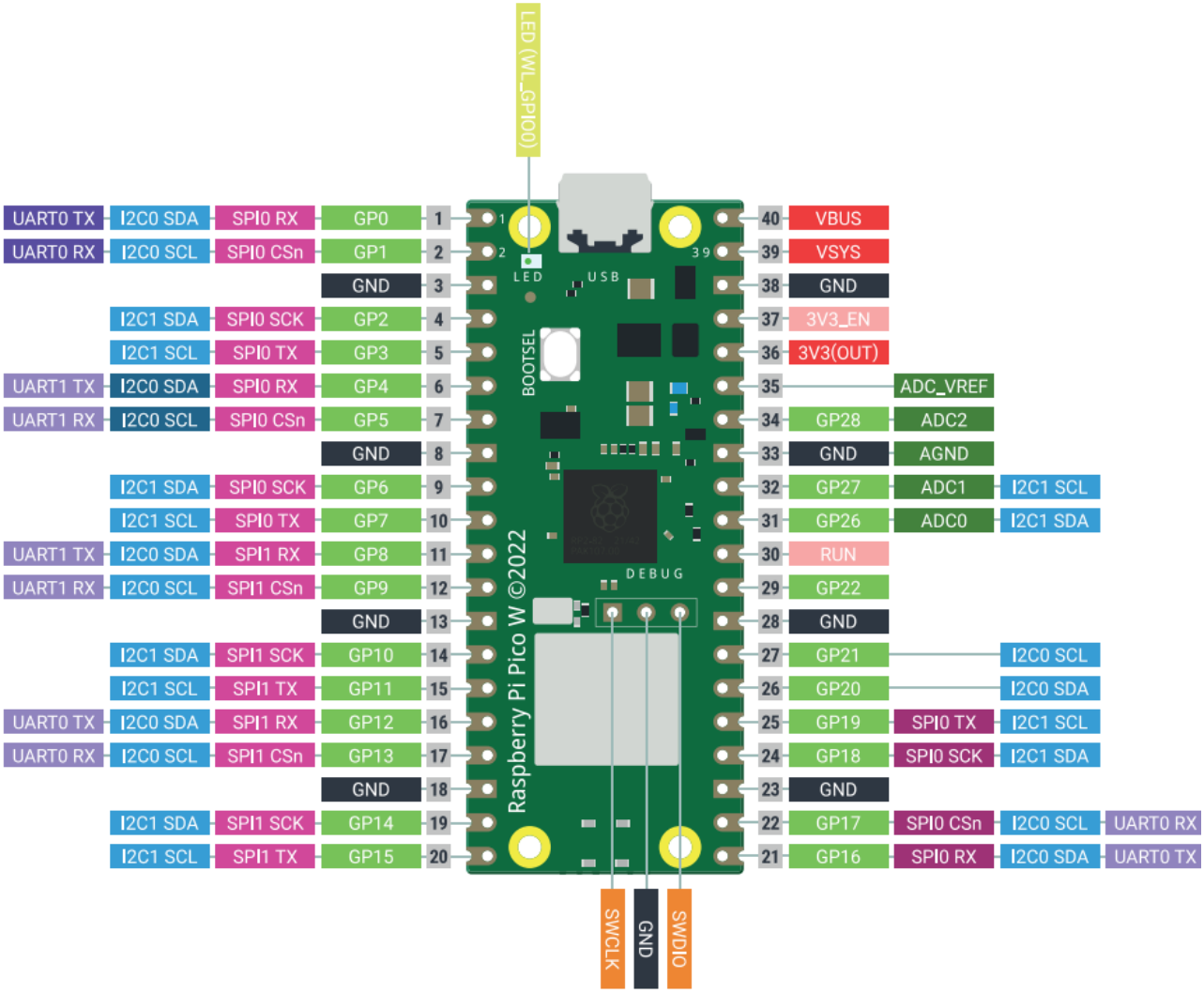



The hardware interfaces are distributed as follows:




| Frame color | Description |
|---|---|
| | Pins |
| | BOOTSE button |
| | USB port |
| | LED |
| | Debugging |
| | Wireless |

Function definition of pins:




| Color | Pins | Color | Pins |
|---|---|---|---|
| | GND | | Power |
| | GPIO | | ADC |
| | UART(default) | | UART |
| | SPI | | I2C |
| | System Control | | 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

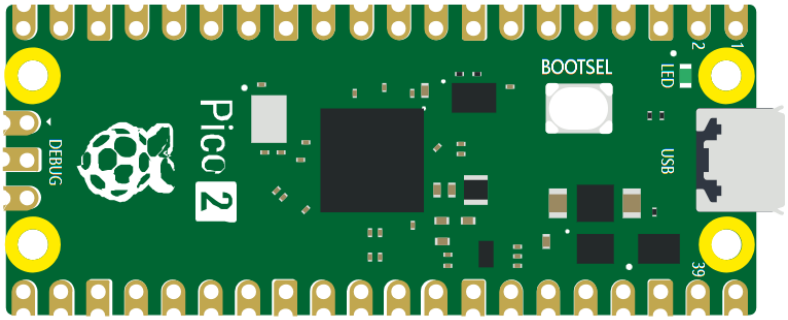
| Function | Default |
|---|---|
| SPI_BAUDRATE | 1000000 |
| SPI_POLARITY | 0 |
| SPI_PHASE | 0 |
| SPI_BITS | 8 |
| SPI_FIRSTBIT | MSB |
| SPI_SCK | Pin 18 |
| SPI_MOSI | Pin 19 |
| SPI_MISO | Pin 16 |
| SPI_SS | Pin 17 |

Wireless

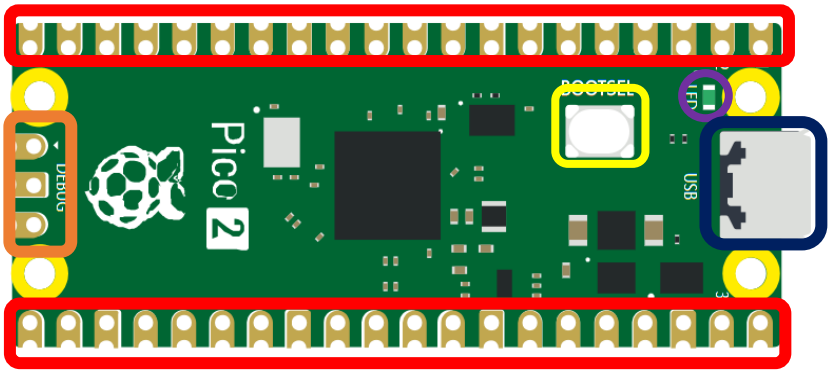
| Function | Default |
|---|---|
| WL_ON | GPIO23 |
| WL_D | GPIO24 |
| WL_CLK | GPIO29_ADC |
| WL_CS | GPIO25 |

## 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.

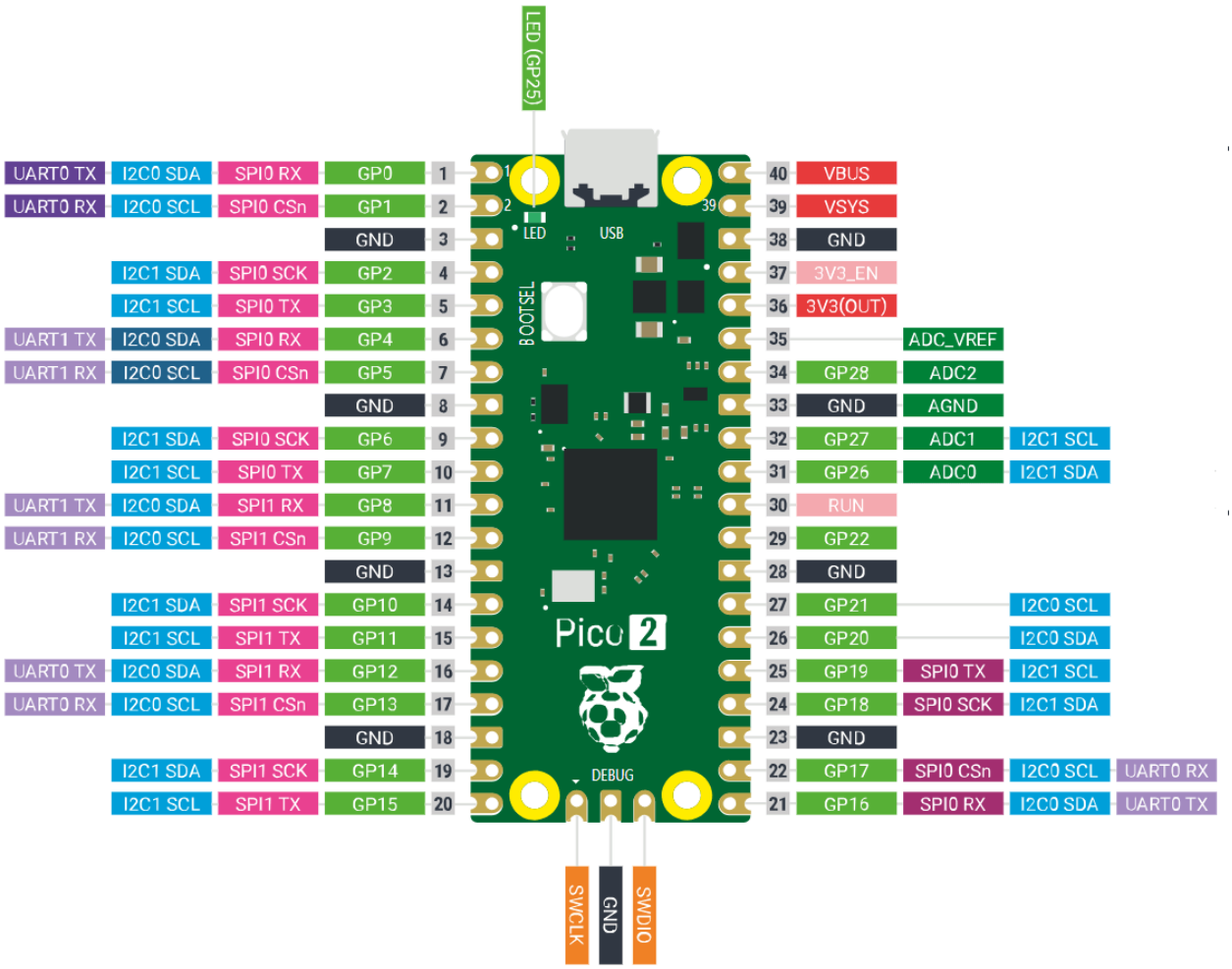



The hardware interfaces are distributed as follows:




| Frame color | Description |
|---|---|
| | Pins |
| | BOOTSE button |
| | USB port |
| | LED |
| | Debugging |

Function definition of pins:




| Color | Pins | Color | Pins |
|---|---|---|---|
| | GND | | Power |
| | GPIO | | ADC |
| | UART(default) | | UART |
| | SPI | | I2C |
| | System Control | | 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

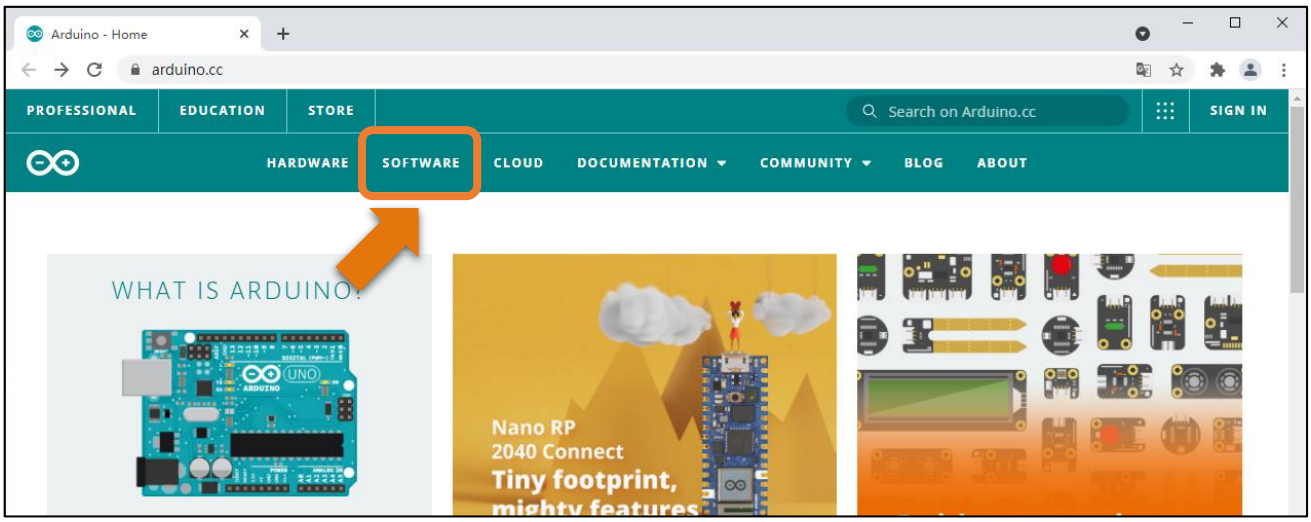
| Function | Default |
|---|---|
| SPI_BAUDRATE | 1000000 |
| SPI_POLARITY | 0 |
| SPI_PHASE | 0 |
| SPI_BITS | 8 |
| SPI_FIRSTBIT | MSB |
| SPI_SCK | Pin 18 |
| SPI_MOSI | Pin 19 |
| SPI_MISO | Pin 16 |
| SPI_SS | Pin 17 |

# Chapter 0 Getting Ready (Important)

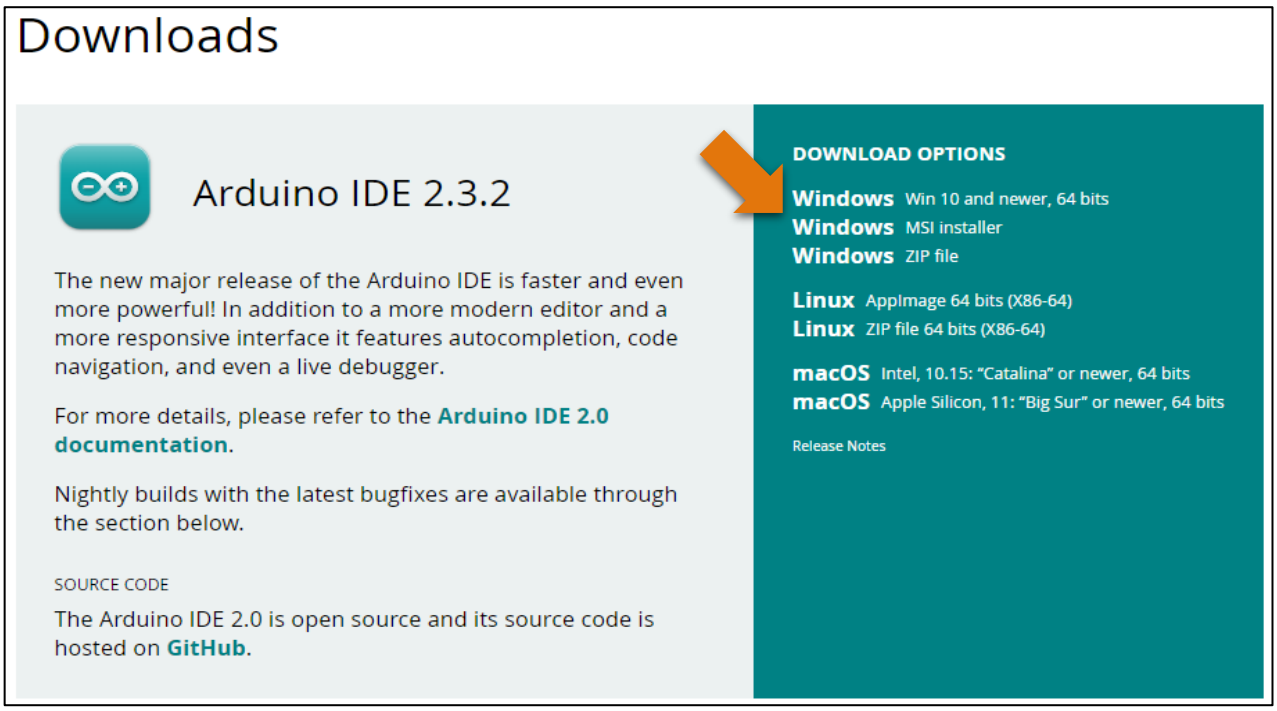
Before starting building the projects, you need to make some preparation first, which is so crucial that you must not skip.

## 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.

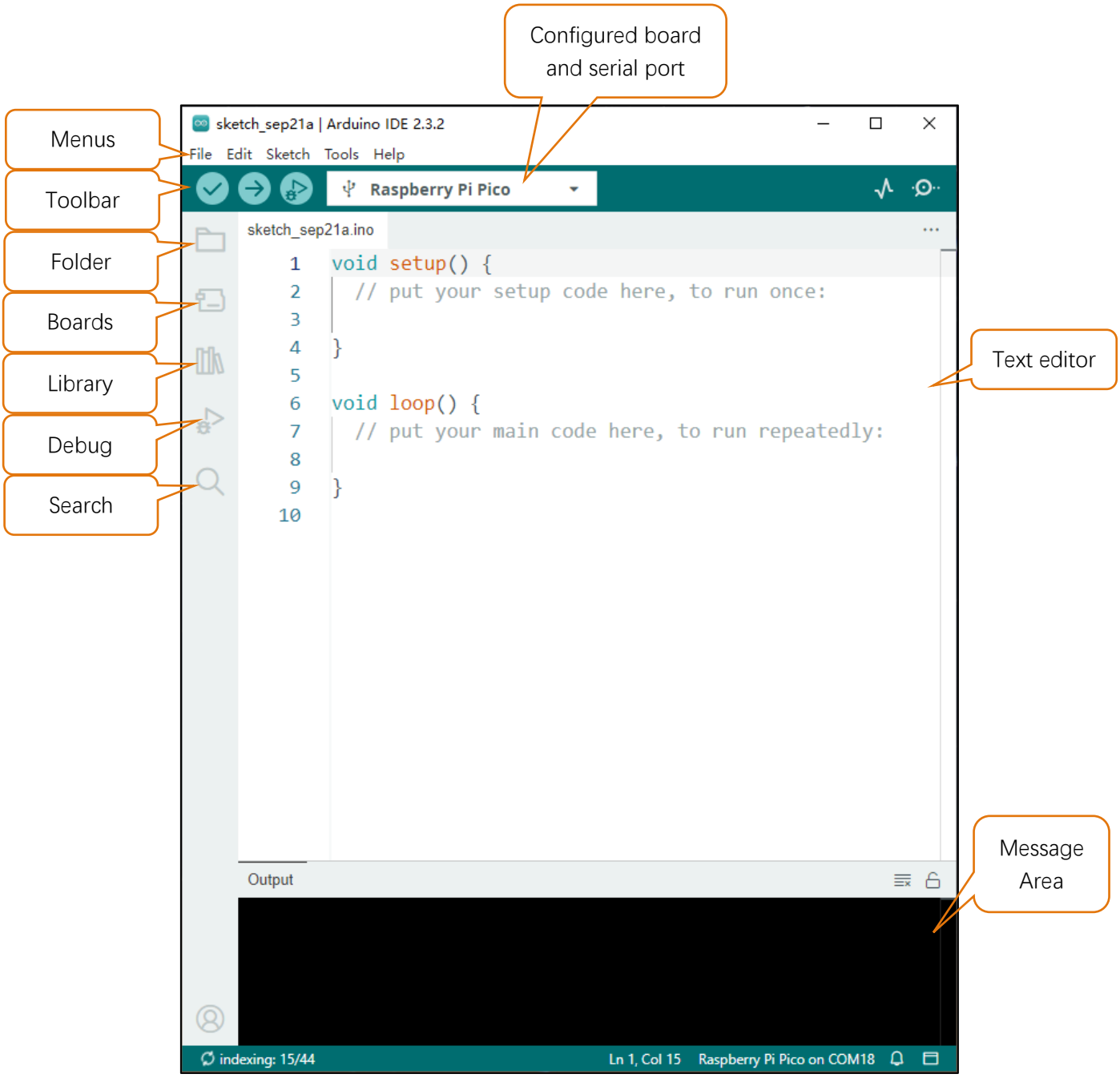



Select and download corresponding installer according to your operating system. If you are a windows user, please select the "Windows Installer" to download to install the driver correctly.



After the download completes, run the installer. For Windows users, there may pop up an installation dialog box of driver during the installation process. When it popes up, please allow the installation.
After installation is complete, an Arduino Software shortcut will be generated in the desktop. Run the Arduino Software.


The interface of Arduino Software is as follows:



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

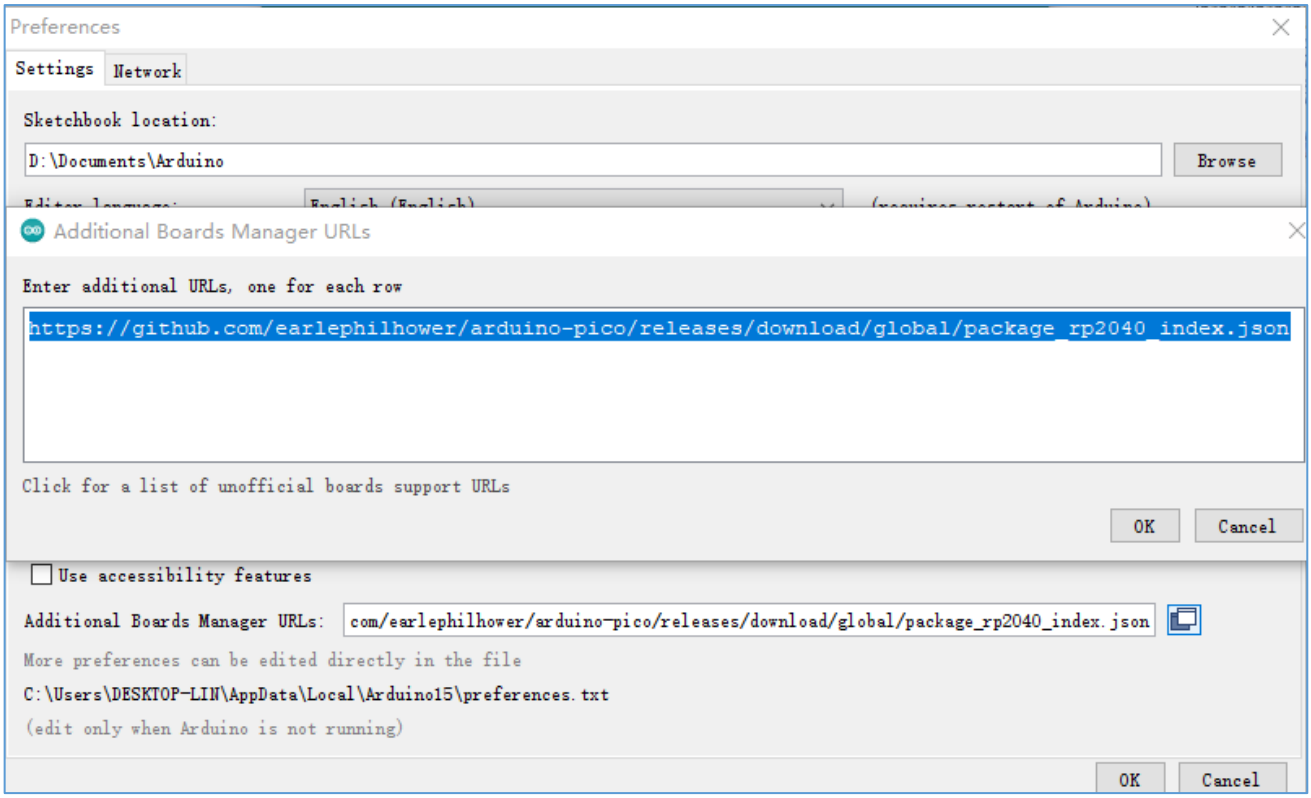
Additional commands are found within the five menus: File, Edit, Sketch, Tools, Help. The menus are context sensitive, which means only those items relevant to the work currently being carried out are available.

# Installation of Development Board Support Package

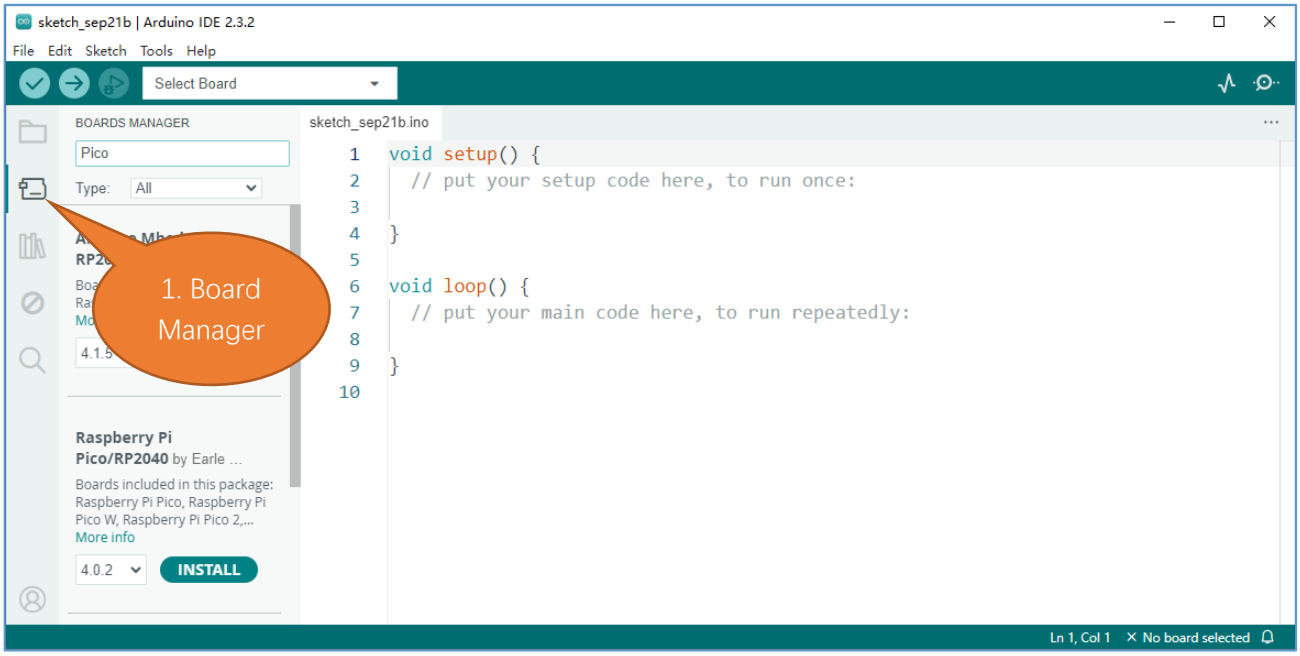
1. Make sure your network is of good connection.
2. Open Arduino IDE, and click File>Preference. In new pop-up window, find "Additional Boards Manager URLs", and replace with a new line:

https://github.com/earlephilhower/arduino-pico/releases/download/global/package_rp2040_index.json

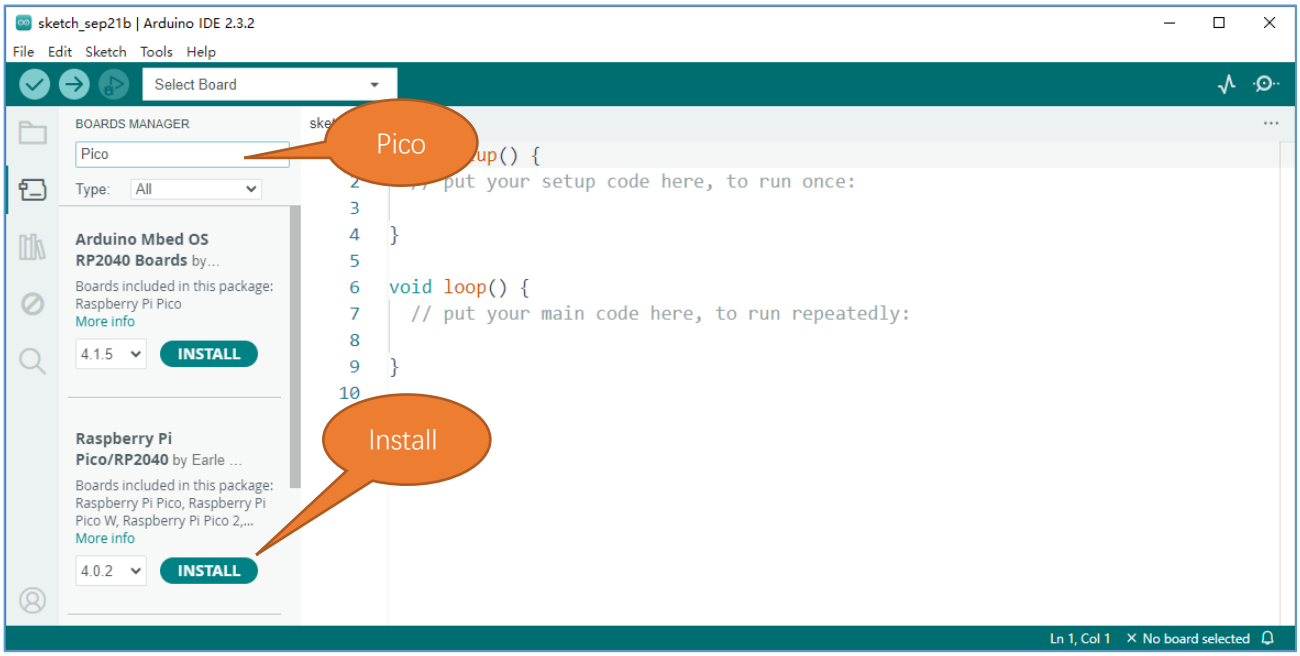
As shown below:




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



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

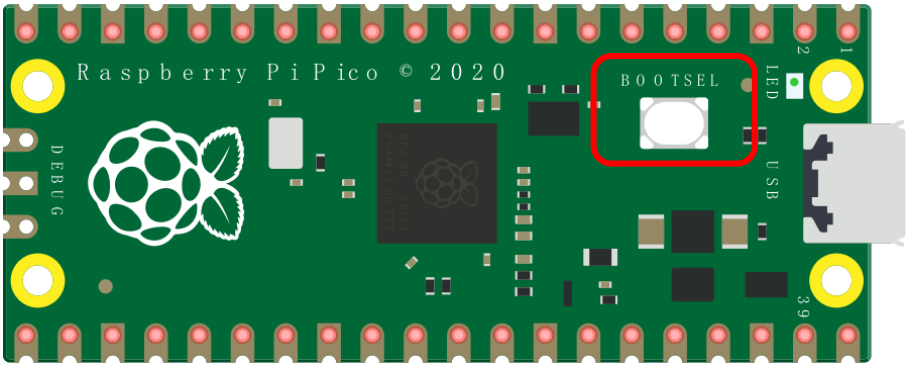



5. Click Yes in the pop-up "**dpinst-amd64.exe**" installation window. (Without it, you will fail to communicate with Arduino.) Thus far, we have finished installing the development support package.

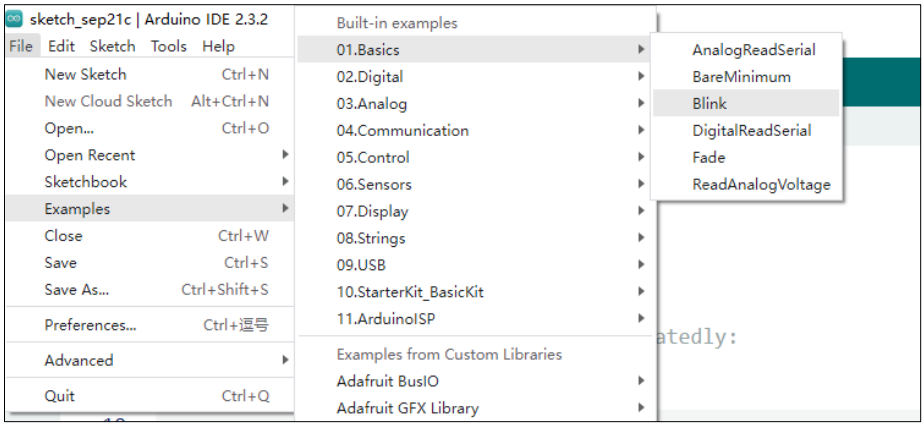
# Uploading Arduino-compatible Firmware for Pico

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.

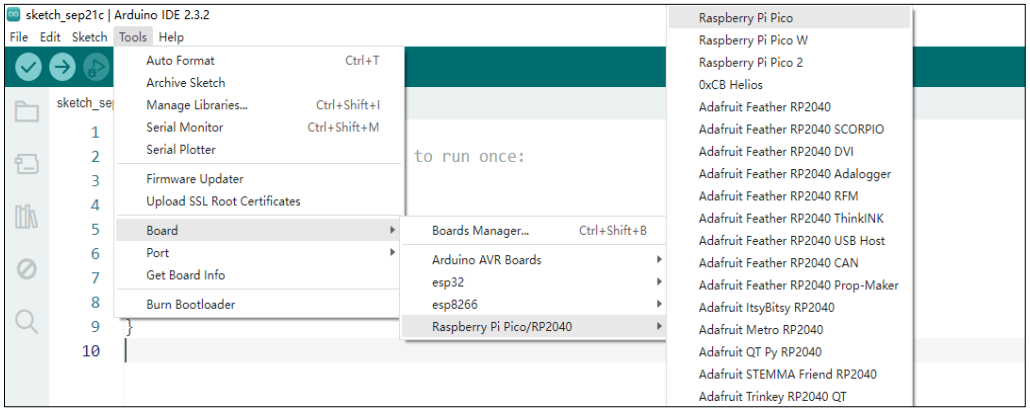
1. Disconnect Pico from computer. Keep pressing the white button (BOOTSEL) on Pico, and connect Pico to computer before releasing the button. (Note: Be sure to keep pressing the button before powering the Pico, otherwise the firmware will not download successfully)



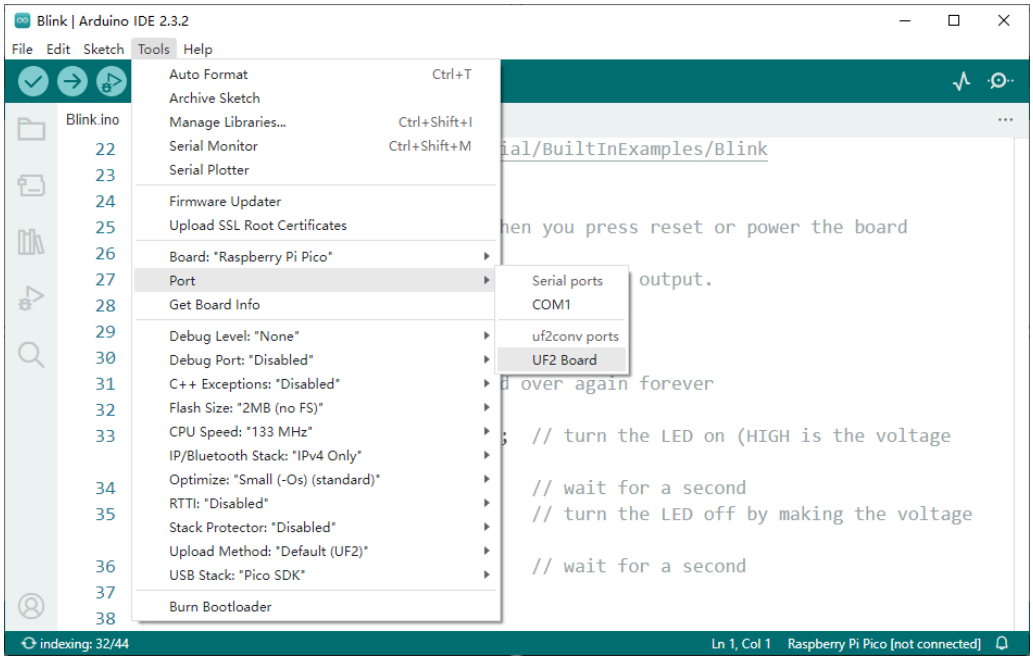

2. Open Arduino IDE. Click File>Examples>01.Basics>Blink.



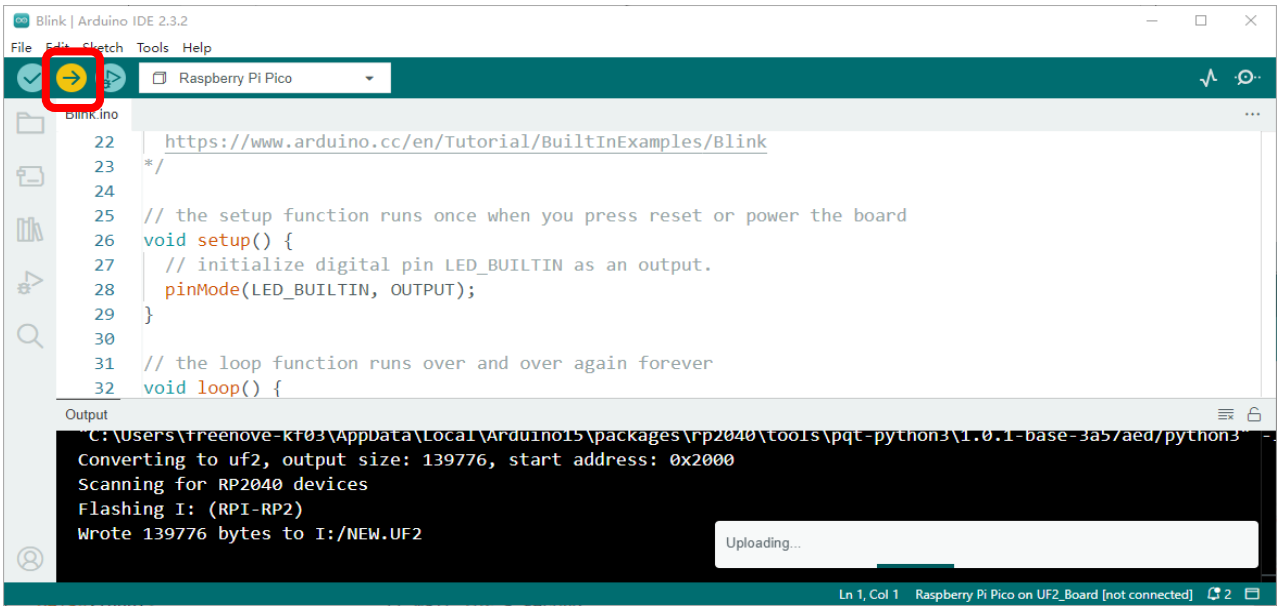
3. Click **Tools>Board>Raspberry Pi RP2040 Boards>Raspberry Pi Pico**.



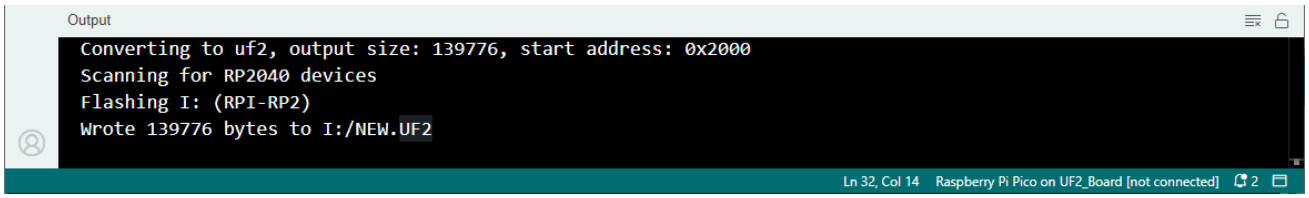

4. Click **Tools>Port>UF2 Board**.



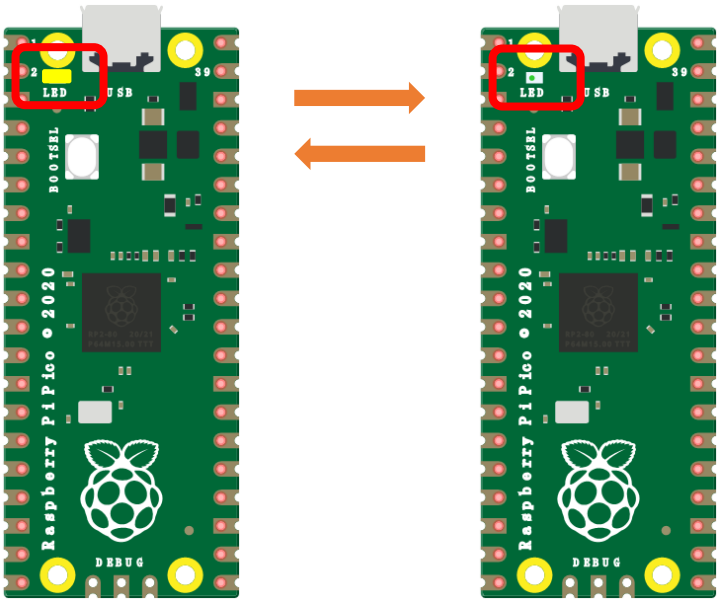

5. Upload sketch to Pico.



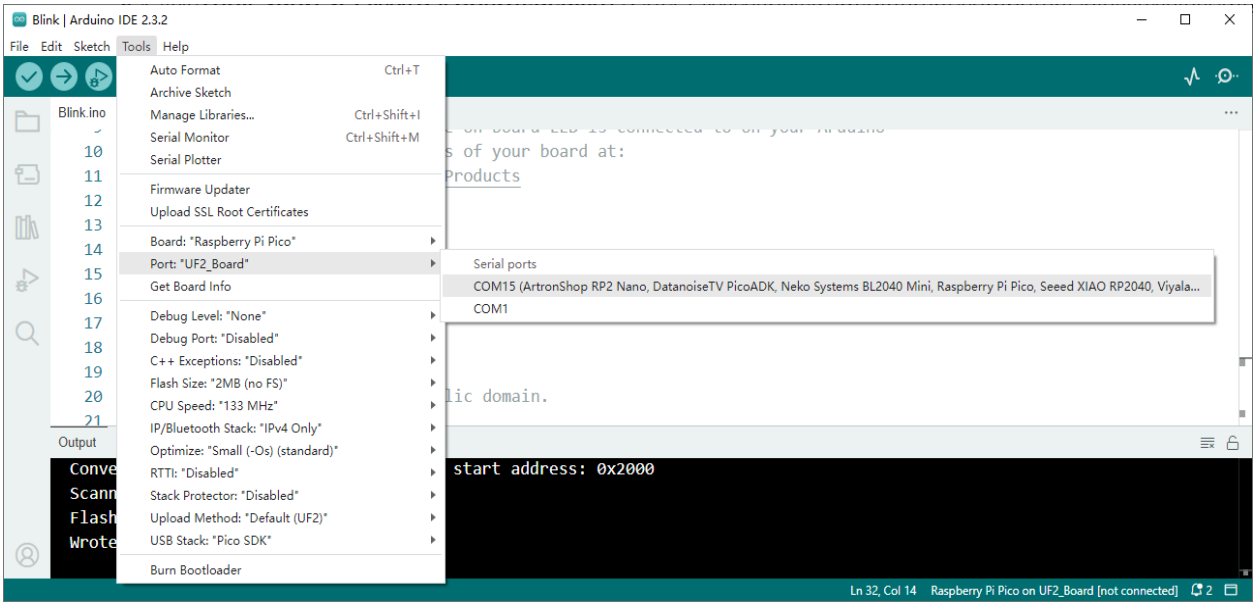
When the sketch finishes uploading, you can see the following prompt.



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.

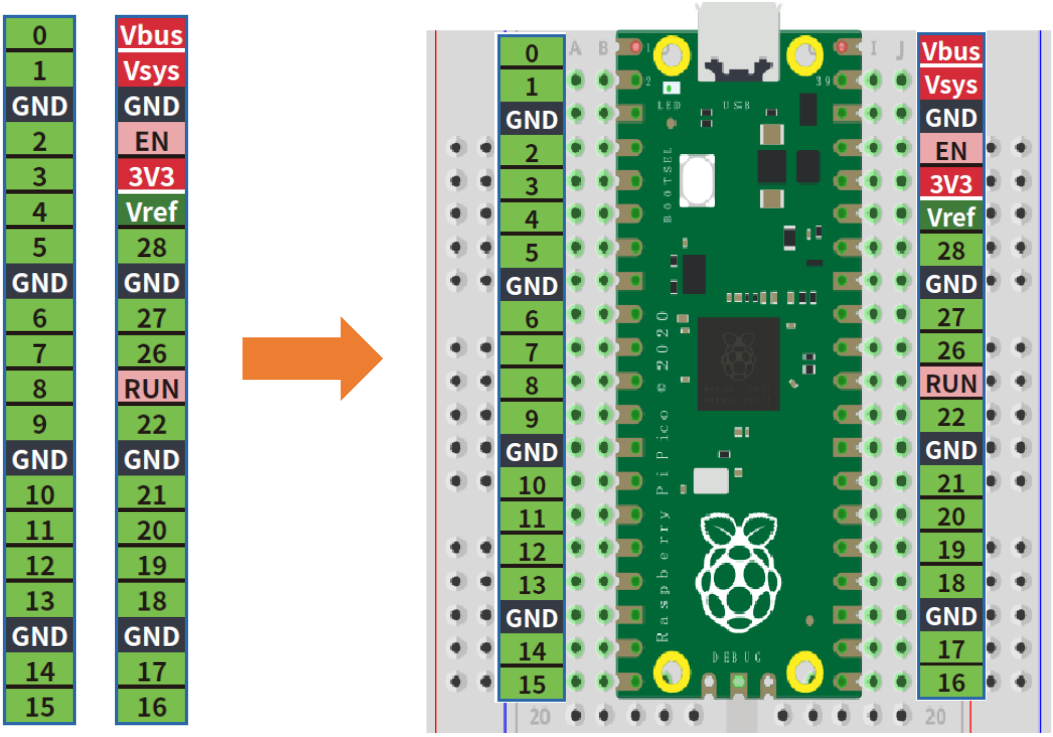



**Note:**

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

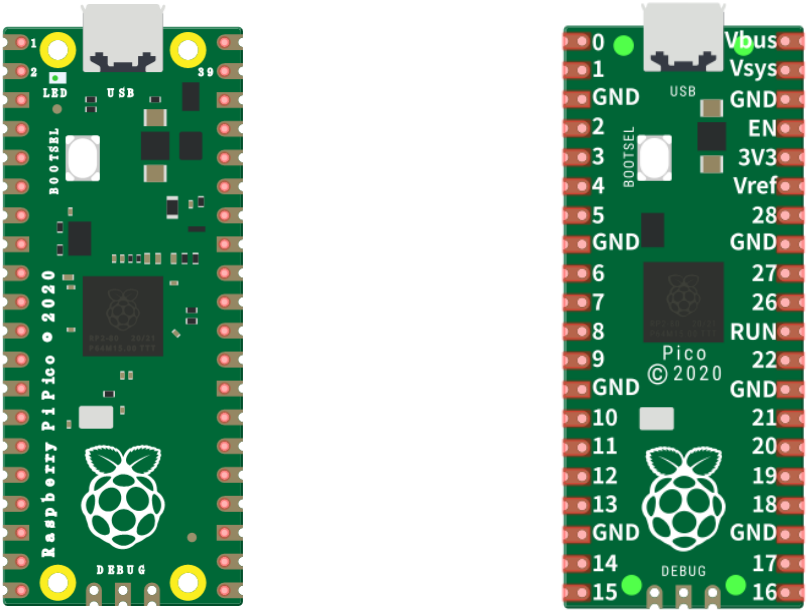
It is not difficult to use the Pico. However, officially, the pin functions are printed on the back of the board, which makes it inconvenient to use. To help users finish each project in the tutorial faster and easier, we provide stickers of the pin functions as follows:




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.

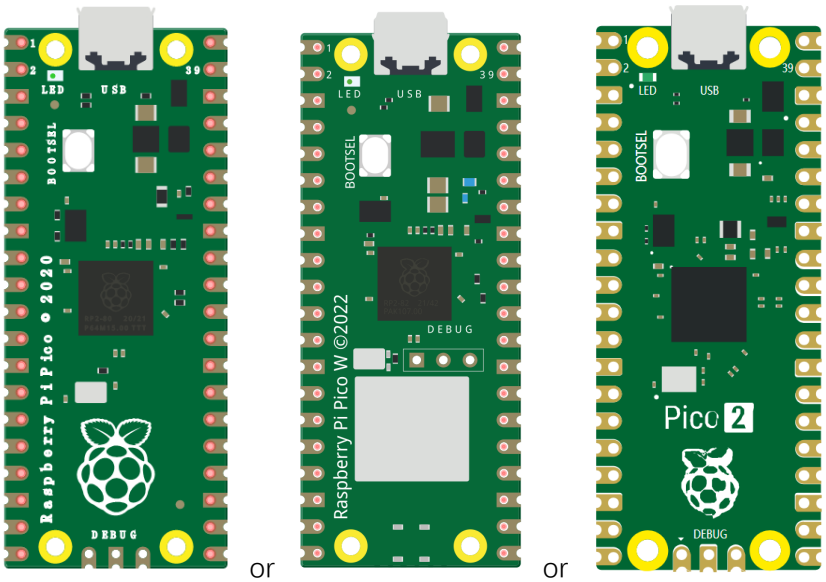
This chapter is the Start Point in the journey to build and explore Pico electronic projects. We will start with simple “Blink” project.

## Project 1.1 Blink

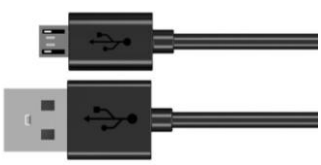
In this project, we will use Raspberry Pi Pico to control blinking a common LED.
If you have not installed Arduino IDE, you can click Here.
If you have not uploaded firmware for Pico, you can click Here to upload.

### Component List

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



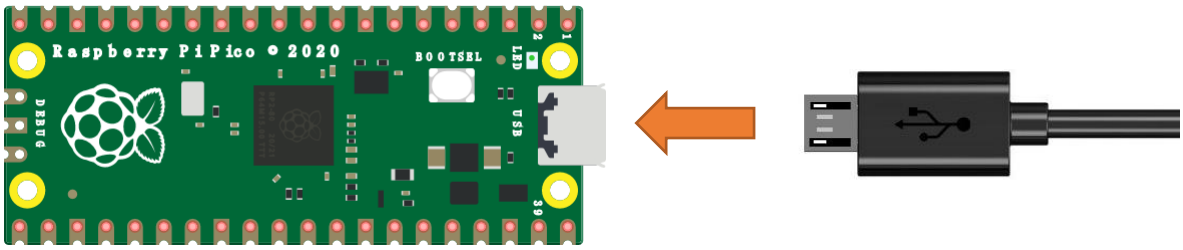

USB cable x1



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.

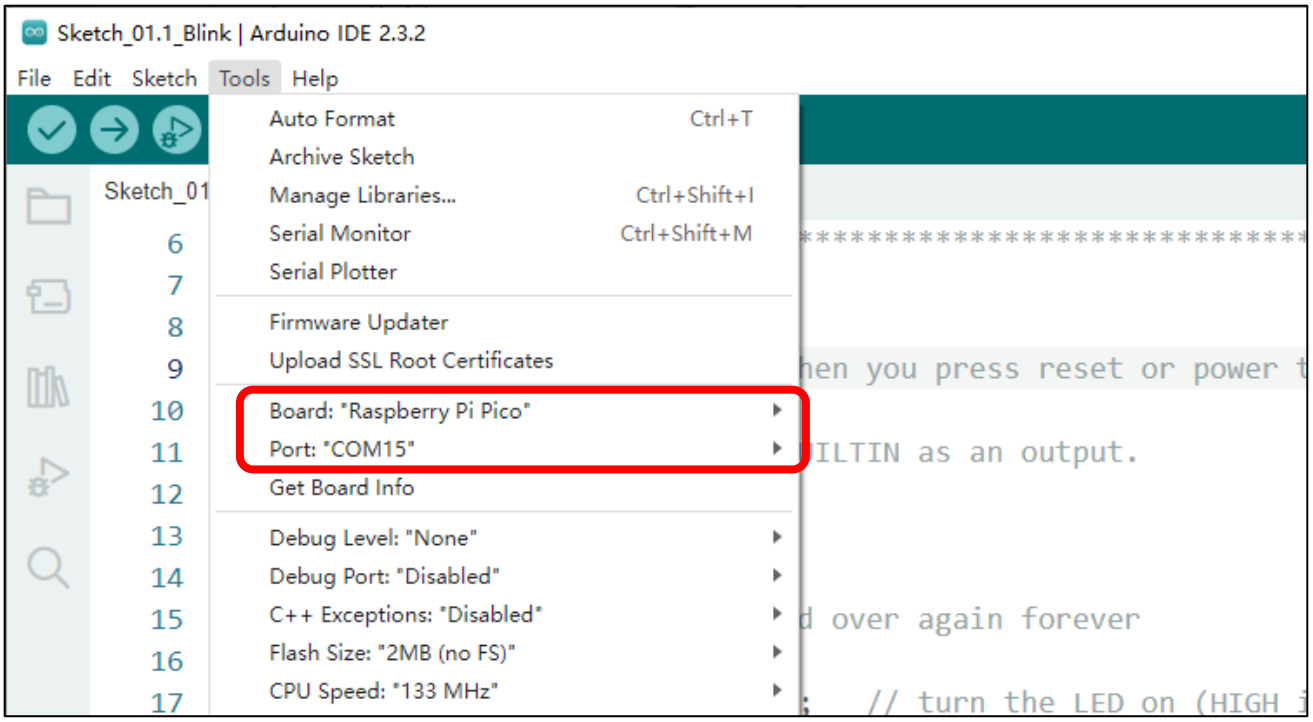


## Sketch

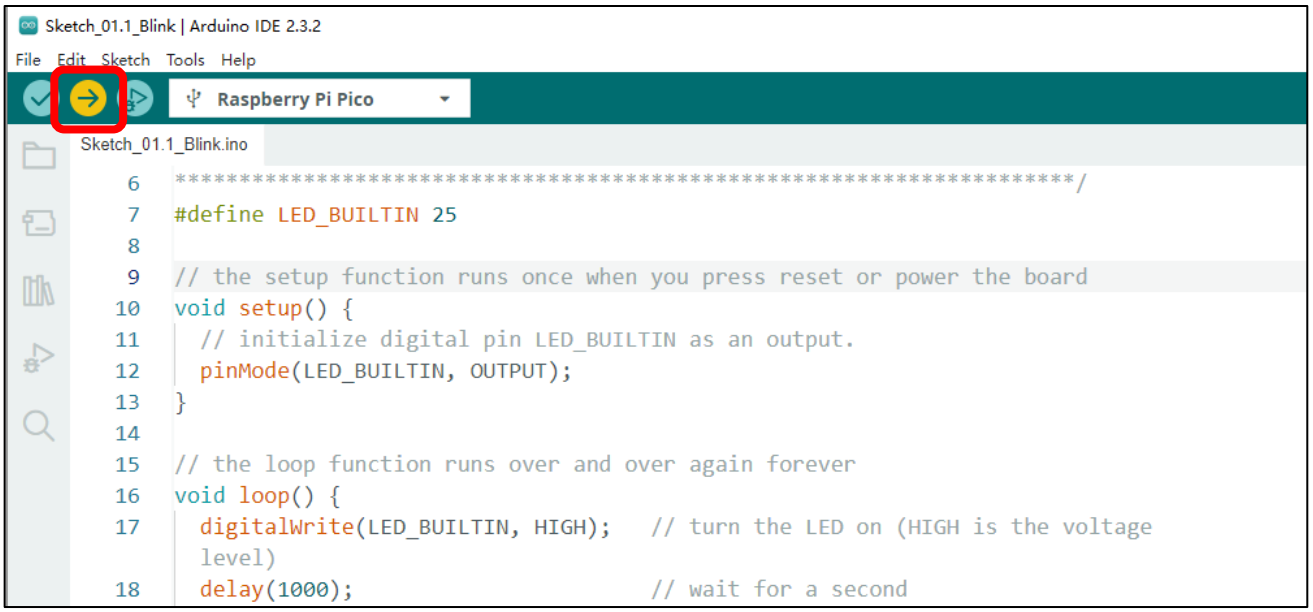
The onboard LED of Raspberry Pi Pico is controlled by GP25. When GP25 outputs high level, LED lights up; when it outputs low, LED lights off. You can open the provided code: **Freenove_Basic_Starter_Kit_for_Raspberry_Pi_Pico\C\Sketches\Sketch_01.1_Blink**.

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

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

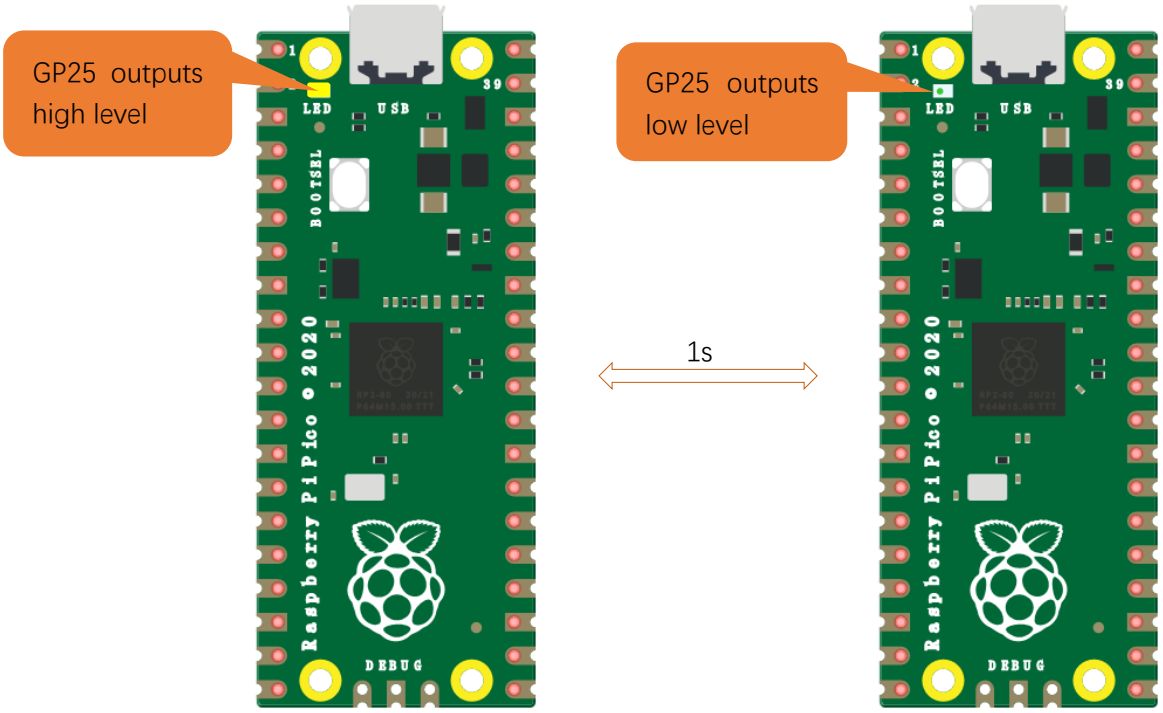



Click "Upload" to upload the sketch to Pico.



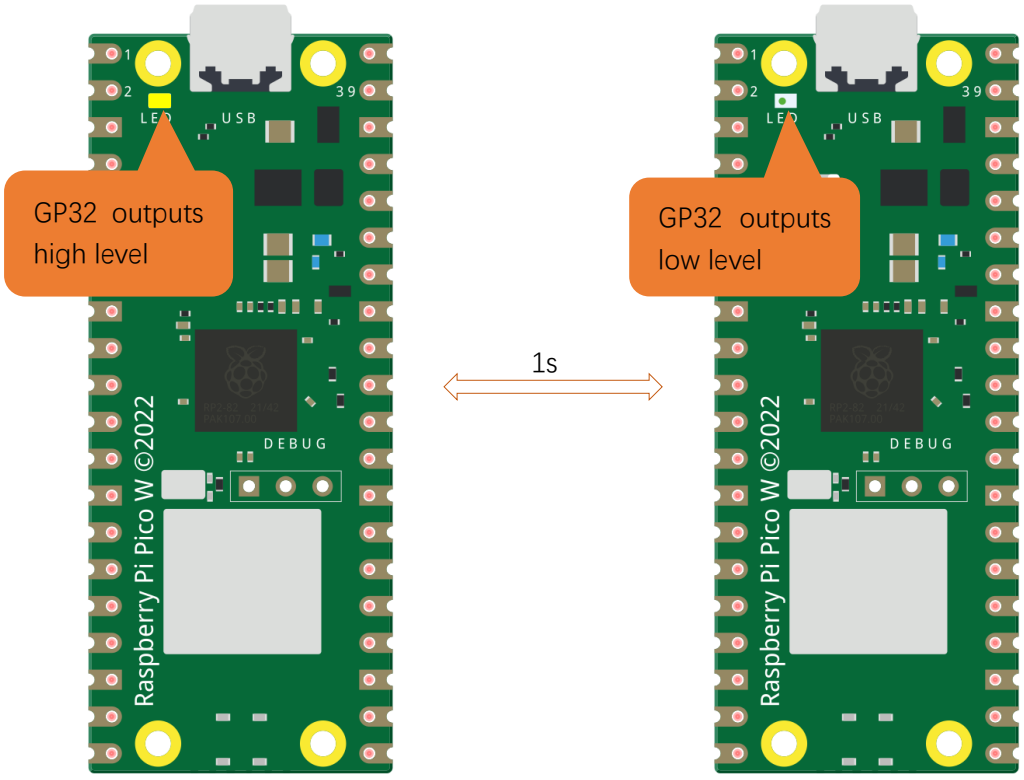
**If you have any concerns, please contact us at support@freenove.com**

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.


```
1  // the setup function runs once when you press reset or power the board
2  void setup() {
…    …
5  }
6
7  // the loop function runs over and over again forever
8  void loop() {
…    …
13 }
```

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
```

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_PULLDOWM, or INPUT_PULLUP.

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

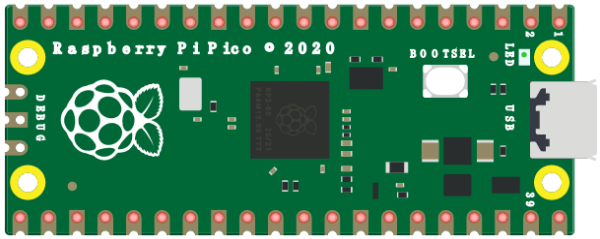
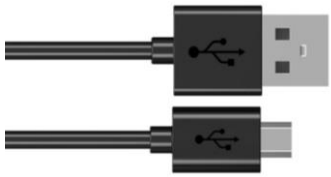
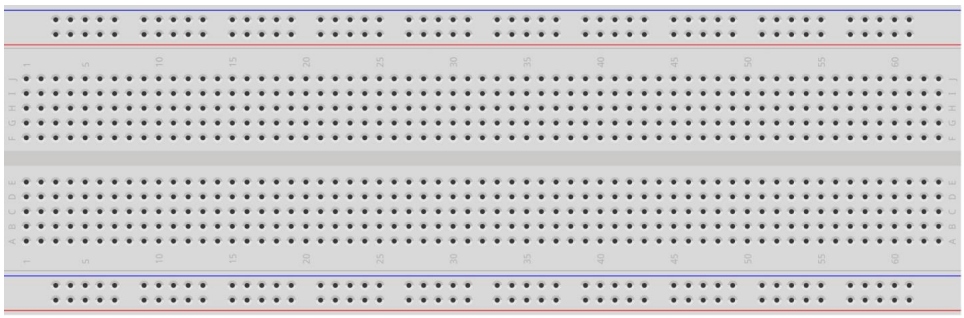
Writes the value HIGH or LOW (1 or 0) to the given pin that must have been previously set as an output.

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

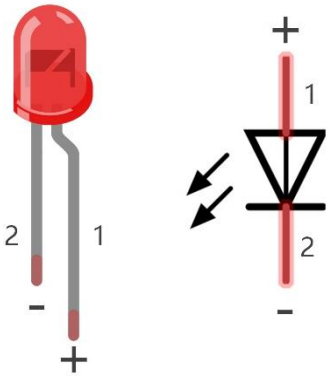
| | | |
|---|---|---|
| Raspberry Pi Pico x1  | | USB Cable x1  |
| Breadboard x1  | | |
| LED x1  | Resistor 220Ω x1  | Jumper  |

# 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.



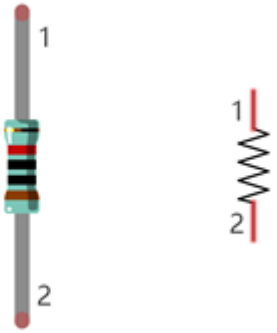

| LED | Voltage | Maximum current | Recommended current |
|---|---|---|---|
| Red | 1.9-2.2V | 20mA | 10mA |
| Green | 2.9-3.4V | 10mA | 5mA |
| Blue | 2.9-3.4V | 10mA | 5mA |
| Volt ampere characteristics conform to diode | | | |

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 (Ω) as the unit of measurement of their resistance (R). 1MΩ=1000kΩ, 1kΩ=1000Ω.

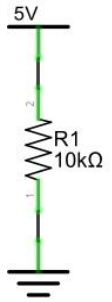
A resistor is a passive electrical component that limits or regulates the flow of current in an electronic circuit. On the left, we see a physical representation of a resistor, and the right is the symbol used to represent the presence of a resistor in a circuit diagram or schematic.




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/10kΩ=0.0005A=0.5mA.

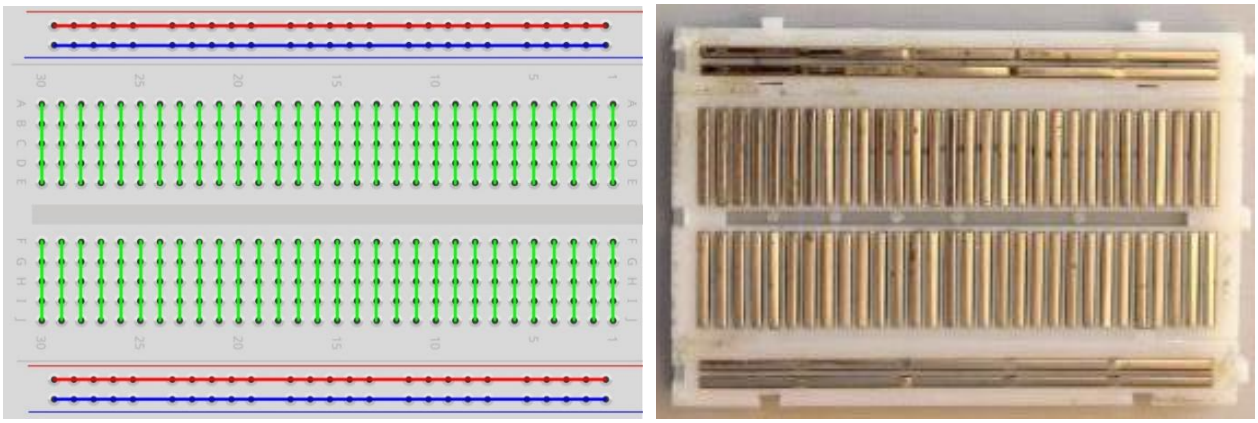



WARNING: Never connect the two poles of a power supply with anything of low resistance value (i.e. a metal object or bare wire) this is a Short and results in high current that may damage the power supply and electronic components.

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

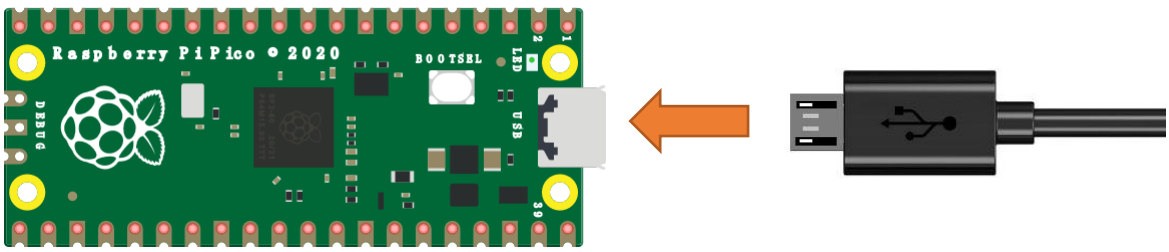
## Breadboard

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.

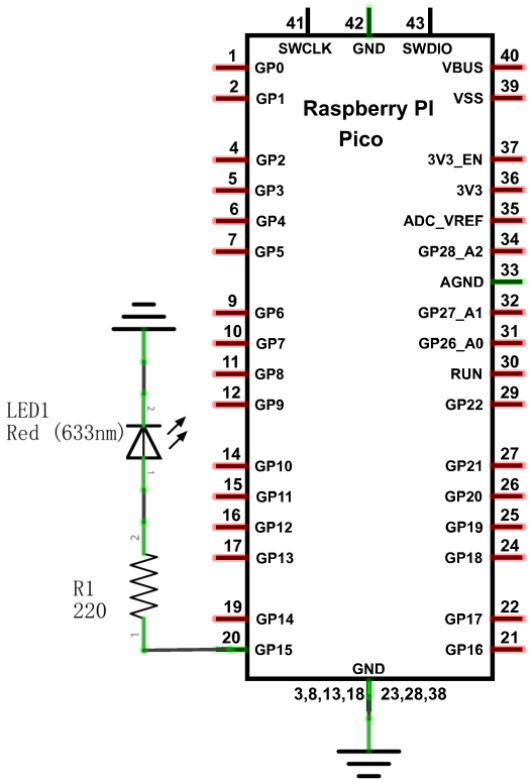


## Circuit

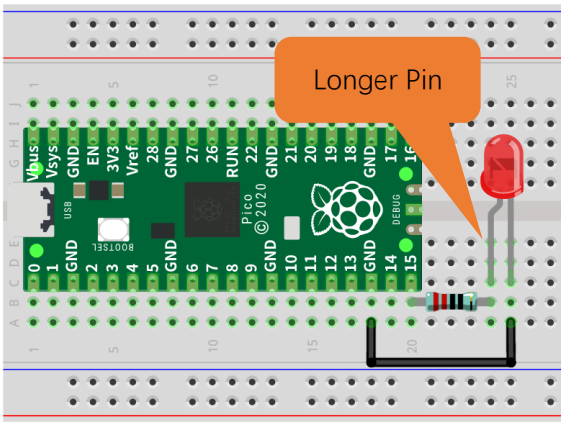
First, disconnect all power from the Raspberry Pi Pico. Then build the circuit according to the circuit and hardware diagrams. After the circuit is built and verified correct, connect the PC to Raspberry Pi Pico.

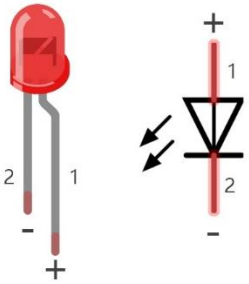
CAUTION: Avoid any possible short circuits (especially connecting 3.3V and GND)!
WARNING: A short circuit can cause high current in your circuit, create excessive component heat and cause permanent damage to your hardware!

Schematic diagram




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




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**

## Sketch

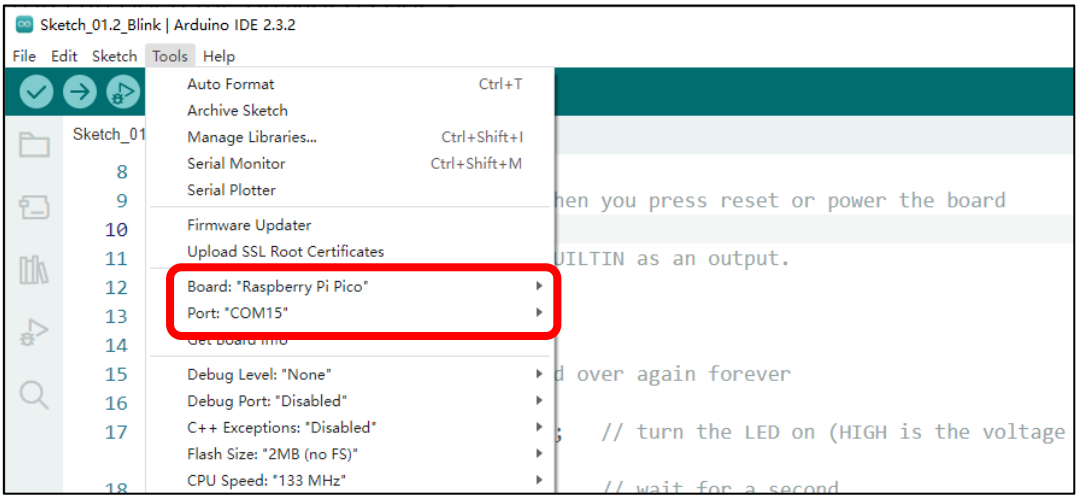
According to the circuit diagram, when GP15 of Pico outputs high level, LED lights up; when it outputs low, LED lights off. Therefore, we can make LED flash repeatedly by controlling GP15 to output high and low repeatedly.

You can open the provided code:

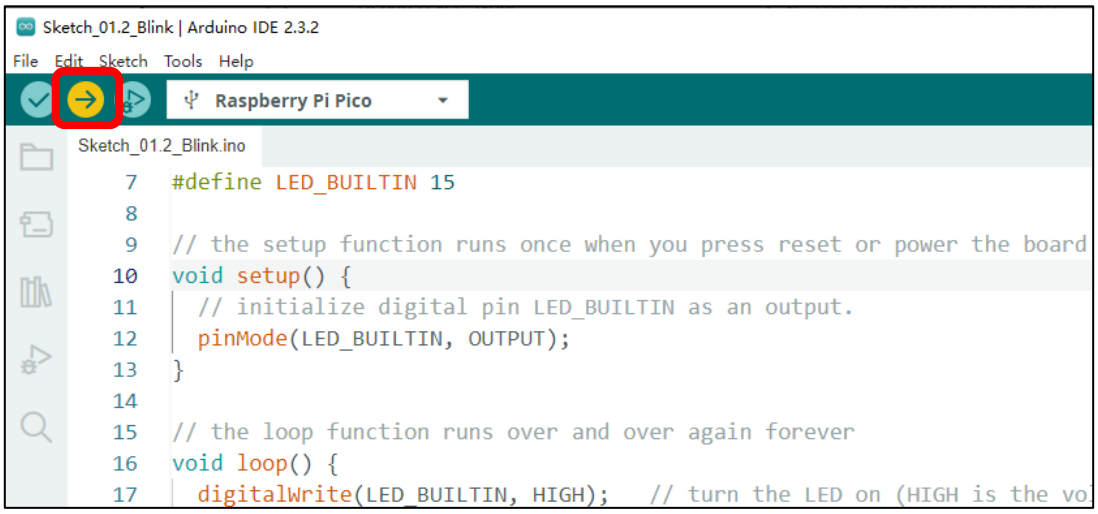
**Freenove_Basic_Starter_Kit_for_Raspberry_Pi_Pico\C\Sketches\Sketch_01.2_Blink**.

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

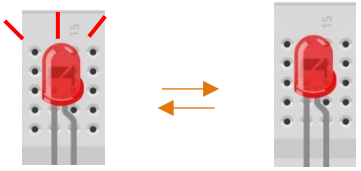
Click Tools, make sure Board and Port are as follows:




Click "Upload" to upload the sketch to Pico.



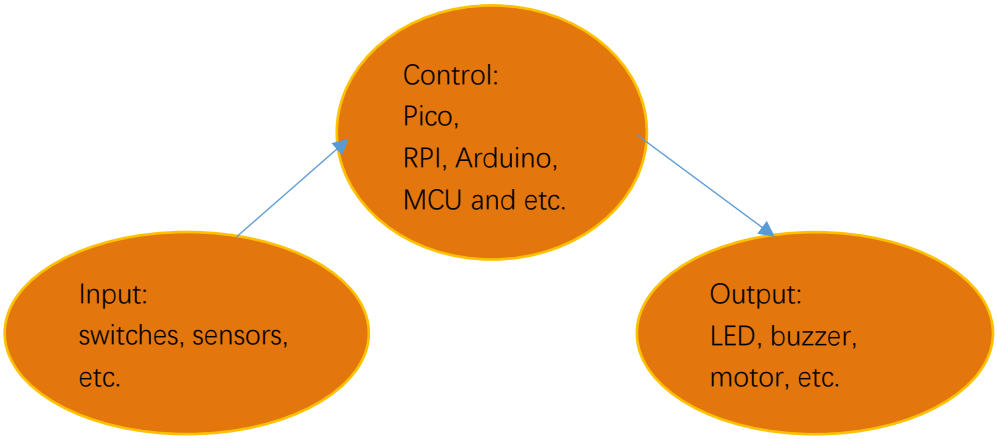

Click "Upload". Download the code to Pico and your LED in the circuit starts Blink.



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

# 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.



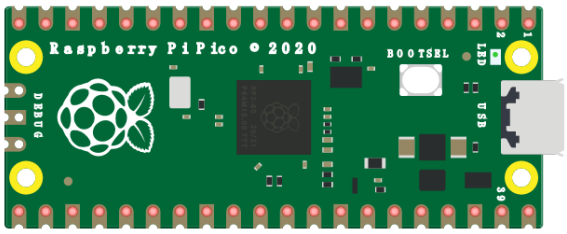
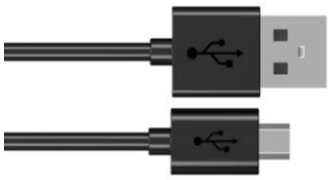
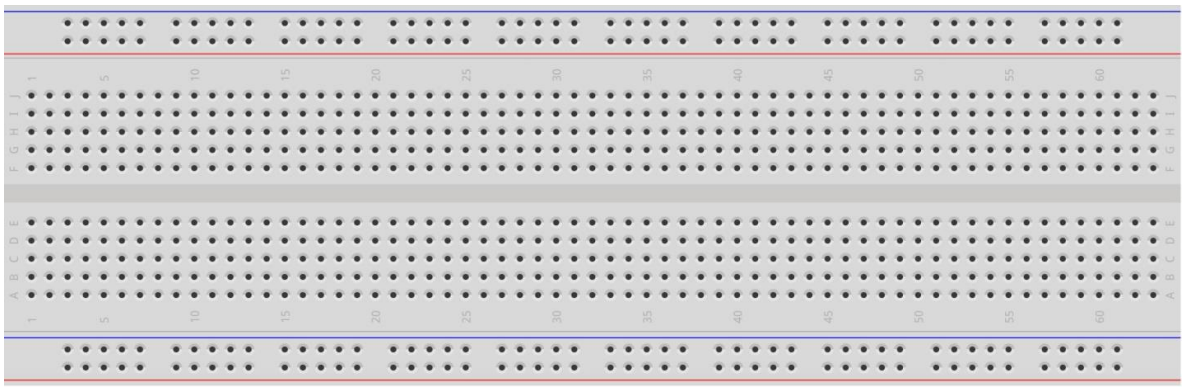

Next, we make a simple project: build a control system with button, LED and Raspberry Pi Pico.
Input: Button
Control: Raspberry Pi Pico
Output: LED

# 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.

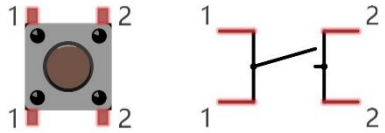
## Component List

<table>
<tr><td colspan="3">Raspberry Pi Pico x1<br>  </td><td colspan="2">USB cable x1<br>  </td></tr>
<tr><td colspan="5">Breadboard x1<br>  </td></tr>
<tr><td>Jumper<br>  </td><td>LED x1<br>  </td><td>Resistor<br>220Ω x1<br>  </td><td>Resistor<br>10kΩ x2<br>  </td><td>Push button<br>x1<br>  </td></tr>
</table>

# Component Knowledge

## Push button

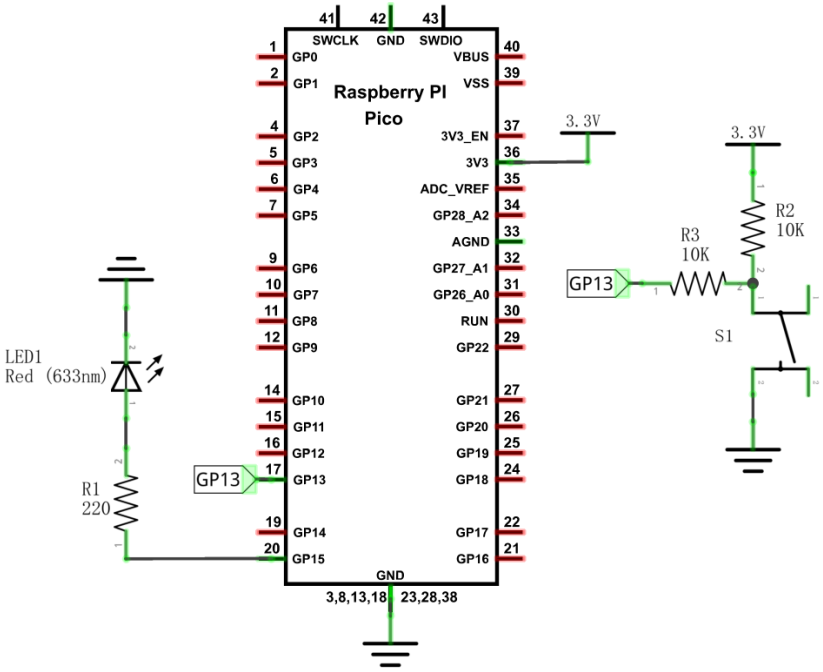
This type of Push Button Switch has four pins (2 Pole Switch). Two pins on the left are connected, and both left and right sides are the same per the illustration:



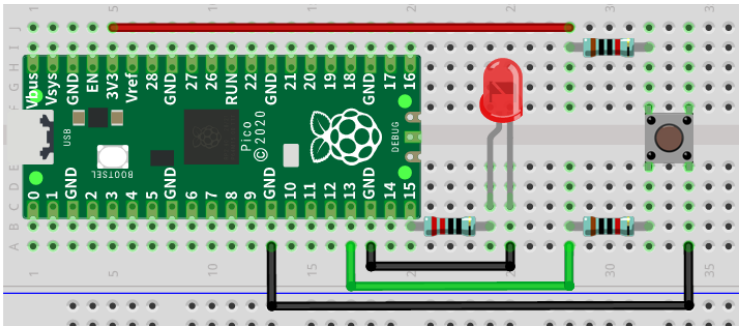

When the button on the switch is pressed, the circuit is completed (your project is Powered ON).

# Circuit

Schematic diagram




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



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.

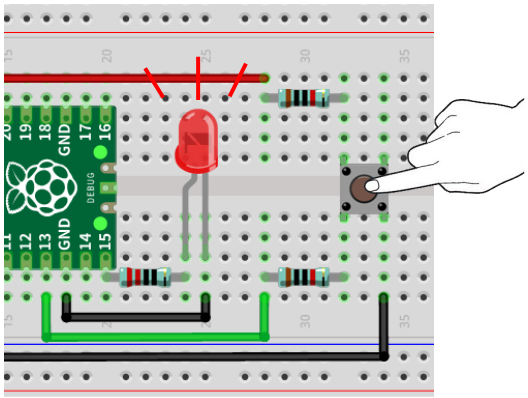
**Any concerns? ✉ support@freenove.com**

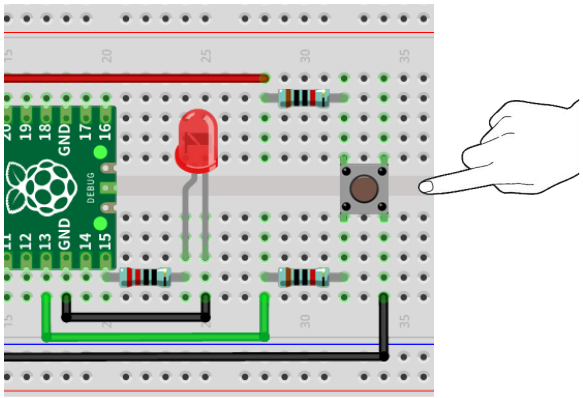
## Sketch

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_Basic_Starter_Kit_for_Raspberry_Pi_Pico\C\Sketches\Sketch_02.1_ButtonAndLed**.
Sketch_02.1_ButtonAndLed


```
#define PIN_LED    15
#define PIN_BUTTON 13

void setup() {
  // initialize digital pin PIN_LED as an output.
  pinMode(PIN_LED, OUTPUT);
  pinMode(PIN_BUTTON, INPUT);
}

// the loop function runs over and over again forever
void loop() {
  if (digitalRead(PIN_BUTTON) == LOW) {
    digitalWrite(PIN_LED,HIGH);
  }else{
    digitalWrite(PIN_LED,LOW);
  }
}
```

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:

```
#define PIN_LED    15
#define PIN_BUTTON 13
// the setup function runs once when you press reset or power the board
void setup() {
  // initialize digital pin PIN_LED as an output.
  pinMode(PIN_LED, OUTPUT);
  pinMode(PIN_BUTTON, INPUT);
}

// the loop function runs over and over again forever
void loop() {
  if (digitalRead(PIN_BUTTON) == LOW) {
    digitalWrite(PIN_LED,HIGH);
  }else{
    digitalWrite(PIN_LED,LOW);
  }
}
```

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

```
#define PIN_LED    15
#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.

```
void loop() {
  if (digitalRead(PIN_BUTTON) == LOW) {
    digitalWrite(PIN_LED,HIGH);
  }else{
    digitalWrite(PIN_LED,LOW);
  }
}
```

Reference

**int digitalRead (int pin);**

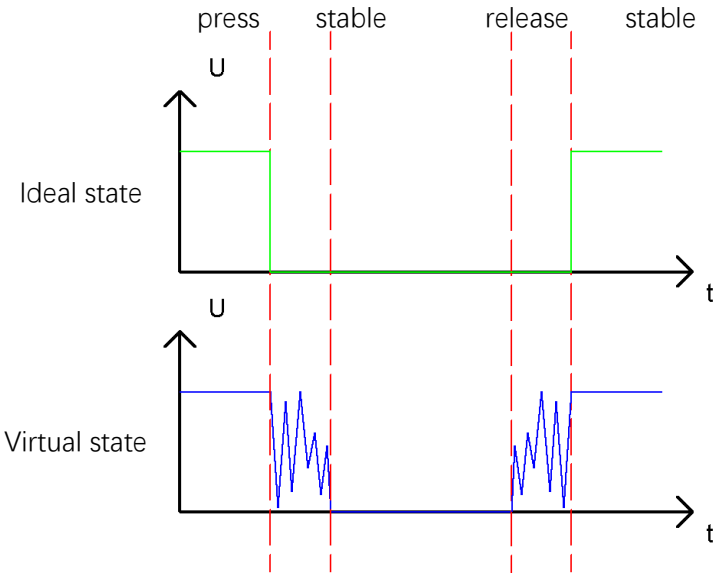
This function returns the value read at the given pin. It will be “HIGH” or “LOW” (1 or 0) depending on the logic level at the pin.

# 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_Basic_Starter_Kit_for_Raspberry_Pi_Pico\C\Sketches\Sketch_02.2_TableLamp**.

Sketch_02.2_TableLamp

Sketch_02.2_TableLamp | Arduino IDE 2.3.2

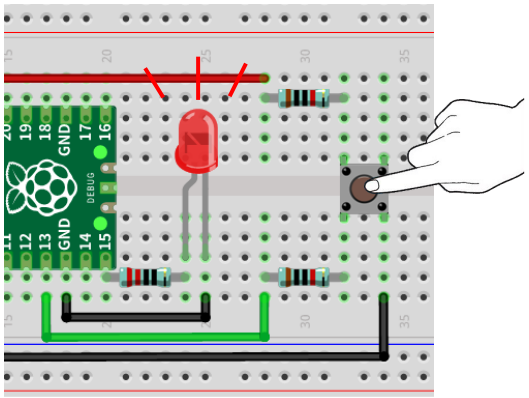
File Edit Sketch Tools Help

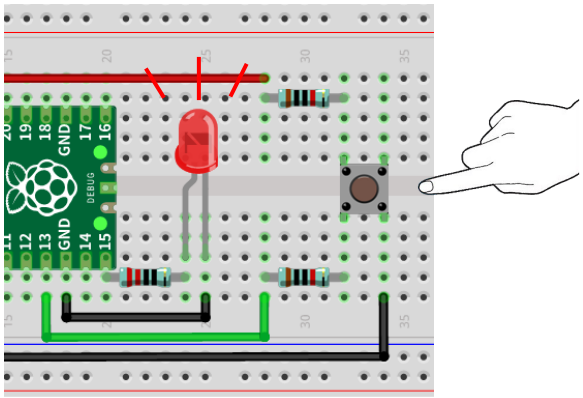
Raspberry Pi Pico

Sketch_02.2_TableLamp.ino

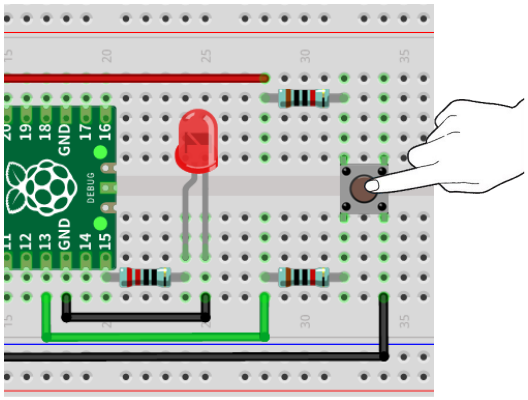
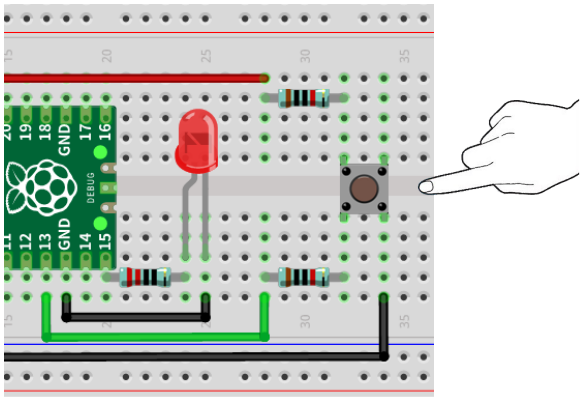
```
#define PIN_LED    15
#define PIN_BUTTON 13
bool ledState = false;

void setup() {
  // initialize digital pin PIN_LED as an output.
  pinMode(PIN_LED, OUTPUT);
  pinMode(PIN_BUTTON, INPUT);
}

// the loop function runs over and over again forever
void loop() {
  if (digitalRead(PIN_BUTTON) == LOW) {
    delay(20);
    if (digitalRead(PIN_BUTTON) == LOW) {
      reverseGPIO(PIN_LED);
    }
    while (digitalRead(PIN_BUTTON) == LOW);
  }
}

void reverseGPIO(int pin) {
  ledState = !ledState;
  digitalWrite(pin, ledState);
}
```

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





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

The following is the program code:

```
#define PIN_LED    15
#define PIN_BUTTON 13
bool ledState = false;

void setup() {
  // initialize digital pin PIN_LED as an output.
  pinMode(PIN_LED, OUTPUT);
  pinMode(PIN_BUTTON, INPUT);
}

// the loop function runs over and over again forever
void loop() {
  if (digitalRead(PIN_BUTTON) == LOW) {
    delay(20);
    if (digitalRead(PIN_BUTTON) == LOW) {
      reverseGPIO(PIN_LED);
    }
    while (digitalRead(PIN_BUTTON) == LOW);
  }
}

void reverseGPIO(int pin) {
  ledState = !ledState;
  digitalWrite(pin, ledState);
}
```

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

```
#define PIN_LED    15
#define PIN_BUTTON 13
```

Define a variable to store the status of LED.

```
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

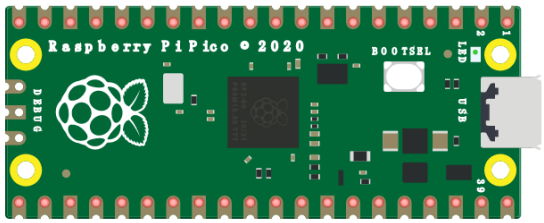
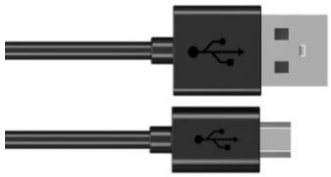
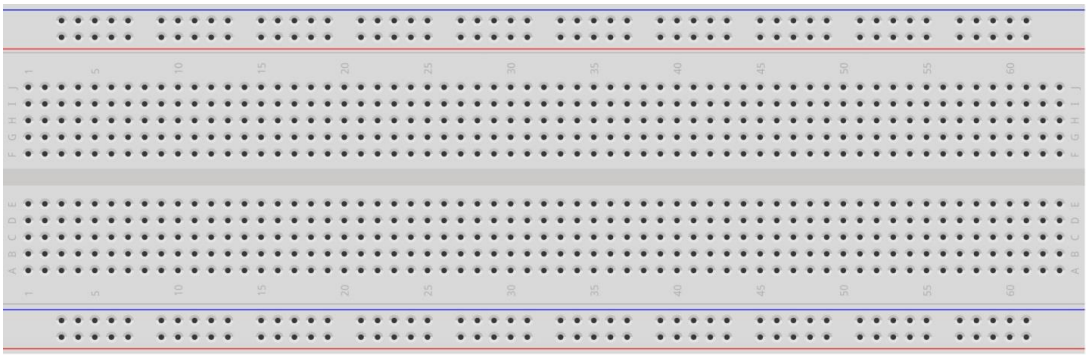
We have learned how to control an LED blinking, next we will learn how to control a number of LEDs.

## 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

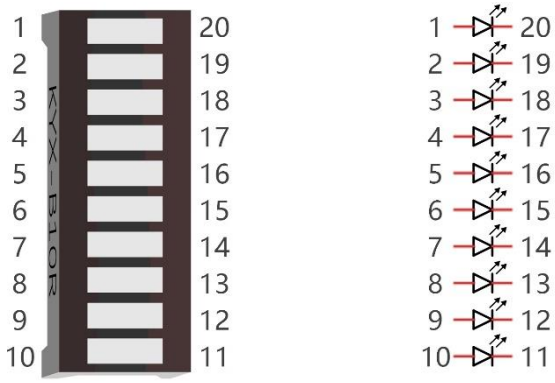
| | | |
|---|---|---|
| Raspberry Pi Pico x1  | USB cable x1  | |
| Breadboard x1  | | |
| Jumper  | LED bar graph x1  | Resistor 220Ω x10  |

## Component Knowledge

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

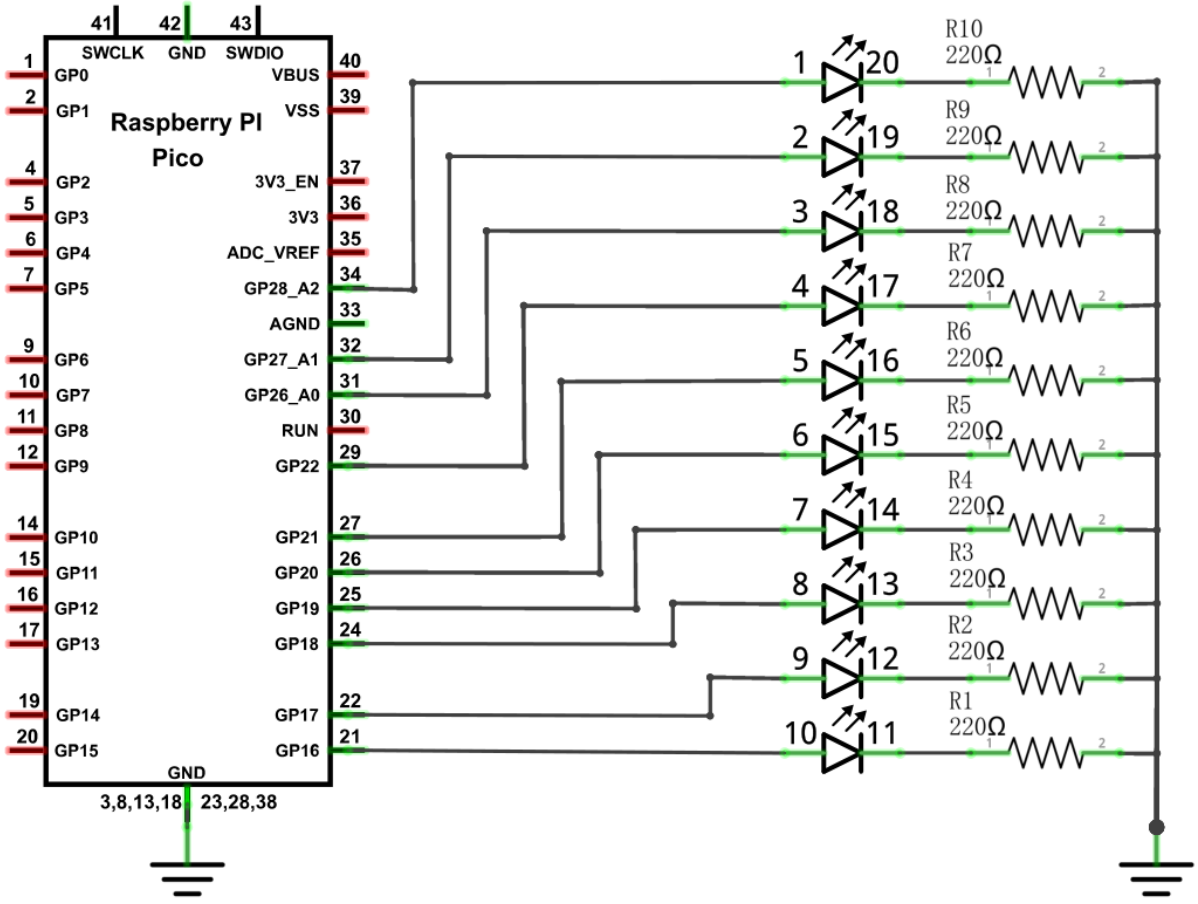
### LED bar

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.

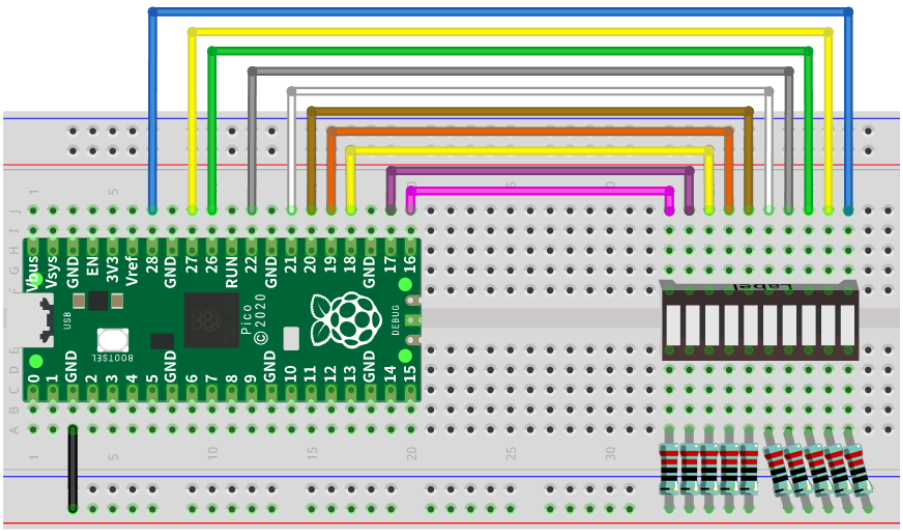


## Circuit

Schematic diagram




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



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.**

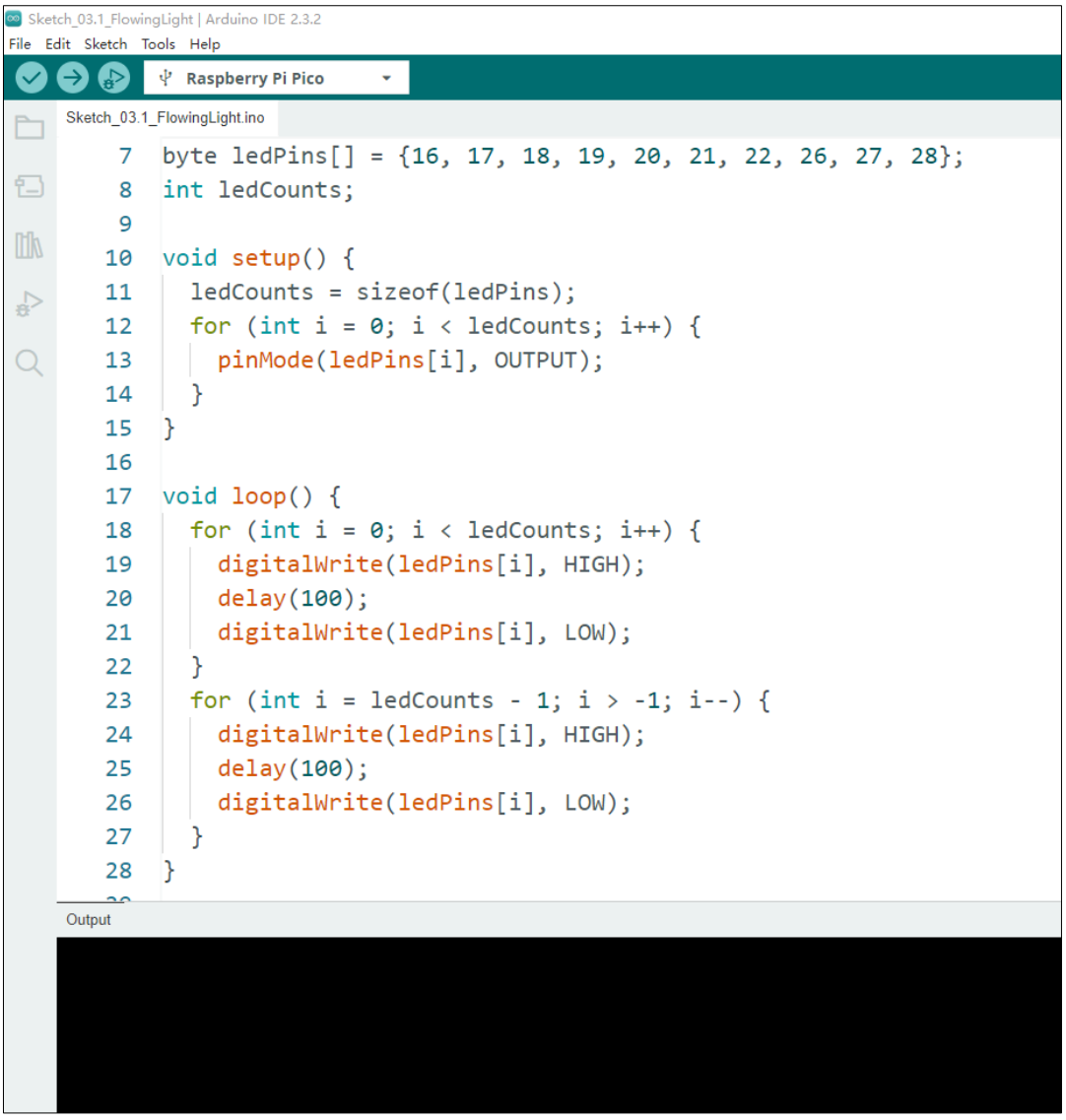
## Sketch

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_Basic_Starter_Kit_for_Raspberry_Pi_Pico\C\Sketches\Sketch_03.1_FlowingLight**.

Sketch_03.1_FlowingLight




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.

The following is the program code:

```
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);
  }
}
```

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

```
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.

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

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

```
  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);
  }
```

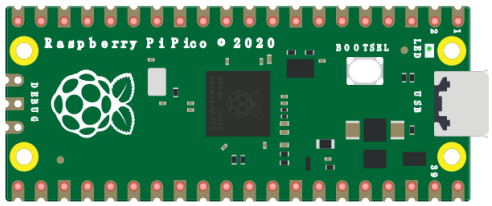
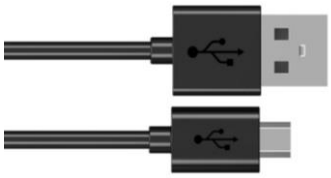
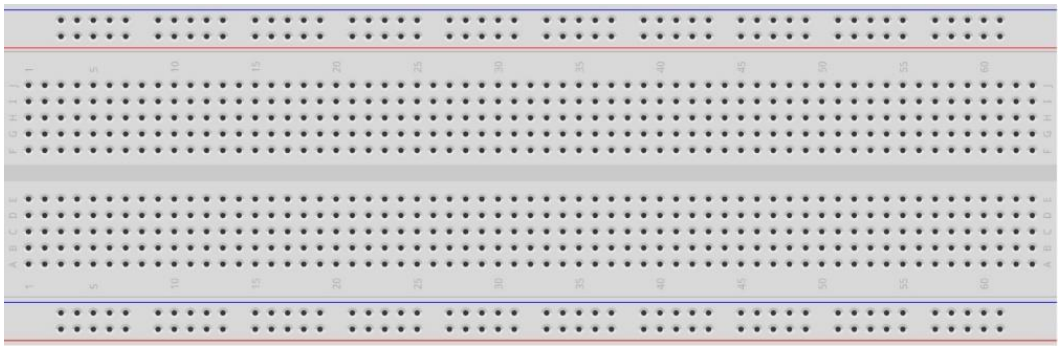
# Chapter 4 Analog & PWM

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.

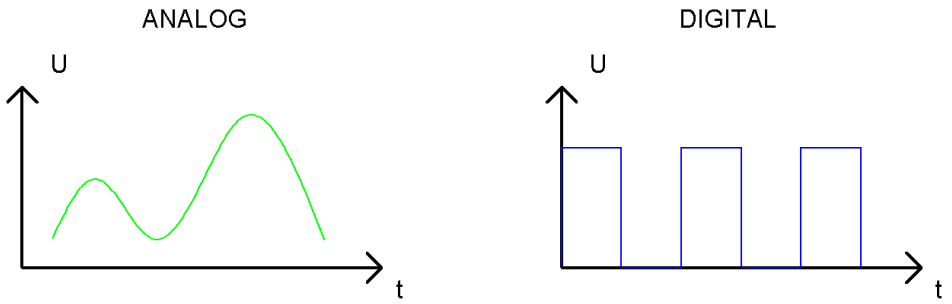
### Component List

<table>
<tr><td colspan="2">Raspberry Pi Pico x1<br>  </td><td>USB cable x1<br>  </td></tr>
<tr><td colspan="3">Breadboard x1<br>  </td></tr>
<tr><td>LED x1<br>  </td><td>Resistor 220Ω x1<br>  </td><td>Jumper<br>  </td></tr>
</table>

# 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℃ to 10℃. 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.



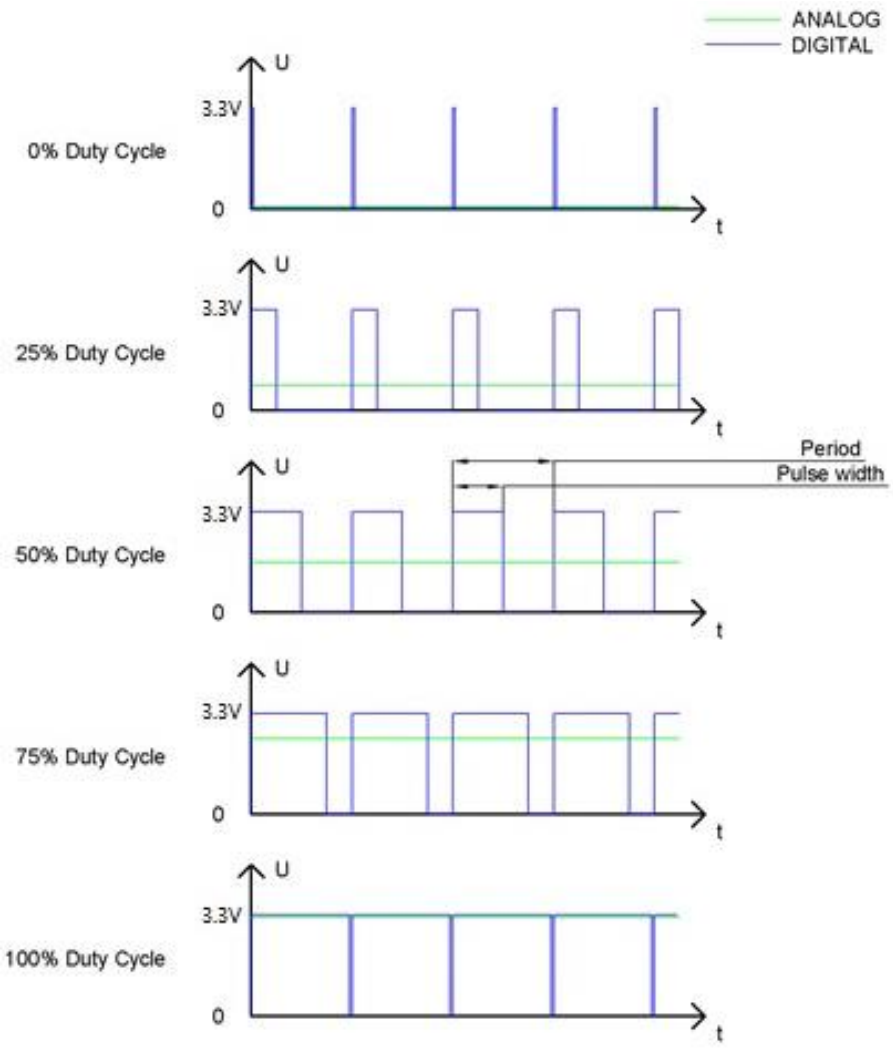

In practical application, we often use binary as the digital signal, that is a series of 0's and 1's. Since a binary signal only has two values (0 or 1), it has great stability and reliability. Lastly, both analog and digital signals can be converted into the other.

## 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.

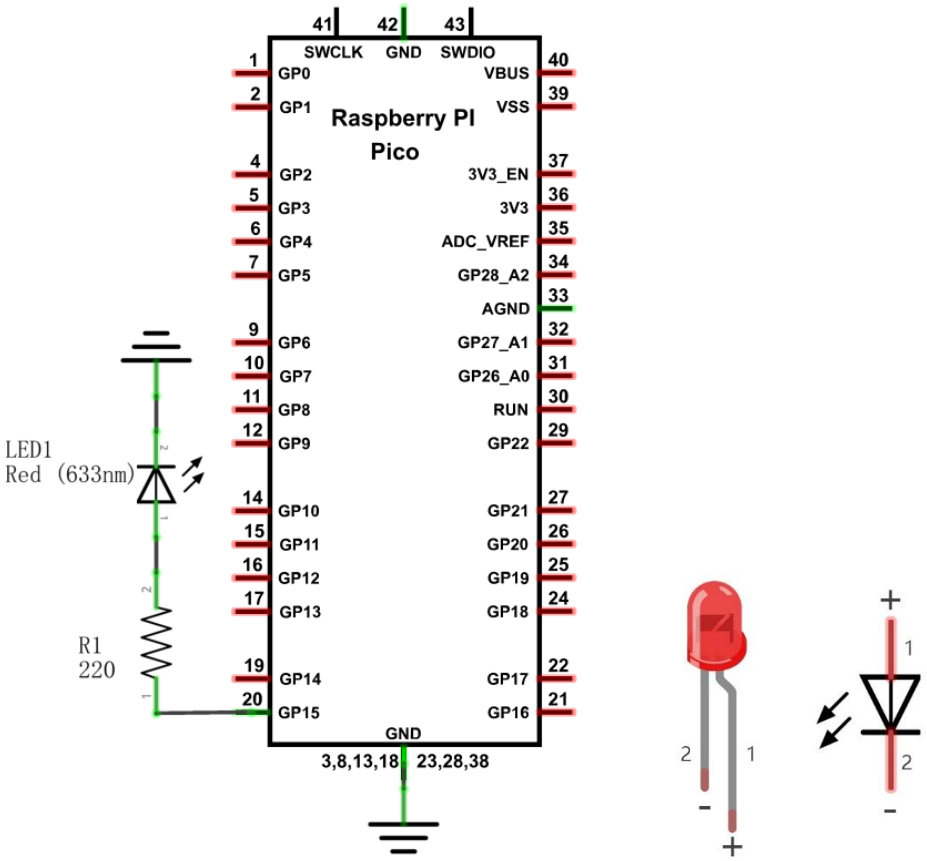
### Raspberry Pi Pico and PWM

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.

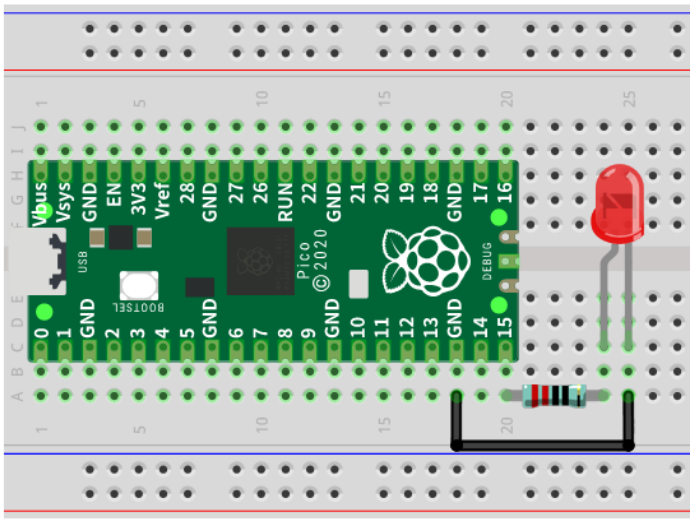
## Circuit

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

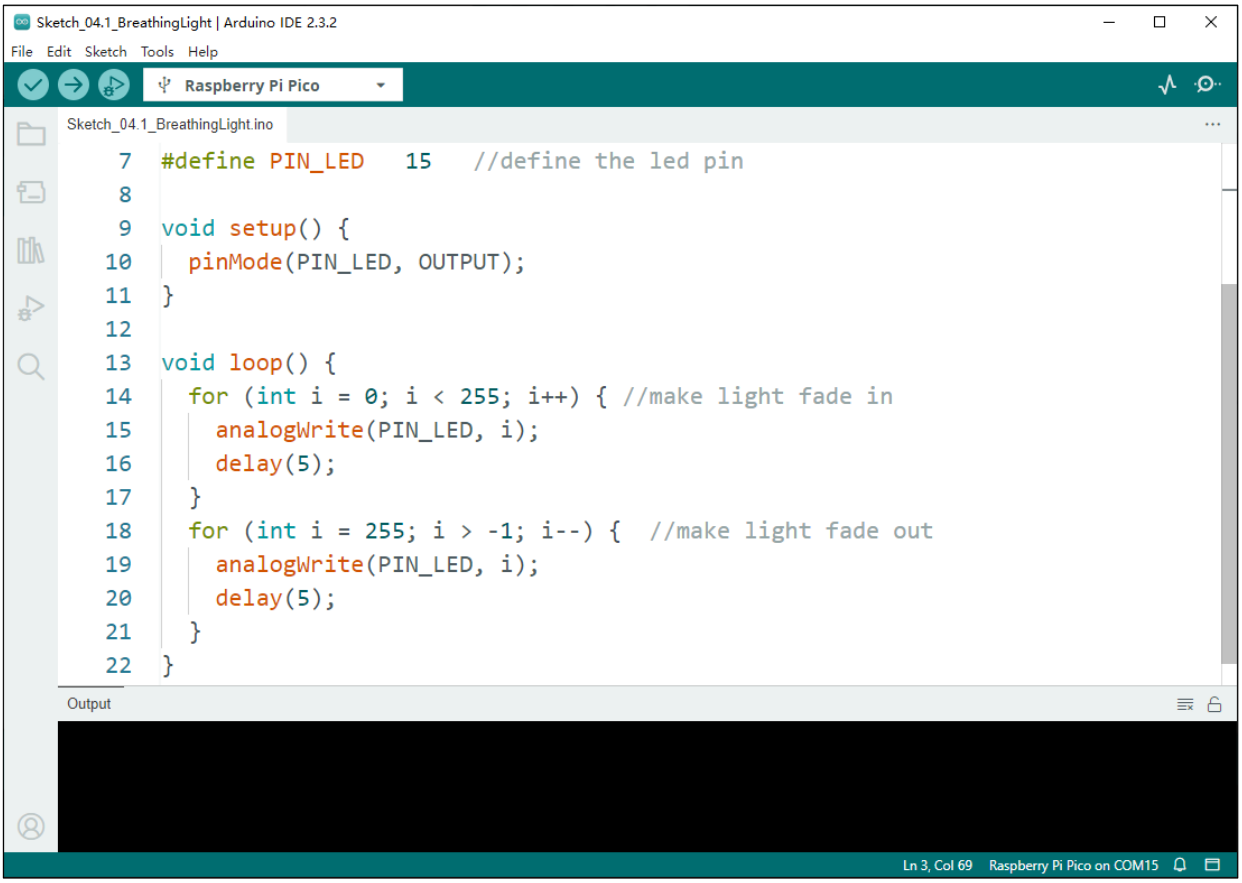


Note: To help users have a better experience when doing the projects, we have made some modifications to Pico's simulation diagram. Please note that there are certain differences between the simulation diagram and the actual board to avoid misunderstanding.

## Sketch

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




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)**

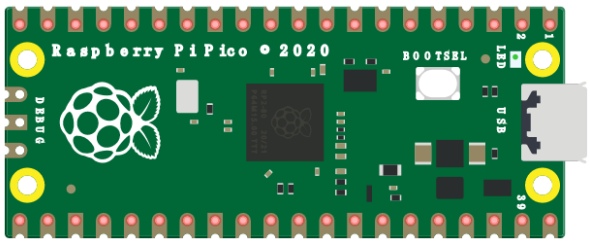
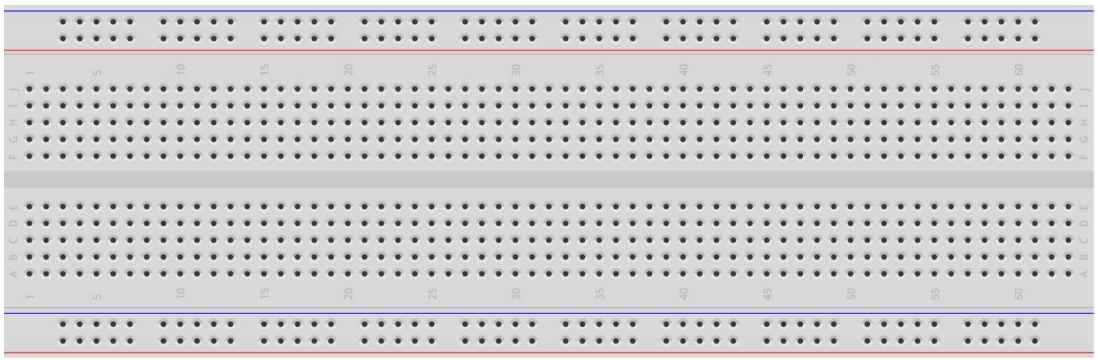
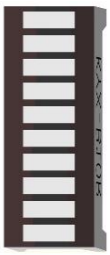
Arduino IDE provides the function, analogWrite(pin, value), which can make ports directly output PWM waves. Every pin on Pico board can be configured to output PWM. In the function called analogWrite(pin, value), the parameter "pin" specifies the port used to output PWM wave. The range of value is 0-255,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

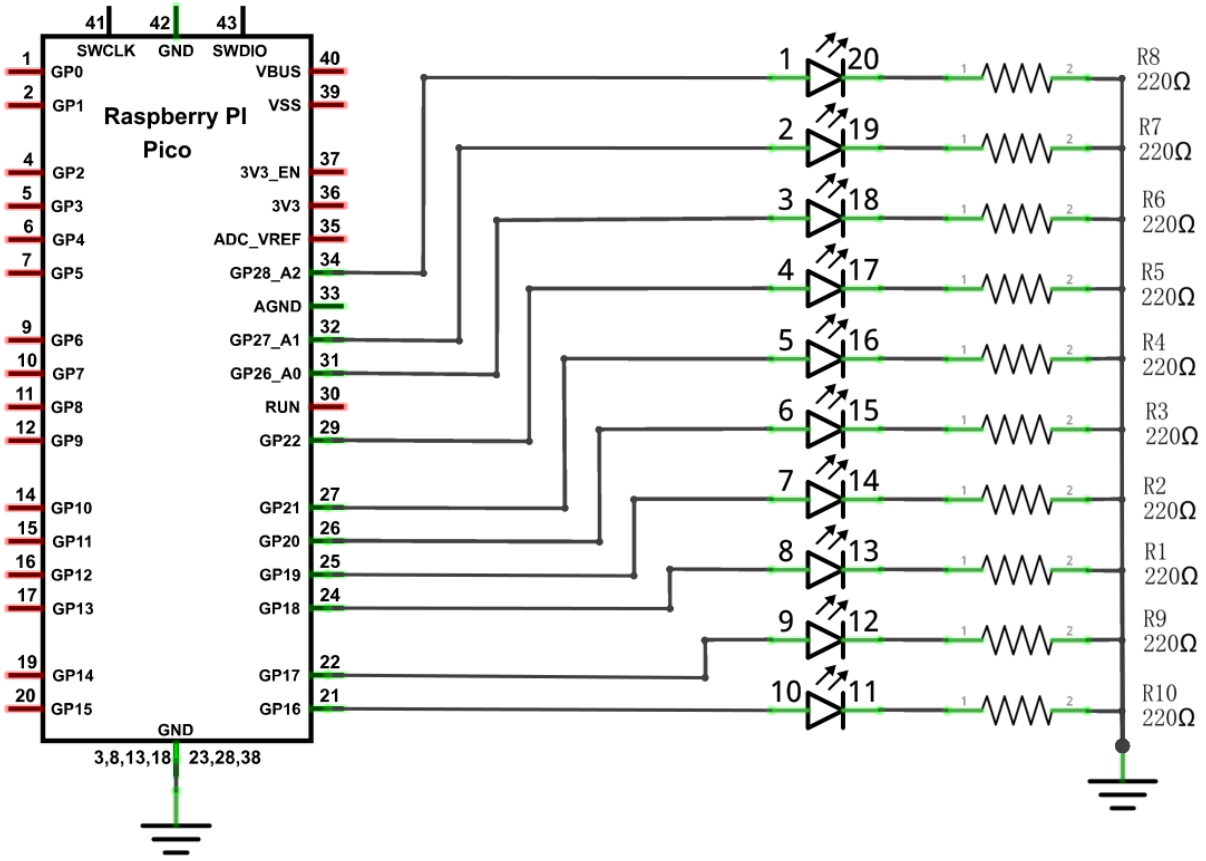
After learning about PWM, we can use it to control LED bar graph and realize a cooler flowing light. The component list, circuit, and hardware are exactly consistent with the project Flowing Light.

## Component List

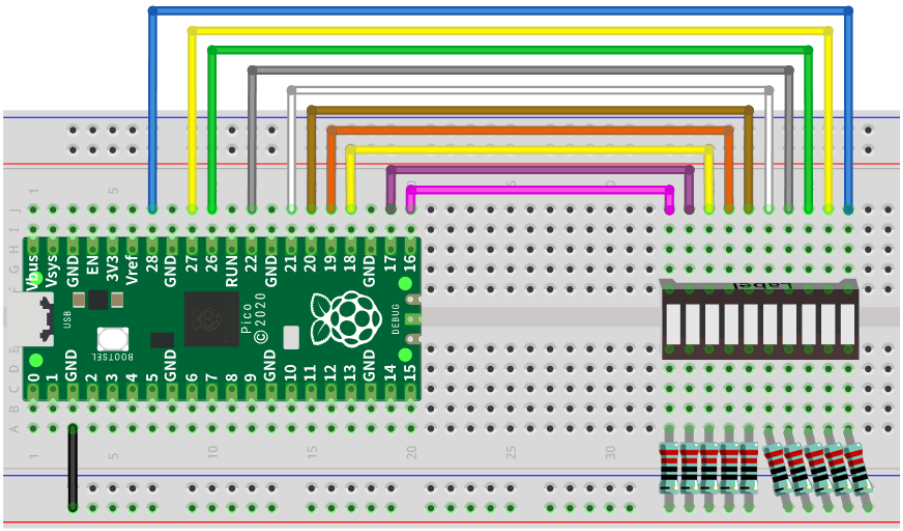
| | | |
|---|---|---|
| Raspberry Pi Pico x1  | USB cable x1  | |
| Breadboard x1  | | |
| Jumper  | LED bar graph x1  | Resistor 220Ω x10  |

## Circuit

Schematic diagram




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



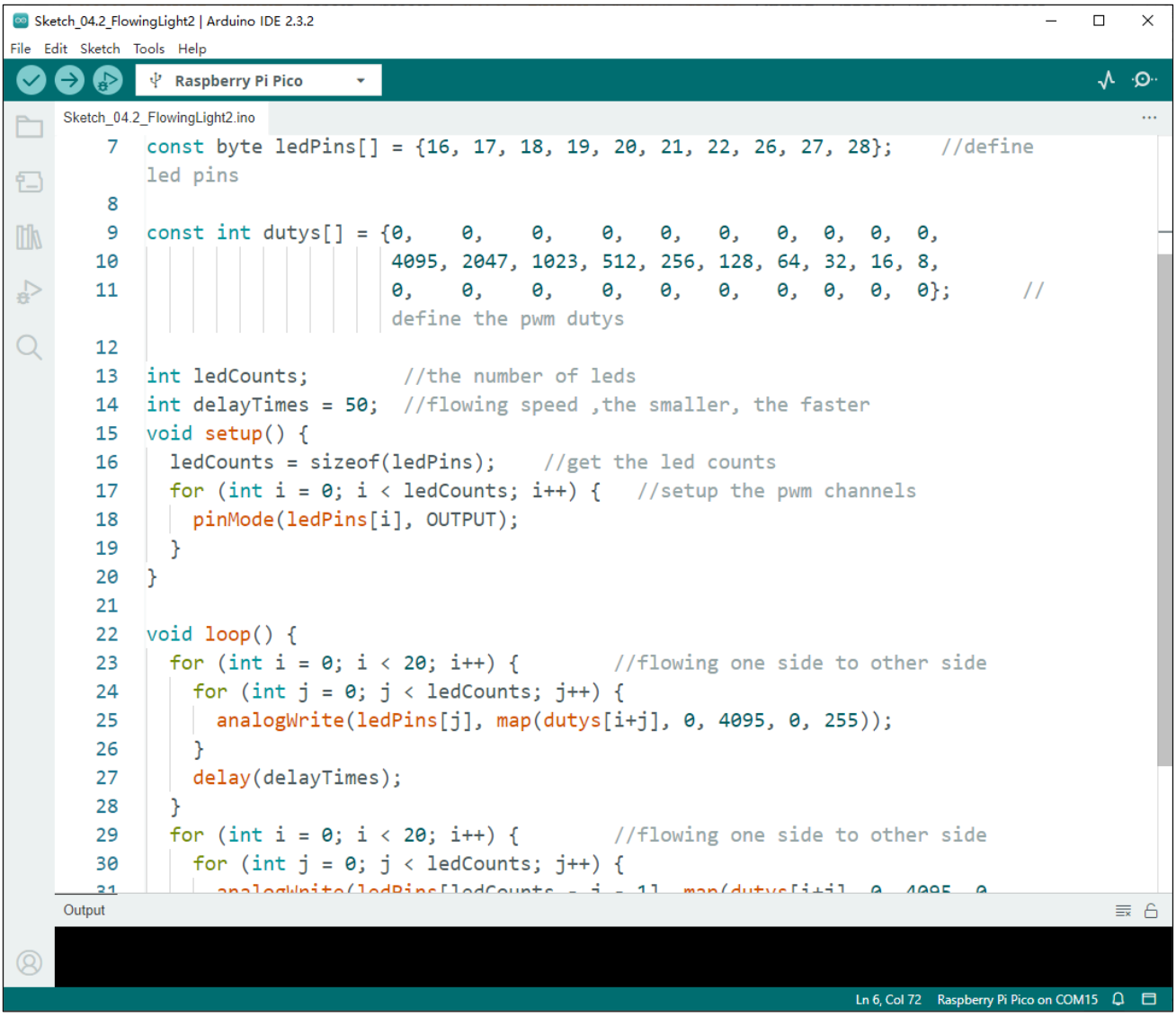
Note: To help users have a better experience when doing the projects, we have made some modifications to Pico's simulation diagram. Please note that there are certain differences between the simulation diagram and the actual board to avoid misunderstanding.

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

## Sketch

Meteor flowing light will be implemented with PWM.

Sketch_04.2_FlowingLight2




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,  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,   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 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| d<br>i | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1023 | 512 | 256 | 128 | 64 | 32 | 16 | 8 | 4 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| ... | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 18 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 19 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 20 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

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.

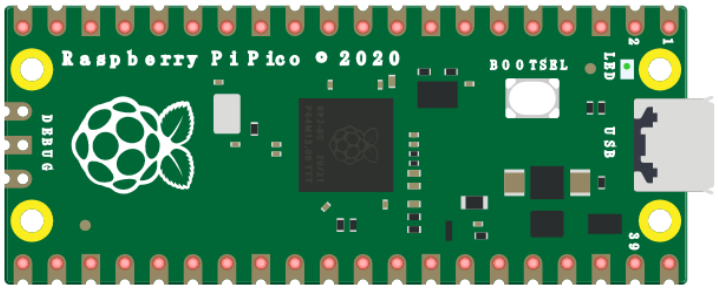
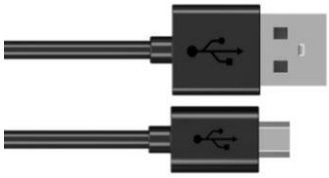
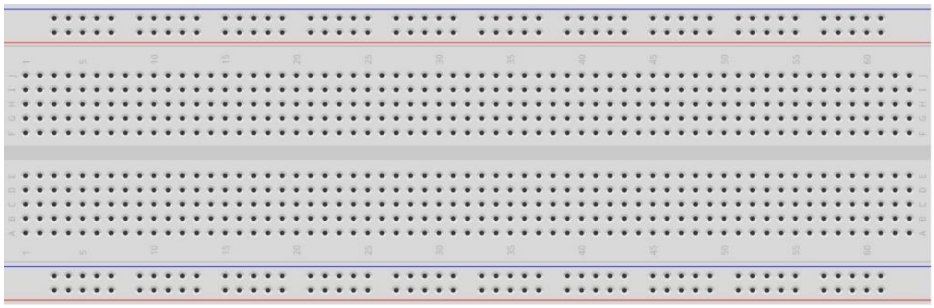
# Chapter 5 RGBLED

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

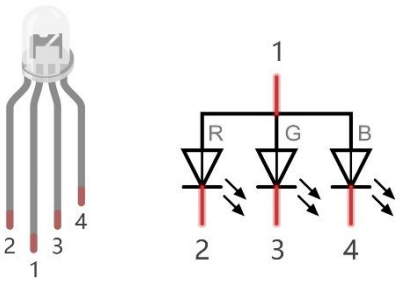
In this project, we will make a multicolored LED. And we can control RGBLED to switch different colors automatically.

### Component List

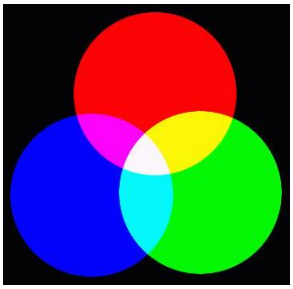
<table>
<tr><td colspan="2">Raspberry Pi Pico x1<br>  </td><td>USB cable x1<br>  </td></tr>
<tr><td colspan="3">Breadboard x1<br>  </td></tr>
<tr><td>RGBLED x1<br>  </td><td>Resistor 220Ω x3<br>  </td><td>Jumper<br>  </td></tr>
</table>

## 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.

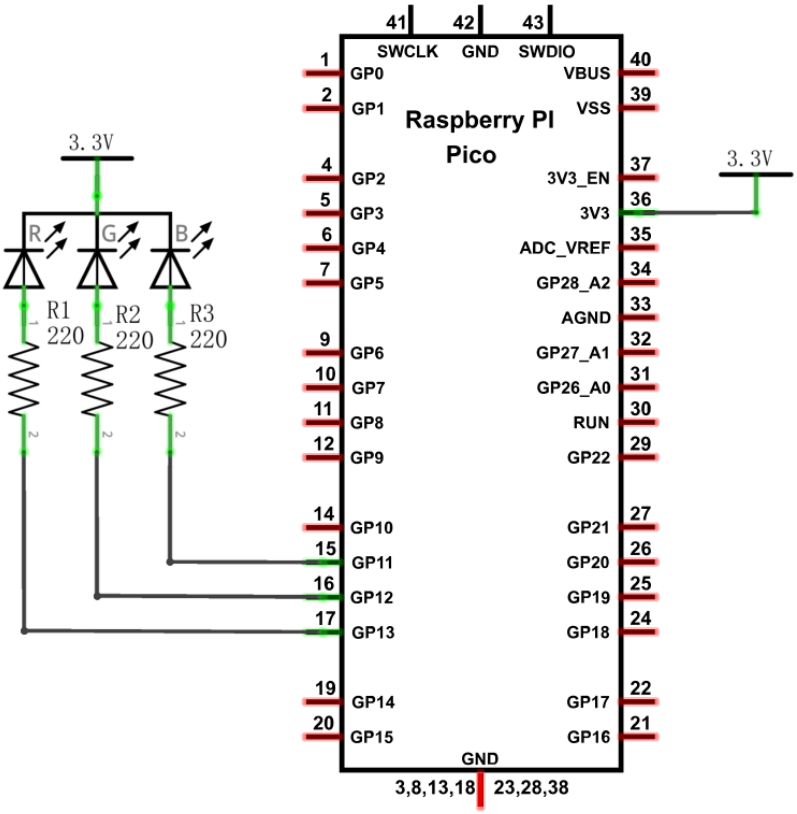


RGB

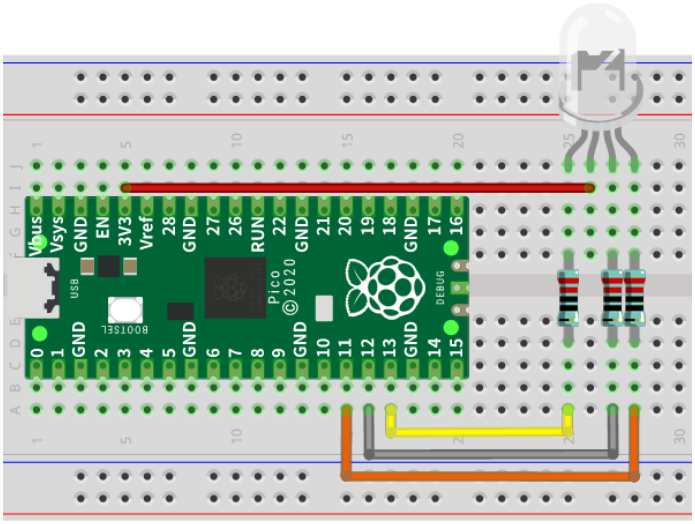
If we use three 8-bit PWMs to control the RGB LED, in theory, we can create $2^8*2^8*2^8$=16777216 (16 million) colors through different combinations.

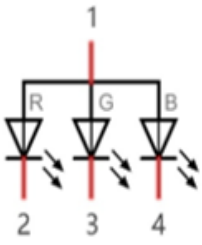
# Circuit

Schematic diagram




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



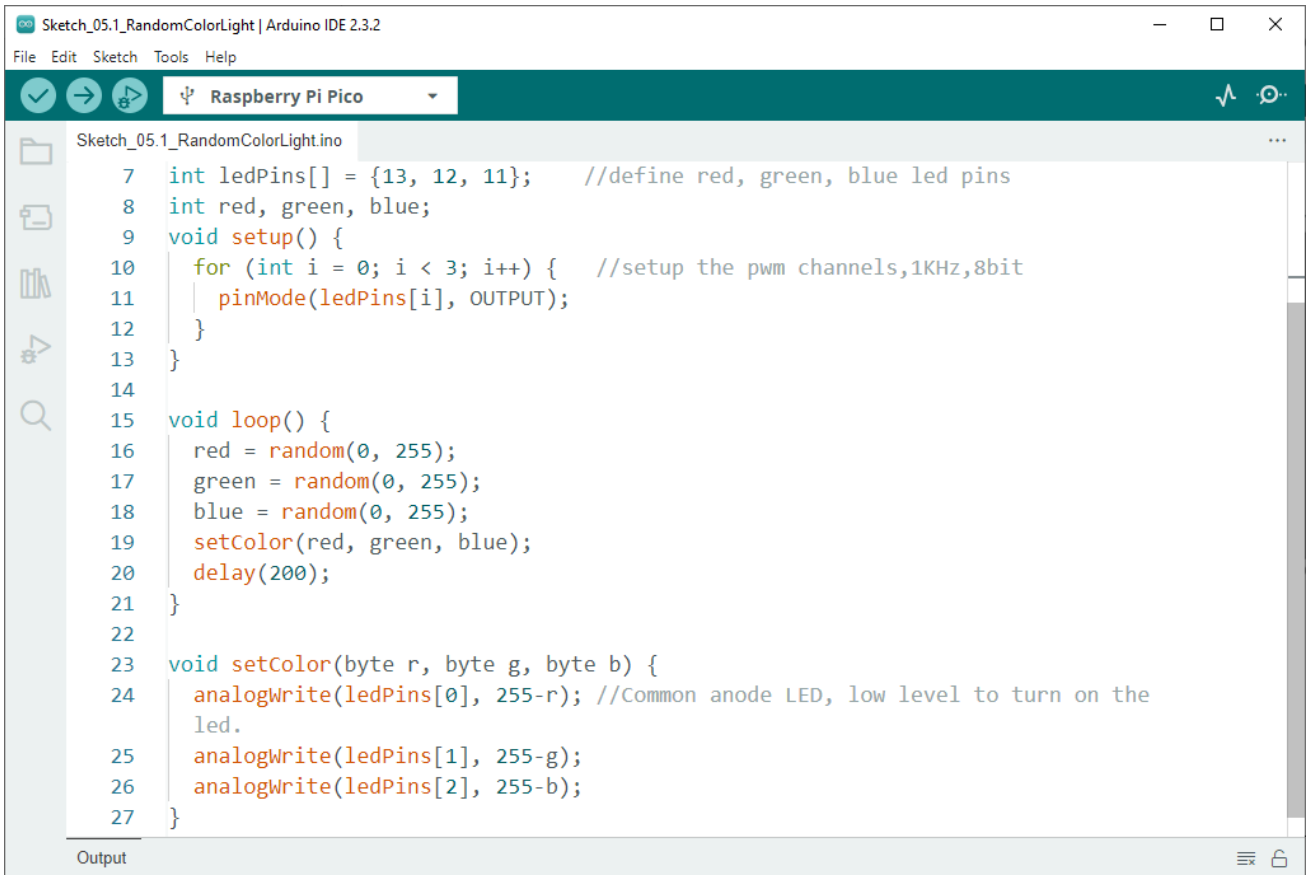



Note: To help users have a better experience when doing the projects, we have made some modifications to Pico's simulation diagram. Please note that there are certain differences between the simulation diagram and the actual board to avoid misunderstanding.

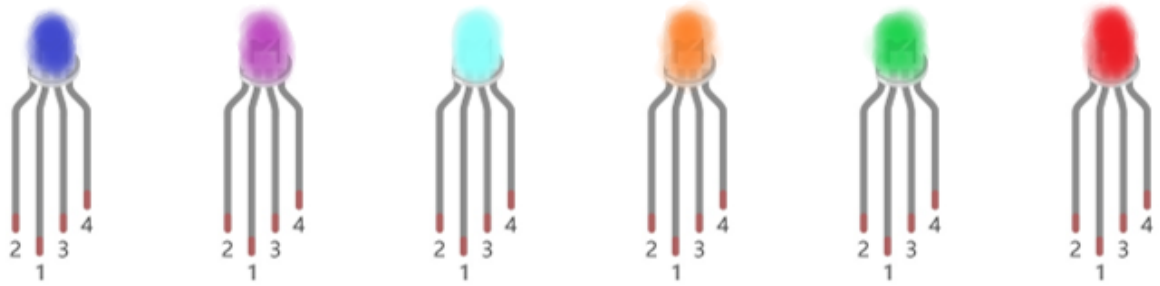
## Sketch

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

Sketch_05.1_ColorfulLight




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




The following is the program code:

```
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
```

```
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:

```
const byte ledPins[] = {13, 12, 11};    //define led pins
void setup() {
  for (int i = 0; i < 3; i++) {   //setup the pwm channels
    pinMode(ledPins[i], OUTPUT);
  }
}

void loop() {
  for (int i = 0; i < 256; i++) {
    setColor(wheel(i));
    delay(100);
  }
}

void setColor(long rgb) {
  analogWrite(ledPins[0], 255 - (rgb >> 16) & 0xFF);
  analogWrite(ledPins[1], 255 - (rgb >> 8) & 0xFF);
  analogWrite(ledPins[2], 255 - (rgb >> 0) & 0xFF);
}

long wheel(int pos) {
  long WheelPos = pos % 0xff;
  if (WheelPos < 85) {
    return ((255 - WheelPos * 3) << 16) | ((WheelPos * 3) << 8);
  } else if (WheelPos < 170) {
```

```
    WheelPos -= 85;
    return (((255 - WheelPos * 3) << 8) | (WheelPos * 3));
  } else {
    WheelPos -= 170;
    return ((WheelPos * 3) << 16 | (255 - WheelPos * 3));
  }
}
```

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

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

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.

```
long wheel(int pos) {
  long WheelPos = pos % 0xff;
  if (WheelPos < 85) {
    return ((255 - WheelPos * 3) << 16) | ((WheelPos * 3) << 8);
  } else if (WheelPos < 170) {
    WheelPos -= 85;
    return (((255 - WheelPos * 3) << 8) | (WheelPos * 3));
  } else {
    WheelPos -= 170;
    return ((WheelPos * 3) << 16 | (255 - WheelPos * 3));
  }
}
```

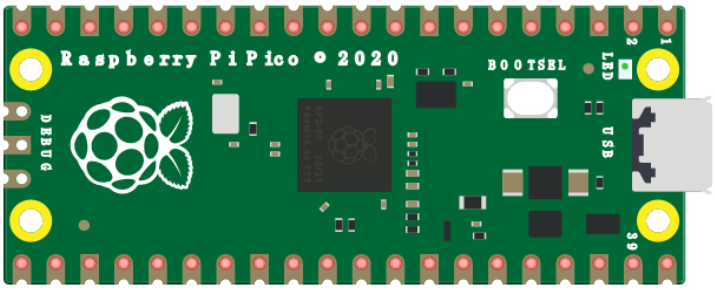
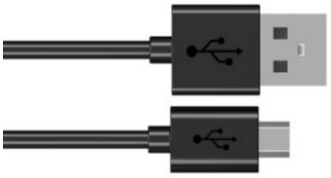
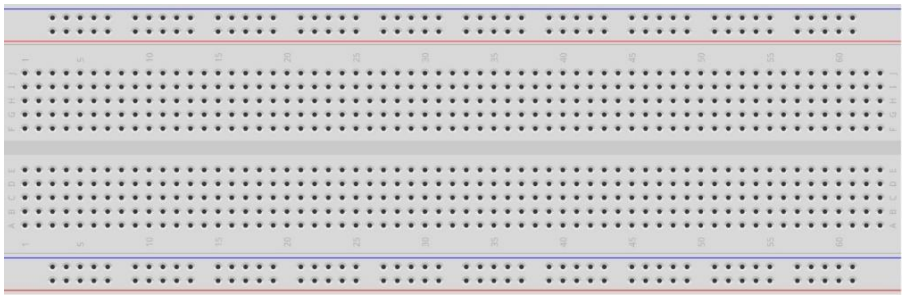
# Chapter 6 Buzzer

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

## Project 6.1 Doorbell

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

### Component List

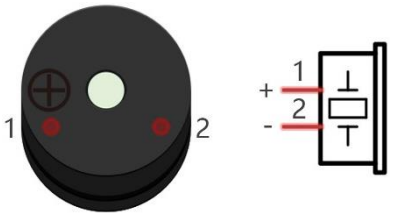
| | | | | |
|---|---|---|---|---|
| Raspberry Pi Pico x1   | | | USB cable x1  | |
| Breadboard x1  | | | | |
| Jumper  | | | | |
| NPN transistorx1 (S8050)  | Active buzzer x1  | Push button x1  | Resistor 1kΩ x1  | Resistor 10kΩ x2  |

# Component Knowledge

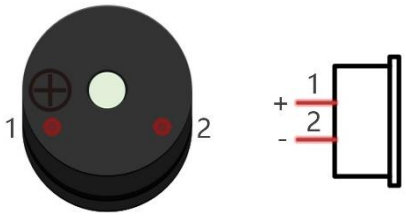
## Buzzer

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

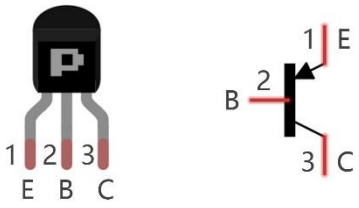
## Transistor

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.

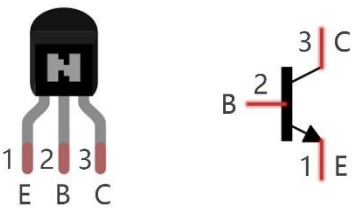
Transistor, the full name: semiconductor transistor, is a semiconductor device that controls current. Transistor

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

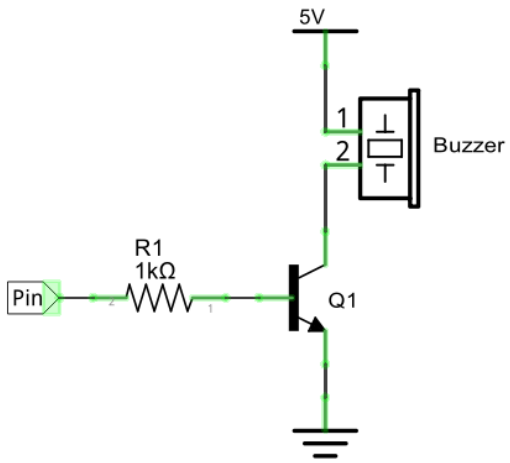
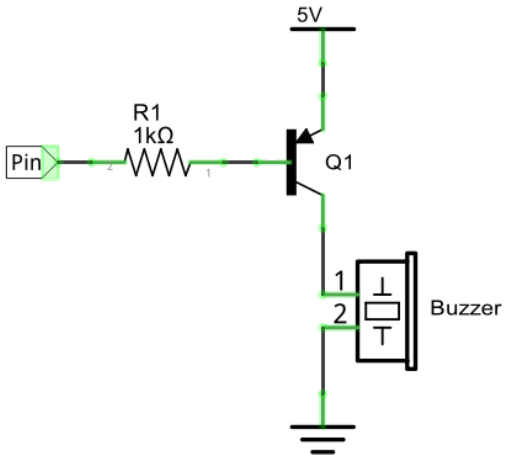



In our kit, the PNP transistor is marked with 8550, and the NPN transistor is marked with 8050.

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.

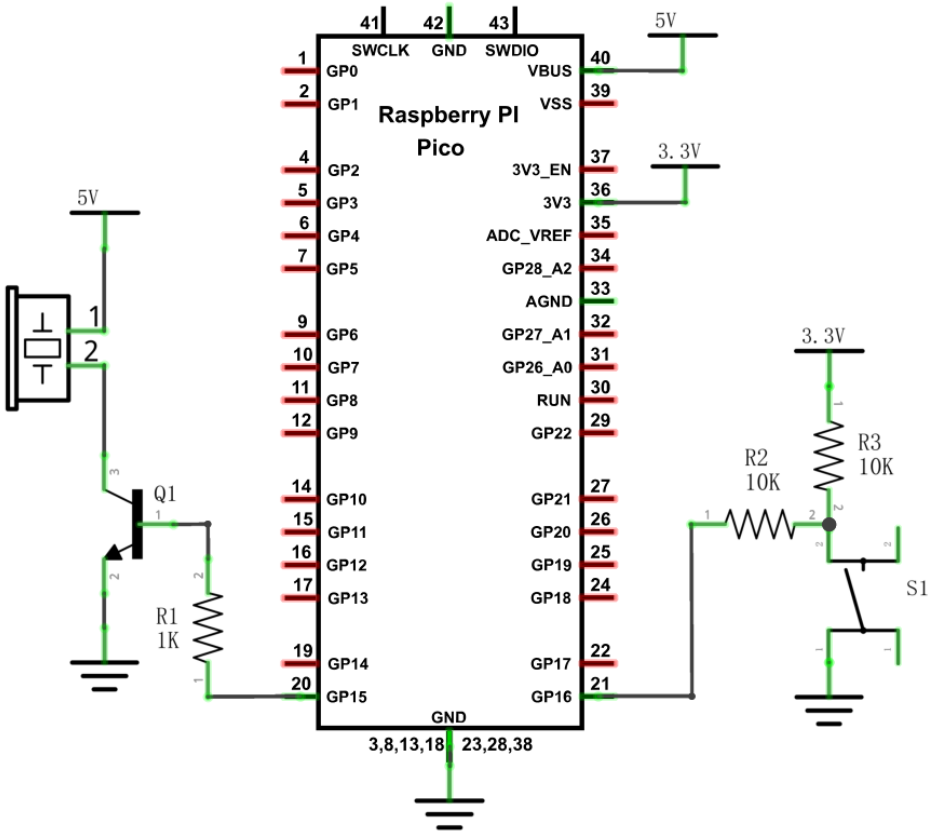
When using NPN transistor to drive buzzer, we often adopt the following method. If GP outputs high level, current will flow through R1, the transistor will be conducted, and the buzzer will sound. If GP outputs low level, no current flows through R1, the transistor will not be conducted, and buzzer will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

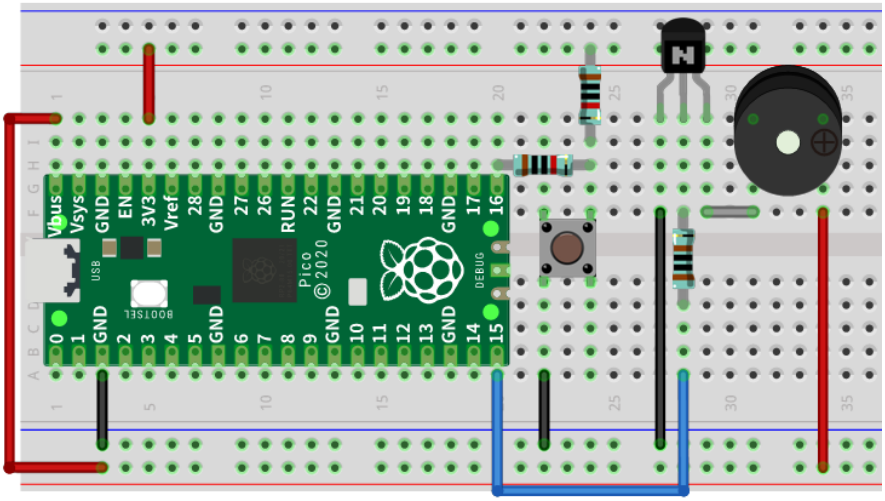
| NPN transistor to drive buzzer | PNP transistor to drive buzzer |
|---|---|
|  |  |

## Circuit

Schematic diagram




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



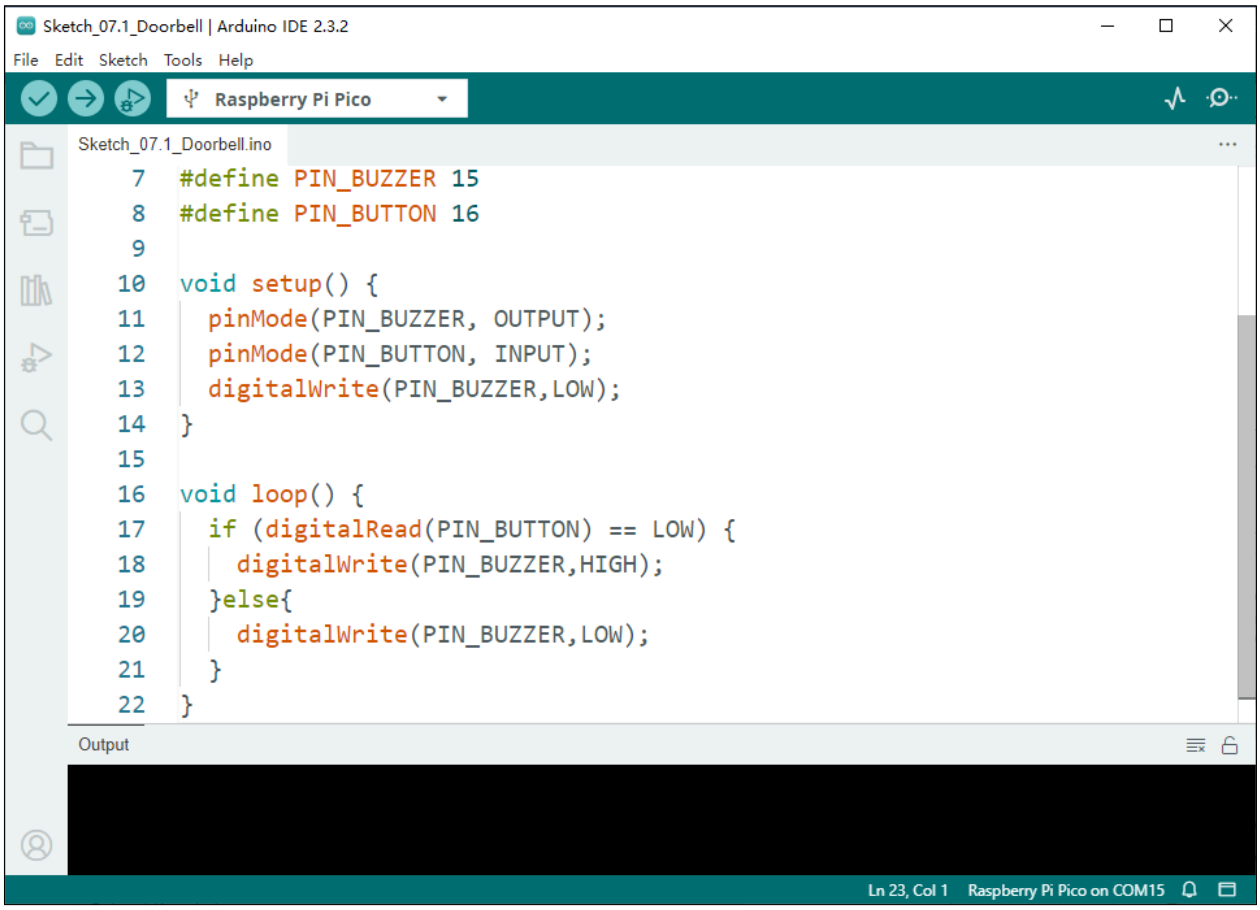
Note:

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.

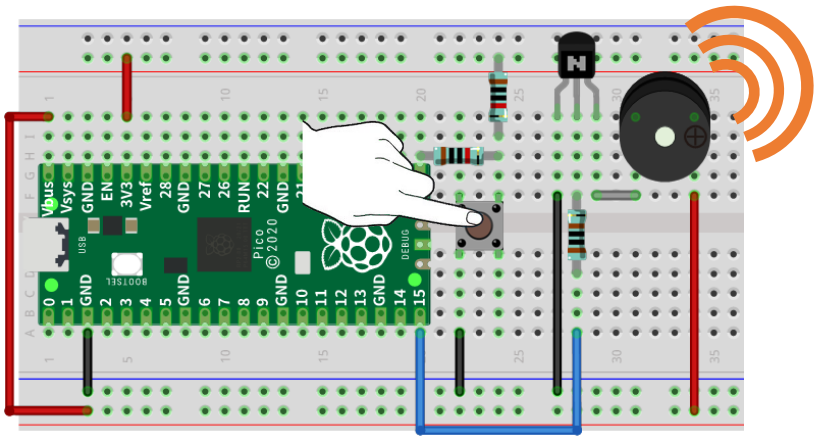
## Sketch

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_06.1_Doorbell




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:

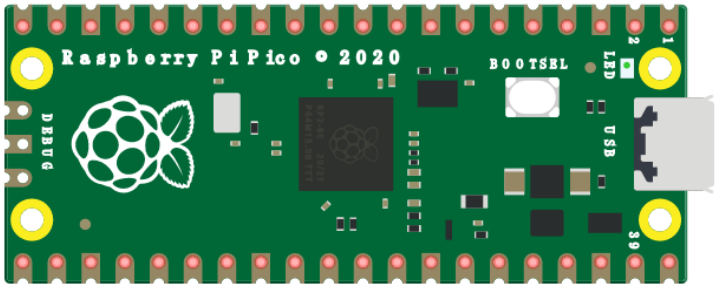
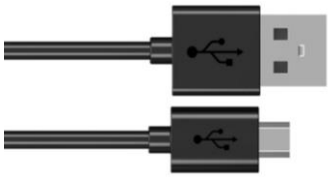
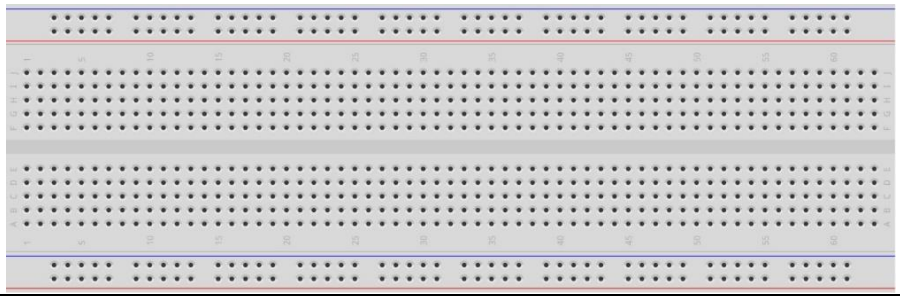
```
#define PIN_BUZZER 15
#define PIN_BUTTON 16

void setup() {
  pinMode(PIN_BUZZER, OUTPUT);
  pinMode(PIN_BUTTON, INPUT);
  digitalWrite(PIN_BUZZER,LOW);
}

void loop() {
  if (digitalRead(PIN_BUTTON) == LOW) {
    digitalWrite(PIN_BUZZER,HIGH);
  }else{
    digitalWrite(PIN_BUZZER,LOW);
  }
}
```

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

# Project 6.2 Alertor

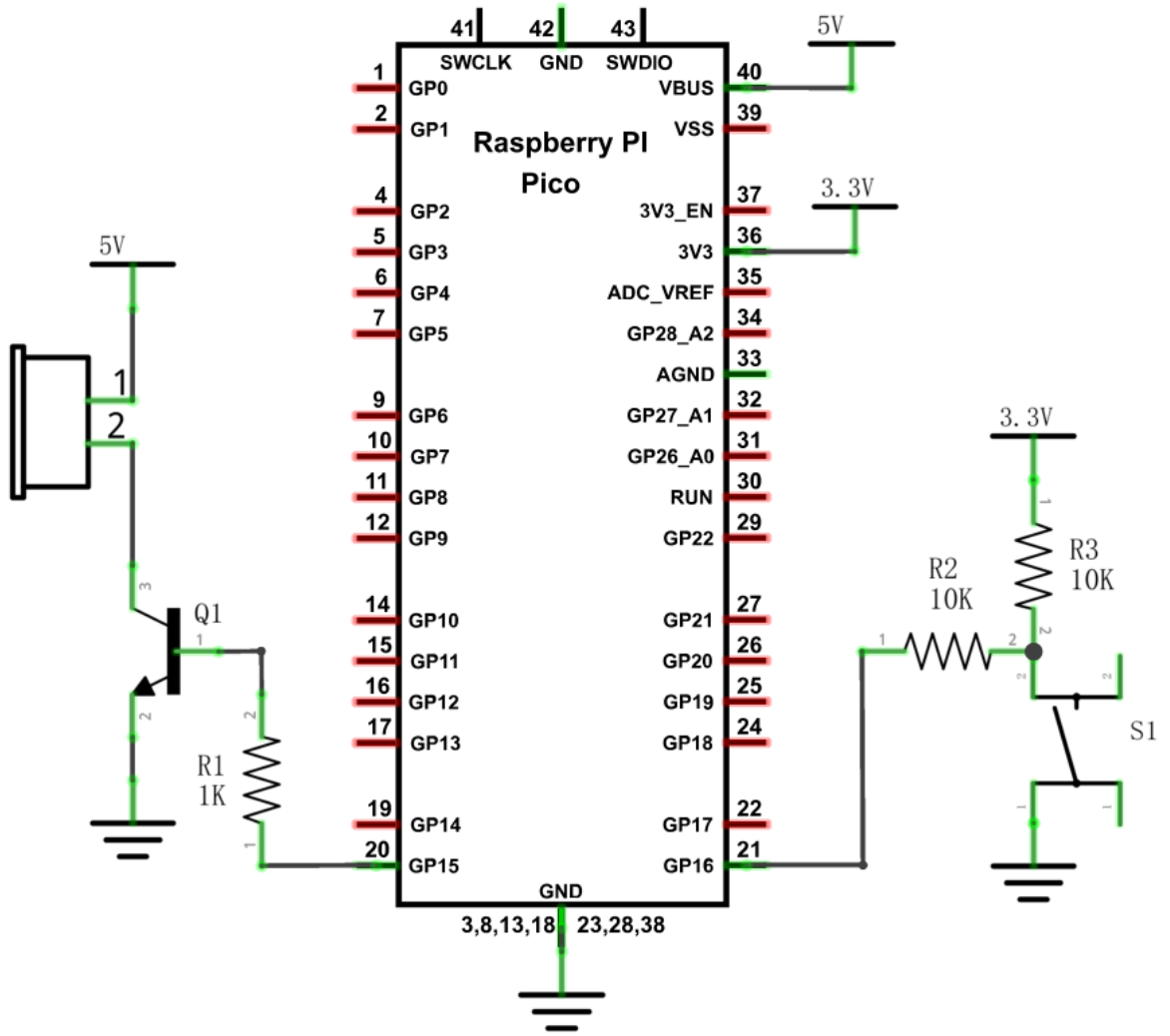
Next, we will use a passive buzzer to make an alarm.
Component list and the circuit part is similar to last section, only the **active buzzer** needs to be **replaced** with a **passive buzzer** for this project.

## Component List

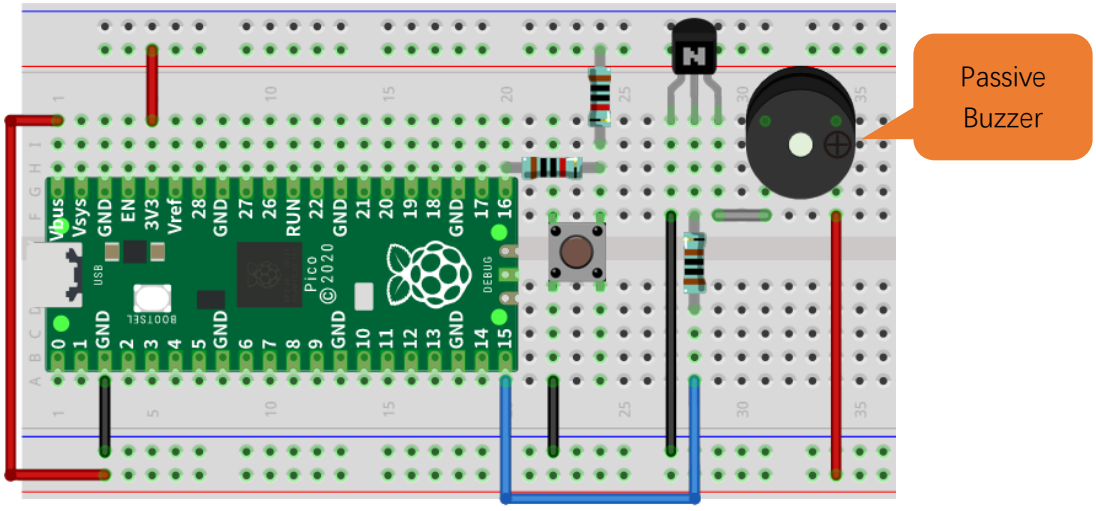
<table>
<tr><td colspan="2">Raspberry Pi Pico x1<br>  </td><td colspan="3">USB cable x1<br>  </td></tr>
<tr><td colspan="5">Breadboard x1<br>  </td></tr>
<tr><td colspan="5">Jumper<br>  </td></tr>
<tr><td>NPN transistorx1<br>(S8050)<br>  </td><td>Passive buzzer x1<br>  </td><td>Push button x1<br>  </td><td>Resistor<br>1kΩ x1<br>  </td><td>Resistor<br>10kΩ x2<br>  </td></tr>
</table>

## Circuit

Schematic diagram



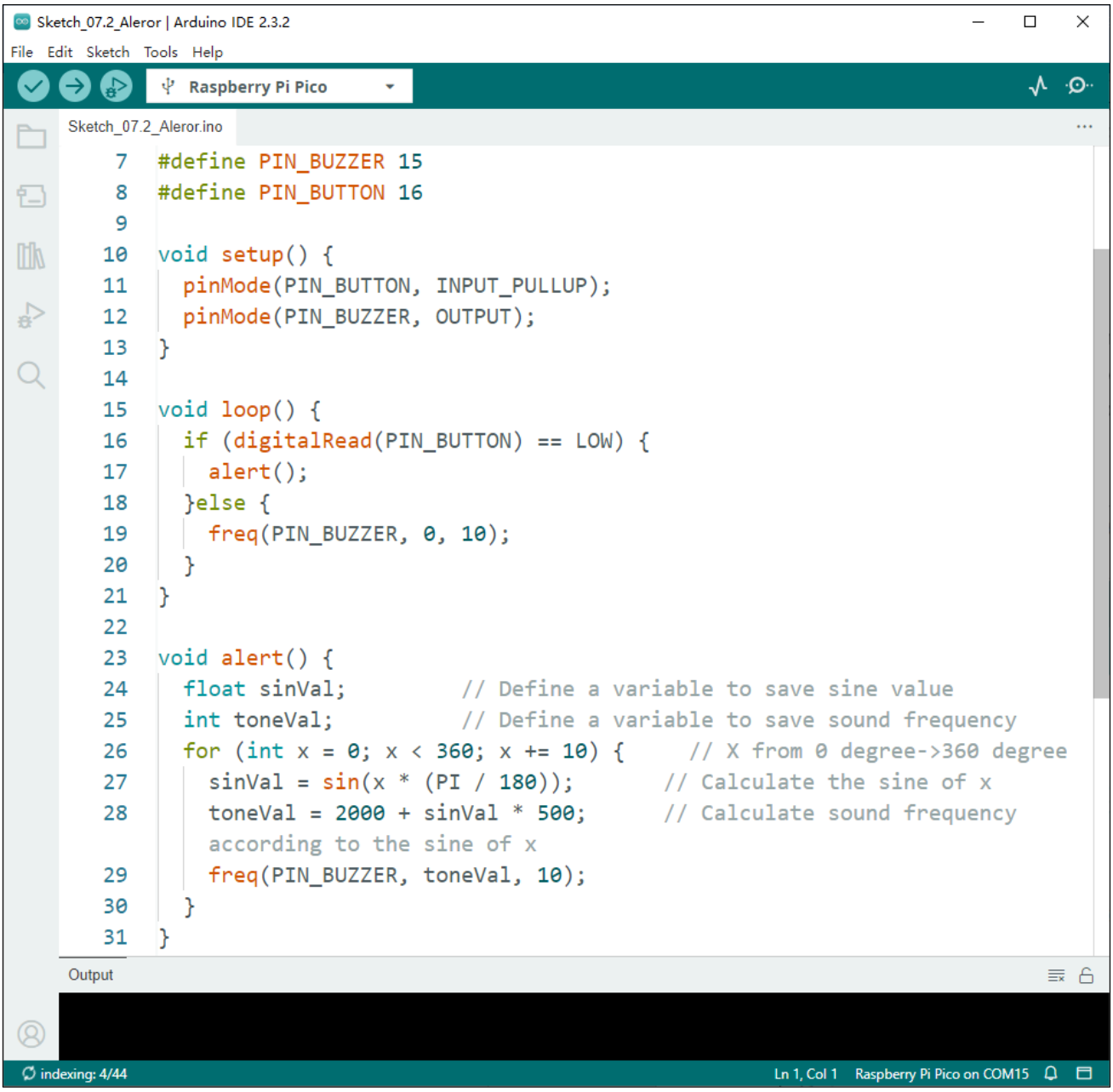

Hardware connection. If you need any support, please feel free to contact us via: support@freenove.com



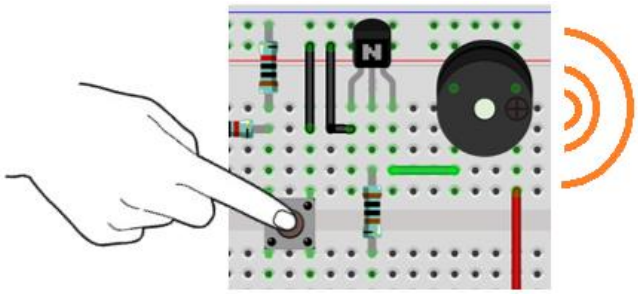
## Sketch

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_06.2_Alertor



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:

```
#define PIN_BUZZER 15
#define PIN_BUTTON 16

void setup() {
  pinMode(PIN_BUTTON, INPUT_PULLUP);
  pinMode(PIN_BUZZER, OUTPUT);
}

void loop() {
  if (digitalRead(PIN_BUTTON) == LOW) {
    alert();
  }else {
    freq(PIN_BUZZER, 0, 10);
  }
}

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

void freq(int PIN, int freqs, int times) {
  if (freqs == 0) {
    digitalWrite(PIN, LOW);
  }
  else {
    for (int i = 0; i < times * freqs / 1000; i ++) {
      digitalWrite(PIN, HIGH);
```

```
        delayMicroseconds(1000000 / freqs / 2);
        digitalWrite(PIN, LOW);
        delayMicroseconds(1000000 / freqs / 2);
      }
    }
}
```

Define the button and pin to control the passive buzzer.

```
#define PIN_BUZZER 15
#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 s = 1000000 us. By the formula $T = \frac{1}{f}$, when the frequency is fixed, the PWM period T is also fixed.

```
void freq(int PIN, int freqs, int times) {
  if (freqs == 0) {
    digitalWrite(PIN, LOW);
  }
  else {
    for (int i = 0; i < times * freqs / 1000; i ++) {
      digitalWrite(PIN, HIGH);
      delayMicroseconds(1000000 / freqs / 2);
      digitalWrite(PIN, LOW);
      delayMicroseconds(1000000 / freqs / 2);
    }
  }
}
```

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.

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

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.

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

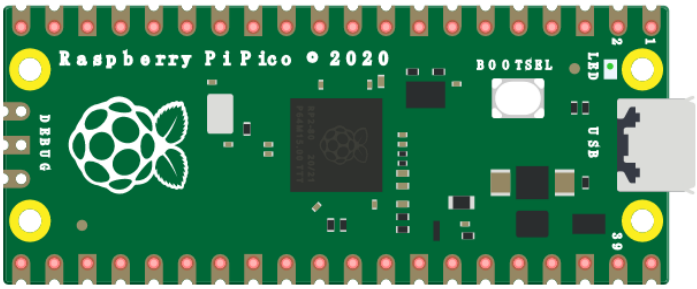
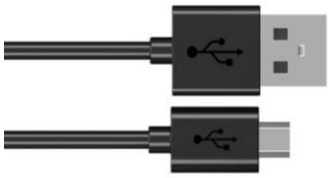
# Chapter 7 Serial Communication

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

## Project 7.1 Serial Print

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

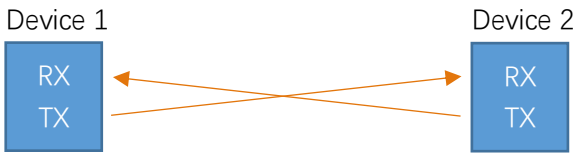
### Component List

| | |
|---|---|
| Raspberry Pi Pico x1  | USB cable x1  |

### Related Knowledge

#### Serial communication

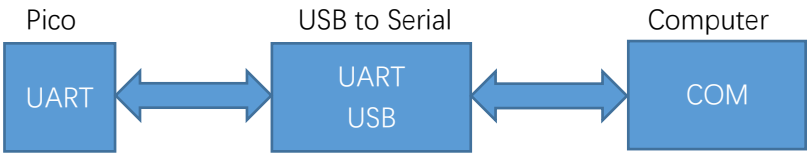
Serial communication generally refers to the Universal Asynchronous Receiver/Transmitter (UART), which is commonly used in electronic circuit communication. It has two communication lines; one is responsible for sending data (TX line) and the other for receiving data (RX line). The serial communication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

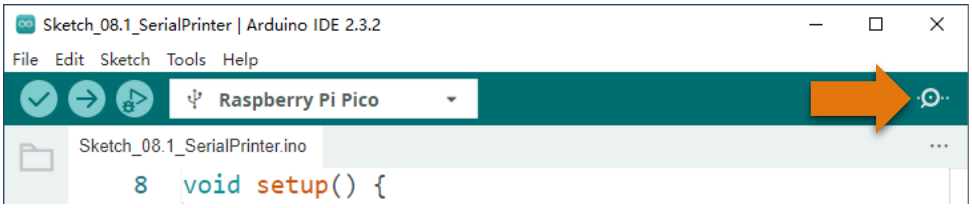
### Serial port on Raspberry Pi Pico

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

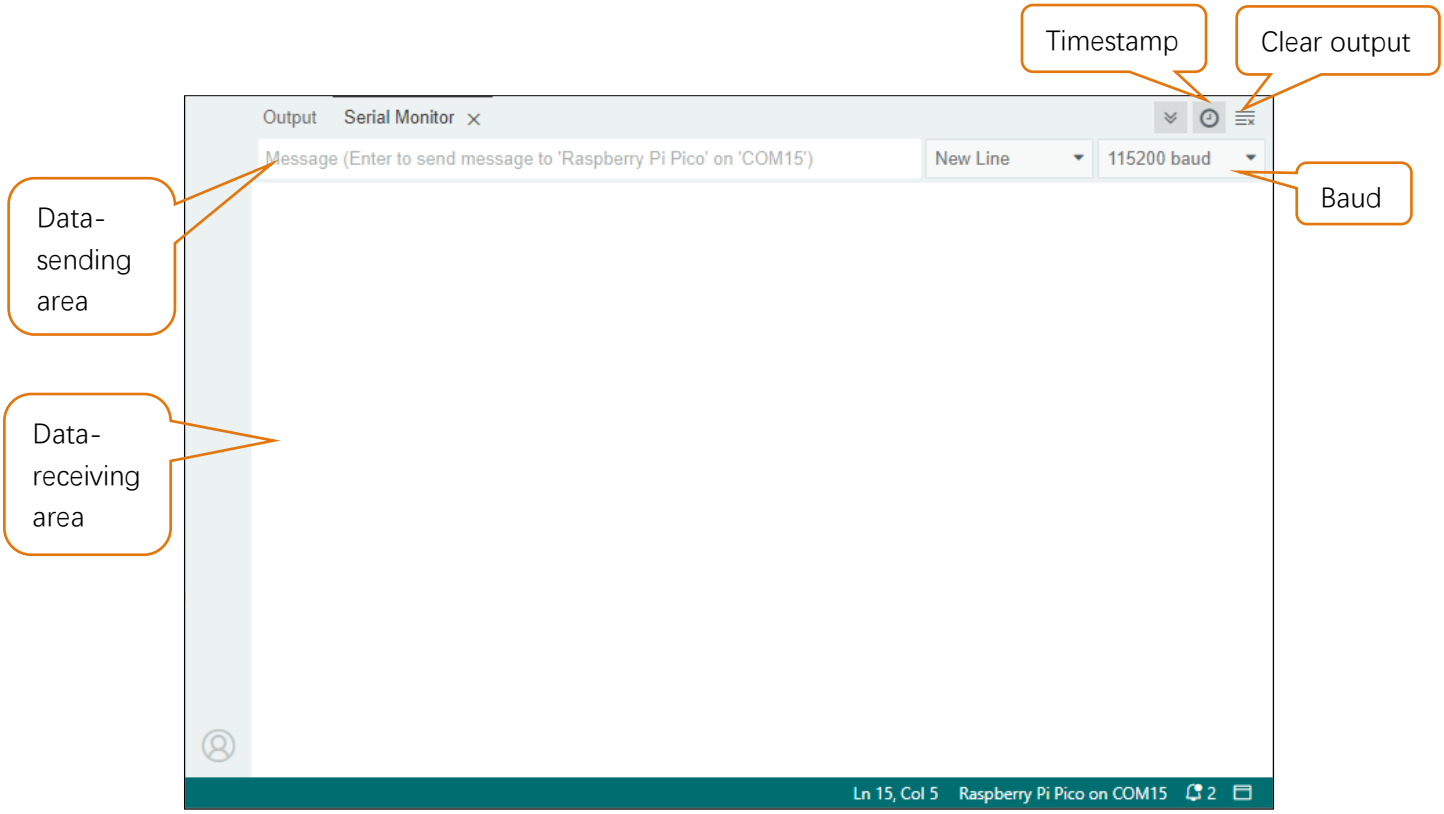



Arduino Software also uploads code to Pico through the serial connection.

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.

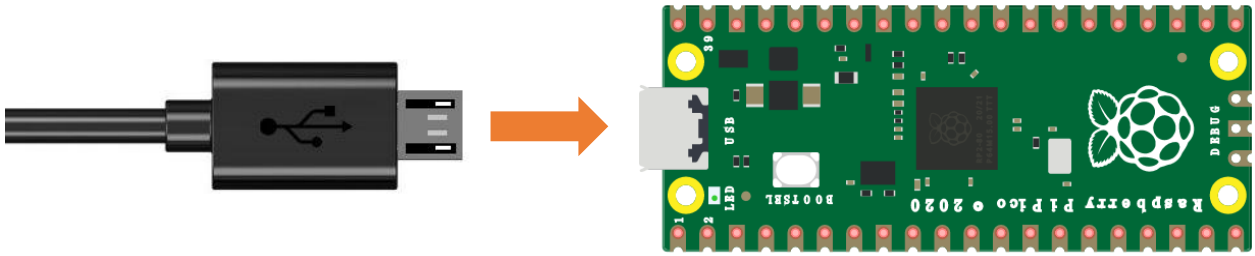



Interface of serial monitor window is as follows. If you cannot open it, make sure Pico has been connected to the computer, and choose the right serial port in the menu bar "Tools".



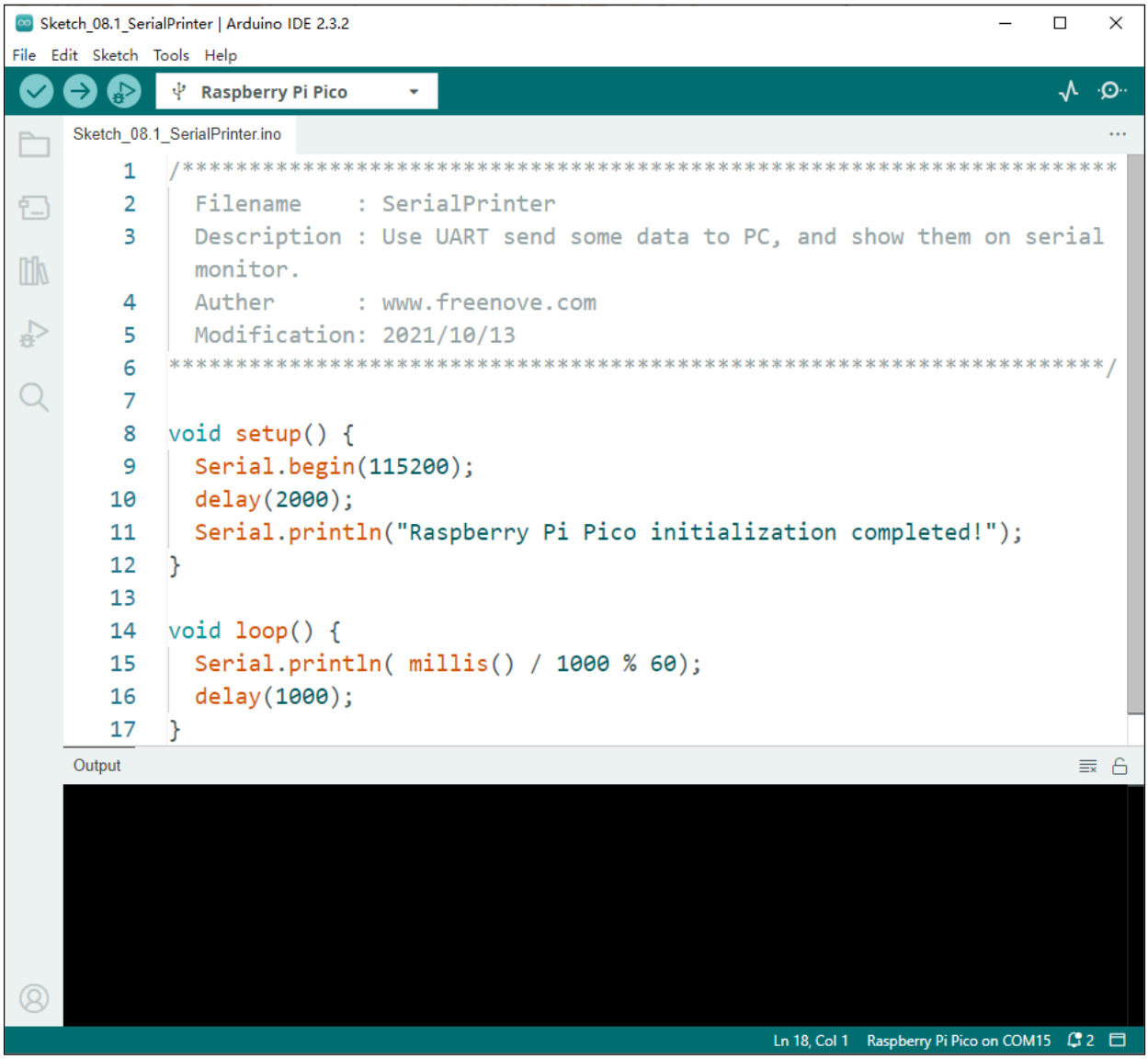
## Circuit

Connect Raspberry Pi Pico to the computer with USB cable.

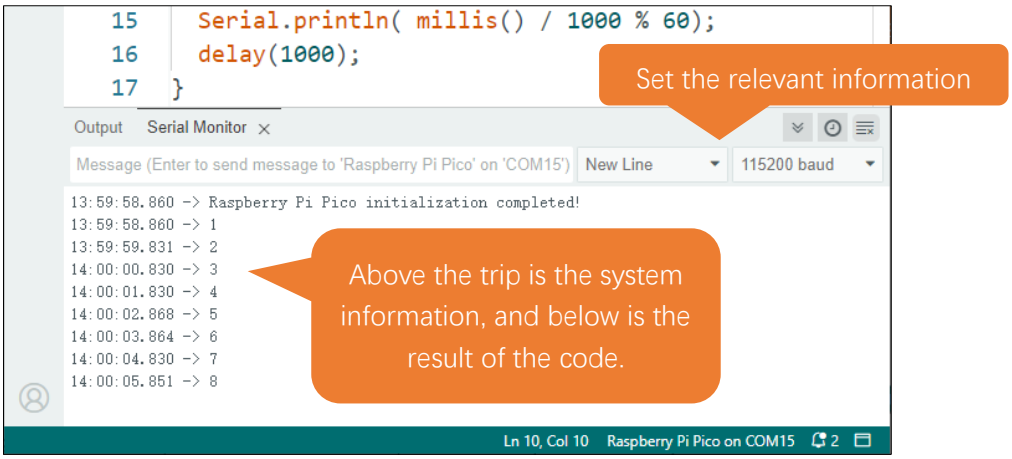


## Sketch

### Sketch_07.1_SerialPrinter



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



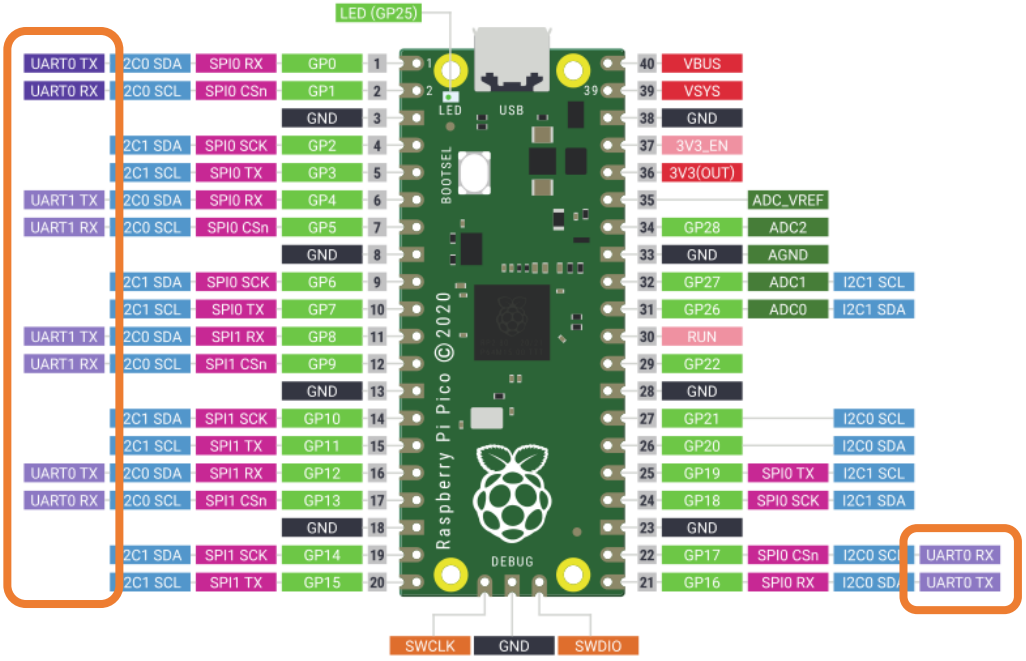

As shown above, when the code runs, the data is printed every one second.

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.



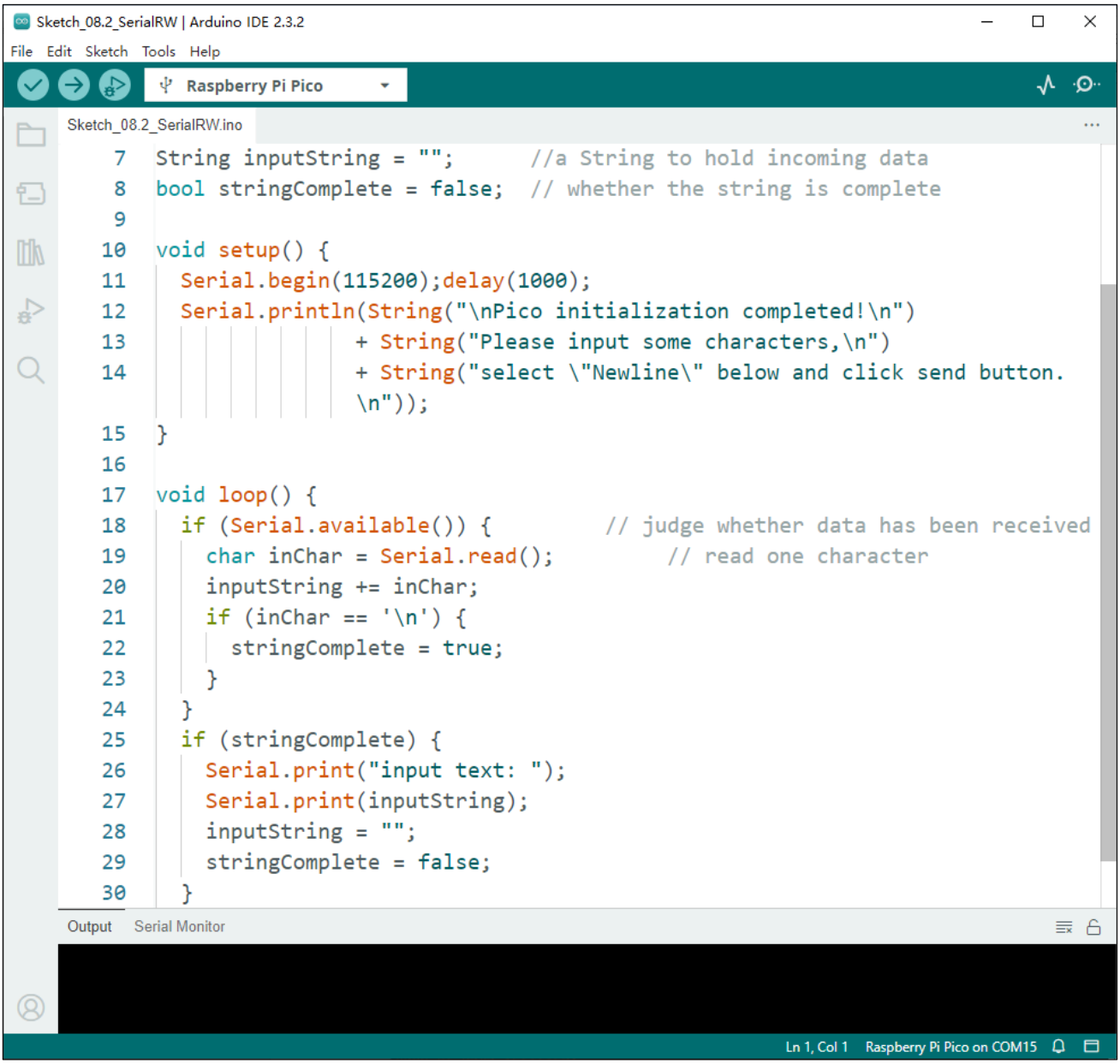
# Project 7.2 Serial Read and Write

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.

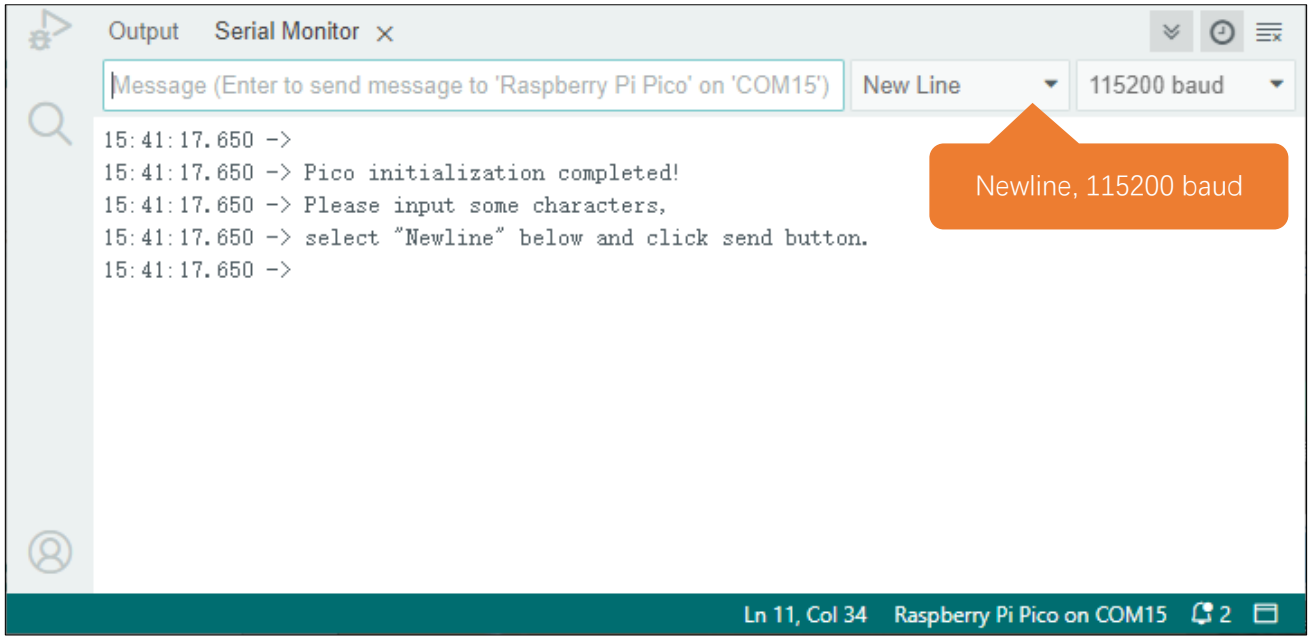
Component and circuit are the same as in the previous project.

## Sketch

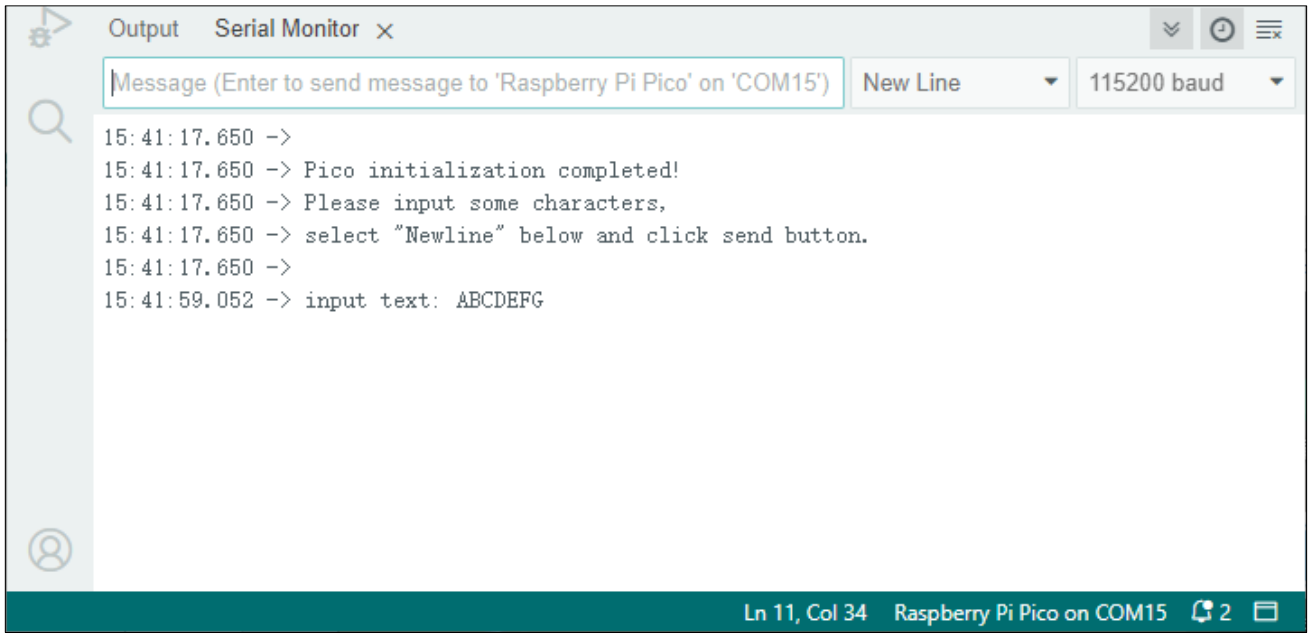
### Sketch_07.2_SerialRW



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:

```
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;
  }
}
```

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.<br>For more information, please visit<br>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. |

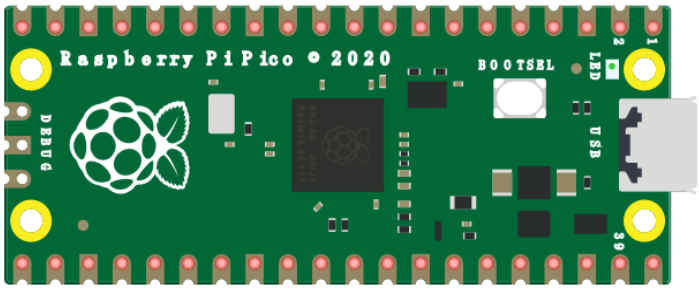
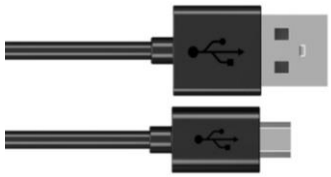
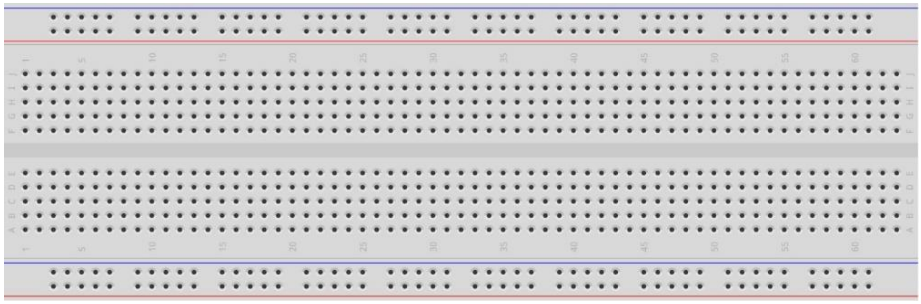
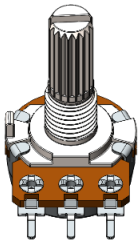
# Chapter 8 AD Converter

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

## Project 8.1 Read the Voltage of Potentiometer

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

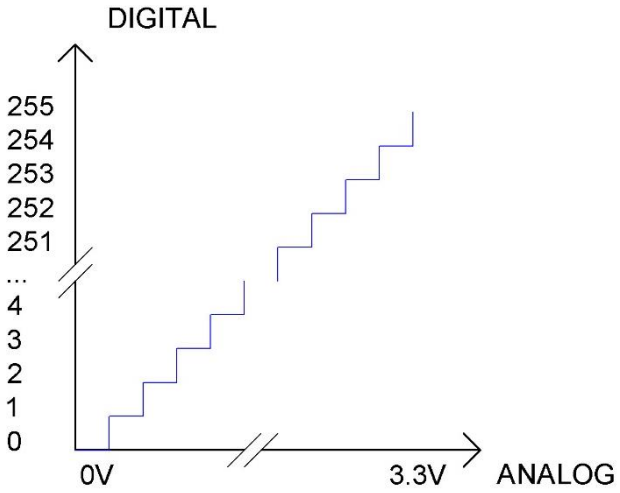
### Component List

| | |
|---|---|
| Raspberry Pi Pico x1  | USB cable x1  |
| Breadboard x1  | |
| Rotary potentiometer x1  | Jumper  |

# 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 rage of analog values corresponds to ADC values. So the more bits the ADC has, the denser the partition of analog will be and the greater the precision of the resulting conversion.




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

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

...

The following analog will be divided accordingly.

The conversion formula is as follows:

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

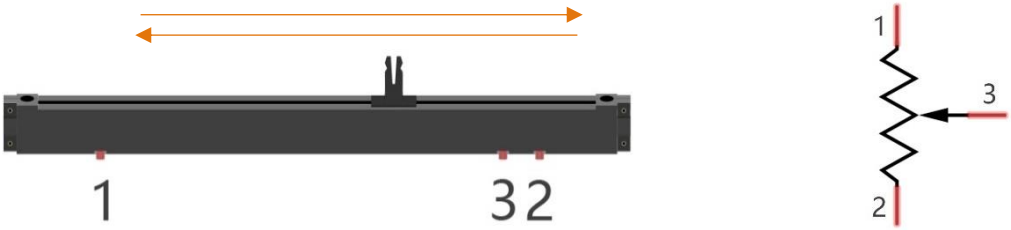
## ADC ChannelsRaspberry Pi Pico

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

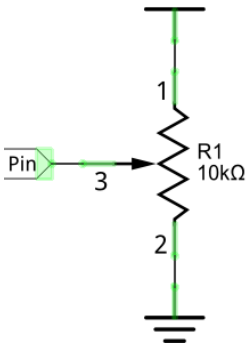
## Potentiometer

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.



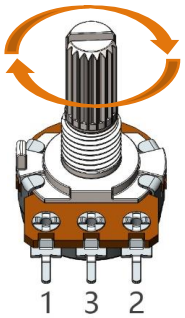

Between potentiometer pin 1 and pin 2 is the resistive element (a resistance wire or carbon) and pin 3 is connected to the brush that makes contact with the resistive element. In our illustration, when the brush moves from pin 1 to pin 2, the resistance value between pin 1 and pin 3 will increase linearly (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.



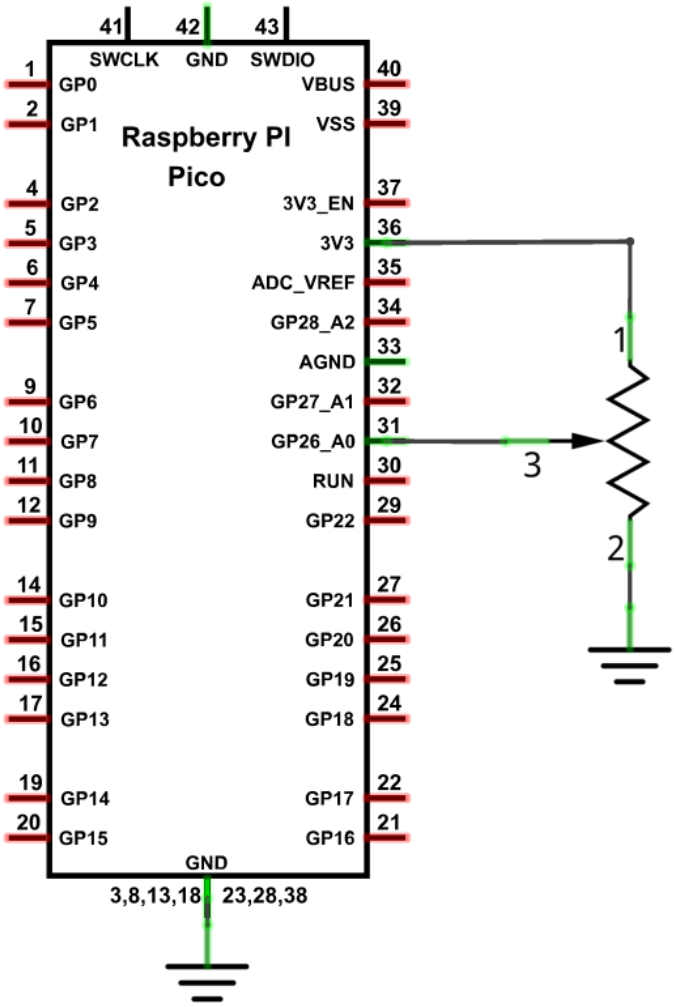

## Rotary potentiometer

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

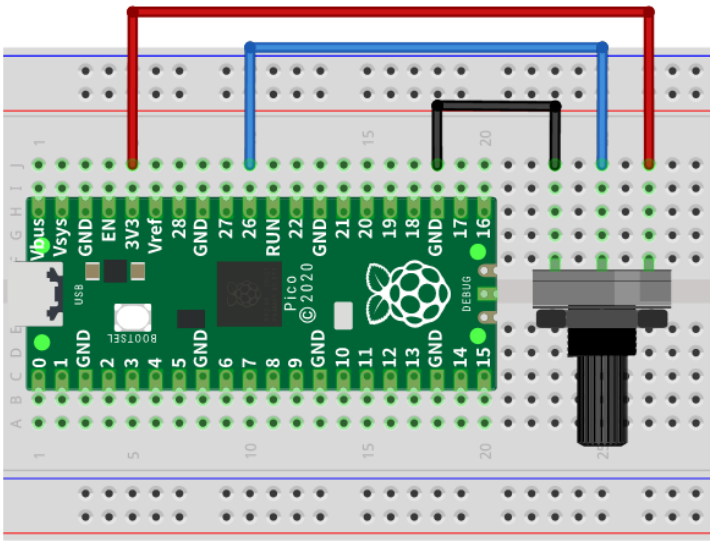


## Circuit

Schematic diagram

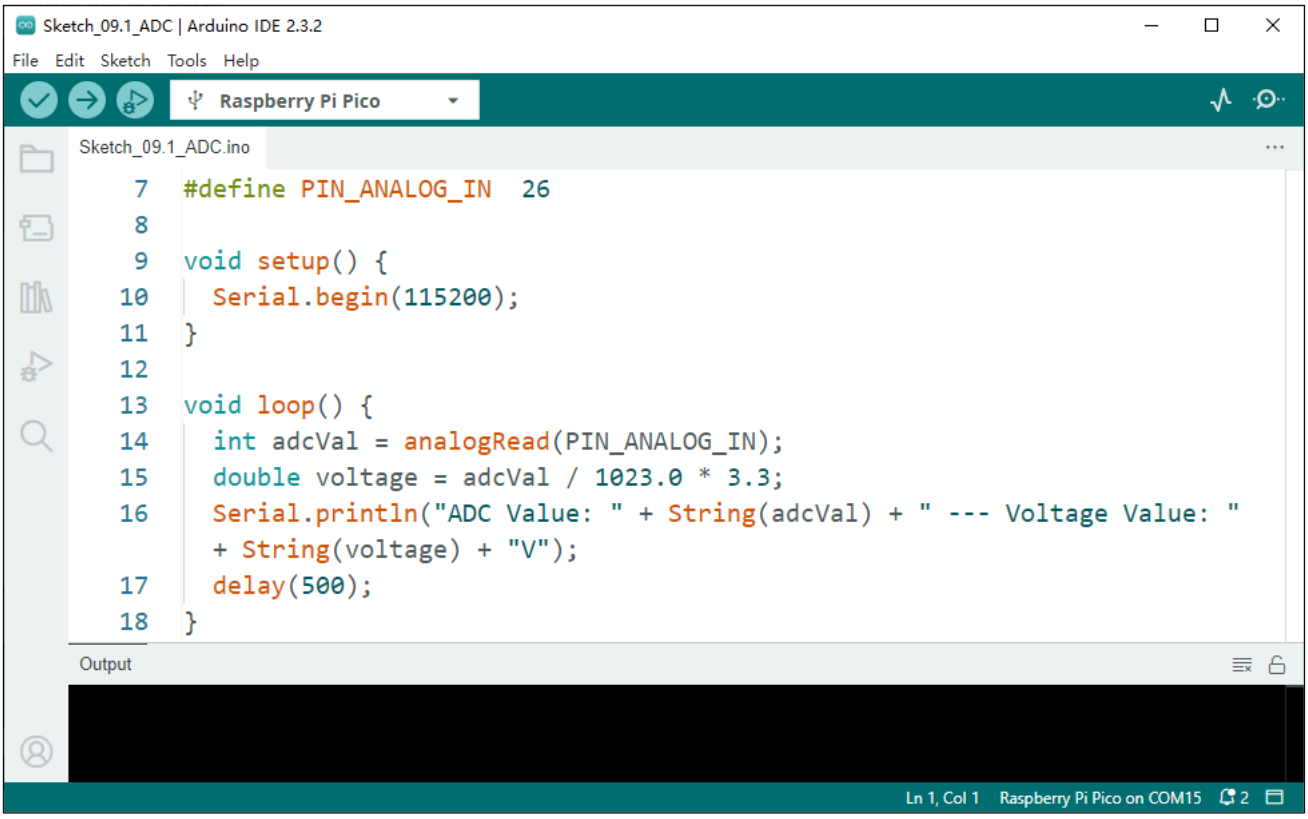



Hardware connection. If you need any support, please feel free to contact us via: support@freenove.com

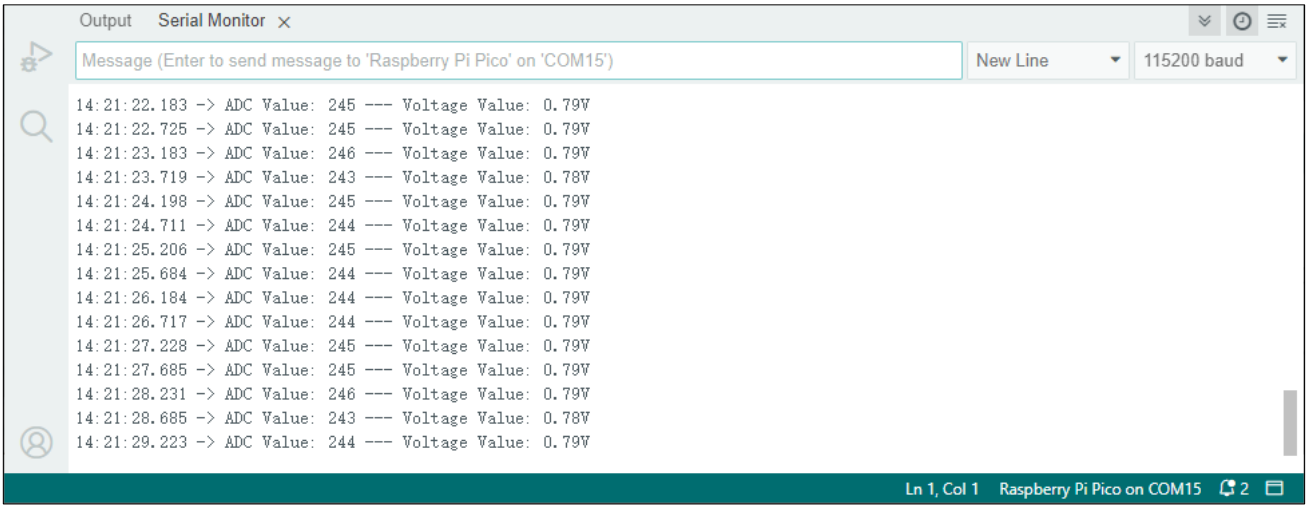


# Sketch

## Sketch_08.1_ADC




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



The following is the code:

```
#define PIN_ANALOG_IN  26

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

void loop() {
  int adcVal = analogRead(PIN_ANALOG_IN);
  double voltage = adcVal / 1023.0 * 3.3;
  Serial.println("ADC Value: " + String(adcVal) + " --- Voltage Value: " + String(voltage) + "V");
  delay(500);
}
```

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.

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

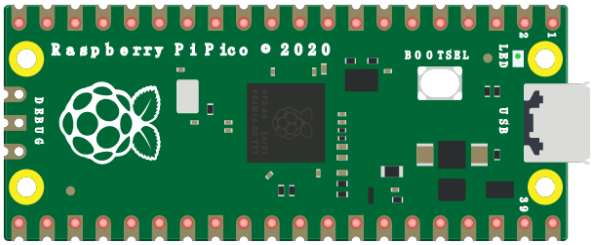
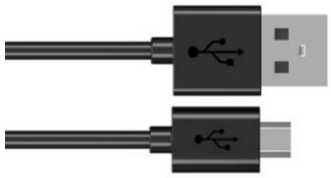
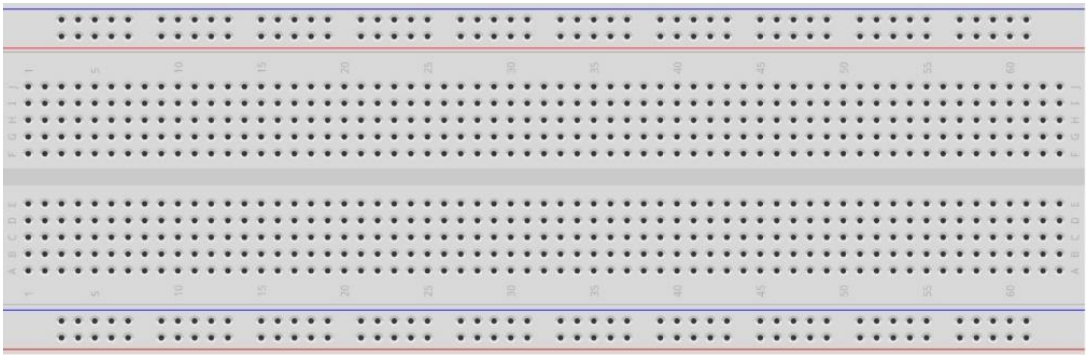
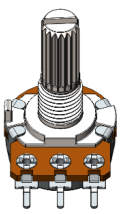
# Chapter 9 Potentiometer & LED

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 9.1 Soft Light

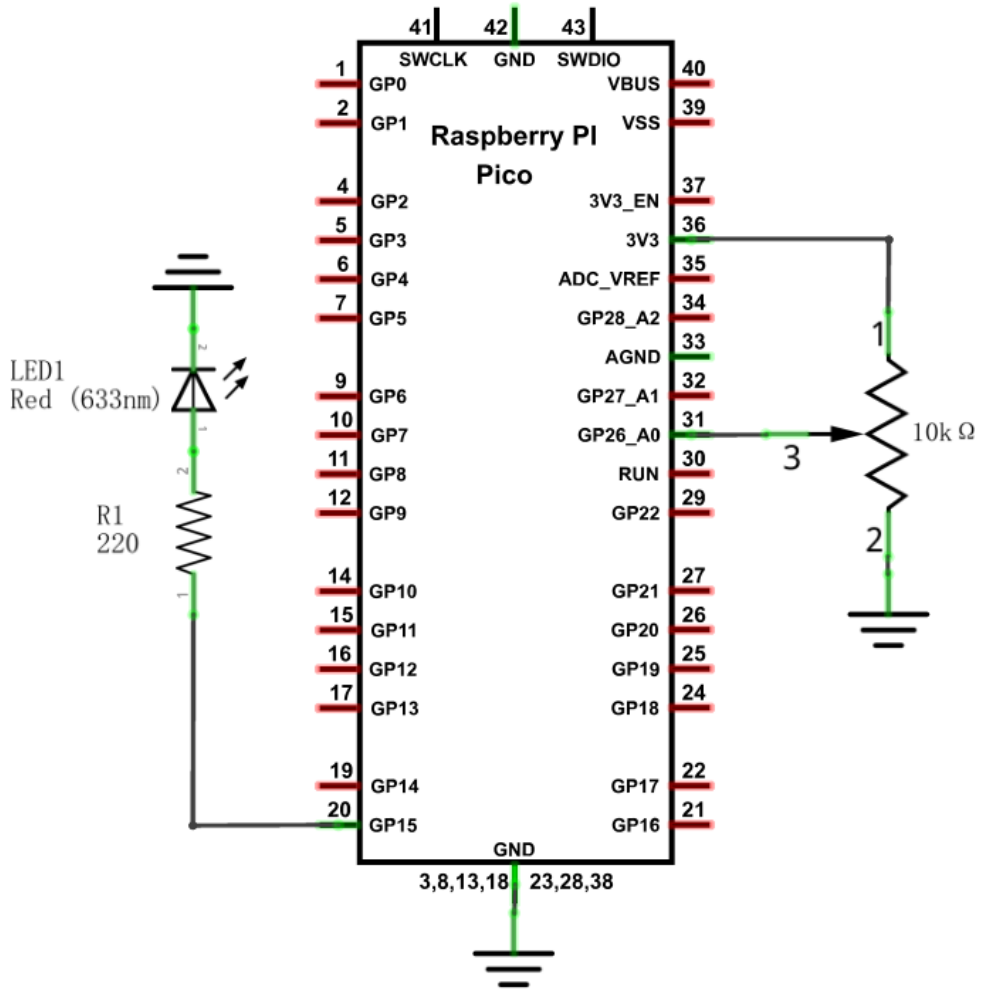
In this project, we will make a soft light. We will use an ADC Module to read ADC values of a potentiometer and map it to duty cycle of the PWM used to control the brightness of an LED. Then you can change the brightness of an LED by adjusting the potentiometer.

### Component List

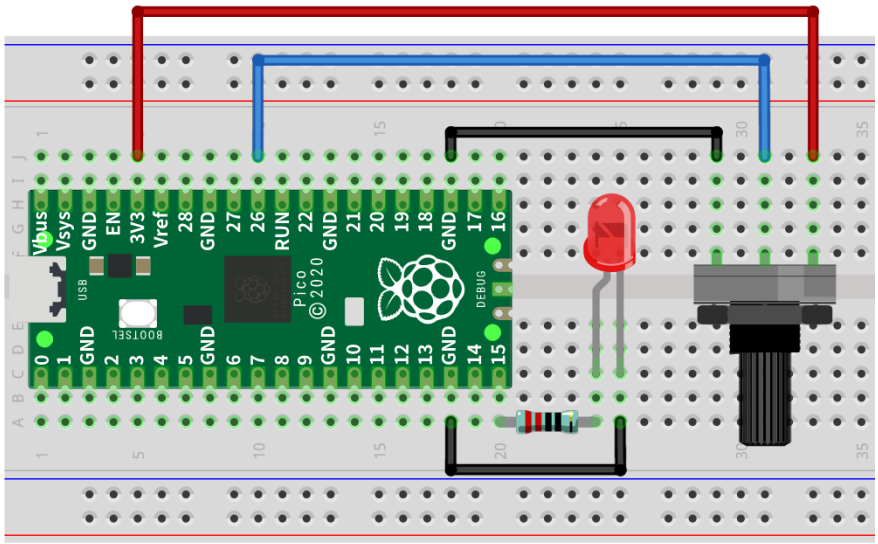
<table>
<tr><td colspan="2">Raspberry Pi Pico x1<br>  </td><td colspan="2">USB cable x1<br>  </td></tr>
<tr><td colspan="4">Breadboard x1<br>  </td></tr>
<tr><td>Rotary potentiometer x1<br>  </td><td>Resistor 220Ω x1<br>  </td><td>LED x1<br>  </td><td>Jumper<br></td></tr>
</table>

## Circuit

Schematic diagram

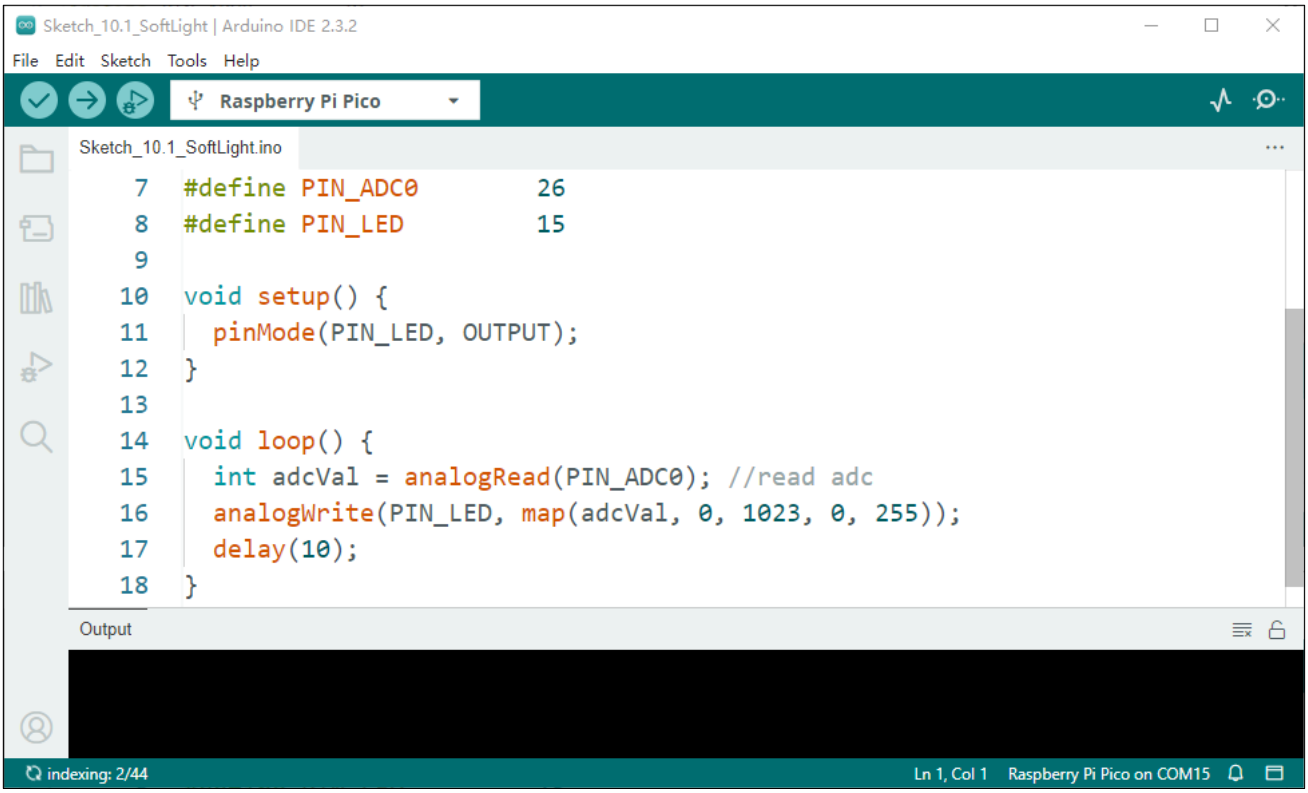



Hardware connection. If you need any support, please feel free to contact us via: support@freenove.com

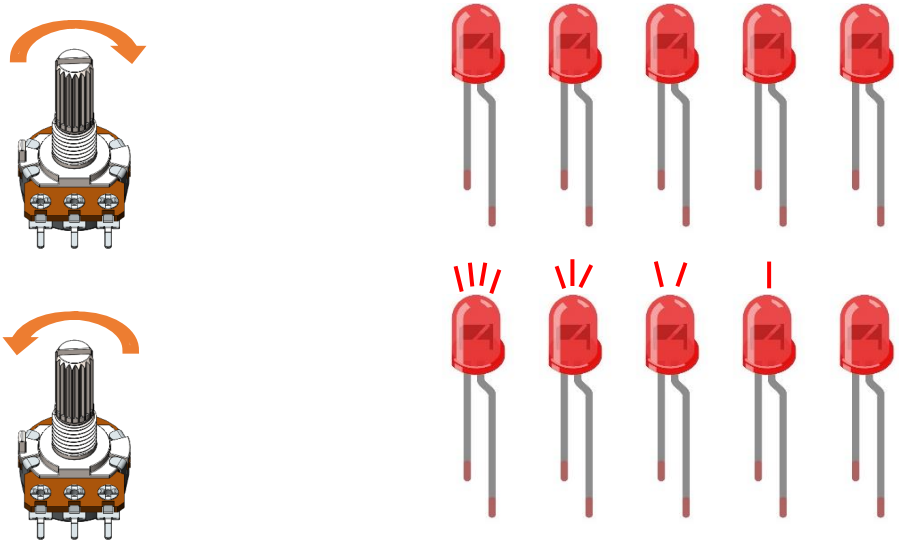


## Sketch

### Sketch_09.1_Softlight




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:

```
#define PIN_ADC0         26
#define PIN_LED          15

void setup() {
  pinMode(PIN_LED, OUTPUT);
}

void loop() {
  int adcVal = analogRead(PIN_ADC0); //read adc
  analogWrite(PIN_LED, map(adcVal, 0, 1023, 0, 255));
  delay(10);
}
```

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

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

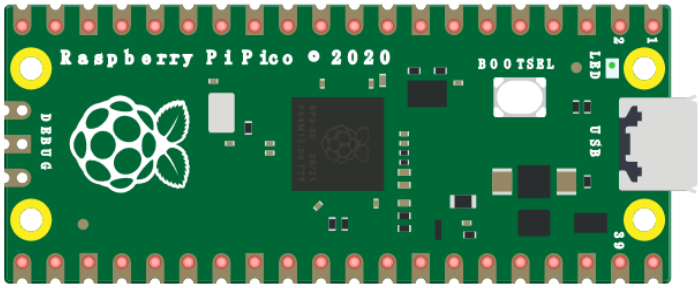
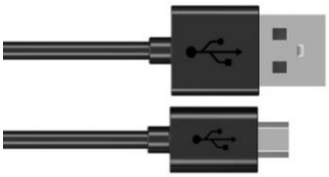
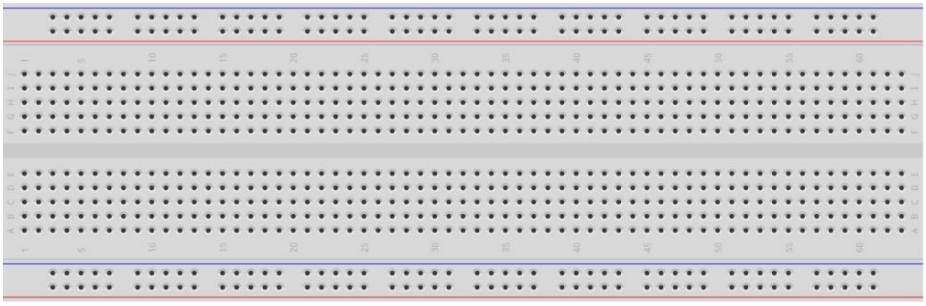
# Chapter 10 Photoresistor & LED

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

## Project 10.1 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.

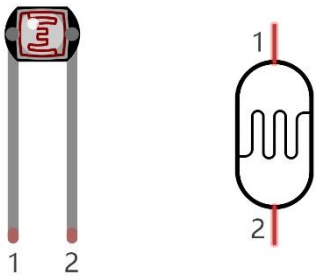
### Component List

<table>
<tr><td colspan="2">Raspberry Pi Pico x1<br>  </td><td colspan="2">USB cable x1<br>  </td></tr>
<tr><td colspan="4">Breadboard x1<br>  </td></tr>
<tr><td>Photoresistor x1<br>  </td><td colspan="2">Resistor<br>220Ω x1<br>  <br>10KΩ x1<br>  </td><td>LED x1<br>  </td><td>Jumper<br></td></tr>
</table>

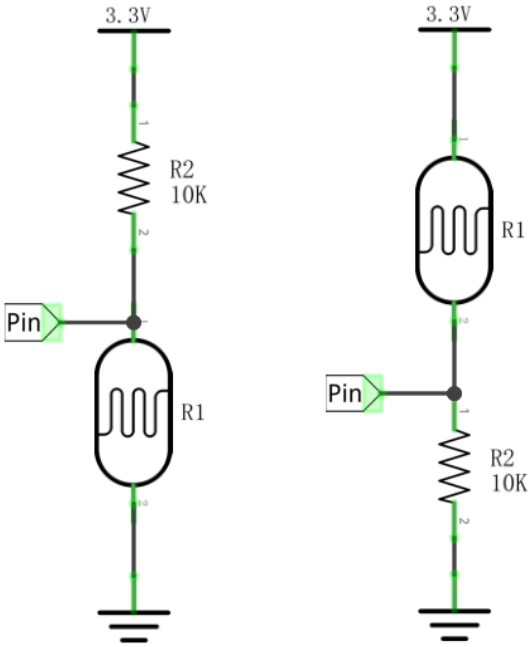
# Component Knowledge

## 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:

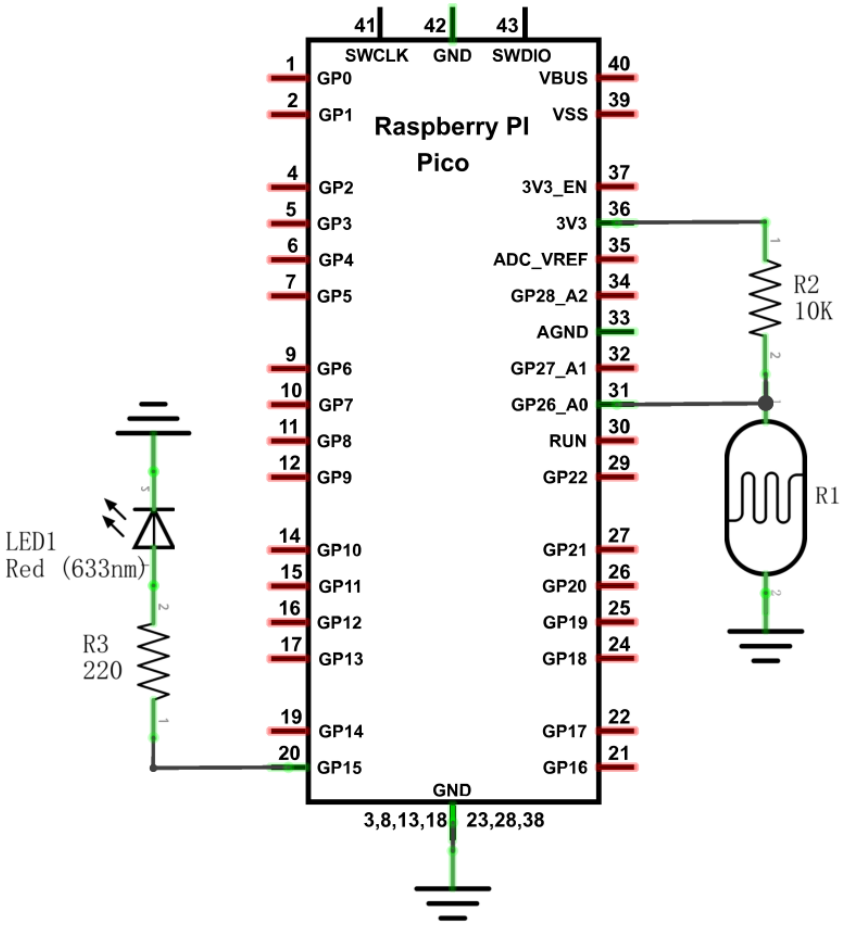



In the above circuit, when a Photoresistor's resistance value changes due to a change in light intensity, the voltage between the Photoresistor and Resistor R1 will also change. Therefore, the intensity of the light can be obtained by measuring this voltage.

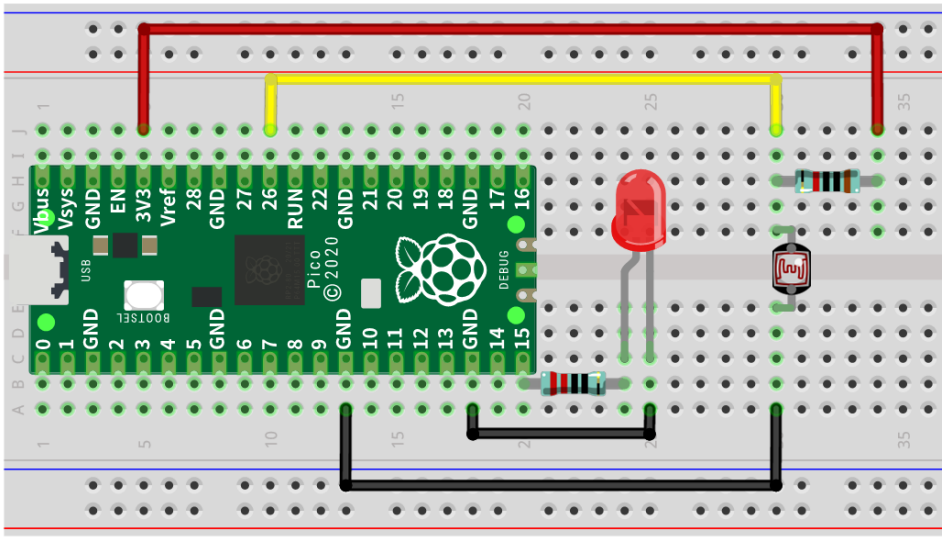
## Circuit

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



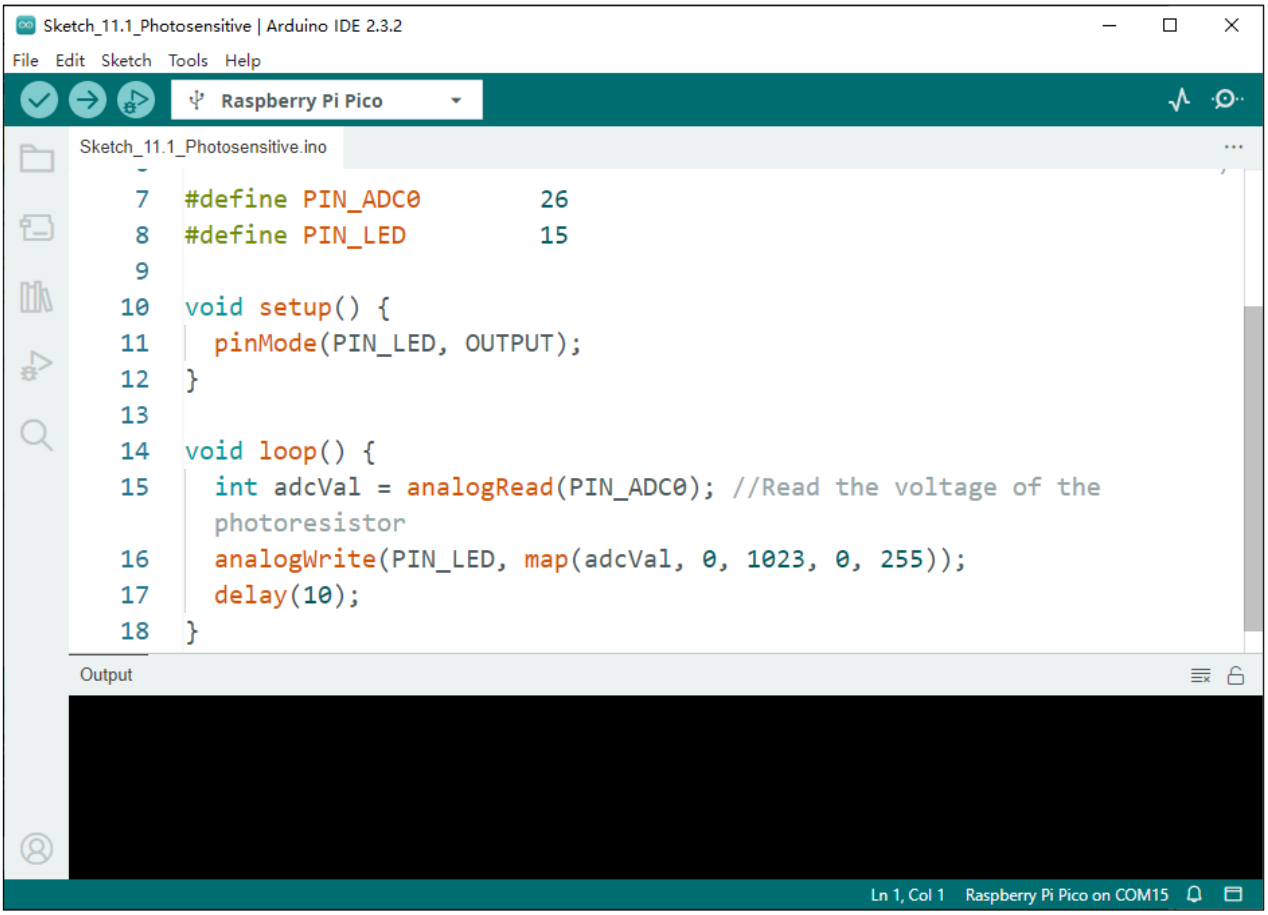

Hardware connection. If you need any support, please feel free to contact us via: support@freenove.com



## 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.

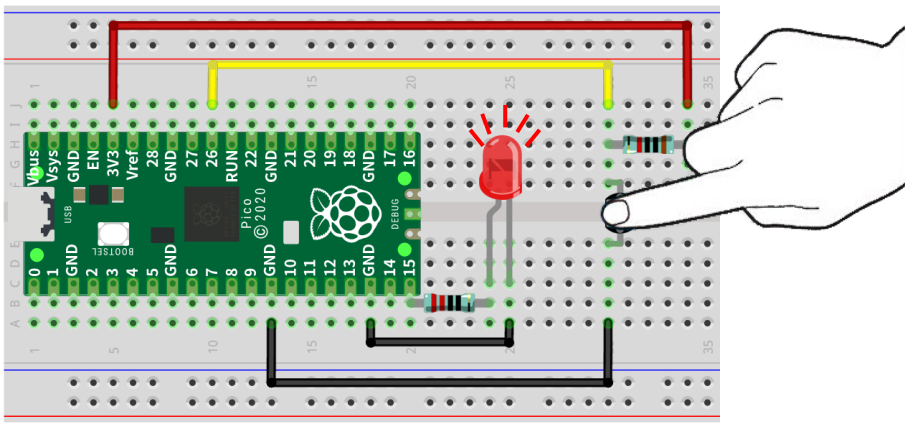
Sketch_10.1_Nightlamp



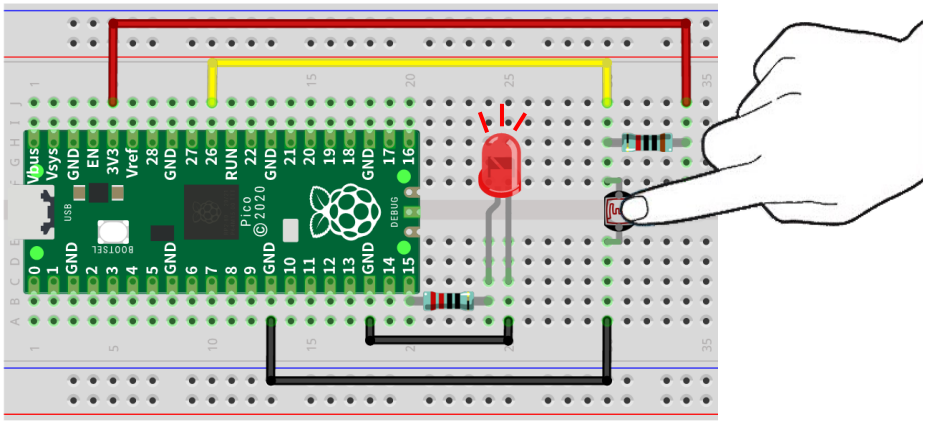

Download the code to Pico, if you cover the photoresistor or increase the light shining on it, the brightness of the LED changes accordingly.

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

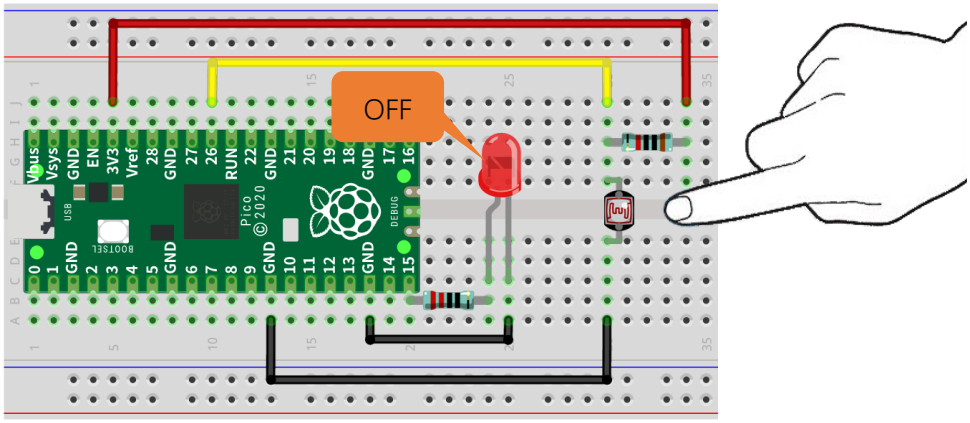
Fully cover the photoresistor:



Half cover the photoresistor:



Not cover the photoresistor:




The following is the program code:

```
#define PIN_ADC0        26
#define PIN_LED         15

void setup() {
  pinMode(PIN_LED, OUTPUT);
}

void loop() {
  int adcVal = analogRead(PIN_ADC0); //Read the voltage of the photoresistor
  analogWrite(PIN_LED, map(adcVal, 0, 1023, 0, 255));
  delay(10);
}
```

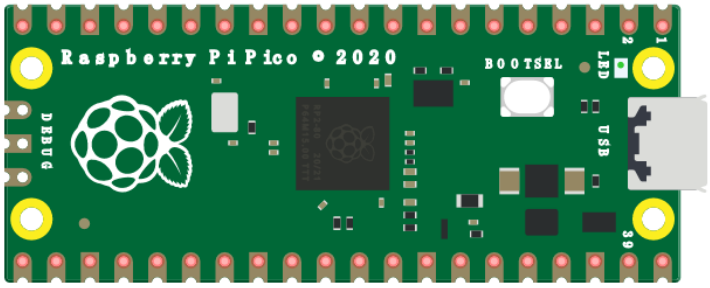
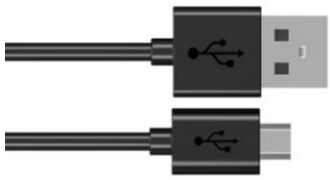
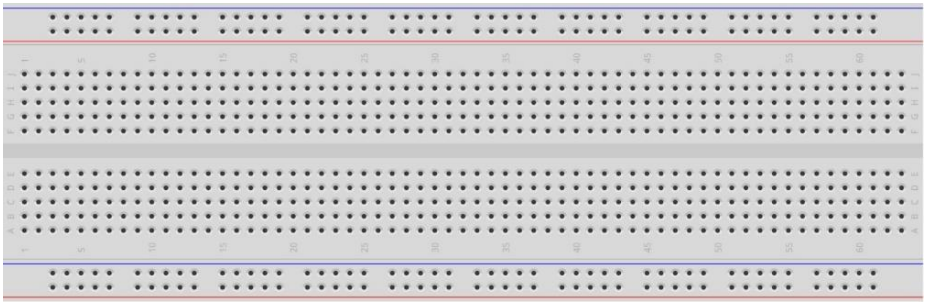
# Chapter 11 Thermistor

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

## Project 11.1 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.

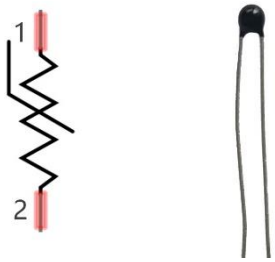
### Component List

<table>
<tr><td colspan="2">Raspberry Pi Pico x1<br>  </td><td>USB cable x1<br>  </td></tr>
<tr><td colspan="3">Breadboard x1<br>  </td></tr>
<tr><td>Thermistor x1<br>  </td><td>Resistor 10kΩ x1<br>  </td><td>Jumper<br>  </td></tr>
</table>

# 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:

$$Rt = R * EXP[\ B * (\frac{1}{T2} - \frac{1}{T1})\ ]$$

**Where:**

Rt is the thermistor resistance under T2 temperature;

**R** is the nominal resistance of thermistor under T1 temperature;

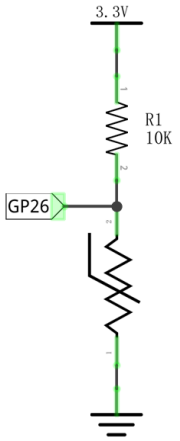
**EXP[n]** is nth power of e;

**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℃.

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.

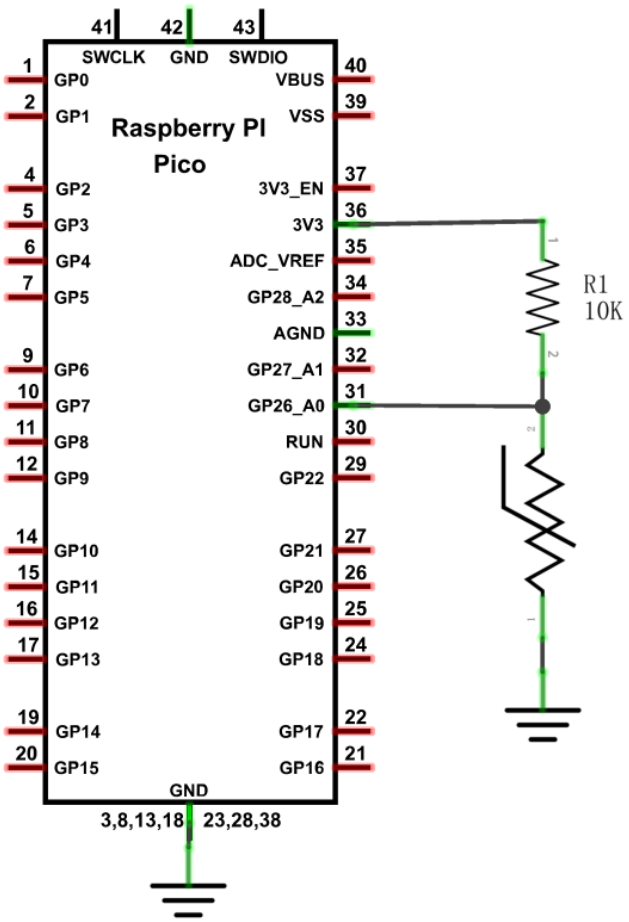
Therefore, the temperature formula can be derived as:

$$T2 = 1/(\frac{1}{T1} + \ln(\frac{Rt}{R})/B)$$

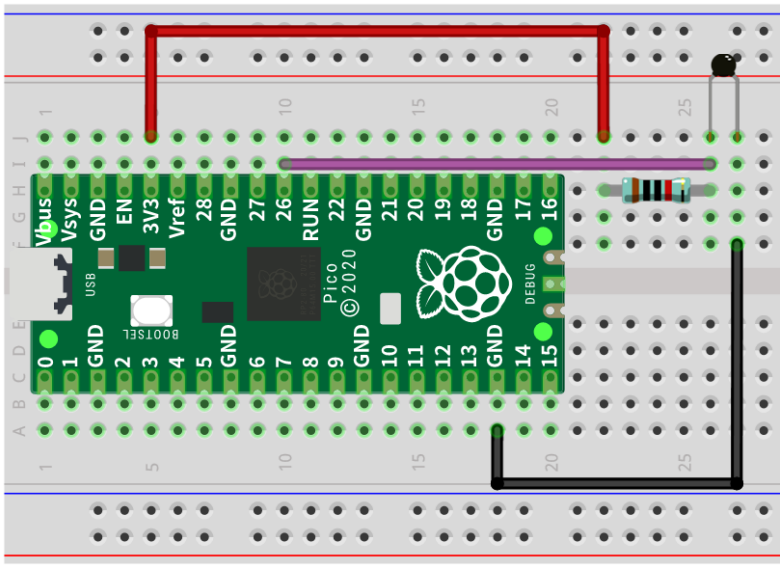
## Circuit

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

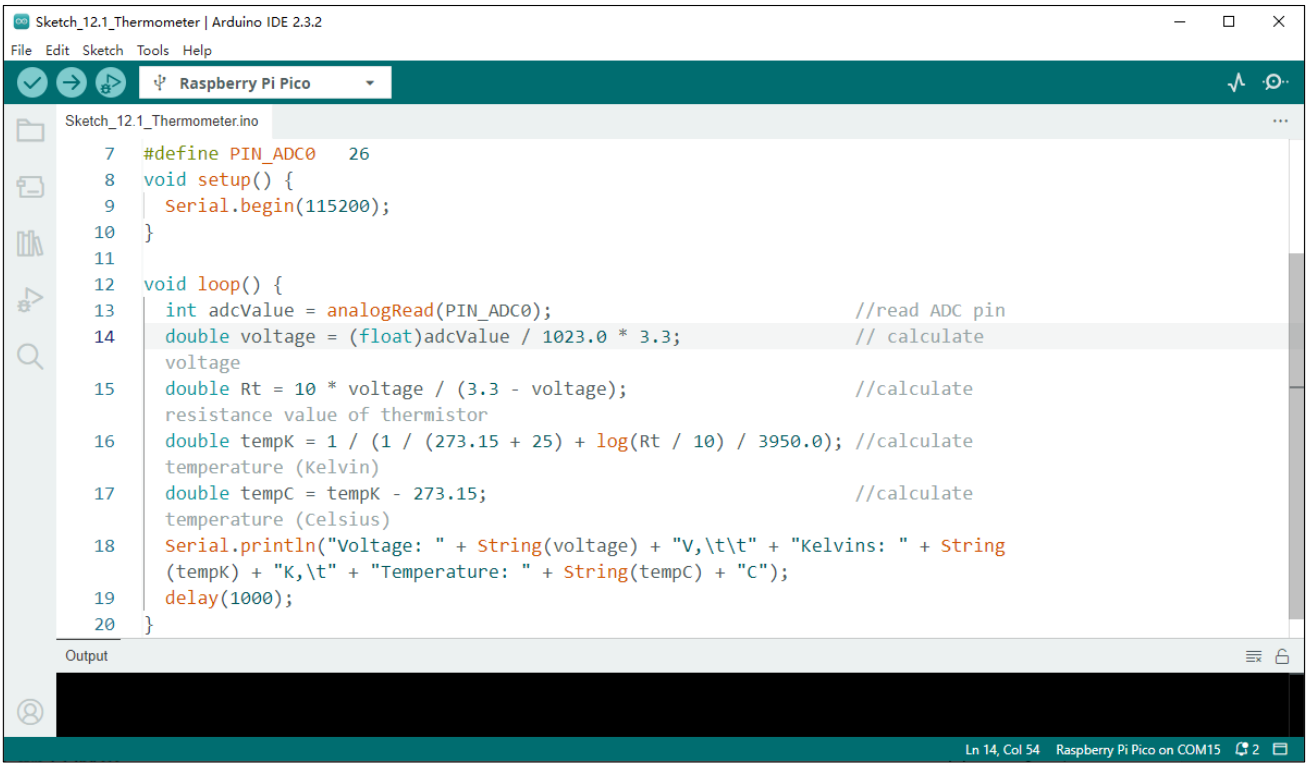



Hardware connection. If you need any support, please feel free to contact us via: support@freenove.com

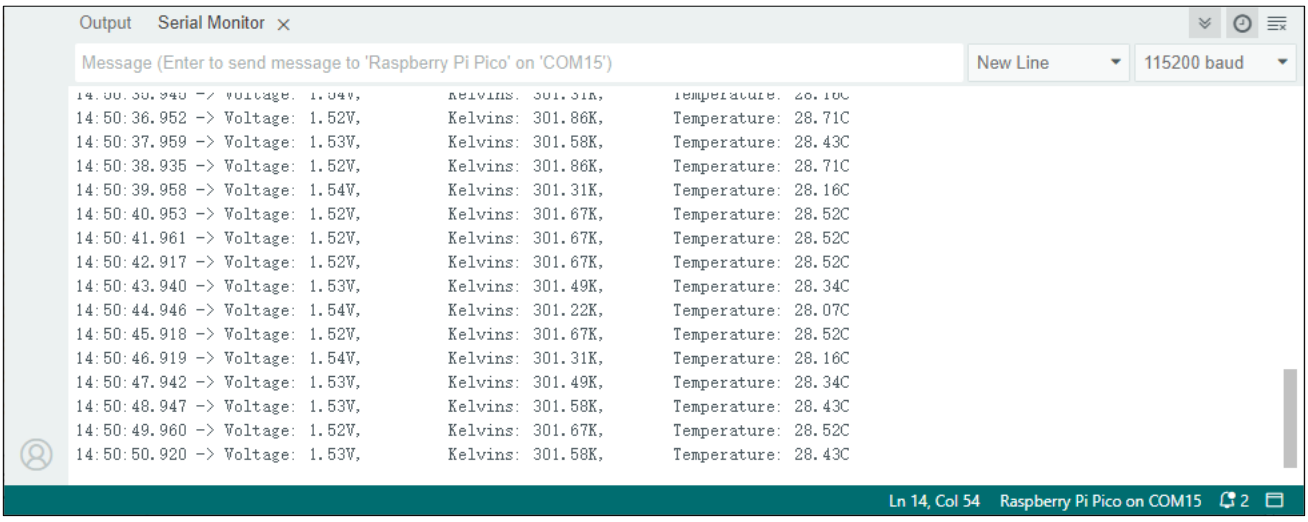


# Sketch

## Sketch_11.1_Thermometer




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 following is the code:

```
#define PIN_ADC0   26
void setup() {
  Serial.begin(115200);
}

void loop() {
  int adcValue = analogRead(PIN_ADC0); //read ADC pin
  double voltage = (float)adcValue / 1023.0 * 3.3;// calculate voltage
  double Rt = 10 * voltage / (3.3 - voltage);//calculate resistance value of thermistor
  double tempK = 1 / (1 / (273.15 + 25) + log(Rt / 10) / 3950.0);//calculate temperature (Kelvin)
  double tempC = tempK - 273.15;//calculate temperature (Celsius)
  Serial.println("Voltage: " + String(voltage) + "V,\t\t" + "Kelvins: " + String(tempK) + "K,\t" + "Temperature: " + String(tempC) + "C");
  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.

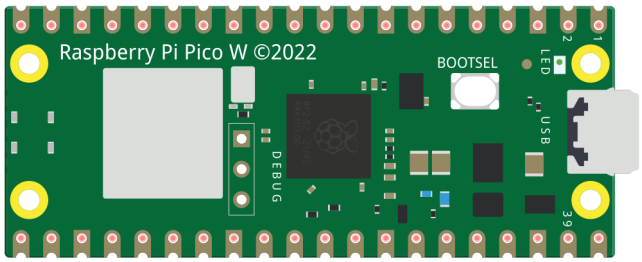
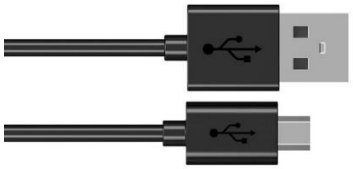
# Chapter 12 WiFi Working Modes (Only for Pico W)

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 12.1 Station mode

### Component List

| | |
|---|---|
| Raspberry Pi Pico W x1   | Micro USB Wire x1  |

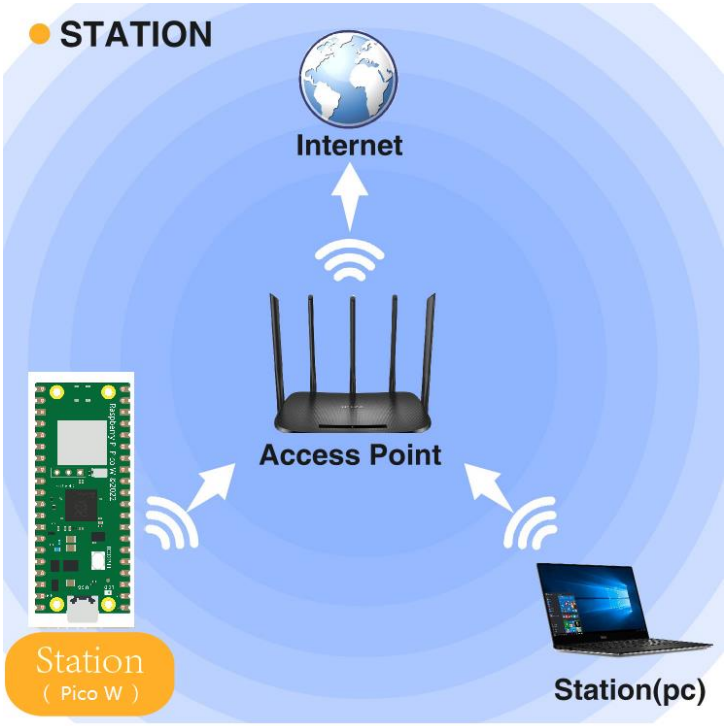
### Component knowledge

#### 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.

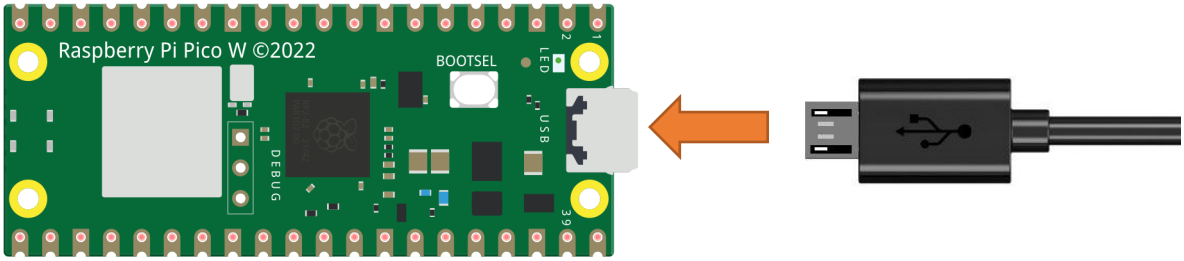
#### Station mode

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.



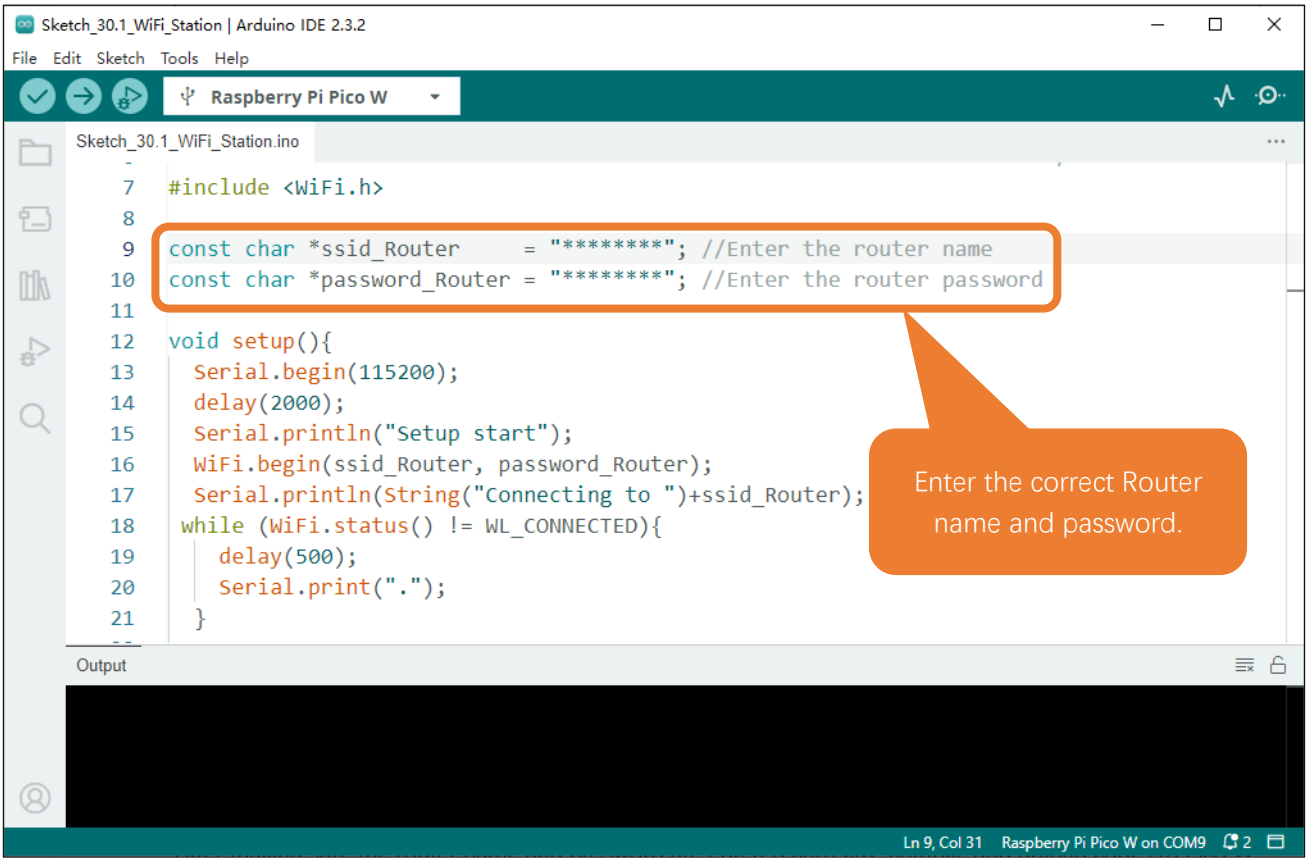

## Circuit

Connect Pico W to the computer using the USB cable.



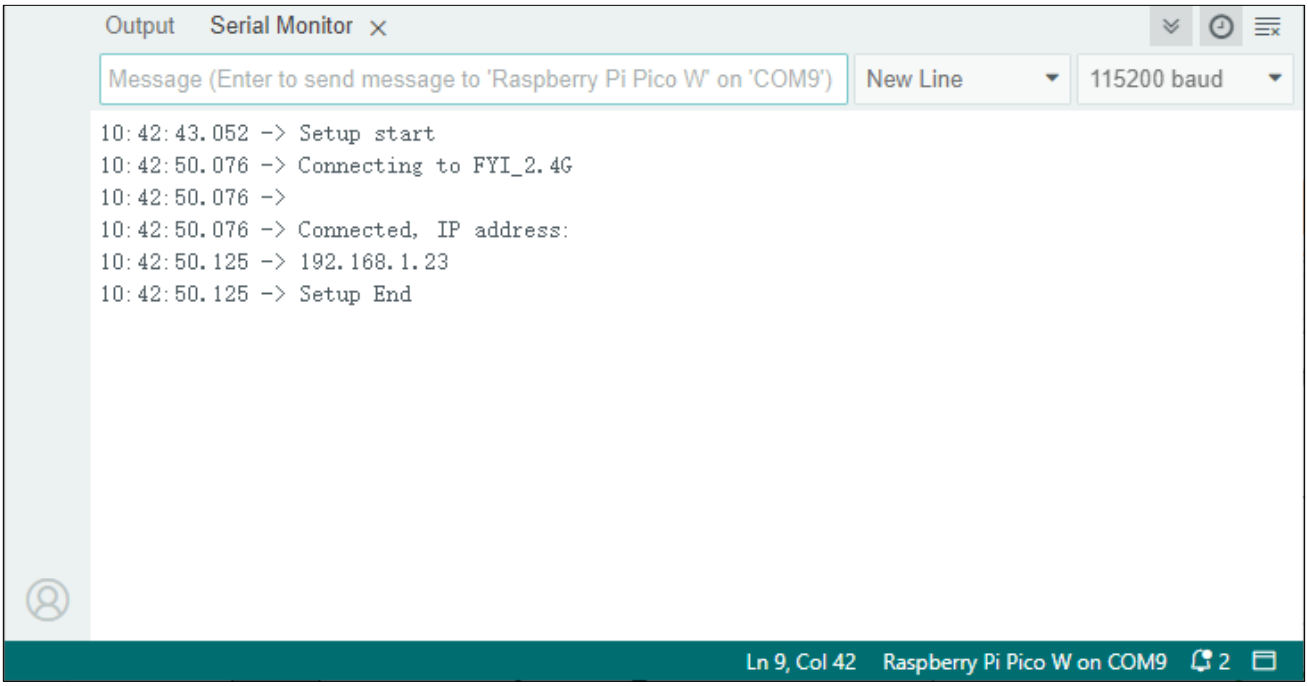
## Sketch

### Sketch_12.1_Station_mode




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:

```
#include <WiFi.h>

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

void setup(){
  Serial.begin(115200);
  delay(2000);
  Serial.println("Setup start");
  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: ");
  Serial.println(WiFi.localIP());
  Serial.println("Setup End");
}
void loop() {
}
```

Include the WiFi Library header file of Pico W.

```
#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**: blloean 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 12.2 AP mode

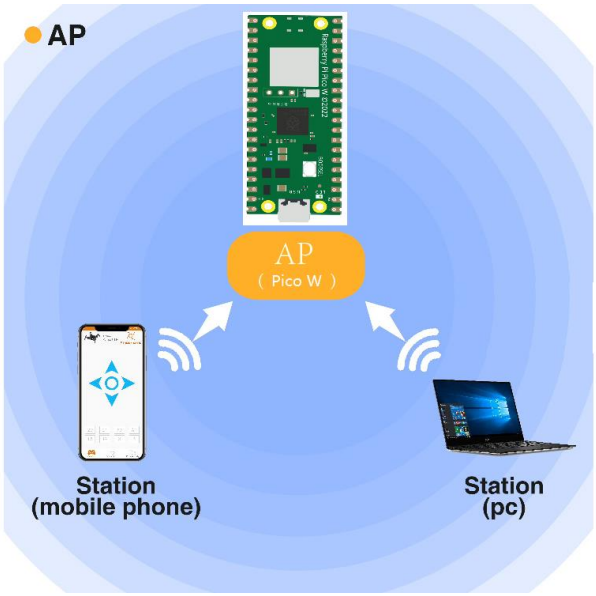
## Component List & Circuit

Component List & Circuit are the same as in Section 30.1.

## Component knowledge

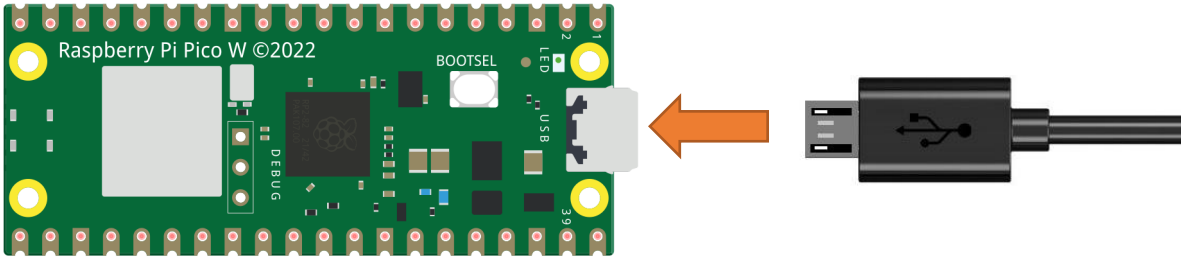
### AP mode

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.



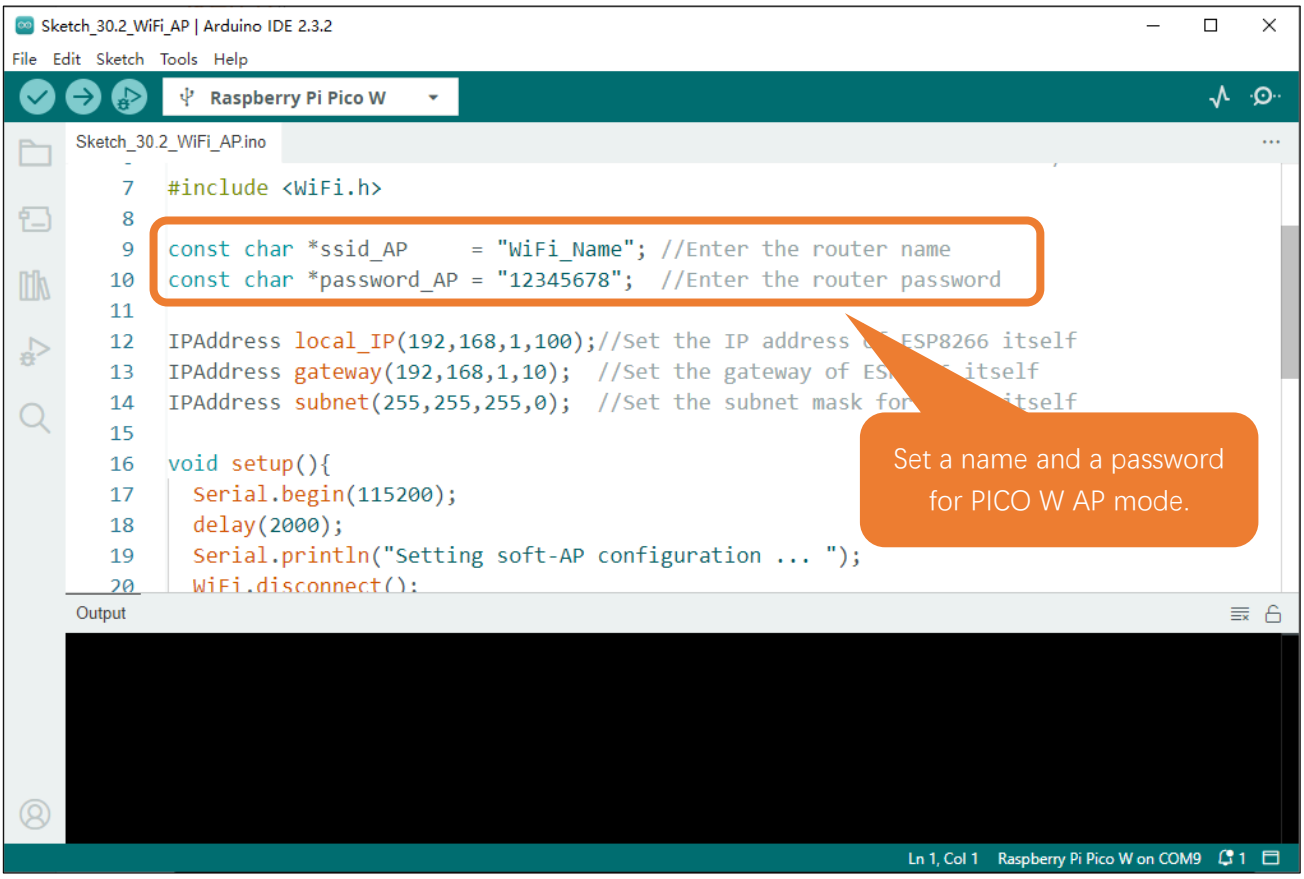

## Circuit

Connect Pico W to the computer using the USB cable.



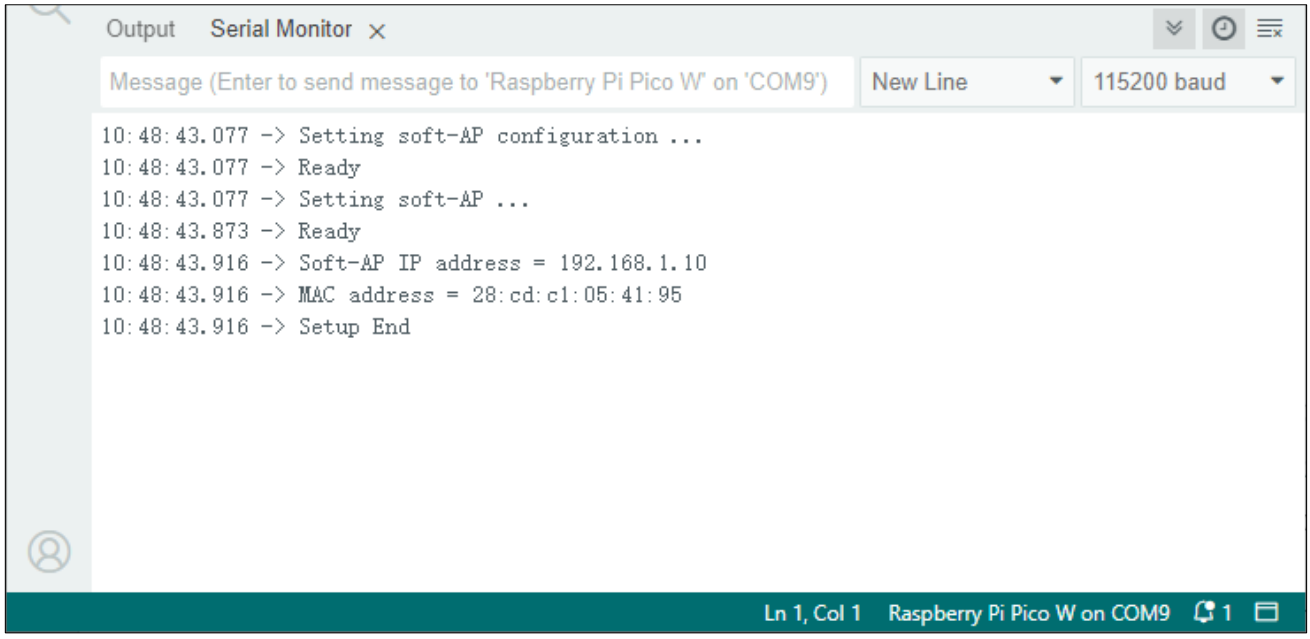
# Sketch

## Sketch_12.2_AP_mode

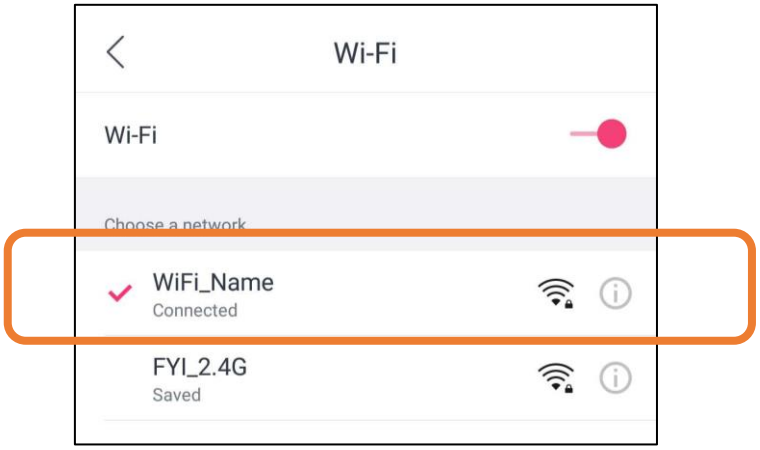



Before the Sketch runs, you can make any changes to the AP name and password for PICO W in the box as shown in the illustration above. Of course, you can leave it alone by default.

Compile and upload codes to PICO W, open the serial monitor and set the baud rate to 115200. Then it will display as follows.




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:

```
#include <WiFi.h>

const char *ssid_AP     = "WiFi_Name"; //Enter the router name
const char *password_AP = "12345678"; //Enter the router password

IPAddress local_IP(192,168,1,100);//Set the IP address of PICO W itself
IPAddress gateway(192,168,1,10);   //Set the gateway of PICO W itself
IPAddress subnet(255,255,255,0);  //Set the subnet mask for PICO W itself

void setup(){
  Serial.begin(115200);
  delay(2000);
  Serial.println("Setting soft-AP configuration ... ");
  WiFi.disconnect();
  WiFi.mode(WIFI_AP);
  Serial.println(WiFi.softAPConfig(local_IP, gateway, subnet) ? "Ready" : "Failed!");
  Serial.println("Setting soft-AP ... ");
  boolean result = WiFi.softAP(ssid_AP, password_AP);
  if(result){
    Serial.println("Ready");
    Serial.println(String("Soft-AP IP address = ") + WiFi.softAPIP().toString());
    Serial.println(String("MAC address = ") + WiFi.softAPmacAddress().c_str());
  }else{
    Serial.println("Failed!");
  }
  Serial.println("Setup End");
}

void loop() {
}
```

Include WiFi Library header file of PICO W.

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

Enter correct AP name and password.

```
const char *ssid_AP     = "WiFi_Name"; //Enter the router name
const char *password_AP = "12345678"; //Enter the router password
```

Set PICO W in AP mode.

```
WiFi.mode(WIFI_AP);
```

Configure IP address, gateway and subnet mask for PICO W.

```
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.

```
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 12.3 AP+Station mode

## Component List & Circuit

Component List & Circuit are the same as in Section 30.1.

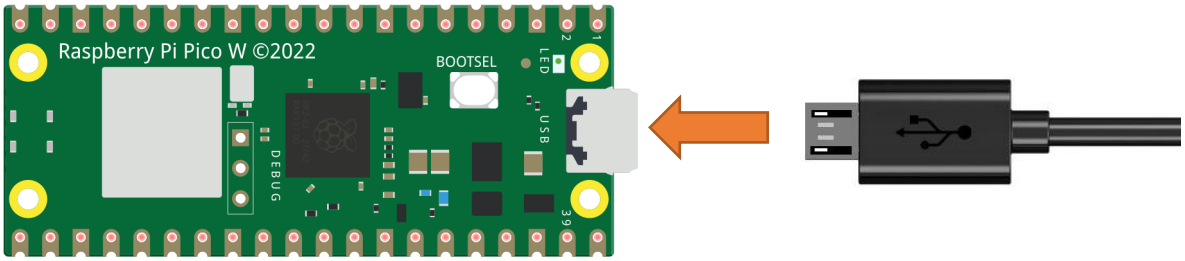
## Component knowledge

### 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.

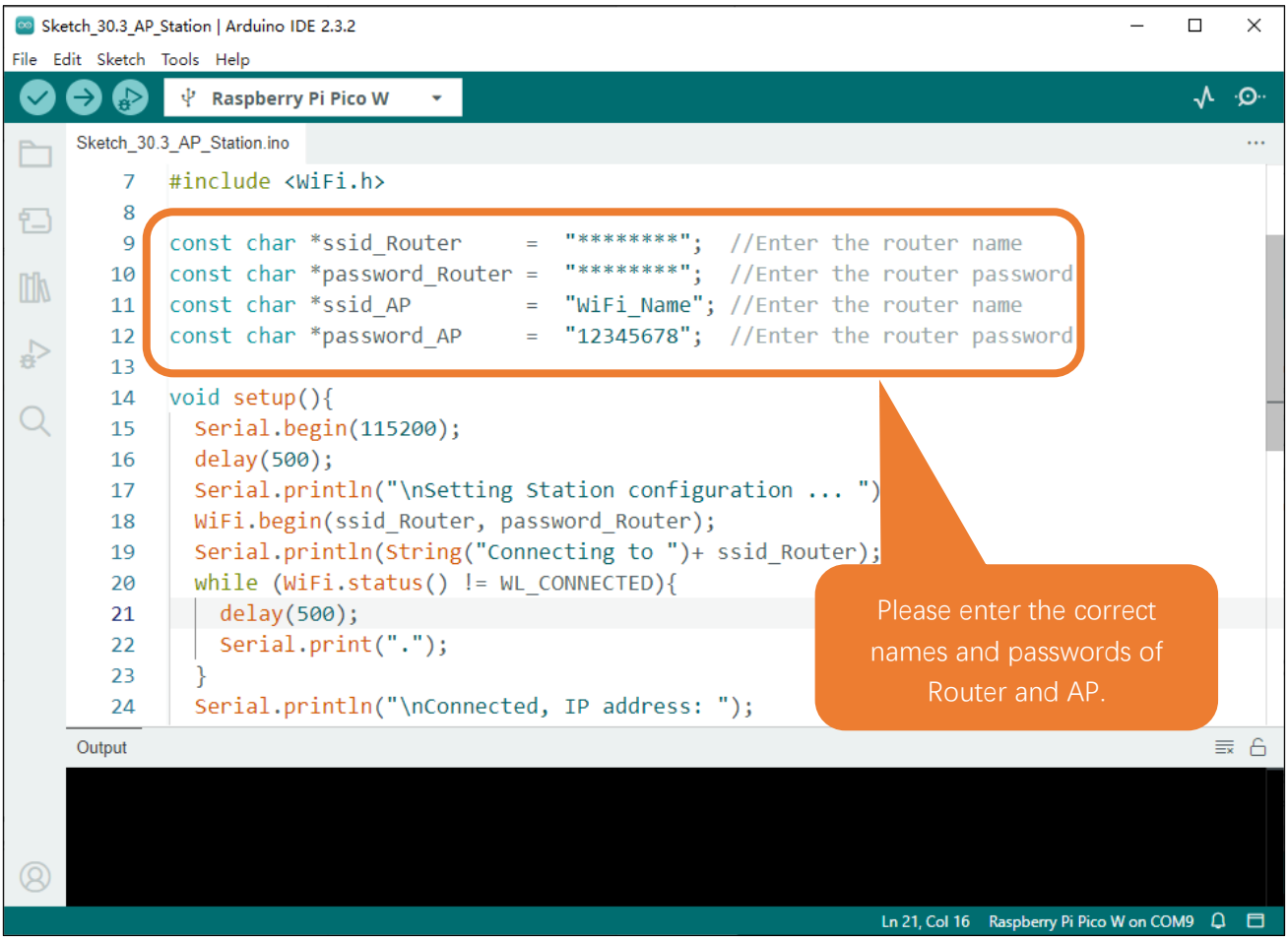
## Circuit

Connect Pico W to the computer using the USB cable.



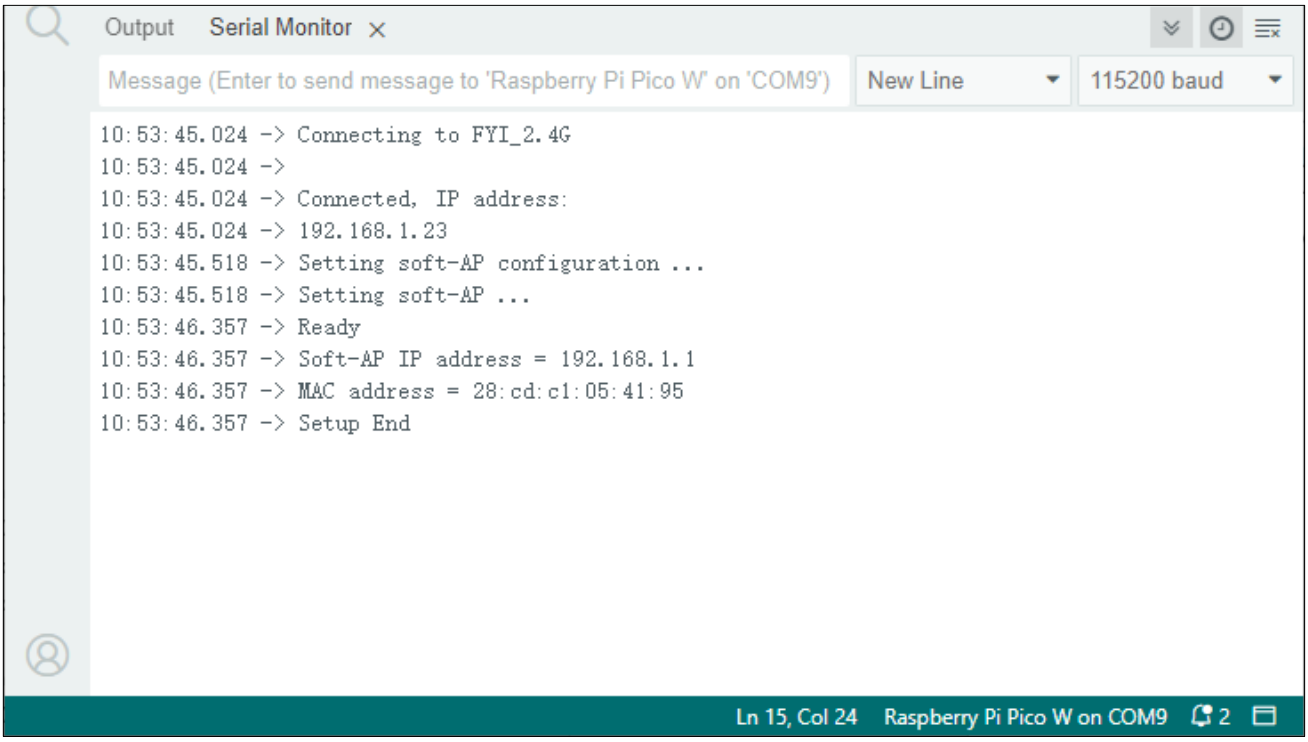
## Sketch

### Sketch_12.3_AP_Station_mode

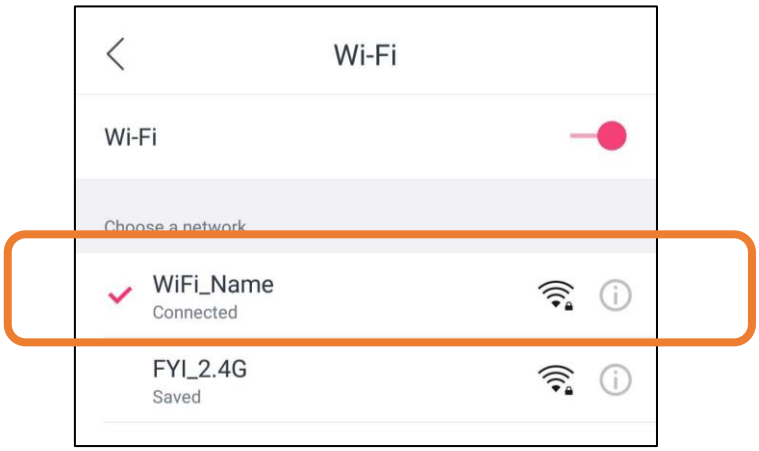



It is analogous to Project 12.1 and Project 12.2. Before running the Sketch, you need to modify ssid_Router, password_Router, ssid_AP and password_AP shown in the box of the illustration above.

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:




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:

```
#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 AP name
const char *password_AP     = "12345678";  //Enter the AP password

void setup(){
  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  }
```

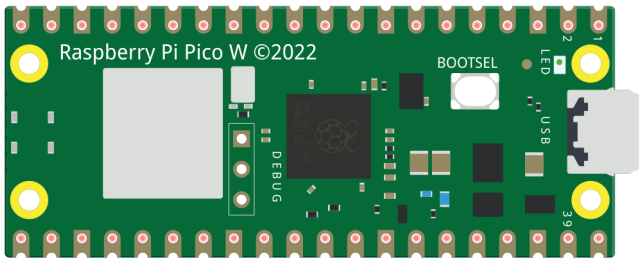
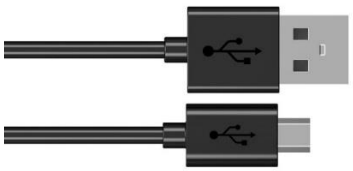
# Chapter 13 TCP/IP (Only for Pico W)

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 13.1 as Client

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

### Component List

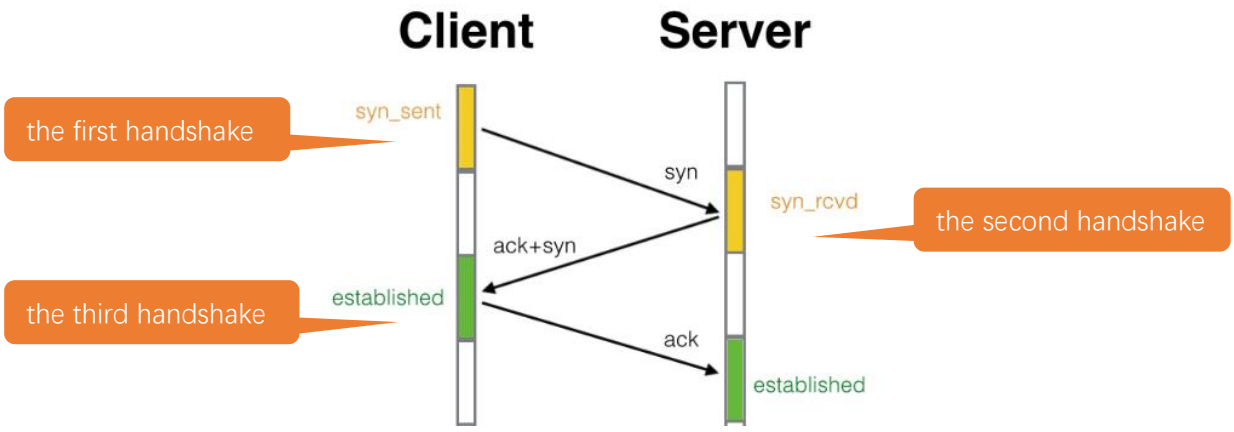
| | |
|---|---|
| Raspberry Pi Pico W x1   | Micro USB Wire x1  |

### Component knowledge

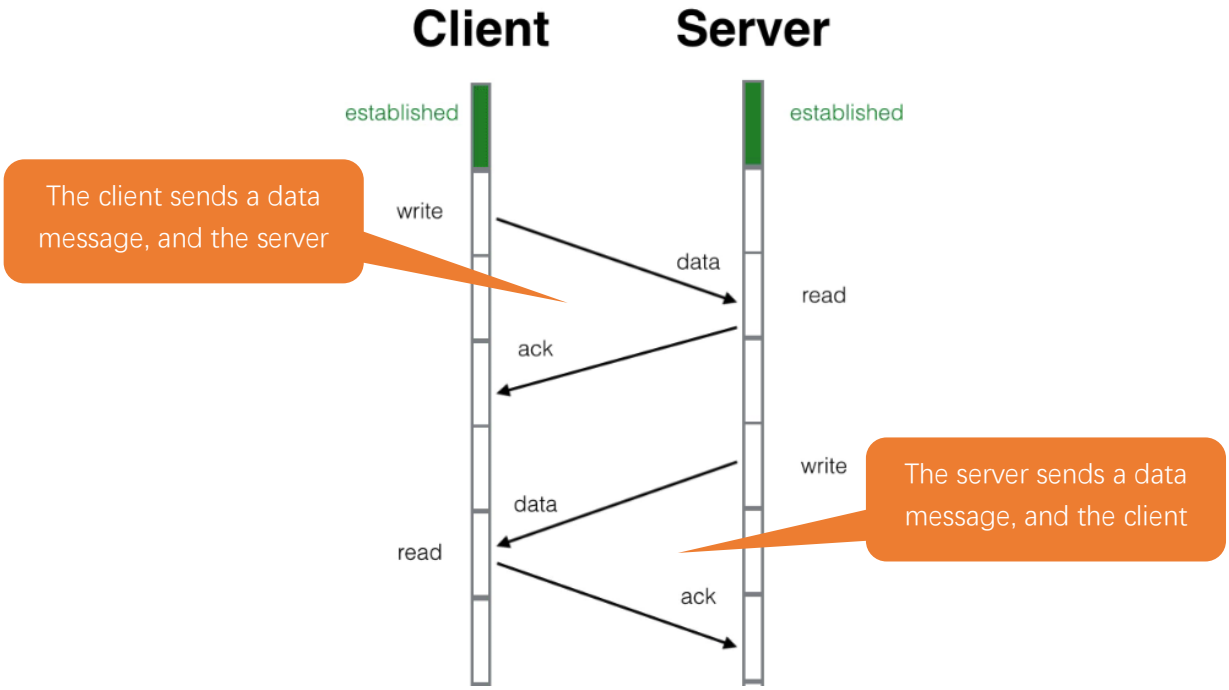
#### TCP connection

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.

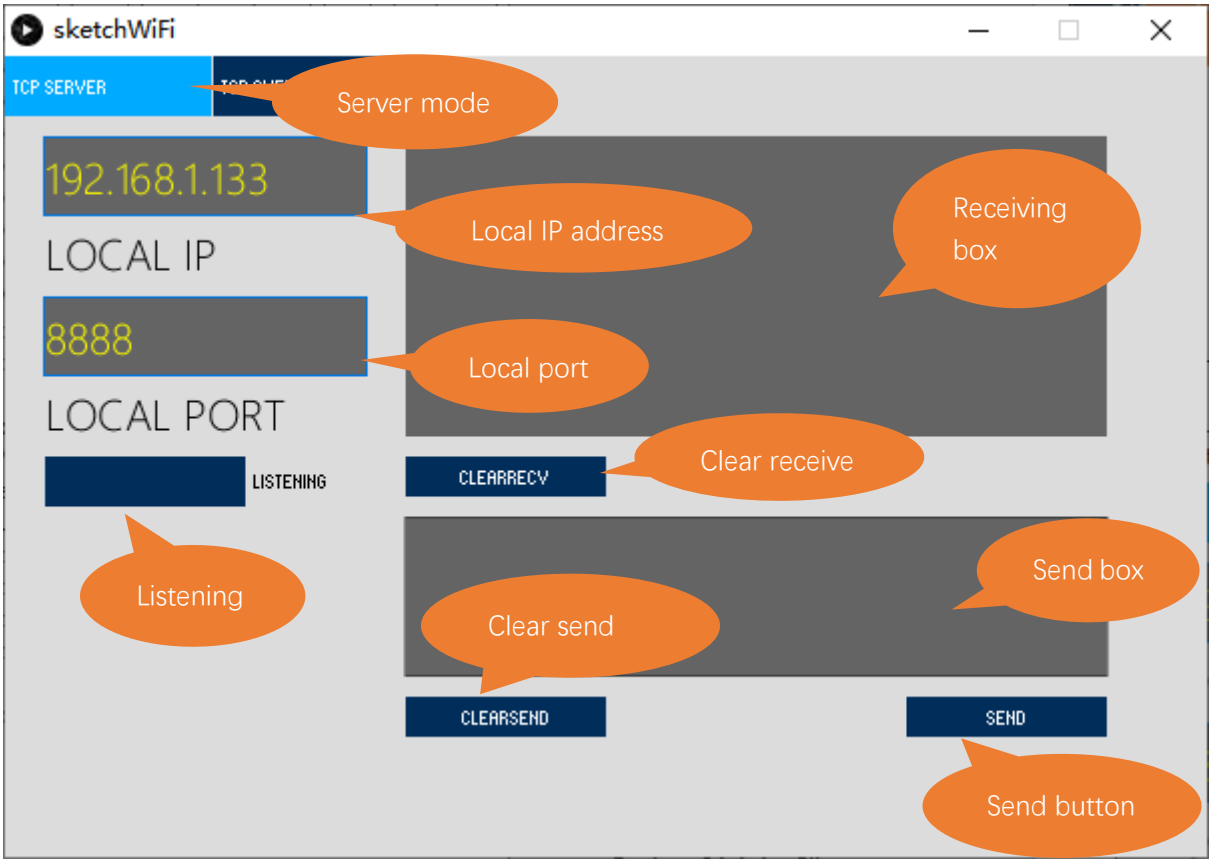
If you have not installed Processing, you can download it by clicking https://processing.org/download/. You can choose an appropriate version to download according to your PC system.


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

Use Server mode for communication

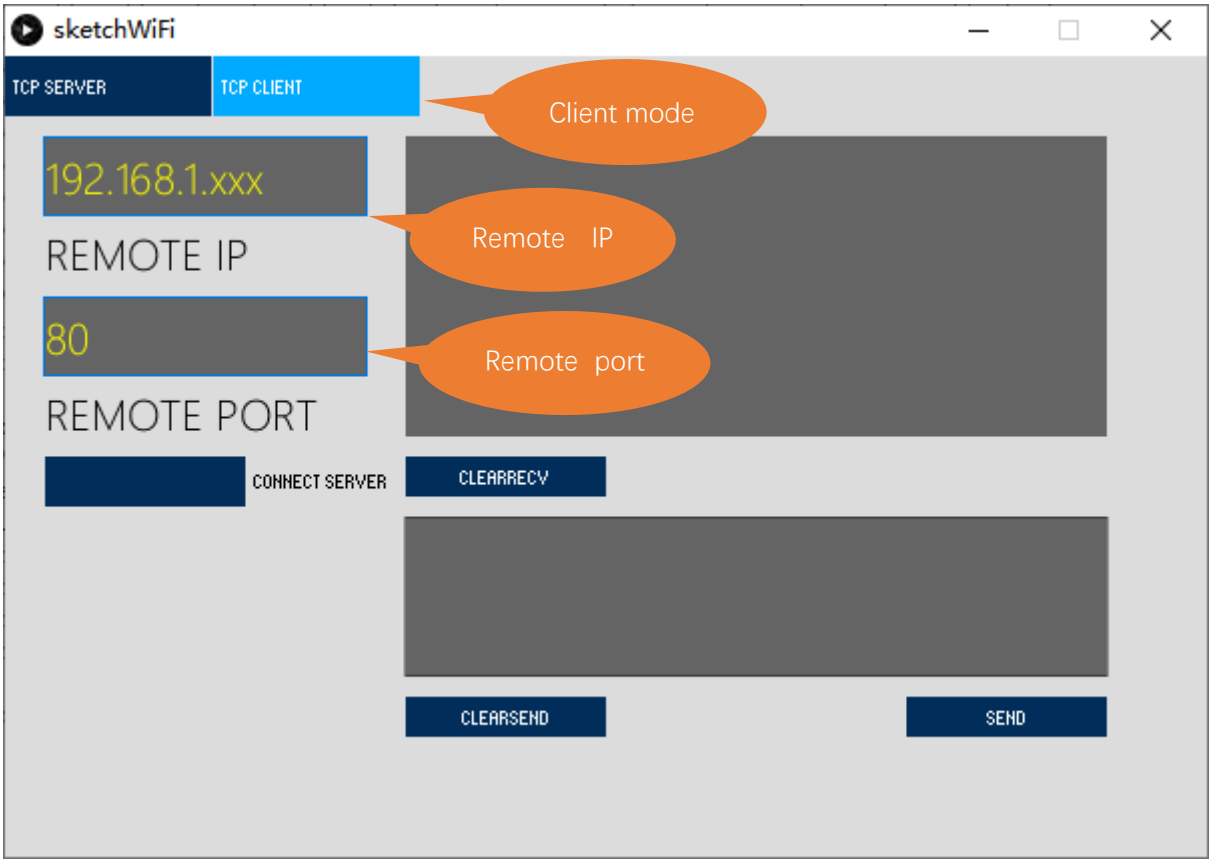
Open the "**Freenove_Basic_Starter_Kit_for_Raspberry_Pi_Pico\C\Sketches\Sketch_13.1_WiFiClient\sketchWiFi\sketchWiFi.pde**", and click "Run".


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.

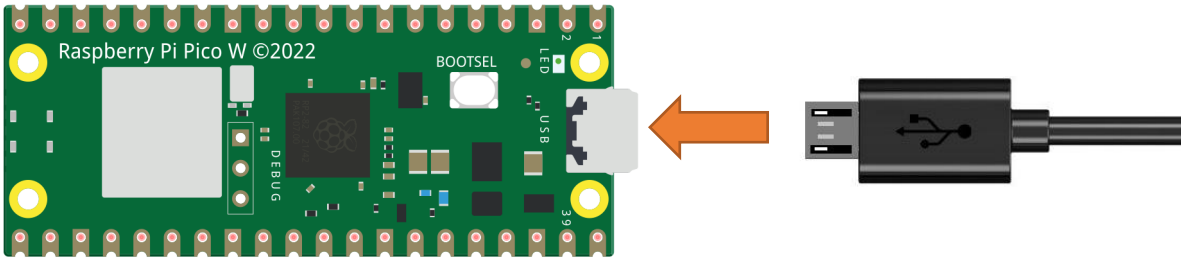
**clear receive**: clear out the content in the receiving text box

**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

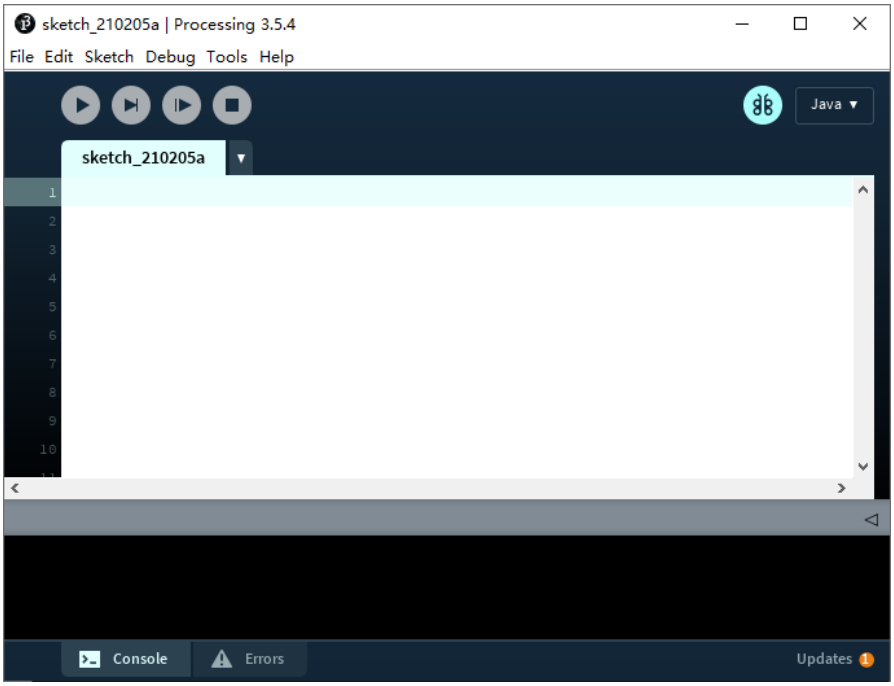
Connect Pico W to the computer using the USB cable.



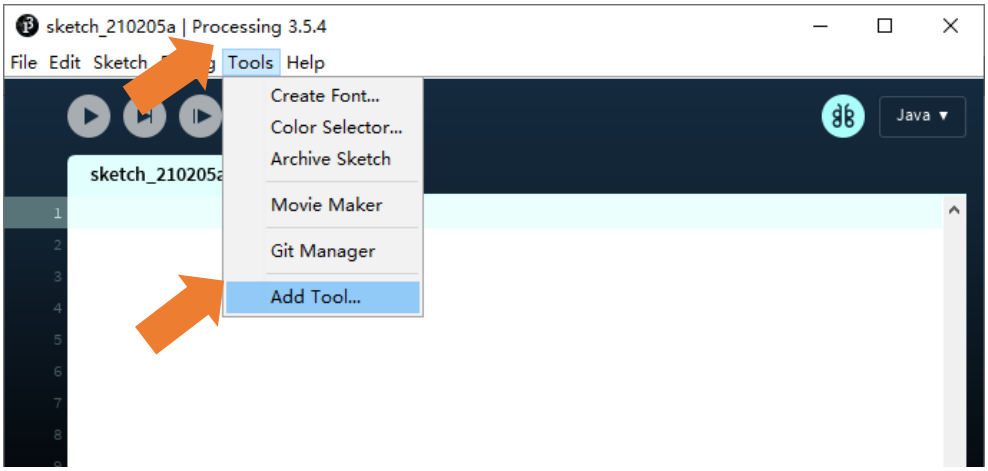

## Sketch

If you have not installed "ControlP5", please follow the following steps to continue the installation, if you have installed, please skip this section.

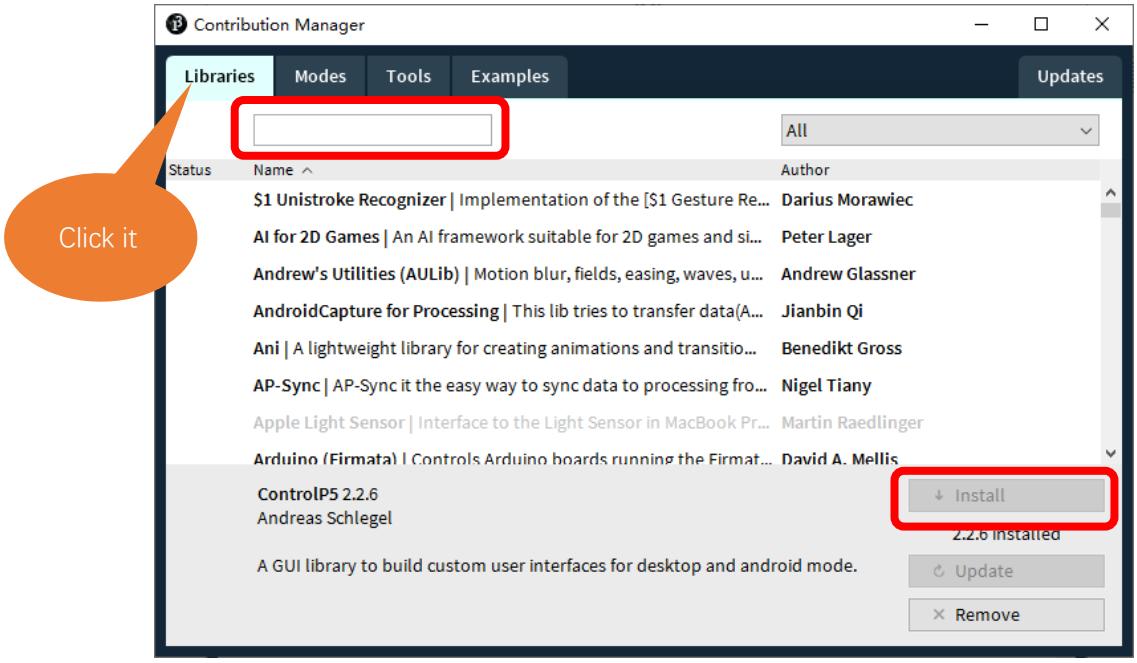
Open Processing.



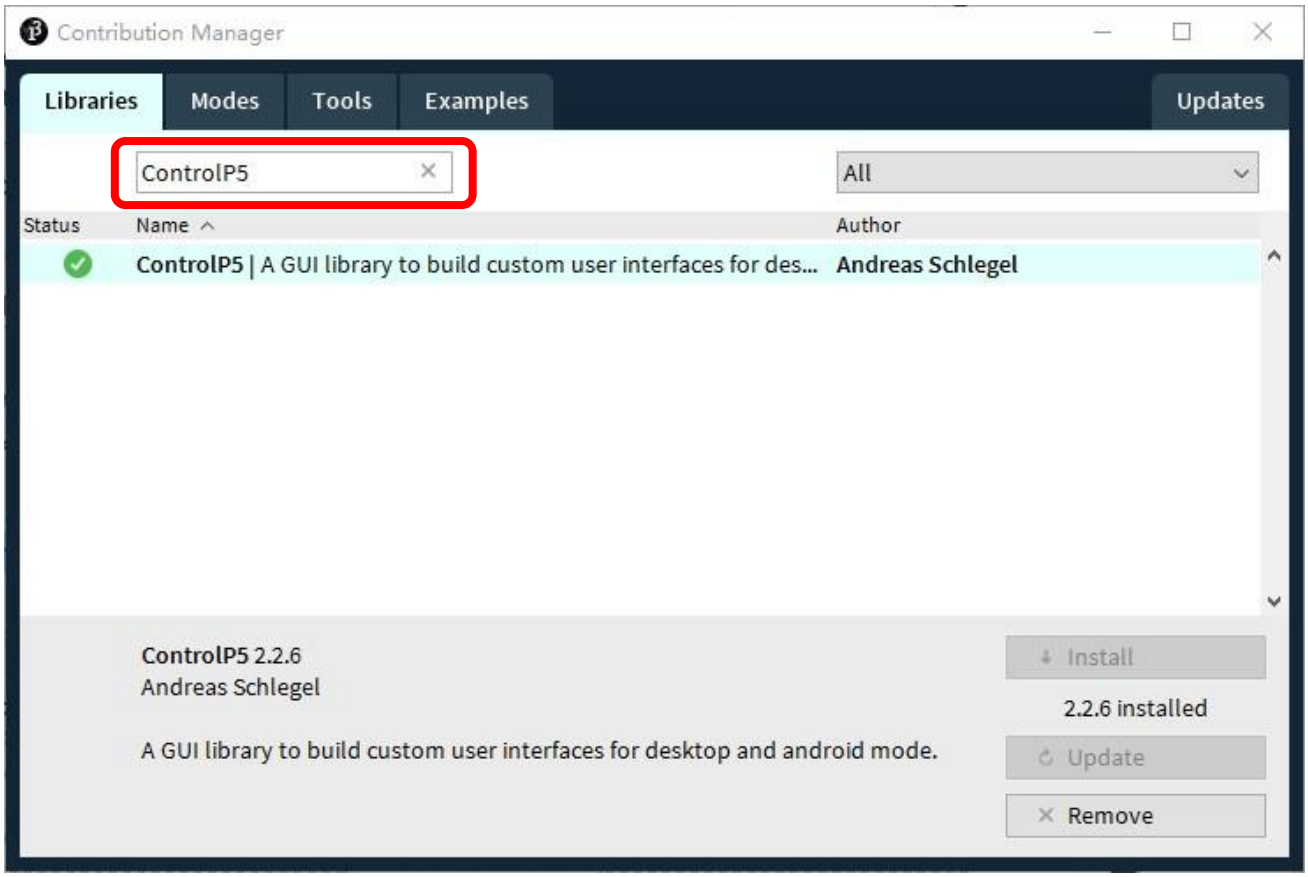
Click Add Tool under Tools.



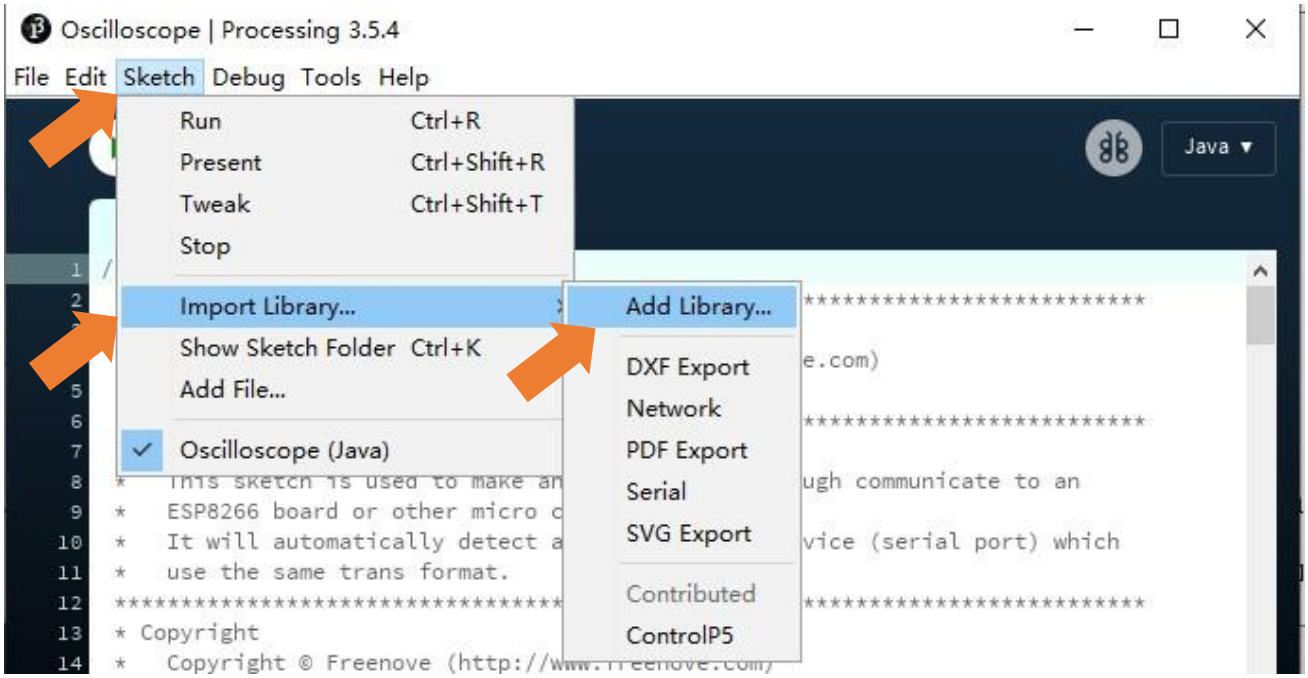

Select Libraries in the pop-up window.




Input "ControlP5" in the searching box, and then select the option as below. Click "Install" and wait for the installation to finish.

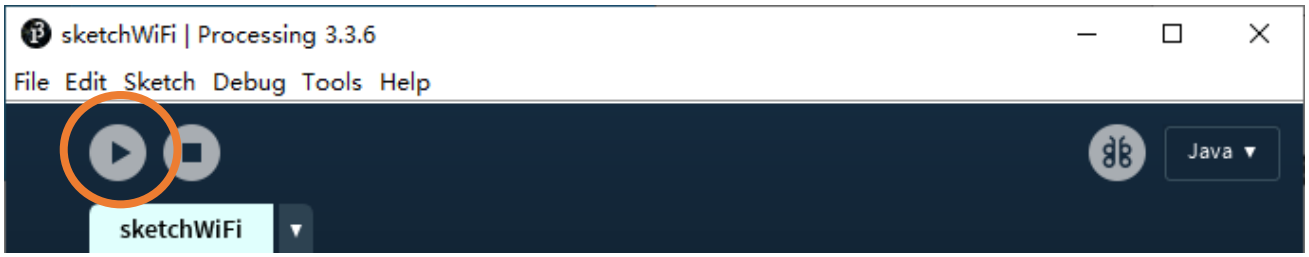



You can also click Add Library under 'Import Library' under 'Sketch'.

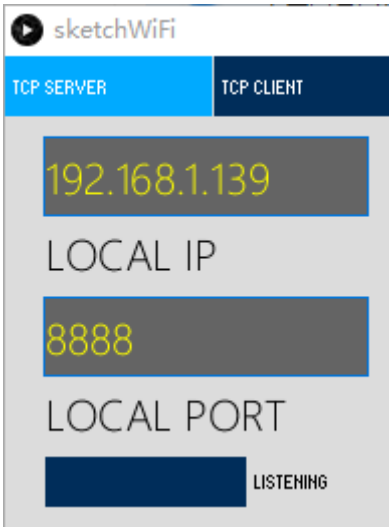


Sketch_13.1_As_Client

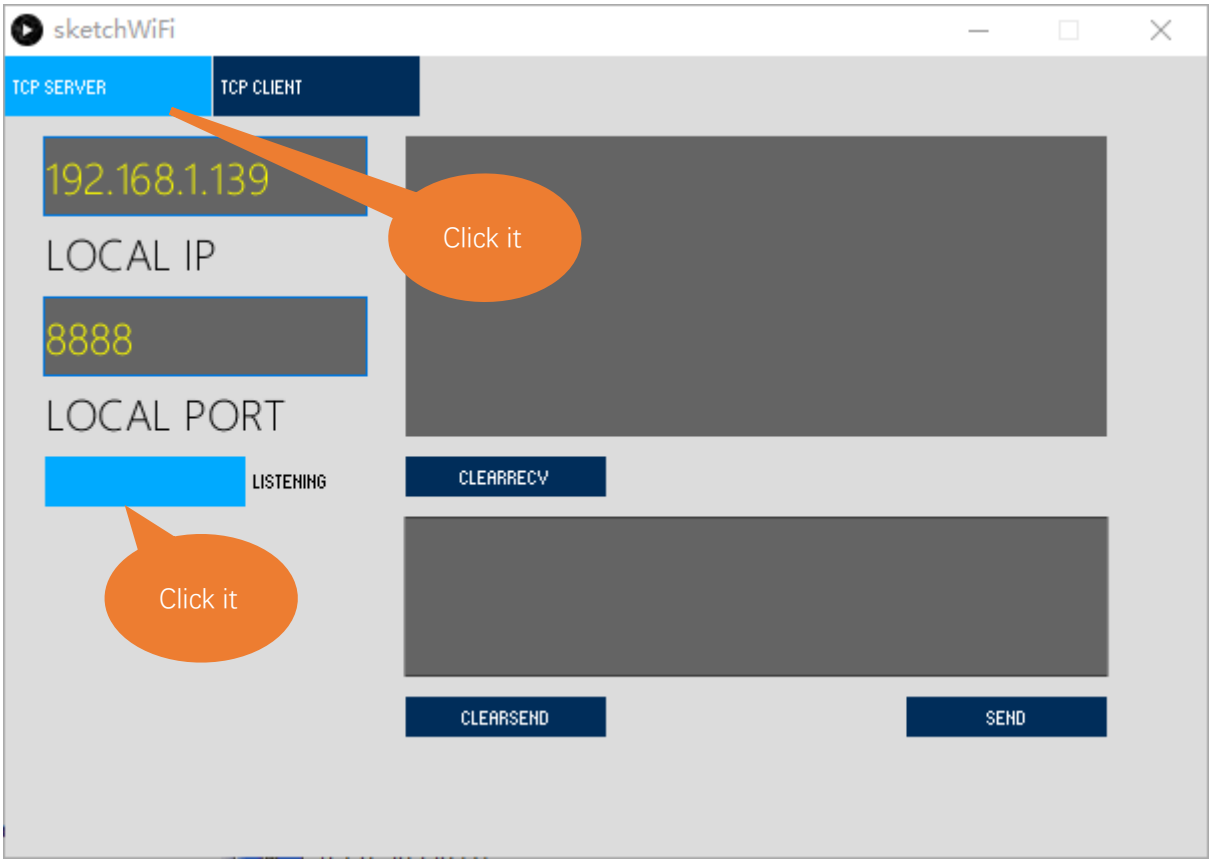
Before running the Sketch, please open "sketchWiFi.pde." first, and click "Run".



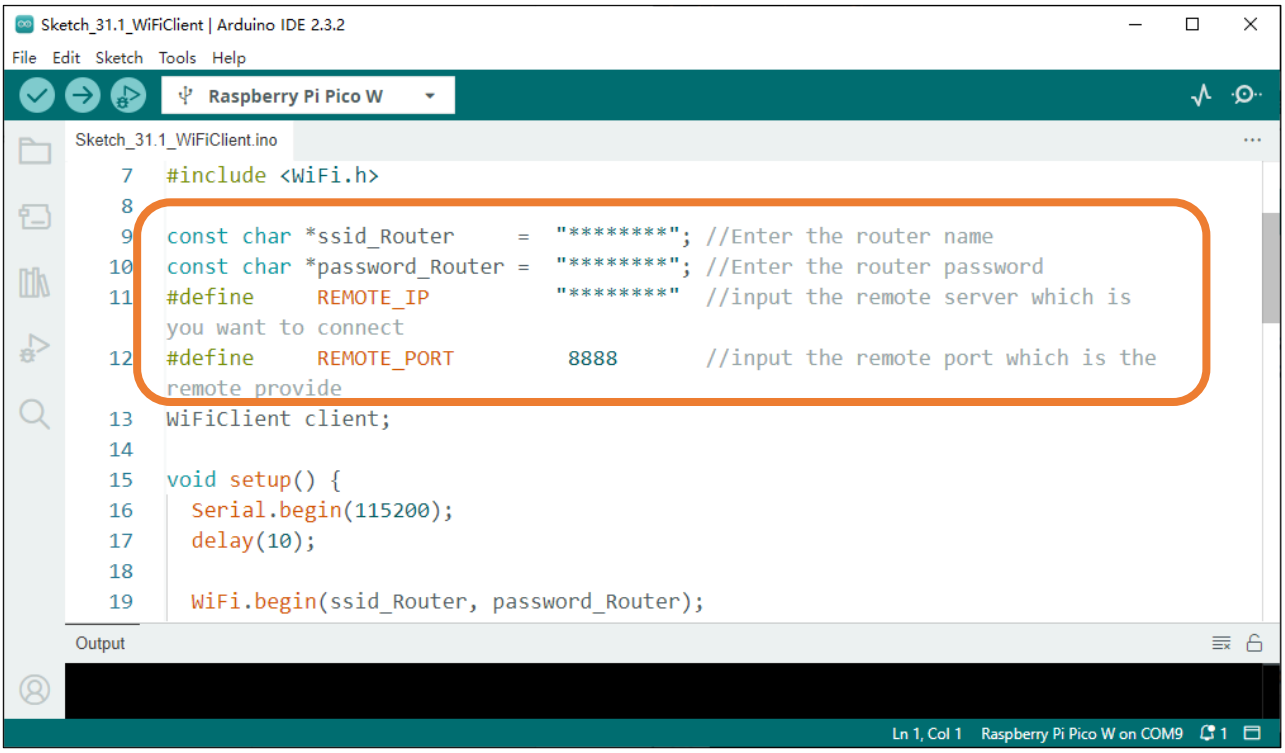

The newly pop up window will use the computer's IP address by default and open a data monitor port.




Click LISTENING, turn on TCP SERVER's data listening function and wait for PICO W to connect.

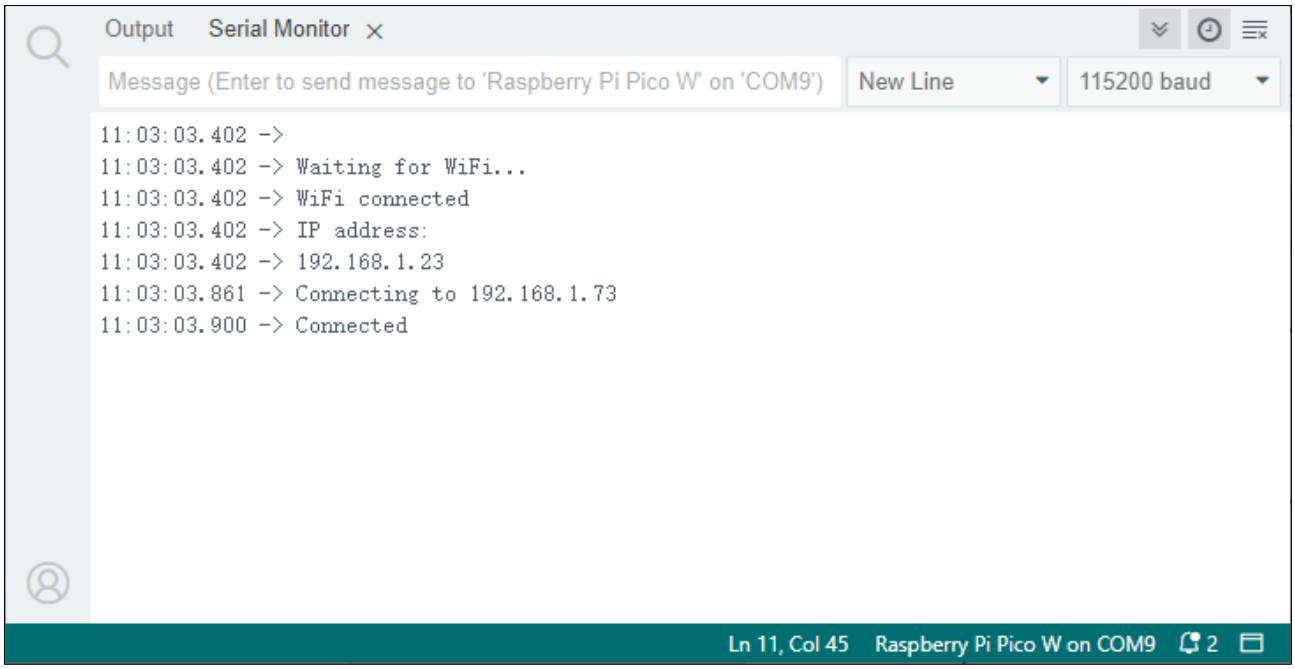


Next, open Sketch_13.1_WiFiClient.ino. Before running it, please change the following information based on "LOCAL IP" and "LOCAL PORT" in the figure above.

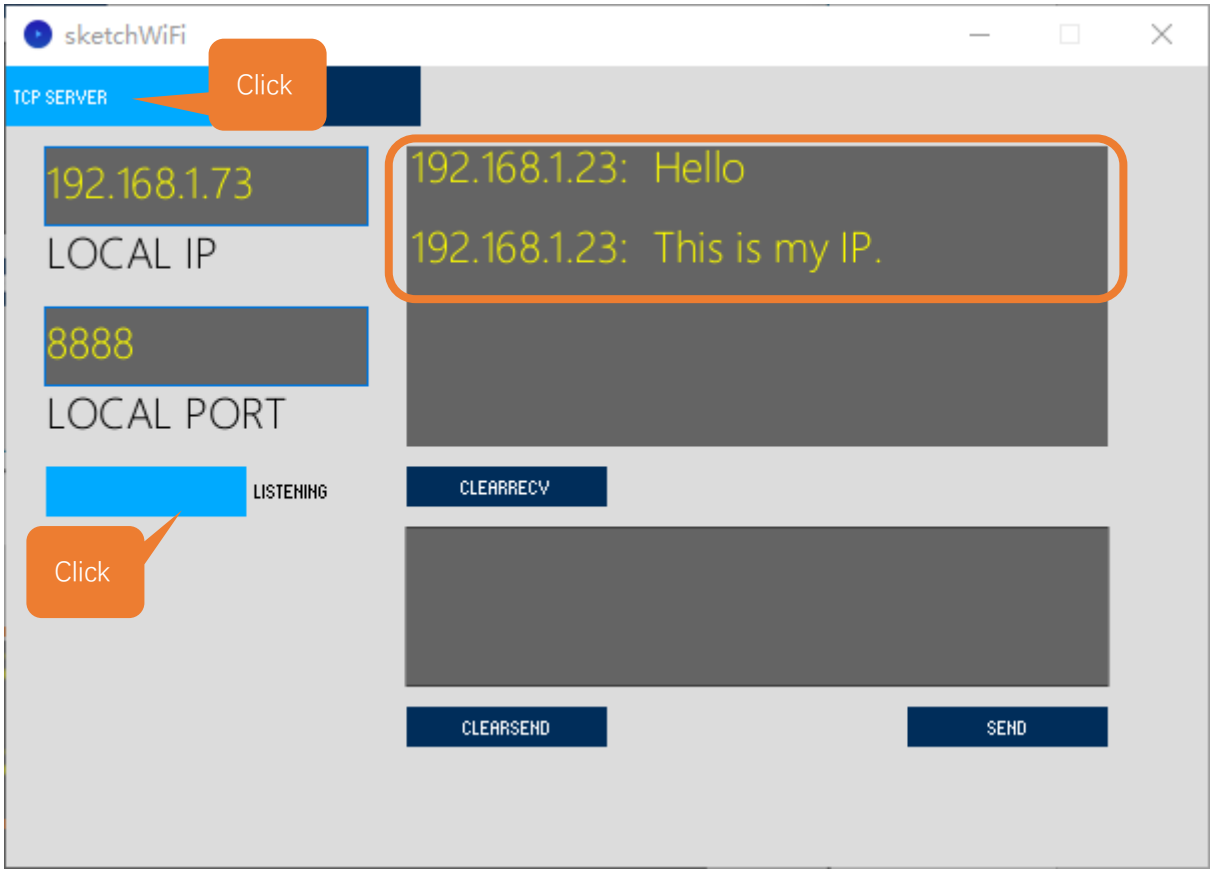



REMOTE_IP needs to be filled in according to the interface of sketchWiFi.pde. Taking this tutorial as an example, its REMOTE_IP is "192.168.1.73". Generally, by default, the ports do not need to change its value.

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.



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:

```
#include <WiFi.h>

const char *ssid_Router     =  "********"; //Enter the router name
const char *password_Router =  "********"; //Enter the router password
#define     REMOTE_IP       "********"  //input the remote server which is you want to connect
#define     REMOTE_PORT      8888       //input the remote port which is the remote provide
WiFiClient client;

void setup() {
  Serial.begin(115200);
  delay(10);

  WiFi.begin(ssid_Router, password_Router);
  Serial.print("\nWaiting for WiFi... ");
  while (WiFi.status() != WL_CONNECTED) {
    Serial.print(".");
    delay(500);
  }
  Serial.println("");
  Serial.println("WiFi connected");
  Serial.println("IP address: ");
  Serial.println(WiFi.localIP());
  delay(500);

  Serial.print("Connecting to ");
  Serial.println(REMOTE_IP);

  while (!client.connect(REMOTE_IP, REMOTE_PORT)) {
    Serial.println("Connection failed.");
    Serial.println("Waiting a moment before retrying...");
  }
  Serial.println("Connected");
  client.print("Hello\n");
  client.print("This is my IP.\n");
}

void loop() {
  if (client.available() > 0) {
    delay(20);
    //read back one line from the server
    String line = client.readString();
    Serial.println(REMOTE_IP + String(":") + line);
  }
```

```
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) {
```

```
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.

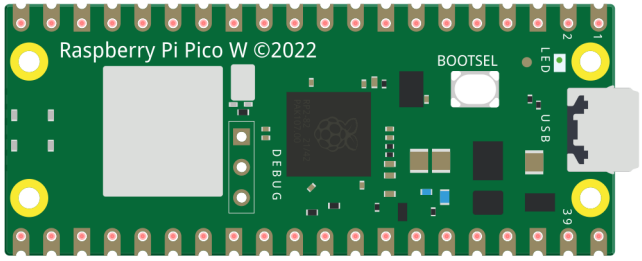
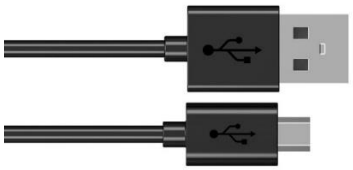
**read()**: read one byte of data in receive buffer

**readString()**: read string in receive buffer

# Project 13.2 as Server

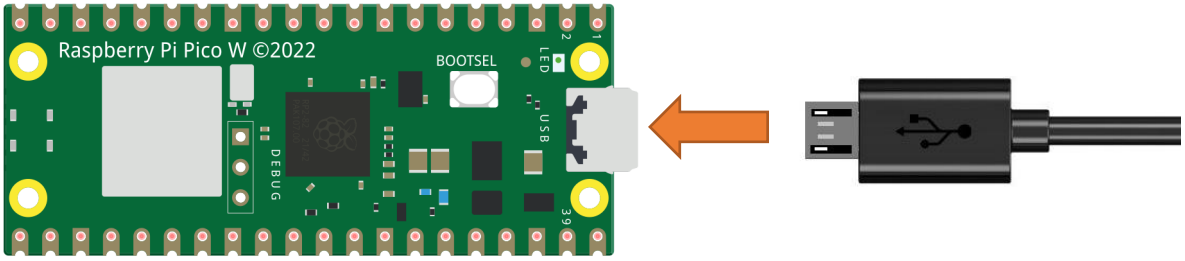
In this section, PICO W is used as a server to wait for the connection and communication of client on the same LAN.

## Component List

| | |
|---|---|
| Raspberry Pi Pico W x1  | Micro USB Wire x1  |

## Circuit

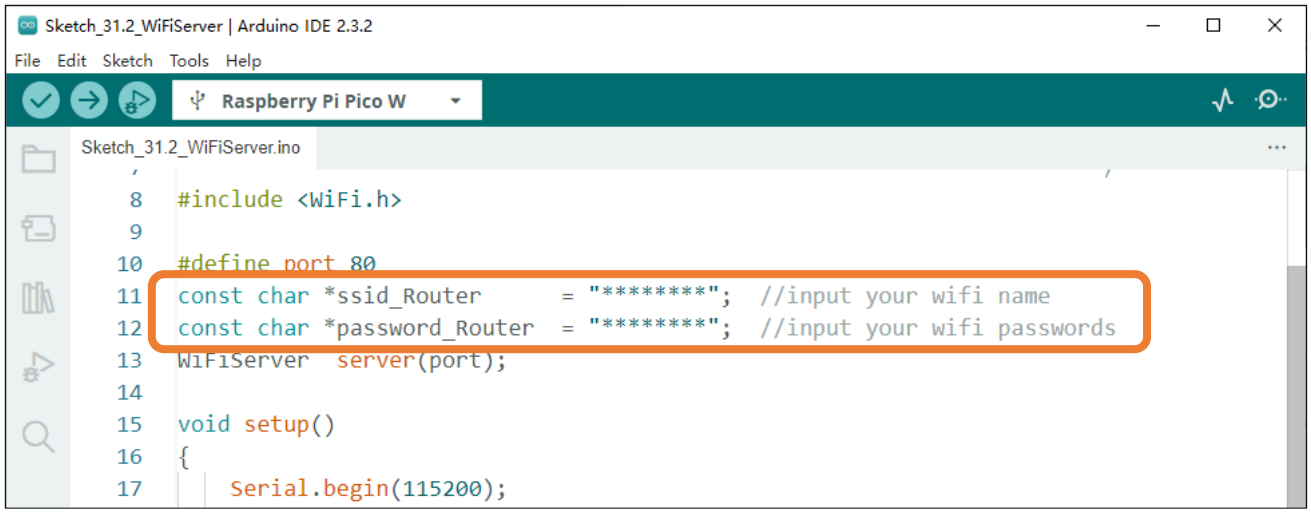
Connect Pico W to the computer using the USB cable.



## Sketch

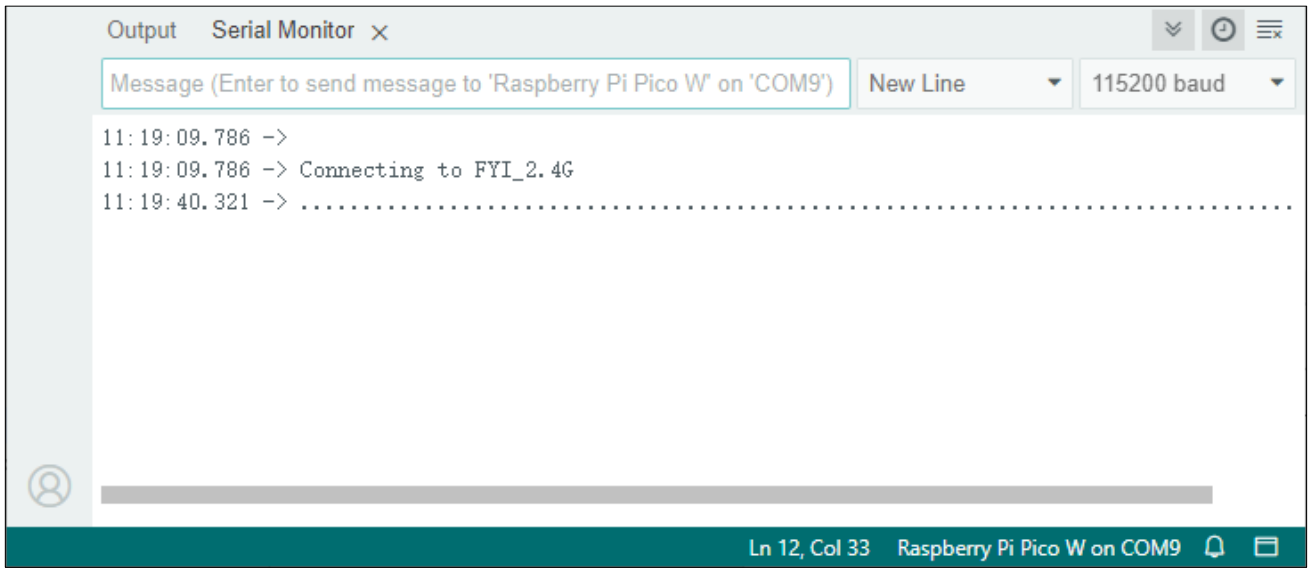
Before running Sketch, please modify the contents of the box below first.

Sketch_13.2_As_Server

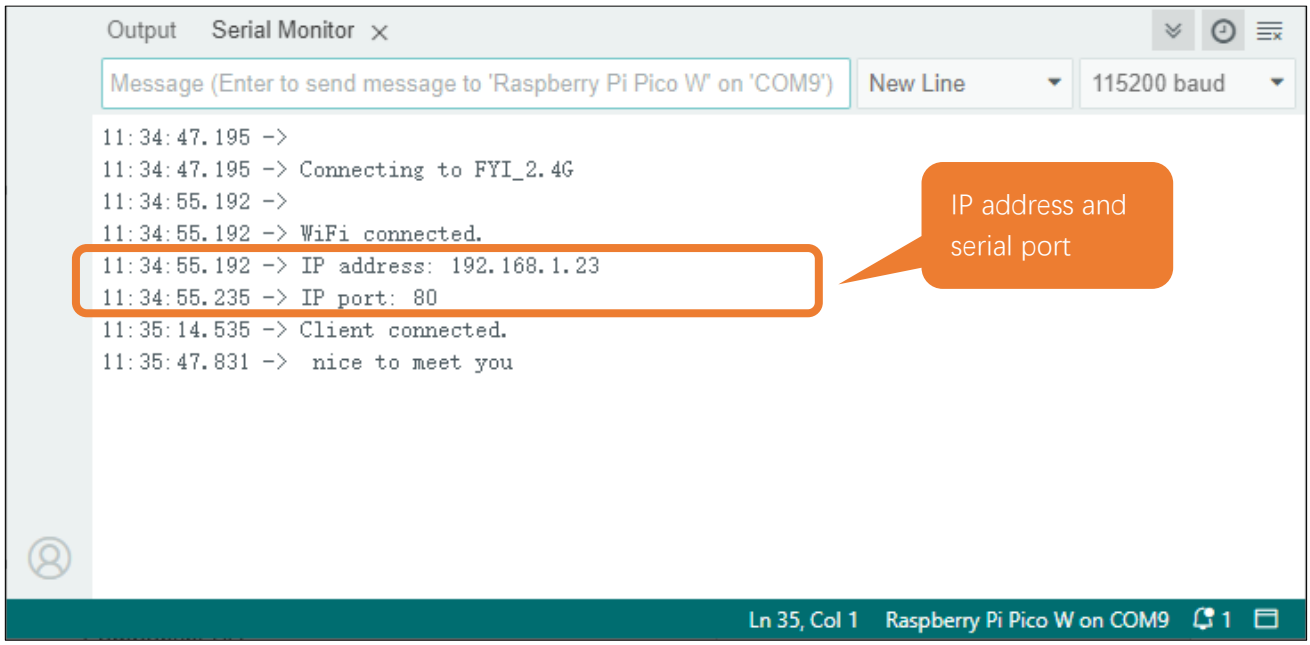



Compile and upload code to PICO W board, open the serial monitor and set the baud rate to 115200. Turn on server mode for PICO W, waiting for the connection of other devices on the same LAN. Once a device connects to server successfully, they can send messages to each other.

If the Pico W fails to connect to router, please disconnect the power supply and try again several times.



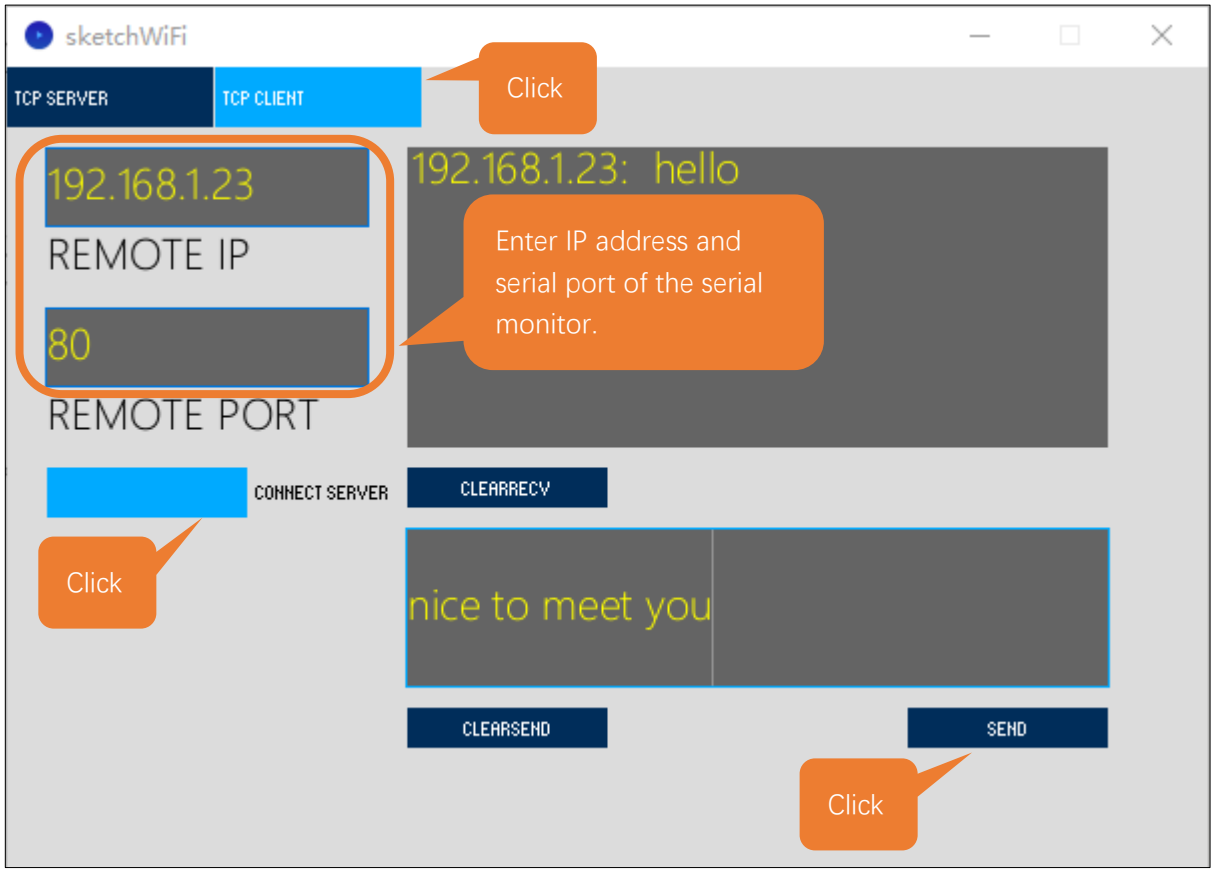
Serial Monitor




Processing:

Open the "**Freenove_Basic_Starter_Kit_for_Raspberry_Pi_Pico\C\Sketches\Sketch_13.2_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:

```
#include <WiFi.h>

#define port 80
const char *ssid_Router      = "********";  //input your wifi name
const char *password_Router  = "********";  //input your wifi passwords
WiFiServer  server(port);

void setup()
{
    Serial.begin(115200);
    Serial.printf("\nConnecting to ");
    Serial.println(ssid_Router);
    WiFi.disconnect();
    WiFi.begin(ssid_Router, password_Router);
    delay(1000);
    while (WiFi.status() != WL_CONNECTED) {
        delay(500);
        Serial.print(".");
    }
    Serial.println("");
    Serial.println("WiFi connected.");
    Serial.print("IP address: ");
    Serial.println(WiFi.localIP());
    Serial.printf("IP port: %d\n",port);
    server.begin(port);
}

void loop(){
 WiFiClient client = server.available();            // listen for incoming clients
  if (client) {                                     // if you get a client
    Serial.println("Client connected.");
    while (client.connected()) {                    // loop while the client's connected
      if (client.available()) {                     // if there's bytes to read from the
client
        Serial.println(client.readStringUntil('\n')); // print it out the serial monitor
        while(client.read()>0);                     // clear the wifi receive area cache
      }
      if(Serial.available()){                       // if there's bytes to read from the
serial monitor
        client.print(Serial.readStringUntil('\n')); // print it out the client.
        while(Serial.read()>0);                     // clear the wifi receive area cache
      }
    }
```

```
    client.stop();                                  // stop the client connecting.
    Serial.println("Client Disconnected.");
  }
}
```

Apply for method class of WiFiServer.

```
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.

```
    WiFi.disconnect();
    WiFi.begin(ssid_Router, password_Router);
    delay(1000);
    while (WiFi.status() != WL_CONNECTED) {
        delay(500);
        Serial.print(".");
    }
    Serial.println("");
    Serial.println("WiFi connected.");
```

Print out the IP address and port number of PICO W.

```
    Serial.print("IP address: ");
    Serial.println(WiFi.localIP());                  //print out IP address of PICO W
    Serial.printf("IP port: %d\n",port);             //Print out PICO W's port number
```

Turn on server mode of PICO W.

```
    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.

```
      if (client.available()) {                     // if there's bytes to read from the
client
        Serial.println(client.readStringUntil('\n')); // print it out the serial monitor
        while(client.read()>0);                     // clear the wifi receive area cache
      }
      if(Serial.available()){                       // if there's bytes to read from the
serial monitor
        client.print(Serial.readStringUntil('\n')); // print it out the client.
        while(Serial.read()>0);                     // clear the wifi receive area cache
      }
```

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.

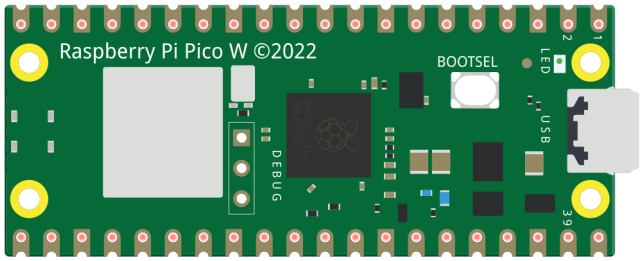
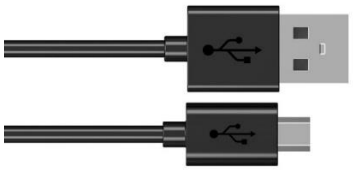
# Chapter 14 Control LED with Web (Only for Pico W)

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 14.1 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

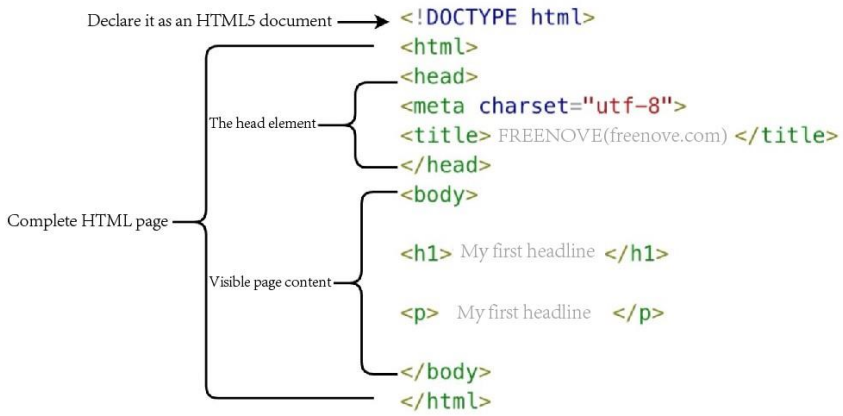
## HTML

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

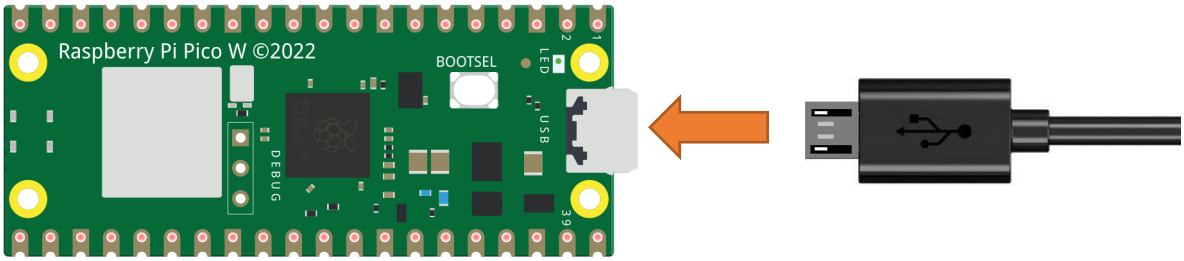
**<h1>:** Define a big heading

**<p>:** Define a paragraph

For more information, please visit: https://developer.mozilla.org/en-US/docs/Web/HTML

## Circuit

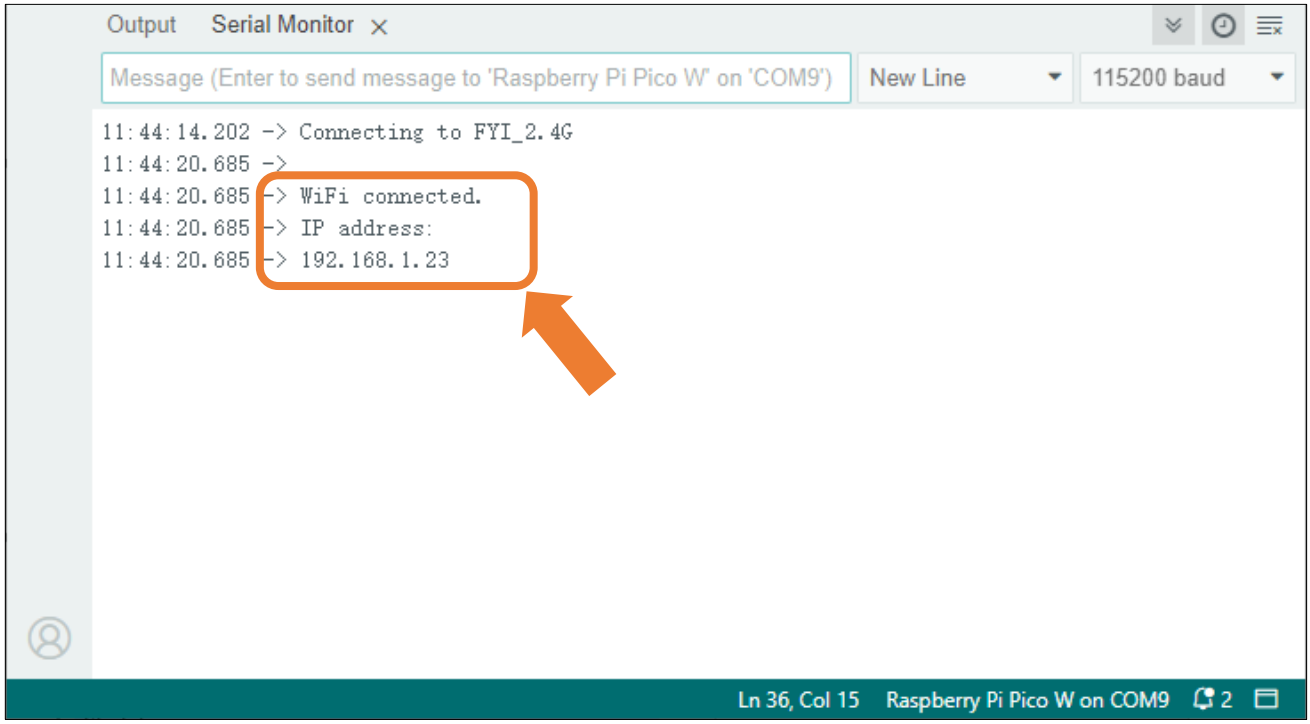
Connect Pico W to the computer using the USB cable.




## Sketch

### Sketch_14.1_Control_the_LED_with_Web

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:




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:

```
#include <WiFi.h>

// Replace with your network credentials
const char* ssid     = "********";
const char* password = "********";

// Set web server port number to 80
WiFiServer server(80);
// Variable to store the HTTP request
String header;
// Auxiliar variables to store the current output state
String PIN_LEDState = "OFF";

// Current time
unsigned long currentTime = millis();
// Previous time
unsigned long previousTime = 0;
// Define timeout time in milliseconds (example: 2000ms = 2s)
const long timeoutTime = 2000;

void setup() {
  Serial.begin(115200);
  // Initialize the output variables as outputs
  pinMode(LED_BUILTIN, OUTPUT);
  digitalWrite(LED_BUILTIN, LOW);

  // Connect to Wi-Fi network with SSID and password
  Serial.print("Connecting to ");
  Serial.println(ssid);
  WiFi.begin(ssid, password);
  while (WiFi.status() != WL_CONNECTED) {
    delay(500);
    Serial.print(".");
  }
  // Print local IP address and start web server
  Serial.println("");
  Serial.println("WiFi connected.");
  Serial.println("IP address: ");
  Serial.println(WiFi.localIP());
  server.begin();
}
void loop() {
  WiFiClient client = server.available();  // Listen for incoming clients
```

```
  if (client) {                             // If a new client connects,
    Serial.println("New Client.");          // print a message out in the serial port
    String currentLine = "";                // make a String to hold incoming data from the client
    currentTime = millis();
    previousTime = currentTime;
    while (client.connected() && currentTime - previousTime <= timeoutTime) {  // loop while the client's connected
      currentTime = millis();
      if (client.available()) {  // if there's bytes to read from the client,
        char c = client.read();  // read a byte, then
        Serial.write(c);         // print it out the serial monitor
        header += c;
        if (c == '\n') {  // if the byte is a newline character
          // if the current line is blank, you got two newline characters in a row.
          // that's the end of the client HTTP request, so send a response:
          if (currentLine.length() == 0) {
            // HTTP headers always start with a response code (e.g. HTTP/1.1 200 OK)
            // and a content-type so the client knows what's coming, then a blank line:
            client.println("HTTP/1.1 200 OK");
            client.println("Content-type:text/html");
            client.println("Connection: close");
            client.println();
            // turns the GPIOs on and off
            if (header.indexOf("GET /LED_BUILTIN/ON") >= 0) {
              Serial.println("LED_BUILTIN ON");
              PIN_LEDState = "ON";
              digitalWrite(LED_BUILTIN, HIGH);
            } else if (header.indexOf("GET /LED_BUILTIN/OFF") >= 0) {
              Serial.println("LED_BUILTIN OFF");
              PIN_LEDState = "OFF";
              digitalWrite(LED_BUILTIN, LOW);
            }
            // Display the HTML web page
            client.println("<!DOCTYPE html><html>");
            client.println("<head> <title>Pico W Web Server</title> <meta name=\"viewport\" content=\"width=device-width, initial-scale=1\">");
            client.println("<link rel=\"icon\" href=\"data:,\">");
            // CSS to style the on/off buttons
            // Feel free to change the background-color and font-size attributes to fit your preferences
            client.println("<style>html {font-family: Helvetica; display:inline-block; margin: 0px auto; text-align: center;}");
            client.println(" h1{color: #0F3376; padding: 2vh;} p{font-size: 1.5rem;}");
```

```
83              client.println(".button{background-color: #4286f4; display: inline-block; border:
                none; border-radius: 4px; color: white; padding: 16px 40px;text-decoration: none; font-size:
                30px; margin: 2px; cursor: pointer;}");
84              client.println(".button2{background-color: #4286f4;display: inline-block; border:
                none; border-radius: 4px; color: white; padding: 16px 40px;text-decoration: none; font-size:
                30px; margin: 2px; cursor: pointer;}</style></head>");
85              // Web Page Heading
86              client.println("<body><h1>Pico W Web Server</h1>");
87              client.println("<p>GPIO state: " + PIN_LEDState + "</p>");
88              client.println("<p><a href=\"/LED_BUILTIN/ON\"><button class=\"button
                button2\">ON</button></a></p>");
89              client.println("<p><a href=\"/LED_BUILTIN/OFF\"><button class=\"button
                button2\">OFF</button></a></p>");
90              client.println("</body></html>");
91              // The HTTP response ends with another blank line
92              client.println();
93              // Break out of the while loop
94              break;
95            } else {  // if you got a newline, then clear currentLine
96              currentLine = "";
97            }
98          } else if (c != '\r') {  // if you got anything else but a carriage return character,
99            currentLine += c;      // add it to the end of the currentLine
100         }
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);
```

```
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              }
```

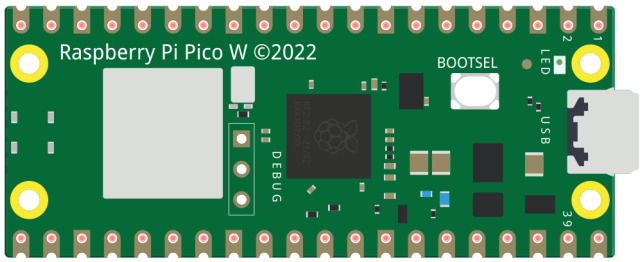
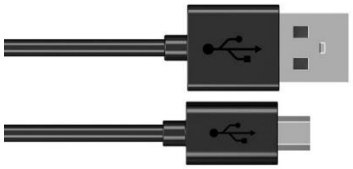
# Chapter 15 Bluetooth (Only for Pico W)

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 15.1 Bluetooth Passthrough

### Component List

| | |
|---|---|
| Raspberry Pi Pico W x1   | Micro USB Wire x1  |

### 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

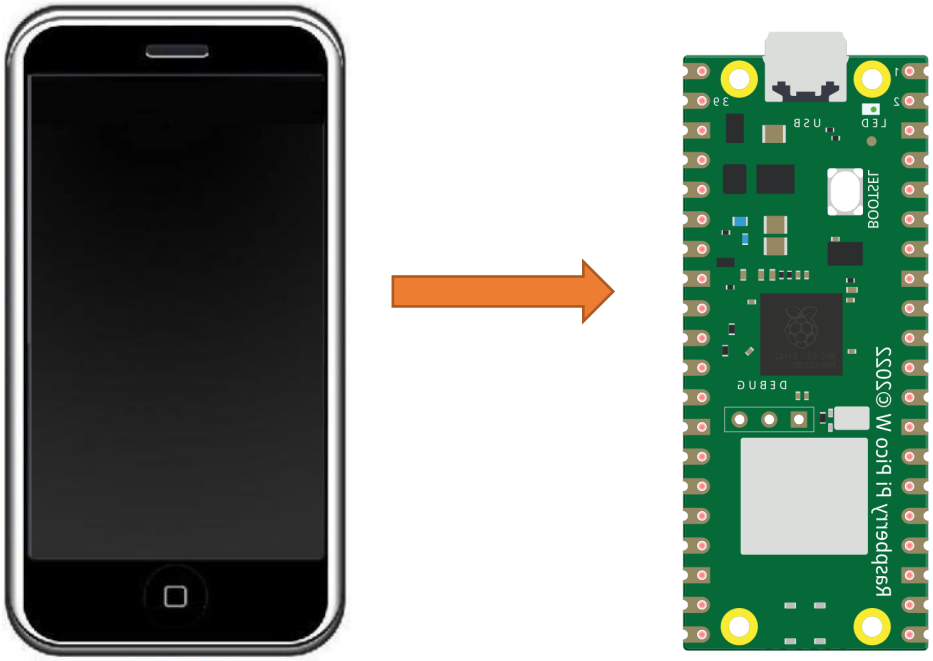
A device works in master mode can connect to one or more slave devices.
We can search and select the slave devices nearby to connect.
When a device initiates a connection request in master mode, it requires information about other Bluetooth devices, including their addresses and pairing keys.
Once the 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.

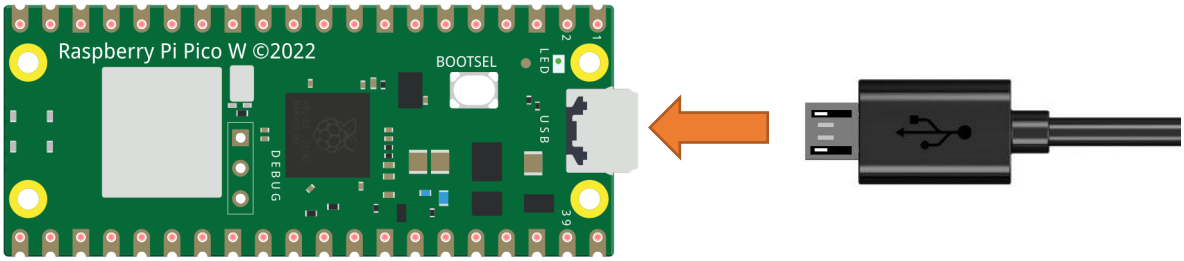
In the case of data exchange between a smartphone and a Raspberry Pi Pico W, the smartphone typically operates in master mode, while the Raspberry Pi Pico W functions in slave mode.



Master Slave

## Circuit

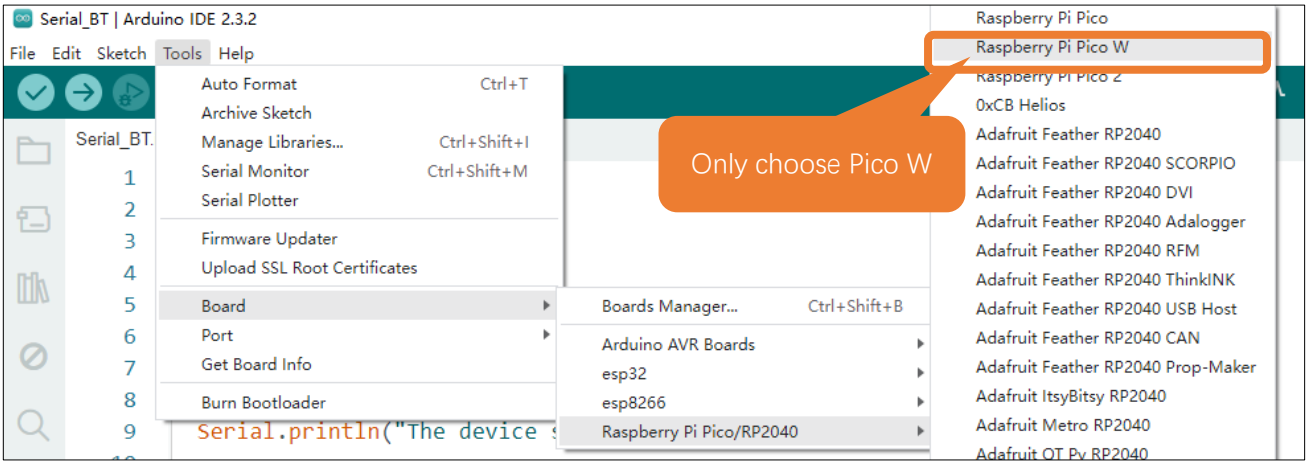
Connect Pico W to the computer using the USB cable.

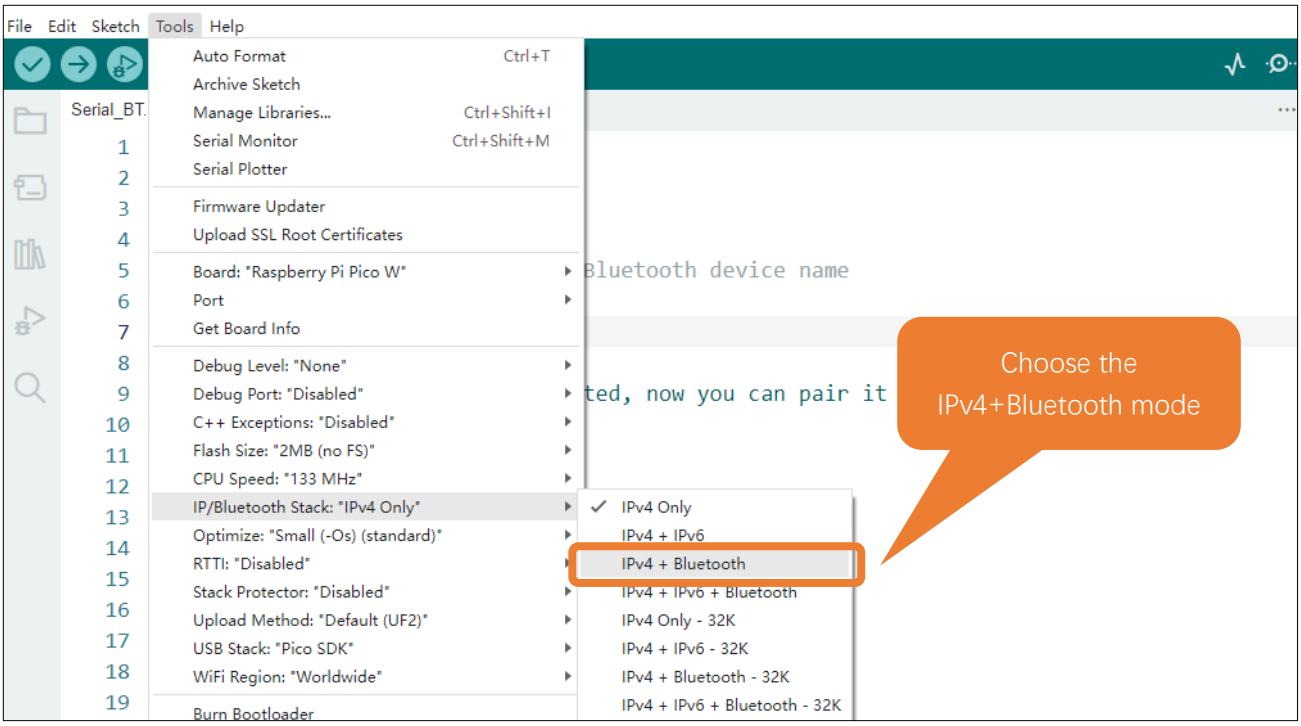


# Sketch

## 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:



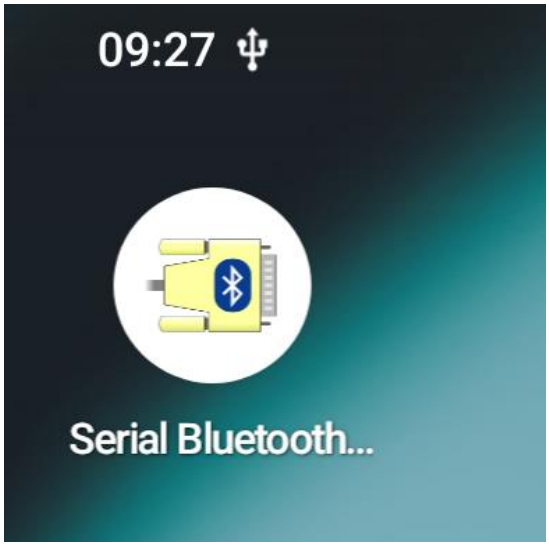
Sketch_15.1_Serial_BT

```
File Edit Sketch Tools Help
Raspberry Pi Pico W
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
13 void loop() {
14   if(Serial.available()){
15     SerialBT.print(Serial.readString());
16   }
17   if(SerialBT.available()){
18     Serial.print(SerialBT.readString());
19   }
20   delay(5);
21 }
```

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.

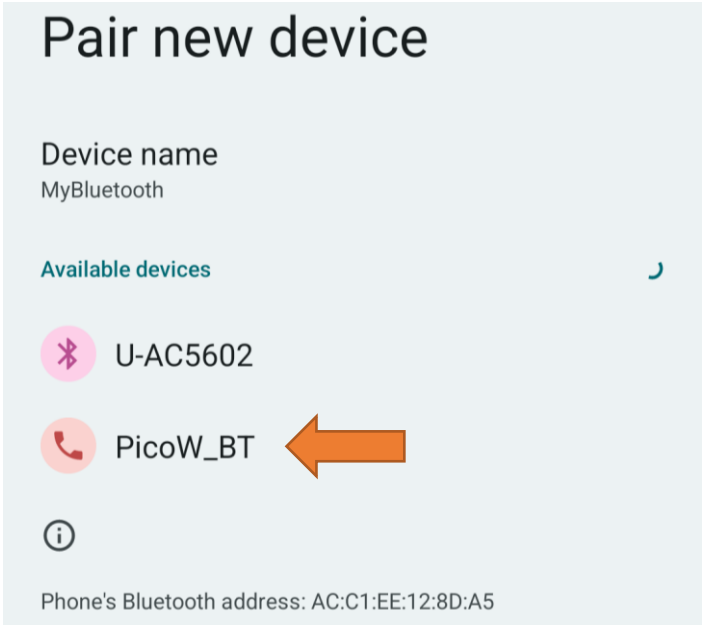
```
Output  Serial Monitor ×
Message (Enter to send message to 'Raspberry Pi Pico W' on 'COM9')  New Line  115200 baud
09:01:40.810 -> The device started, now you can pair it with bluetooth!
Ln 1, Col 22  Raspberry Pi Pico W on COM9  2
```

Please make sure the Bluetooth of your phone is turn ON and the App Serial Bluetooth Terminal has installed on your phone.

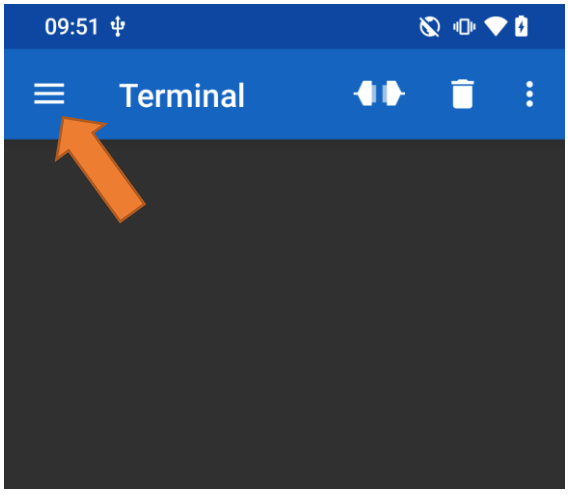


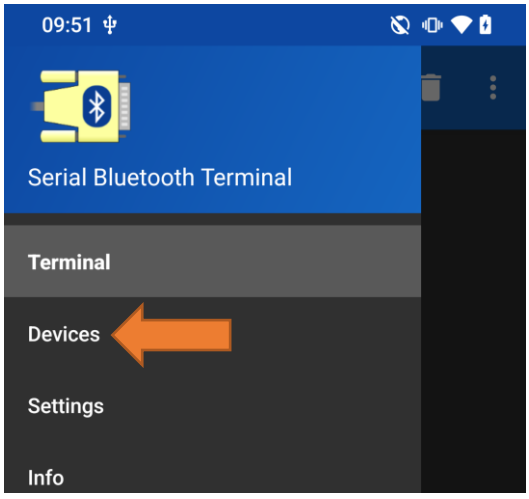


Click Pair new device and select "PicoW_BT" to connect.

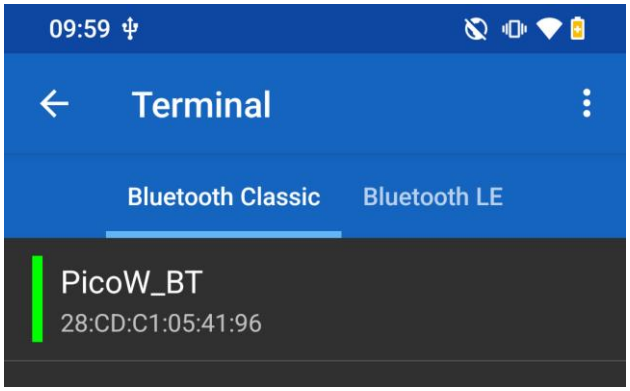


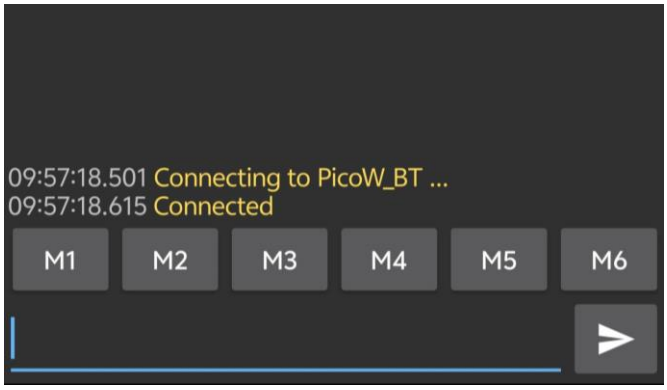

Open the App "Serial Bluetooth Terminal", expand the menu and select "Devices".



In Bluetooth Classic mode, select PicoW_BT, and you will see “Connected”, which indicates a successful connection.

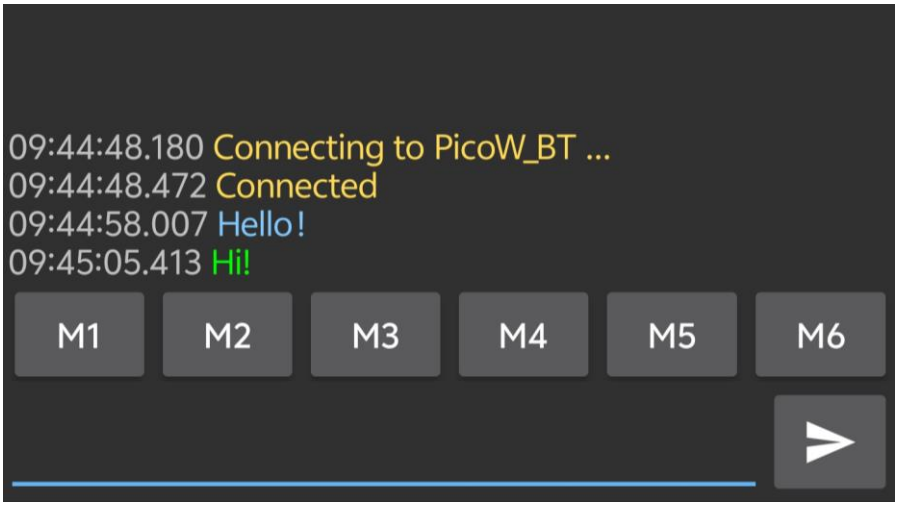



Now, the data can be transfer between your phone and computer (Pico W).

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:

```
#include <SerialBT.h>

void setup(){
  Serial.begin(115200);
  SerialBT.setName("PicoW_BT"); //Bluetooth device name
  SerialBT.begin();
  while(!Serial);
  Serial.println("The device started, now you can pair it with bluetooth!")
}

void loop() {
  if(Serial.available()){
    SerialBT.print(Serial.readString());
  }
  if(SerialBT.available()){
    Serial.print(SerialBT.readString());
  }
  delay(5);
}
```

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.

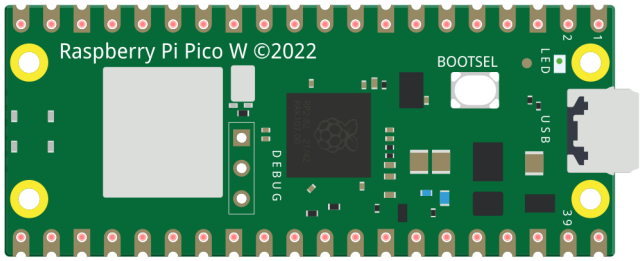
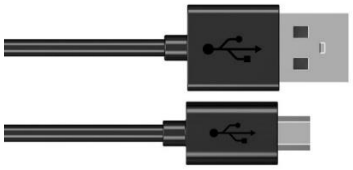
**write(const uint8_t *p, size_t len)**: Sends the first len bytes of data stored at pointer address p to Bluetooth.

**print()**: Sends all types of data to Bluetooth for printing.

**end()**: Disconnects all Bluetooth devices and turns off Bluetooth, freeing up all occupied space.

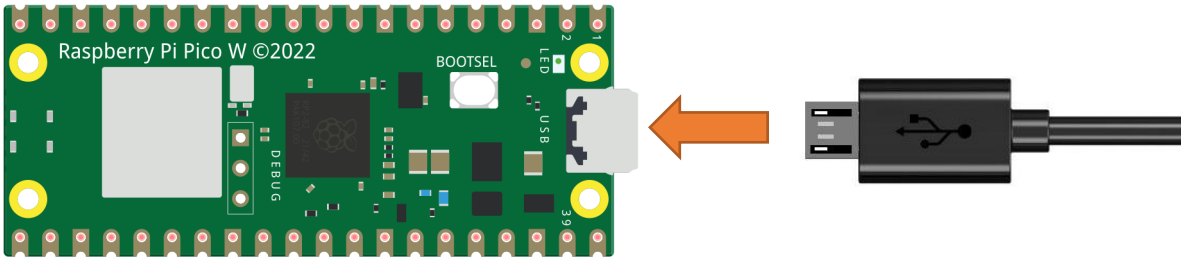
# Project 15.2 Bluetooth Low Energy Data Passthrough

## Component List

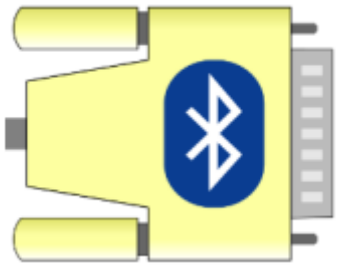
| | |
|---|---|
| Raspberry Pi Pico W x1  | Micro USB Wire x1  |

## 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_15.2_Serial_BT

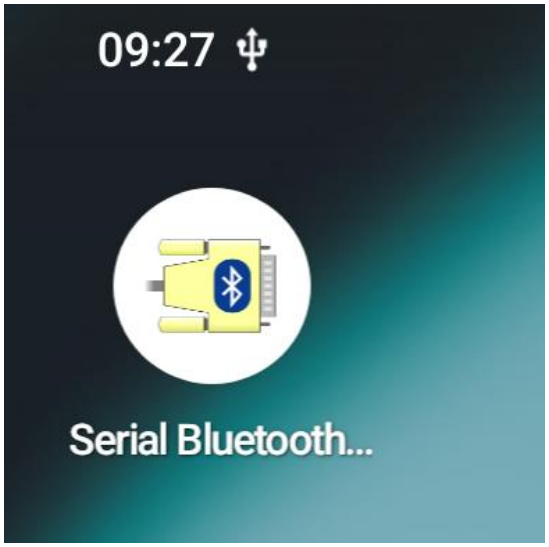
```
File Edit Sketch Tools Help
Raspberry Pi Pico W
Serial_BLE.ino
42  void setup(void) {
43    Serial.begin(115200);
44    while(!Serial);
45
46    setupBLE("PicoW_BLE");
47  }
48
49  void loop(void) {
50    BTstack.loop();
51
52    if (Serial.available() > 0) {                    // Check if there is serial
53      String input = Serial.readStringUntil('\n');
54      input.trim();                                  // Remove front and back bla
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.

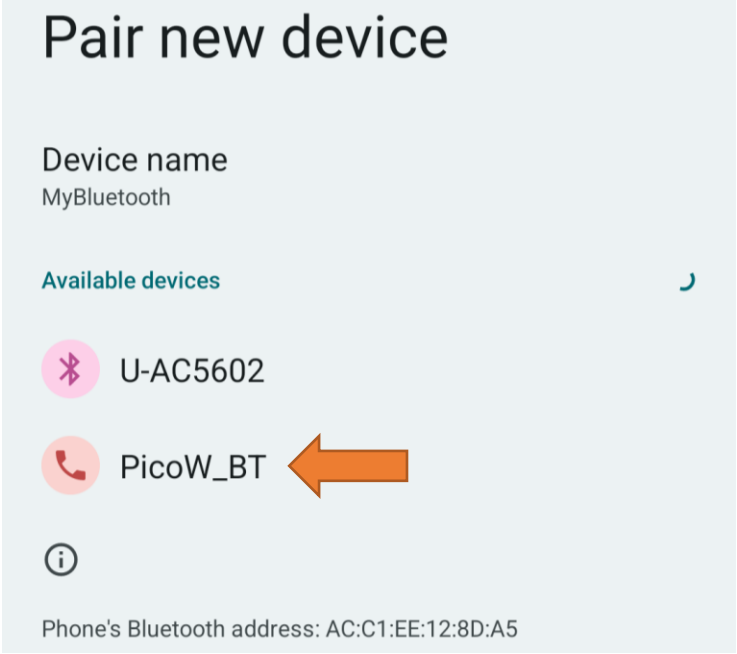
Serial Bluetooth

Compile and upload sketch th Pico W. The opration is similar to that in the previous section.

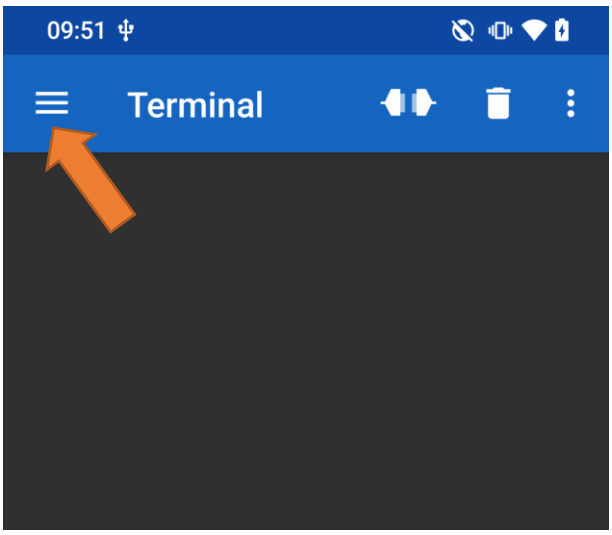
First, make sure Bluetooth on your phone is turned ON, and open Serial Bluetooth Terminal.

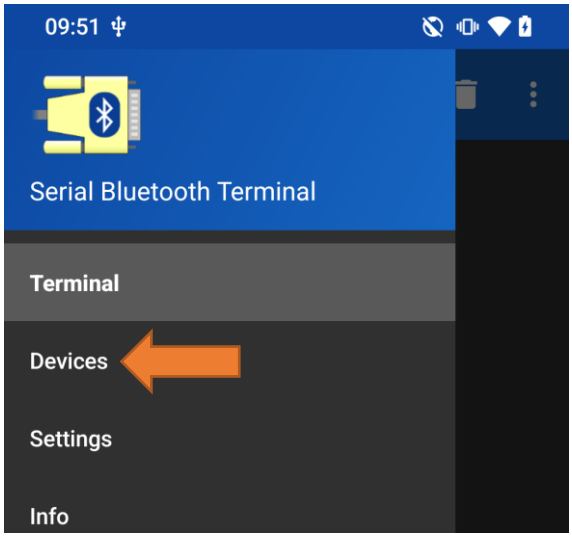



Click Pair new device, select “PicoW_BT” to connect.

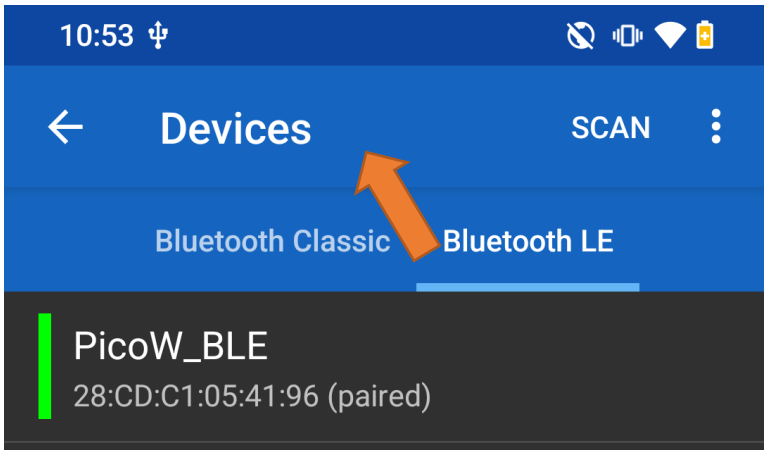



Expand the menu at the left of the app, and select "Devices".

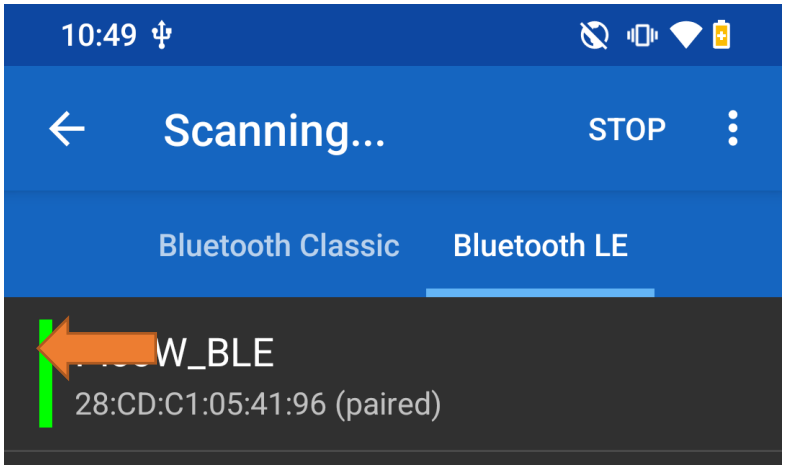



SelectBLUETOOTH LE and click scan to search for BLE devices nearby.



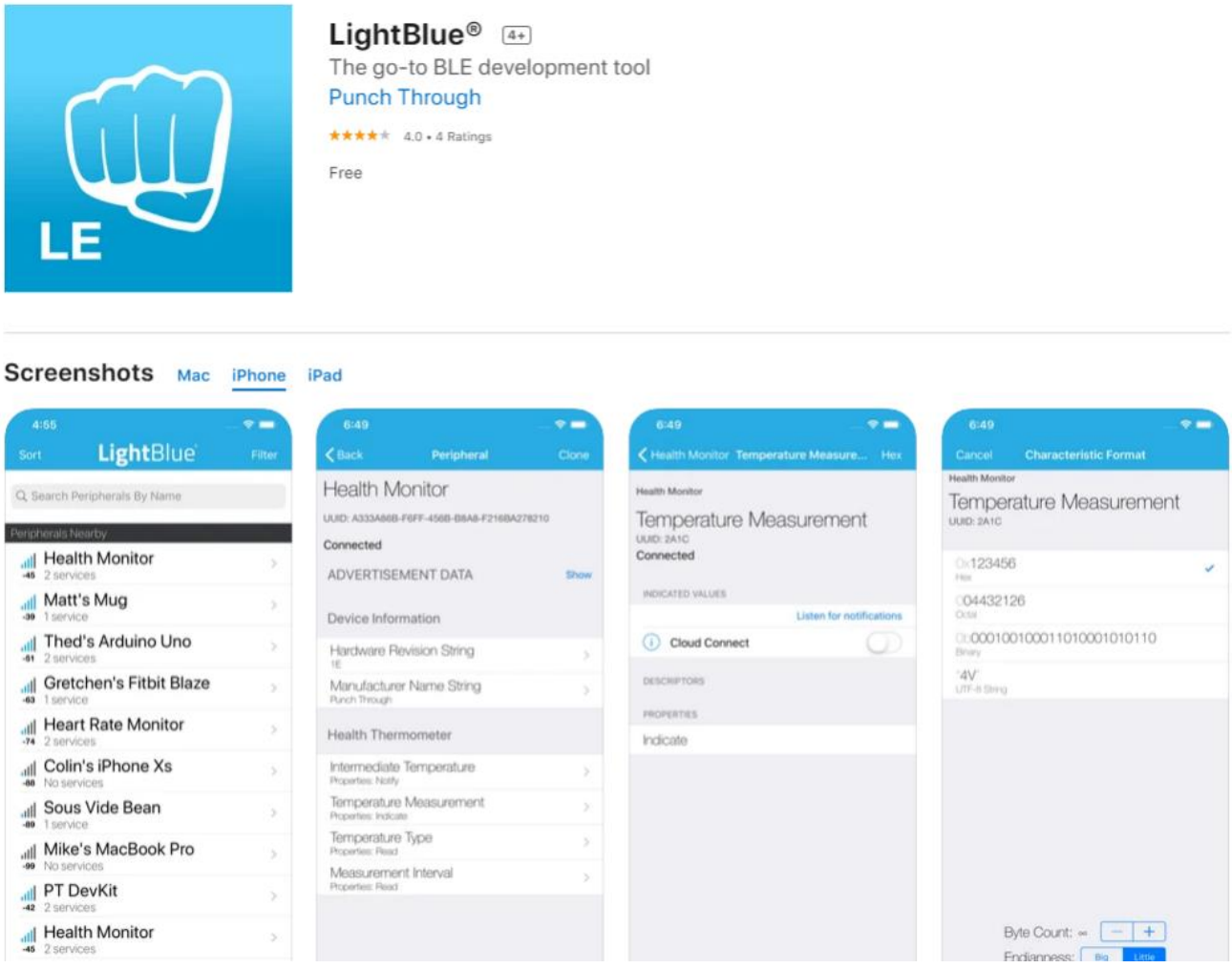
Select “PicoW_BLE”.




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:

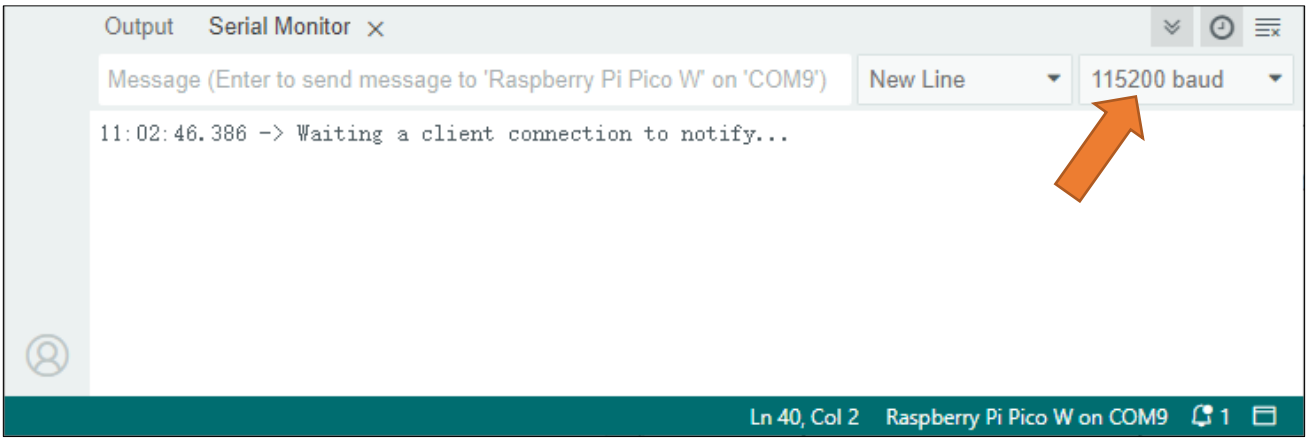
iPhone:https://apps.apple.com/us/app/lightblue/id557428110?platform=iphone



Step 1. Upload sketch 33.1 to Pico W.

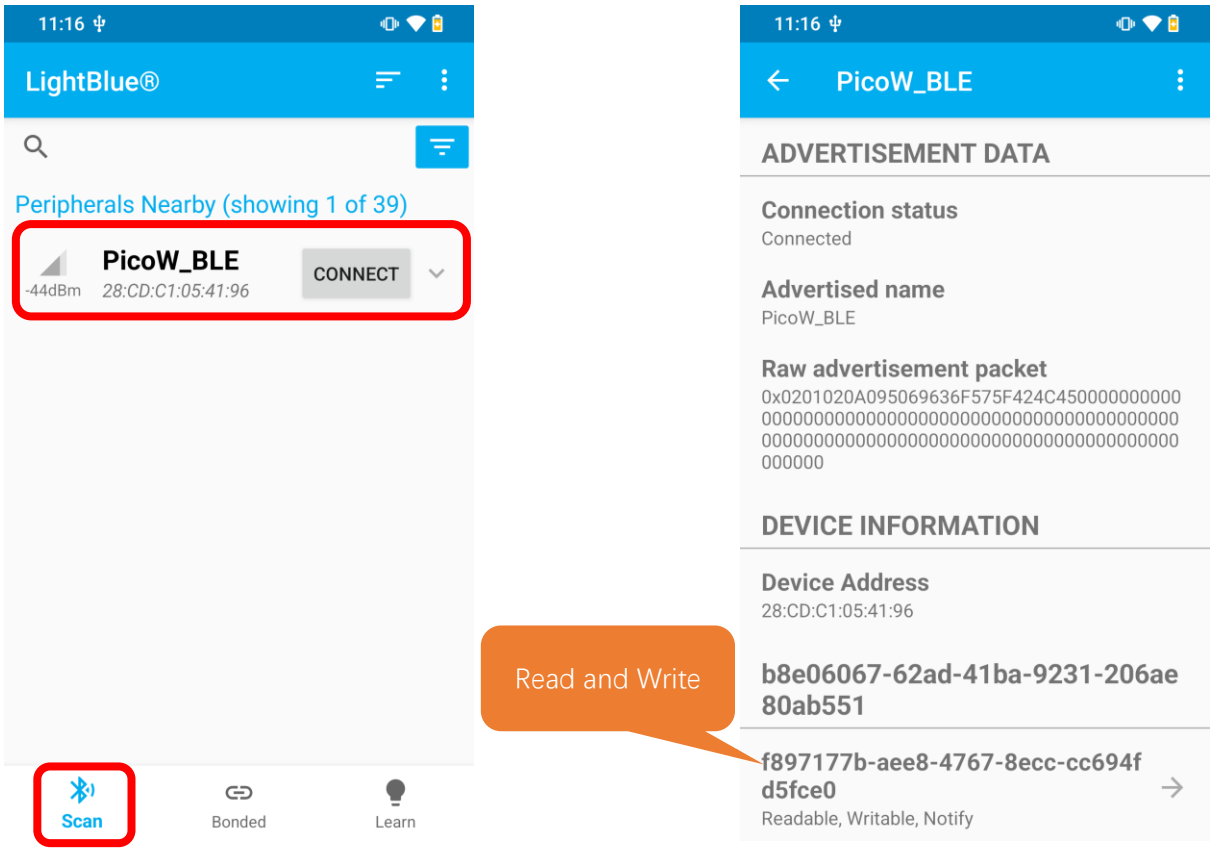
Step 2. Open Serial Monitor.


Step 3. Set the baud rate to 115200.

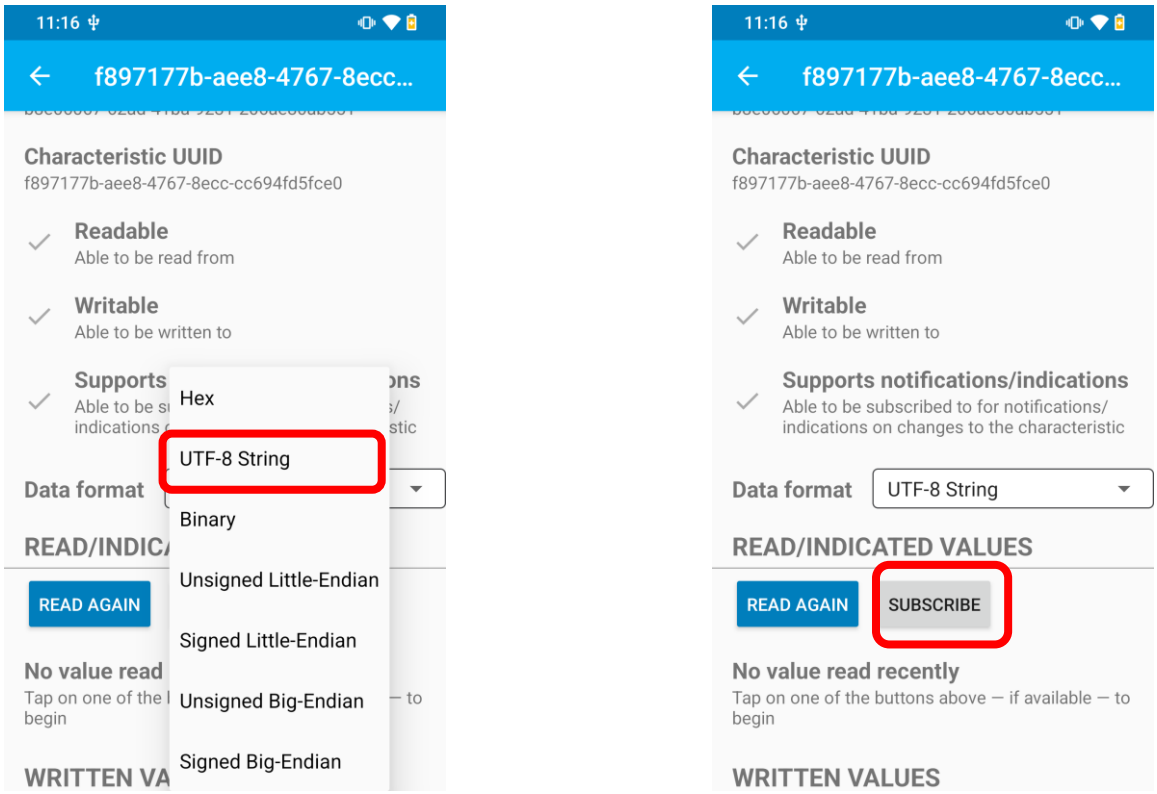



Turn ON Bluetooth on your phone and open LightBlue App.

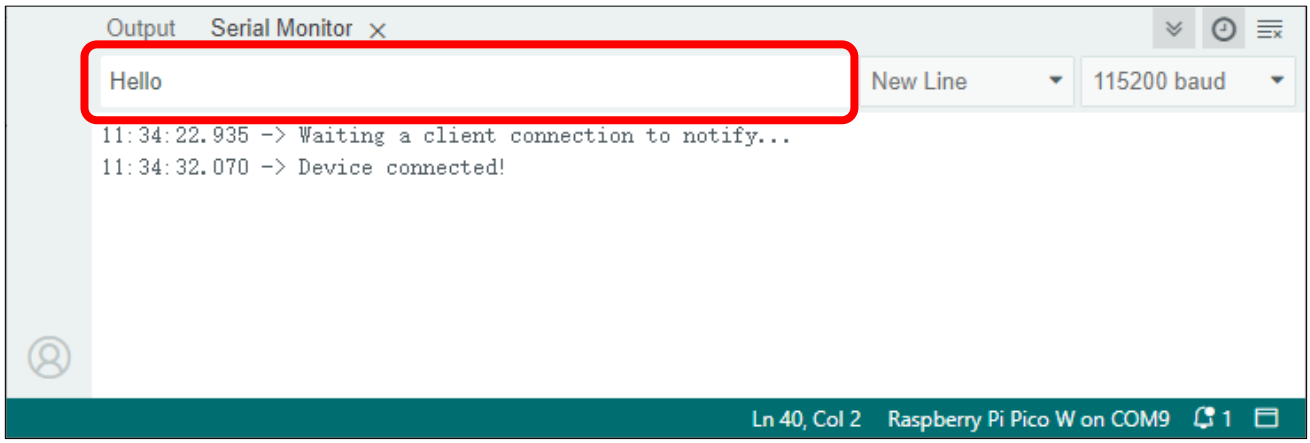

At the device scan page, scroll down to refresh the devices nearby. Select PicoW_BLE to connect.



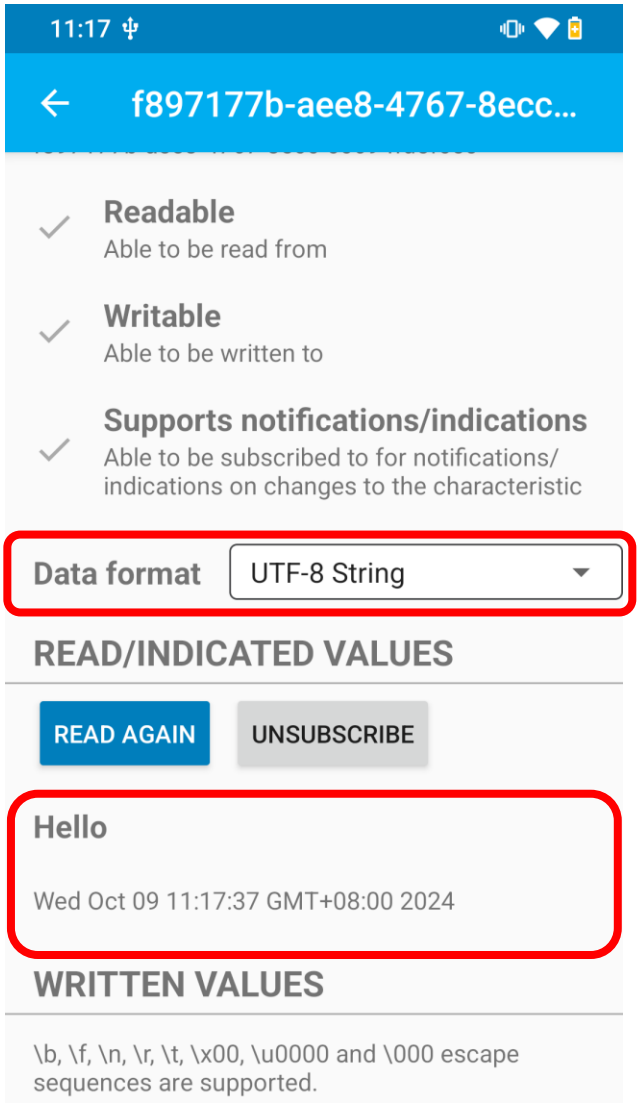

Click “Read and Write”. Click on "Read and Write". Select the corresponding data format in the box on the right side of the data format, such as HEX hexadecimal, utf-string string, Binary binary, etc. Then click SUBSCRIBE.



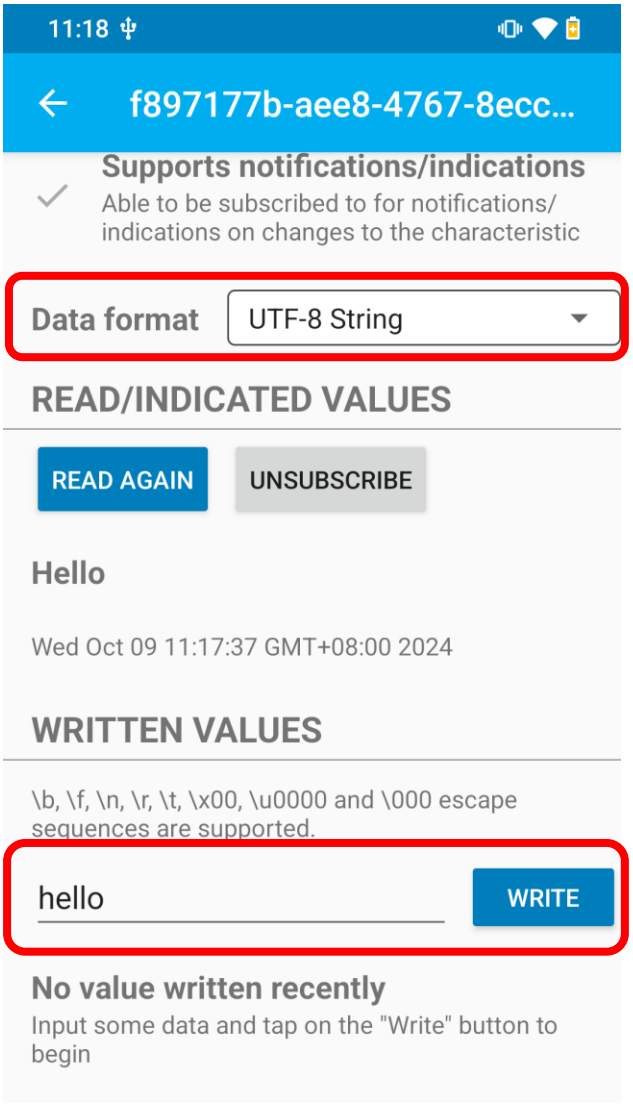
Return to the serial monitor on Arduino IDE, you can input any message and hit the Enter key to send.



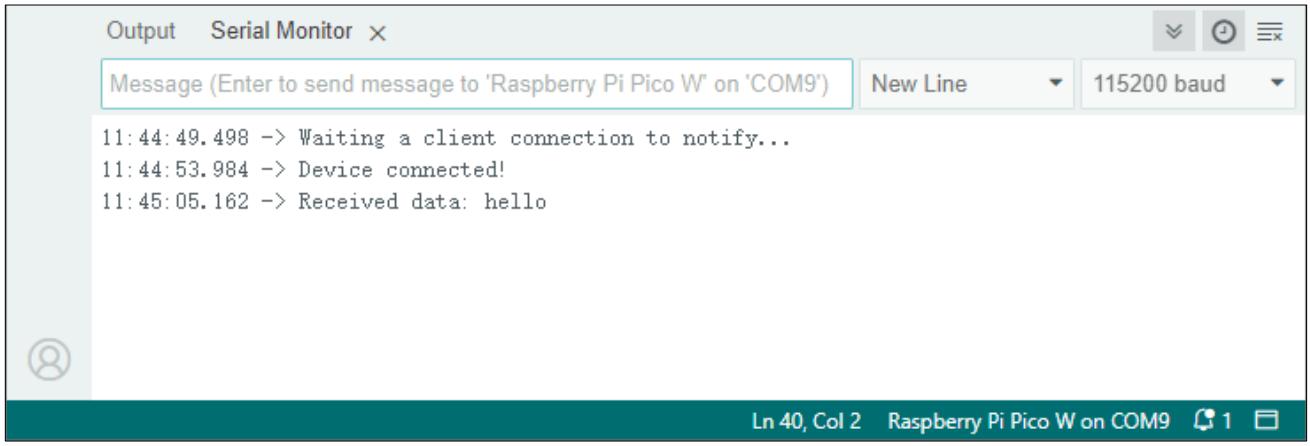

Then you can see LightBlue on your phone receive the data.



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 transfer between your phone and pico W.

The following is the program code:

```
#include <BTstackLib.h>
#include <SPI.h>
#include <btstack.h>

#define MAX_LENGTH 256
static char characteristic_data[MAX_LENGTH] = "Pico W Bluetooth";

// Track subscription status
bool isSubscribed = false;

// The handle of the connection
hci_con_handle_t connection_handle = HCI_CON_HANDLE_INVALID;

// characteristic handle
uint16_t characteristic_handle = 0;

// Assuming the handle of CCCD is a characteristic handle+1
#define CCCD_HANDLE (characteristic_handle + 1)

void setupBLE(const char *BLEName){
  //Set callback function
  BTstack.setBLEDeviceConnectedCallback(deviceConnectedCallback);
  BTstack.setBLEDeviceDisconnectedCallback(deviceDisconnectedCallback);
  BTstack.setGATTCharacteristicRead(gattReadCallback);
  BTstack.setGATTCharacteristicWrite(gattWriteCallback);

  //Set GATT database
  BTstack.addGATTService(new UUID("B8E06067-62AD-41BA-9231-206AE80AB551"));
  characteristic_handle = BTstack.addGATTCharacteristicDynamic(
    new UUID("f897177b-aee8-4767-8ecc-cc694fd5fce0"),
    ATT_PROPERTY_READ | ATT_PROPERTY_WRITE | ATT_PROPERTY_NOTIFY,
    0
    );

  //Activate Bluetooth and broadcast
  BTstack.setup(BLEName);
  BTstack.startAdvertising();

  Serial.println("Waiting a client connection to notify...");
}

void setup(){
  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   return 0;
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) {
```

```
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:

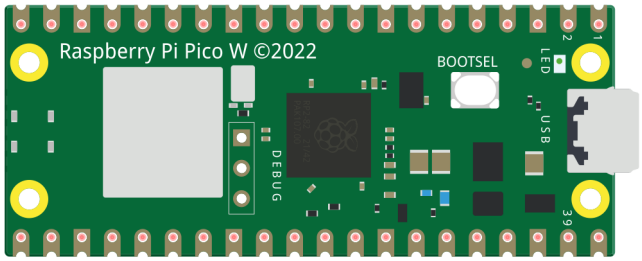
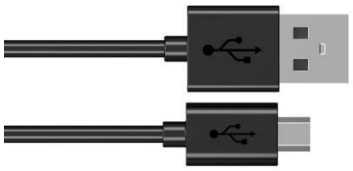
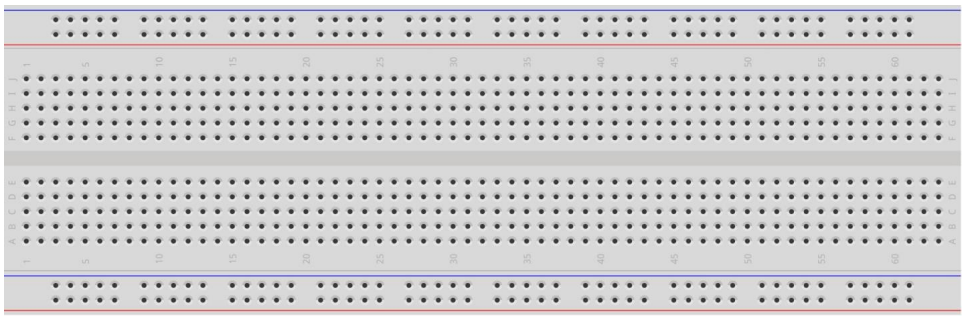
1. Set up a connection Callback function.
2. Set up a Callback function for disconnection.
3. Set up GATT read characteristic.
4. Set up GATT write characteristic.
5. Add GATT service.
6. Add GATT dynamic characteristic (read, write, notify).
7. Initialize BLE.
8. Start advertising.

```
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 15.3 Bluetooth Control LED

In this project, we will control an LED via Pico W's Bluetooth function.

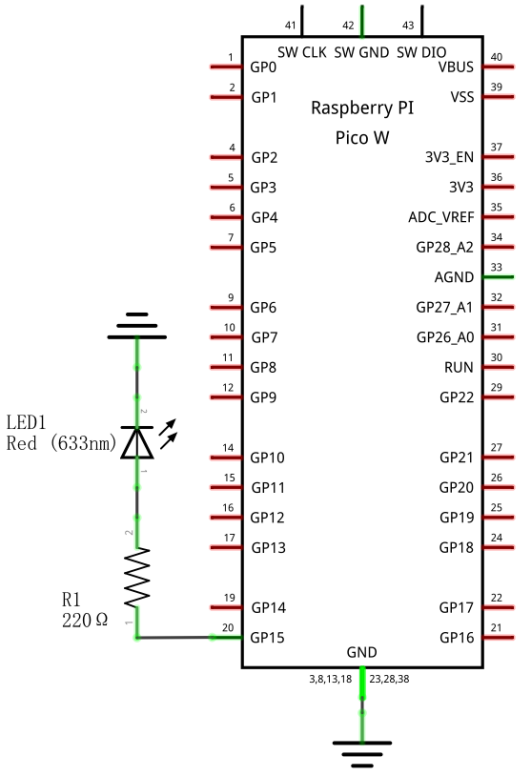
## Component List

| | |
|---|---|
| Raspberry Pi Pico W x1   | Micro USB Wire x1  |
| Breadboard x1  | |
| LED x1  | Resistor 220Ω x1  |
| Jumper  | |

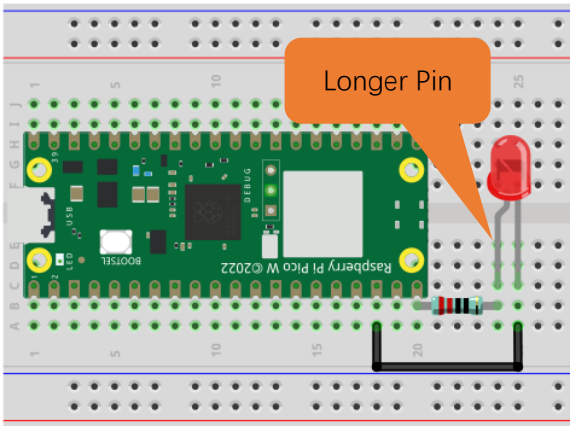
## Circuit

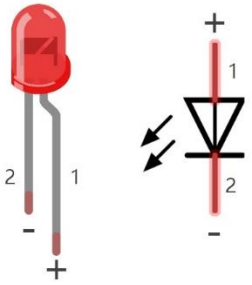
Connect Pico W to your phone with the USB cable.

Schematic diagram




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

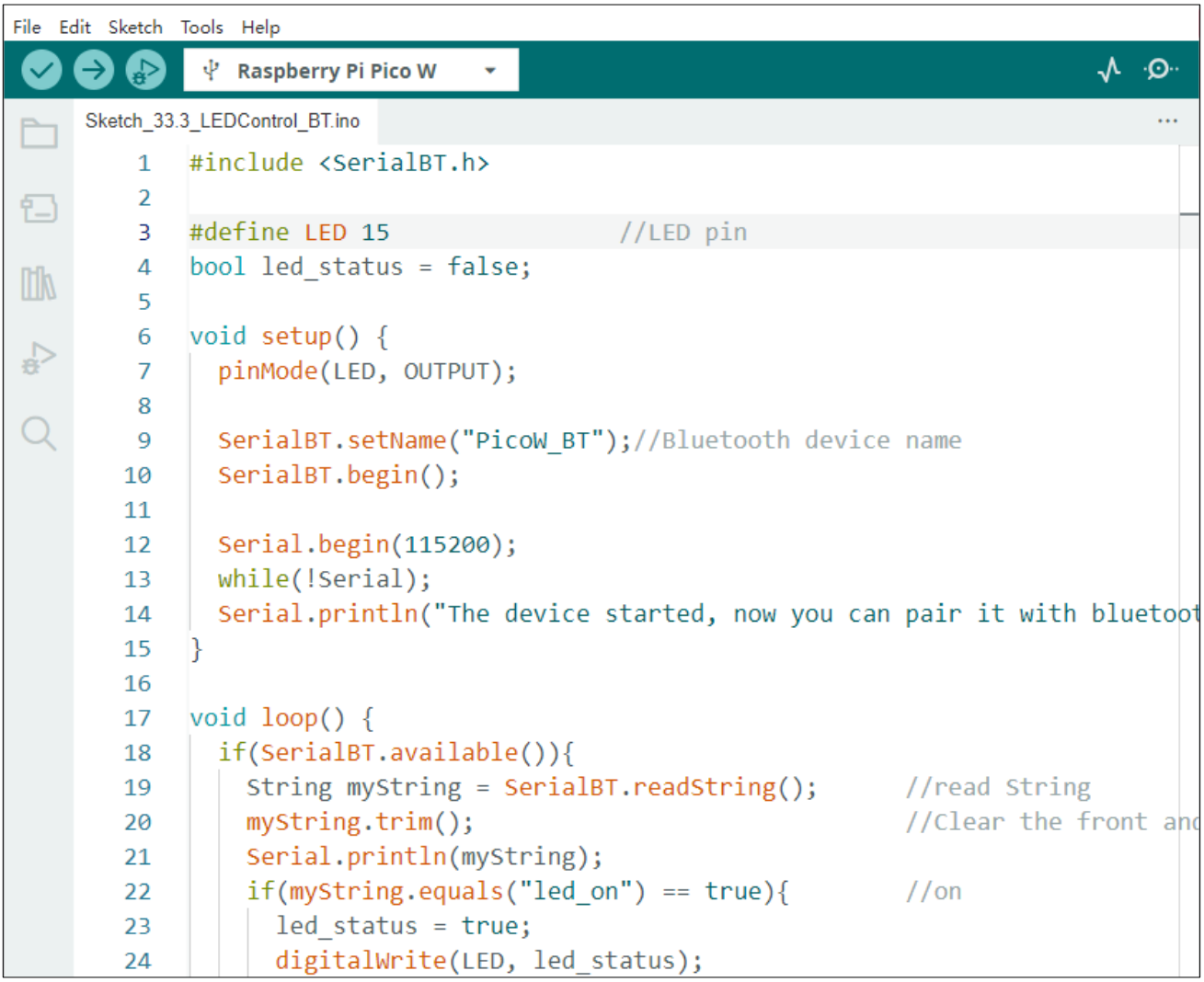



Note: To help users have a better experience when doing the projects, we have made some modifications to Pico's simulation diagram. Please note that there are certain differences between the simulation diagram and the actual board to avoid misunderstanding.

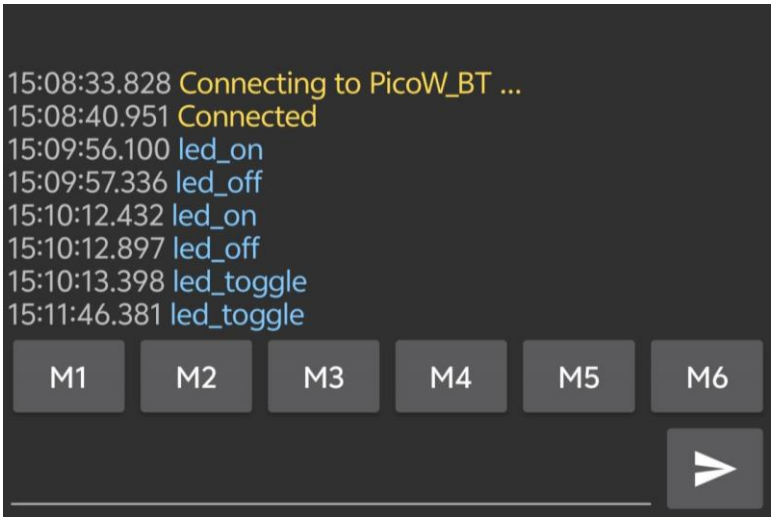
## Sketch

Sketch_15.3_LEDControl_BT

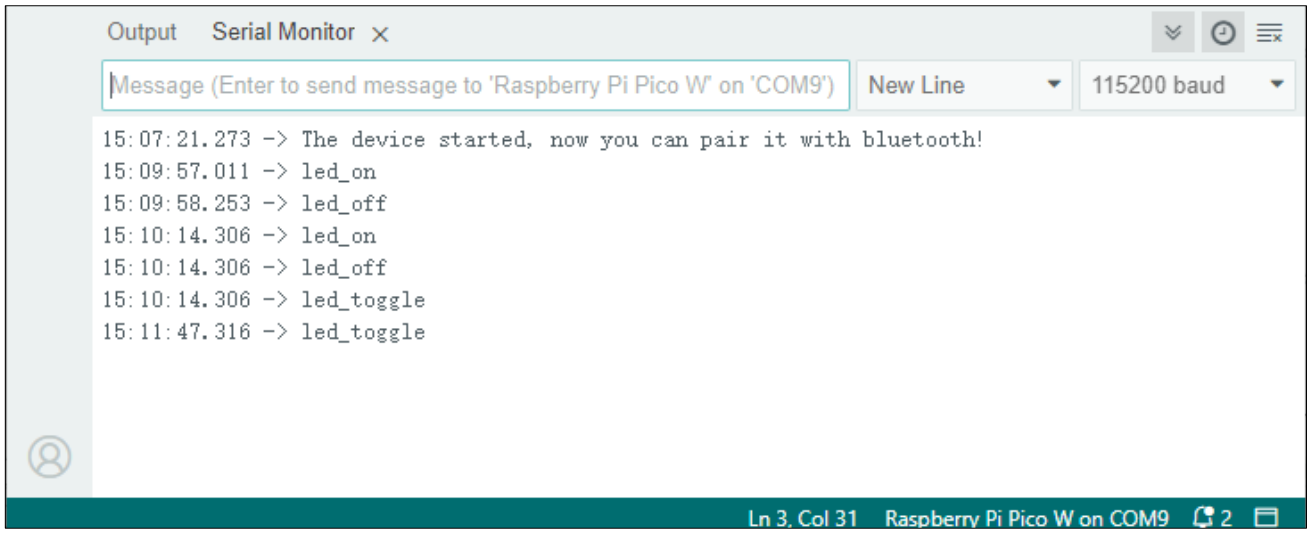



Upload the sketch to Pico W.

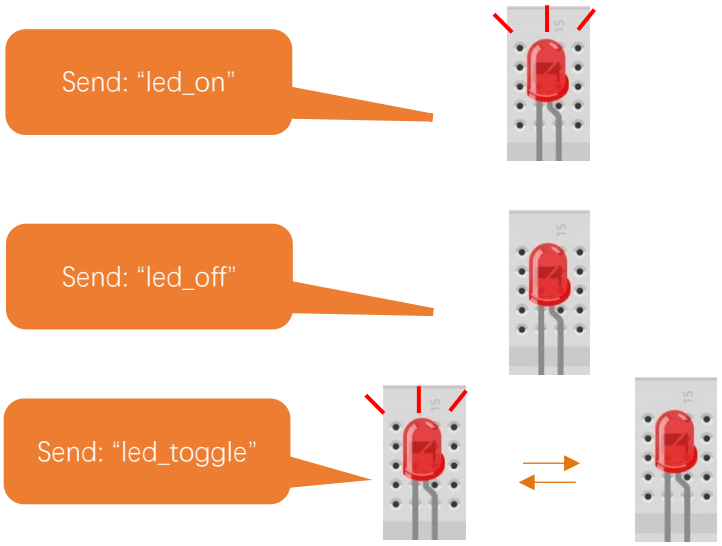
The operation on the phone app is similar to that in Project 15.1. You just need to change the sending messages to "led_on", "led_off" and "led_toggle" to control the status of the LED.




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.

The following is the program code:

```
#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 blank spaces
    Serial.println(myString);
    if(myString.equals("led_on") == true){       //on
      led_status = true;
      digitalWrite(LED, led_status);
    }
    if(myString.equals("led_off") == true){      //off
      led_status = false;
      digitalWrite(LED, led_status);
    }
    if(myString.equals("led_toggle") == true){  //toggle
      led_status = !led_status;
      digitalWrite(LED, led_status);
    }
  }
}
```

Define the pin of LED and set its default status as false.

```
#define LED 15                    //LED pin
bool led_status = false;
```

Set the LED pin to output mode.

```
  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.

```
  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.

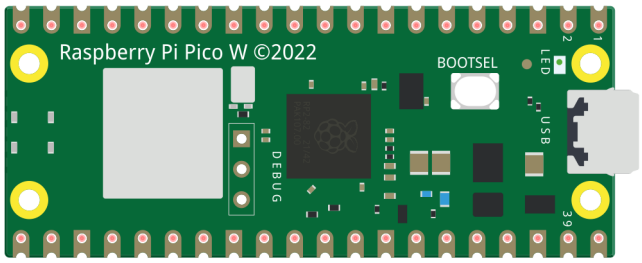
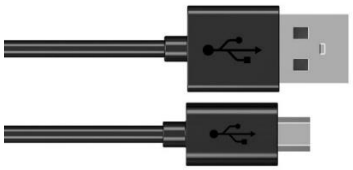
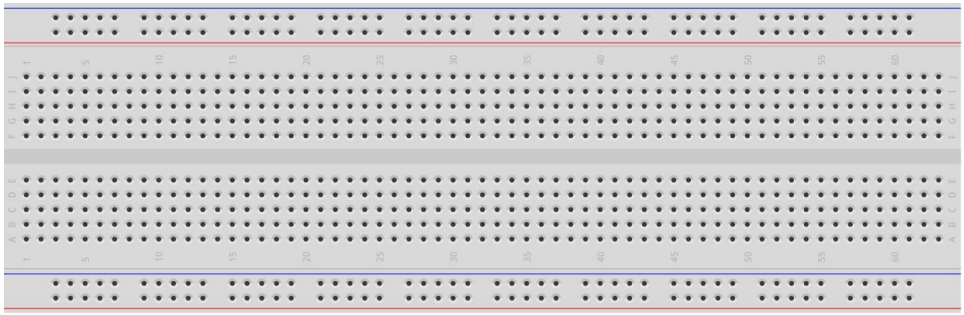
If s2 is equal to the current string, the return value is 1.

Note: Both data being compared must be of string type.

# Project 15.4 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.

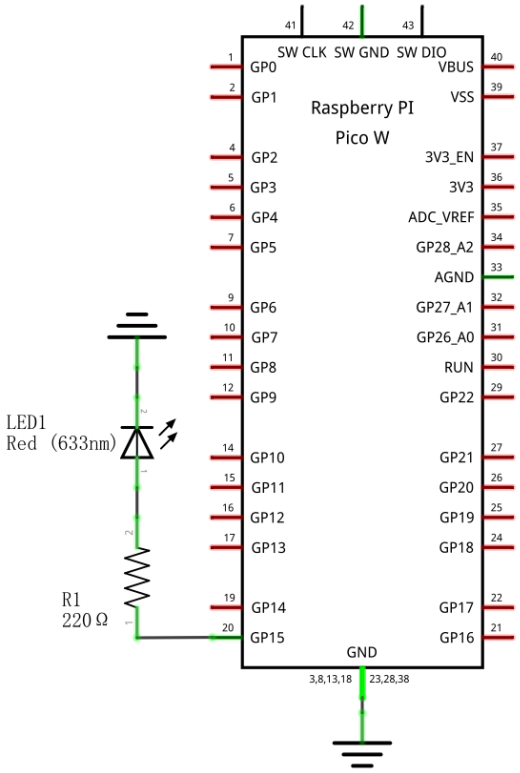
## Component List

| | | |
|---|---|---|
| Raspberry Pi Pico W x1   | Micro USB Wire x1  | |
| Breadboard x1  | | |
| LED x1  | Resistor 220Ω x1  | Jumper  |

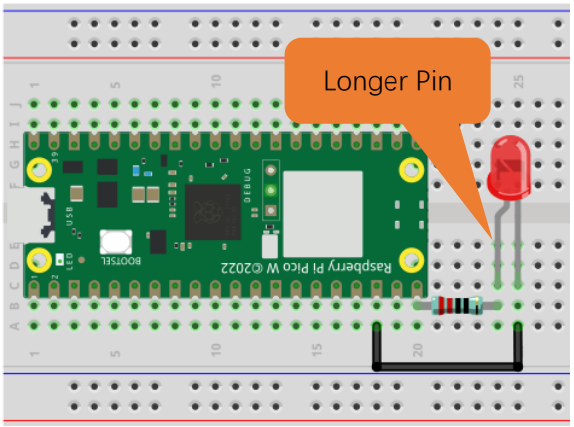
## Circuit

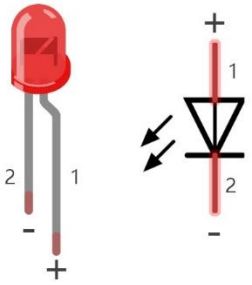
Connect the Pico W to your computer with a USB cable.

Schematic diagram




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

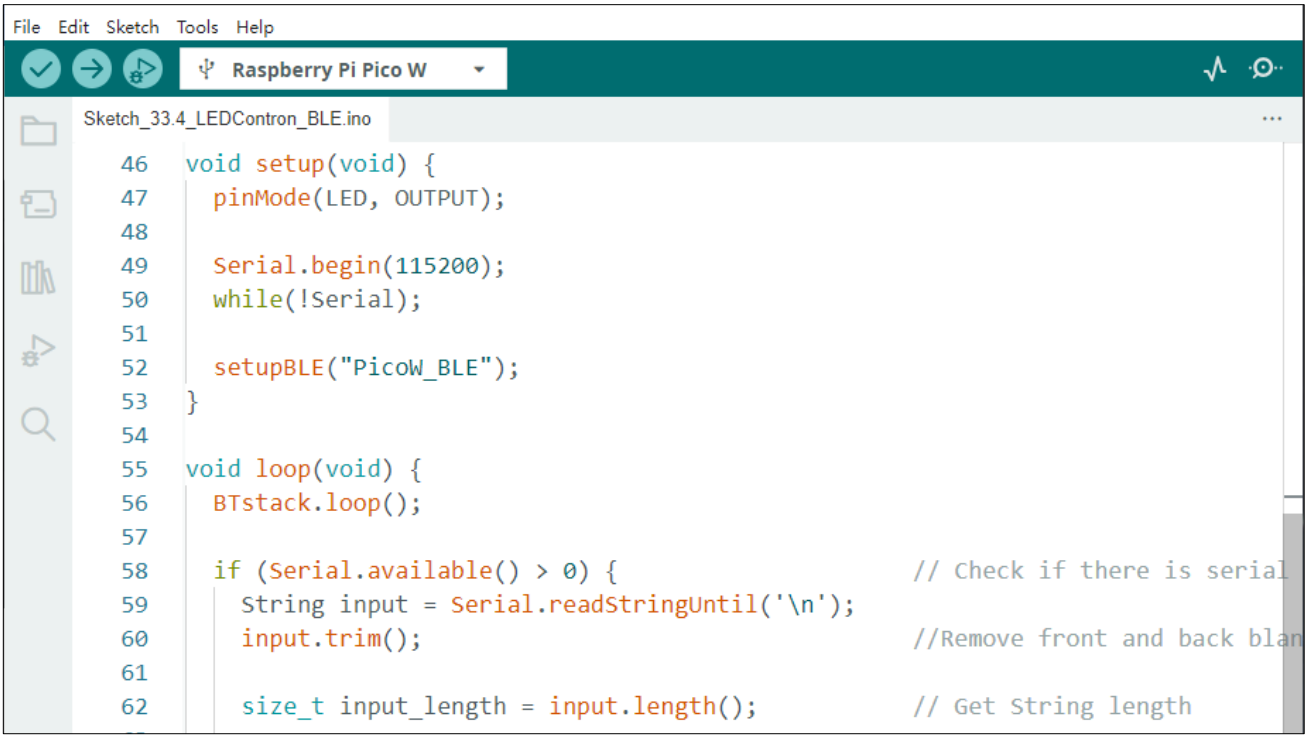


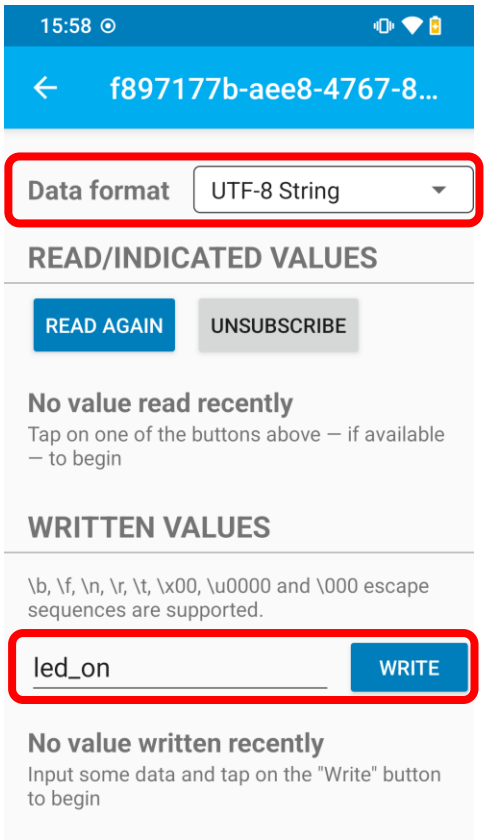

Note: To help users have a better experience when doing the projects, we have made some modifications to Pico's simulation diagram. Please note that there are certain differences between the simulation diagram and the actual board to avoid misunderstanding.

## Sketch

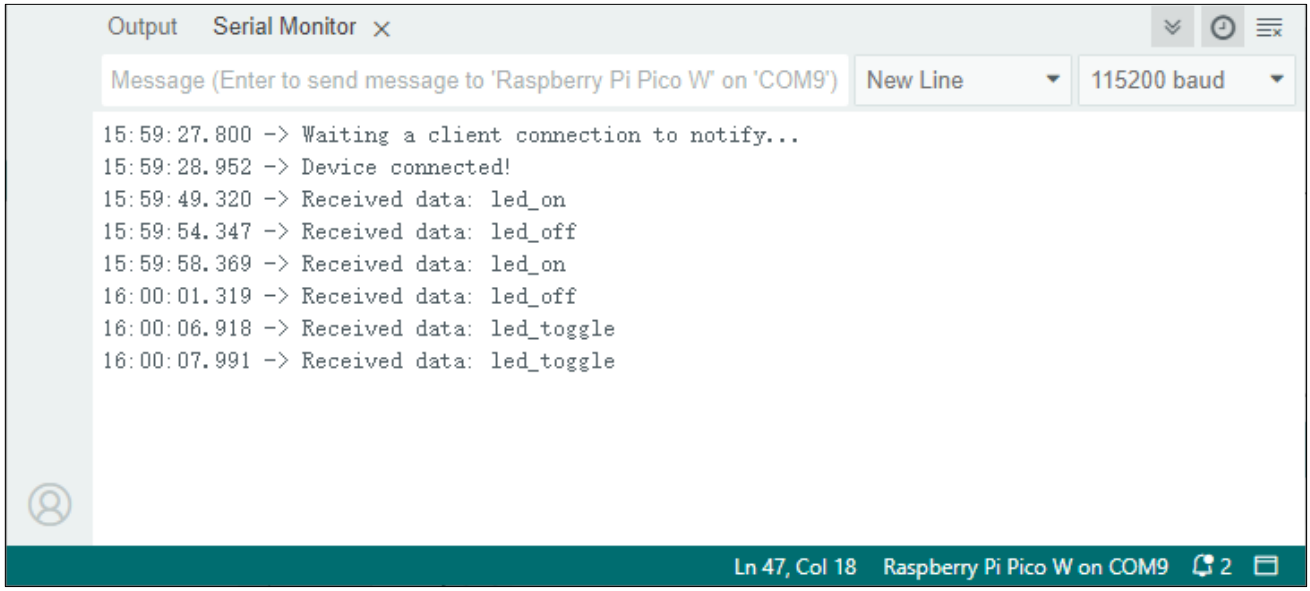
Sketch_15.4_LEDControl_BLE



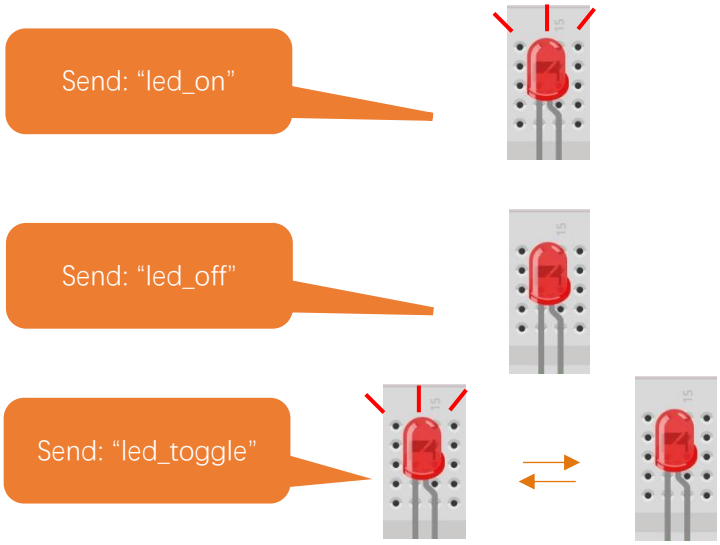

Upload the sketch to Pico W. As previously mentioned, you can input "led_on", "led_off", or "led_toggle" to change the status of the LED.



Displays on the serial monitor.




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:

```
#include <BTstackLib.h>
#include <SPI.h>
#include <btstack.h>

#define LED 15                          // LED pin
bool led_status = false;

#define MAX_LENGTH 256
static char characteristic_data[MAX_LENGTH] = "Pico W Bluetooth";

// Track subscription status
bool isSubscribed = false;

// The handle of the connection
hci_con_handle_t connection_handle = HCI_CON_HANDLE_INVALID;

// characteristic handle
uint16_t characteristic_handle = 0;

// Assuming the handle of CCCD is a characteristic handle+1
#define CCCD_HANDLE (characteristic_handle + 1)

void setupBLE(const char *BLEName){
  //Set callback function
  BTstack.setBLEDeviceConnectedCallback(deviceConnectedCallback);
  BTstack.setBLEDeviceDisconnectedCallback(deviceDisconnectedCallback);
  BTstack.setGATTCharacteristicRead(gattReadCallback);
  BTstack.setGATTCharacteristicWrite(gattWriteCallback);

  //Set GATT database
  BTstack.addGATTService(new UUID("B8E06067-62AD-41BA-9231-206AE80AB551"));
  characteristic_handle = BTstack.addGATTCharacteristicDynamic(
    new UUID("f897177b-aee8-4767-8ecc-cc694fd5fce0"),
    ATT_PROPERTY_READ | ATT_PROPERTY_WRITE | ATT_PROPERTY_NOTIFY,
    0
    );

  //Activate Bluetooth and broadcast
  BTstack.setup(BLEName);
  BTstack.startAdvertising();

  Serial.println("Waiting a client connection to notify...");
}
```

```
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;
```

```
  isSubscribed = false;                          // Reset subscription status
}

// Callback function for reading data
uint16_t gattReadCallback(uint16_t value_handle, uint8_t * buffer, uint16_t buffer_size) {
  (void) value_handle;
  if (buffer && buffer_size > 0) {
    Serial.print("Read data: ");
    Serial.println(characteristic_data);

    size_t data_length = strlen(characteristic_data); // Get characteristic_data length
    if (data_length > buffer_size) {                  // Limit length
      data_length = buffer_size;
    }

    memcpy(buffer, characteristic_data, data_length); // Copy String
    return data_length;
  }
  return 0;
}

// Callback function for writing data
int gattWriteCallback(uint16_t value_handle, uint8_t *buffer, uint16_t size) {
  if (value_handle == CCCD_HANDLE) {                  // Processing CCCD writing
    if (size >= 2) {
      uint16_t cccd_value = buffer[0] | (buffer[1] << 8);
      isSubscribed = true;                            //Subscription status is true
    }
  } else {                                            // Writing of processing feature data
    size_t copy_size = (size < (MAX_LENGTH - 1)) ? size : (MAX_LENGTH - 1);
    memcpy(characteristic_data, buffer, copy_size);   // Copy String
    characteristic_data[copy_size] = '\0';            // Ensure that the string ends

    String myString = String(characteristic_data)     // Convert to String
    myString.trim();                                  // Remove front and back blank spaces
    if(myString.equals("led_on") == true){            // led on
      led_status = true;
      digitalWrite(LED, led_status);
    }
    if(myString.equals("led_off") == true){           // led off
      led_status = false;
      digitalWrite(LED, led_status);
    }
    if(myString.equals("led_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 }
```

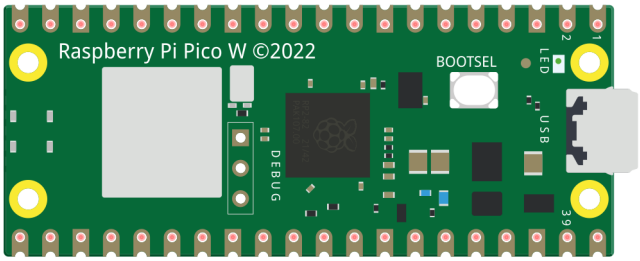
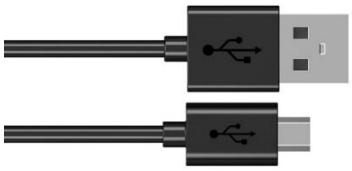
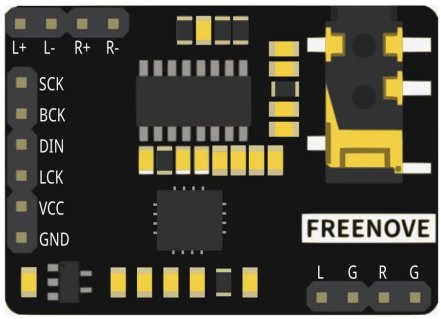
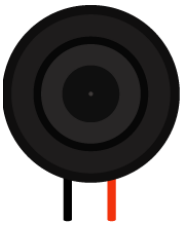
# Chapter 16 Bluetooth Audio (Only for Pico W)

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 15.1 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.

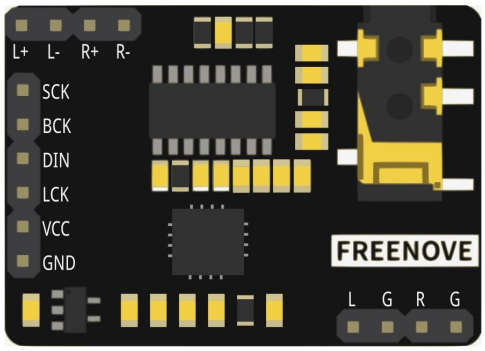
### Component List

<table>
<tr><td>Raspberry Pi Pico W x1<br>  </td><td>Micro USB Wire x1<br>  </td></tr>
<tr><td>Audio Converter & Amplifier<br>  </td><td>Speaker*1<br>  </td></tr>
<tr><td colspan="2">Jumper wire F/M*4<br>  </td></tr>
</table>

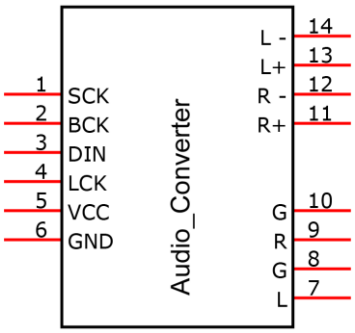
# Component knowledge

## Audio Converter & Amplifier module

front view

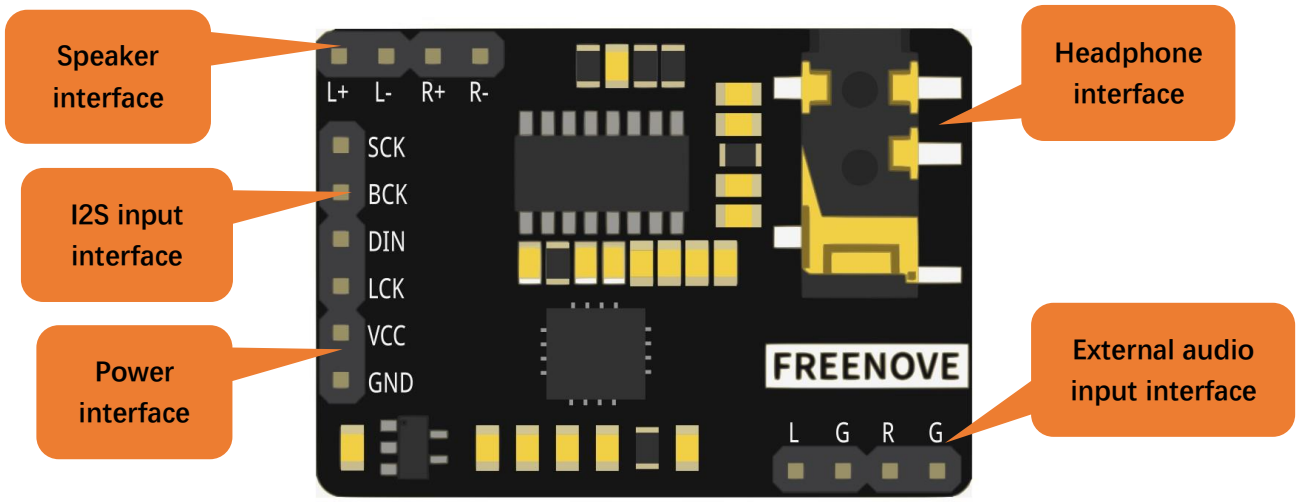



schematic diagram




Interface description for Audio Converter & Amplifier module

| Pin | Name | Introductions |
|---|---|---|
| 1 | SCK | System clock input |
| 2 | BCK | Audio data bit clock input |
| 3 | DIN | Audio data input |
| 4 | LCK | Audio data word clock input |
| 5 | VCC | Power input，3.3V~5.0V |
| 6 | GND | Power Ground |
| 7 | L | External audio left channel input |
| 8 | G | Power Ground |
| 9 | R | External audio right channel input |
| 10 | G | Power Ground |
| 11 | R+ | Positive pole of right channel horn |
| 12 | R- | Negative pole of right channel horn |
| 13 | L+ | Positive pole of left channel horn |
| 14 | L- | Negative pole of left channel horn |



Speaker interface: Connect left channel speaker and right channel speaker. Group L: L+ & L-; Group R: R+& R-. The two interfaces of the speaker can be connected to the interfaces of group L or group R. 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.

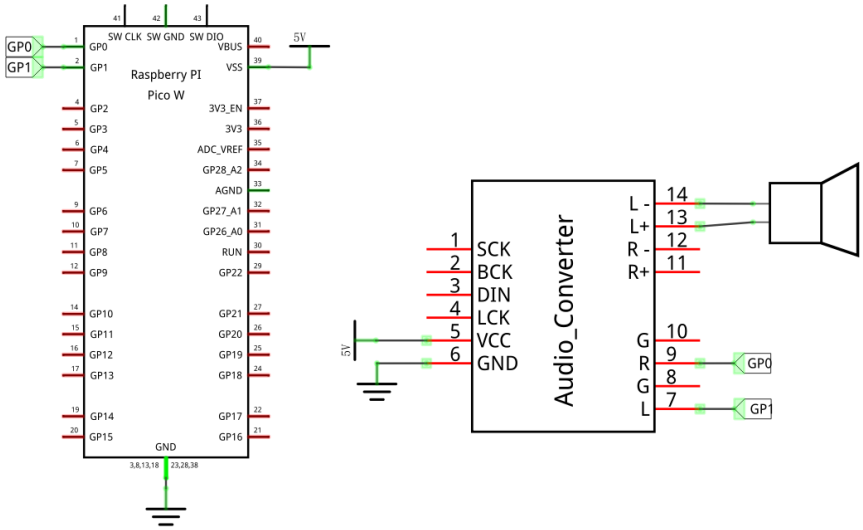
External audio input interface: connect to external audio equipment. Used to amplify externally input audio signals.

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

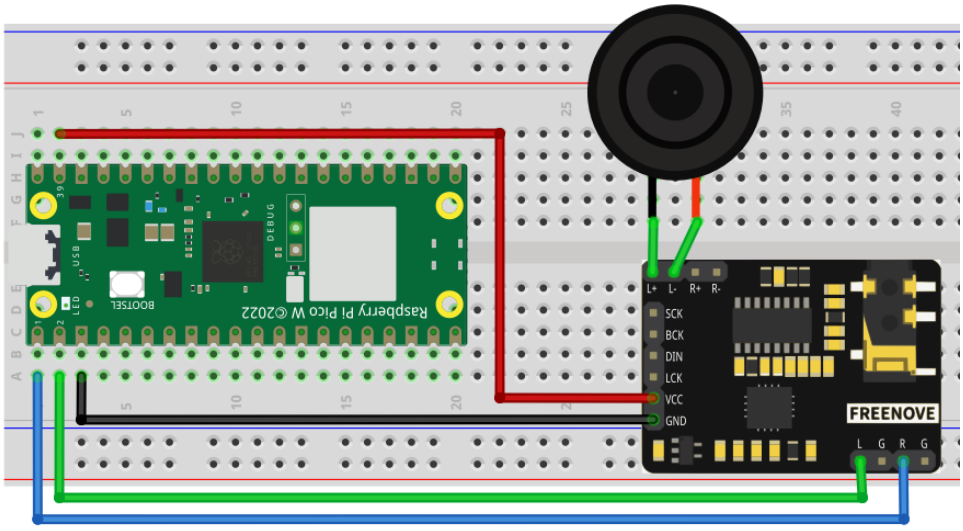
## Circuit

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 feel free to contact us via: support@freenove.com



## Sketch

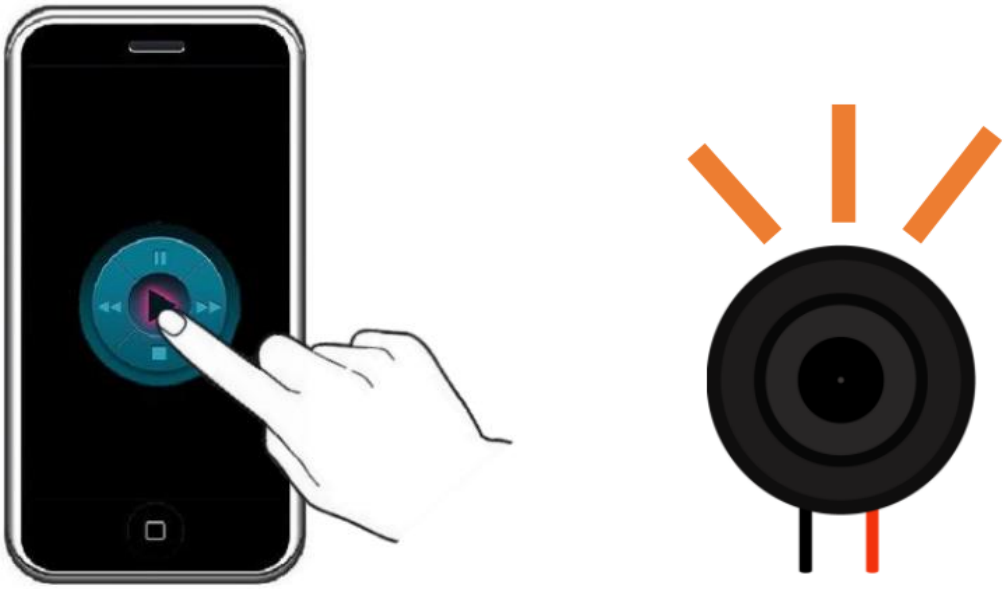
### Sketch_15.4_Bluetooth_By_PCM5102A

```
#include <BluetoothAudio.h>
#include <PWMAudio.h>

PWMAudio pwm;
A2DPSink a2dp;

// Define a playback state
volatile A2DPSink::PlaybackStatus status = A2DPSink::STOPPED;

// Volume callback function
void volumeCB(void *param, int pct) {
  (void) param;
  Serial.printf("Speaker volume changed to %d%%\n", pct);
}

// Connect callback function
void connectCB(void *param, bool connected) {
  (void) param;
  if (connected) {
    //Print the address of the connected device
    Serial.printf("A2DP connection started to %s\n", bd_addr_to_str(a2dp.getSourceAddress()));
  } else {
    Serial.printf("A2DP connection stopped\n");
  }
}

// Play status callback function
void playbackCB(void *param, A2DPSink::PlaybackStatus state) {
  (void) param;
  status = state;
}
```

When you see the messages as shown below, it indicates that the Pico W's Bluetooth is ready for connection and playing music.

```
Output  Serial Monitor
Message (Enter to send message to 'Raspberry Pi Pico W' on 'COM9')  New Line  115200 baud
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:
Ln 1, Col 1  Raspberry Pi Pico W on COM9  1
```

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:

```
#include <BluetoothAudio.h>
#include <PWMAudio.h>

PWMAudio pwm;
A2DPSink a2dp;

// Define a playback state
volatile A2DPSink::PlaybackStatus status = A2DPSink::STOPPED;

// Volume callback function
void volumeCB(void *param, int pct) {
  (void) param;
  Serial.printf("Speaker volume changed to %d%%\n", pct);
}

// Connect callback function
void connectCB(void *param, bool connected) {
  (void) param;
  if (connected) {
    //Print the address of the connected device
    Serial.printf("A2DP connection started to %s\n", bd_addr_to_str(a2dp.getSourceAddress()));
  } else {
    Serial.printf("A2DP connection stopped\n");
  }
}

```

```
// Play status callback function
void playbackCB(void *param, A2DPSink::PlaybackStatus state) {
  (void) param;
  status = state;
}

void setup(){
  Serial.begin(115200);
  while(!Serial);

  Serial.printf("Starting, connect to the PicoW and start playing music\n");
  Serial.printf("Use BOOTSEL to pause/resume playback\n");

  a2dp.setName("PicoW Boom 00:00:00:00:00:00");
  // Set the audio consumer to PWM audio output
  a2dp.setConsumer(new BluetoothAudioConsumerPWM(pwm));
  a2dp.onVolume(volumeCB);
  a2dp.onConnect(connectCB);
  a2dp.onPlaybackStatus(playbackCB);
  a2dp.begin();
}

char *nowPlaying = nullptr;   //Store the name of the currently playing track

void loop(){
  if (BOOTSEL) {
    if (status == A2DPSink::PAUSED) {          // if the playback status is paused
      a2dp.play();                             // play
      Serial.printf("Resuming\n");
    } else if (status == A2DPSink::PLAYING) {  // if the playback status is playing
      a2dp.pause();                            // pause
      Serial.printf("Pausing\n");
    }
    while (BOOTSEL);
  }
  if (!nowPlaying || strcmp(nowPlaying, a2dp.trackTitle())) {
    free(nowPlaying);
    nowPlaying = strdup(a2dp.trackTitle());
    Serial.printf("NOW PLAYING: %s\n", nowPlaying);
  }
}
```

Include two libraries: “BluetoothAudio.h” and “PWMAudio.h”.

```
#include <BluetoothAudio.h>
#include <PWMAudio.h>
```

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.

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