# Welcome

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## Get Support & Offer Input

You may find somethings missing or broken, or some difficulty to learn the kit.
Freenove provides free and quick support, including but not limited to:

- Quality problems of products
- Problems in using products
- Questions for learning and technology
- Opinions and suggestions
- Ideas and thoughts

If you have any concerns, please send email to us:

**support@freenove.com**

And suggestions and feedbacks are welcomed. Many customers offered great feedbacks. According to that, we are keeping updating the kit and the tutorial to make it better. Thank you.

## Safety

Pay attention to safety when using and storing this product:

- Do not expose children under 6 years of age to this product. Put it out of their reach.
- Children lack safety ability should use this product under the guardianship of adults.
- This product contains small and sharp parts. Do not swallow, prick and scratch to avoid injury.
- This product contains conductive parts. Do not hold them to touch power supply and other circuits.
- Some parts will rotate or move when it works. Do not touch them to avoid being bruised or scratched.
- The wrong operation may cause overheat. Do not touch and disconnect the power supply immediately.
- Operate in accordance with the requirements of the tutorial. Otherwise, the parts may be damaged.
- Store the product in a dry place and avoid direct sunlight.
- Turn off the power of the circuit before leaving.

# About

Freenove provides open source electronic products and services.

Freenove is committed to helping customers learn programming and electronic knowledge, quickly realize their creative ideas and product prototypes and launching innovative products. Our services include:

- Kits of robots, smart cars and drones
- Kits for learning Arduino, Raspberry Pi and micro:bit
- Electronic components and modules, tools
- **Product customization service**

You can learn more about us or get our latest information through our website:

http://www.freenove.com

# Copyright

# Contents

# Preface

Do you want to learn programming?

Nowadays, Program is developed into the younger age group, and everyone programming is a trend. From Arduino and Raspberry Pi to micro:bit, simple graphical programming makes programming for kids possible. Maybe you haven't heard of them, it doesn't matter. With this product and the tutorial, you can easily complete a programming project and experience the fun as a Maker.

Micro:bit is a powerful and simple development board. Even if you've never programmed before, its simple graphical programming interface allows you to master it easily. It doesn't require any professional programming software; just simply a browser is enough to program it. So, no matter your computer system is Windows, Linux or Mac, you can program it. And you can also program it with Python.

It attracts a lot of fans in the world who are keen to exploration, innovation and DIY and have contributed a great number of high-quality open-source code, circuit and rich knowledge base. So we can realize our own creativity more efficiently by using these free resource. Of course, you can also contribute your own strength to the resource.

With Micro:bit, we can make a lot of projects and by adding kits to breadboard, we can carry out more interesting projects like ultrasonic ranging, gravity control, playing music, etc.

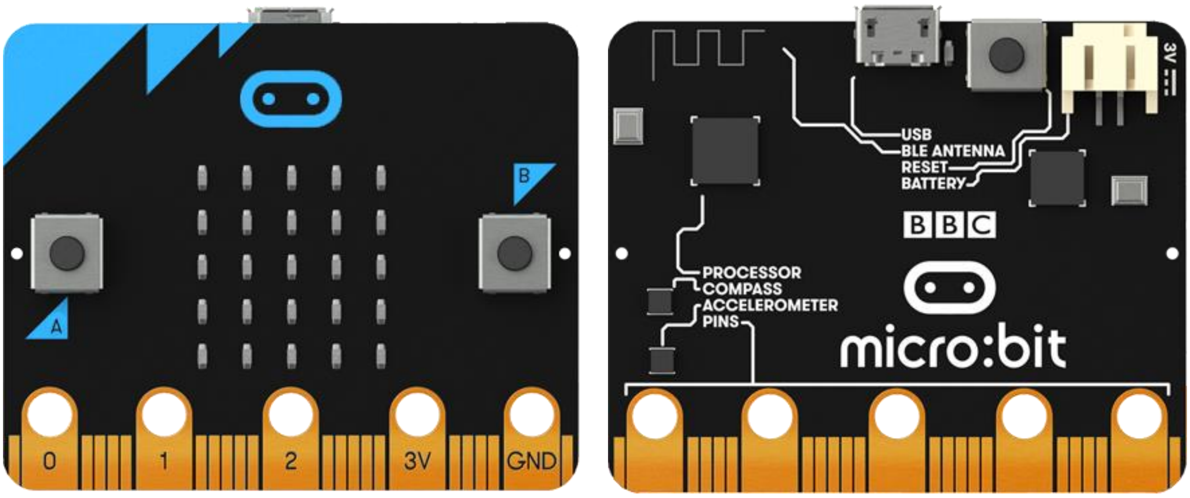
In each learning chapter of this tutorial, we provide program source code with detailed program explanations and burnable binaries, so that you can understand the meaning of each section of program.

Additionally, if you have any difficulties or questions about this tutorial and the kit, you can always ask us for quick and free technical support.

# Micro:bit

This chapter is the Start Point in the journey to build and explore Micro:bit and Micro:Rover electronic projects.

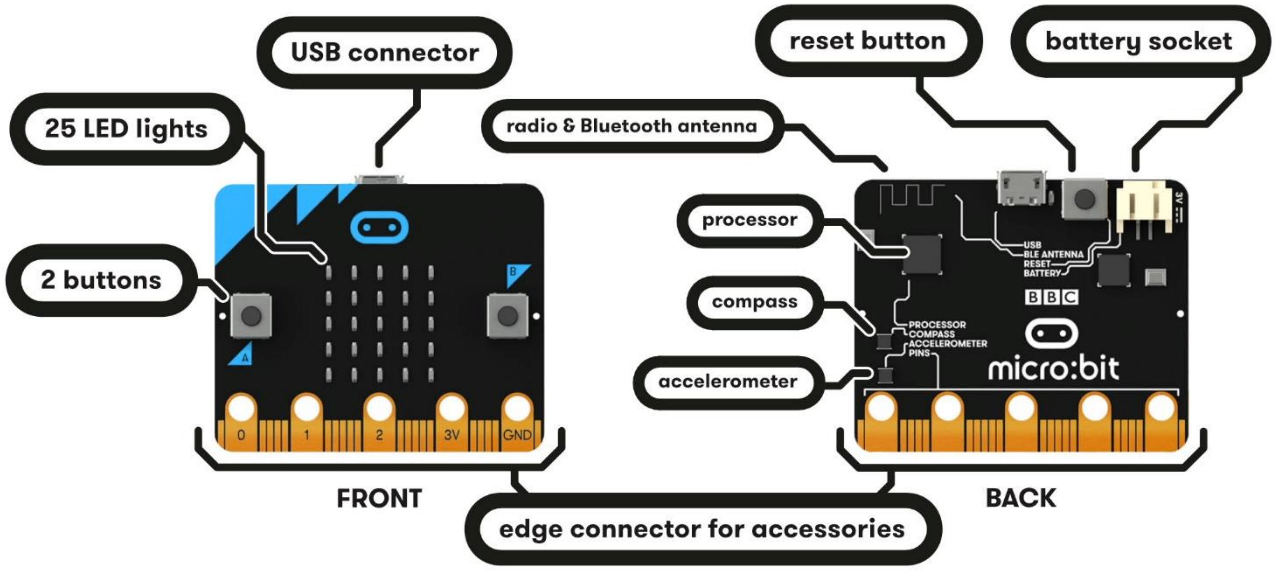
## Meet micro:bit




The BBC micro:bit is a pocket-size, programmable micro-computer that can be used for all sorts of cool creations, from robots to musical instruments – the possibilities are infinite.

For more contents, please refer to:
https://microbit.org/guide/

# Features




Your micro:bit has the following physical features:

- 25 individual programmable LEDs
- 2 programmable buttons
- Physical connection pins
- Light and temperature sensors
- Motion sensors (accelerometer and compass)
- Wireless Communication, via Radio and Bluetooth
- USB interface

For more details, please refer to:
https://microbit.org/guide/features/

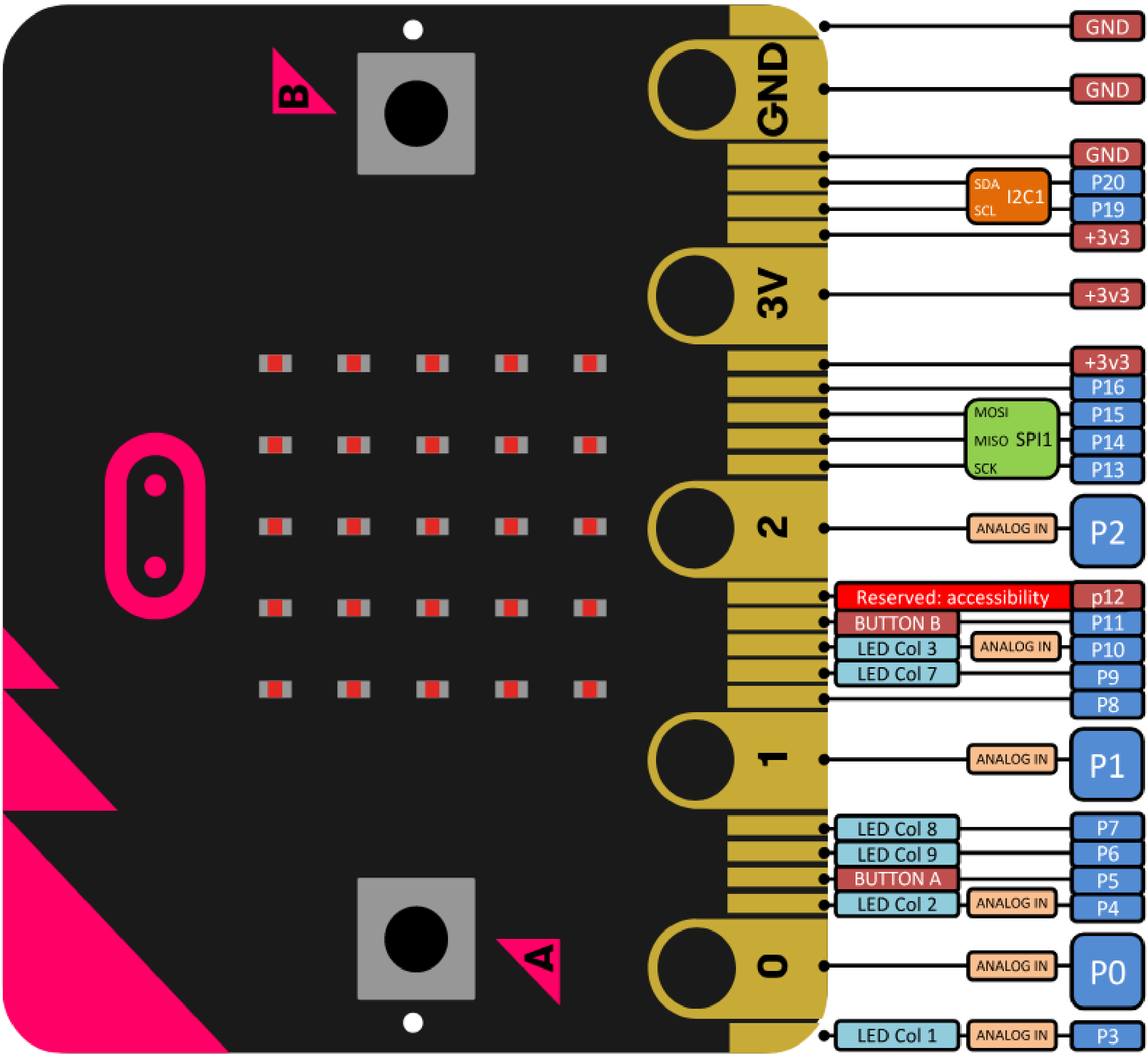
# Hardware

It is not required for beginners to master this section, but a brief understanding is necessary. However, if you want to be a developer, hardware information will be very helpful. Detailed hardware information about micro:bit can be found here: https://tech.microbit.org/hardware/.

First, get to know the micro:bit GPIO.

## GPIO

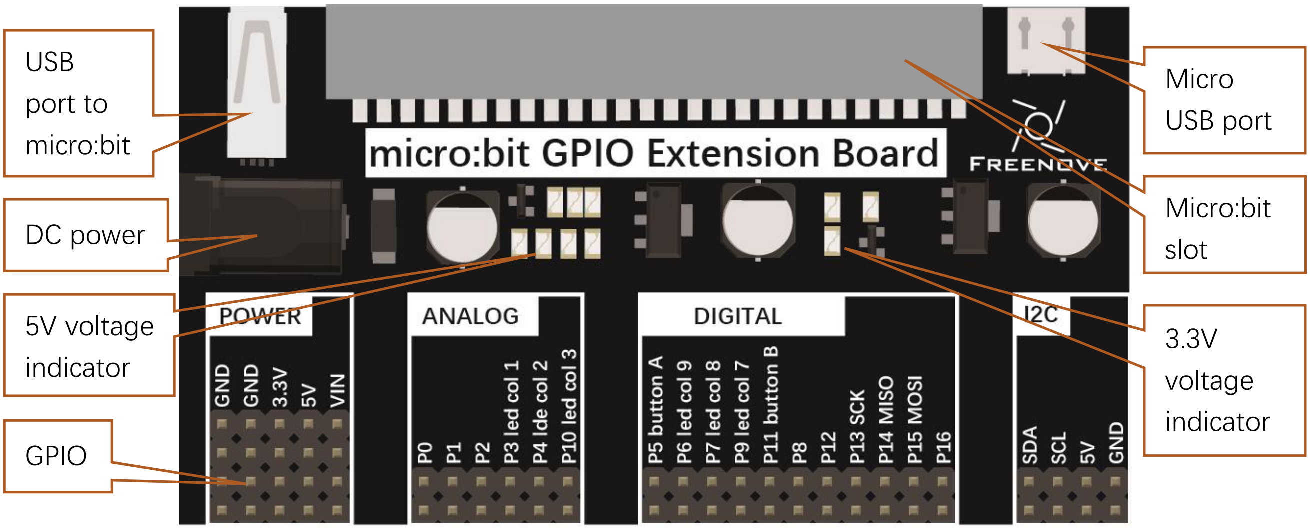
GPIO, namely General Purpose Input/output Pins, is an important part of micro:bit for connecting external devices. All sensors and devices on Rover communicate with each other through micro:bit GPIO. The following is the GPIO serial number and function diagram of micro:bit:



# Micro:bit GPIO Extension Board

## Hardware and Feature

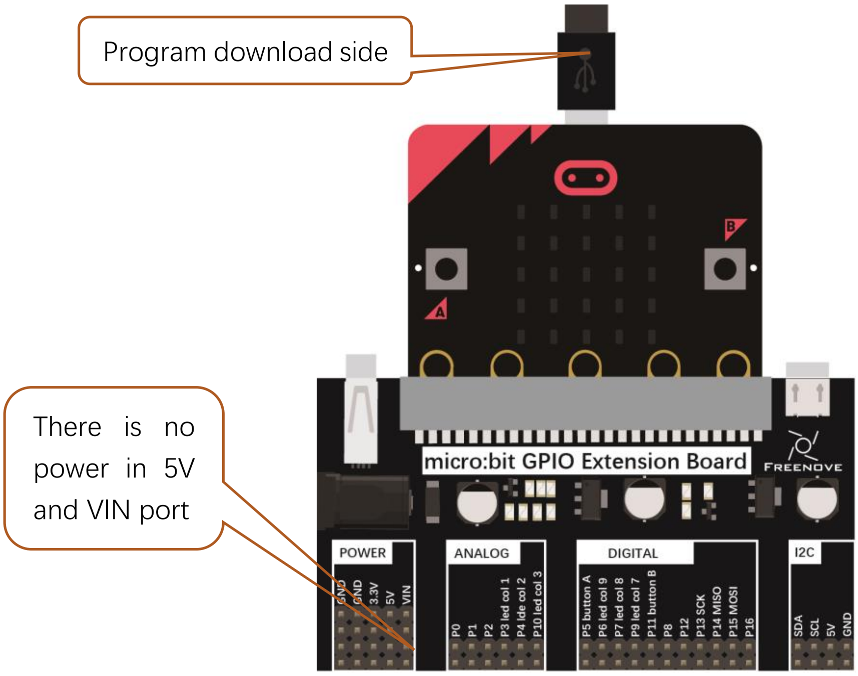
Micro:bit GPIO Extension Board is shown as below:



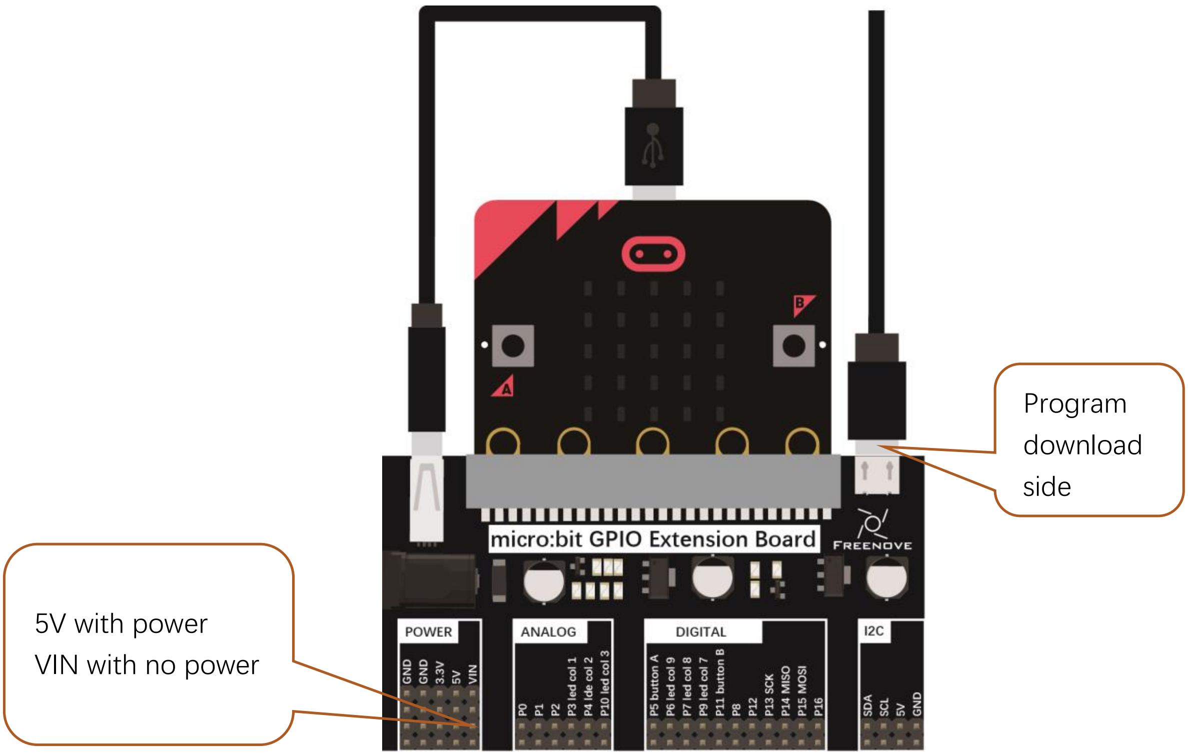

Micro:bit GPIO Extension Board is connected to micro:bit board via a slot with its GPIO connected to micro:bit's GPIO. In addition, there are also 5V and VIN(9V) IO port on the extension board to meet requirement of more devices.

# How to use?

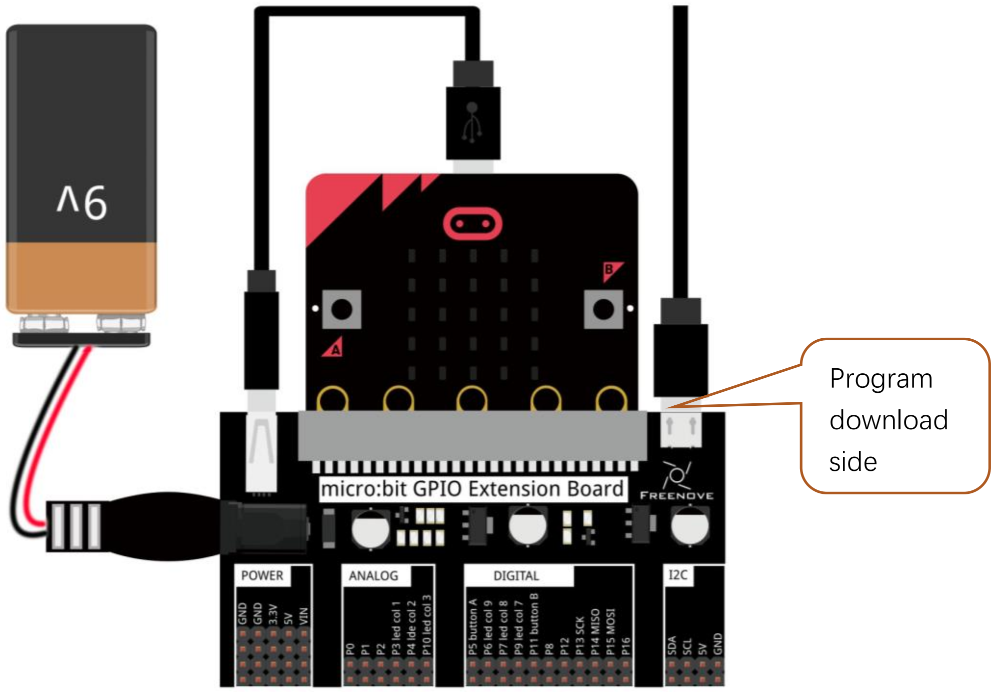
If external device doesn't require voltage of 5V and 9V, you can use the following wiring.




If external device uses 5v voltage, but power needed is not large, you can use the following wiring.



If external device uses 5v voltage, but power needed is large, you can use the following wiring.



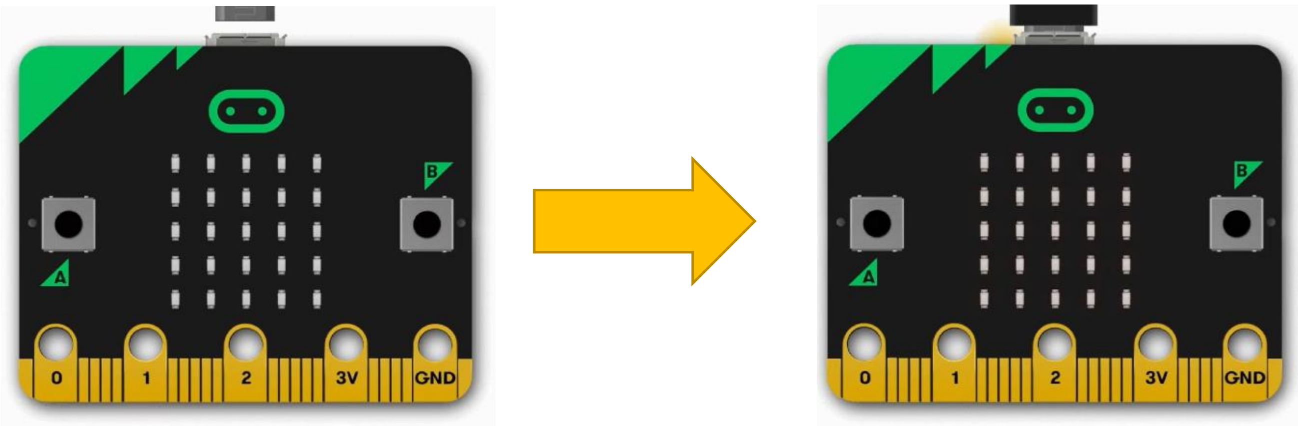
# Code & Programming

## Quick Start

This section describes how to write programs for micro:bit and how to download them to micro:bit. There are very detailed tutorials on the official website. You can refer to: [Https://microbit.org/guide/quick/](Https://microbit.org/guide/quick/).

### Step 1: Connecting Micro:bit

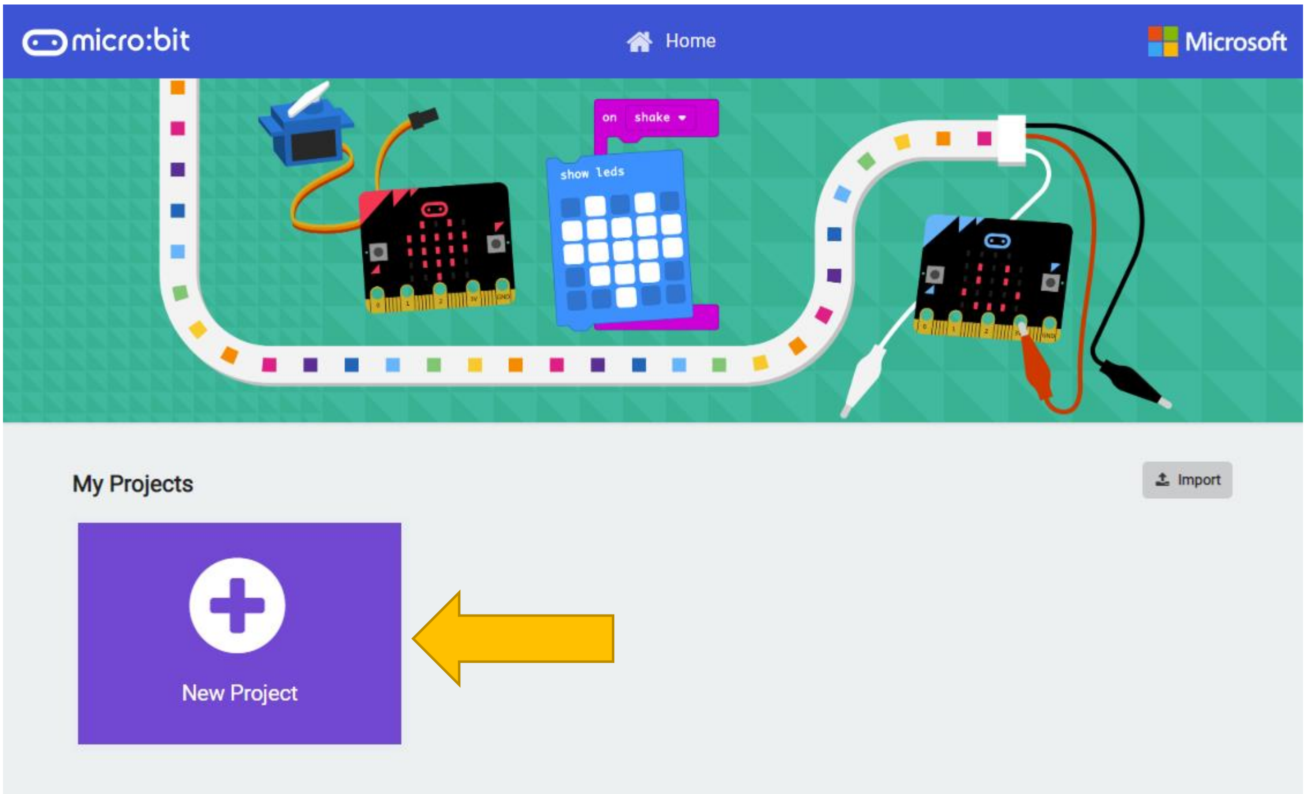
Connect the micro:bit to your computer via a micro USB cable. Macs, PCs, Chromebooks and Linux systems (including Raspberry Pi) are all supported.



## Step 2: Write Program

Visit https://makecode.microbit.org/. Then click "New Project" and start programming.

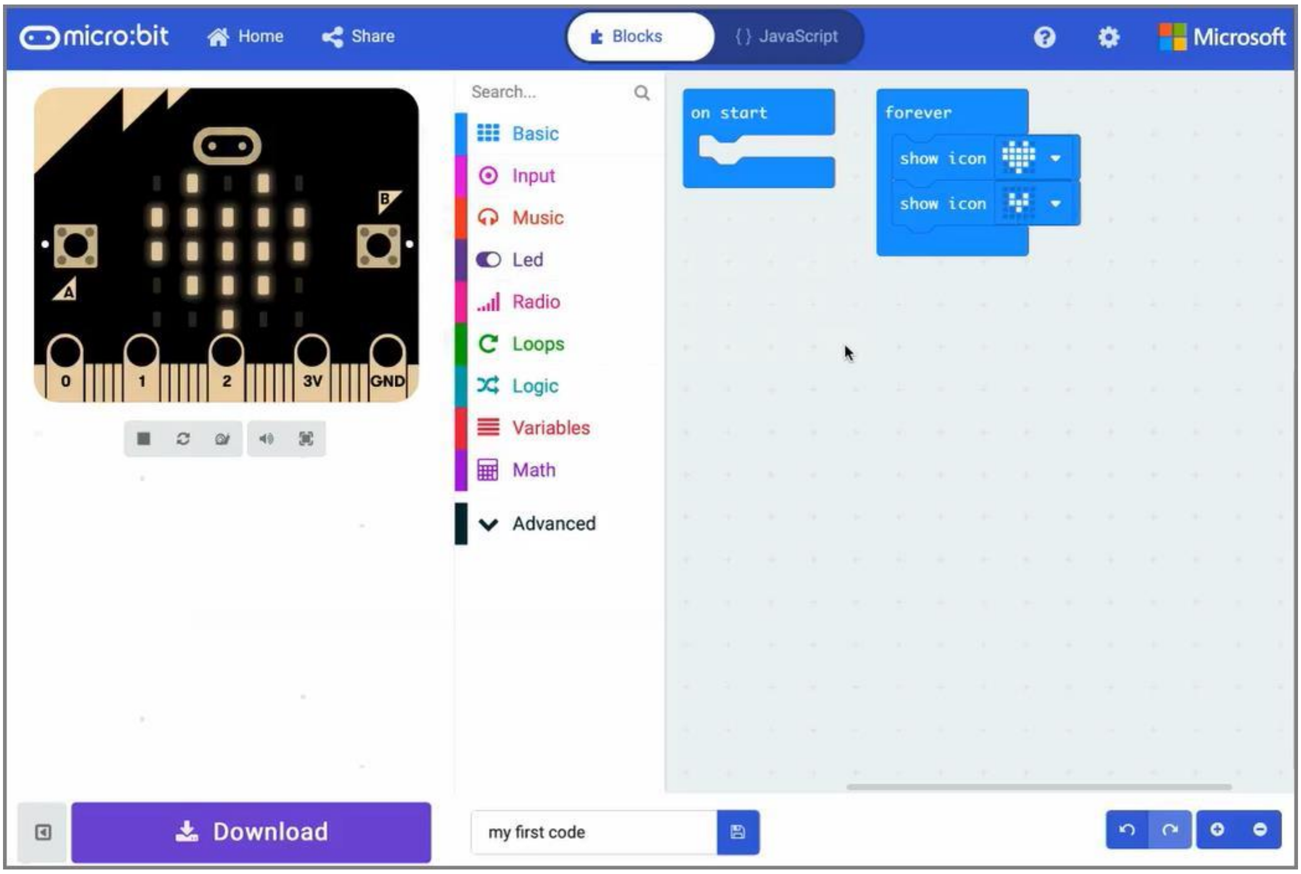
If your computer has Windows 10 operating system, you can also use Windows 10 App for programming, which is exactly the same as programming on browsers. Get windows 10 App(Click).



Write your first micro:bit code. For example, drag and drop some blocks and try your program on the Simulator in the MakeCode Editor, like in the image below that shows how to program a Flashing Heart.

Here is a demo video: https://microbit.org/images/quickstart/makecode-heart.mp4

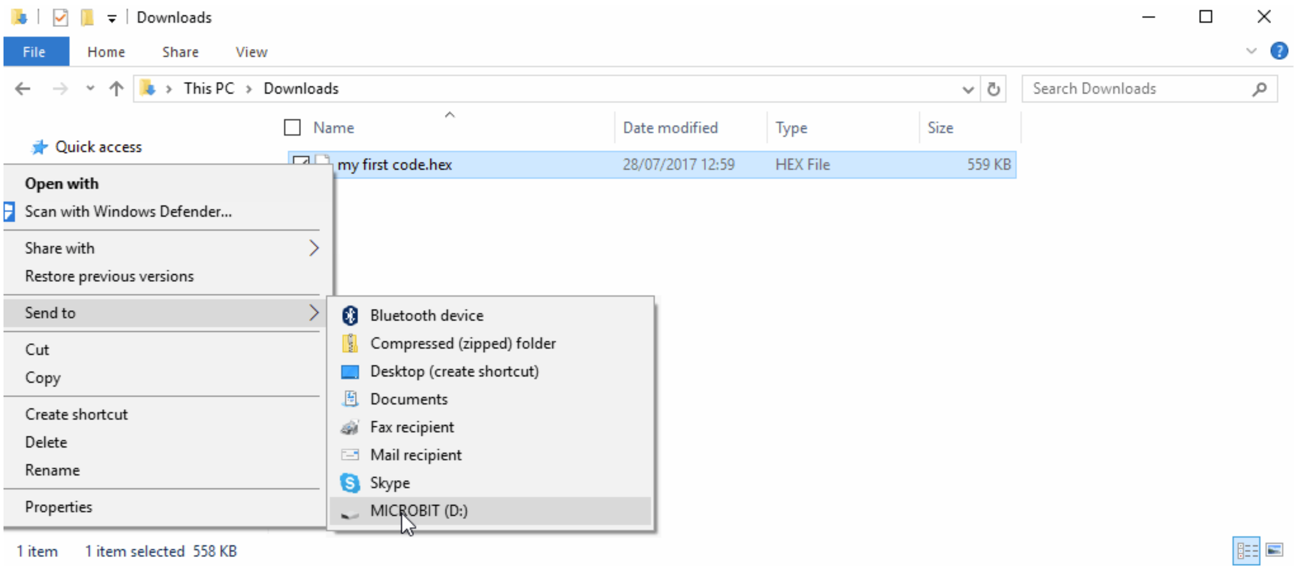
MakeCode will be further introduced in next section.



## Step 3: Flashing Code to your Micro:bit

The process of transferring the .HEX file to the BBC micro:bit is called flashing.
If you write program using Windows 10 App, you just need to click the “Download” button, then the program will be downloaded directly to micro:bit without any other actions.

If you write program using browser, please follow steps below:
Click the Download button in the editor. This will download a 'hex' file, which is a compact format of your program that your micro:bit can read. Once the hex file has been downloaded, copy it to your micro:bit just like copying a file to a USB drive. On Windows you can right click and choose "Send to→MICROBIT."




## Step 4: Run the Program

The micro:bit will pause and the yellow LED on the back of the micro:bit will blink while your code is flashed. Once that's finished the code will run automatically! The micro:bit can only run one program at a time - every time you drag-and-drop a hex file onto the device over USB it will erase the current program and replace it with the new one.

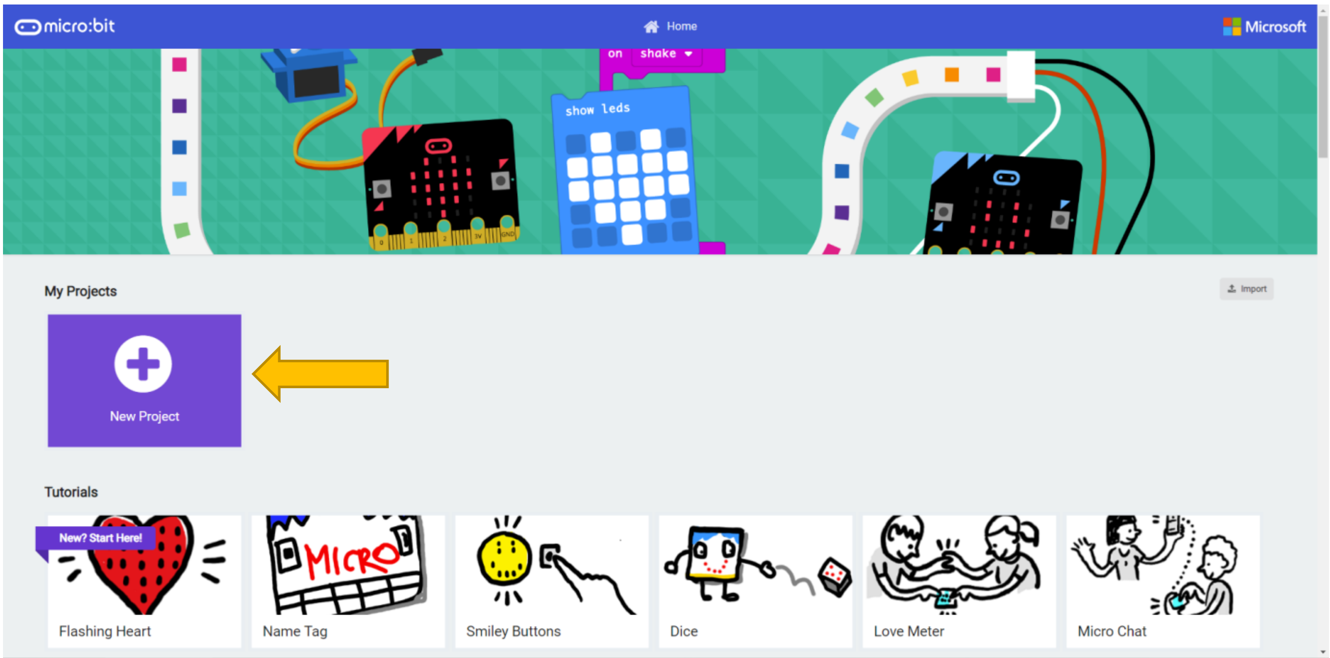
## Warning

**The MICROBIT drive will automatically eject and reconnect each time you program it, but your hex file will be gone. The micro:bit can only receive hex files and won't store anything else!**

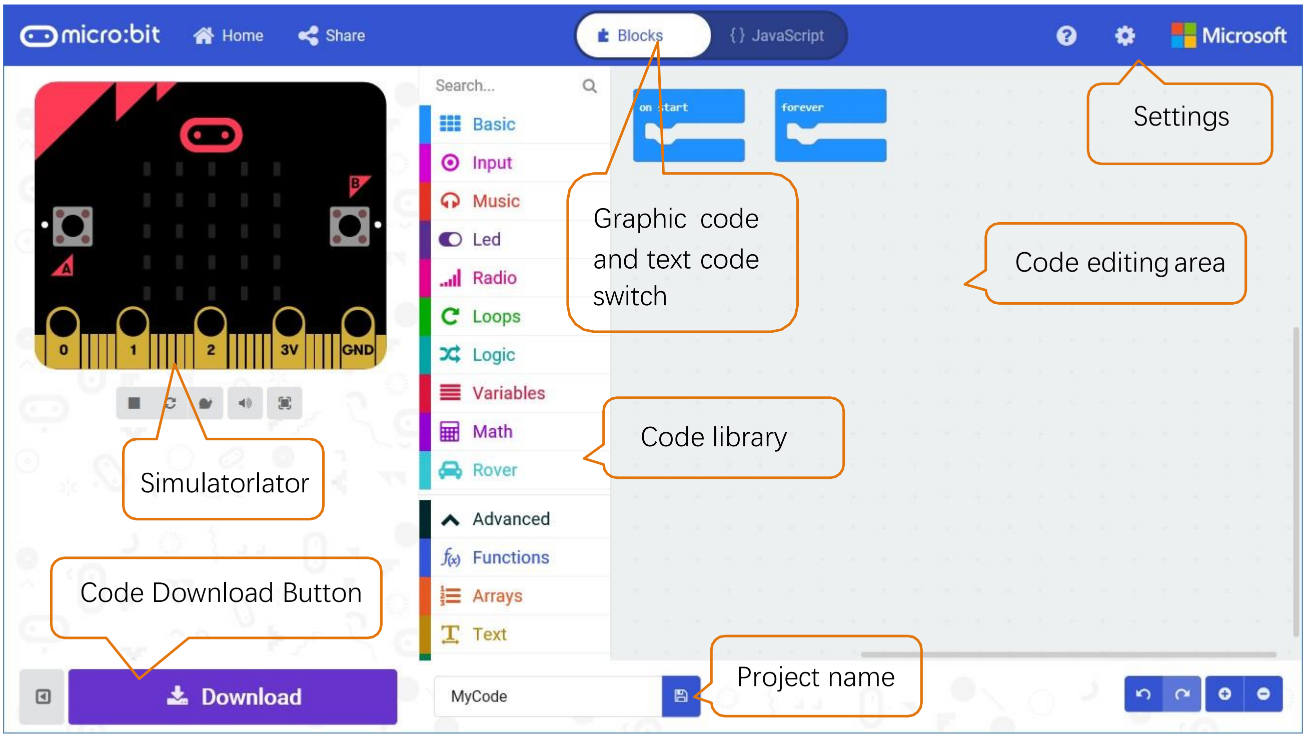
# MakeCode

Open web version of [MakeCode](https://makecode.microbit.org/) or **windows 10 app version of MakeCode**, which can be downloaded on **Microsoft store.**

https://makecode.microbit.org/




Click "New Project", MakeCode editor is as below:




In the code area, there are two fixed blocks "on start" and "forever".

The code in the "on start" block will be executed only once after power-on or reset. And the code in "forever" block will be executed circularly.

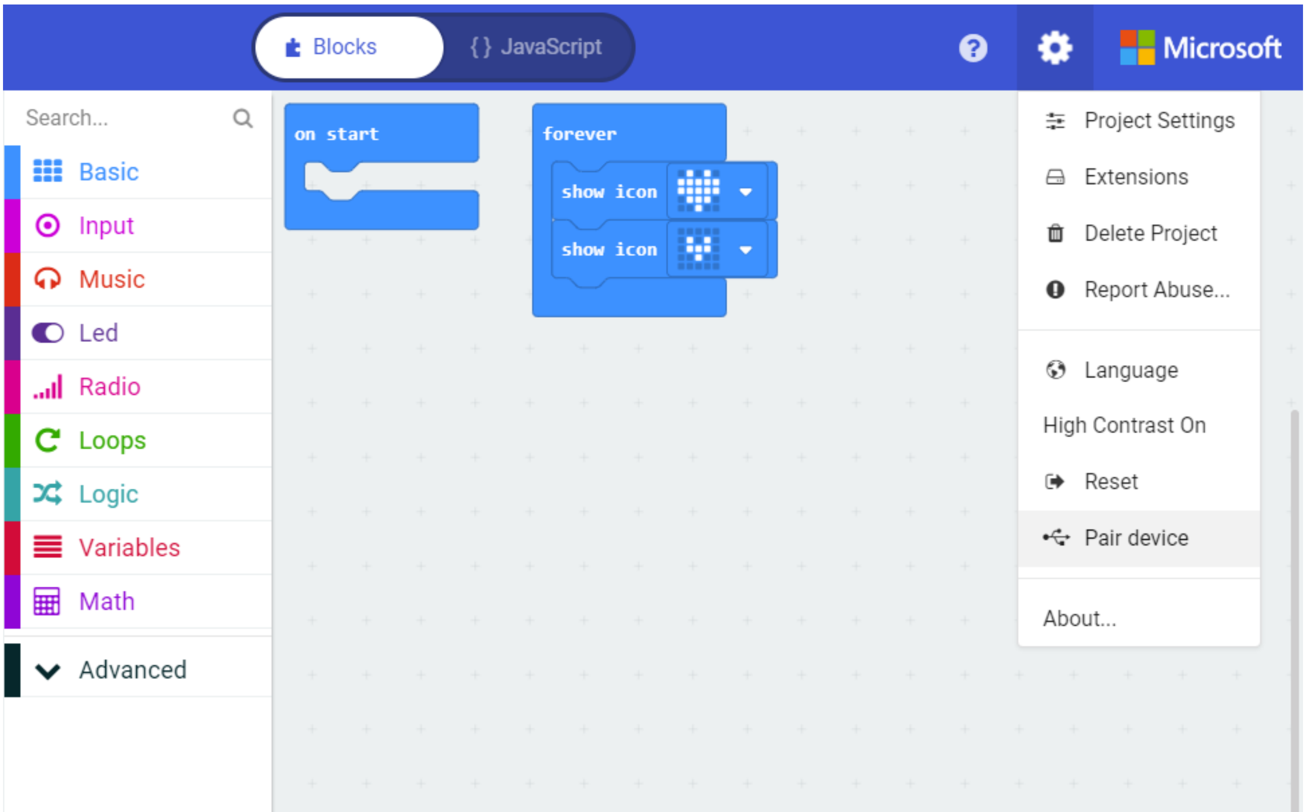
# Quick Download

As mentioned earlier, if you use **Windows 10 App of MakeCode (recommended)**, you can **quickly** download the code to micro:bit by **clicking the download button**. Using **browser version of MakeCode** may require **more steps**.

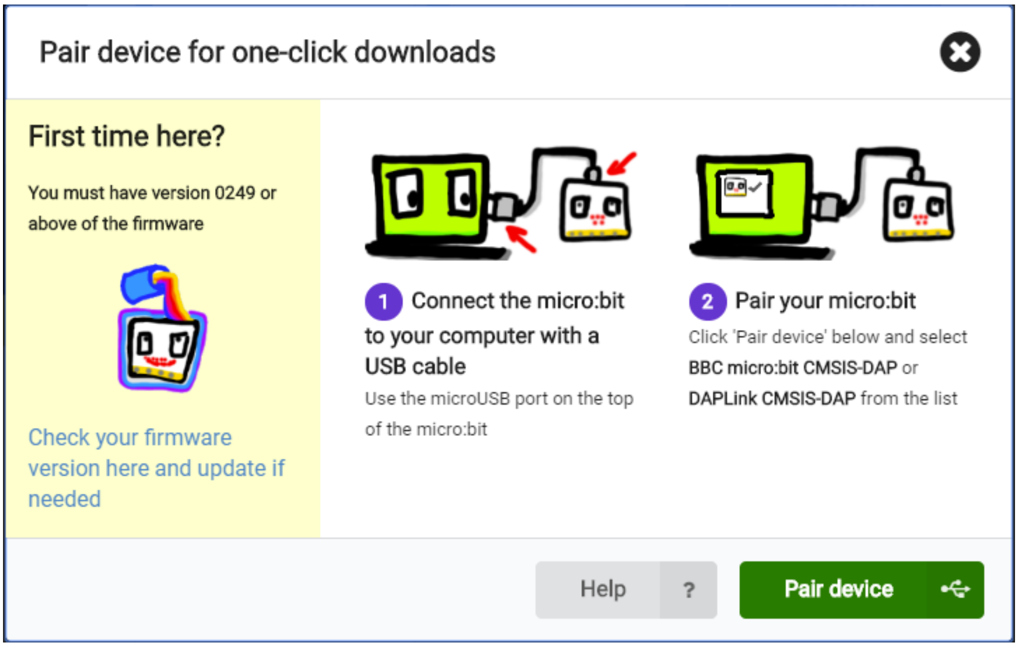
If you use browser version of MakeCode on **Google Chrome 65+ for platform Android, Chrome OS, Linux, macOS and Windows 10**, you can also download file quickly.
Here we use webUSB feature of Chrome, which allows web pages to access your USB hardware devices. We will complete the connection and pairing of the micro:bit device with the webpage in the following steps.

## Pair device

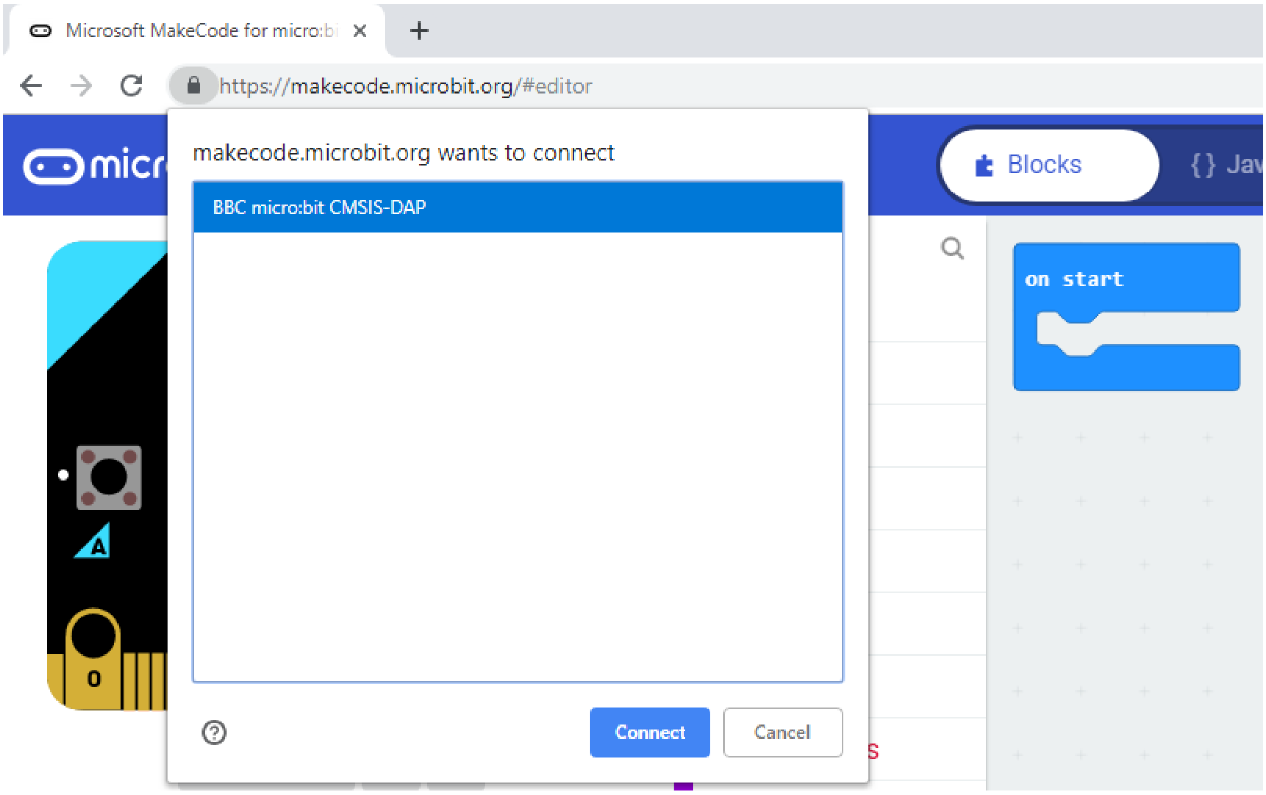
Connect your computer and Micro:bit with a USB cable.
Click the gear menu in the top right corner and then click on "Pair device".




Then continue to click "Pair device" button.




Select device on the pop-up window and click "Connect" button. If there are no devices shown on the pop-up window, please refer to following content:
https://makecode.microbit.org/device/usb/webusb/troubleshoot
We have save the page as a file "**Troubleshooting downloads with WebUSB - Microsoft MakeCode.pdf**". You can read it directly in the folder of this tutorial.
And the file "**Firmware microbit.pdf**" introduces how to update firmware of micro:bit. Its content come from:
https://microbit.org/guide/firmware/




After the connection succeeds, click the Download button and the program will be downloaded directly to Micro: bit.

# Import Code

We provide hex file (project files) for each project, which contains all the contents of the project and can be imported directly. You can also complete the code of project manually. If you choose to complete the code by dragging code block, you may need to add necessary extensions.

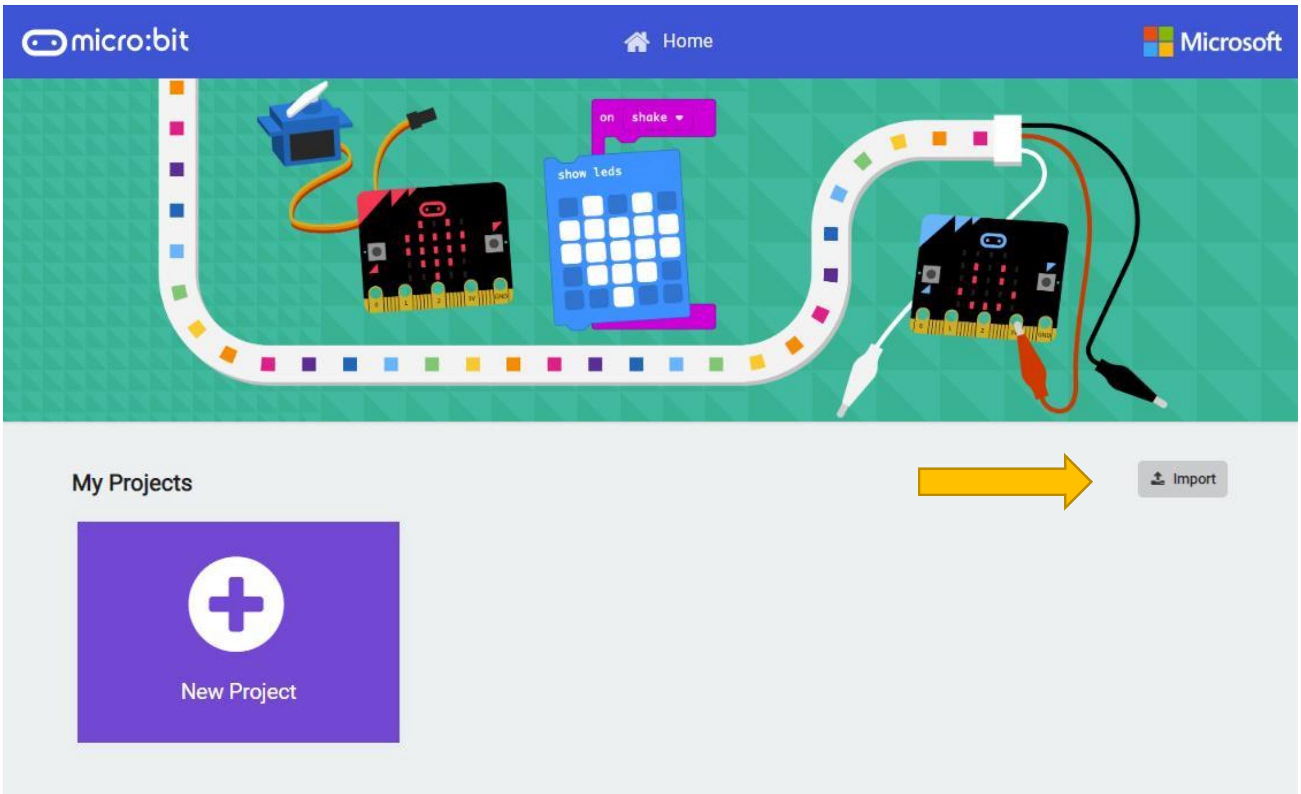
**As for simple projects, it is recommended to complete the project by dragging code block.**

**As for complicated projects, it is recommended to complete the project by importing Hex code file.**

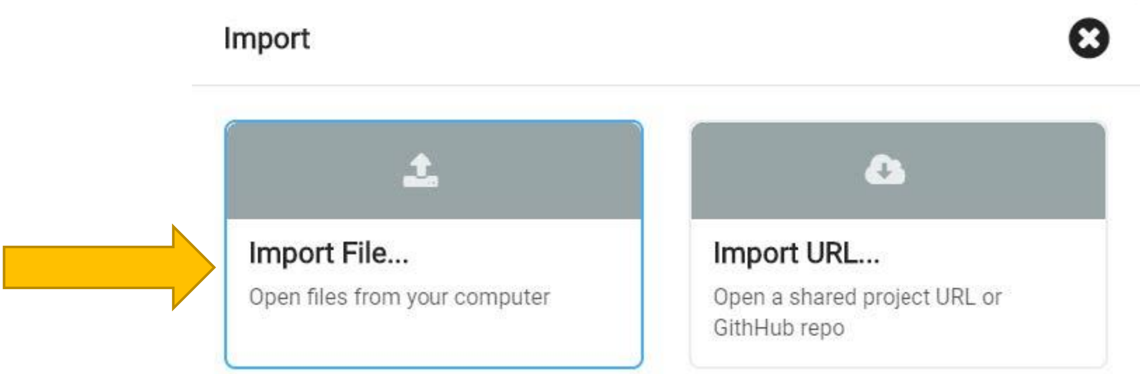
Next, we will take "Heartbeat" project as an example to introduce how to load code.

Open web version of [makecode]() or windows 10 app version of MakeCode.

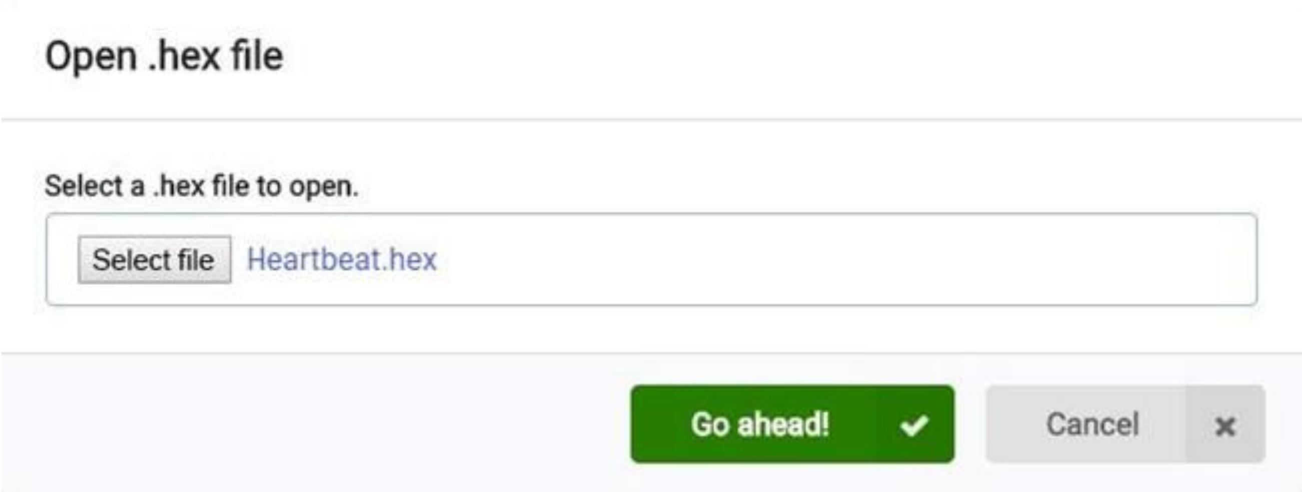
Click "Import" button on the right of HOME page.



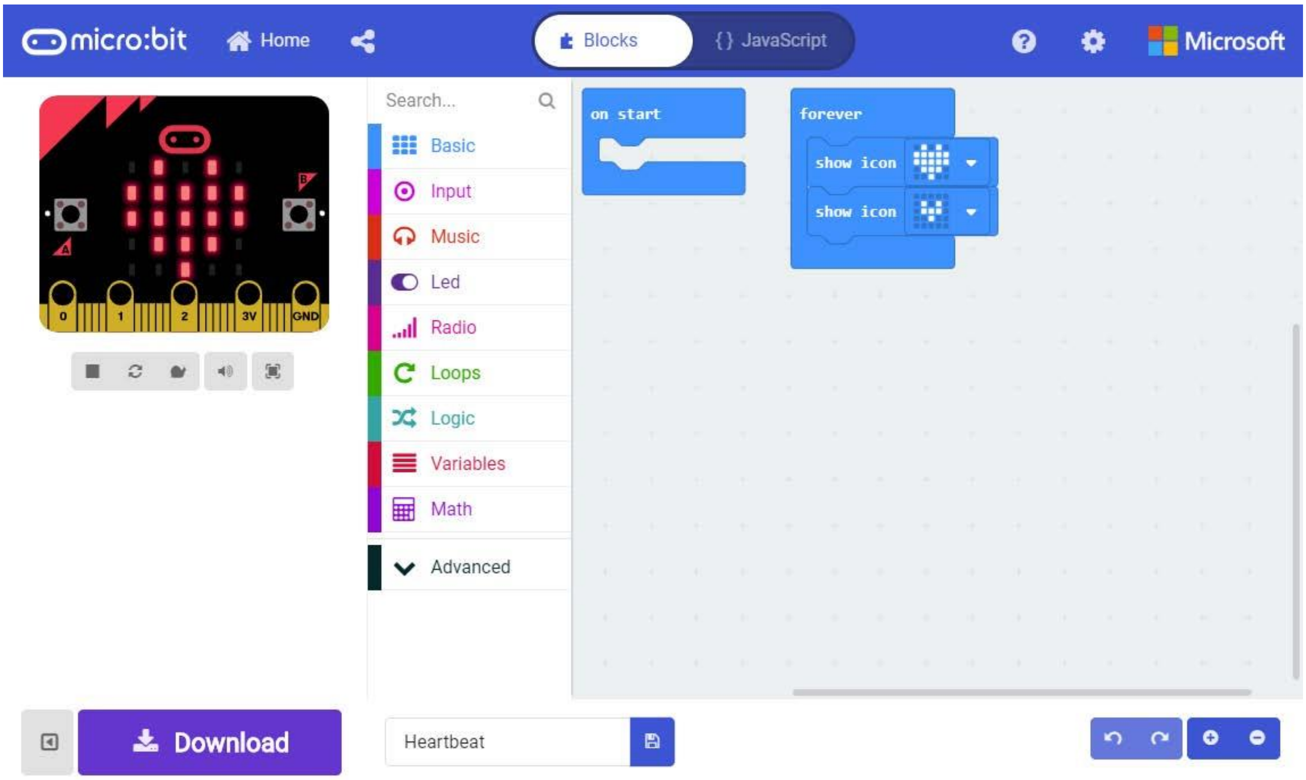

In the pop-up dialog box, click "Import File".



Select file“.. Projects/BlockCode/01.1_Heartbeat/Heartbeat.hex”. Then click “Go ahead!”




A few seconds later, the project is loaded successfully.

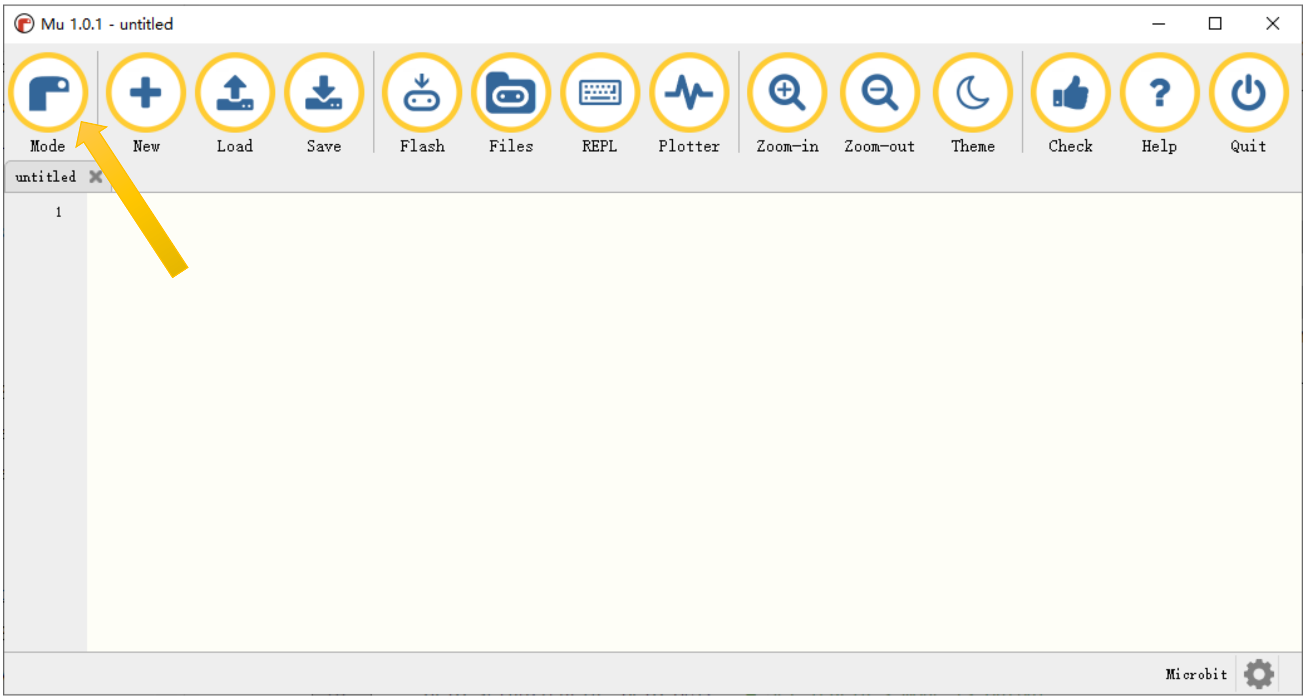


# Python

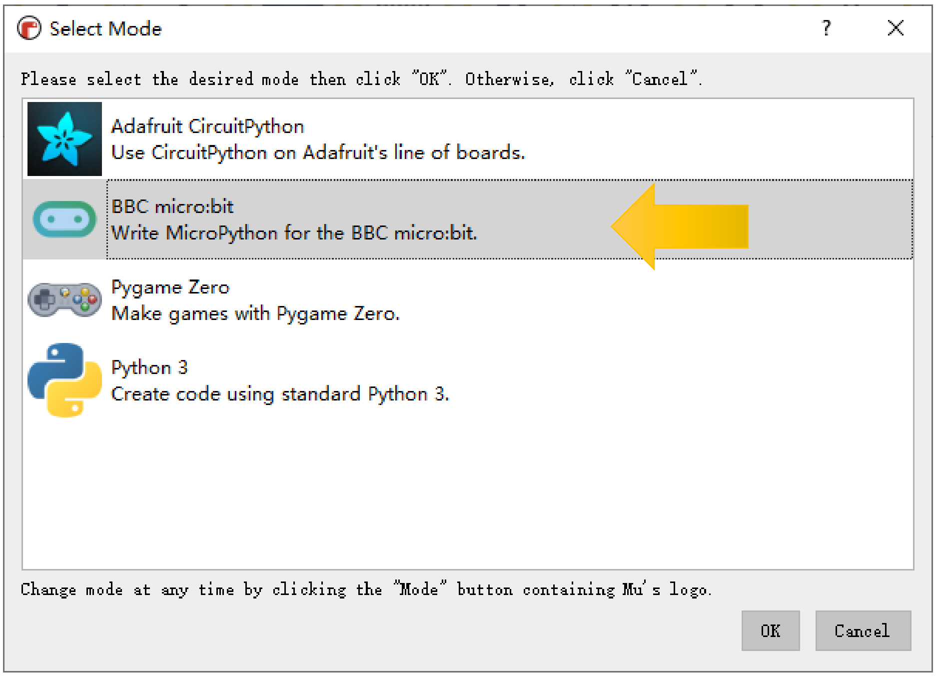
If you are not interested in python, you can skip this section.
Micro:bit can be programmed in Python. Since micro:bit is a microcontroller, the hardware difference makes it not support pure Python. Here we use MicroPython, which is specially designed for micro:bit.
MicroPython is a lean and efficient implementation of the Python 3 programming language that includes a small subset of the Python standard library and is optimized to run on microcontrollers and in constrained environments.
We designed block code and Python code with similar function for each project.
There are two kinds of python editors for micro:bit, web version and software.
**It is highly recommended to use software Mu as a Python educator.**
Mu. (https://codewith.mu/en/download)
Next, we will introduce Mu.

## Mu

Mu is a Python code editor for beginner programmers based on extensive feedback given by teachers and learners.
Official website: https://codewith.mu/
You can download it here: https://codewith.mu/en/download
Download and install it.
And you will see the following interface when opening it.




Click the Mode button in the menu bar and select "BBC micro:bit" in the pop-up dialog box. Click "OK".

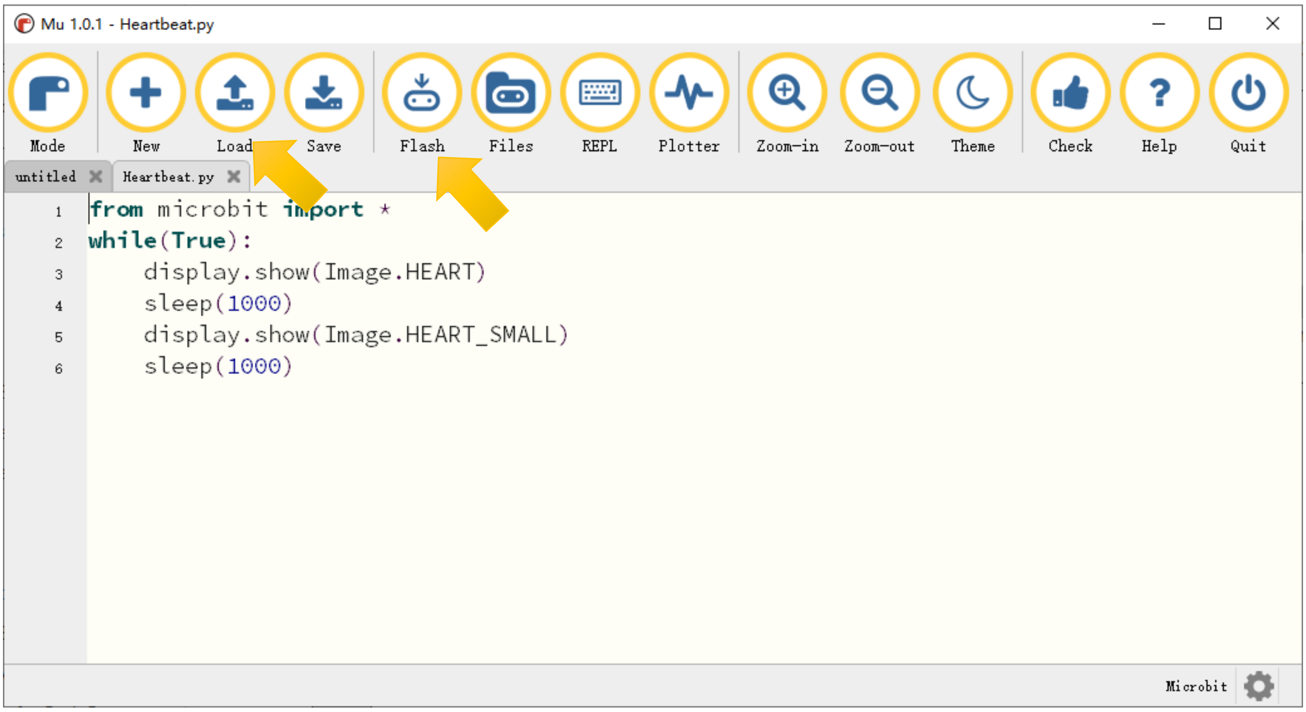



Import the .hex file. The path is as below:

| File type | Path | File name |
|---|---|---|
| **Python file** | ../project/1.1.Heartbeat | Heartbeat.py |

Successful loading is shown below.

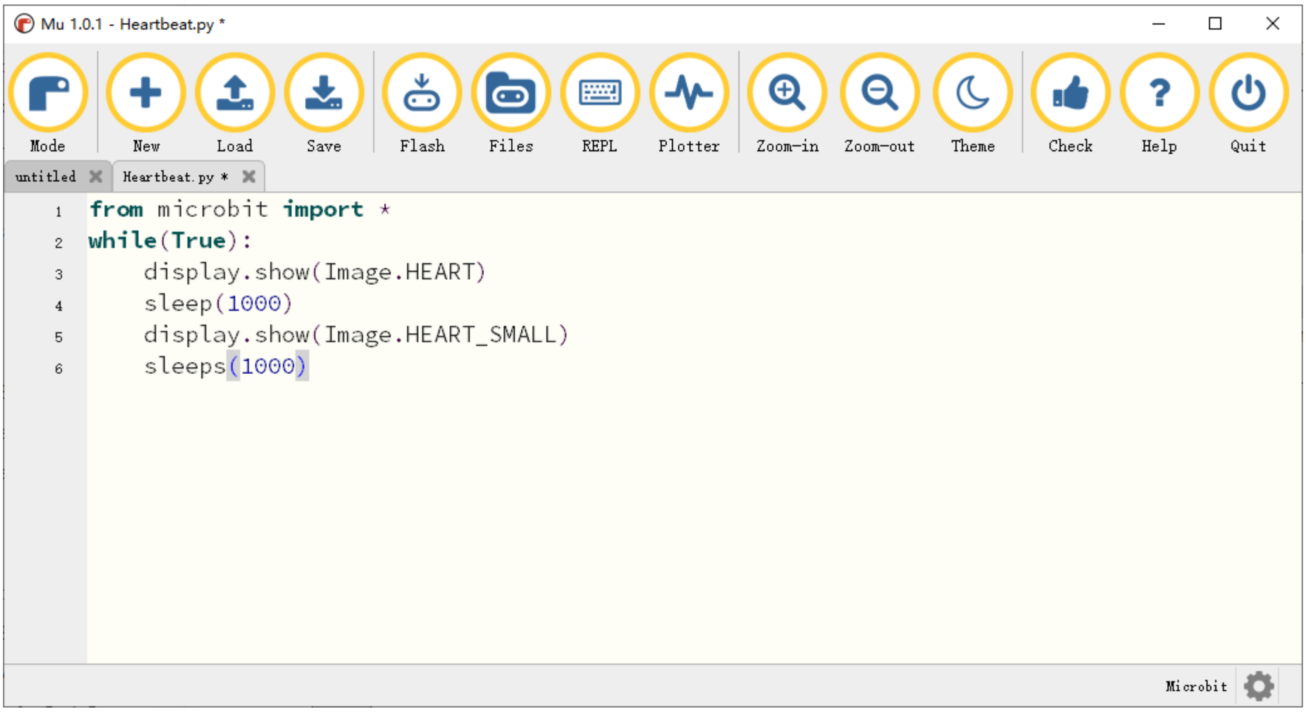
You can also type the code by yourself.



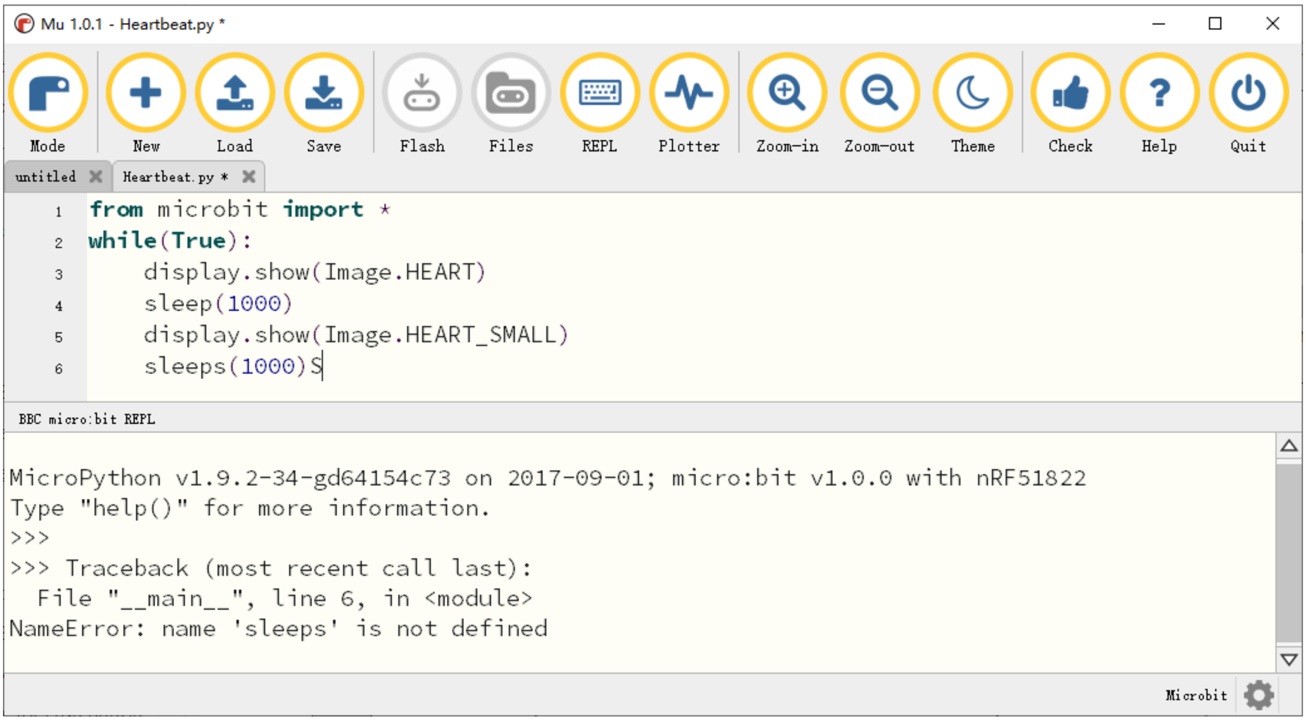

Use the micro USB cable to connect micro:bit and PC, and click the **Flash** button to download the program into micro:bit.

If there are errors in your code, you may be able to successfully download it to micro:bit, but it will not work properly.

For example, the function sleep() was written as sleeps() in the following illustration. Click the button and the code can be uploaded to Micro:bit successfully. However, after the downloading completes, LED matrix prompts some error information and the number of the wrong line.

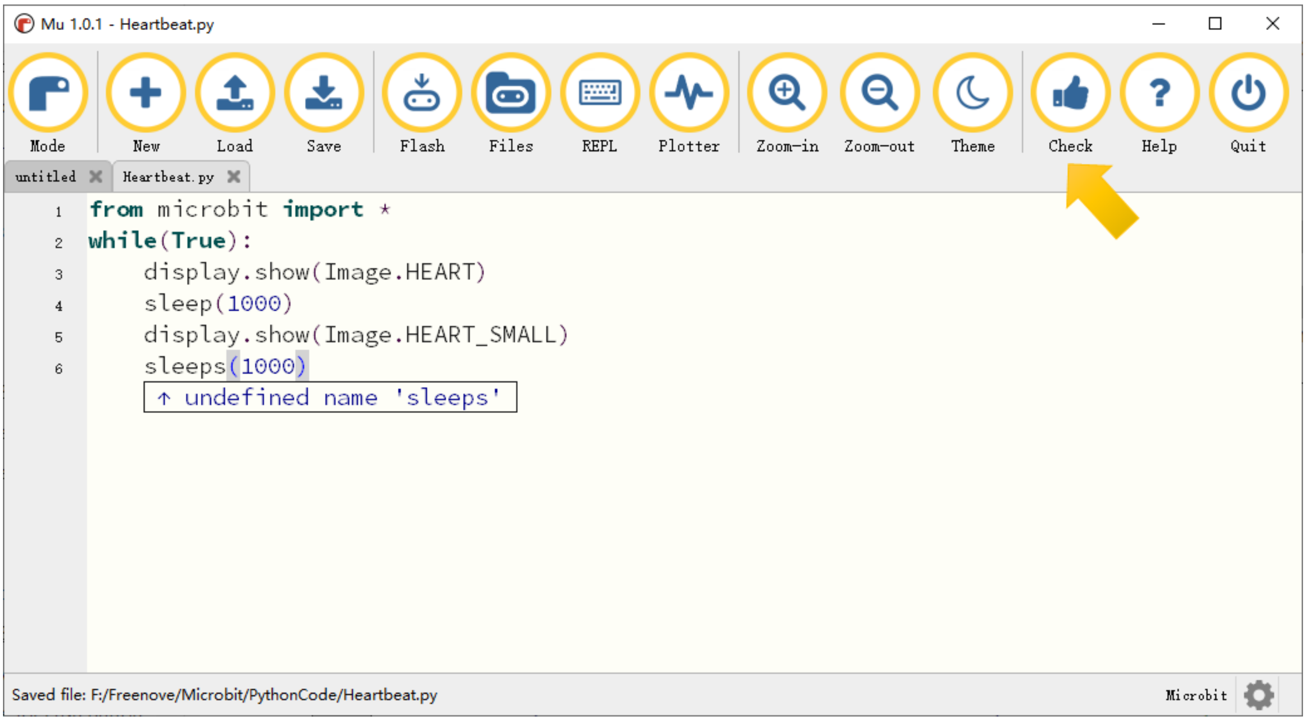



Click the “REPL” button and press the reset button (the button on the back, not A, B) on micro:bit. The error message will be displayed in the REPL box, as shown below:

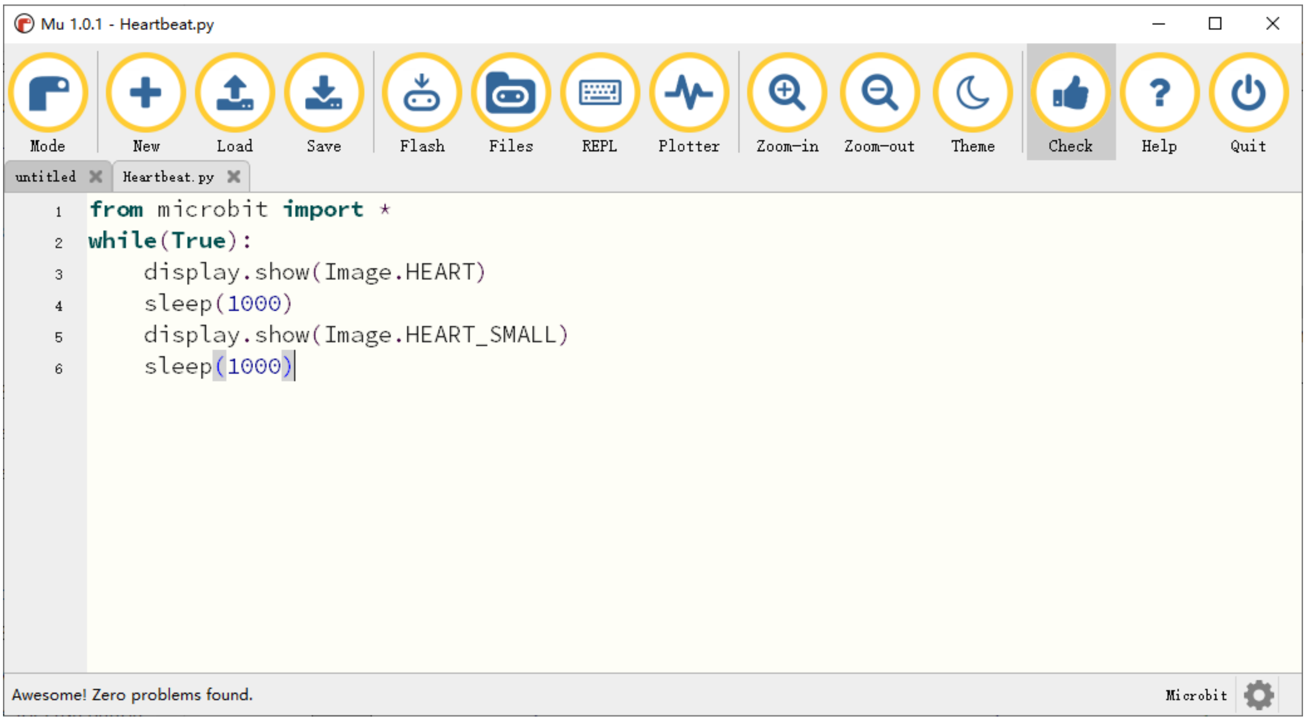



**Click REPL again**, you will close REPL mode. And then you can flash new code.

To ensure the code is correct, after completing the code, click the "**Check**" button to check the code for errors. As shown below, click the “Check” button. Then Mu will indicate the error of the code.




Correct the code according to the error prompt. Then click the "Check" button again, Mu displays no error on the bar below.

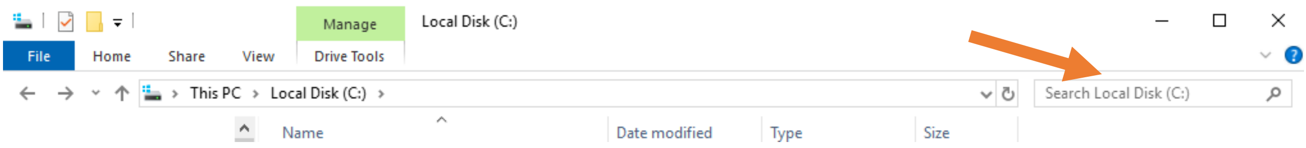


## Import necessary Python file into micro:bit

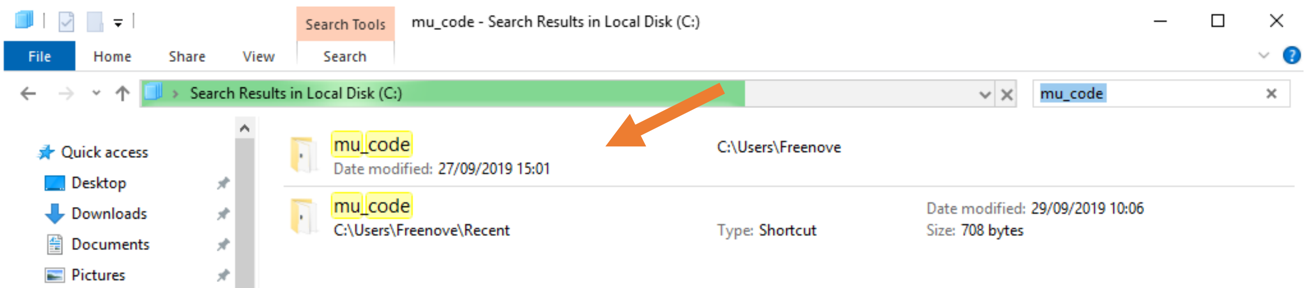
In the code of this tutorial, the LCD1602 module and DHT11 module are used, so it is necessary to import "I2C_LCD1602_Class.py" and "DHT11_RW.py" into the micro:bit. You can skip this section if you don't use them. When you need, you can come back to import them.

The import method is as follows:

Search on the C drive and find the "mu_code" folder.



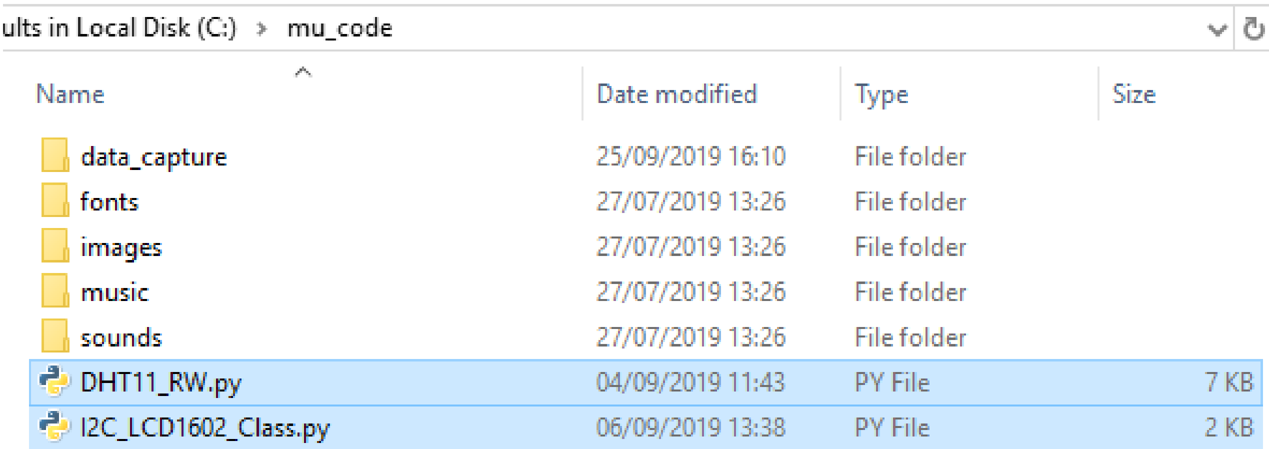

Double click on "mu_code" to enter the folder.



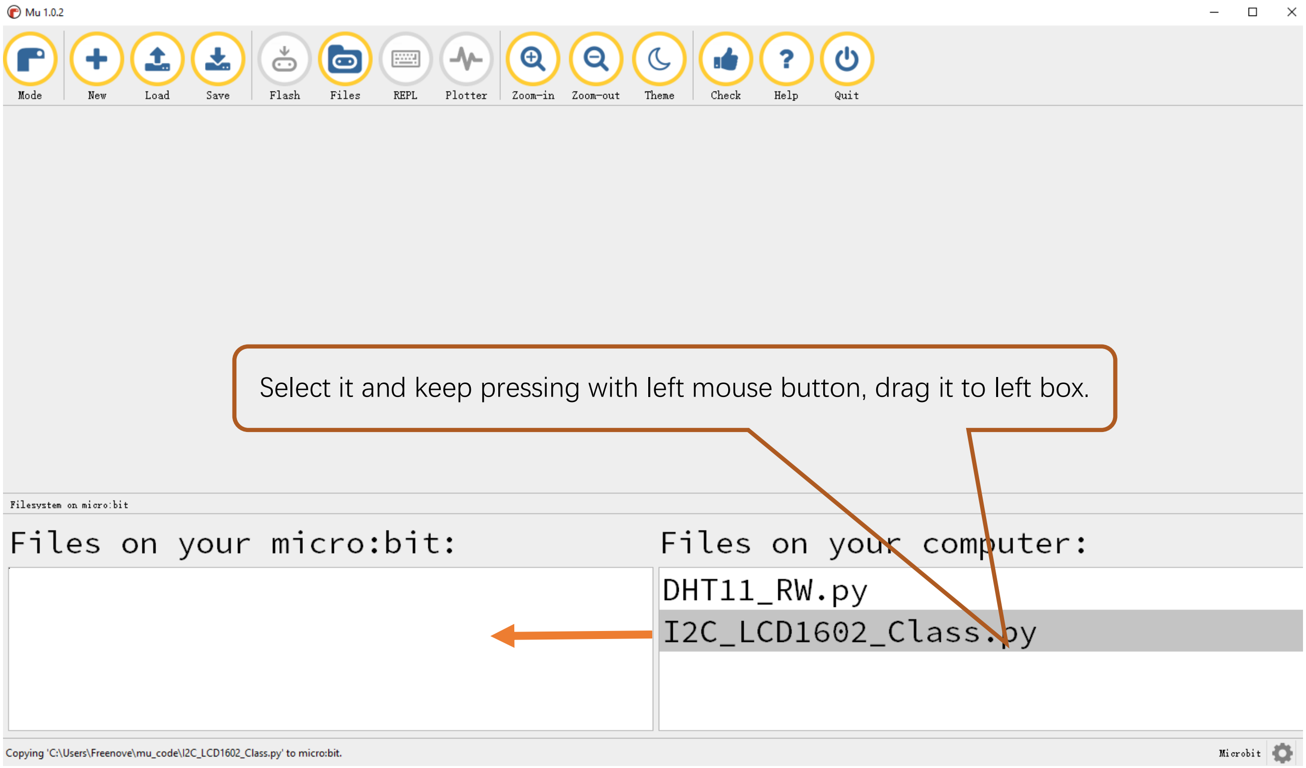

Copy "I2C_LCD1602_Class.py" and "DHT11_RW.py" from following path into "mu_code" directory.

| File type | Path | File name | |
|---|---|---|---|
| **Python file** | .. /Projects/PythonLibrary | I2C_LCD1602_Class.py | DHT11_RW.py |

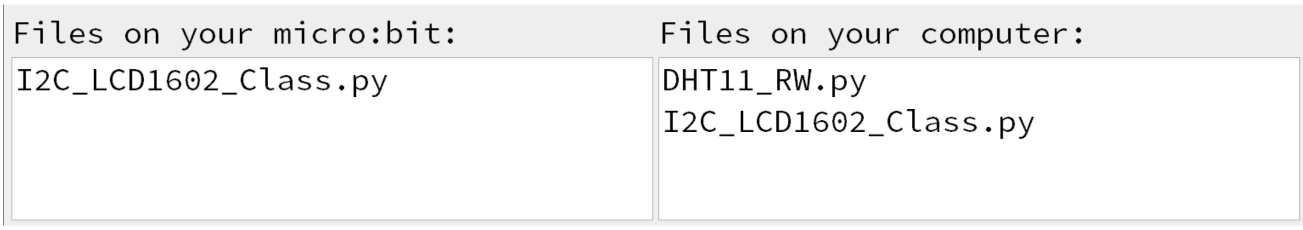
After pasting successfully, you can see them as below:



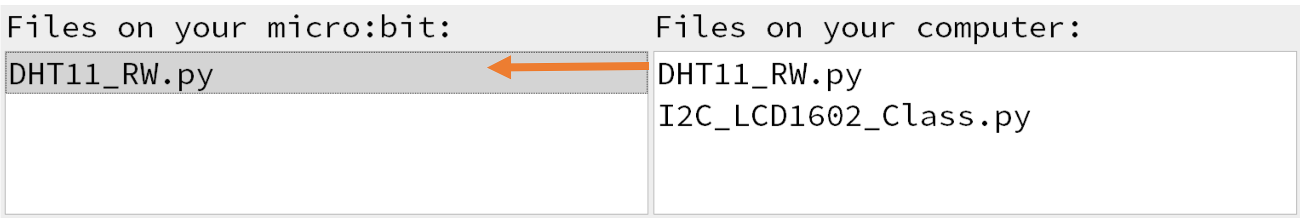
Open the Mu software, click "Files". Here we take "I2C_LCD1602_Class.py" as an example, drag "I2C_LCD1602_Class.py" into micro:bit.




After importing successfully, you will see it on the left.




The import method of "DHT11_RW.py" is the same as described above. You just need to import the one you need to use.




**Note, after you upload other file into micro:bit, the original content will be covered. You need to import it next time you use it.**

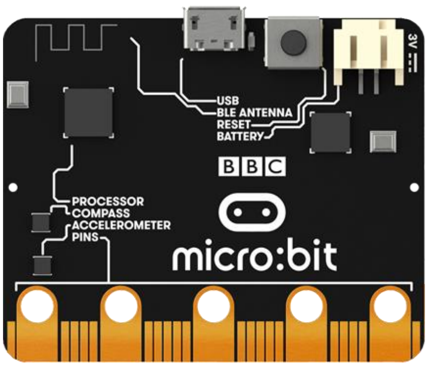
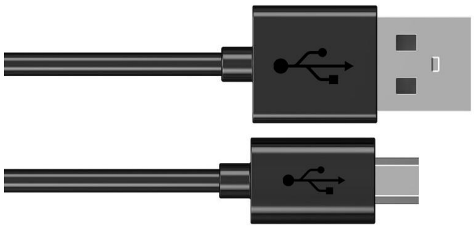
# Chapter 1 LED matrix

The micro:bit integrates a 5x5 LED matrix, which is used as a display to display numbers, text, or simple images, which is useful and interesting.

## Project 1.1 Heartbeat

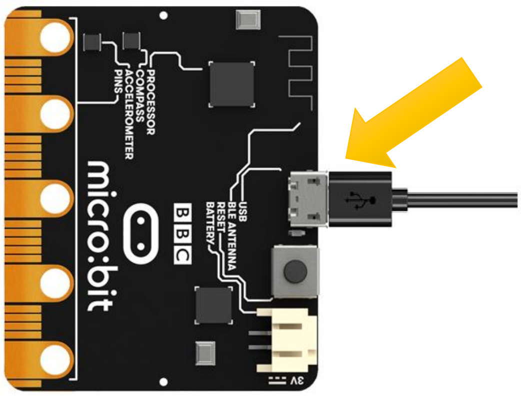
This project uses a pattern built in MakeCode to make a heartbeat animation.

### Component List

| micro:bit x1 | micro USB cable x1 |
|---|---|
|  |  |

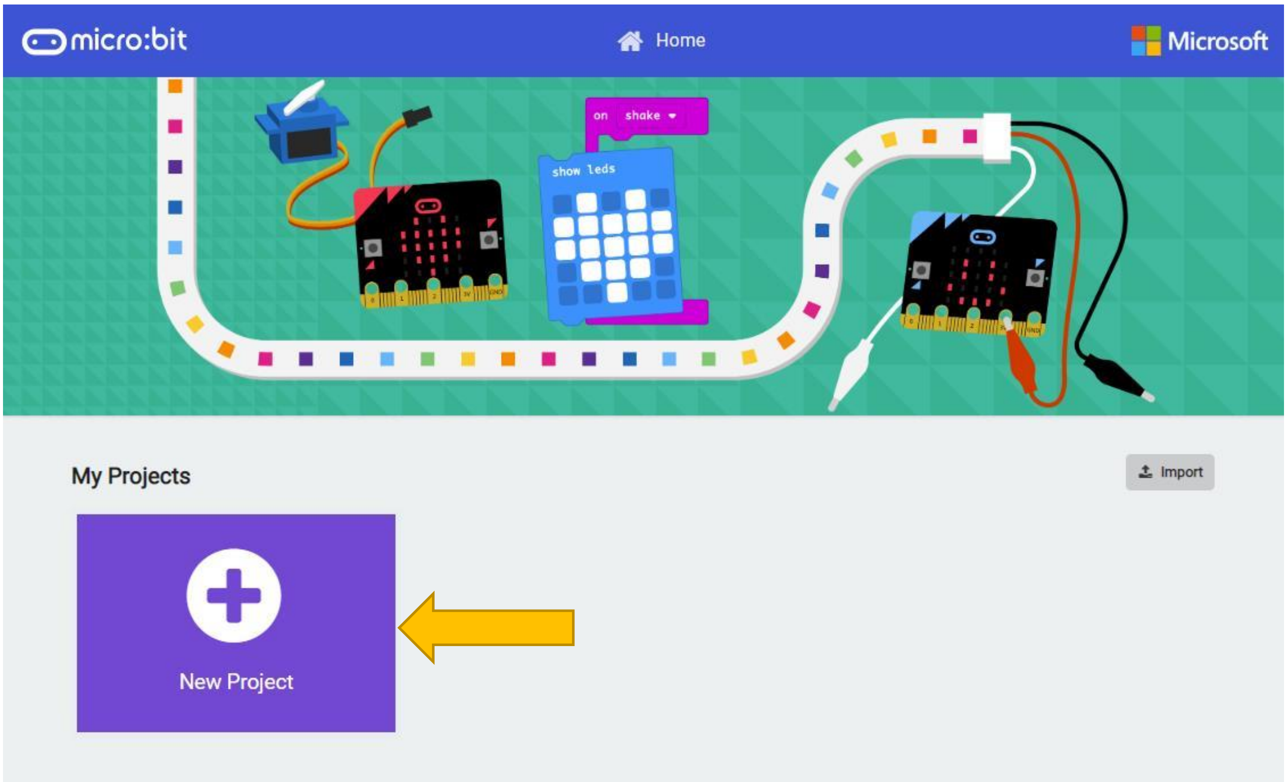
### Circuit

Connect micro:bit and PC via a micro USB cable.

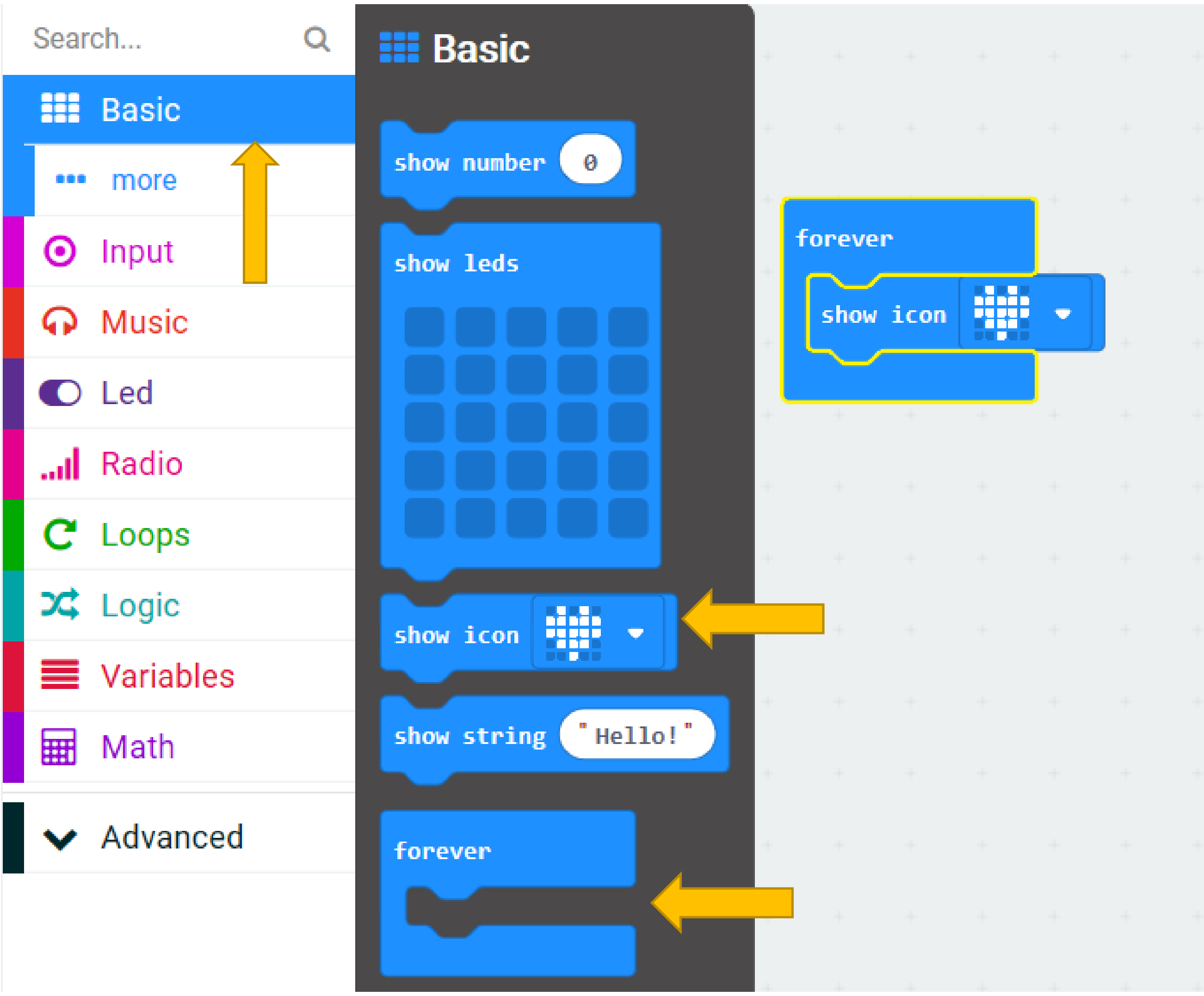
| Hardware connection |
|---|
|  |

## Block code

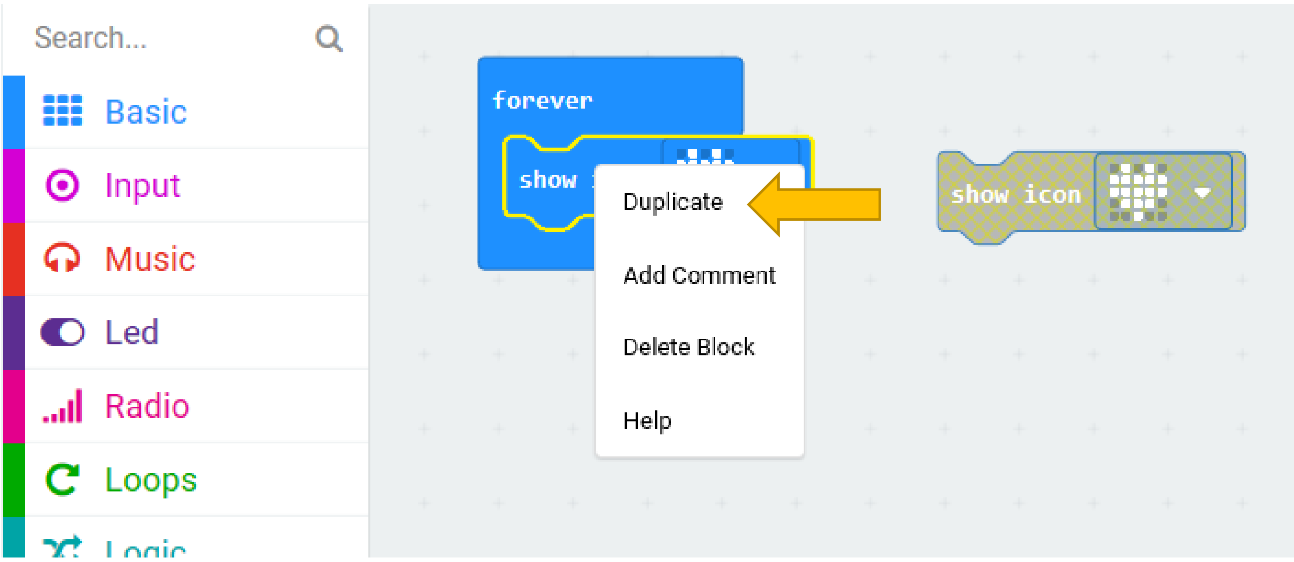
Open the MakeCode for the web version or MakeCode for the win10 version. Click on "New Project"



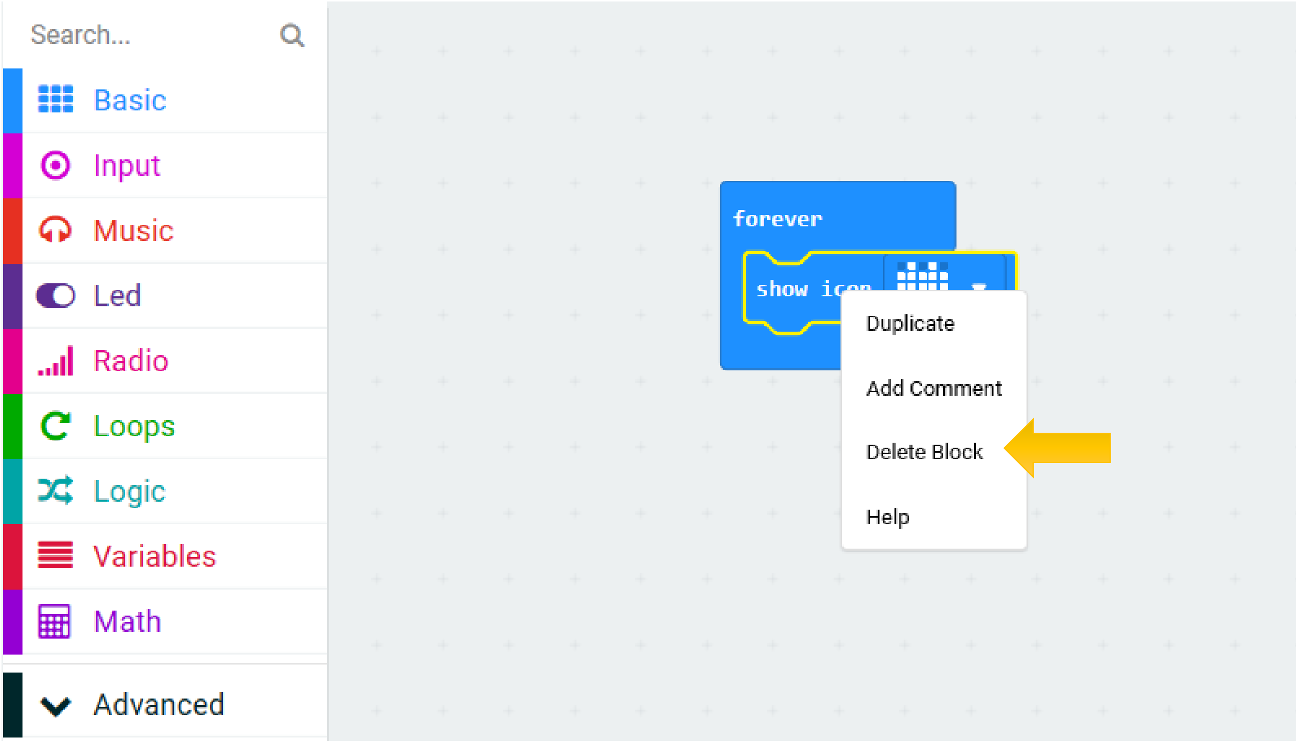
Click **basic** in the list on the left, select the desired code block, and drag it into the right code editing area.



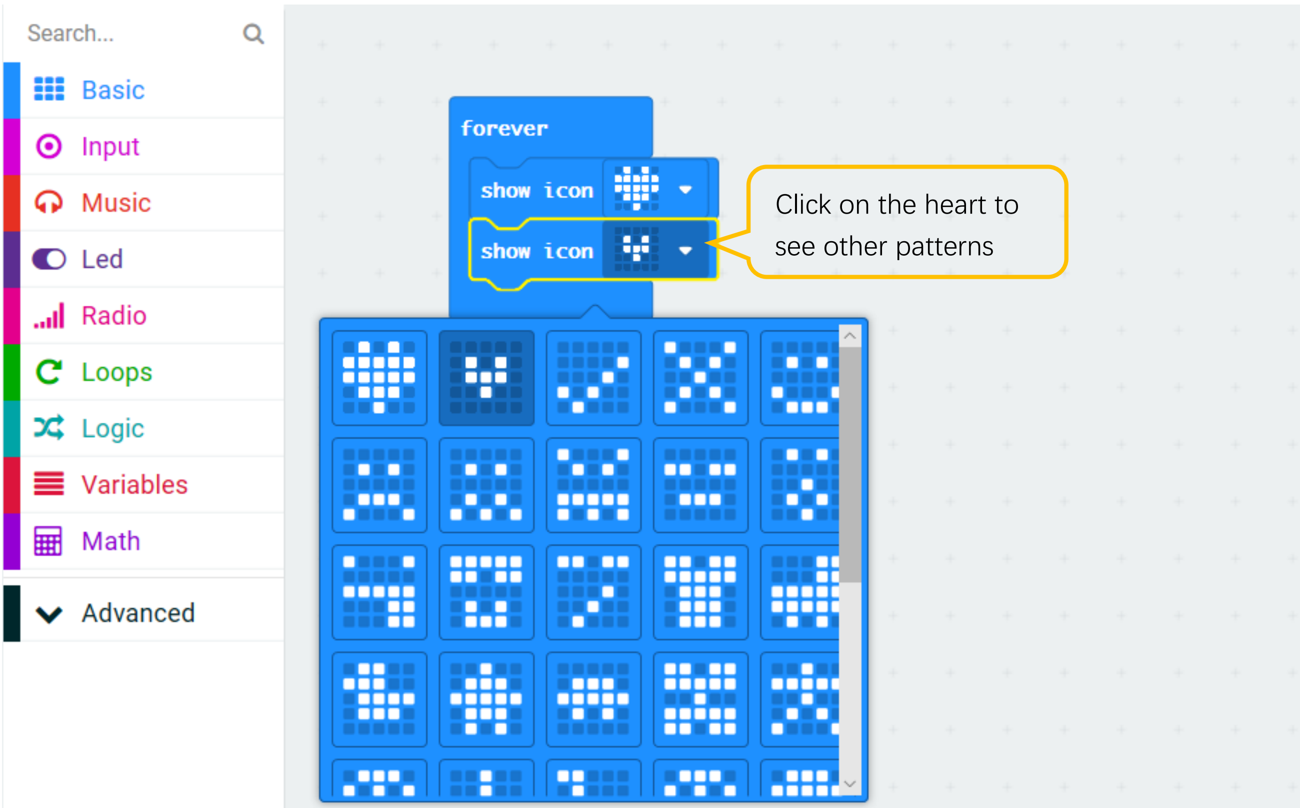

Right click the mouse and select Duplicate to duplicate the code block.



If you want to delete the block, you can right click on the block and select "Delete Block". **You can also drag it to left to delete it.**




On the second block, click on the drop-down triangle next to the heart-shaped pattern on the block to display all the optional built-in patterns, select the second pattern, a small heart shape.

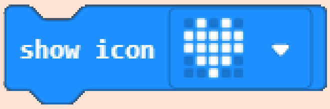


This completes the block code thie project.

Download the program to the microbit, the LED matrix on the micro:bit will continue to display a large heart-shaped pattern and a small heart-shaped pattern, just like heartbeating.

If you did not master downloading, please refer to contents (How to download? How to quick download?).

## Reference

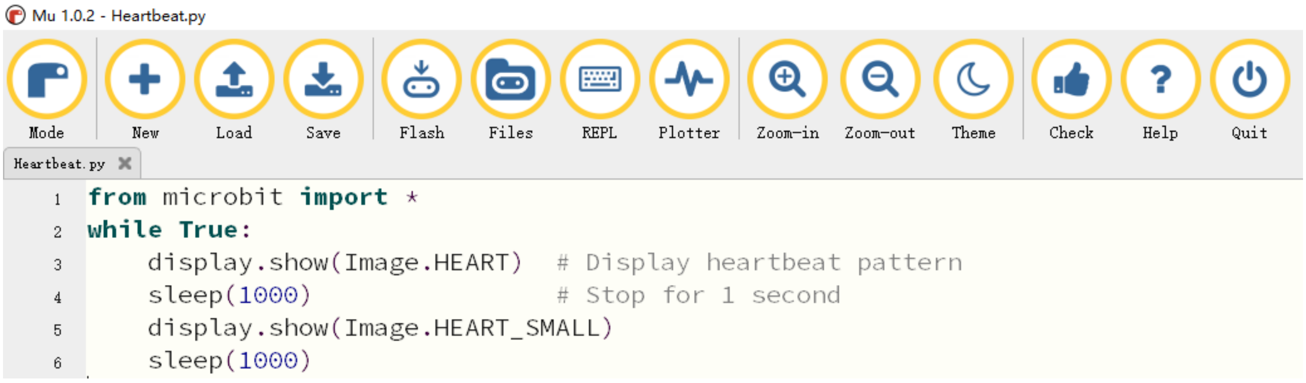
| Block | Function |
|---|---|
|  | Shows the selected icon on the LED screen |

# Python Code

Open the .py file with Mu. Code, the path is as below:

| File type | Path | File name |
|---|---|---|
| **Python file** | ../Projects/PythonCode/01.1_Heartbeat | Heartbeat.py |

After loading successfully, the code is shown below:




Download the program to the microbit, theLED matrix on the micro:bit will continue to display a large heart-shaped pattern and a small heart-shaped pattern, just like heartbeating.

The following is the program code:

```
from microbit import *
while True:
    display.show(Image.HEART)
    sleep(1000)
    display.show(Image.HEART_SMALL)
    sleep(1000)
```

Python language is an interpreted language that is executed sequentially. In the code of this project, the micro:bit module is first imported, and then in a infinite loop statement, a large heart pattern and a small heart pattern are alternately displayed.

Next, we will explain the code line by line.

```
from microbit import *
```

Import everything in the microbit module, including functions, classes, variables, etc. You can also use **import microbit** directly. If you do this, you need to add "microbit." when you call the contents of this module in the program.

```
while True:
```

An infinite loop that will be executed circularly by microbit constantly.

```
display.show(Image.HEART)
```

Display heart pattern on LED matrix.

```
sleep(1000)
```

Delay for one second.

```
display.show(Image.HEART)
sleep(1000)
display.show(Image.HEART_SMALL)
sleep(1000)
```

Display the heart pattern on the LED matrix for one second, and then display the small heart pattern for another second.

## Reference

| `from microbit import *` |
|---|
| Import everything in the microbit module, including functions, classes, variables, etc. You can use all the available contents in the micro:bit module in the next program. |
| `while True:` |
| While is a loop statement, if the condition is true, the code in while is executed.<br>This code with True means that the code in the while is always executed circularly. |
| `display.show(image)` |
| Display the image.<br>For more details about display,<br>please refer to: https://microbit-micropython.readthedocs.io/en/latest/display.html<br>For more details about image,<br>Please refer to: https://microbit-micropython.readthedocs.io/en/latest/image.html |
| `sleep(t)` |
| Delay for given number of milliseconds, should be positive or 0.<br>For more details about sleep function, please refer to:<br>https://microbit-micropython.readthedocs.io/en/latest/utime.html |

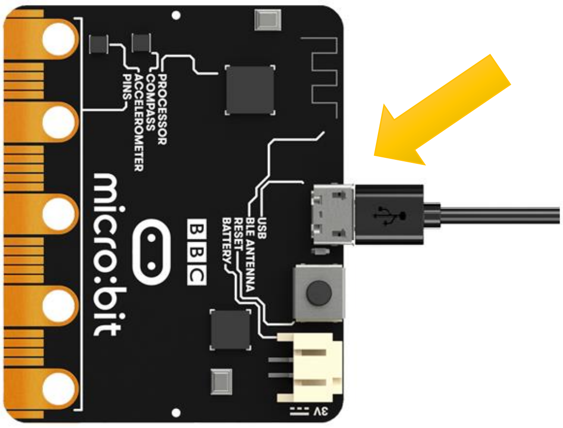
# Project 1.2 Displaying Number

In this project, we will use the LED matrix of the micro:bit to display numbers.

## Circuit

Connect micro:bit and PC via a micro USB cable.

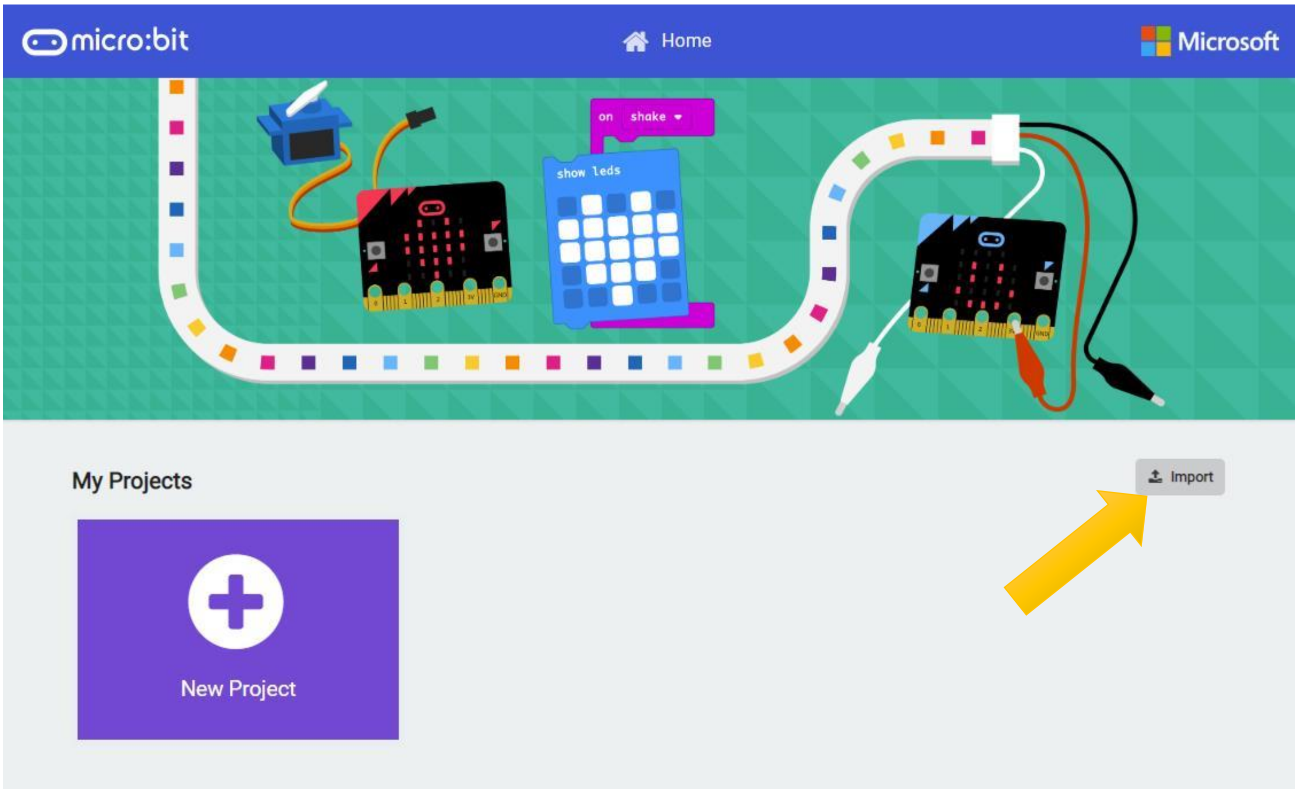
Hardware connection



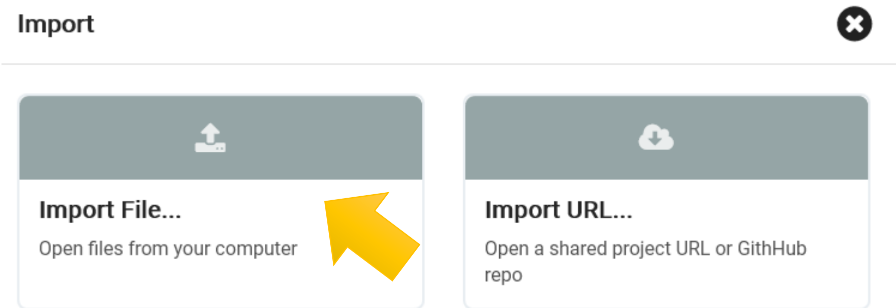
## Block code

Open MakeCode first.

In this project, we will import the block code.



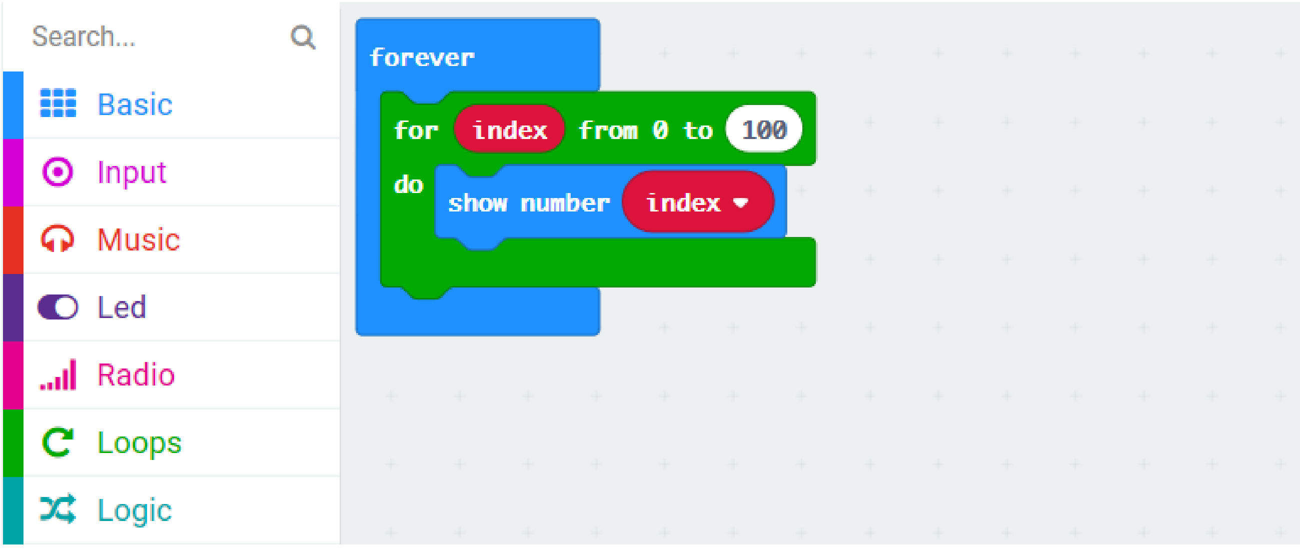

Click **Import**. Then click **Import File**.



Import the .hex file. The path is as below:

| File type | Path | File name |
|---|---|---|
| **HEX file** | ../ Projects/BlockCode/01.2_ShowNumber | ShowNumber.hex |

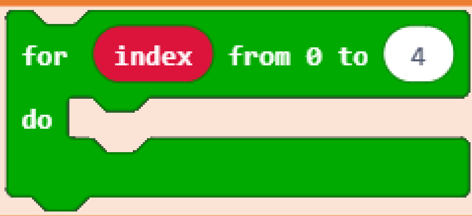
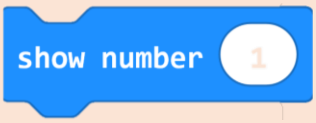
After load successfully, the code is shown as below:




Download the code into the micro:bit. After the downloading completes, the micro:bit LED matrix will start to display the numbers 1, 2, 3, 4...100. Then start again from 1 to 100, so that it will cycle permanently.

In this code, a for loop is used. Each time the loop is executed, the value of the variable index is increased by 1. When the value is greater than 100, the for loop is exited. In the body of the loop, the value of the numeric index is displayed.

## Reference

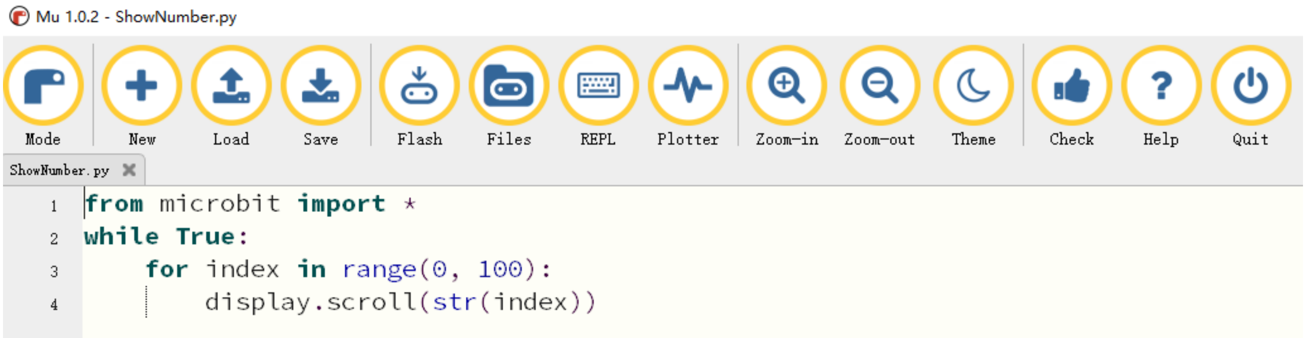
| Block | Function |
|---|---|
|  | This is a for loop, the number (4) of loops can be changed, each time the index is incremented by 1. The loop won't end until the index is greater than the set value. |
|  | Show a number on the LED screen. It will slide left if the number is more than one digit.. |

## Python code

Open the .py file with Mu. Code, the path is as below:

| File type | Path | File name |
|---|---|---|
| **Python file** | ../Projects/PythonCode/01.2_ShowNumber | ShowNumber.py |

After loading successfully, the code is shown as below:




Download the code into the microbit. After the downloading completes, the micro:bit LED matrix will start to display the numbers 1, 2, 3, 4...100. Then start again from 1 to 100, so that it will repeat endlessly.

The following is the program code:

```
from microbit import *
while True:
    for index in range(0, 100):
        display.scroll(str(index))
```

The code of this project, in a 0-100 for loop, scrolls through the cyclic number index, which is incremented by 1.

### Reference

| display.scroll(value) |
|---|
| Scrolls value horizontally on the display. If value is an integer or float it is first converted to a string using str().<br>For more information, please refer to: https://microbit-micropython.readthedocs.io/en/latest/utime.html |

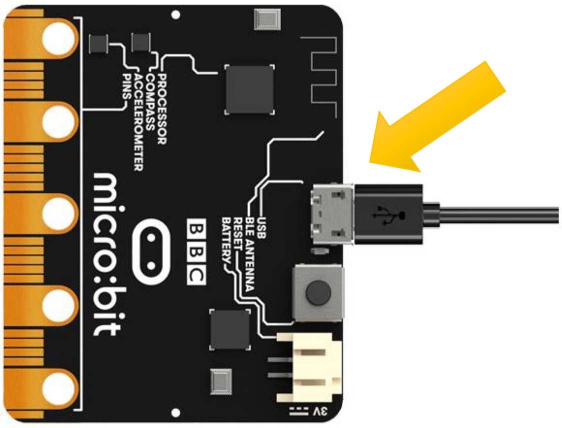
# Project 1.3 Displaying Text

This project uses the LED matrix of micro:bit to display text (ASCII).

## Circuit

Connect micro:bit and PC via micro USB cable.

Hardware connection




## Block code

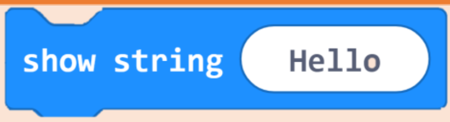
Open MakeCode first.Import the .hex file. The path is as below:(How to import project)

| File type | Path | File name |
|---|---|---|
| HEX file | ../Projects/BlockCode/01.3_ShowText | ShowText.hex |

After loading successfully, the code is shown as below:


Download the code into the microbit, the micro:bit LED matrix will scroll from left to right to display "Hello, Freenove!"

## Reference

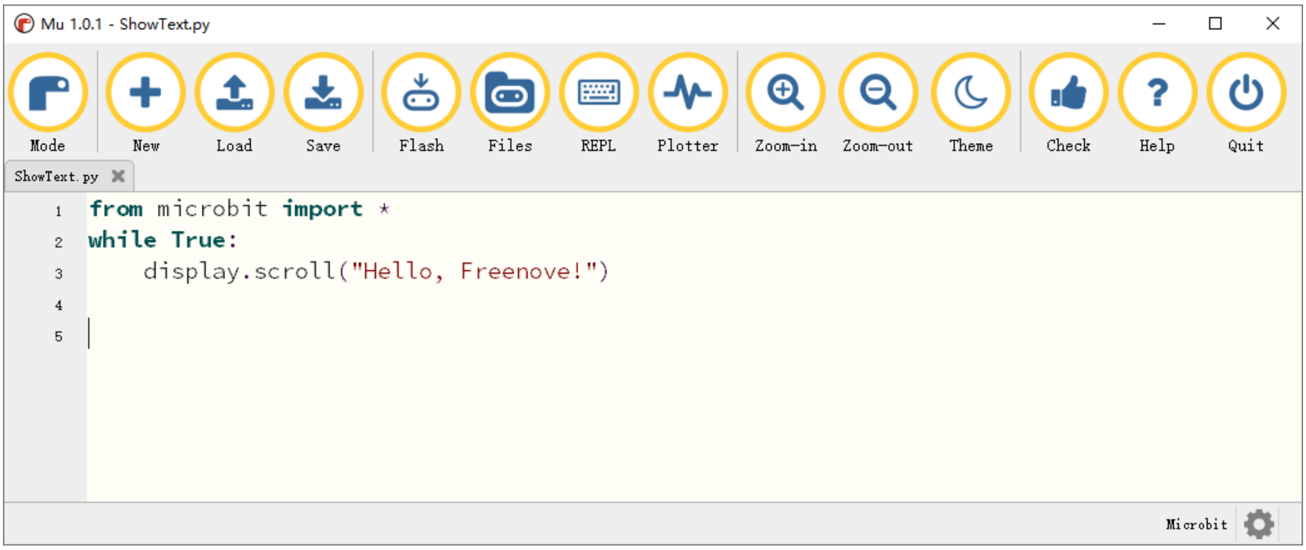
| Block | Function |
|---|---|
|  | Displays a string on the LED screen. It will scroll to left if it's beyond the screen. |

# Python code

Open the .py file with Mu. Code, the path is as below:

| File type | Path | File name |
|---|---|---|
| **Python file** | ../Projects/PythonCode/01.3_ShowText | ShowText.py |

After loading successfully, the code is shown as below:




Download the code into the microbit, the micro:bit LED matrix will scroll from left to right to display "Hello, Freenove!"

The following is the program code:

```
from microbit import *
while True:
    display.scroll("Hello, Freenove!")
```

This code scrolls through the text "Hello, Freenove!" in a while loop.

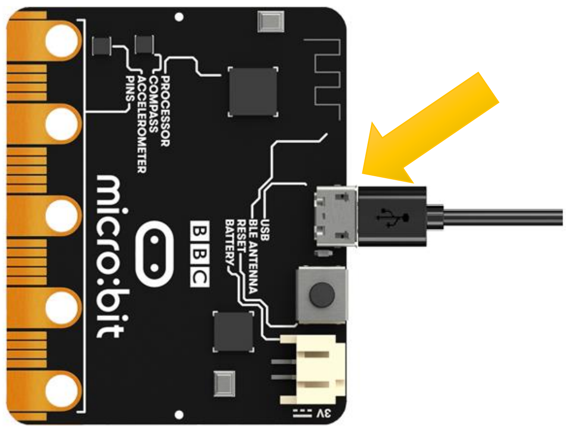
# Project 1.4 Displaying Custom

This project uses a micro:bit LED matrix to display a custom pattern.

## Circuit

Connect micro:bit and PC via micro USB cable.

Hardware connection

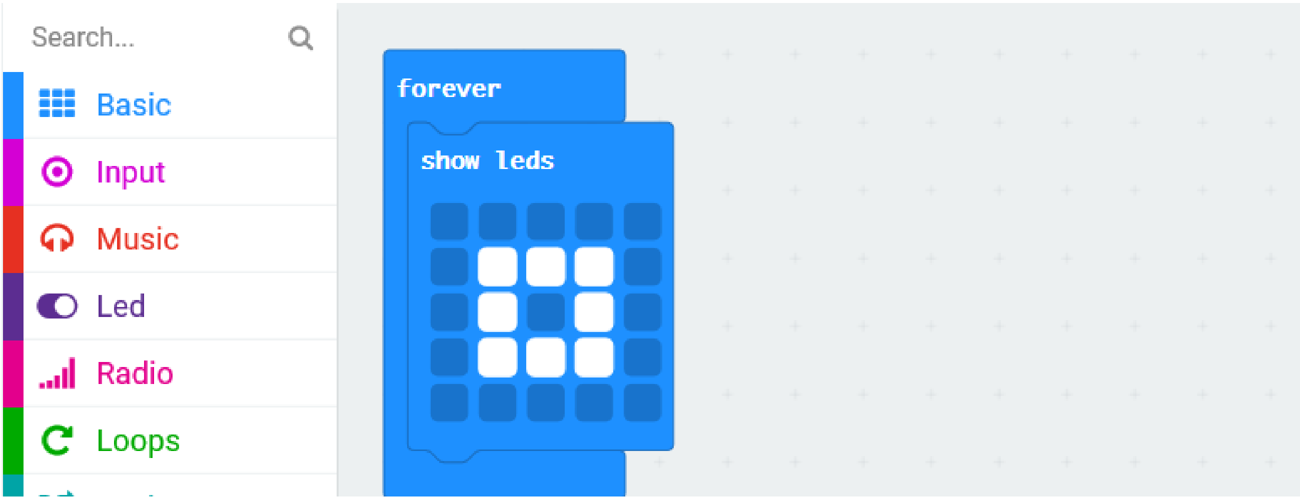


## Block code

Open MakeCode first.
Import the .hex file. The path is as below:
(How to import project)

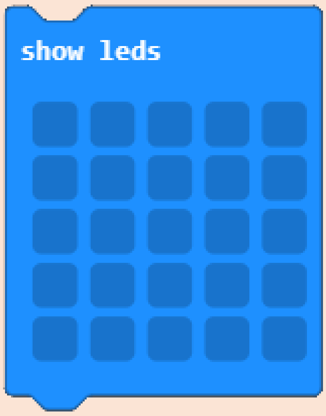
| File type | Path | File name |
|---|---|---|
| HEX file | ../Projects/BlockCode/01.4_ShowCustom | ShowCustom.hex |

After loading successfully, the code is shown as below:




Check the connection of the circuit and verify it correct.. Then download the code into the microbit, and the square pattern shown above will appear on the LED matrix of the micro:bit.

## Reference

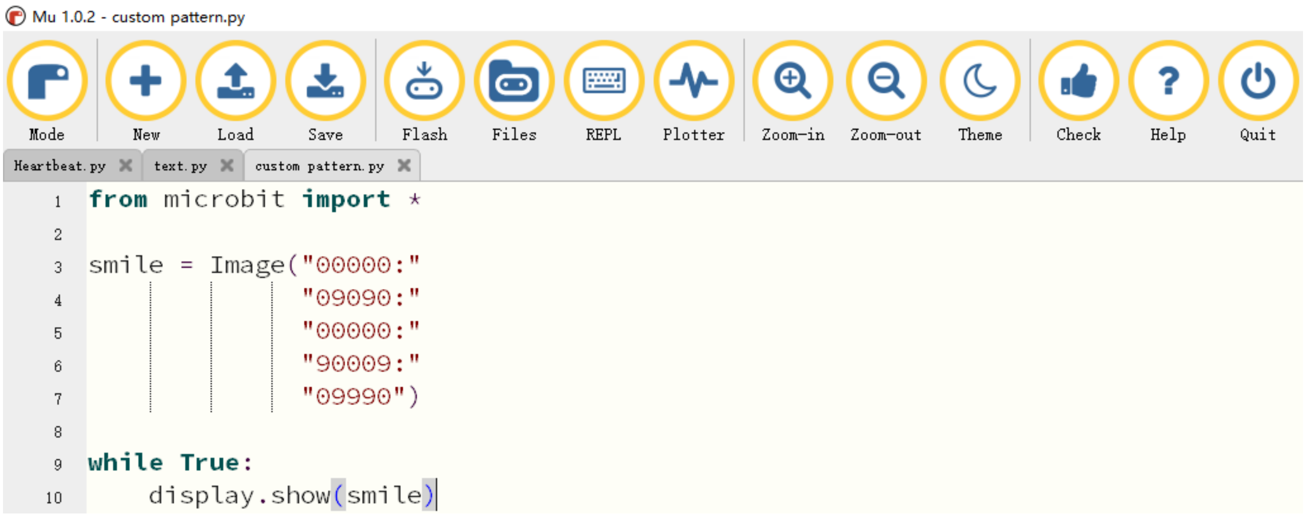
| Block | Function |
|---|---|
|  | Shows a picture on the LED screen. |

# Python code

Open the .py file with Mu. Code, the path is as below:

| File type | Path | File name |
|---|---|---|
| **Python file** | ../Projects/PythonCode/01.4_ShowCustom | ShowCustom.py |

After loading successfully, the code is shown as below:




Download the code into the microbit, and a square pattern will appear on the micro:bit LED matrix. (How to download?)

The following is the program code:

```
from microbit import *

img = Image("00000:"
            "09990:"
            "09090:"
            "09990:"
            "00000")

while True:
    display.show(img)
```

Create an image in the code and define it as **img**, then display the defined image in a while loop. As shown in the code below, the parameters in Image consist of 5 strings. Each line of characters corresponds to a row of LEDs. Each digit represents the brightness of an LED. The value ranges from 0 to 9, the larger the number, the brighter the LED.

```
img = Image("00000:"
            "09990:"
            "09090:"
            "09990:"
            "00000")
```

## Reference

```
img = Image("00000:"
            "09990:"
            "09090:"
            "09990:"
            "00000")
```

Create an image of LED, and set brightness of LED.
For more information, please refer to:
https://microbit-micropython.readthedocs.io/en/latest/image.html

# Chapter 2 Built-in Button

Keyboards or buttons are important tools for human-computer interaction. We often use keyboards to enter text, type commands, control devices, etc. Two programmable buttons A and B are integrated on the micro:bit to easily control the micro:bit to make actions.

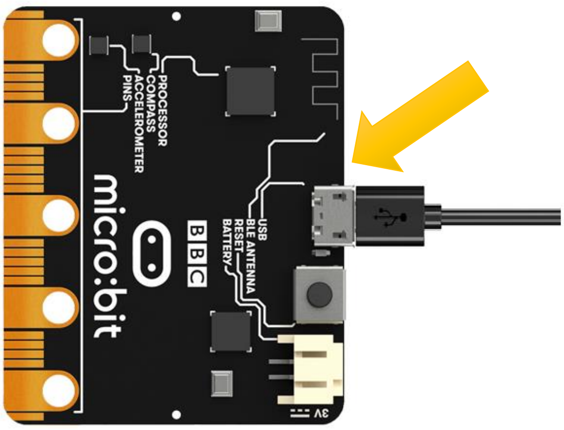
## Project 2.1 Button A and B

This project uses micro:bit integrated buttons A and B. When different buttons are pressed, micro:bit displays different patterns.

### Circuit

Connect micro:bit and PC via micro USB cable.

Hardware connection



### Block code

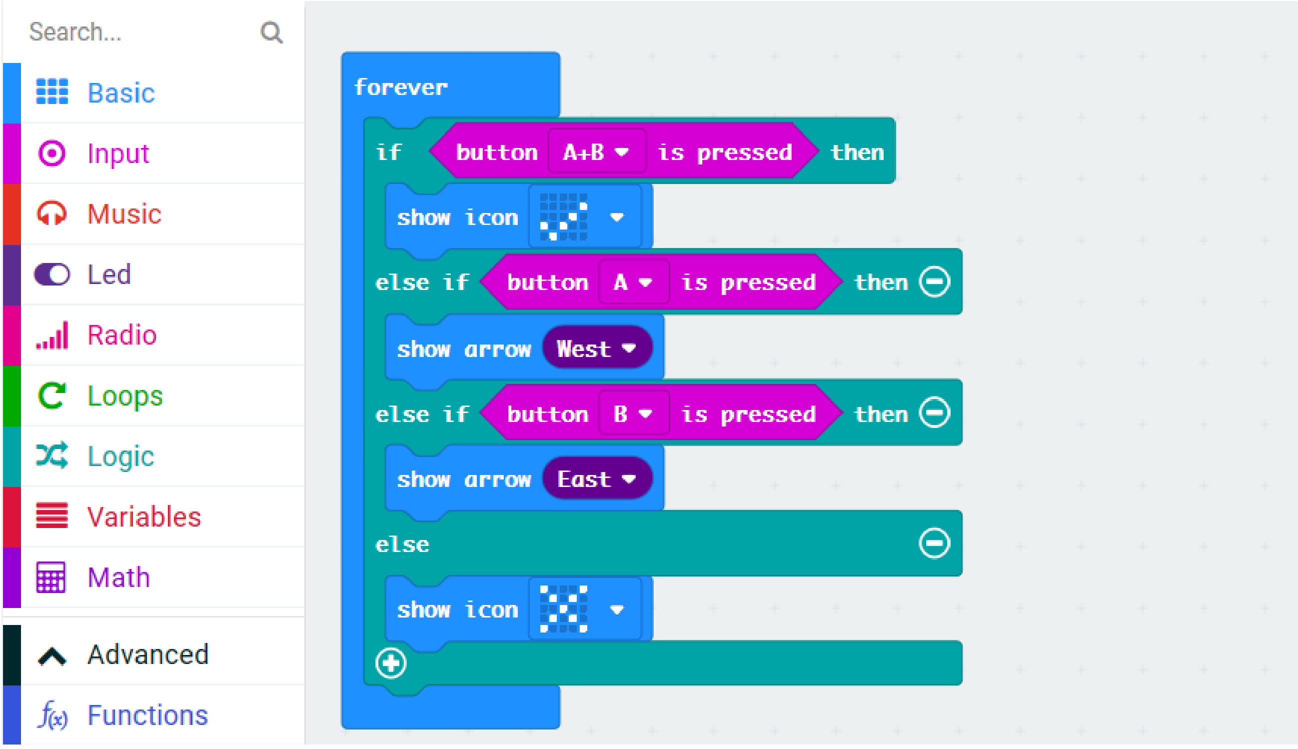
Open MakeCode first.

Import the .hex file. The path is as below:

(How to import project)

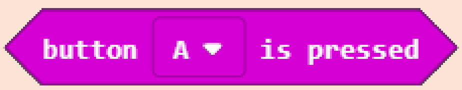
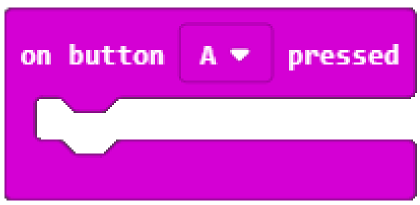
| File type | Path | File name |
|---|---|---|
| **HEX file** | ../Projects/BlockCode/02.1_BuiltInButton | BuiltInButton.hex |

After loading successfully, the code is shown as below:




Download the code into micro:bit. When button A is pressed, the micro:bit LED matrix will display an arrow pointing to button A. When button B is pressed, the micro:bit LED matrix will display an arrow pointing to button B. When the buttons A and B are pressed at the same time, the micro:bit LED matrix will display a check mark. When no button is pressed, the micro:bit LED matrix displays a cross.

## Reference

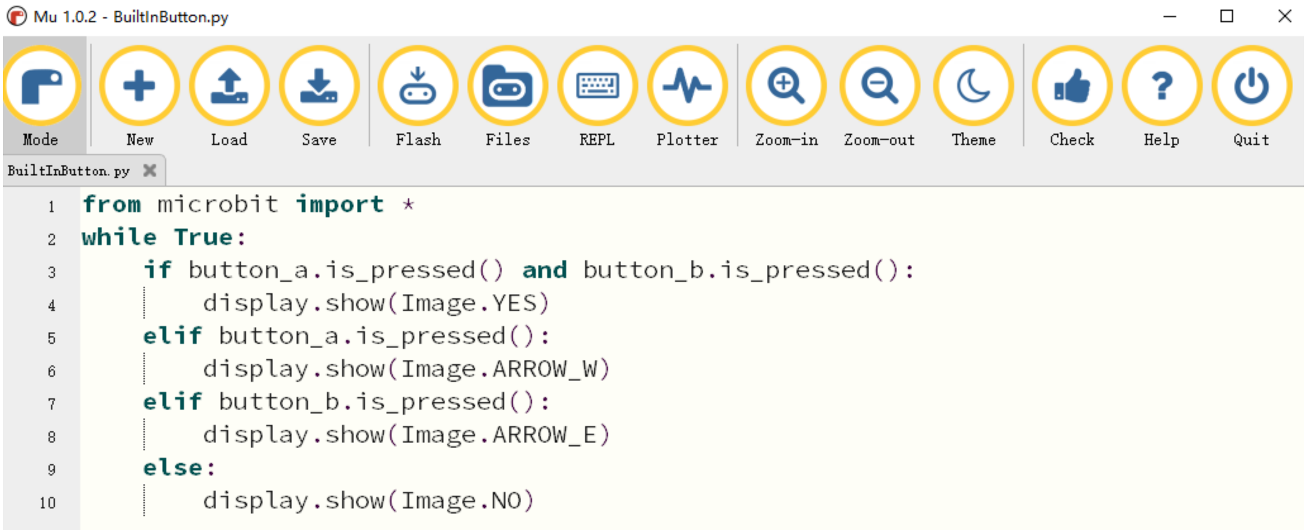
| Block | Function |
|---|---|
|   | Check whether a button is pressed at the moment. The micro:bit has two buttons: button A and button B. |
|   | This handler works when button A or B is pressed, or A and B together. |

# Python code

Open the .py file with Mu. Code, the path is as below:

| File type | Path | File name |
|---|---|---|
| **Python file** | ../Projects/PythonCode/02.1_BuiltInButton | BuiltInButton |

After loading successfully, the code is shown as below:




Download the code into micro:bit. When button A is pressed, the micro:bit LED matrix will display an arrow pointing to button A. When button B is pressed, the micro:bit LED matrix will display a an arrow pointing to button B.When the buttons A and B are pressed at the same time, the micro:bit LED matrix will display a check mark. When no button is pressed, the micro:bit LED matrix displays a cross.

The following is the program code:

```
from microbit import *

while True:
    if button_a.is_pressed() and button_b.is_pressed():
        display.show(Image.YES)
    elif button_a.is_pressed():
        display.show(Image.ARROW_W)
    elif button_b.is_pressed():
        display.show(Image.ARROW_E)
    else:
        display.show(Image.NO)
```

Use the if-elif-else statement to determine when the button is pressed. First, when the buttons A and B are pressed at the same time, a check mark is displayed.

```
    if button_a.is_pressed() and button_b.is_pressed():
        display.show(Image.YES)
```

Then, determine in turn if the buttons A or B is pressed seperately, and the case where no button is pressed.

```
    elif button_a.is_pressed():
        display.show(Image.ARROW_W)
    elif button_b.is_pressed():
        display.show(Image.ARROW_E)
    else:
        display.show(Image.NO)
```

Note that it is necessary to first determine if buttons A and B are pressed at the same time. If-elif-else statement will make the micro:bit execute only one situation. If the state with two buttoon pressed is placed in last, the result of pressing A or B will appear first, then the statement will end, and then sentence met the state with two button pressed will never be executed.

## Reference

| is_pressed() |
|---|
| Returns True if the specified button is currently being pressed, and False otherwise.<br>For more information, please refer to https://microbit-micropython.readthedocs.io/en/latest/button.html |

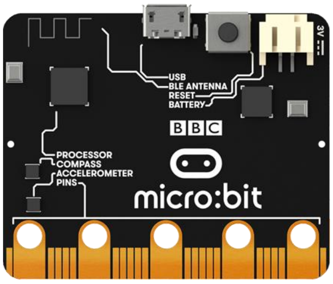
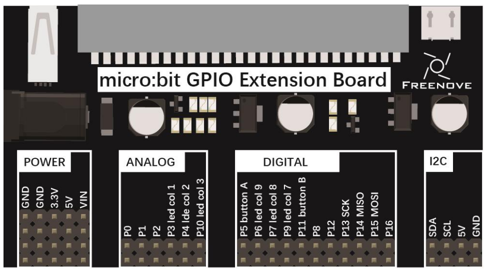
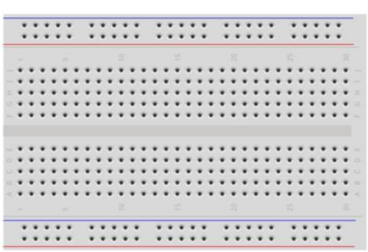
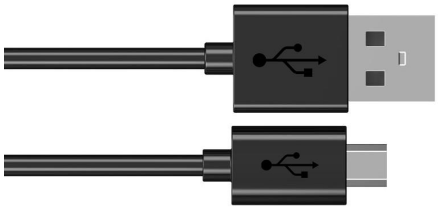
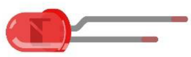
# Chapter 3 LED

This section we will learn how to control external LEDs.

## Project 3.1 Blink

This project uses micro:bit to control LED blinking.

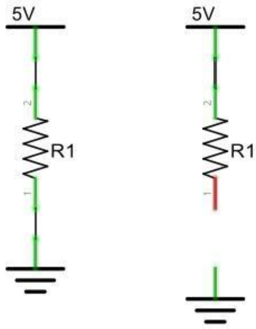
### Component List

<table>
<tr><td colspan="3">Microbit x1<br>
</td><td colspan="3">Expansion board x1<br>
</td></tr>
<tr><td colspan="3">Breakboard x1<br></td><td colspan="3">USB cable x1<br></td></tr>
<tr><td colspan="2">Jumper F/M x2<br></td><td colspan="2">Resistor 220Ω x1<br></td><td colspan="2">LED x1<br></td></tr>
</table>

# Circuit Knowledge

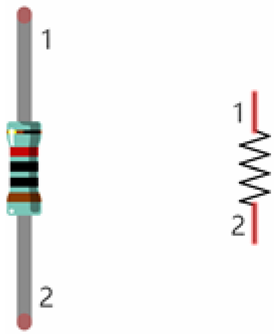
## Current

The unit of current (I) is ampere (A). 1A=1000mA, 1mA=1000μA.
Closed loop consisting of electronic components is necessary for current.
In the figure below: the left is a loop circuit, so current flows through the circuit. The right is not a loop circuit, so there is no current.

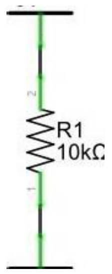



## Resistor

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.



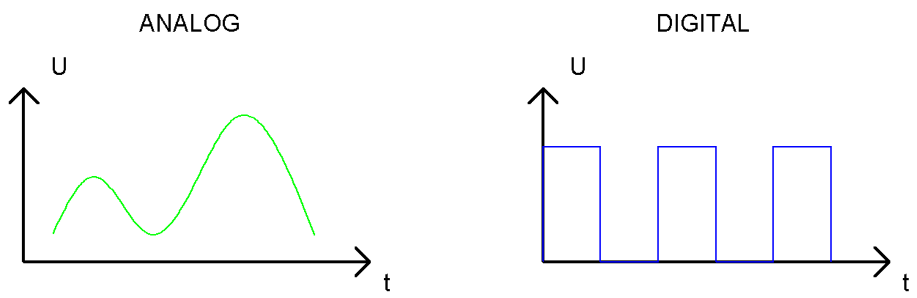

The bands of color on a resistor is a shorthand code used to identify its resistance value. For more details of resistor color codes, please refer to the card in the kit package.
With a fixed voltage, there will be less current output with greater resistance added to the circuit. The relationship between 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)

## Analog signal and Digital signal

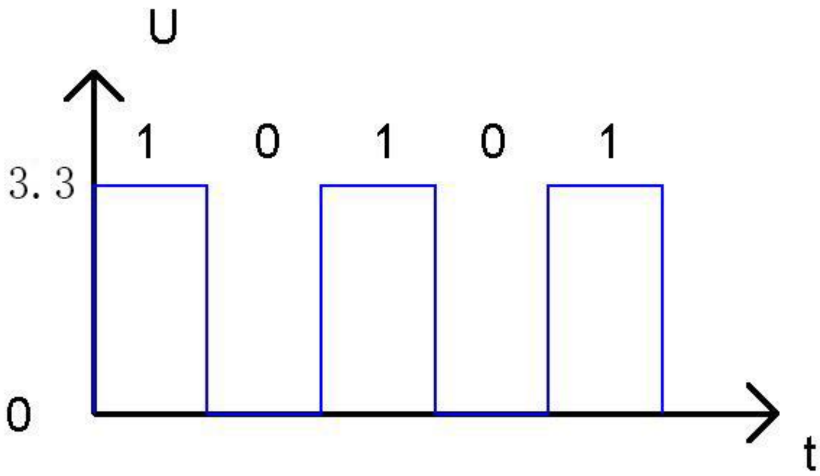
An Analog Signal is a continuous signal in both time and value. On the contrary, a Digital Signal or discrete-time signal is a time series consisting of a sequence of quantities. Most signals in life are analog signals. A familiar example of an Analog Signal would be how the temperature throughout the 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.




Note that the Analog signals are curved waves and the Digital signals are "Square Waves".
In practical applications, 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.

## Low level and high level

In circuit, the form of binary (0 and 1) is presented as low level and high level.
Low level is generally equal to ground voltage (0V). High level is generally equal to the operating voltage of components.
The low level of Micro:bit is 0V and high level is 3.3V, as shown below. When IO port on Micro:bit outputs high level, low-power components can be directly driven, like LED.




## Component knowledge

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

### Jumper

Jumper is a kind of wire, which is designed to connect the components together by inserting its two terminals.
Jumpers have male end (pin) and female end (slot), so jumpers can be divided into the following 3 types.

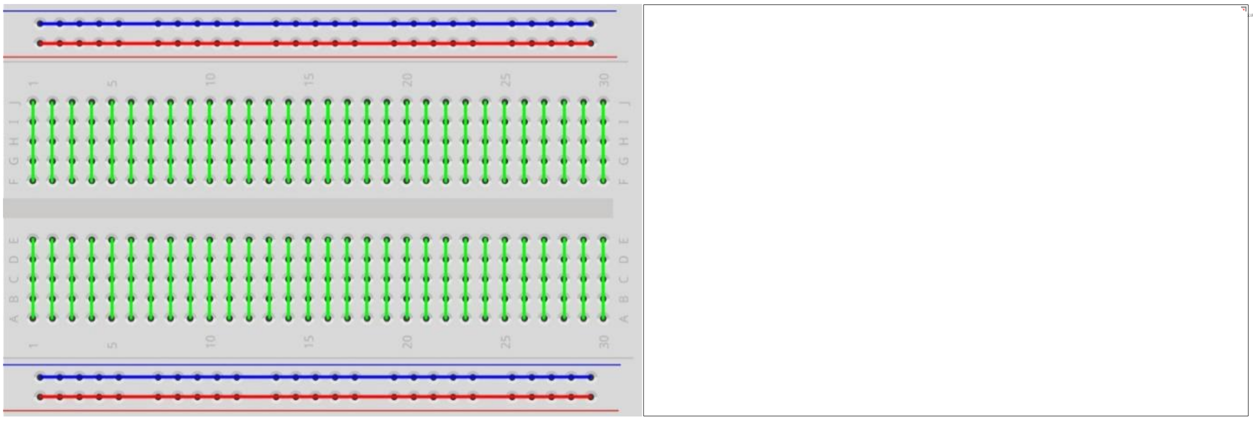
Jumper M/M 

Jumper F/F 

Jumper F/M 

### Breadboard

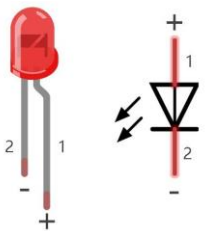
There are many small holes on breadboard to connect Jumper.
Some small holes are connected inside breadboard. Here we have a small breadboard as an example of how the rows of holes (sockets) are electrically attached. The left picture shows the ways the pins have shared electrical connection and the right picture shows the actual internal metal, which connect these rows electrically.



## 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 also referred to as Ground (GND). This type of component is known as “Polar” (think One-Way Street).

All common 2 lead diodes are the same in this respect. Diodes work only if the voltage of its positive electrode is higher than its negative electrode and there is a narrow range of operating voltage for most all common diodes of 1.9 and 3.4V. If you use much more than 3.3V the LED will be damaged and burn out.




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.

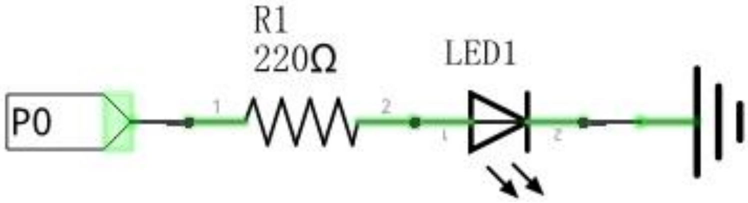
## Circuit

When wiring, it is recommended to disconnect all the power supplies in the circuit, and then build the circuit according to the circuit (**micro:bit board cannot be inserted reverse**),

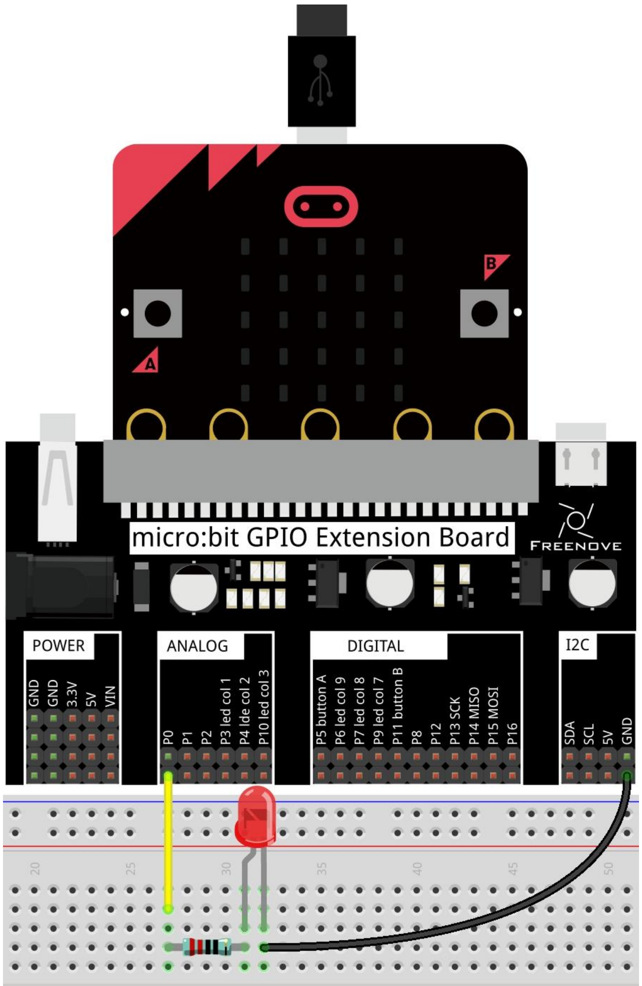
**LED’s positive pole (long pin) should be connected to resistor while its negative pole (short pin) should be connected to GND. After the circuit is built and verified correct, use the USB cable to connect the PC to the micro:bit to power the circuit.**

**CAUTION: Avoid any possible short circuits (especially connecting 5V or GND, 3.3V and GND)!**
**WARNING: A short circuit can cause high current in your circuit, create excessive component heat and cause permanent damage to your micro:bit!**

Schematic diagram




Hardware connection



## Block code

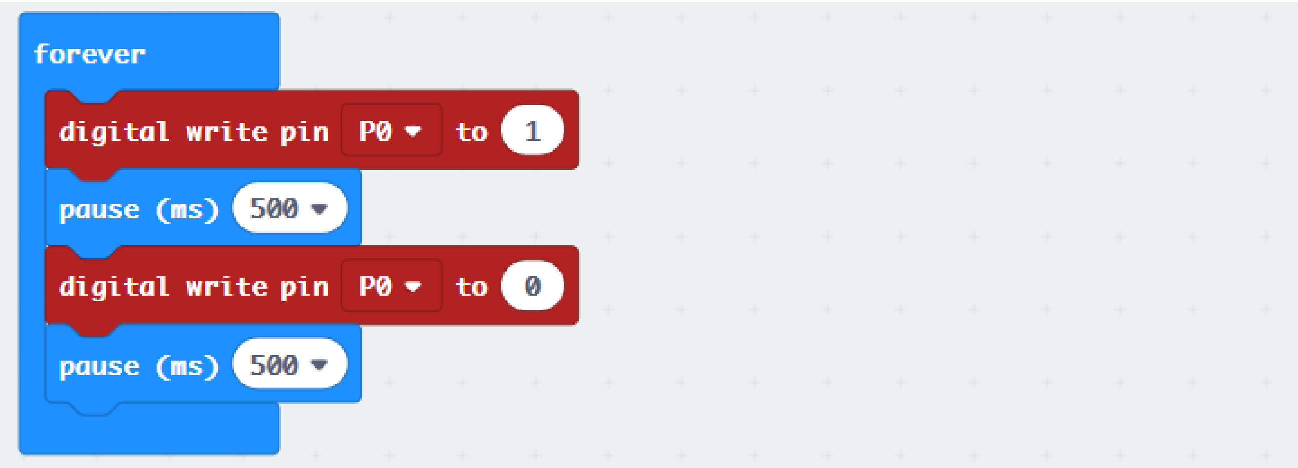
Open MakeCode first. Import the .hex file. The path is as below:
(How to import project)

| File type | Path | File name |
|---|---|---|
| **HEX file** | ../Projects/BlockCode/03.1_Blink | Blink.hex |

After import successfully, the code is shown as below:


Download the code into the micro:bit and the LED on the breadboard will begin to blink.

In the code, write 1 to the P0 port to turn ON the LED. After waiting for 500ms, write 0 to the P0 port to turn OFF the LED. After waiting for 500ms, the LED will be turned ON again. Repeat the loop, then LED will start blinking.



## Reference

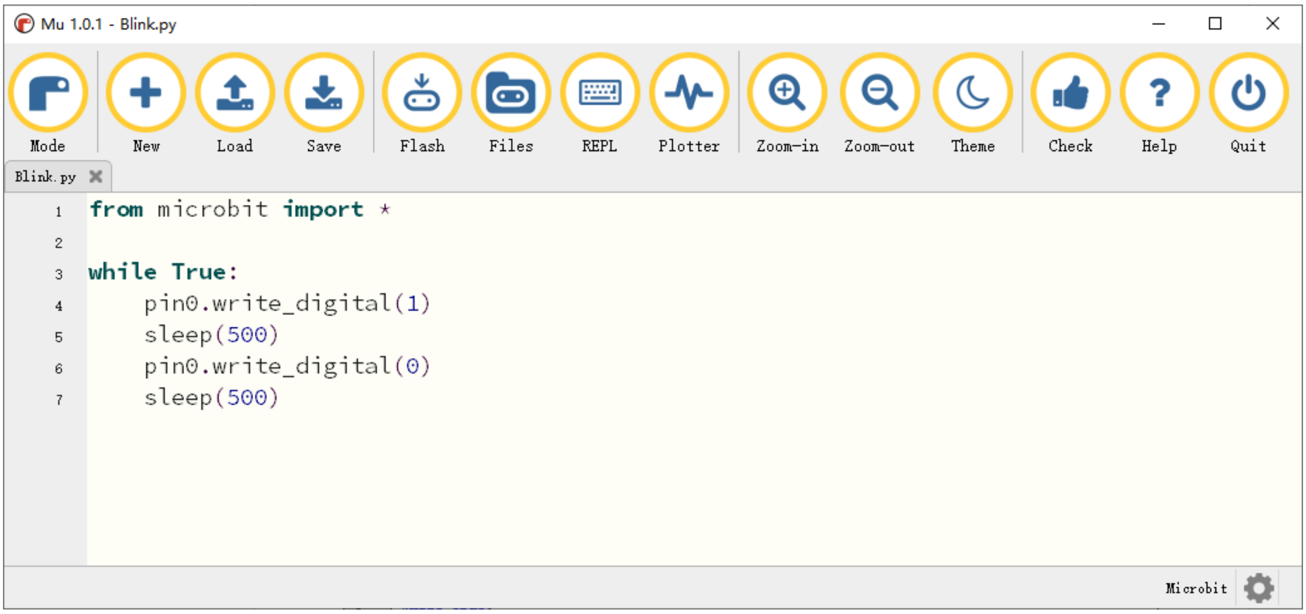
| Block | Function |
|---|---|
| `pause (ms) 100` | Pause the program for the number of milliseconds you set. You can use this function to slow your program down. |
| `digital write pin P0 to 1` | Write a digital (0 or 1) signal to a pin on the micro:bit board. |

# Python code

Open the .py file with Mu. Code, the path is as below:

| File type | Path | File name |
|---|---|---|
| **Python file** | ../Projects/PythonCode/03.1_Blink | Blink.py |

After loading successfully, the code is shown as below:




Download the code into micro:bit and the LED on the breadboard will start to blink.

(How to download?)

The following is the program code:

```
from microbit import *

while True:
    pin0.write_digital(1)
    sleep(100)
    pin0.write_digital(0)
    sleep(100)
```

In the code, write 1 to the P0 port to turn ON the LED. After waiting for 500ms, write 0 to the P0 port to turn OFF the LED. After waiting for 500ms, the LED will be turned ON again. Repeat the loop, then LED will start blinking.

Write a high level to pin P0.

```
pin0.write_digital(1)
```

Delay 500ms

```
sleep(500)
```

Then write low level, and then delay 500ms. Repeat actions above.

## Reference

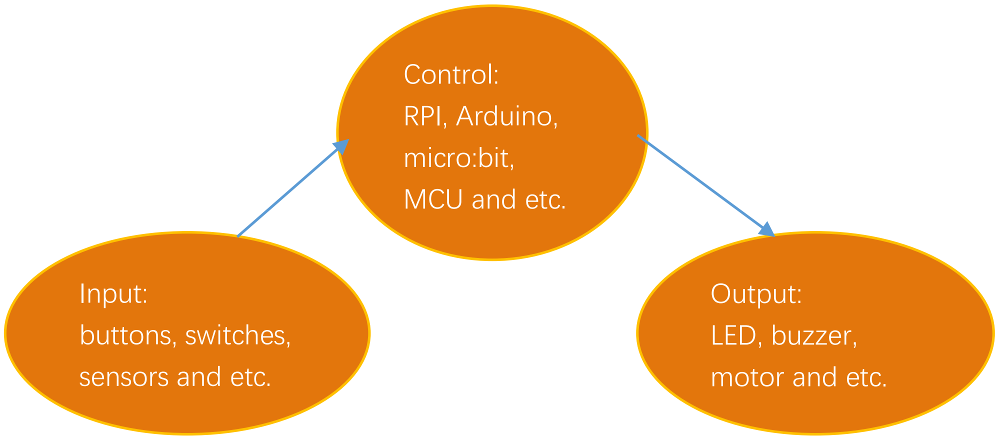
`pin.write_digital(value)`

Set the pin to high if value is 1, or to low, if it is 0.

For more information, please refer to:https://microbit-micropython.readthedocs.io/en/latest/pin.html

# Chapter 4 Button and 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 micro:bit was the control part. In practical applications, we not only make the LEDs flash, but also make a device sense the surrounding environment, receive instructions and then take the appropriate action such as turn on LEDs, make a buzzer beep and so on.

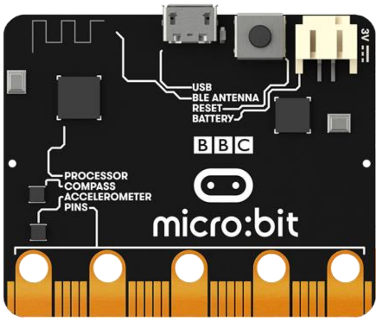
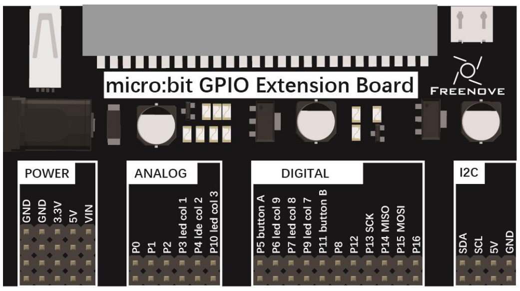
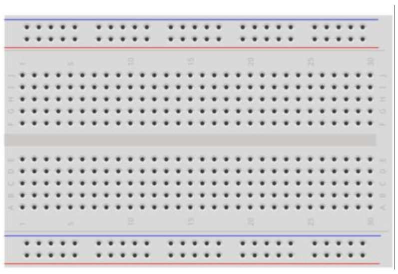
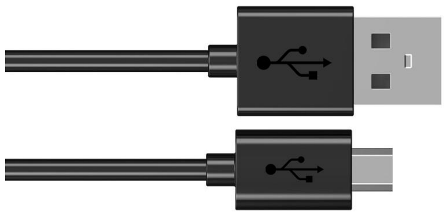
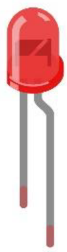



Next, we will build a simple control system to control an LED through a push button switch.

# Project 4.1 Control LED by Button

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. This describes a Momentary Switch.

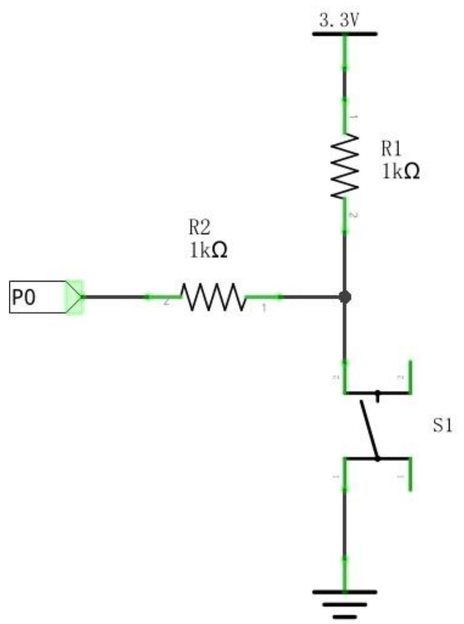
## Component list

| | | | |
|---|---|---|---|
| Microbit x1   | | Expansion board x1   | |
| Breakboard x1  | | USB cable x1  | |
| FM x4 MM x1  | Resistor<br>220Ω x1 <br>1kΩ x2  | LED x1  | Push Button Switch x1  |

# Circuit knowledge

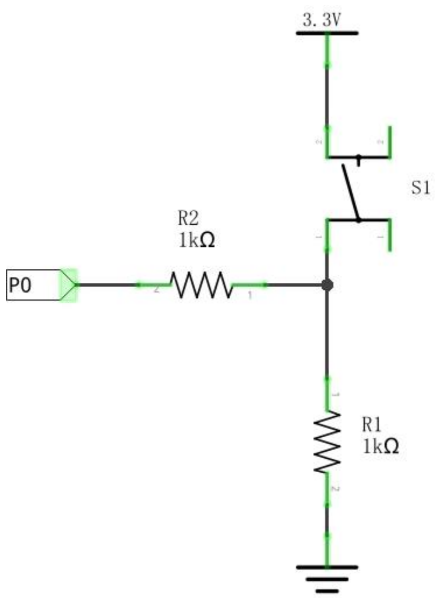
## Connection of Push Button Switch

We connect a push button switch directly to the circuit to turn ON or OFF the LED. In digital circuits, we need to use the push button switch as an input signal. The recommended connection is as follows:



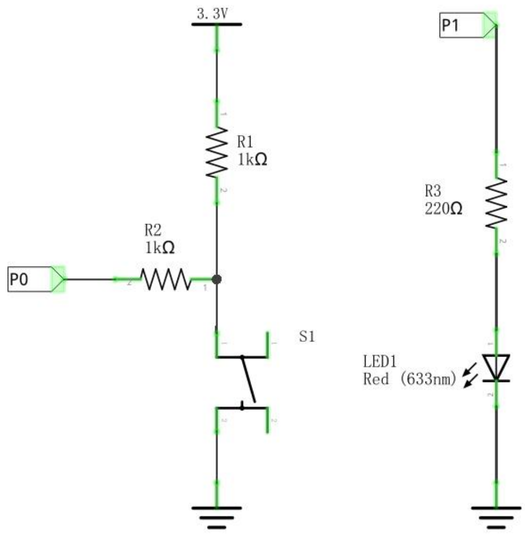
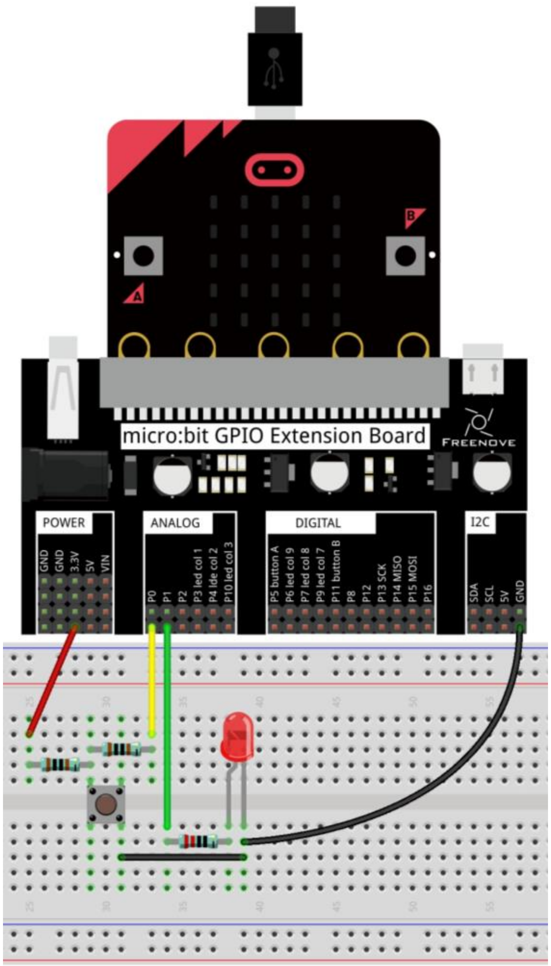

In the above circuit diagram, when the button is not pressed, 3.3V (high level) will be detected by I/O port; and when the button is pressed, it will be 0V (low level). Resistor R2 here is used to prevent the port from being set to output high level by accident. Without R2, the port maybe connected directly to the cathode and cause a short circuit when the button is pressed.

The following diagram shows another connection, in which the level detected by I/O port is opposite to above diagram, when the button is pressed or not.



## Circuit

The P0 pin detects the button and the P1 pin controls the LED.

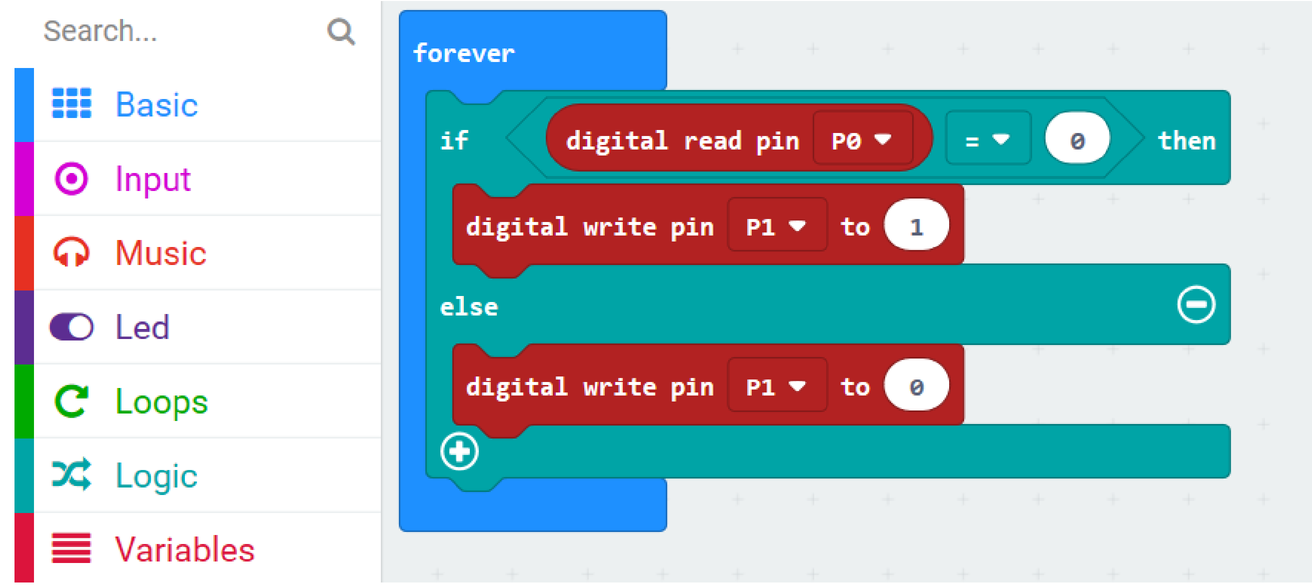
| Schematic diagram |
|---|
|  |
| Hardware connection |
|  |

## Block code

Open MakeCode first. Import the .hex file. The path is as below:
(How to import project)

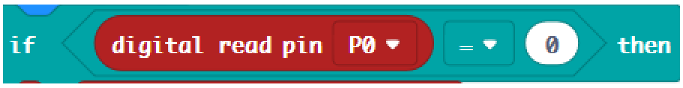
| File type | Path | File name |
|---|---|---|
| **HEX file** | . ../Projects/BlockCode/04.1_ButtonAndLED | ButtonAndLED.hex |

After import successfully, the code is shown as below:




Download the code into micro:bit. When the button is pressed, the LED will be turned on. When the button is released, the LED will be turned off.

In the program, read the level of the P0 pin to determine if the button is pressed.




If P0 pin is low level, it indicates that the button is pressed, and make P1 pin output 1, then LED will be turned ON.


Otherwise, P1 pin outputs 0, and the LED will be turned OFF.


### Reference

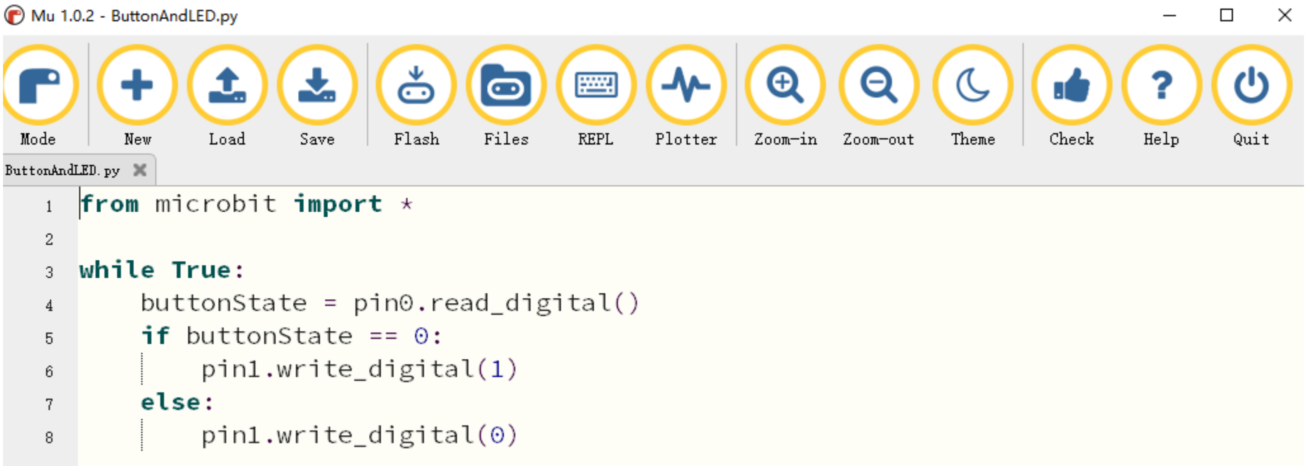
| Block | Function |
|---|---|
|  | Read a digital (0 or 1) signal from a pin on the micro:bit board. |

## Python code

Open the .py file with Mu. Code, the path is as below:

| File type | Path | File name |
|---|---|---|
| **Python file** | ../Projects/PythonCode/04.1_ButtonAndLED | ButtonAndLED.py |

After loading successfully, the code is shown as below:




Download the code into micro:bit. When the button is pressed, the led will be turned ON. When the button is released, the led will be turned OFF.

(How to download?)

The following is the program code:

```python
from microbit import *
while True:
    buttonState = pin0.read_digital()
    if buttonState == 0:
        pin1.write_digital(1)
    else:
        pin1.write_digital(0)
```

In the program, read the level of the P0 pin, save the read level value in the variable buttonState, and then determine whether the button is pressed.

```
buttonState = pin0.read_digital()
```

If the read P0 pin is low, it indicates that the button is pressed, and then make P1 pin output 1, so LED will be turned ON. Otherwise, the P1 pin outputs 0, and the LED will be turned OFF.

```
    if buttonState == 0:
        pin1.write_digital(1)
    else:
        pin1.write_digital(0)
```

## Reference

| pin.read_digital() |
|---|
| Return 1 if the pin is high level, and 0 if it's low.<br>For more information, please refer to:https://microbit-micropython.readthedocs.io/en/latest/pin.html |

# Project 4.2 Table Lamp

In this project, we will make a table lamp. The components and circuits used are exactly the same as the previous one, 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.

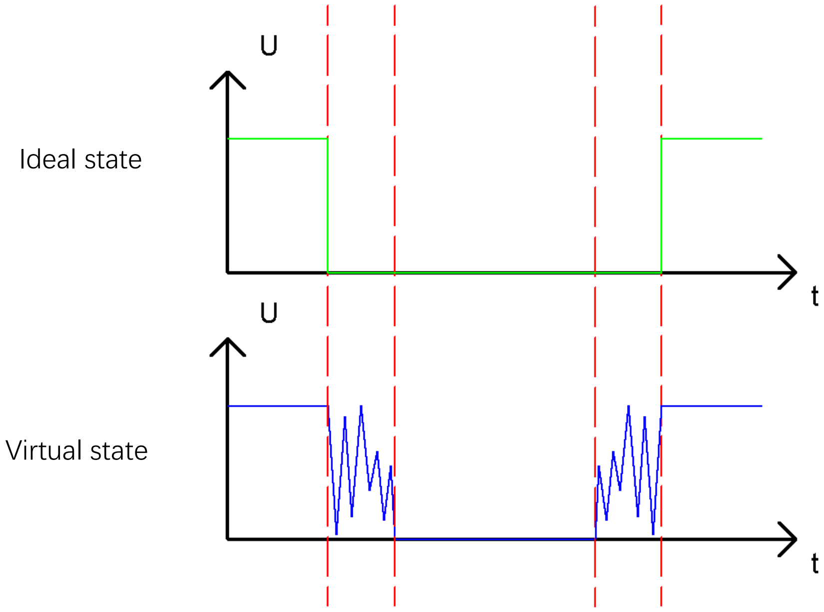
## Component list

It is same as the previous project.

## Circuit knowledge

### 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 stabilizes in a new 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.

## Circuit

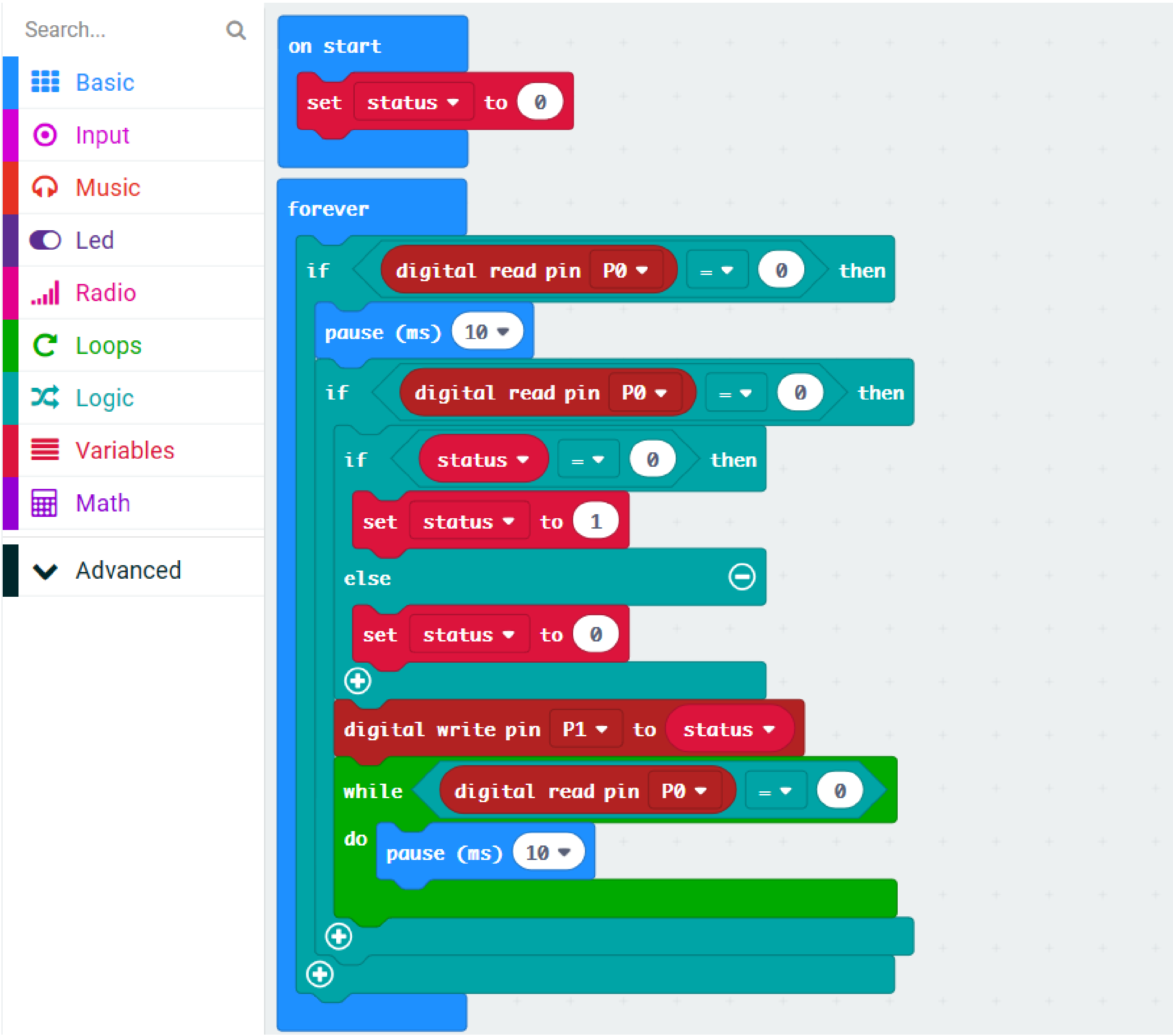
It is same as the previous section.

## Block code

Open MakeCode first. Import the .hex file. The path is as below:
(How to import project)

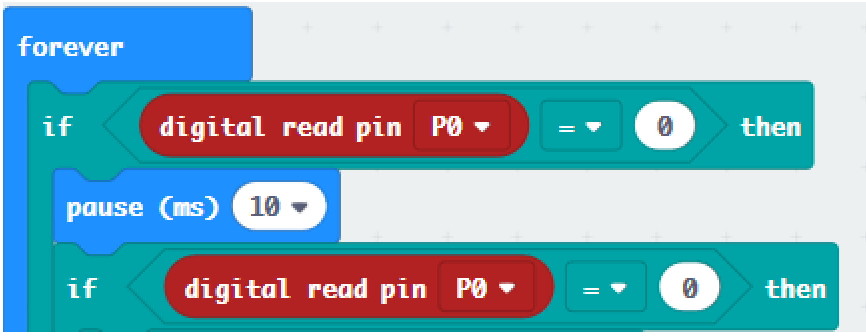
| File type | Path | File name |
|---|---|---|
| HEX file | ../Projects/BlockCode/04.2_TableLamp | TableLamp.hex |

After importing successfully, the code is shown as below:

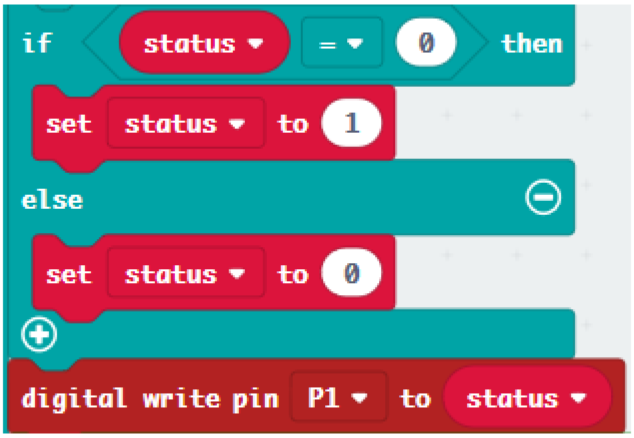



Download the code to micro:bit, press the button once, the LED turns ON, press the button again, the LED turns OFF. .

In the program, when it is detected for the first time that the button is pressed, wait for 10ms to detect whether the button is pressed again, to skip the bounce when the button is pressed. And if the button is still detected as pressed for the second time, the button is considered to have been pressed and in a steady state. Otherwise, it is considered to be a bounce and the program will stop detecting..

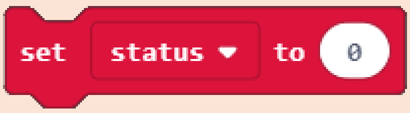



When it is determined that the key is pressed, change the status value. Status is used to save the state of LED. And then write the new value of status to the P1 port to control the LED.




After the above operations done, the program will detect whether the button is released. And similarly, it will first eliminate the bounce of the button.


## Reference

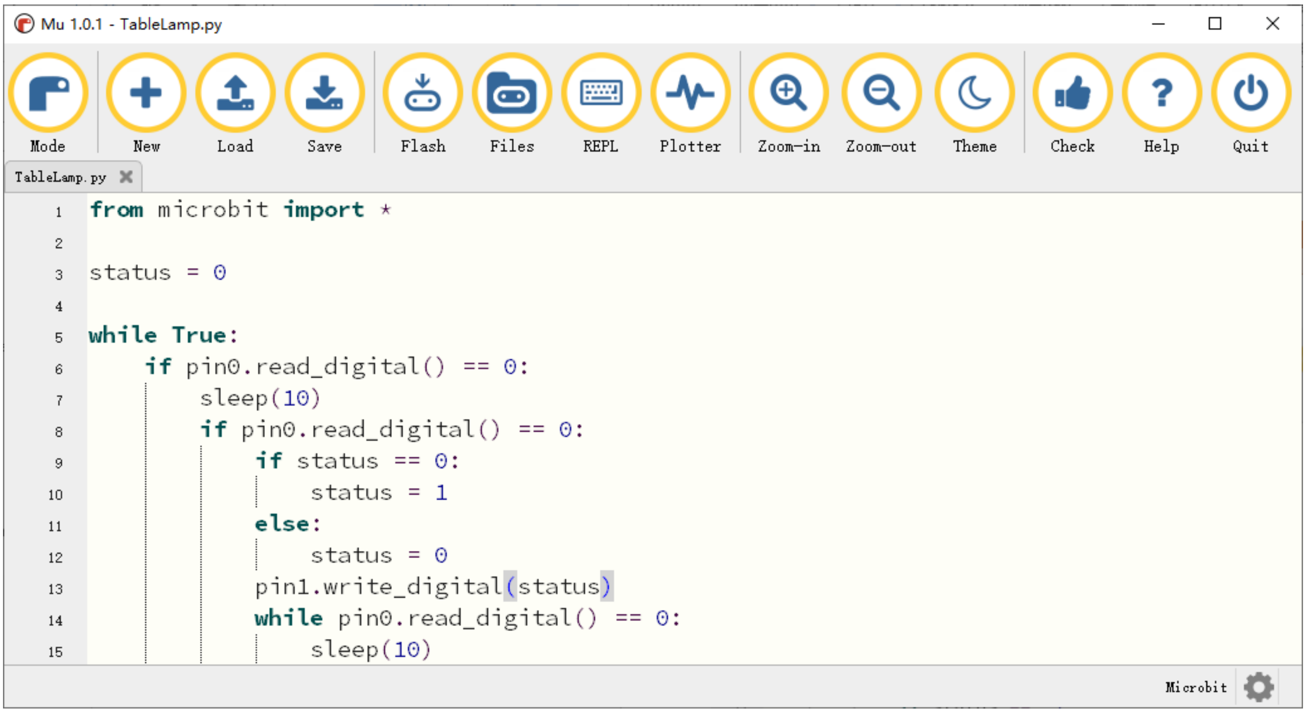
| Block | Function |
|---|---|
|  | Use an equal sign to make a variable store the number or string you set. |

## Python code

Open the .py file with Mu. Code, the path is as below:

| File type | Path | File name |
|---|---|---|
| Python file | ../Projects/PythonCode/04.2_TableLamp | TableLamp.py |

After loading successfully, the code is shown as below:




Download the code to micro:bit, press the button once, the LED turns ON; press the button again, the LED turns OFF.

The following is the program code:

```python
from microbit import *
status = 0
while True:
    if pin0.read_digital() == 0:
        sleep(10)
        if pin0.read_digital() == 0:
            if status == 0:
                status = 1
            else:
                status = 0
            pin1.write_digital(status)
            while pin0.read_digital() == 0:
                sleep(10)
```

In the program, when it is detected for the first time that the button is pressed, wait for 10ms to detect whether the button is pressed again, to eliminate the impact of bounce when the button is pressed. And if the button is still pressed for the second time, the button is considered to have been pressed and in a steady state. Otherwise, it is considered to be a bounce and exit this judgment.

```
    if pin0.read_digital() == 0:
        sleep(10)
        if pin0.read_digital() == 0:
```

When it is determined that the key is pressed, change the status value. Status is used to save the state of LED. And then write the new value of status to the P1 port to control the LED.

```
            if status == 0:
                status = 1
            else:
                status = 0
            pin1.write_digital(status)
```

After the above operations done, the program will detect whether the button is released. And similarly, it will first eliminate the bounce of the button.

```
            while pin0.read_digital() == 0:
                sleep(10)
```

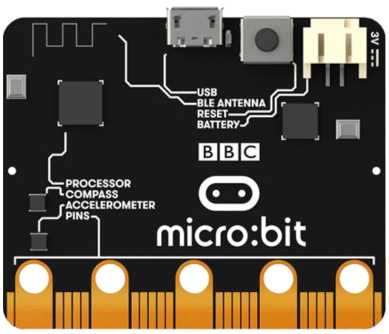
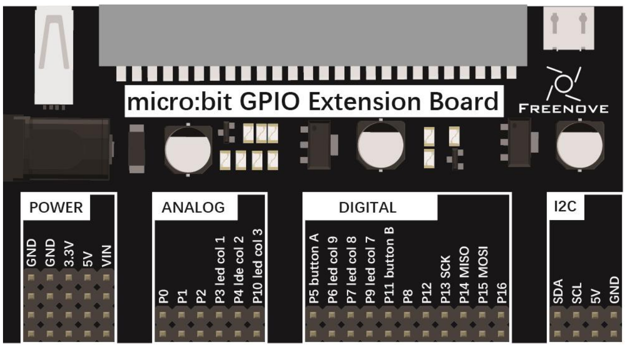
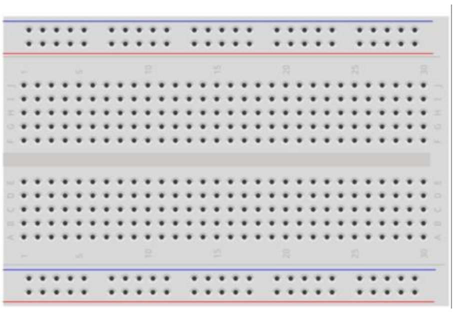
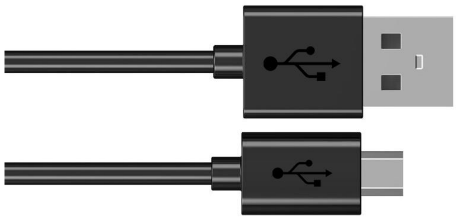
# Chapter 5 LED Bar Graph

We have learned how to control LED blink. Next step, we will learn a new component LED bar graph.

## Project 5.1 Flowing Light

In this project, we use LED Bar Graph to make a flowing water light.

### Component list

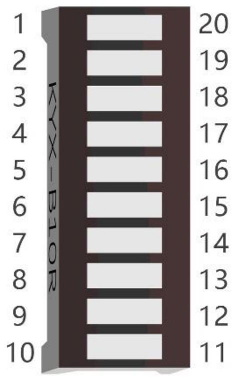
<table>
<tr><td>Microbit x1<br>
</td><td colspan="2">Expansion board x1<br>
</td></tr>
<tr><td>Breakboard x1<br></td><td>Resistor 220Ω x10<br></td><td>Jumper F/M x11<br></td></tr>
<tr><td>LED bar graph x1<br></td><td colspan="2">USB cable x1<br></td></tr>
</table>

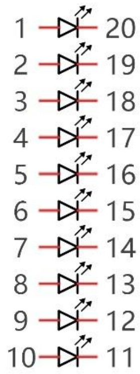
## Component knowledge

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

LED Bar Graph

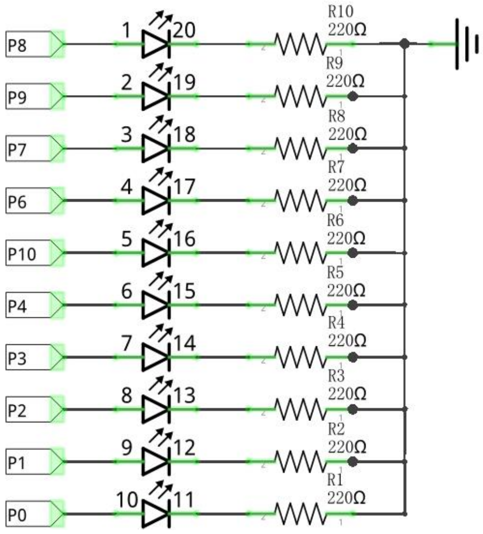
A Bar Graph LED has 10 LEDs integrated into one compact component. The two rows of pins at its bottom are paired to identify each LED like the single LED used earlier.



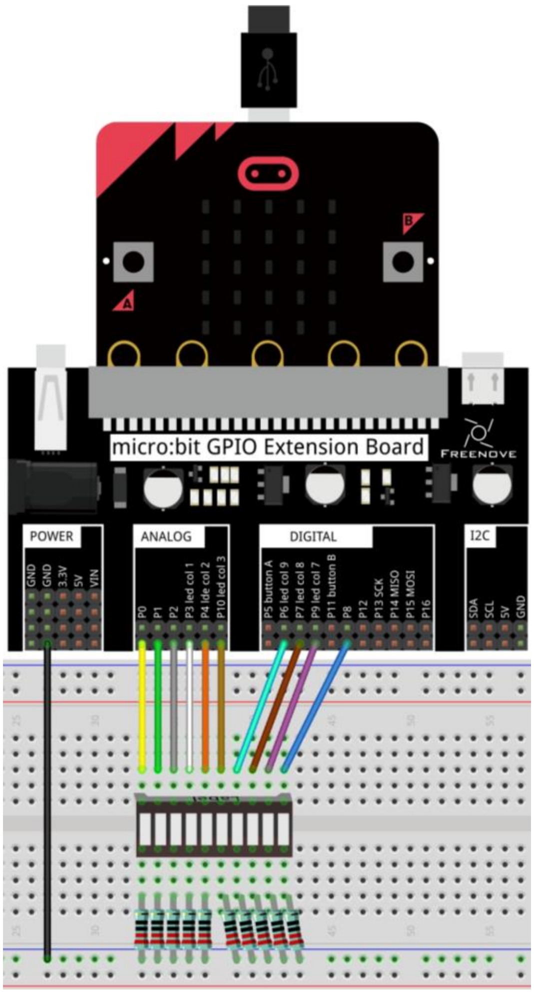
## Circuit

Schematic diagram




Hardware connection

**If your project doesn't work, please rotate LED bar 180°.**

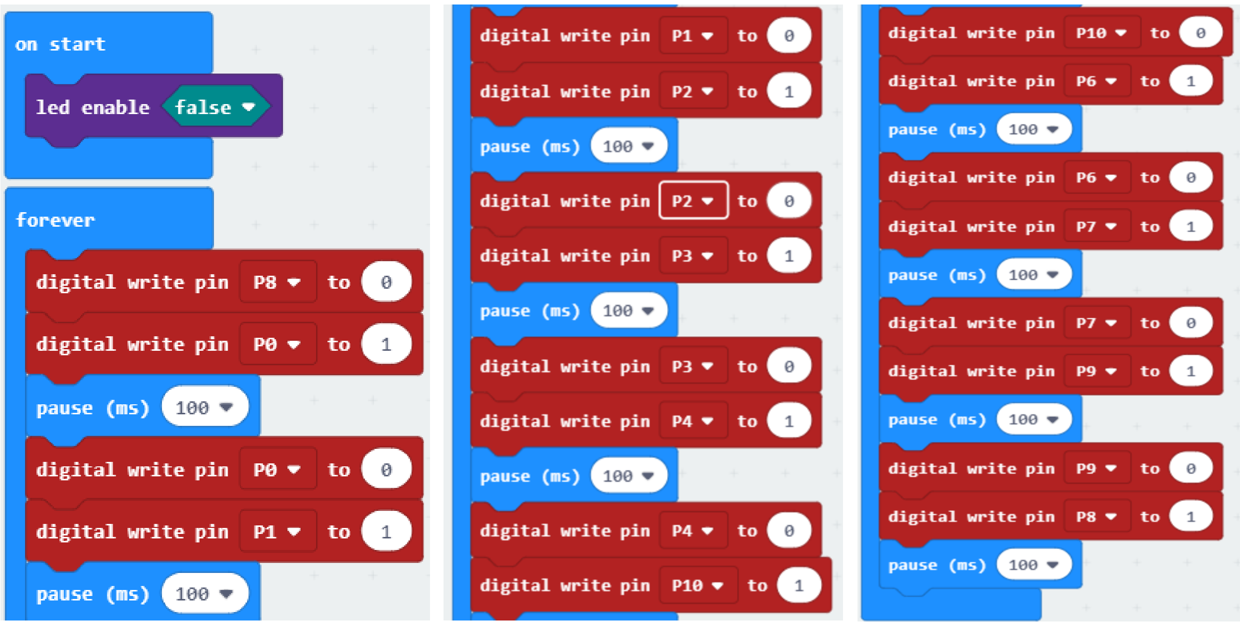


## Block code

Open MakeCode first. Import the .hex file. The path is as below:
(How to import project)

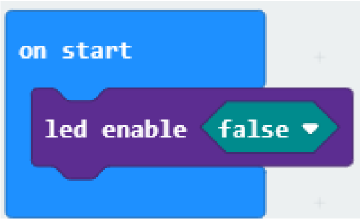
| File type | Path | File name |
|---|---|---|
| HEX file | ../Projects/BlockCode/05.1_FlowingLight01 | FlowingLight01.hex |

After importing successfully, the code is shown as below:

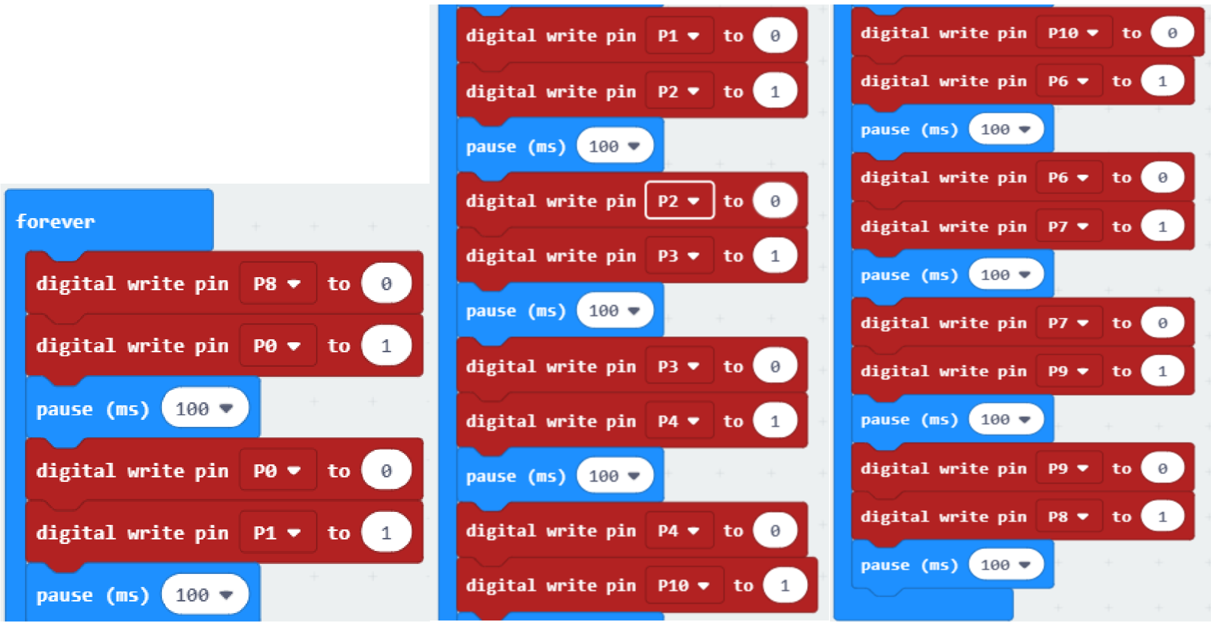



Check the connection of the circuit, verify that the circuit is connected correctly, download the code into micro:bit, after the program is executed, you will see the LED turns ON from left to right, which repeats This process is repeated to achieve the “movements” of flowing water.

**In the code, we need turn OFF the LED screen (which allows the GPIO pin associated with the LED screen to be reused for other purposes).**




Set one pin to high and the rest of 9 pins to low level at a time; Until all the 10 pins are set to high and low level in turn.




## Reference

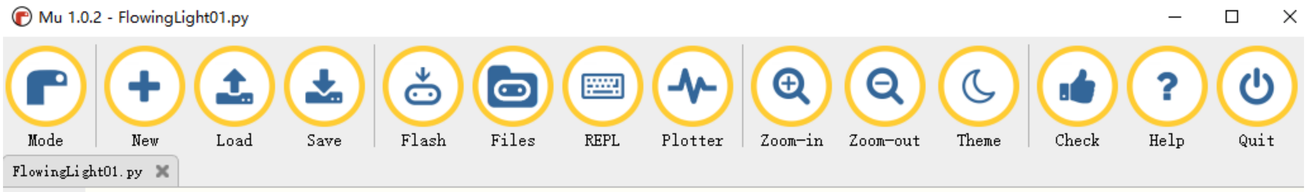
| Block | Function |
|---|---|
|   | Turns the LED screen on and off (thus allowing you to re-use the GPIO pins associated with the display for other purposes). |

## Python code

Open the .py file with Mu. Code, the path is as below:

| File type | Path | File name |
|---|---|---|
| Python file | ../Projects/PythonCode/05.1_FlowingLight01 | FlowingLight01.py |

After loading successfully, the code is shown as below:




```
from microbit import *
display.off()
outPin = [pin0, pin1, pin2, pin3, pin4, pin10, pin6, pin7, pin9, pin8]
while True:
    for p in outPin:
        p.write_digital(1)
        sleep(100)
        p.write_digital(0)
        sleep(100)
```

Check the connection of the circuit, verify that the circuit is connected correctly, download the code into micro:bit, after the program is executed, you will see the LED turns ON from left to right, which repeats to achieve the “movements” of flowing water.

The following is the program code:

```
from microbit import *
display.off()
outPin = [pin0, pin1, pin2, pin3, pin4, pin10, pin6, pin7, pin9, pin8]
while True:
    for p in outPin:
        p.write_digital(1)
        sleep(100)
        p.write_digital(0)
        sleep(100)
```

**In the code, we need to turn OFF the LED screen (which allows the GPIO pin associated with the LED screen to be reused for other purposes).**

```
display.off()
```

Define an array to save the pin variable.

```
outPin = [pin0, pin1, pin2, pin3, pin4, pin6, pin7, pin8, pin9, pin10]
```

Change the level of the currently selected pin every 100ms to implement the effect of flowing water light.

```
for p in outPin:
    p.write_digital(1)
    sleep(100)
    p.write_digital(0)
    sleep(100)
```

## Reference

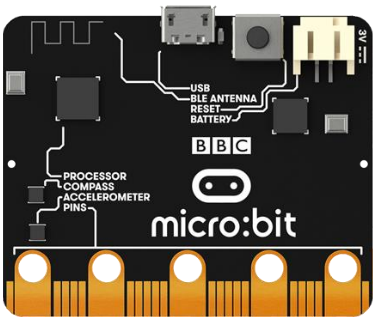
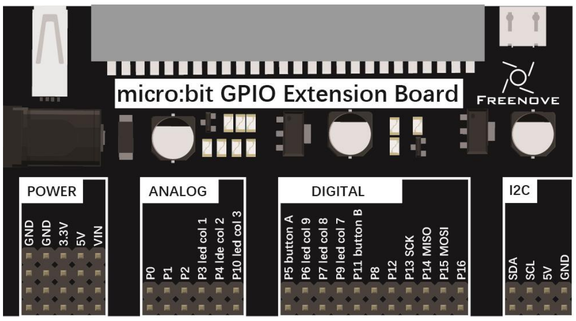
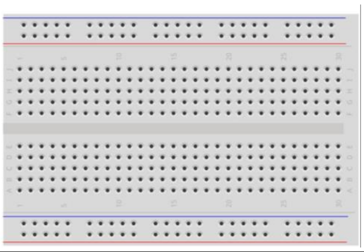
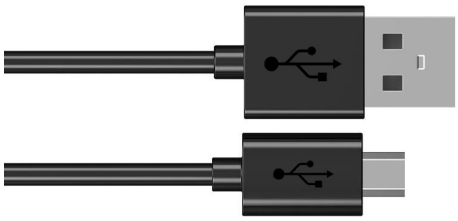
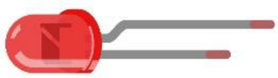
| display.off() |
|---|
| Use off() to turn OFF the display (thus allowing you to re-use the GPIO pins associated with the display for other purposes) |

# Chapter 6 PWM

In this chapter, we will learn how to make a breathing LED.

## Project 6.1 Breathing Light

### Component list

<table>
<tr>
<td colspan="2">Microbit x1<br><br></td>
<td colspan="2">Expansion board x1<br><br></td>
</tr>
<tr>
<td colspan="2">Breakboard x1<br></td>
<td colspan="2">USB cable x1<br></td>
</tr>
<tr>
<td>Jumper F/M x2<br></td>
<td colspan="2">Resistor 220Ω  x1<br></td>
<td>LED x1<br></td>
</tr>
</table>

## Circuit knowledge

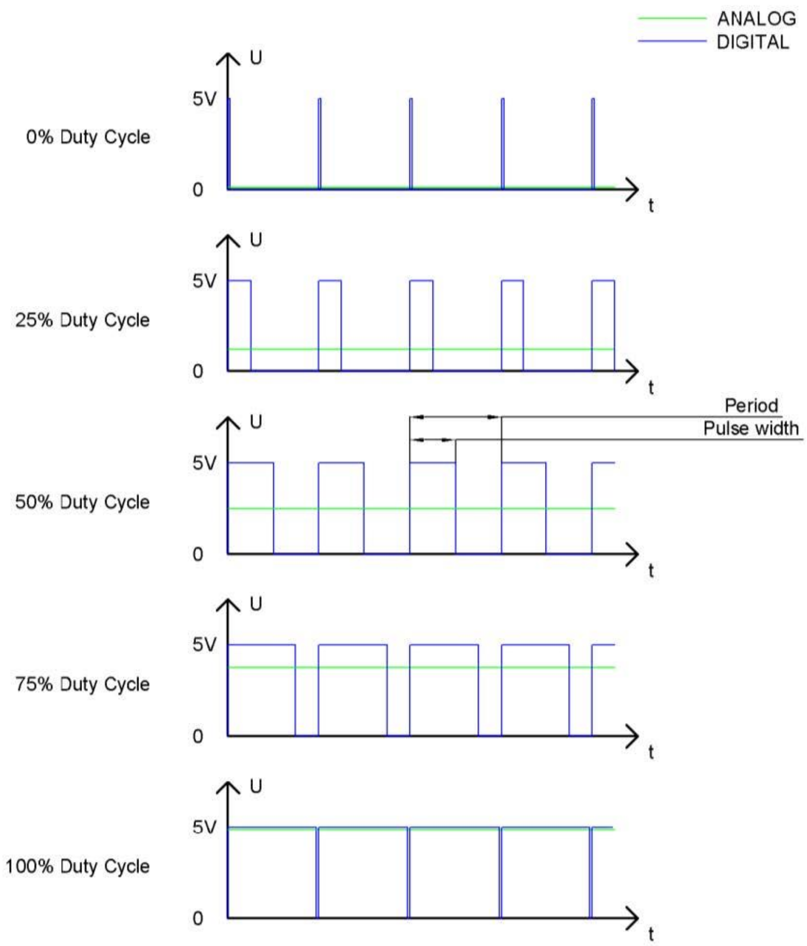
At first, let us learn the knowledge how to use the circuit to make LED emit different brightness of light,

### PWM

PWM, Pulse-Width Modulation, is a very effective method for using digital signals to control analog circuits. Digital 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.

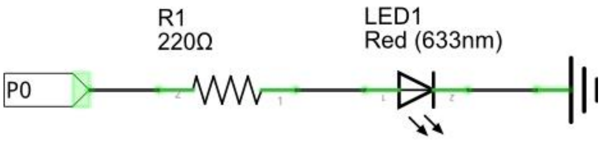
The longer the output of high levels last, the longer the duty cycle and the higher the corresponding voltage in the analog signal will be. The following figures show how the analog signal voltages vary between 0V-5V (high level is 5V) corresponding to the pulse width 0%-100%:




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.

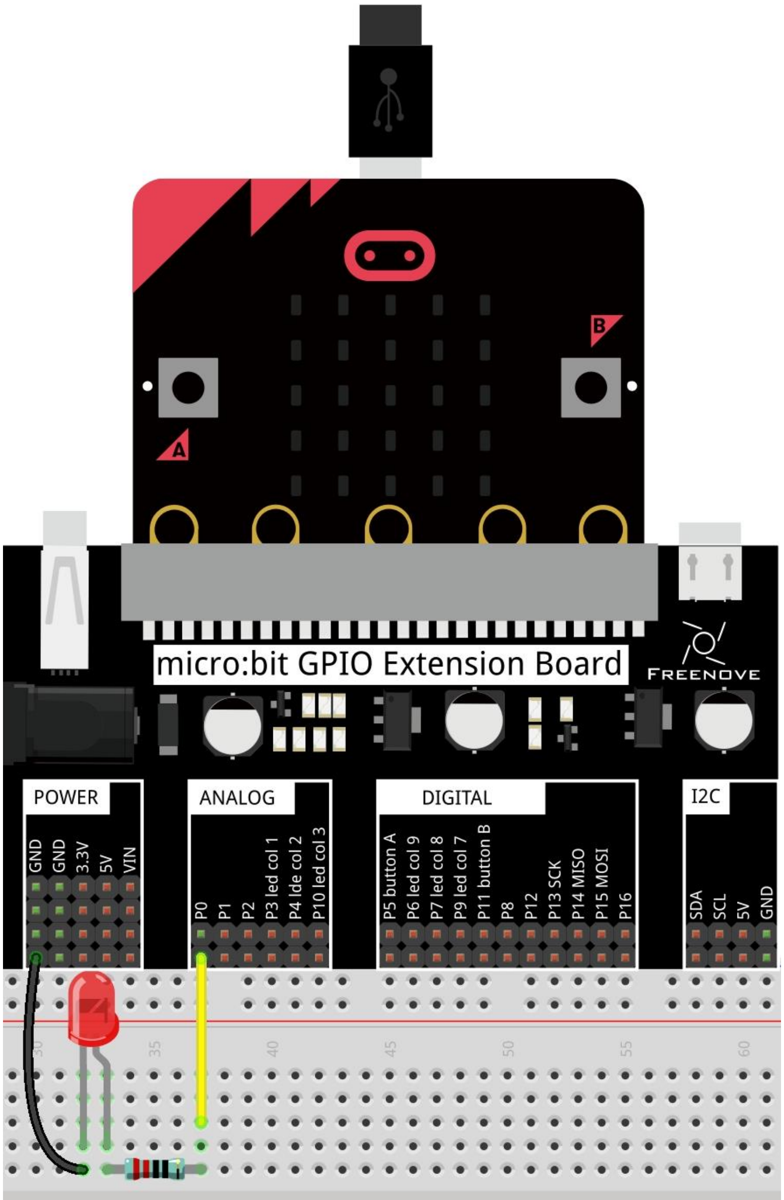
## Circuit

Schematic Diagram




hardware connection

The pin for the circuit is P0. The long pin (positive) of LED is connected to the resistor, and the short pin (negative) to ground.

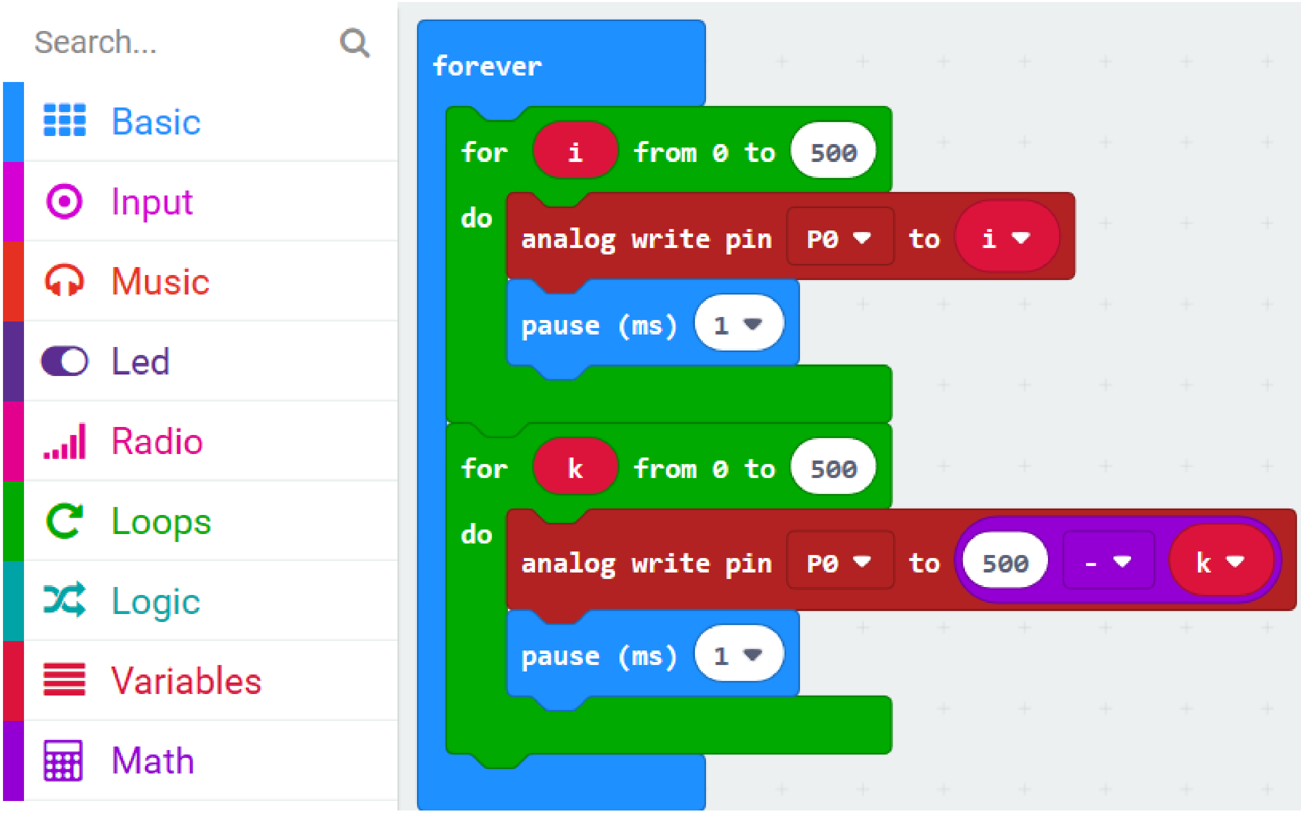


## Block code

Open MakeCode first. Import the .hex file. The path is as below:
(How to import project)

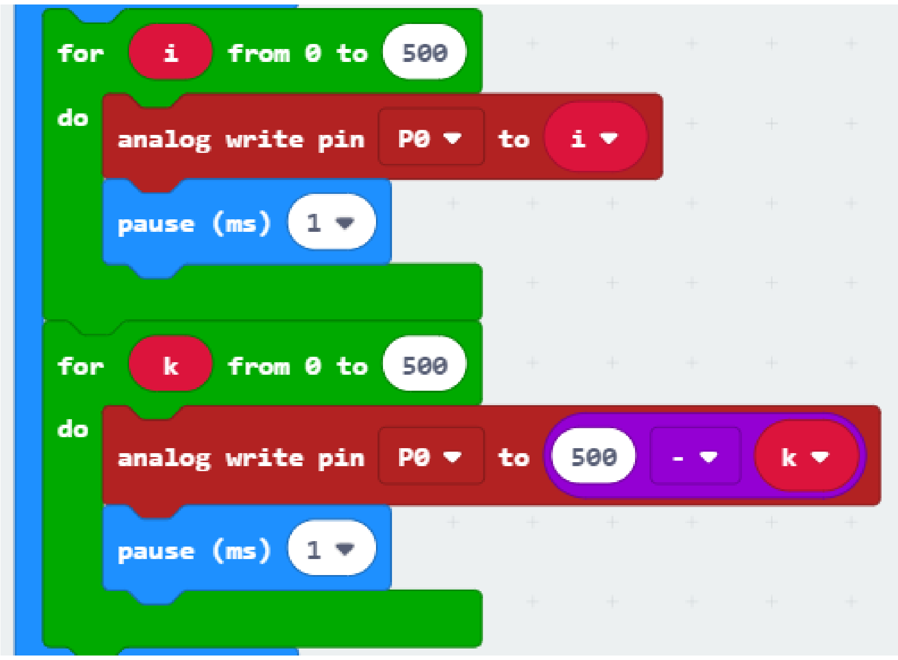
| File type | Path | File name |
|---|---|---|
| HEX file | ../Projects/BlockCode/06.1_BreathingLight | BreathingLight.hex |

After import successfully, the code is shown as below:




Check the connection of the circuit, confirm that the circuit is connected correctly, download the code into micro:bit. The LED will becomes brighter gradually, and then dimmer and dimmer. This process will be repeated to achieve the effect of breathing.

P0 outputs PWM signal, from 0 to 500, then from 500 to 0.




## Reference

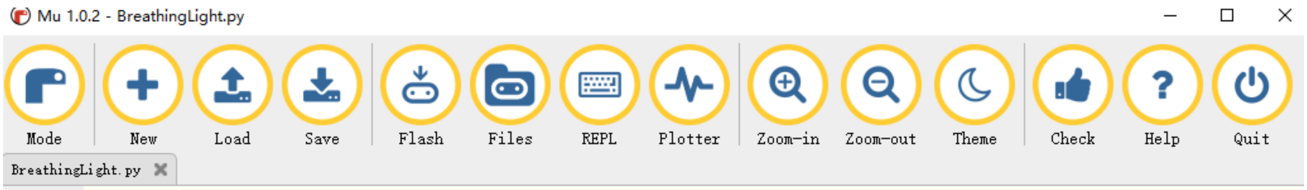
| Block | Function |
|---|---|
|   | Write an analog signal (0 through 1023) to the pin you set. |

## Python code

Open the .py file with Mu. Code, the path is as below:

| File type | Path | File name |
|---|---|---|
| **Python file** | ../Projects/PythonCode/06.1_BreathingLight | BreathingLight.py |

After loading successfully, the code is shown as below:




```
from microbit import *
while True:
    for i in range(0, 500, 1):
        pin0.write_analog(i)
        sleep(1)

    for i in range(500, 0, -1):
        pin0.write_analog(i)
        sleep(1)
```

Check the connection of the circuit, verify it correct and download the code into micro:bit, the LED will becomes brighter gradually, and then dimmer and dimmer. This process will be repeated to achieve the effect of breathing. (How to download?)

The following is the program code:

```
from microbit import *

while True:
    for i in range(0, 500, 1):
        pin0.write_analog(i)
        sleep(1)

    for i in range(500, 0, -1):
        pin0.write_analog(i)
        sleep(1)
```

P0 outputs PWM signal, from 0 to 500,

```
for i in range(0, 500, 1):
        pin0.write_analog(i)
        sleep(1)
```

Then from 500 to 0.

```
for i in range(500, 0, -1):
        pin0.write_analog(i)
        sleep(1)
```

## Reference

| pin.write_analog(value) |
|---|
| Output a PWM signal on the pin, with the duty cycle proportional to the provided value. The value may be either an integer or a floating point number between 0 (0% duty cycle) and 1023 (100% duty).. <br>For more information, please refer to: <br>https://microbit-micropython.readthedocs.io/en/latest/pin.html |

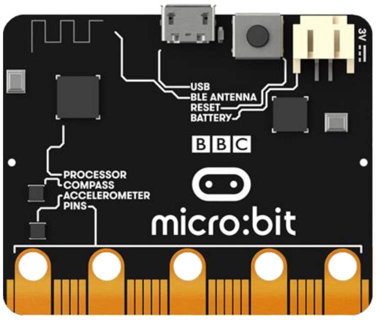
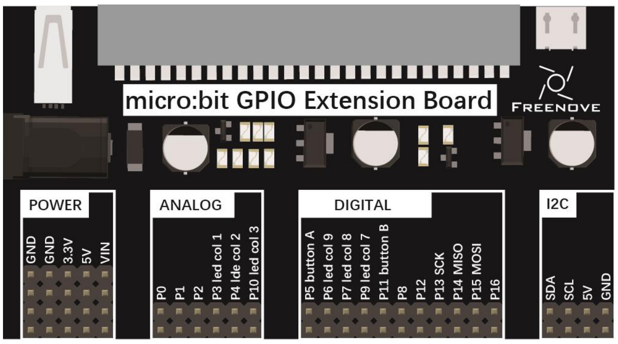
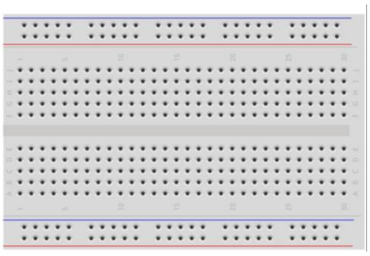
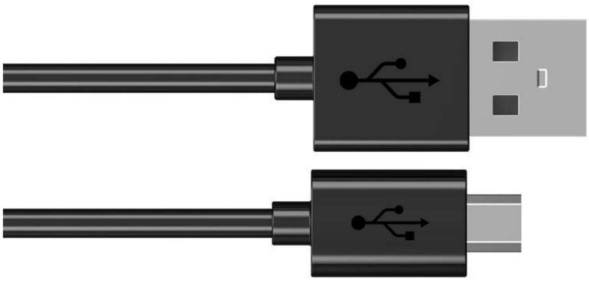
# Chapter 7 RGBLED

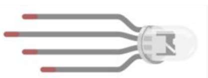
In this chapter, we will learn a new component, RGBLED.

## Project 7.1 Monochromatic Light

This project will use RGBLED to show one color.

### Component list

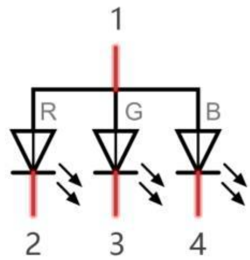
| Microbit x1 | Extension board x1 |
|---|---|
|  |  |
| Breadboard x1 | USB cable x1 |
|  |  |

| RGB_LED x1 | Jumper F/M x4 | Resistor 220Ω x3 |
|---|---|---|
|  |  |  |

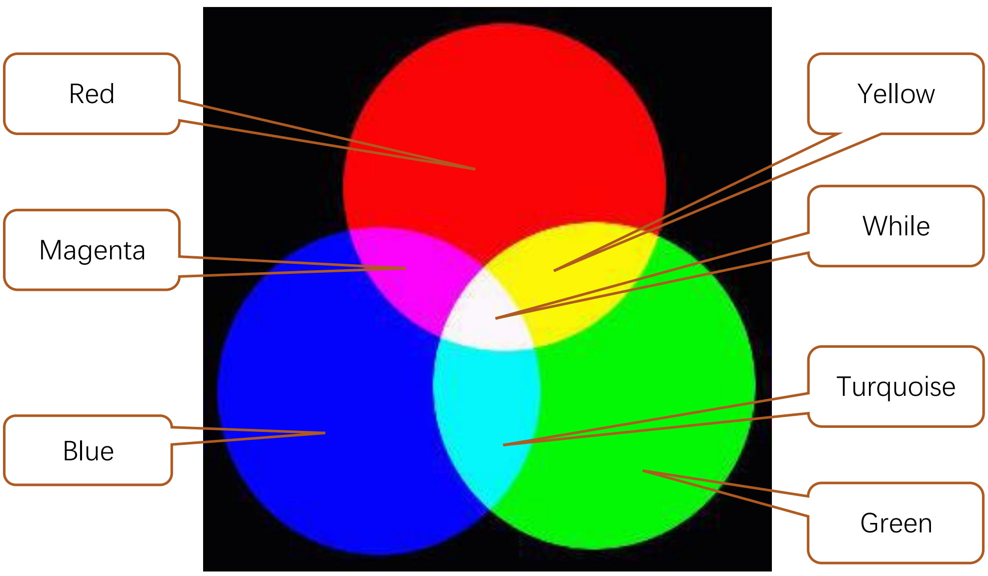
# Component knowledge

## RGB LED

A RGB LED has 3 LEDs integrated into one LED component. It can respectively emit Red, Green and Blue light. In order to do this, it requires 4 pins (this is also how you identify it). The long pin (1) is the common which is the Anode (+) or positive lead, the other 3 are the Cathodes (-) or negative leads. A rendering of a RGB LED and its electronic symbol are shown below. We can make RGB LED emit various colors of light and brightness by controlling the 3 Anodes (2, 3 & 4) of the RGB LED


Red, Green, and Blue light are called 3 Primary Colors when discussing light (Note: for pigments such as paints, the 3 Primary Colors are Red, Blue and Yellow). When you combine these three Primary Colors of light with varied brightness, they can produce almost any color of visible light. Computer screens, single pixels of cell phone screens, neon lamps, etc. can all produce millions of colors due to phenomenon

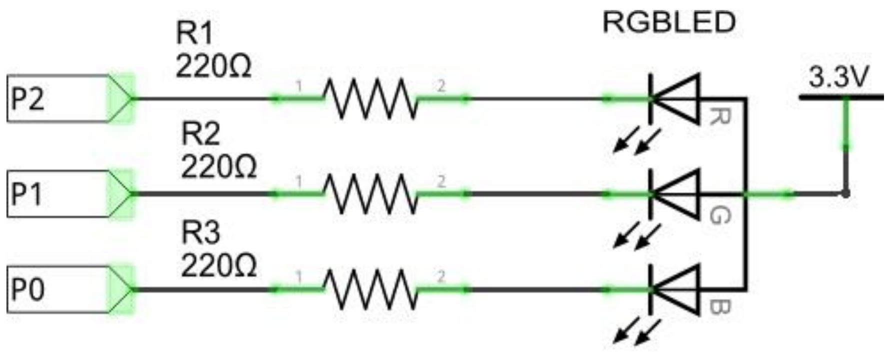



If we use a three 8 bit PWM to control the RGB LED, in theory, we can create 28*28*28=16777216 (16 million) colors through different combinations of RGB light brightness.

## Circuit

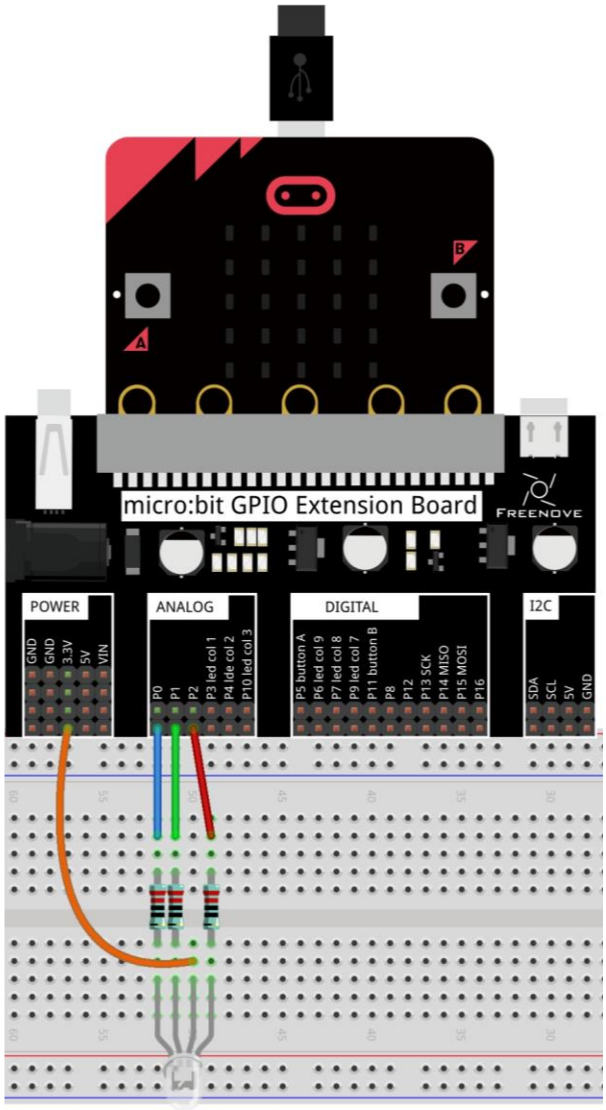
This circuit uses pins P2, P1, and P0 to connect the negative electrodes of the RGBLED.

Schematic diagram




Hardware connection

**The longest pin of the RGB LED is connected to the power supply 3.3V.**

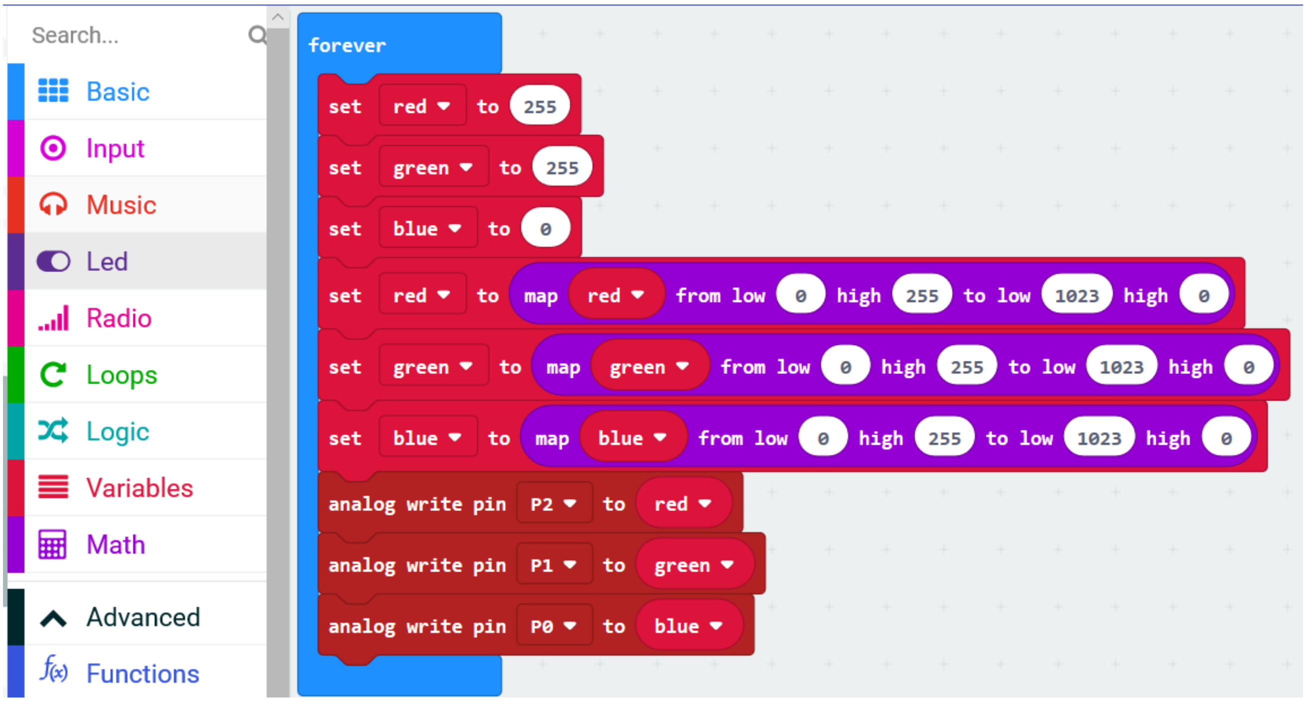


## Block code

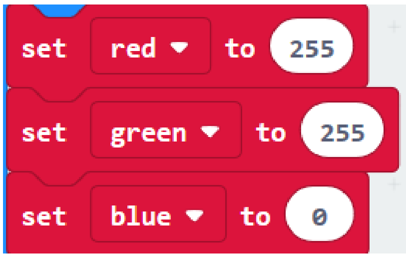
Open MakeCode first. Import the .hex file. The path is as below: (how to import project)

| File type | Path | File name |
|---|---|---|
| HEX file | ../Projects/BlockCode/07.1_RGBLED | RGBLED.hex |

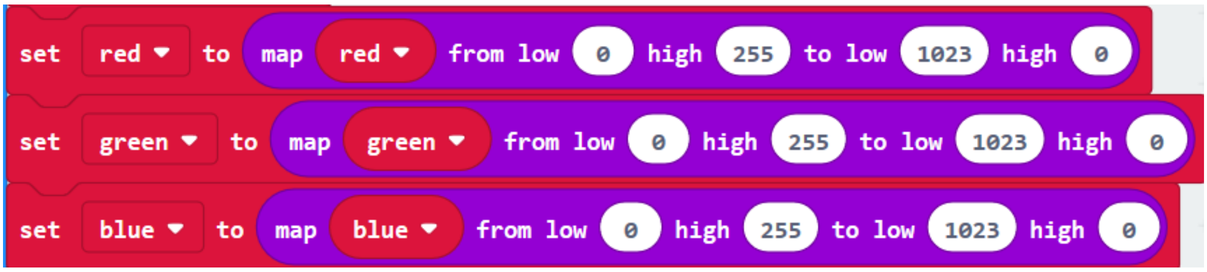
After importing successfully, the code is shown as below:




Check the connection of the circuit, confirm that the circuit is connected correctly, download the code into micro:bit, and RGBLED will emit yellow color. RGB value of yellow is (255,255,0).




In this kit, three LEDs of RGB LED share a common anode(+) and their negative pins need to be set to LOW level to have the RGB LED work. And the value of variables 'red', 'green', and 'blue' need to be converted from the value ranging from 0-255 to analog signal values ranging from1023-0.



Write the ‘red’,‘green’,‘blue’ to corresponding pins P2, P1, P0.


## Reference

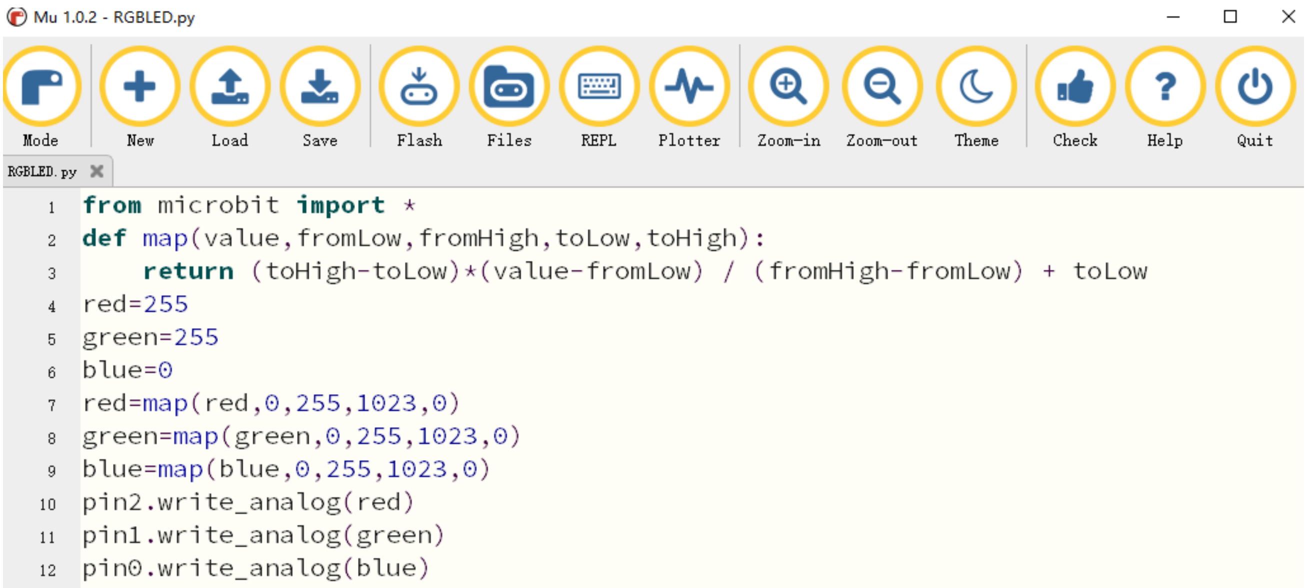
| Block | Function |
|---|---|
|   | Convert a value in one number range to a value in another number range. |

## Python code

Open the .py file with Mu. Code, the path is as below:

| File type | Path | File name |
|---|---|---|
| **Python file** | ../Projects/PythonCode/07.1_RGBLED | RGBLED.py |

After loading successfully, the code is shown as below:




Check the connection of the circuit, confirm that the circuit is connected correctly, download the code into micro:bit, and RGBLED will emit yellow color. (How to download?)

The following is the program code:

```
from microbit import *
def map(value, fromLow, fromHigh, toLow, toHigh):
    return (toHigh-toLow)*(value-fromLow) / (fromHigh-fromLow) + toLow
red=255
green=255
blue=0
red=map(red, 0, 255, 1023, 0)
green=map(green, 0, 255, 1023, 0)
blue=map(blue, 0, 255, 1023, 0)
pin2.write_analog(red)
pin1.write_analog(green)
pin0.write_analog(blue)
```

A custom map() function is used to convert a value in one range to another range.

```
def map(value, fromLow, fromHigh, toLow, toHigh):
    return (toHigh-toLow)*(value-fromLow) / (fromHigh-fromLow) + toLow
```

RGB value of yellow is (255,255,0).

```
red=255
green=255
blue=0
```

In this kit, three LEDs of RGB LED share a common anode(+) and their negative pins need to be set to LOW level to have the RGB LED work. And the value of variables 'red', 'green', and 'blue' need to be converted from the value ranging from 0-255 to analog signal values ranging from1023-0.

```
red=map(red, 0, 255, 1023, 0)
green=map(green, 0, 255, 1023, 0)
blue=map(blue, 0, 255, 1023, 0)
```

Write the 'red', 'green', 'blue' to corresponding pins P2, P1, P0.

```
pin2.write_analog(red)
pin1.write_analog(green)
pin0.write_analog(blue)
```

## Reference

| map(value, fromLow, fromHigh, toLow, toHigh) |
| --- |
| A custom function that converts a value in a range of numbers to a value in another range of numbers. For example, map(8,0,10,0,100) returns a value of 80; map(8,0,10,100,0)=20.<br>map(8,0,10,0,100)=80. |

# Project 7.2 Multicolored Light

In this project, we will use an RGB LED to emit different colors.

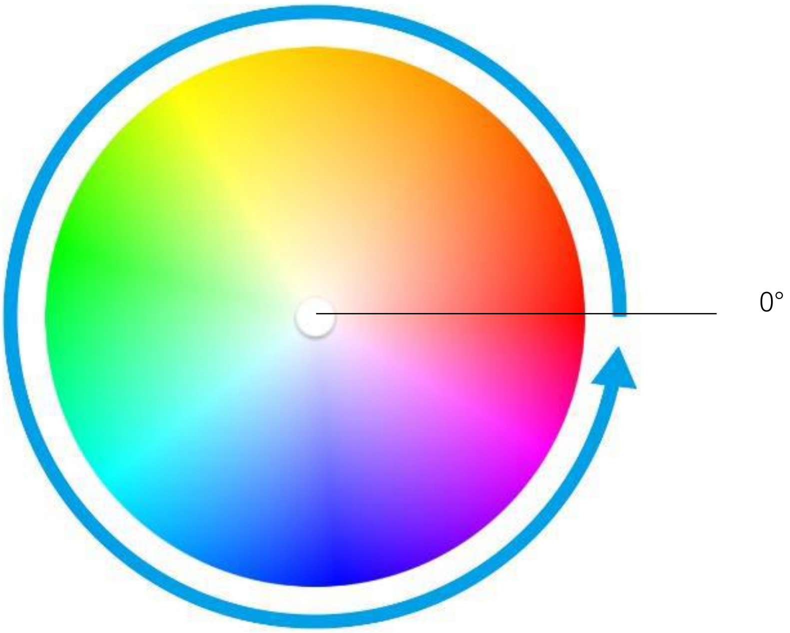
## Component list

It is same with the previous project.

## HSL color

The HSL color mode is another color standard in the industry. It obtains a variety of colors by changing the three color channels of hue (H), saturation (S), and lightness (L) and superimposing them with each other. This color mode covers almost all colors that human vision can perceive. It is one of the most widely used color systems to date.

As shown in the hue circle below, the 0 degree of the hue is R (red) color, 120 degrees is G (green) color, and 240 degrees is B (blue) color. Each angle represents a color. The default saturation (S) takes the maximum value 100, the brightness (L) takes 50. If the hue angle is changed, the color will be changed. And the HSL color system can be converted to the RGB color system, to change the color of the LED.



## Circuit

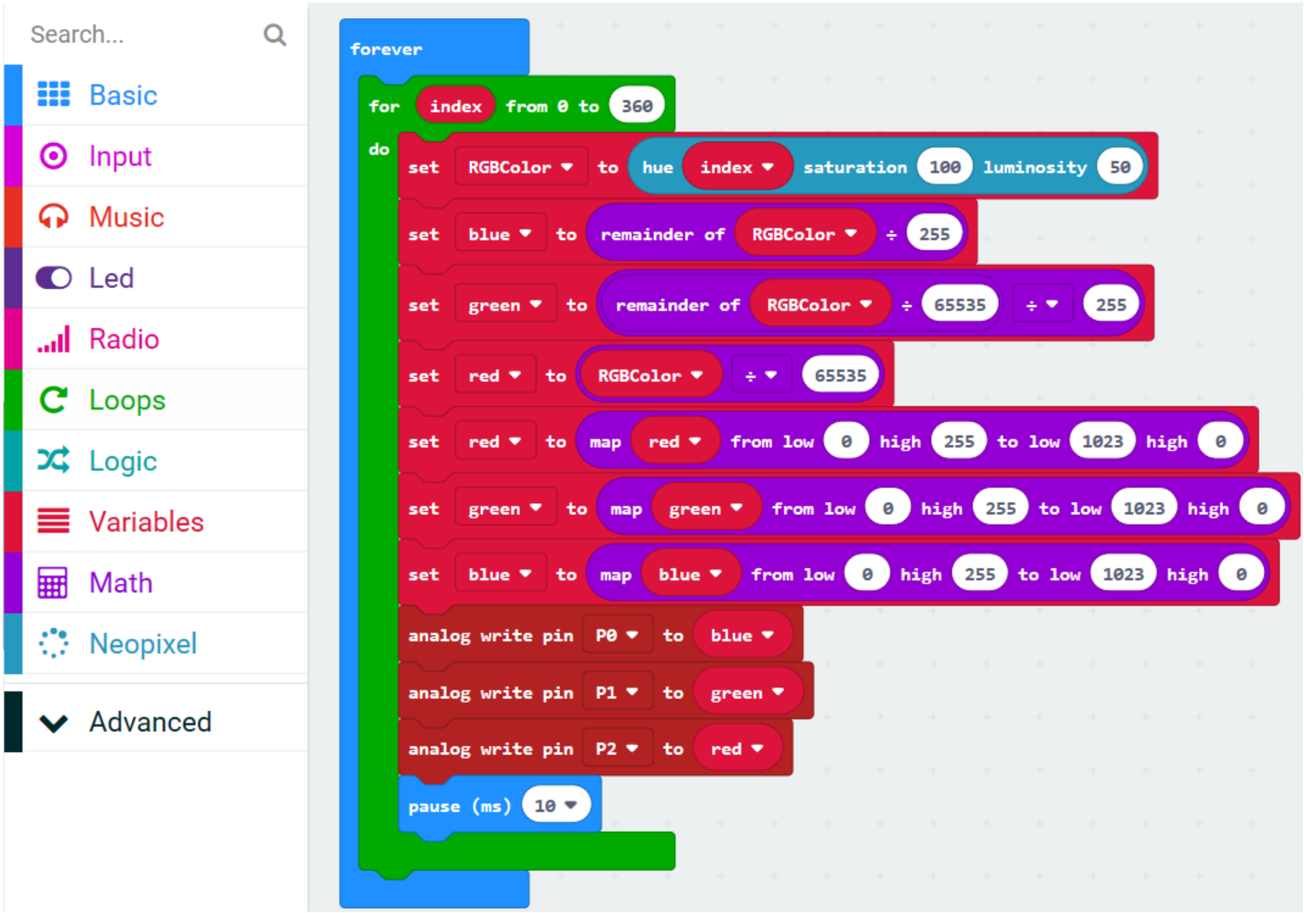
It is same with last project.

## Block code

Open MakeCode first. Import the .hex file. The path is as below:
(How to import project)

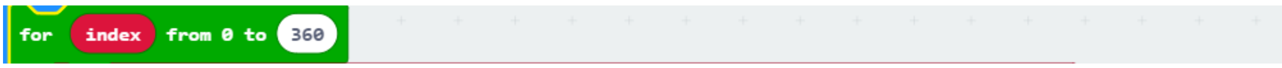
| File type | Path | File name |
|---|---|---|
| HEX file | ../Projects/BlockCode/07.2_ColorfulLight | ColorfulLight.hex |

After importing successfully, the code is shown as below:




Check the connection of the circuit, confirm that the circuit is connected correctly, download the code into the microbit, and RGBLED will emit different colors.

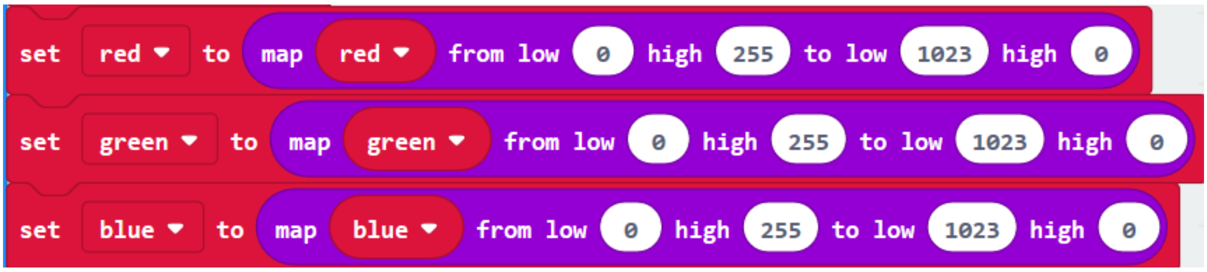
From the knowledge of HSL color, we can know that different hue angles correspond different colors. The variable index represents hue angle, ranging from 0 to 360.



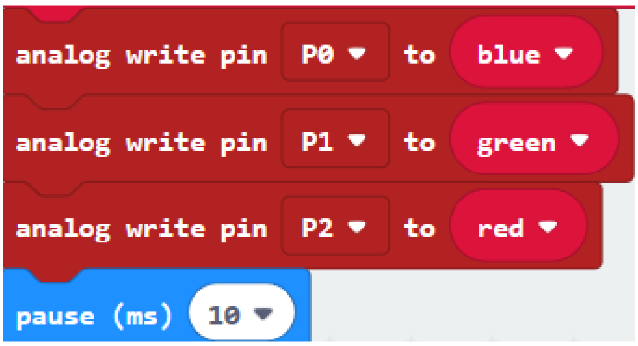
This block is to convert the HSL color system to the RGB color system, return the RGB value corresponding to the current hue angle, and store the value in the variable RGBColor. For example: hexadecimal RGB value 0xFF0000 means red, FF is the value of the red channel in RGB, and 00 and 00 are the values of the green and blue channels, respectively.


Assign the value of the lower eight-bit to blue channel, the value of the middle eight-bit to green channel, and the value of the upper eight-bit to red channel.


In this kit, three LEDs of RGB LED share a common anode (+) and their negative pins need to be set to LOW level to have the RGB LED work. And the variables 'red', 'green', and 'blue' need to be converted from the value ranging from 0-255 to analog signal values ranging from1023-0.




Every 10ms, write the 'red', 'green', 'blue' to corresponding pins P2, P1, P0.

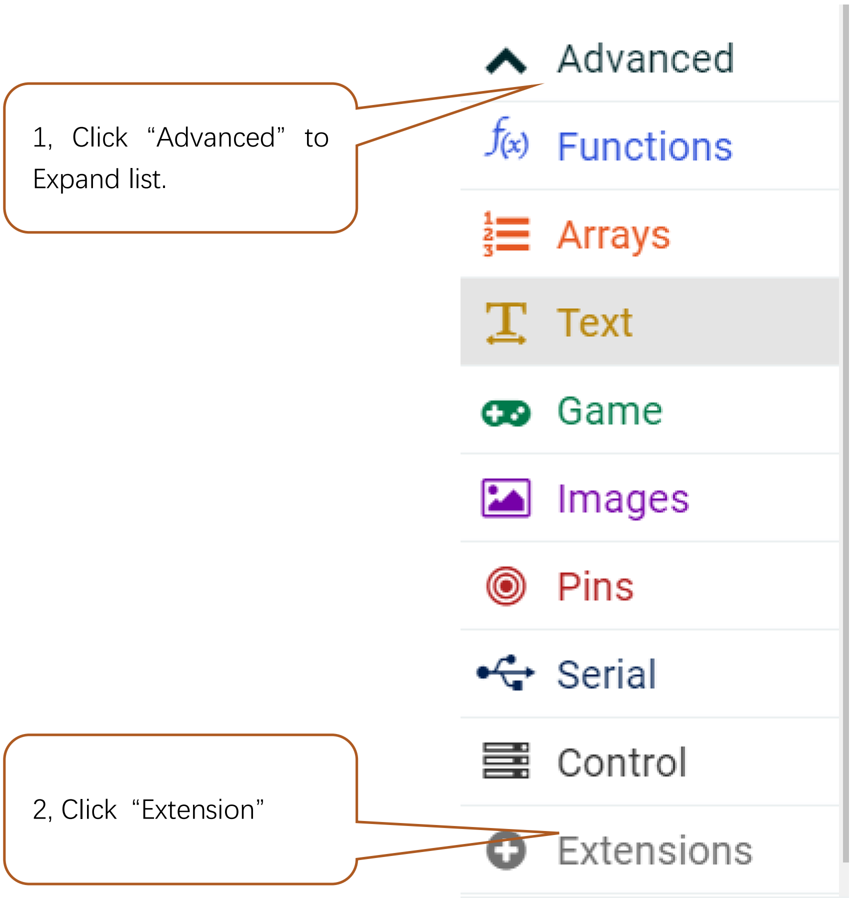


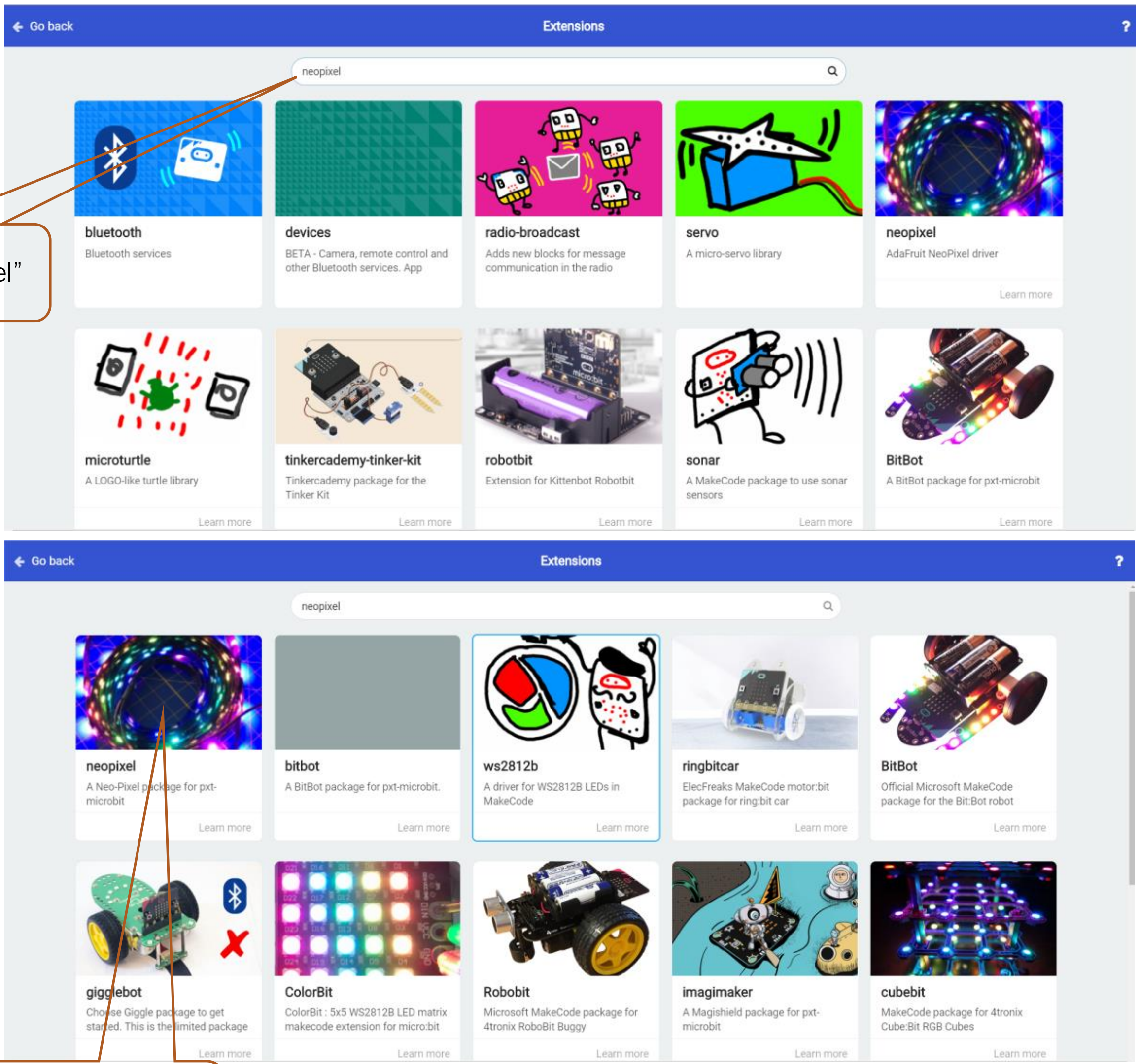
## Reference

| Block | Function |
|---|---|
| remainder of 0 ÷ 1 | This is an extra operator for division. You can find out how much is left over if one number doesn't divide into the other number evenly. |
| hue 0 saturation 0 luminosity 0 | Convert HSL color system to RGB color system, and return the RGB value corresponding to the current hue angle. It belongs to Neopixel expansion block. |

## Extensions

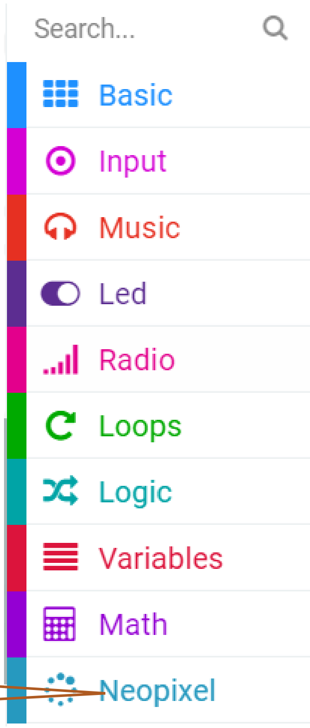
You can import Neopixel expansion block into new project as below:






3, Search "neopixel"

4, Click this neopixel




It is completed.

## Python code

Open the .py file with Mu. Code, the path is as below:

| File type | Path | File name |
|---|---|---|
| Python file | ../Projects/PythonCode/07.2_ColorfulLight | ColorfulLight.py |

After loading successfully, the code is shown as below:


```
from microbit import *
def map(value,fromLow,fromHigh,toLow,toHigh):
    return (toHigh-toLow)*(value-fromLow) / (fromHigh-fromLow) + toLow
def HSL_RGB(degree):
    degree=degree/360*255
    if degree < 85:
        red = 255 - degree * 3
        green = degree * 3
        blue = 0
    elif degree < 170:
        degree = degree - 85
        red = 0
        green = 255 - degree * 3
        blue = degree * 3
    else:
        degree = degree - 170
        red = degree * 3
        green = 0
        blue = 255 - degree * 3
    return red,green,blue
while True:
    for i in range(360):
        red,green,blue=HSL_RGB(i)
        red=map(red,0,255,1023,0)
        green=map(green,0,255,1023,0)
        blue=map(blue,0,255,1023,0)
        pin2.write_analog(red)
        pin1.write_analog(green)
        pin0.write_analog(blue)
        sleep(10)
```

Check the connection of the circuit, confirm that the circuit is connected correctly, download the code into the microbit, and RGBLED will emit different colors. (How to download?)

The following is the program code:

```
from microbit import *
def map(value,fromLow,fromHigh,toLow,toHigh):
    return (toHigh-toLow)*(value-fromLow) / (fromHigh-fromLow) + toLow
def HSL_RGB(degree):
    degree=degree/360*255
    if degree < 85:
        red = 255 - degree * 3
        green = degree * 3
        blue = 0
    elif degree < 170:
        degree = degree - 85
        red = 0
        green = 255 - degree * 3
        blue = degree * 3
    else:
        degree = degree - 170
        red = degree * 3
        green = 0
        blue = 255 - degree * 3
    return red,green,blue
while True:
    for i in range(360):
        red,green,blue=HSL_RGB(i)
        red=map(red,0,255,1023,0)
        green=map(green,0,255,1023,0)
        blue=map(blue,0,255,1023,0)
        pin2.write_analog(red)
        pin1.write_analog(green)
        pin0.write_analog(blue)
        sleep(10)
```

The map() function is used to convert a value in one range to another range.

```
def map(value,fromLow,fromHigh,toLow,toHigh):
    return (toHigh-toLow)*(value-fromLow) / (fromHigh-fromLow) + toLow
```

The HSL_RGB() function is used to convert the HSL color system to RGB color, and return the RGB value corresponding to the current hue angle.

```
def HSL_RGB (degree):
    degree=degree/360*255
    if degree < 85:
        red = 255 - degree * 3
        green = degree * 3
        blue = 0
    elif degree < 170:
        degree = degree - 85
        red = 0
        green = 255 - degree * 3
        blue = degree * 3
    else:
        degree = degree - 170
        red = degree * 3
        green = 0
        blue = 255 - degree * 3
    return red,green,blue
```

Repeat 360 times, display the hue angle color corresponding to 0 to 360 degrees, and replace it every 10ms.

```
while True:
    for i in range(360):
        red,green,blue=HSL_RGB(i)
        red=map(red,0,255,1023,0)
        green=map(green,0,255,1023,0)
        blue=map(blue,0,255,1023,0)
        pin2.write_analog(red)
        pin1.write_analog(green)
        pin0.write_analog(blue)
        sleep(10)
```

## Reference

| HSL_RGB(degree) |
|---|
| Custom function, used to convert HSL color system to RGB color system, return the RGB value corresponding to the current hue angle, for example: HSL_RGB(0), return red RGB value: red=255, green=0, blue=0. |

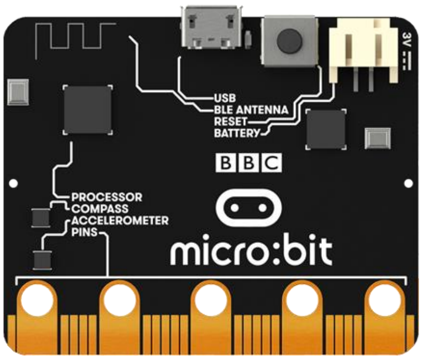
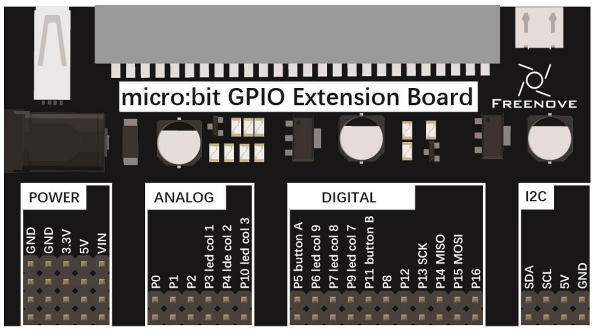
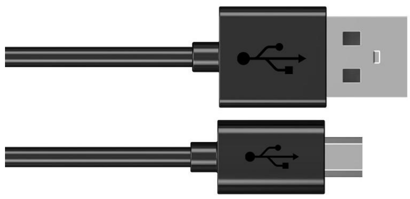
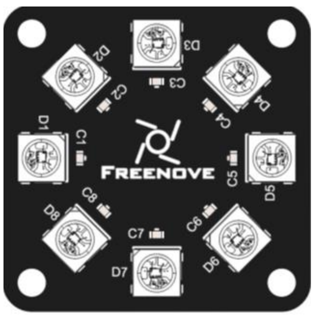
# Chapter 8 Neopixel

In this chapter, we will learn Freenove 8 RGB LED Module

## Project 8.1 Rainbow Water Light

This project will achieve rainbow water light.

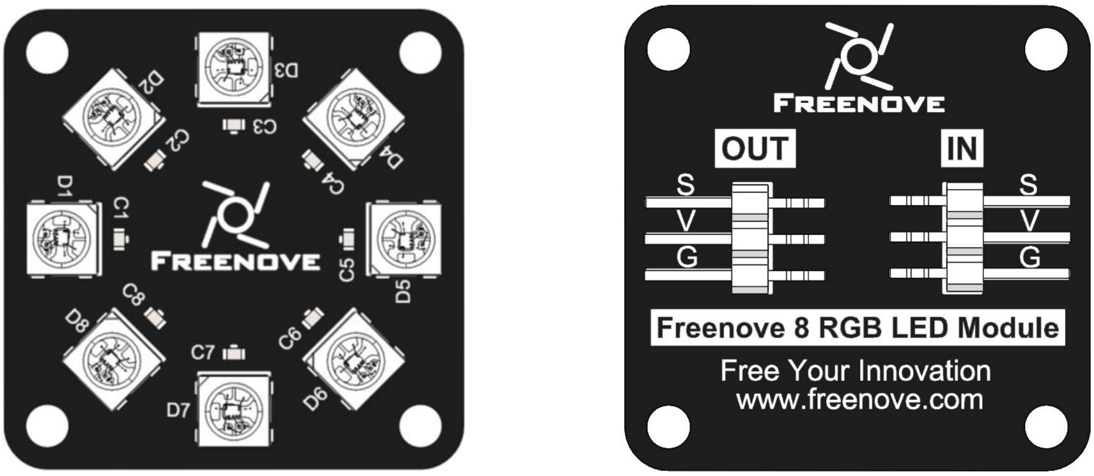
### Component list

<table>
<tr>
<td>Microbit x1<br>
</td>
<td>Extension board x1<br>
</td>
</tr>
<tr>
<td>Jumper F/F x3<br></td>
<td>USB cable x2<br></td>
</tr>
<tr>
<td>Freenove 8 RGB LED Module x1<br>
</td>
<td></td>
</tr>
</table>

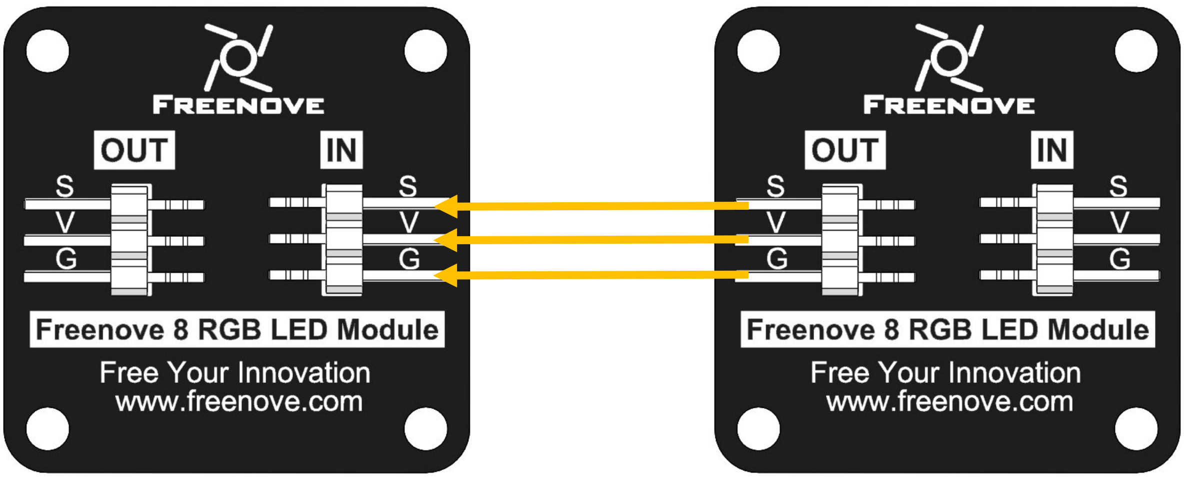
# Component knowledge

## Freenove 8 RGB LED Module

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




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

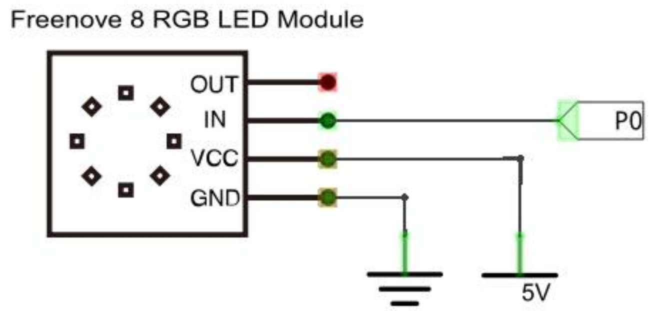



Pin description:

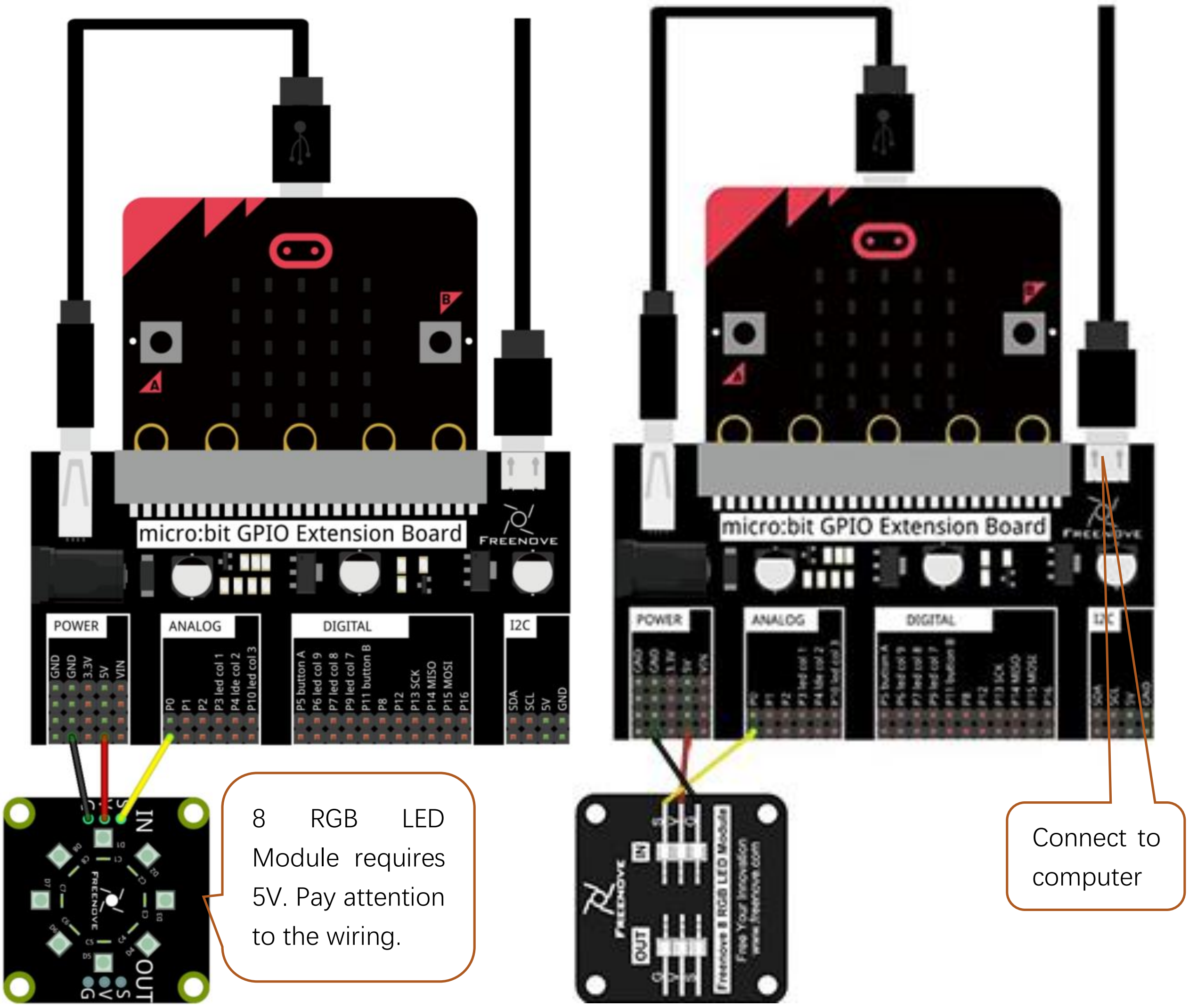
| (IN) | | (OUT) | |
|---|---|---|---|
| symbol | Function | symbol | Function |
| S | Input control signal | S | Output control signal |
| V | Power supply pin, +3.5V~5.5V | V | Power supply pin, +3.5V~5.5V |
| G | GND | G | GND |

## Circuit

Schematic diagram




Hardware connection

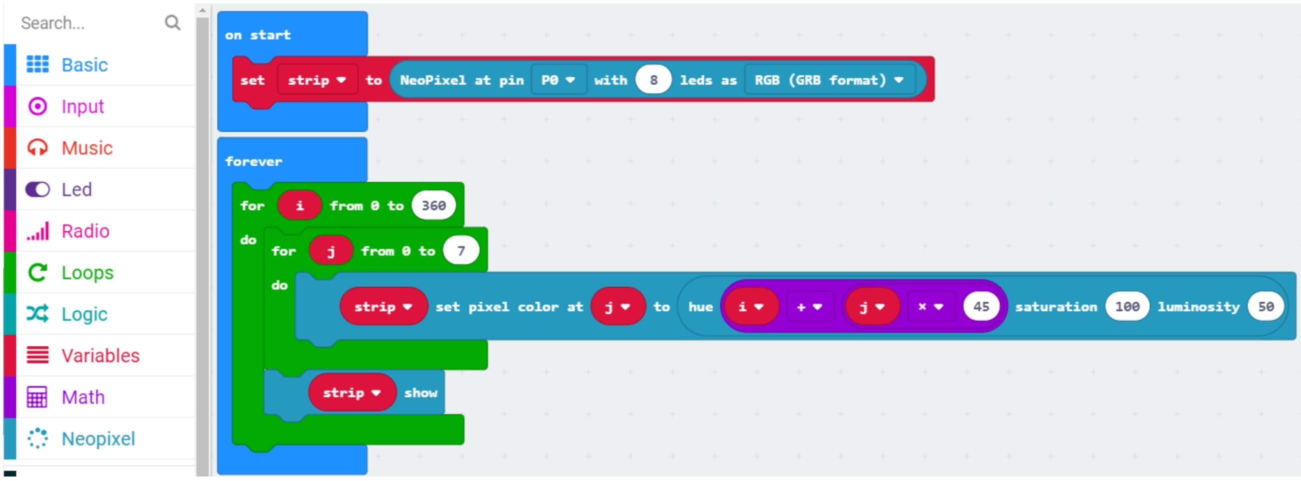


## Block code

Open MakeCode first. Import the .hex file. The path is as below:
(How to import project)

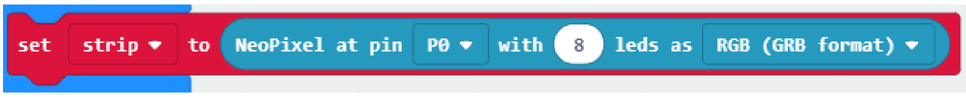
| File type | Path | File name |
|---|---|---|
| **HEX file** | ../Projects/BlockCode/08.1_Neopixel | Neopixel.hex |

After import successfully, the code is shown as below:

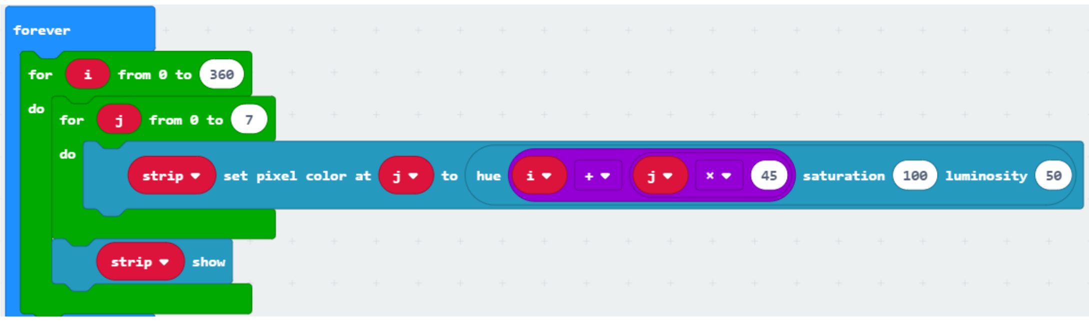



Check the connection of the circuit and verify it correct, download the code into the micro:bit, and then you can see the rainbow water light.

Set the number of data pins and LEDs at "on start", as well as the type of LED.




In the 0-360 for loop, the hue difference between each two LEDs is 45. When the hue changes, each LED succeeds the hue of the previous LED. And then the program converts the HSL color system to the RGB color system, returns the RGB value corresponding to the current hue angle and write the value to LED to achieve the effect of the rainbow water light.



## Reference

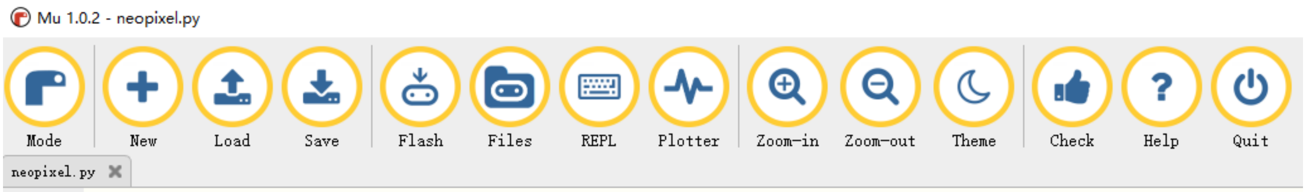
| Block | Function |
|---|---|
| `NeoPixel at pin P0 ▾ with 24 leds as RGB (GRB format) ▾` | Set the number of data pins and LEDs, as well as the type of LED. |
| `strip ▾ set pixel color at 0 to red ▾` | Set LED color |
| `strip ▾ show` | Turn on LED |

## Python code

Open the .py file with Mu. Code, the path is as below:

| File type | Path | File name |
|---|---|---|
| **Python file** | ../Projects/PythonCode/08.1_Neopixel | Neopixel.py |

After loading successfully, the code is shown as below:




```python
from microbit import *
import neopixel
np = neopixel.NeoPixel(pin0, 8)
def HSL_RGB(degree):
    degree=degree/360*255
    if degree < 85:
        red = 255 - degree * 3
        green = degree * 3
        blue = 0
    elif degree < 170:
        degree = degree - 85
        red = 0
        green = 255 - degree * 3
        blue = degree * 3
    else:
        degree = degree - 170
        red = degree * 3
        green = 0
        blue = 255 - degree * 3
    return int(red),int(green),int(blue)
while True:
    for value in range(0,360,5):
        for i in range(8):
            value=value+i*45
            if value > 360 :
                value = value-360
            red,green,blue=HSL_RGB(value)
            np[i] = (red,green,blue)

        np.show()
```

Check the connection of the circuit, confirm that the connection of the circuit is correct, download the code into the micro:bit, and then you can see the rainbow water light. ([How to download?](#))

The following is the code:

```
from microbit import *
import neopixel
np = neopixel.NeoPixel(pin0, 8)
def HSL_RGB(degree):
    degree=degree/360*255
    if degree < 85:
        red = 255 - degree * 3
        green = degree * 3
        blue = 0
    elif degree < 170:
        degree = degree - 85
        red = 0
        green = 255 - degree * 3
        blue = degree * 3
    else:
        degree = degree - 170
        red = degree * 3
        green = 0
        blue = 255 - degree * 3
    return int(red),int(green),int(blue)
while True:
    for value in range(0,360,5):
        for i in range(8):
            value=value+i*45
            if value > 360 :
                value = value-360
            red,green,blue=HSL_RGB(value)
            np[i] = (red,green,blue)
        np.show()
```

Set the number of data pins and LEDs.

```
np = neopixel.NeoPixel(pin0, 8)
```

Custom HSL_RGB() function is used to convert HSL color to RGB color, returning the RGB value corresponding to the current hue angle.

```
def HSL_RGB(degree):
    degree=degree/360*255
    if degree < 85:
        red = 255 - degree * 3
        green = degree * 3
        blue = 0
    elif degree < 170:
        degree = degree - 85
        red = 0
        green = 255 - degree * 3
        blue = degree * 3
    else:
        degree = degree - 170
        red = degree * 3
        green = 0
        blue = 255 - degree * 3
    return int(red),int(green),int(blue)
```

In the 0-360 for loop, the hue difference between each two LEDs is 45. When the hue changes, each LED succeeds the hue of the previous LED. And then the program converts the HSL color system to the RGB color system, returns the RGB value corresponding to the current hue angle, and writes the value to LED to achieve the effect of the rainbow water light.

```
while True:
    for value in range(0,360,5):
        for i in range(8):
            value=value+i*45
            if value > 360 :
                value = value-360
            red,green,blue=HSL_RGB(value)
            np[i] = (red,green,blue)
        np.show()
```

## Reference

| |
|---|
| neopixel.NeoPixel(pin, n) |
| Initialize a new strip of n number of neopixel LEDs controlled via pin pin. |
| show() |
| Show the pixels. Must be called for any updates to become visible. |
| np[i] |
| Set pixels by indexing them (like with a Python list). |

# Chapter 9 Buzzer

In this chapter, we will learn about buzzers and the sounds they make. There are two kinds of buzzer: active buzzer and passive buzzer.

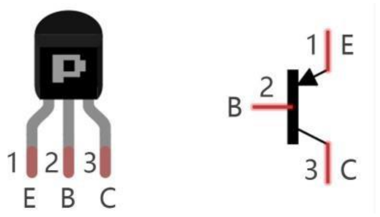
## Component knowledge

### Transistor

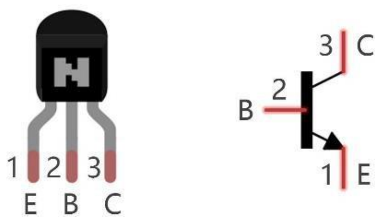
A transistor is required in this project due to the buzzer’s current being so great that GPIO of RPi’s output capability cannot meet the power requirement necessary for operation. A NPN transistor is needed here to amplify the current.

Transistors, full name: semiconductor transistor, is a semiconductor device that controls current (think of a transistor as an electronic “amplifying or switching device”. Transistors can be used to amplify weak signals, or to work as a switch. Transistors have three electrodes (PINs): base (b), collector (c) and emitter (e). When there is current passing between "be" then "ce" will have a several-fold current increase (transistor magnification), in this configuration the transistor acts as an amplifier. When current produced by "be" exceeds a certain value, "ce" will limit the current output. at this point the transistor is working in its saturation region and acts like a switch. Transistors are available as 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.
Thanks to the transistor's characteristics, they are often used as switches in digital circuits. As micro-controllers output current capacity is very weak, we will use a transistor to amplify its current in order to drive components requiring higher current.

## Buzzer

A buzzer is an audio component. They are widely used in electronic devices such as calculators, electronic alarm clocks, automobile fault indicators, etc. There are both active and passive types of buzzers. Active buzzers have oscillator inside, these will sound as long as power is supplied. Passive buzzers require an external oscillator signal (generally using PWM with different frequencies) to make a sound.

Active buzzer

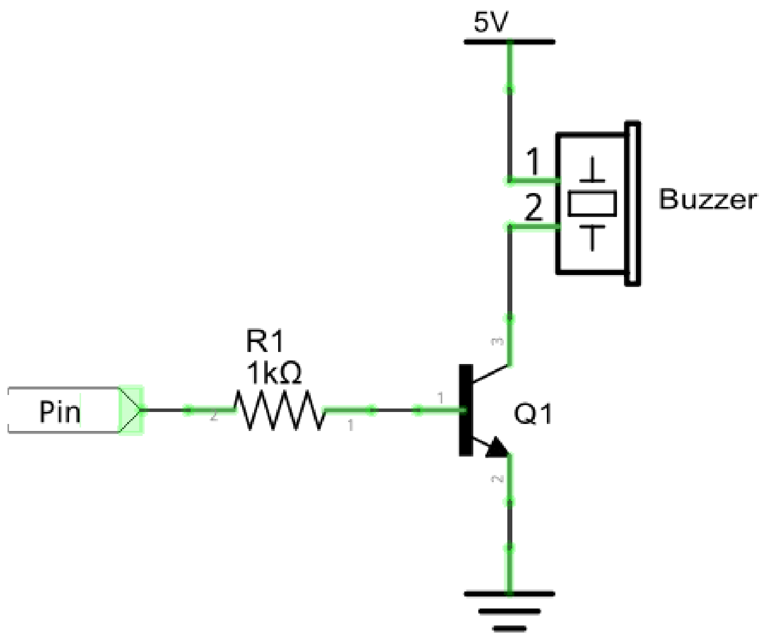
Passive buzzer


(A white label is attached on the active buzzer)

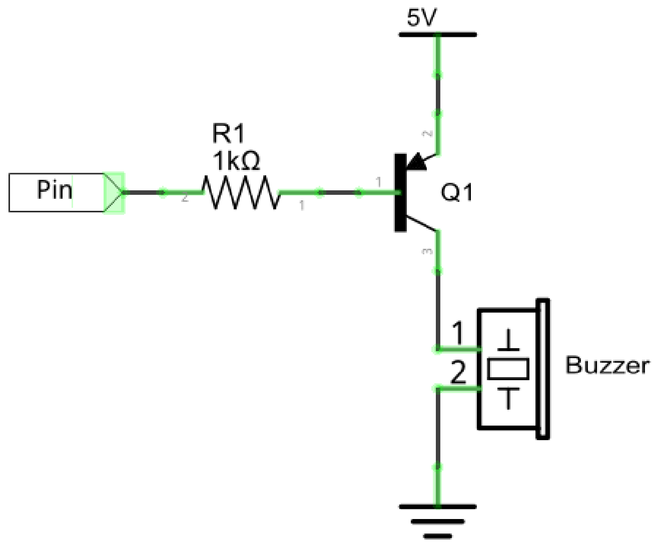
Active buzzers are easier to use. Generally, they only make a specific sound frequency. Passive buzzers require an external circuit to make sounds, but passive buzzers can be controlled to make sounds of various frequencies. The resonant frequency of the passive buzzer in this Kit is 2kHz, which means the passive buzzer is the loudest when its resonant frequency is 2kHz.

Buzzer requires large current when it works. But generally, microcontroller port cannot provide enough current for that. In order to control buzzer through micro:bit, a transistor can be used to drive a buzzer indirectly.

When we use a NPN transistor to drive a buzzer, we often use the following method. If GPIO outputs high level, current will flow through R1 (Resistor 1), the transistor conducts current and the buzzer will make sounds. If GPIO outputs low level, no current will flow through R1, the transistor will not conduct current and buzzer will remain silent (no sounds).




When we use a PNP transistor to drive a buzzer, we often use the following method. If GPIO outputs low level, current will flow through R1. The transistor conducts current and the buzzer will make sounds. If GPIO outputs high level, no current flows through R1, the transistor will not conduct current and buzzer will remain silent (no sounds). Below are the circuit schematics for both a NPN and PNP transistor to power a buzzer.



How to identify active and passive buzzer?

1. As a rule, there is a label on an active buzzer covering the hole where sound is emitted, but there are exceptions to this rule.
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, view 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.

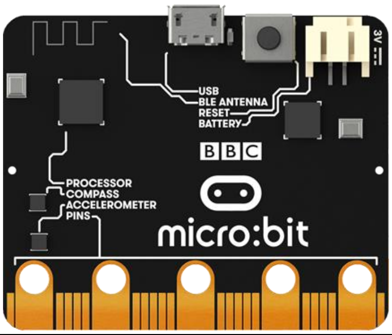
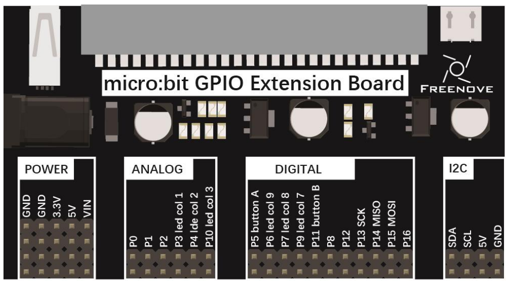
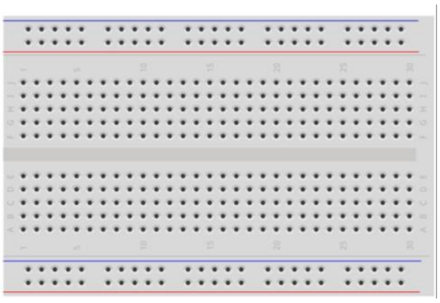
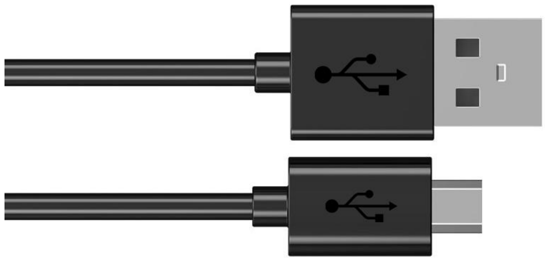
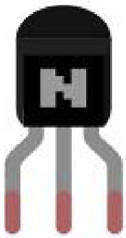
Active buzzer bottom

Passive buzzer bottom

# Project 9.1 Active Buzzer

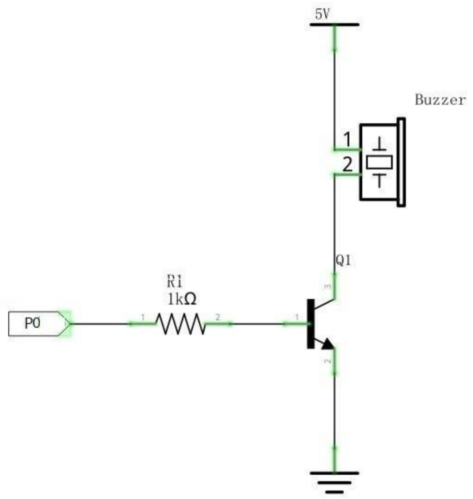
In this project, we will use an active buzzer to play a fixed melody.

## Component list

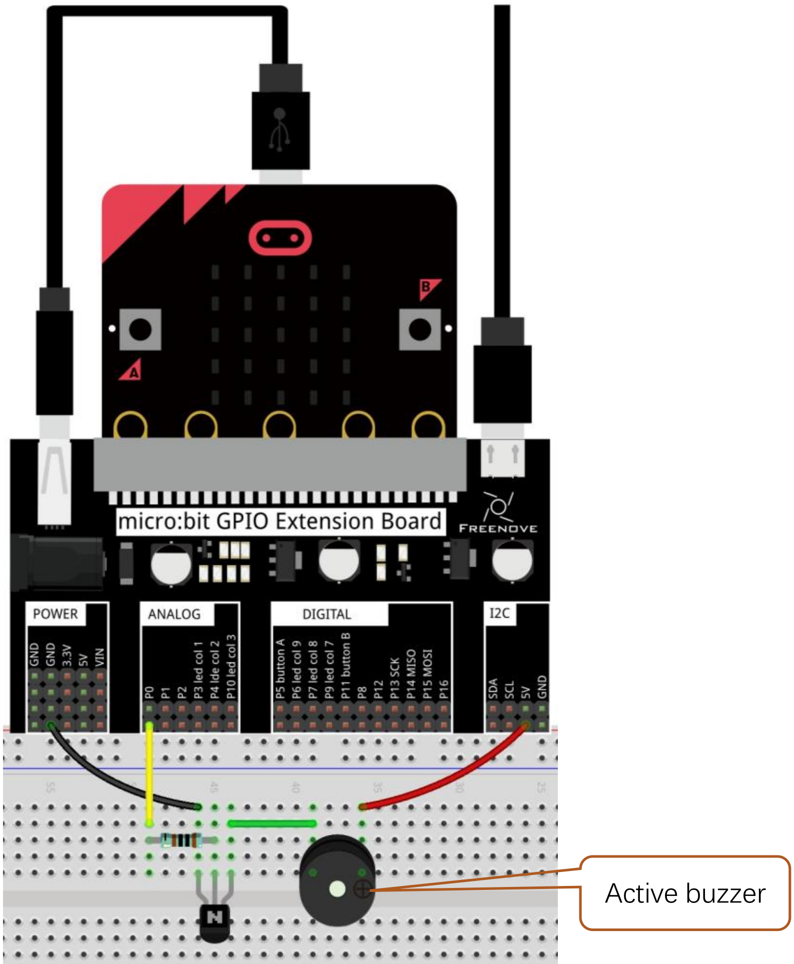
<table>
<tr><td colspan="2">Microbit x1<br>
</td><td colspan="2">Extension board x1<br>
</td></tr>
<tr><td colspan="2">Breadboard x1<br></td><td colspan="2">USB cable x2<br></td></tr>
<tr><td>F/M x 3 M/M x1<br></td><td>NPN(8050) transistor x1<br></td><td>Resistor 1kΩ x1<br></td><td>Active buzzer x1<br></td></tr>
</table>

## Circuit

Schematic diagram




Hardware connection

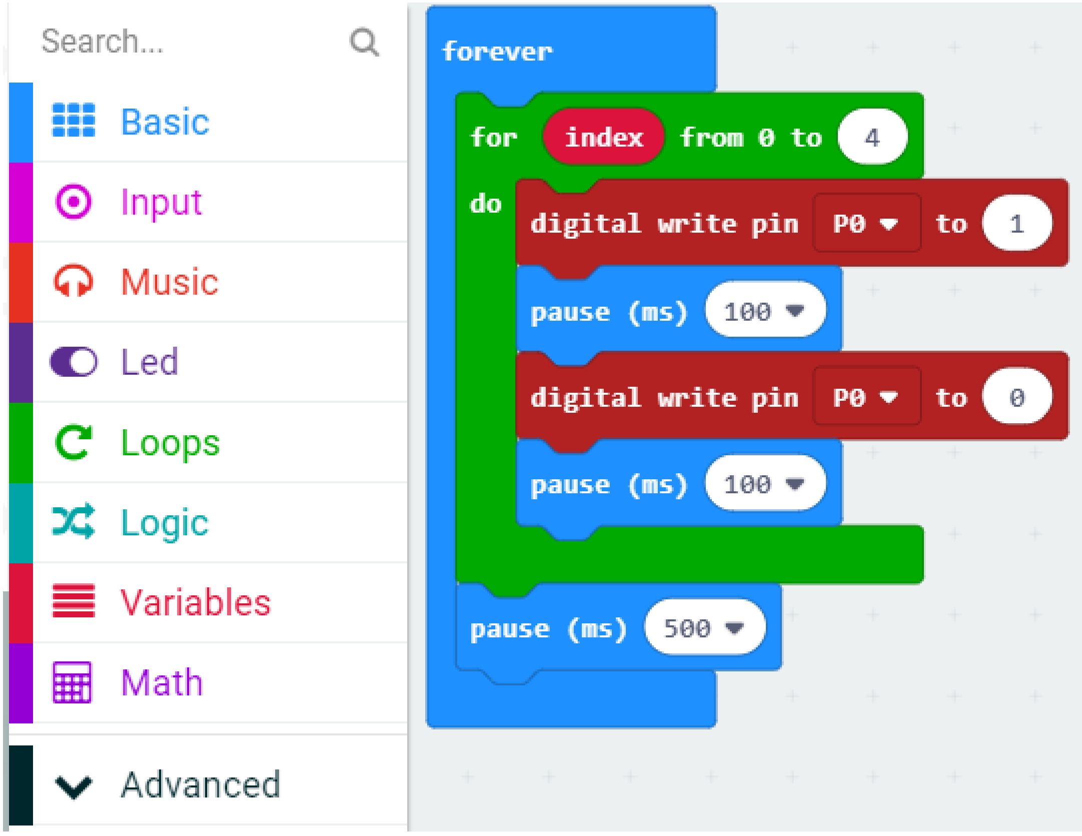


## Block code

Open MakeCode first. Import the .hex file. The path is as below:
(How to import project)

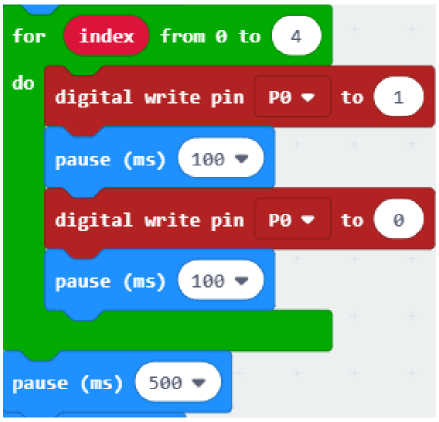
| File type | Path | File name |
|---|---|---|
| HEX file | ../Projects/BlockCode/09.1_ActiveBuzzer | ActiveBuzzer.hex |

After importing successfully, the code is shown as below:




Check the connection of the circuit, download the code into the micro:bit, and the buzzer on the breadboard will make sounds.

In the for loop, P0 outputs a high level to make the buzzer sounds, then delay 100ms. And then P0 outputs a low level to stop the buzzer. Then delay 100ms. After the loop ends, delay 500ms.

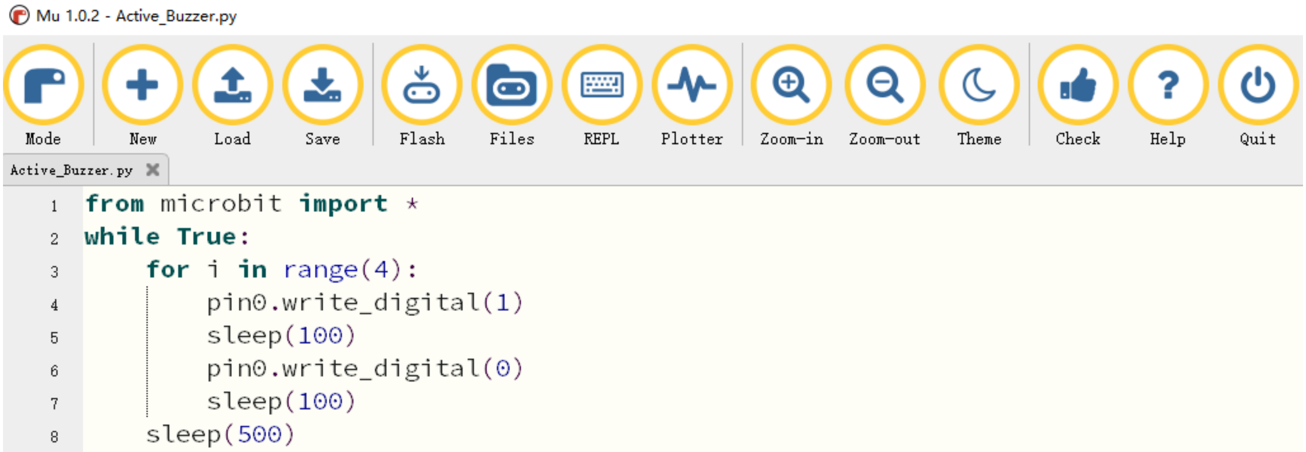


## Python code

Open the .py file with Mu. Code, the path is as below:

| File type | Path | File name |
|---|---|---|
| Python file | ../Projects/PythonCode/09.1_ActiveBuzzer | ActiveBuzzer.py |

After load successfully, the code is shown as below:




Check the connection of the circuit, download the code into the micro:bit, and the buzzer on the breadboard will sound.

The following is the program code:

```
from microbit import *
while True:
    for i in range(4):
        pin0.write_digital(1)
        sleep(100)
        pin0.write_digital(0)
        sleep(100)
    sleep(500)
```

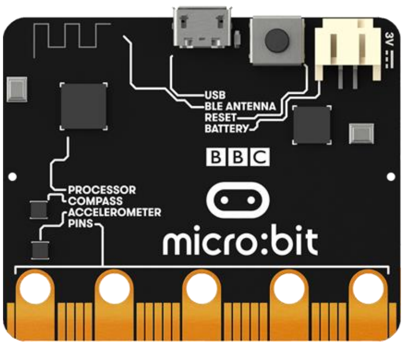
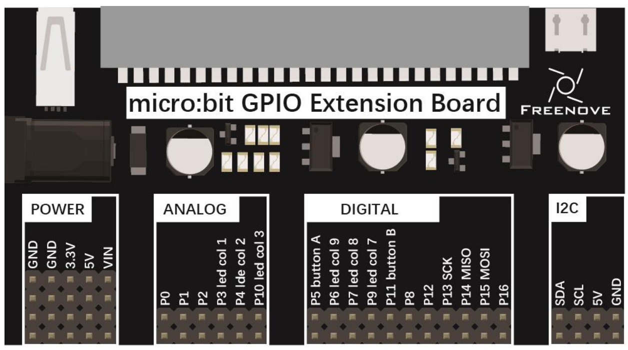
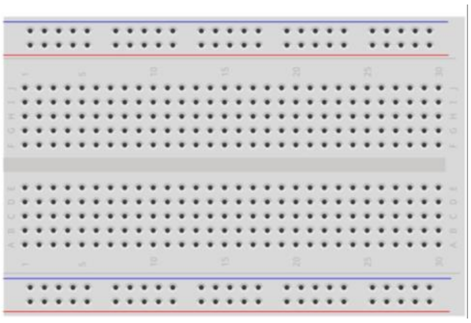
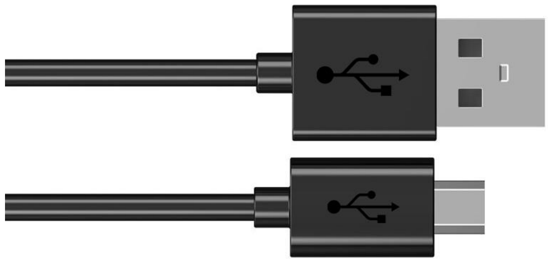
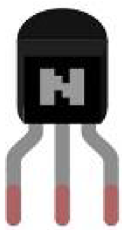
In the for loop, P0 outputs a high level to make the buzzer sound, then delay 100ms. And then P0 outputs a low level to stop the buzzer. Then delay 100ms. After the loop ends, delay 500ms.

```
while True:
    for i in range(4):
        pin0.write_digital(1)
        sleep(100)
        pin0.write_digital(0)
        sleep(100)
    sleep(500)
```

# Project 9.2 Happy Birthday Melody

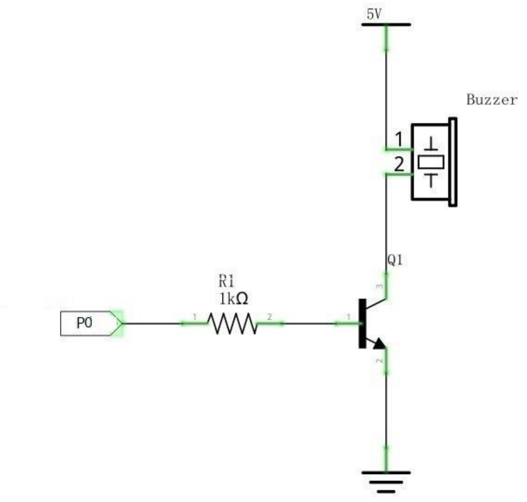
In this project, we will make a passive buzzer to play a happy birthday melody.

## Component list

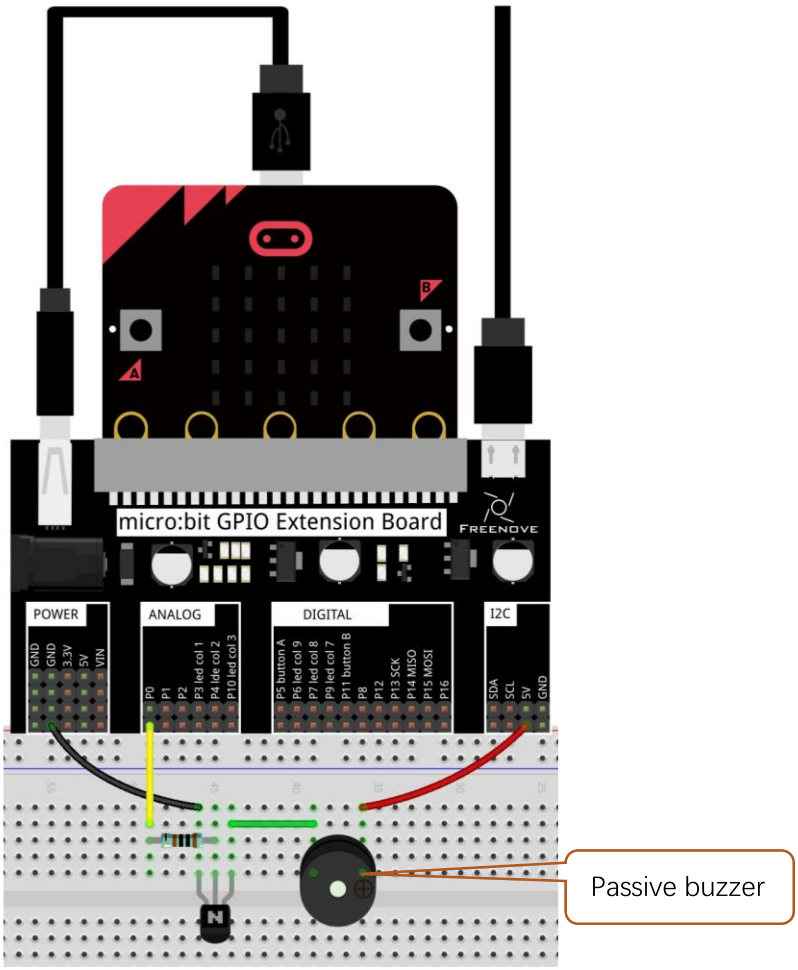
<table>
<tr><td colspan="2">Microbit x1<br>
</td><td colspan="2">Extension board x1<br>
</td></tr>
<tr><td colspan="2">Breadboard x1<br></td><td colspan="2">USB cable x2<br></td></tr>
<tr><td>F/M x3 M/M x1<br></td><td>NPN(8050) transistor x1<br></td><td>Resistor 1kΩ x1<br></td><td>Passive buzzer x1<br></td></tr>
</table>

## Circuit

Schematic diagram




Hardware connection

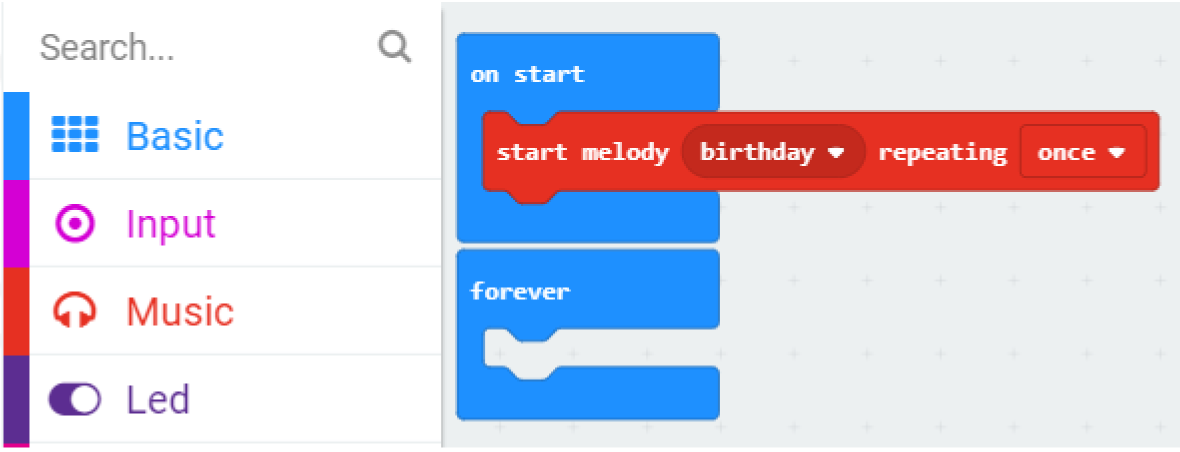


## Block code

Open MakeCode first. Import the .hex file. The path is as below:
(How to import project)

| File type | Path | File name |
|---|---|---|
| **HEX file** | ../Projects/BlockCode/09.2_Play-a-melody | Play-a-melody.hex |

After importing successfully, the code is shown as below:




Check the connection of the circuit, confirm that the circuit is connected correctly, download the code into the micro:bit, and the buzzer on the breadboard will play a song “happy birthday”.

You can click on the small triangle next to "birthday" to expand the list, select other melody, and select the number of times to play by clicking on the small triangle next to "once".

### Reference

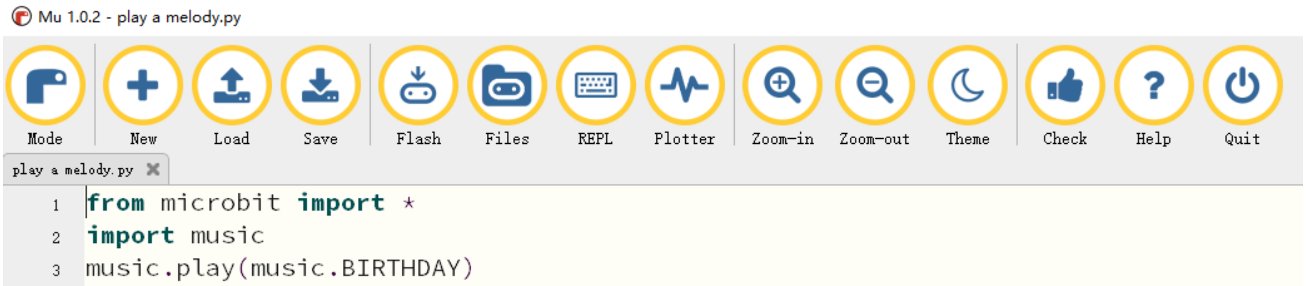
| Block | Function |
|---|---|
|   | Begin playing a musical melody through pin P0 of the micro:bit. There are built-in melodies that you can choose from the start melody block. These are already composed for you and are easy to use by just selecting the one you want. |

# Python code

Open the .py file with Mu. Code, the path is as below:

| File type | Path | File name |
|---|---|---|
| **Python file** | ../Projects/PythonCode/09.2_Play-a-melody | Play-a-melody.py |

After loading successfully, the code is shown as below:




Check the connection of the circuit, confirm that the circuit is connected correctly, and download the code into the micro:bit, and the buzzer on the breadboard will play a song “happy birthday”. ([How to download?](#))

The following is the program code:

```python
from microbit import *
import music
music.play(music.BIRTHDAY)
```

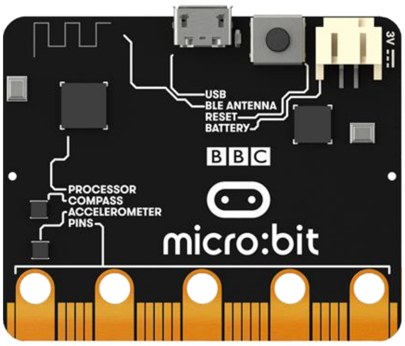
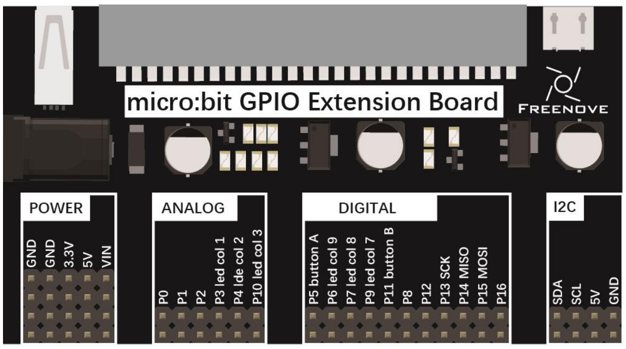
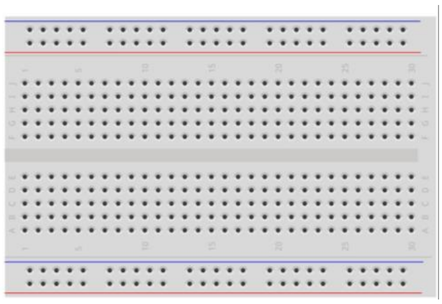
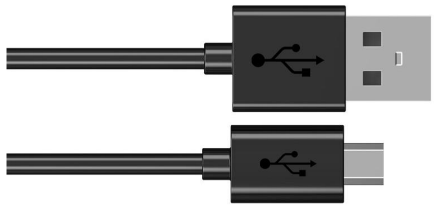
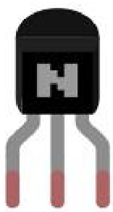
## Reference

| music.play() |
|---|
| It is used to play music. MicroPython has quite a lot of built-in melodies.<br>For more information, please refer to:<br>https://microbit-micropython.readthedocs.io/en/latest/tutorials/music.html |

# Project 9.3 Custom Melody

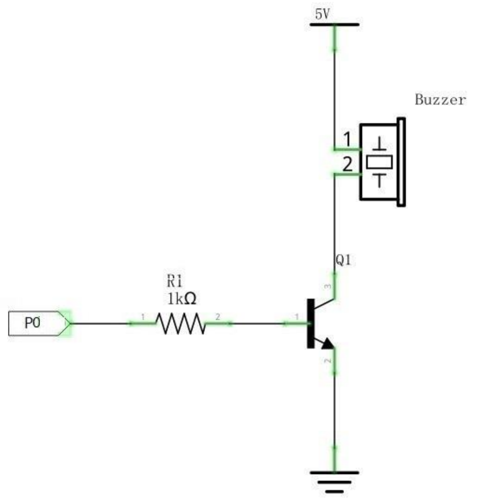
In this project, we will make the passive buzzer play a custom melody.

## Component list

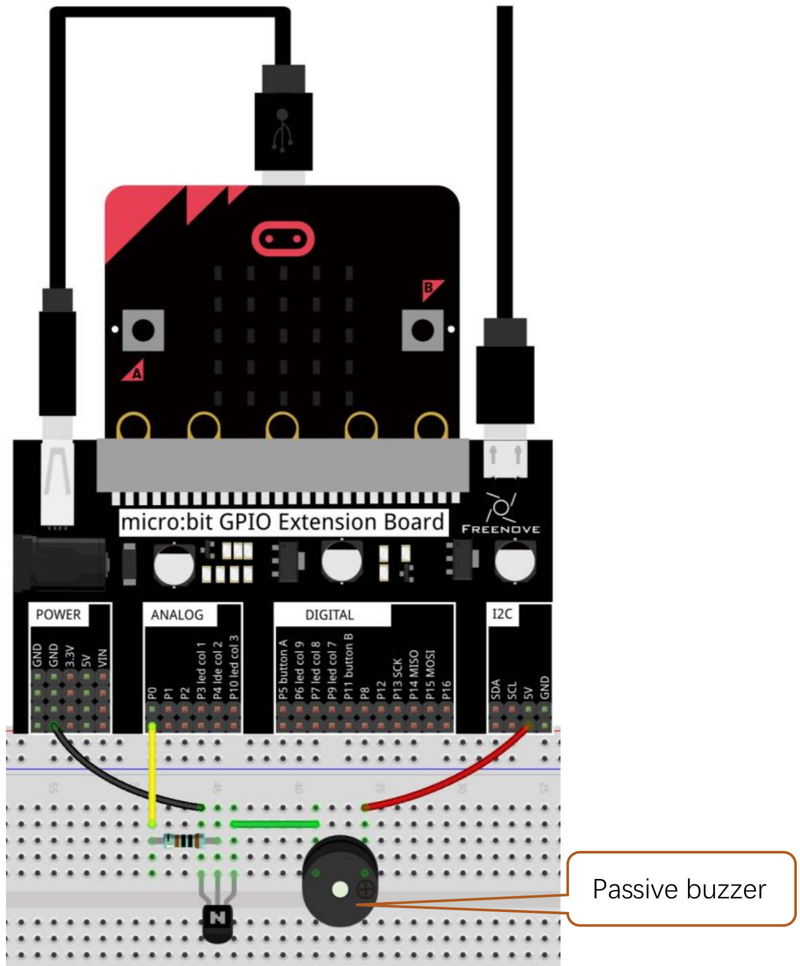
<table>
<tr><td colspan="2">Microbit x1<br>
</td><td colspan="2">Extetnsion board x1<br>
</td></tr>
<tr><td colspan="2">Breadboard x1<br></td><td colspan="2">USB cable x2<br></td></tr>
<tr><td>F/M x3 M/M x1<br></td><td>NPN(8050) transistor x1<br></td><td>Resistor 1kΩ x1<br></td><td>Passive buzzer x1<br></td></tr>
</table>

## Circuit

Schematic diagram




Hardware connection

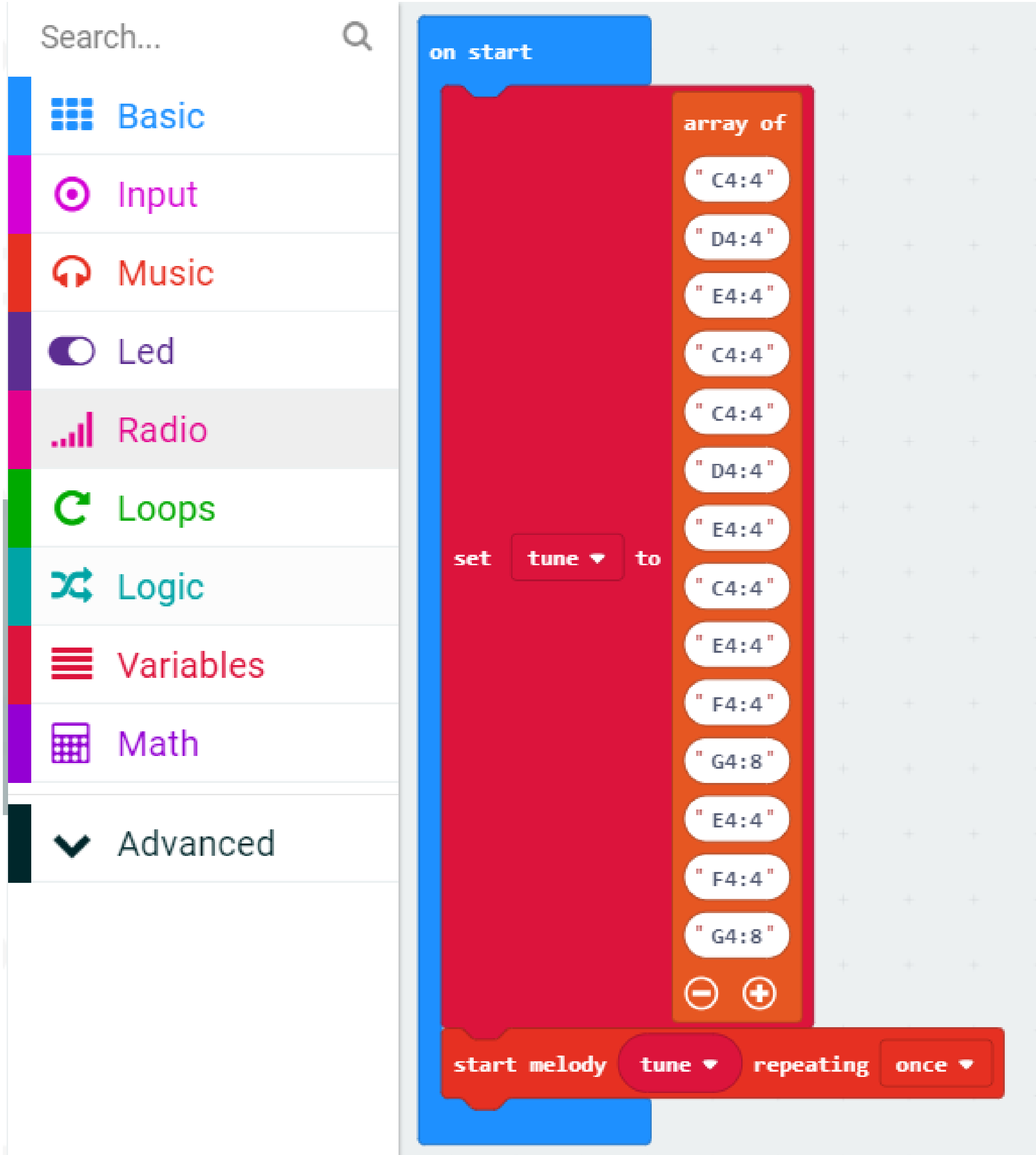


## Block code

Open MakeCode first. Import the .hex file. The path is as below:
(How to import project)

| File type | Path | File name |
|---|---|---|
| HEX file | ../Projects/BlockCode/09.3_Play-a-custom-melody | Play-a-custom-melody.hex |

After importing successfully, the code is shown as below:




Check the connection of the circuit, confirm that the circuit is connected correctly, download the code into the micro:bit, and the buzzer on the breadboard will play a custom melody.

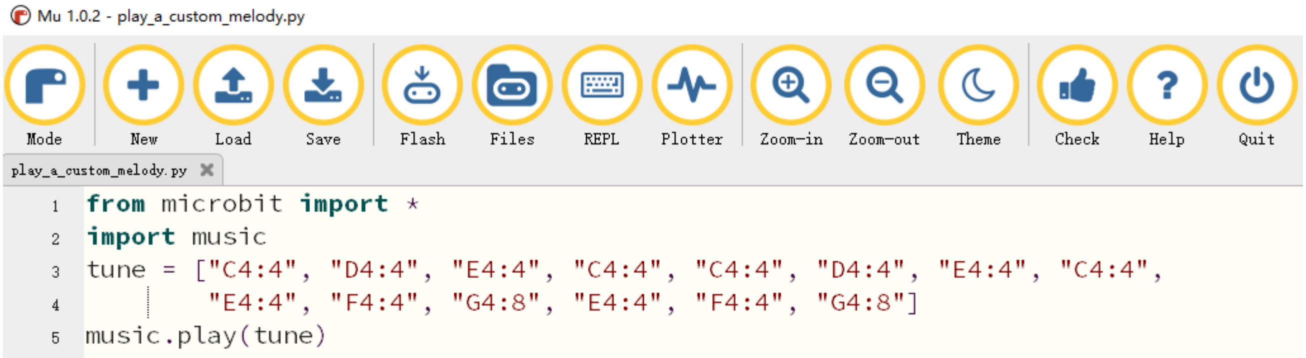
The tune array holds a custom melody, and each element in the array contains notes and beats. For example, "A1:4" refers to the note named A in octave number 1 to be played for a duration of 4.

# Python code

Open the .py file with Mu. Code, the path is as below:

| File type | Path | File name |
|---|---|---|
| **Python file** | ../Projects/PythonCode/09.3_Play-a-custom-melody | Play-a-custom-melody.py |

After loading successfully, the code is shown as below:




Check the connection of the circuit, confirm that the circuit is connected correctly, download the code into the micro:bit, and the buzzer on the breadboard will play a custom song.

The tune array holds a custom melody, and each element in the array contains notes and beats. For example, "A1:4" refers to the note named A in octave number 1 to be played for a duration of 4.

The following is the program code:

```
from microbit import *
import music
tune = ["C4:4", "D4:4", "E4:4", "C4:4", "C4:4", "D4:4", "E4:4", "C4:4",
        "E4:4", "F4:4", "G4:8", "E4:4", "F4:4", "G4:8"]
music.play(tune)
```

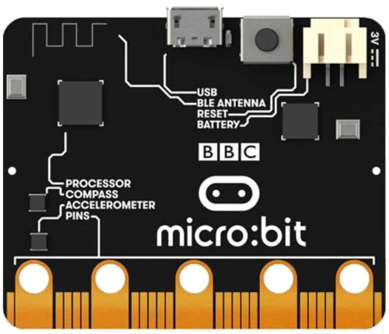
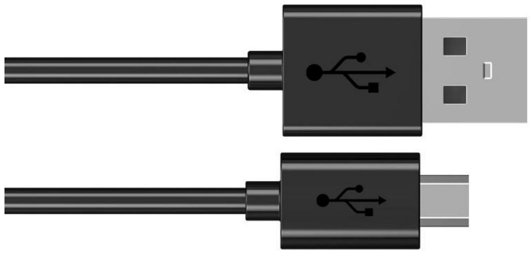
# Chapter 10 Serial Communication

In this chapter, we will learn how to use serial port.

## Project 10.1 Display the Data

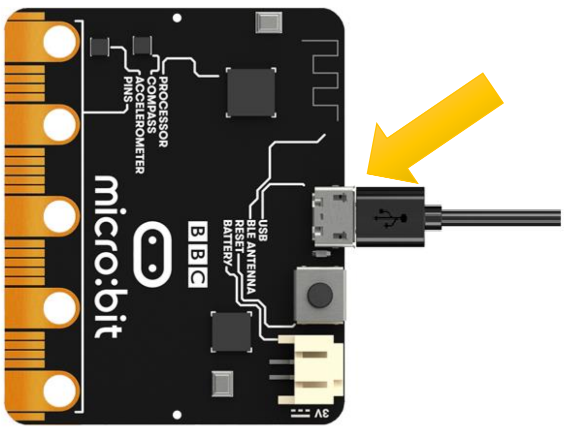
This project uses serial ports to transmit data and display data.

### Component list

| Microbit x1 | USB cable x1 |
|---|---|
|  |  |

### Circuit

Connect micro:bit and PC via a micro USB cable.

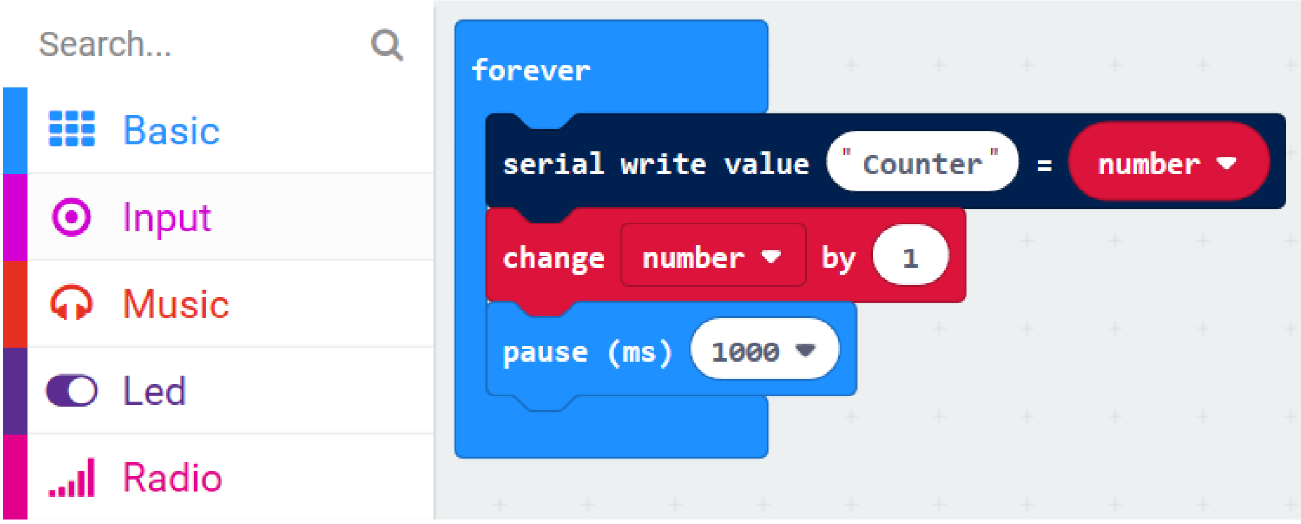
| Hardware connection |
|---|
|  |

## Block code

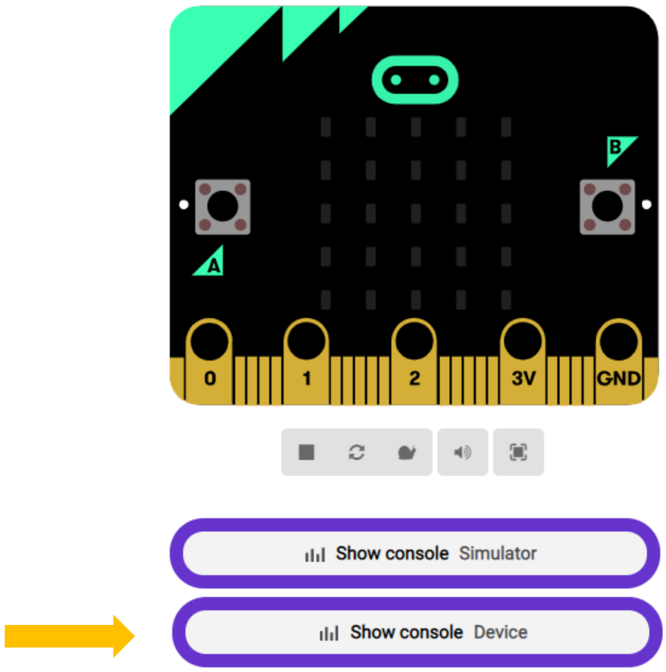
Open MakeCode first. Import the .hex file. The path is as below:
(How to import project)

| File type | Path | File name |
|---|---|---|
| HEX file | ../Projects/BlockCode/10.1_SerialPort | SerialPort.hex |

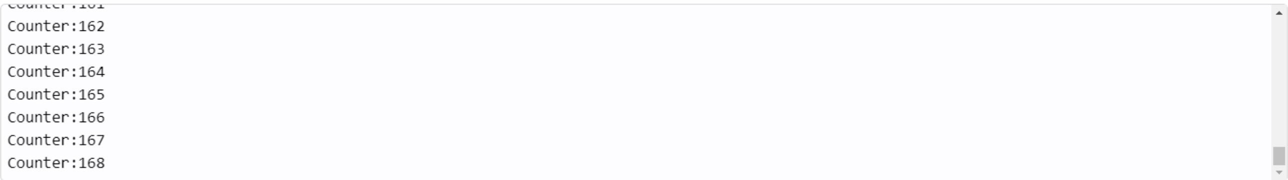
After importing successfully, the code is shown as below:



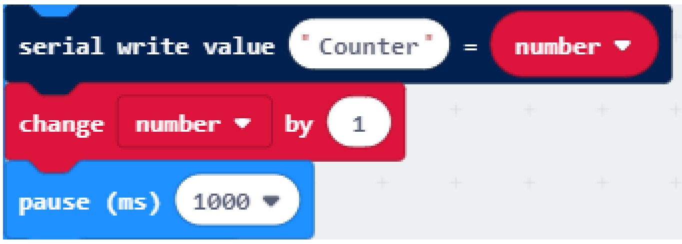

Check the connection of the circuit and verify it correct download the code into the micro:bit, and then open the serial controller, as shown below:



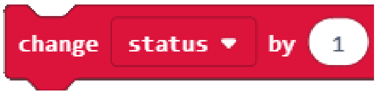

On the serial console, you can see the data sent by the microbit.


Every 1 second, the value of the variable number is incremented by 1, and the new value will be sent to the serial port.




## Reference

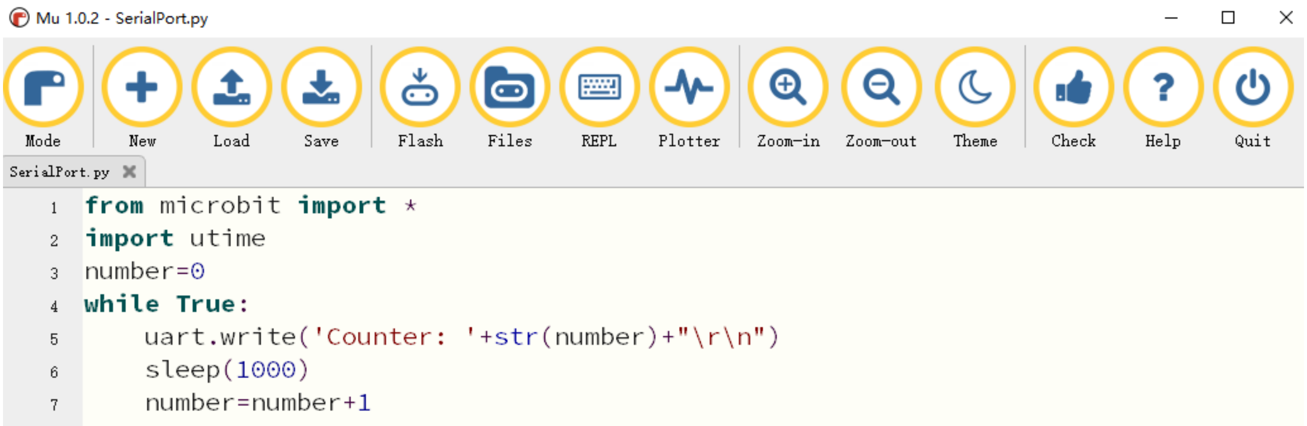
| Block | Function |
|---|---|
|   | Write a name:value pair and a newline character (\r\n) to the serial port. |
|   | The change blocks increase the value in the variable by the amount you want. This is also known as an addition assignment operation. |

## Python code

Open the .py file with Mu. Code, the path is as below:

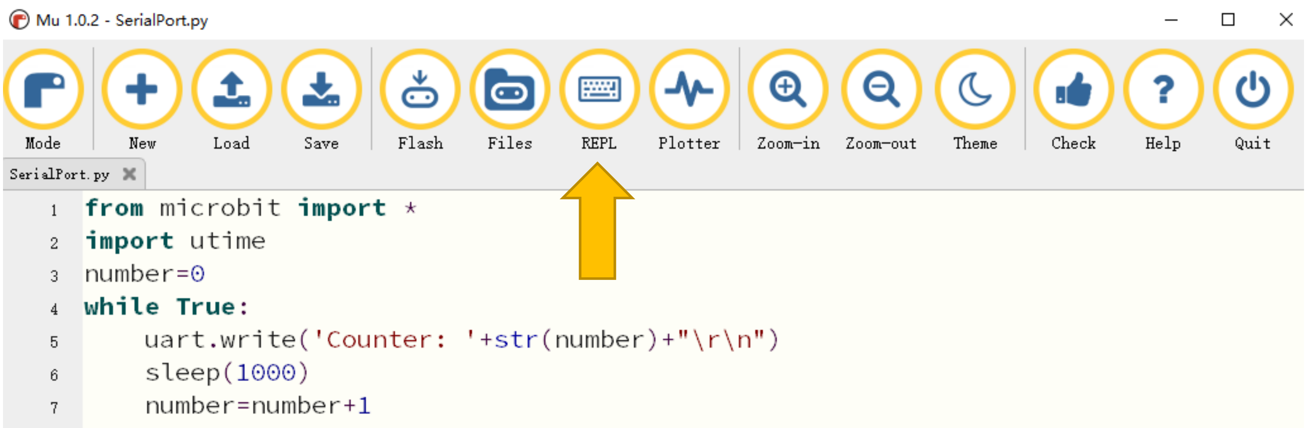
| File type | Path | File name |
| --- | --- | --- |
| Python file | ../Projects/PythonCode/10.1_SerialPort | SerialPort.py |

After loading successfully, the code is shown as below:

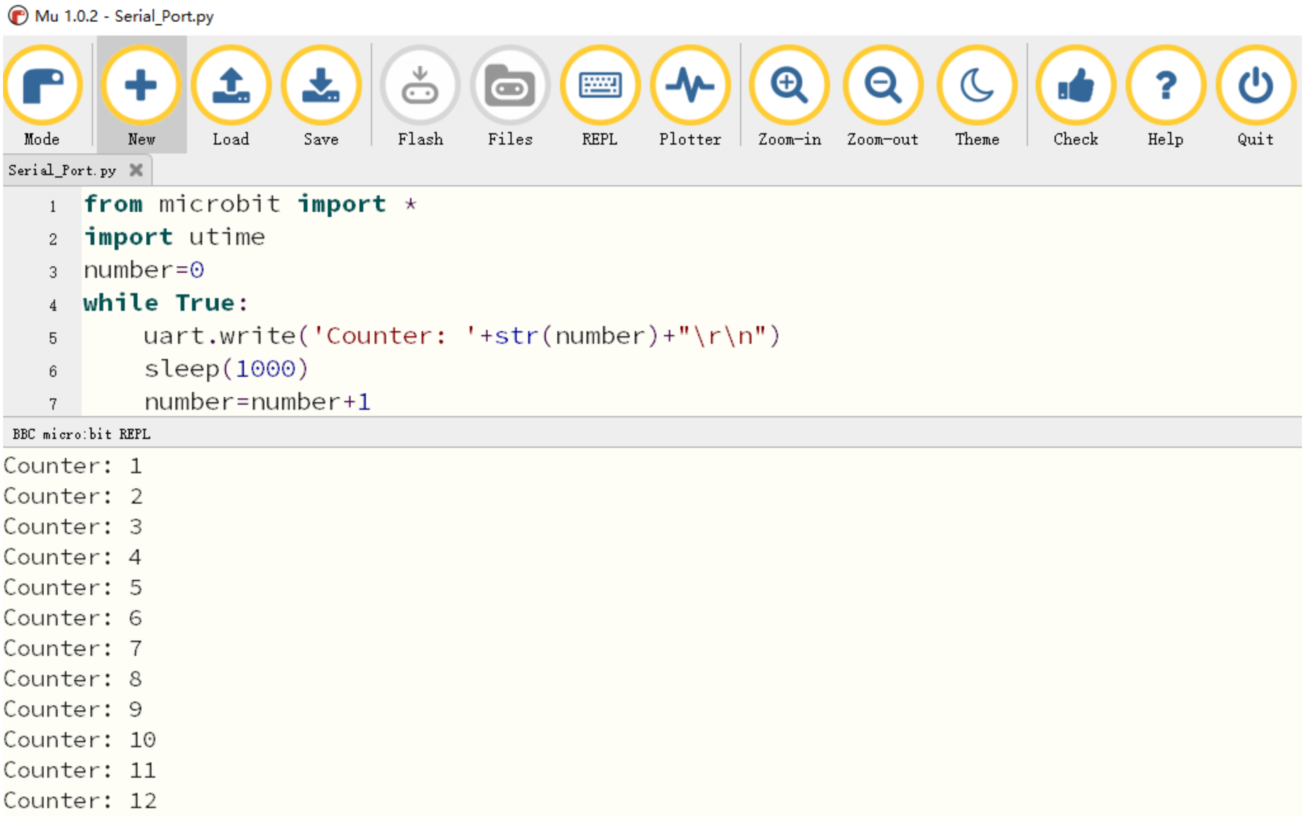



Check the connection of the circuit and verify it correct and then download the code into the micro:bit.

After the program is downloaded, click on REPL as shown below.




Then press the reset button (the button on the back) of the Micro:bit and we will see the change of value.




The following is the program code:

```
from microbit import *
import utime
number=0
while True:
    uart.write('Counter: '+str(number)+ "\r\n")
    sleep(1000)
    number=number+1
```

Every 1 second, the value of the variable number is incremented by 1, and the new value will be sent to the serial port, where "\r\n" is the meaning of the newline.

```
uart.write('Counter: '+str(number)+ "\r\n")
sleep(1000)
number=number+1
```

## Reference

| uart.write(x) |
|---|
| Write the buffer to the bus, it can be a bytes object or a string:<br>uart.write('hello world')<br>uart.write(b'hello world')<br>uart.write(bytes([1, 2, 3]))<br>For more information, please refer to:<br>https://microbit-micropython.readthedocs.io/en/latest/uart.html |

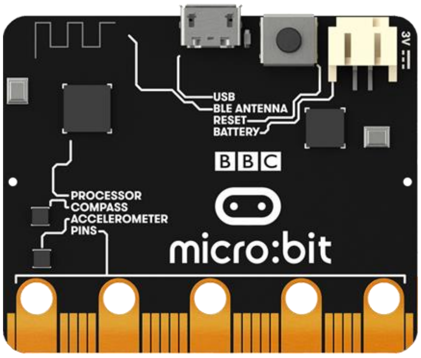
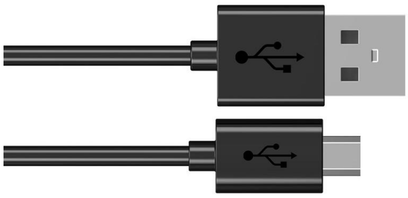
# Chapter 11 Magnetometer

In this chapter, we will learn the micro:bit built-in magnetometer chip.

## Project 11.1 Display Magnetometer Data

This project will print the data obtained from the magnetometer chip on the serial console.

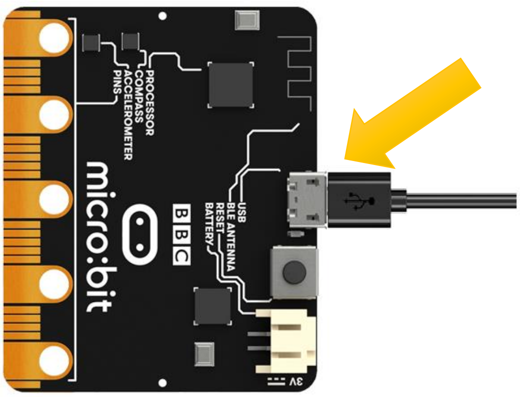
### Component list

| Microbit x1 | USB cable x1 |
|---|---|
|   |  |

### Circuit

Connect micro:bit and PC via micro USB cable.

Hardware connection

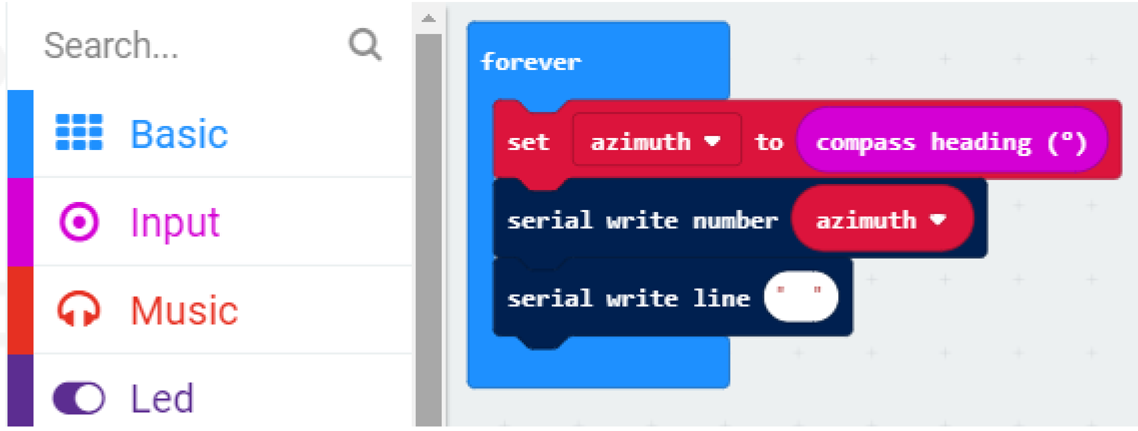


## Block code

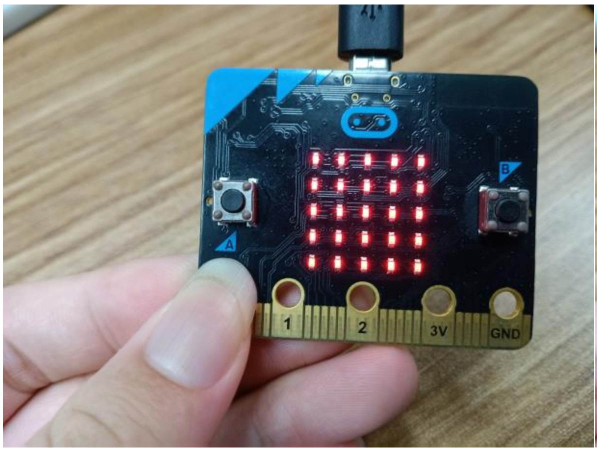
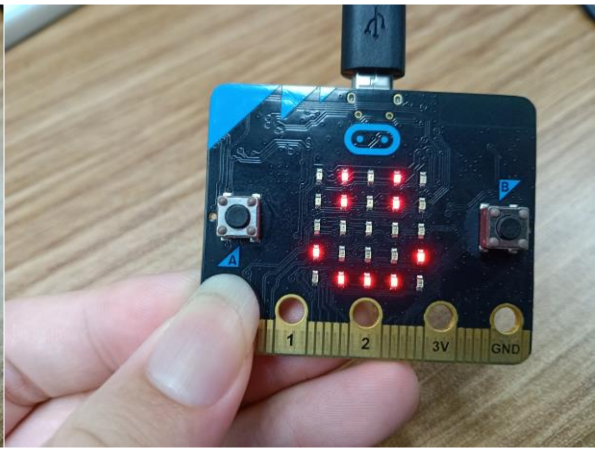
Open MakeCode first. Import the .hex file. The path is as below:
(How to import project)

| File type | Path | File name |
|---|---|---|
| HEX file | ../Projects/BlockCode/11.1_DisplayMagnetometerData | DisplayMagnetometerData.hex |

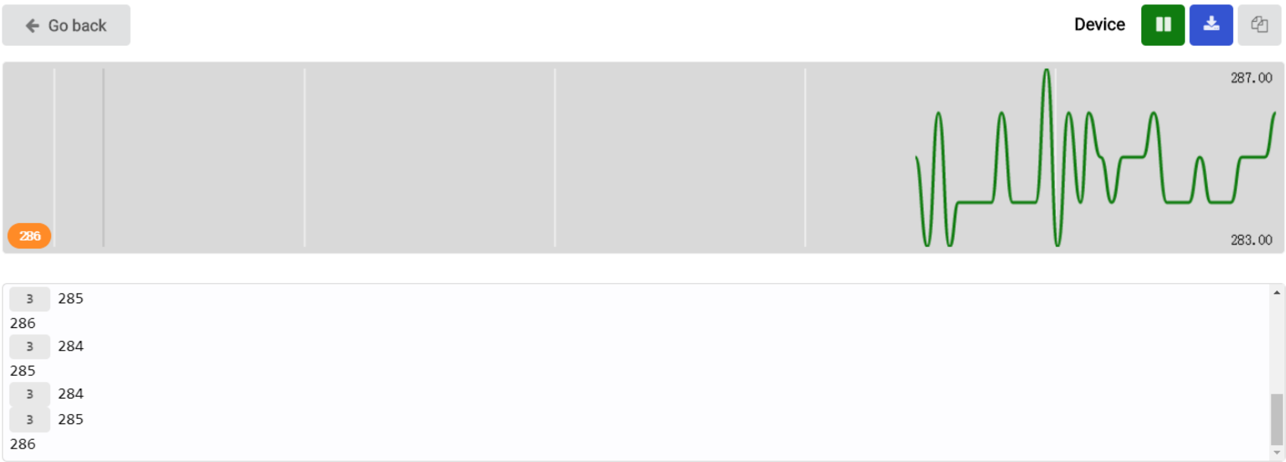
After importing successfully, the code is shown as below:




Check the connection of the circuit and verify it correct, and then download the code into the micro:bit. After completing downloading, the magnetometer needs to be calibrated (calibration must be performed using the magnetometer program). Calibrating the magnetometer will cause the program to pause until the calibration is completed. Start the calibration process, a prompt will scroll on the LED matrix, which indicates that you need to rotate the micro:bit until **all** LEDs on the LED screen are illuminated, and then a smile is displayed which means the calibration is completed, as shown below:

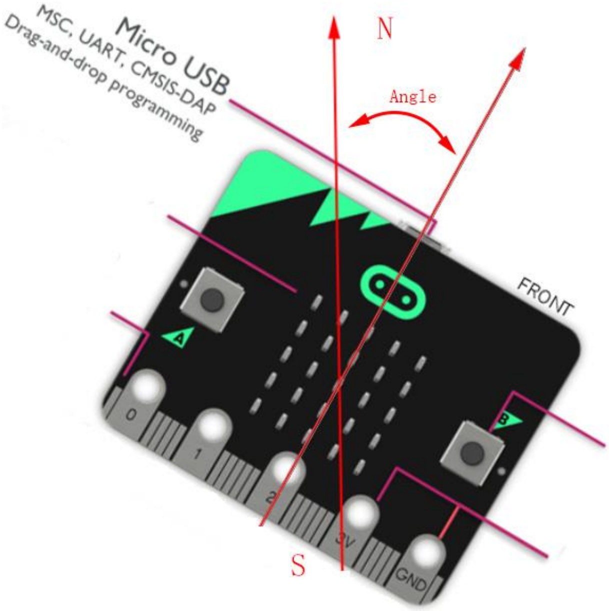



Then open the serial console (Open the Serial Port), place the micro:bit horizontally on the desktop, and rotate the micro:bit (clockwise or counterclockwise) to see the angular offset read from the magnetometer chip. As shown below:




3 indicates the number of times of consecutive readings of the same value.

The angular offset is the angle between the directions of the micro:bit and the geographic North Pole, as shown in the following figure.



The angular offset read from the magnetometer chip is stored in the variable azimuth.

```
set azimuth ▾ to compass heading (°)
```

Then the value of the variable azimuth is printed on the serial port interface.

```
serial write number azimuth ▾
serial write line " "
```

## Reference

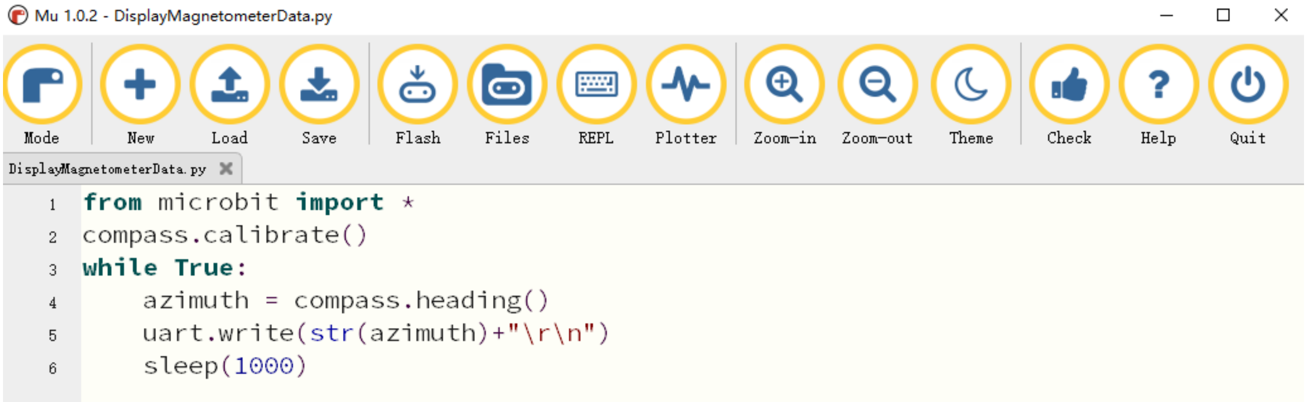
| Block | Function |
| --- | --- |
| serial write line " " | Write a string to the serial port and start a new line of text by writing \r\n. |
| serial write number 0 | Write a number to the serial port. |
| compass heading (°) | The micro:bit measures the compass heading from 0 to 359 degrees with its magnetometer chip. Different numbers mean north, east, south, and west. |

## Python code

Open the .py file with Mu. Code, the path is as below:

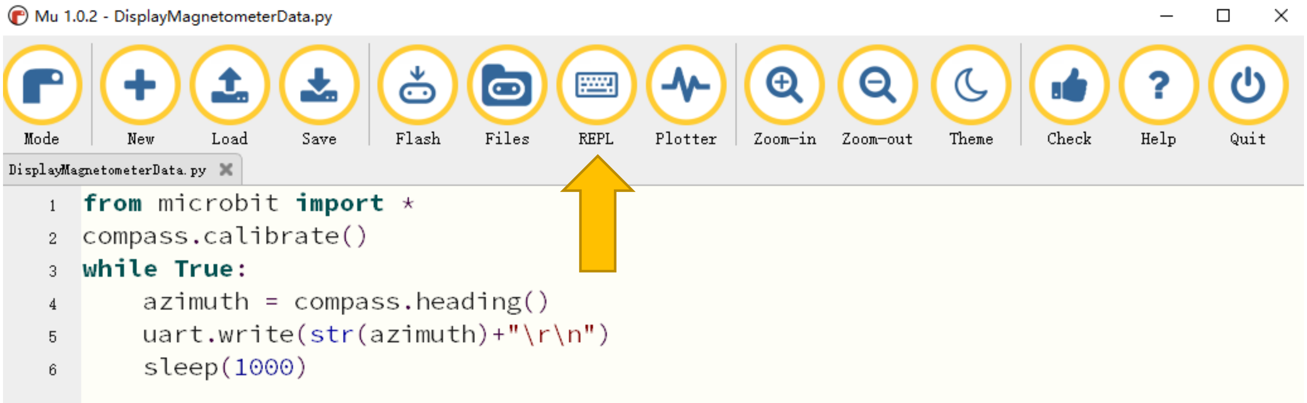
| File type | Path | File name |
|---|---|---|
| Python file | ../Projects/PythonCode/11.1_DisplayMagnetometerData | DisplayMagnetometerData.py |

After loading successfully, the code is shown as below:



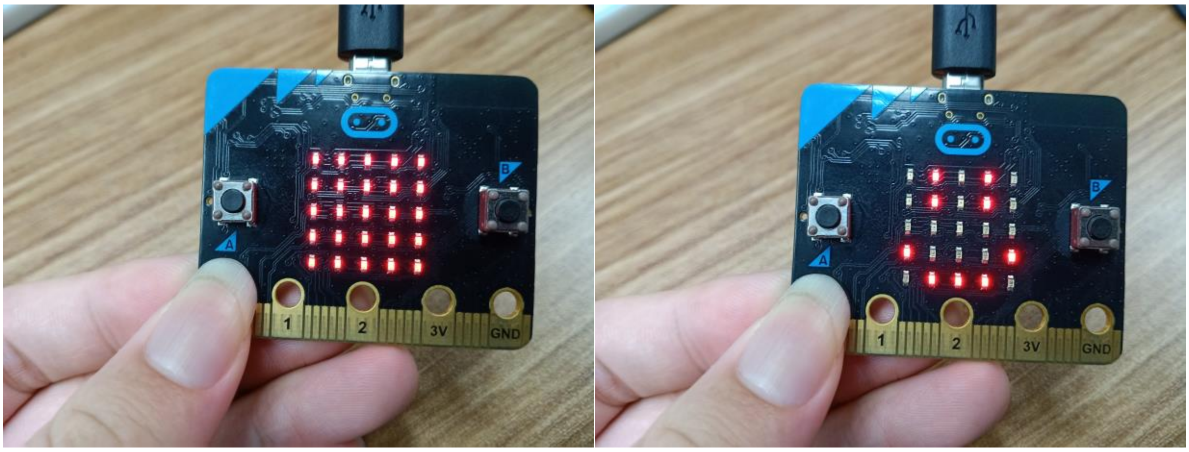

After checking the connection of the circuit and verify it correct, download the code into micro:bit.

After downloading the program, click REPL, as shown below.

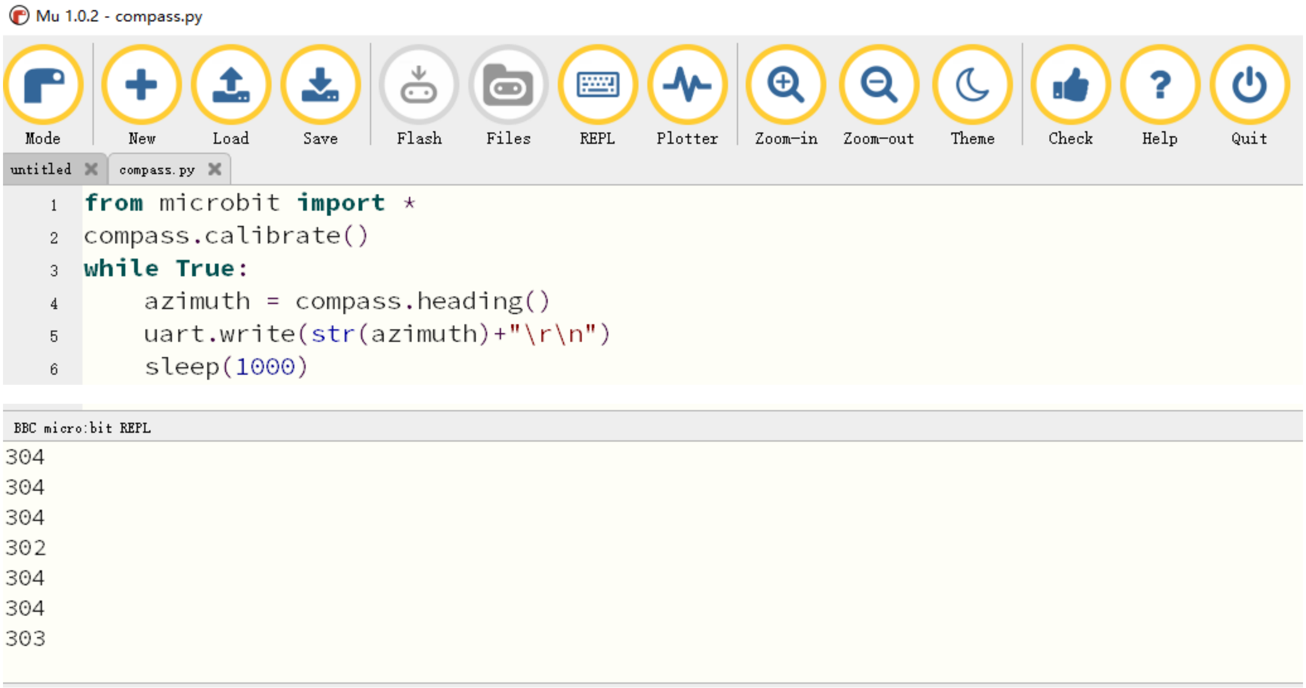



Then press the reset button of the Micro:bit, you need to calibrate the magnetometer (the calibration must be performed when downloading using the magnetometer program).

Calibrating the magnetometer will cause the program to pause until the calibration is complete. Start the calibration process, a prompt will scroll on the LED matrix, which indicates that you need to rotate the micro:bit until **all** LEDs on the LED screen are illuminated, and then a smile is displayed which means the calibration is completed, as shown below:



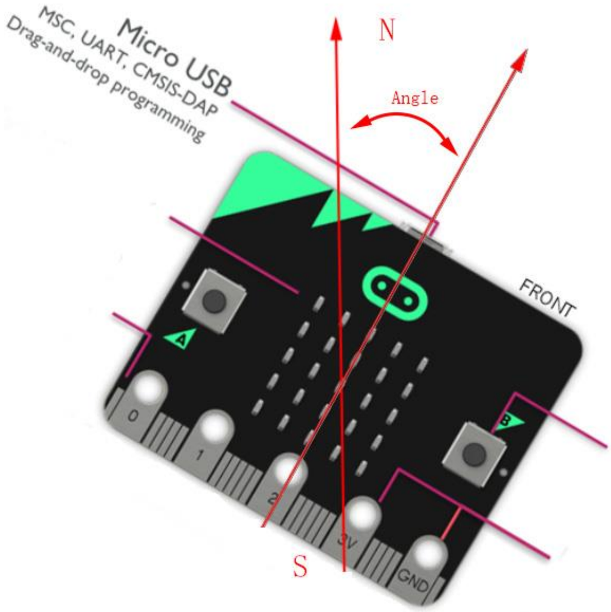

Place the micro:bit horizontally on the desktop, and rotate the micro:bit (clockwise or counterclockwise) to see the angular offset read from the magnetometer chip. As shown below:




```
from microbit import *
compass.calibrate()
while True:
    azimuth = compass.heading()
    uart.write(str(azimuth)+"\r\n")
    sleep(1000)
```

```
304
304
304
302
304
304
303
```

The angular offset is the angle between the direction of the micro:bit and the geographic north pole, as shown in the following figure.




The following is the program code:

```
from microbit import *
compass.calibrate()
while True:
    azimuth = compass.heading()
    uart.write(str(azimuth)+"\r\n")
    sleep(1000)
```

Magnetometer calibration.

```
compass.calibrate()
```

The angular offset read from the magnetometer chip is stored in the variable azimuth and then printed out every 1s through a serial port.

```
azimuth = compass.heading()
uart.write(str(azimuth)+"\r\n")
sleep(1000)
```

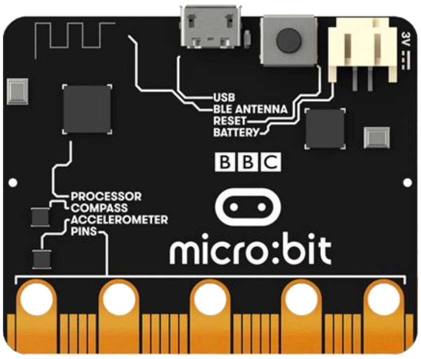
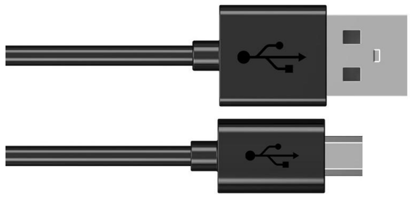
## Reference

| compass.calibrate() |
| --- |
| Starts the calibration process. An instructive message will scroll on the LED matrix, which indicates that you need to rotate the micro:bit until all LEDs are illuminated. |
| **compass.heading()** |
| Gives the compass heading, calculated from the above readings, as an integer in the range from 0 to 360, representing the angle in degrees, clockwise, with north as 0. |

# Project 11.2 Electronic Compass

In this project, we will use micro:bit to make an electronic compass, displaying an arrow on the micro:bit, and the arrow always points to the geographic north pole.

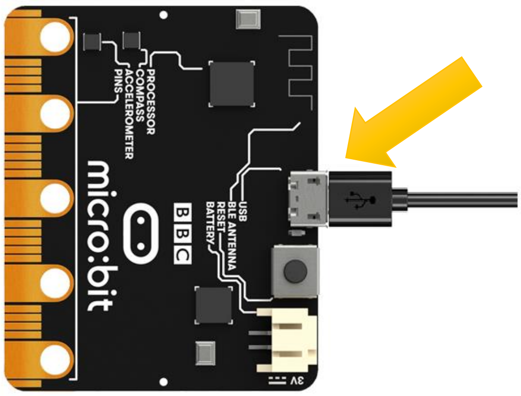
## Component list

| Microbit x1 | USB cable x1 |
|---|---|
|   |  |

## Circuit

Connect micro:bit and PC via micro USB cable.

Hardware connection



## Block code

Open MakeCode first. Import the .hex file. The path is as below:

(How to import project)

| File type | Path | File name |
|---|---|---|
| HEX file | ../Projects/BlockCode/11.2_ElectronicCompass | ElectronicCompass.hex |

After importing successfully, the code is shown as below:

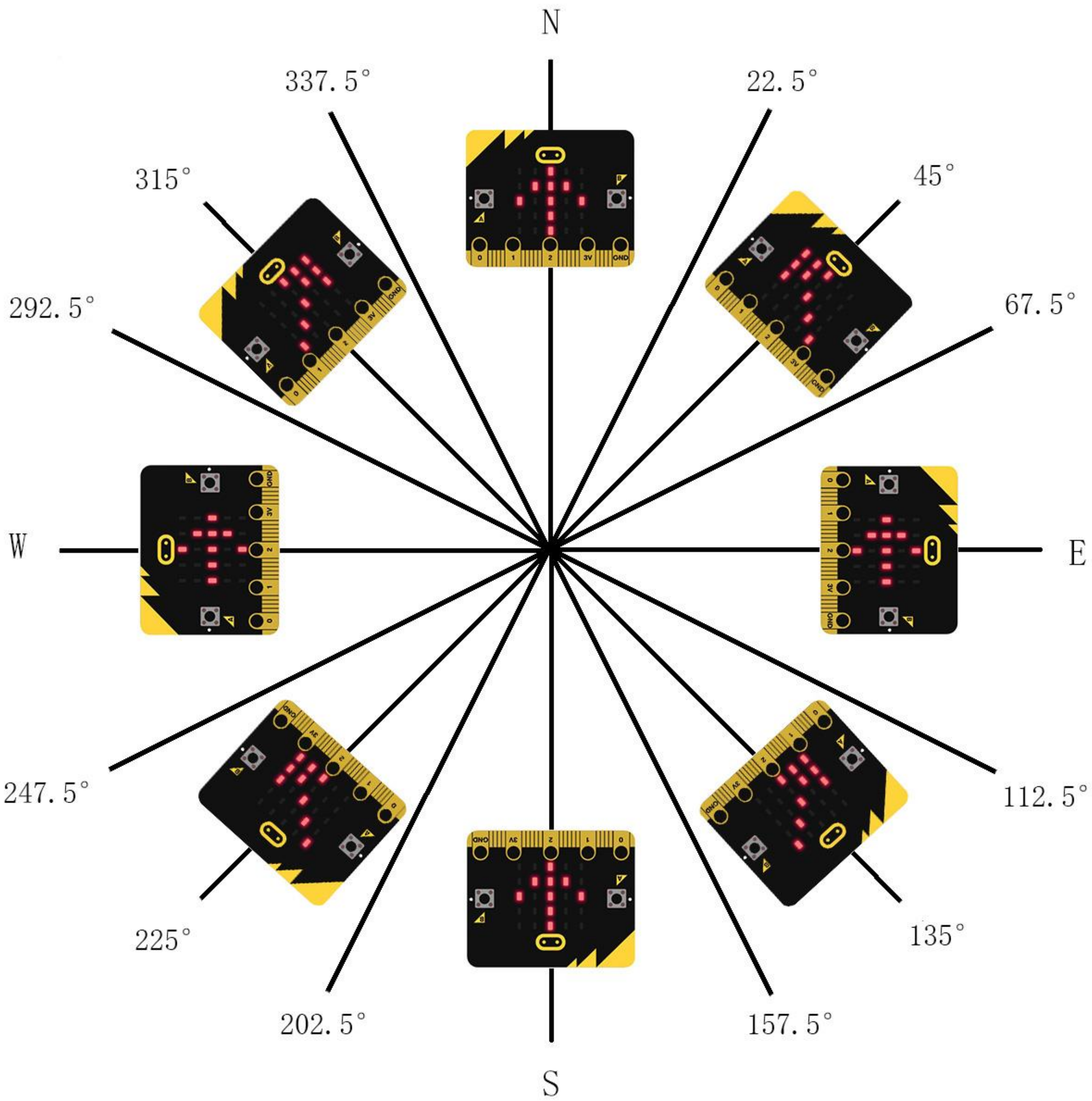

Check the connection of the circuit and verify it correct, and then download the code into the micro:bit. Calibrate the electronic compass. After the calibration is successful, place the micro:bit horizontally and turn the micro:bit to see that the arrow points to the geography Arctic.

The arrow will point to eight directions: northwest, west, southwest, south, southeast, east, northeast, north, each direction is 45 degrees apart. Assuming that the direction of the micro:bit is rotated 45 degrees from the north to the northeast of the geography, the arrow shown should be reversed, that is, it rotates -45 degrees, pointing to the northwest of the micro:bit, which is the geographic north pole. Therefore, we can adjust the direction of the arrow according to its angular offset from the geographic North Pole.

When the variable azimuth is less than 22.5 or greater than 337.5, the arrow points to the due north of the micro:bit.

When the variable azimuth is greater than 22.5 or less than 67.5, the arrow points to the northwest of the micro:bit.

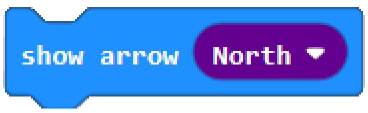
And so on in the same fashion, in every 45 degrees, the arrow points to a particular direction indicating the geographic north, as shown in the following illustration:



The angular offset read from the magnetometer chip is stored in the variable azimuth


Determine the value of the variable azimuth to change the direction of the arrow.


## Reference

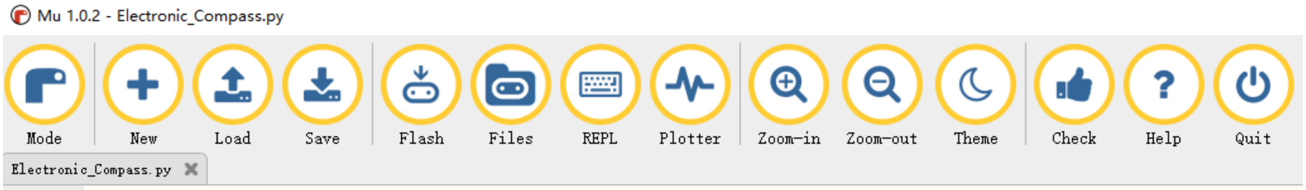
| Block | Function |
|---|---|
|  | Run code depending on whether a Boolean condition is true or false. |
|  | Shows the selected arrow on the LED screen |

# Python code

Open the .py file with Mu. Code, the path is as below:

| File type | Path | File name |
|---|---|---|
| **Python file** | ../Projects/PythonCode/11.2_ElectronicCompass | ElectronicCompass.py |

After loading successfully, the code is shown as below:




```
from microbit import *
compass.calibrate()
while True:
    azimuth = compass.heading()
    if azimuth<22.5 and azimuth<67.5:
        display.show(Image.ARROW_NW)
    elif azimuth<67.5 and azimuth<112.5:
        display.show(Image.ARROW_W)
    elif azimuth<112.5 and azimuth<157.5:
        display.show(Image.ARROW_SW)
    elif azimuth<157.5 and azimuth<202.5:
        display.show(Image.ARROW_S)
    elif azimuth<202.5 and azimuth<247.5:
        display.show(Image.ARROW_SE)
    elif azimuth<247.5 and azimuth<292.5:
        display.show(Image.ARROW_E)
    elif azimuth<292.5 and azimuth<337.5:
        display.show(Image.ARROW_NE)
    elif azimuth<22.5 or azimuth>337.5:
        display.show(Image.ARROW_N)
```

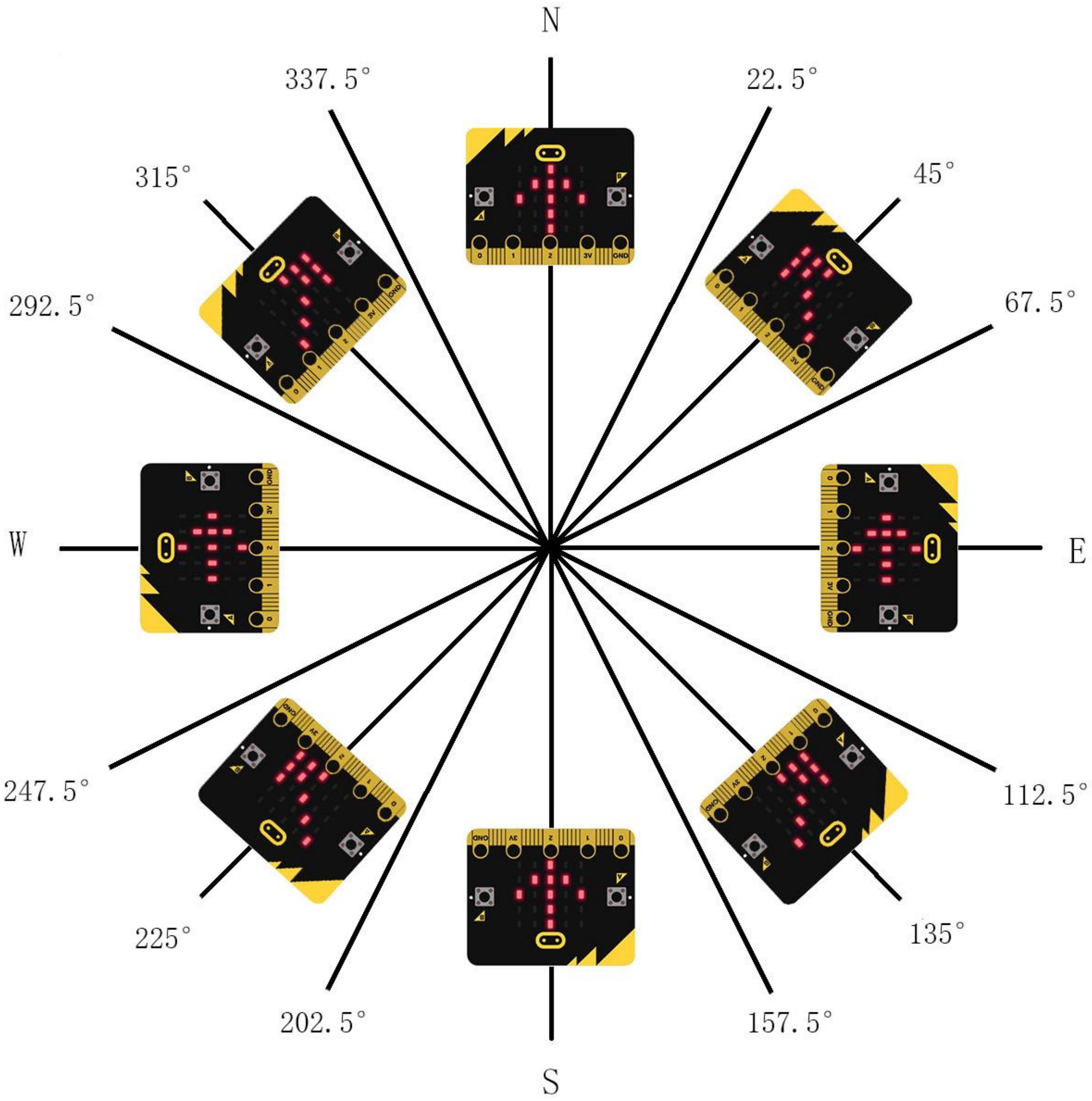
Check the connection of the circuit and verify it correct,, download the code into the micro:bit and calibrate the electronic compass. After the calibration is successful, place the micro:bit horizontally and rotate the micro:bit to see that the arrow points to the geography Arctic.

The arrow will point to eight directions:: northwest, west, southwest, south, southeast, east, northeast, north, each direction is 45 degrees apart. Assuming that the direction of the micro:bit is rotated 45 degrees from the north to the northeast of the geography, the arrow shown should be reversed, that is, rotated -45 degrees, pointing to the northwest of the micro:bit, which is the geographic north pole. Therefore, the direction of the arrow is adjusted according to the angular offset from the geographic North Pole.

When the variable azimuth is less than 22.5 or greater than 337.5, the arrow points to the true north of the micro:bit.

When the variable azimuth is greater than 22.5 and less than 67.5, the arrow points to the northwest of the micro:bit.

And so on in the same fashion, in every 45 degrees, the arrow points to a particular direction indicating the geographic north, as shown in the following figure:



The following is the program code:

```
from microbit import *
compass.calibrate()
while True:
    azimuth = compass.heading()
    if azimuth<22.5 and azimuth<67.5:
        display.show(Image.ARROW_NW)
    elif azimuth<67.5 and azimuth<112.5:
        display.show(Image.ARROW_W)
    elif azimuth<112.5 and azimuth<157.5:
        display.show(Image.ARROW_SW)
    elif azimuth<157.5 and azimuth<202.5:
        display.show(Image.ARROW_S)
    elif azimuth<202.5 and azimuth<247.5:
        display.show(Image.ARROW_SE)
    elif azimuth<247.5 and azimuth<292.5:
        display.show(Image.ARROW_E)
    elif azimuth<292.5 and azimuth<337.5:
        display.show(Image.ARROW_NE)
    elif azimuth<22.5 and azimuth>337.5:
        display.show(Image.ARROW_N)
```

Calibrate the electronic compass first and store the data on the variable azimuth.

```
compass.calibrate()
azimuth = compass.heading()
```

Determine the value of the variable azimuth and change the direction of the arrow.

```
if azimuth<22.5 and azimuth<67.5:
    display.show(Image.ARROW_NW)
elif azimuth<67.5 and azimuth<112.5:
    display.show(Image.ARROW_W)
elif azimuth<112.5 and azimuth<157.5:
    display.show(Image.ARROW_SW)
elif azimuth<157.5 and azimuth<202.5:
    display.show(Image.ARROW_S)
elif azimuth<202.5 and azimuth<247.5:
    display.show(Image.ARROW_SE)
elif azimuth<247.5 and azimuth<292.5:
    display.show(Image.ARROW_E)
elif azimuth<292.5 and azimuth<337.5:
    display.show(Image.ARROW_NE)
elif azimuth<22.5 and azimuth>337.5:
    display.show(Image.ARROW_N)
```

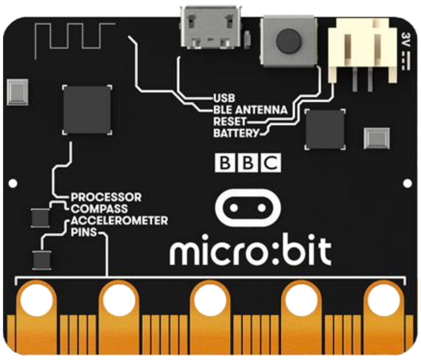
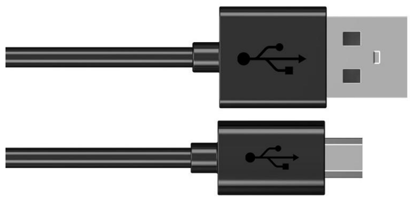
# Chapter 12 Accelerometer

In this chapter, we will learn about the built-in accelerometer sensor of micro:bit.

## Project 12.1 Display Accelerometer Data

In this project, we will obtain data from the accelerometer sensor and print it on the serial console.

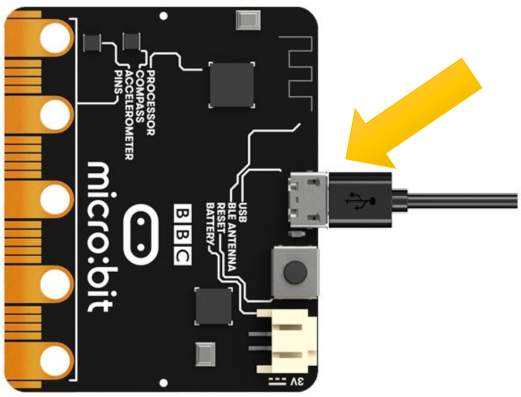
### Component list

| Microbit x1 | USB cable x1 |
| --- | --- |
|  |  |

### Circuit

Connect micro:bit and PC via a micro USB cable.

Hardware connection

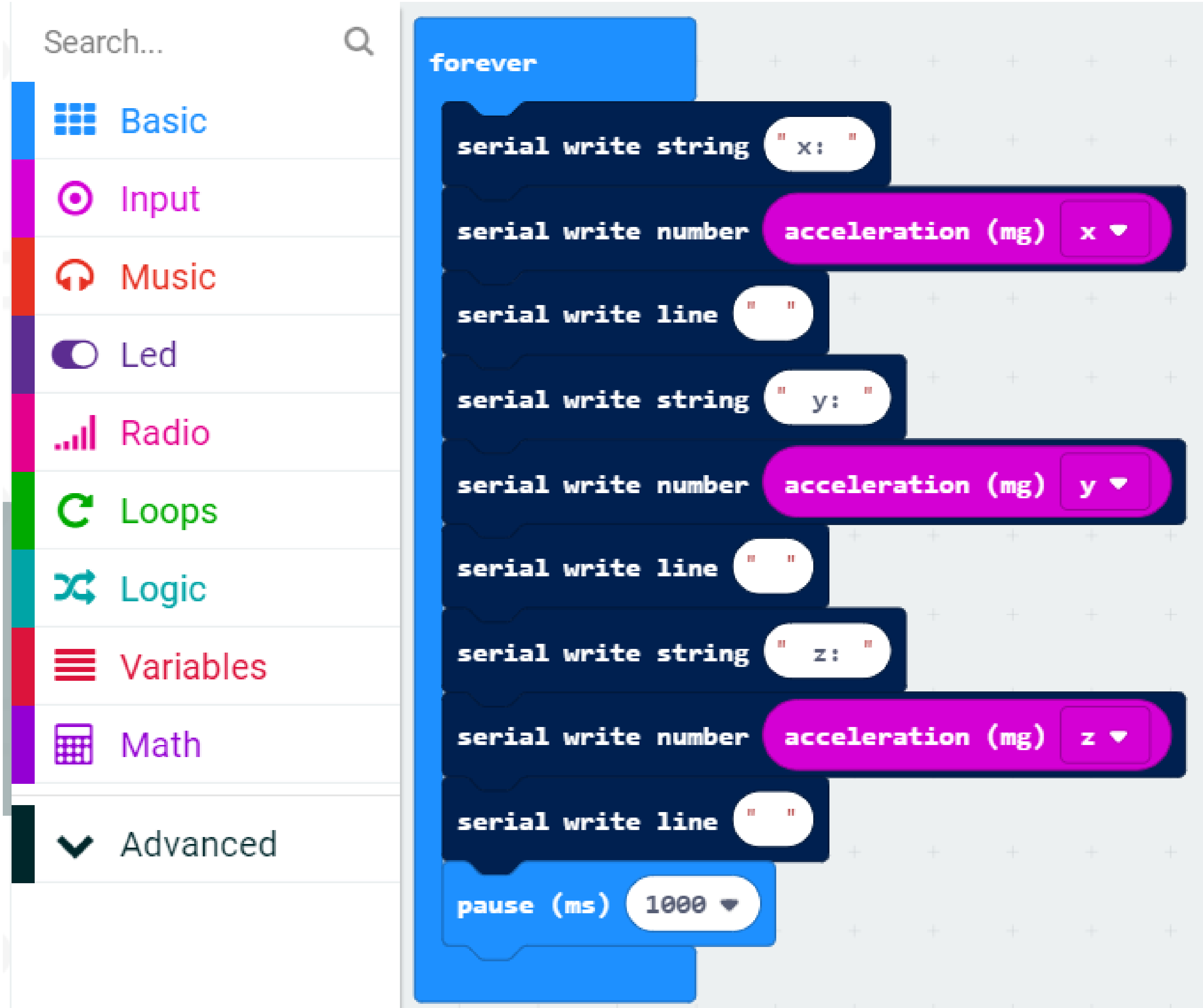


## Block code

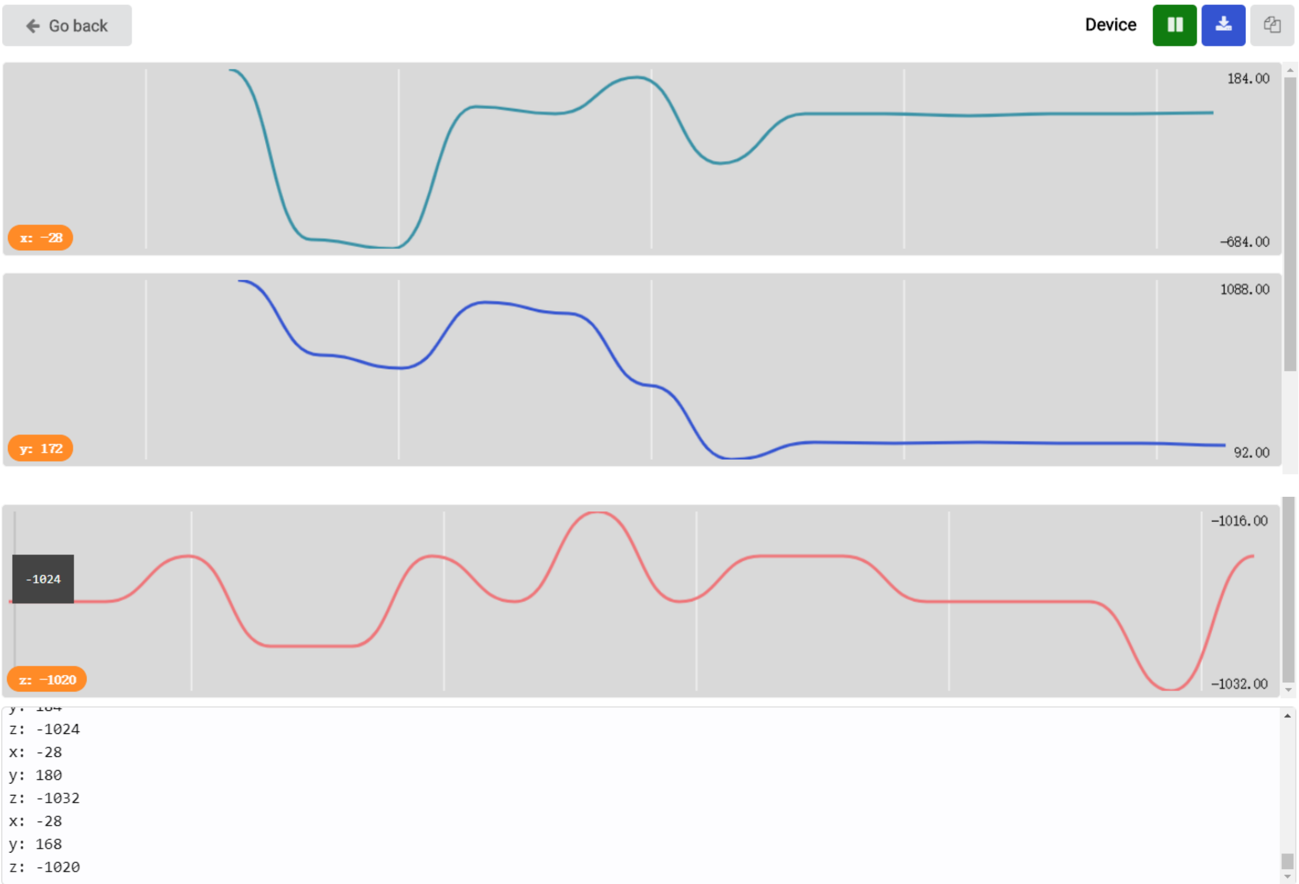
Open MakeCode first.
Import the .hex file. The path is as below:
(How to import project)

| File type | Path | File name |
|---|---|---|
| HEX file | ../Projects/BlockCode/12.1_DisplayAccelerometerData | DisplayAccelerometerData.hex |

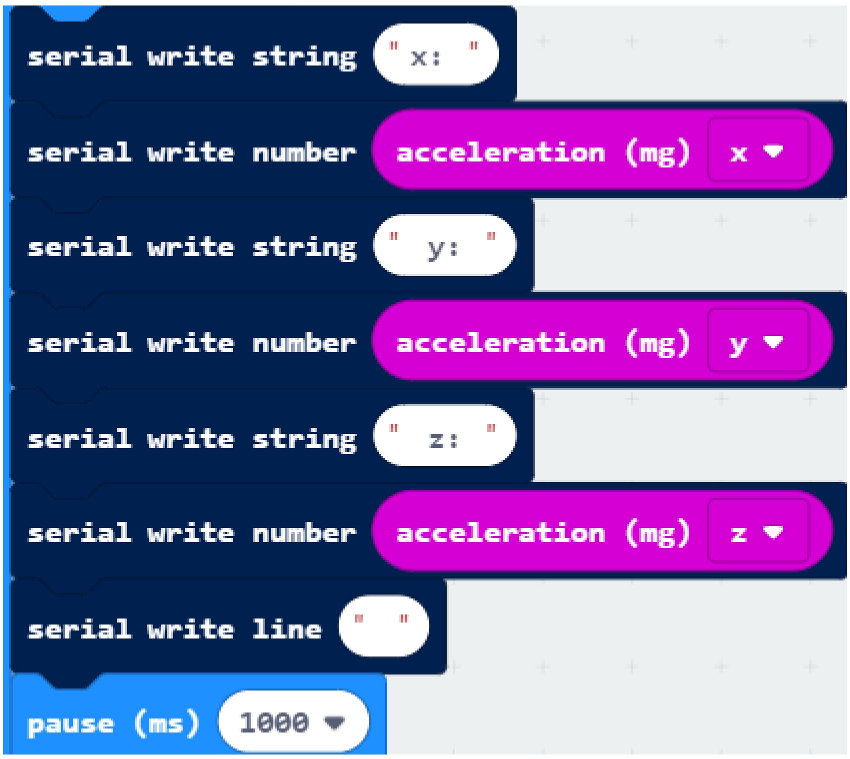
After importing successfully, the code is shown as below:




Check the connection of the circuit and verify it correct, download the code into the micro:bit, and then open the serial console, you can see the data of the accelerometer, as shown below:




Read the value of the accelerometer in three directions and print it out through the serial port every second.



## Reference

| Block | Function |
|---|---|
|  | Get the acceleration value in one of three dimensions, or the combined value in all directions (x, y, and z). |

# Python code

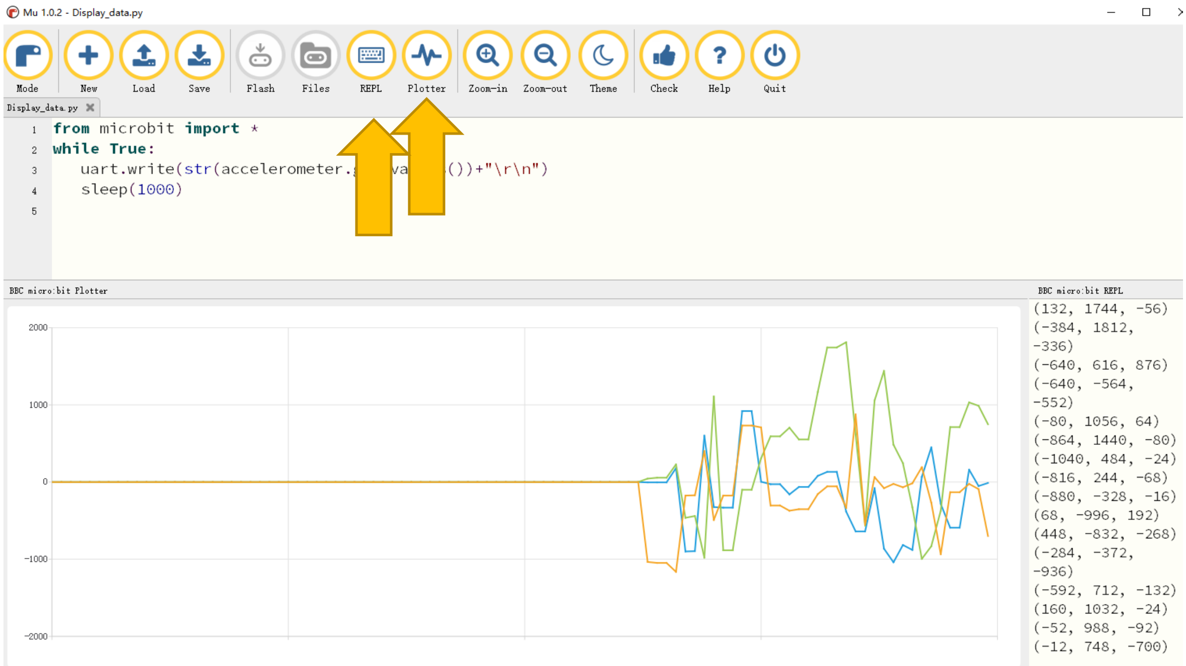
Open the .py file with Mu. Code, the path is as below:

| File type | Path | File name |
|---|---|---|
| **Python file** | ../PythonCode/12.1_DisplayAccelerometerData | DisplayAccelerometerData.py |

After loading successfully, the code is shown as below:


Check the connection of the circuit and verify it correct, and then download the code into the micro:bit.

After the program is downloaded, open the plotter (Plotter), click on the REPL, you can see the x-axis, y-axis, z-axis data collected by the accelerometer, as shown below:




The following is the program code:

```
from microbit import *
while True:
    uart.write(str(accelerometer.get_values())+"\r\n")
    sleep(1000)
```

Every 1 second, the accelerometer data will be obtained and printed through the serial port.

```
uart.write(str(accelerometer.get_values())+"\r\n")
sleep(1000)
```

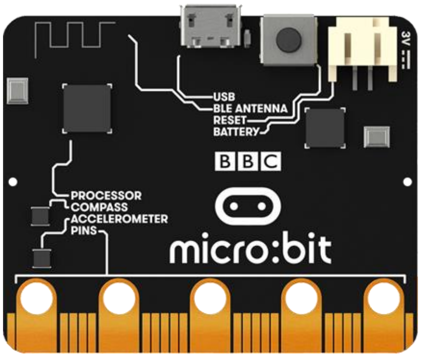
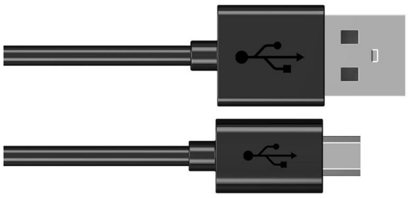
## Reference

| accelerometer.get_values() |
|---|
| Get the acceleration measurements in all axes at once, as a three-element tuple of integers ordered as X, Y, Z. By default the accelerometer is configured with a range of +/- 2g, so X, Y, and Z will be within the range of +/-2000mg. |

# Project 12.2 Gradiometer

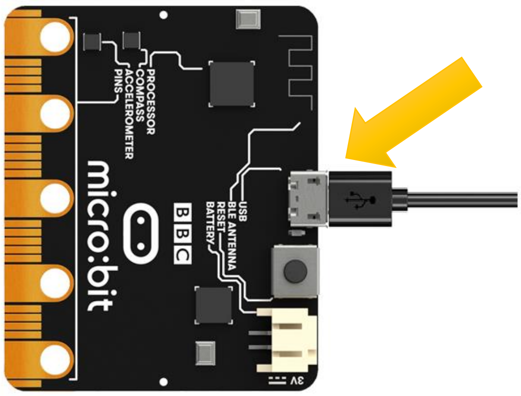
In this project, we will use the accelerometer to make a level instrument.

## Component list

| Microbit x1 | USB cable x1 |
|---|---|
|  |  |

## Circuit

Connect micro:bit and PC via a micro USB cable.

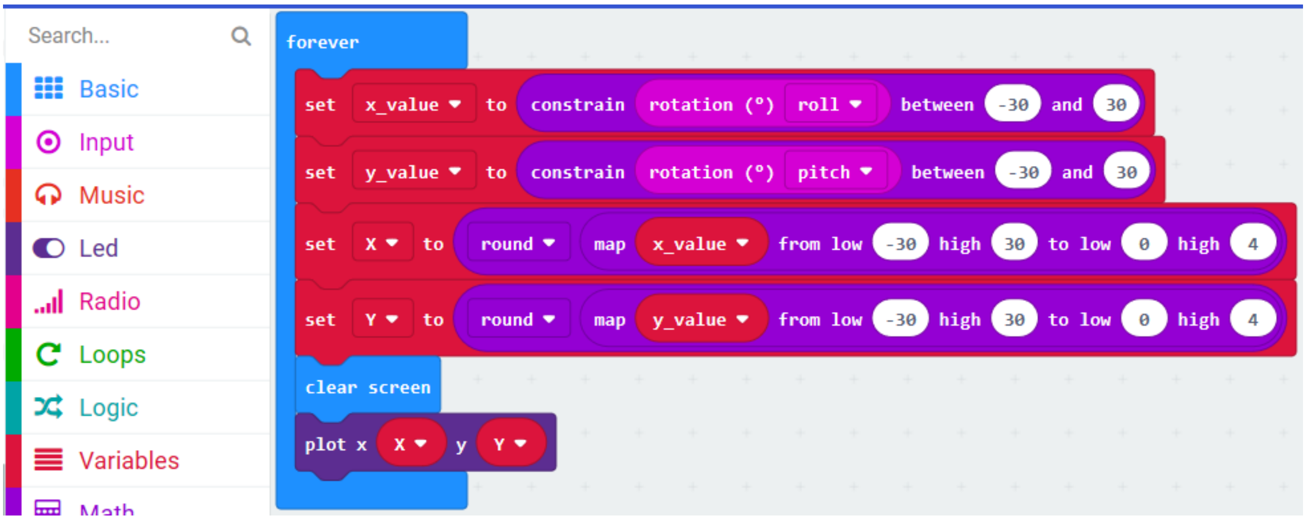
| Hardware connection |
|---|
|  |

## Block code

Open MakeCode first.
Import the .hex file. The path is as below:
(How to import project)

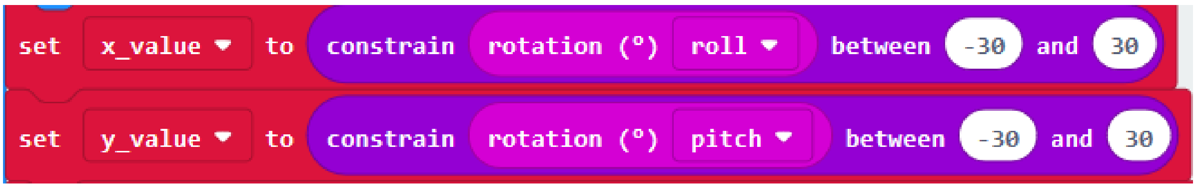
| File type | Path | File name |
|---|---|---|
| HEX file | ../Projects/BlockCode/12.2_Gradienter | Gradienter.hex |

After importing successfully, the code is shown as below:



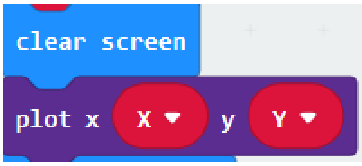

Check the connection of the circuit and verify it correct and download the code into micro:bit, you will observe that the LED dot matrix will change with the tilt of micro:bit.

Detect the flip angle of the microbit in the x-axis and the y-axis. The return value ranges from -180 to 180 degrees. This project does not require such a wide range of flip angles, so we just set it within -30 to 30 degrees.

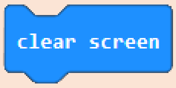



Since the LED screen is 5x5, map the range of -30-30 to the range of 0-4, and assign it to the X, Y variable.

Turn OFF all the LED first, then turn ON the corresponding LED according to the value of the X, Y variables.




## Reference

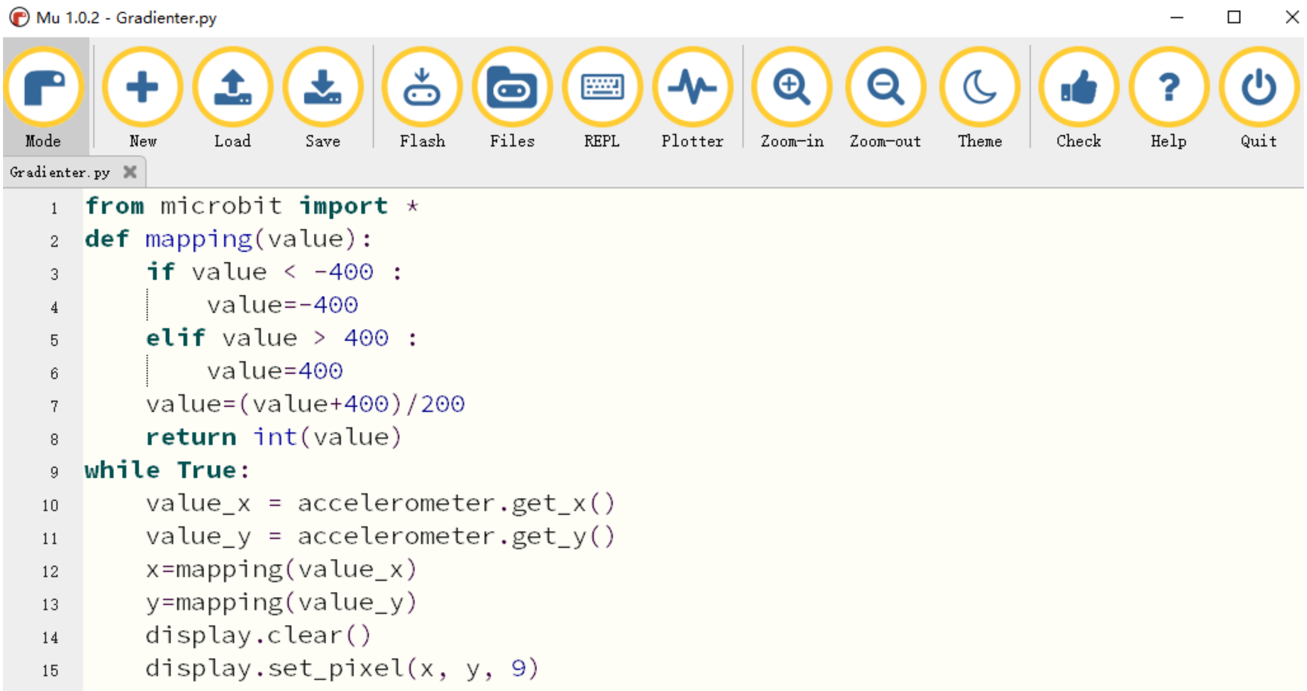
| Block | Function |
|---|---|
|   | Find how much the micro:bit is tilted in different directions. |
|   | Turn ON the LED you set on the LED screen. |
|   | If a number has a fractional part, you can change the number to the nearest integer value. |
|   | A map is a conversion of one span of numbers to another. |
|   | Turn OFF all the LED lights on the LED screen. |
|   | Make sure that the value of the number you give is within the range. |

# Python code

Open the .py file with Mu. Code, the path is as below:

| File type | Path | File name |
|---|---|---|
| **Python file** | ../Projects/PythonCode/12.2_Gradienter | Gradienter.py |

After loading successfully, the code is shown as below:




Check the connection of the circuit and verify it correct, download the code into micro:bit, you will observe that the LED dot matrix will change with the tilt of micro:bit.

The following is the program code:

```
from microbit import *
def mapping(value):
    if value < -400 :
        value=-400
    elif value > 400 :
        value=400
    value=(value+400)/200
    return int(value)
while True:
    value_x = accelerometer.get_x()
    value_y = accelerometer.get_y()
    x=mapping(value_x)
    y=mapping(value_y)
    display.clear()
    display.set_pixel(x, y, 9)
```

A custom mapping() function limits the input value to a range of -400 to 400 and maps to a range of 0-4.

```
def mapping(value):
    if value < -400 :
        value=-400
    elif value > 400 :
        value=400
    value=(value+400)/200
    return int(value)
```

Read the value of the accelerometer X, Y-axis direction. The return value range is -2000-2000. This project does not require such a wide range, So we set it to the range of -400to 400. Call the mapping() function to return the value ranging from 0-4 , lighting the LED corresponding to the x row and the y column.

```
while True:
    value_x = accelerometer.get_x()
    value_y = accelerometer.get_y()
    x=mapping(value_x)
    y=mapping(value_y)
    display.clear()
    display.set_pixel(x, y, 9)
```

## Reference

| |
|---|
| display.clear() |
| Set the brightness of all LEDs to 0 (off). |
| display.set_pixel(x,y,9) |
| Set the brightness value of the LED at column x and row y, which has to be an integer between 0 and 9. |
| accelerometer.get_x() |
| Get the acceleration measurement in the x axis, as a positive or negative integer, depending on the direction. The measurement is given in milli-g. By default the accelerometer is configured with a range of +/- 2g, and so this method will return a value within the range of +/- 2000mg |
| accelerometer.get_y() |
| Get the acceleration measurement in the y axis, as a positive or negative integer, depending on the direction. The measurement is given in milli-g. By default the accelerometer is configured with a range of +/- 2g, and so this method will return a value within the range of +/- 2000mg. |

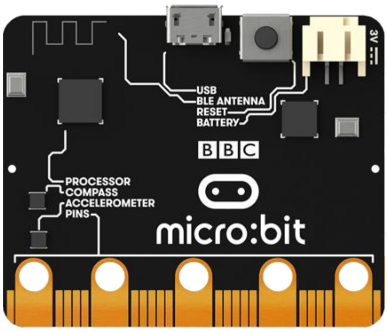
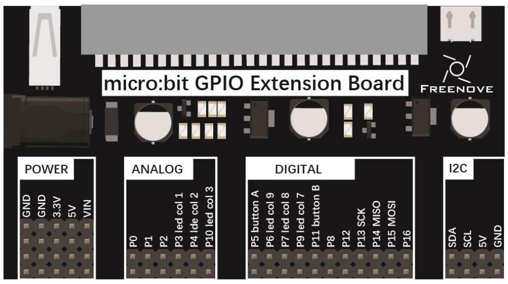
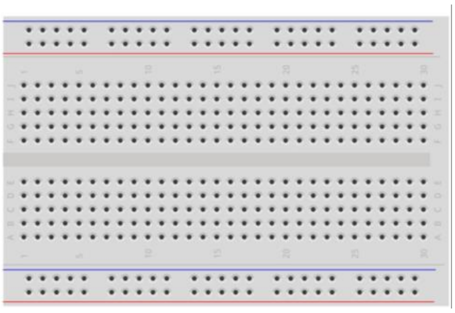
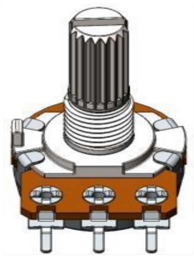
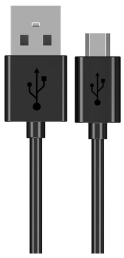
# Chapter 13 Potentiometer

In this chapter, we will learn a new component: potentiometer

## Project 13.1 Potentiometer

This project enables a rotatary potentiometer to output different voltages.

### Component list

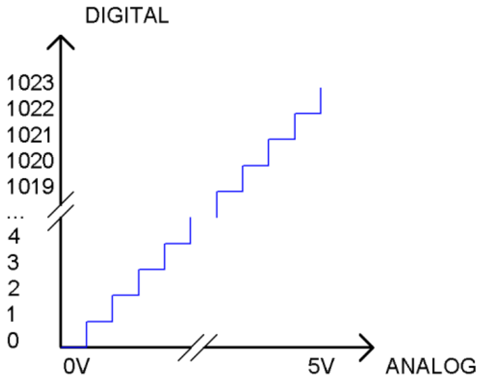
<table>
<tr><td>Microbit x1<br>
</td><td colspan="3">Extension board x1<br>
</td></tr>
<tr><td>Breadboard x1<br></td><td>Potentiometer x1<br></td><td>USB cable x1<br></td><td>F/M x3<br></td></tr>
</table>

# Component 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 module is 10 bits, that means the resolution is 2^10=1024, so that its range (at 3.3V) will be divided equally to 1024 parts.

Any analog value can be mapped to one digital value using the resolution of the converter. 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-3.3/1024V corresponds to digital 0;

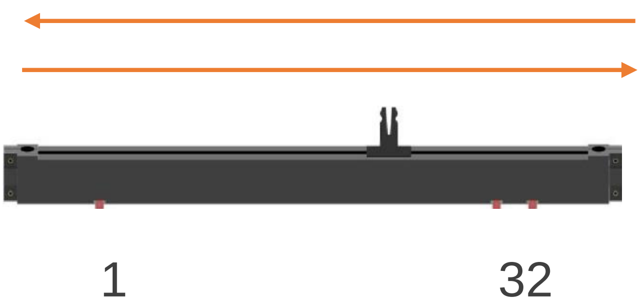
Subsection 2: the analog in rang of 3.3 /1024V-2*3.3/1024V corresponds to digital 1;

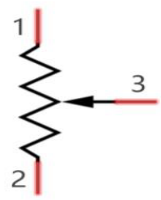
...

The resultant analog signal will be divided accordingly.

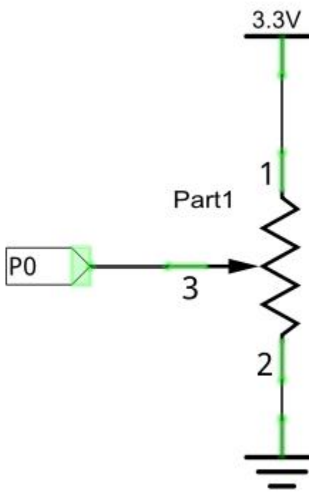
## Potentiometer

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.



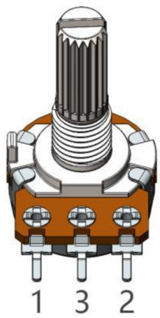



Between potentiometer pin 1 and pin 2 is the resistive element (a resistance wire or carbon) and pin 3 is connected to the brush that makes contact with the resistive element. In our illustration, when the brush moves from pin 1 to pin 2, the resistance value between pin 1 and pin 3 will increase linearly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



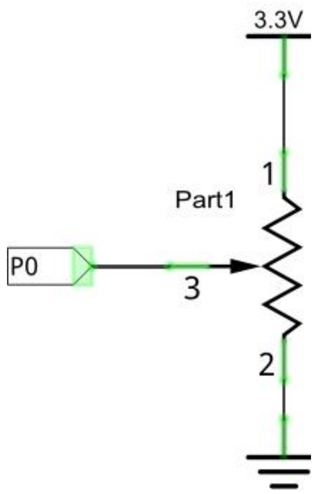

## Rotary potentiometer

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

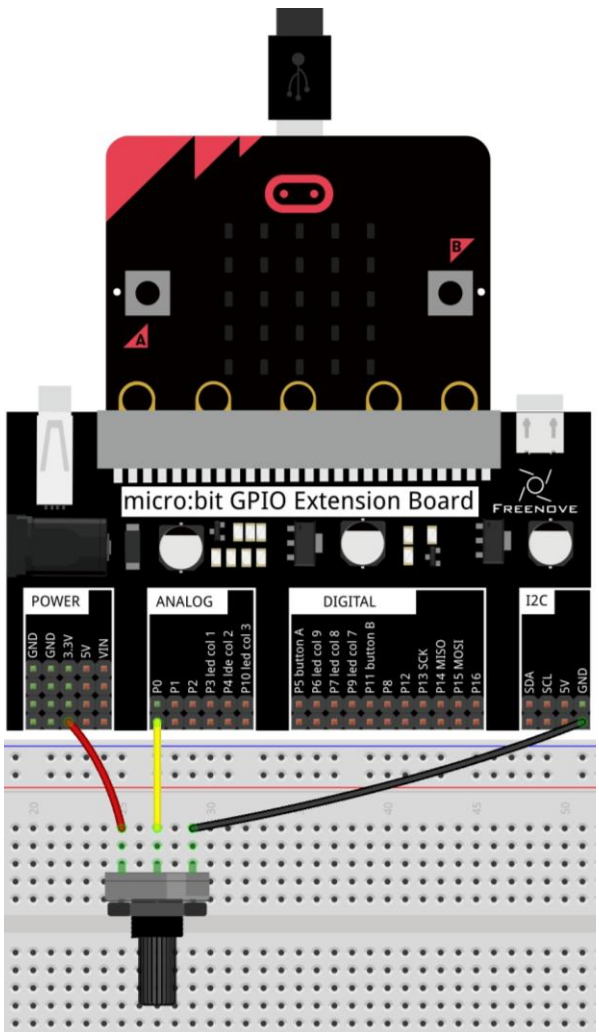


## Circuit

Schematic diagram




Hardware connection

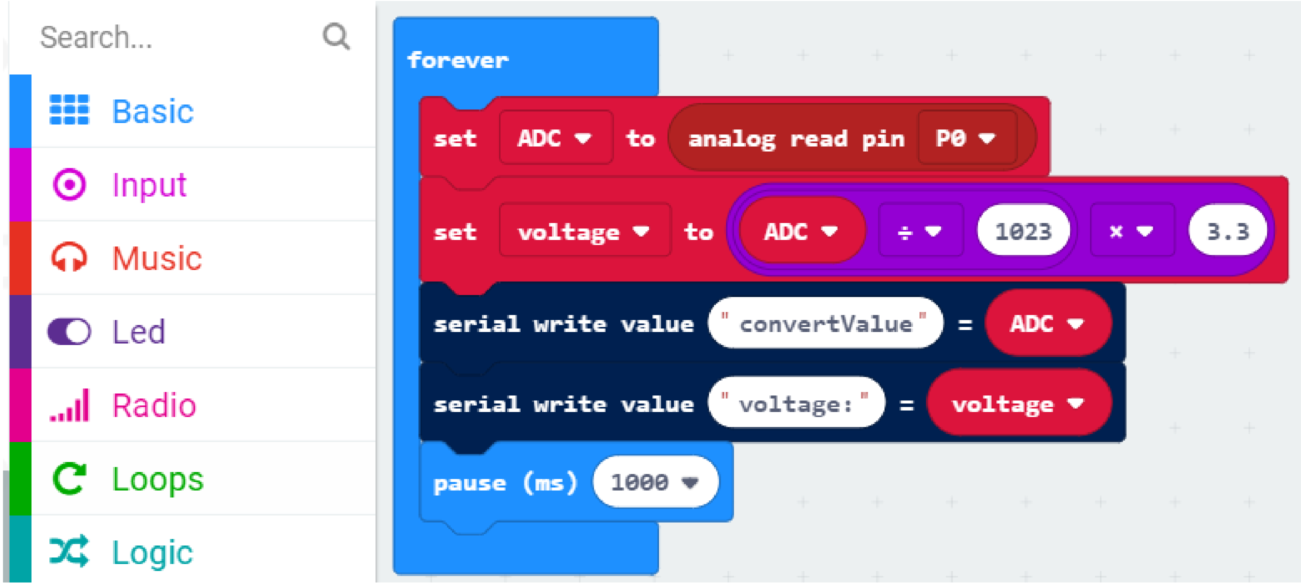


# Block code

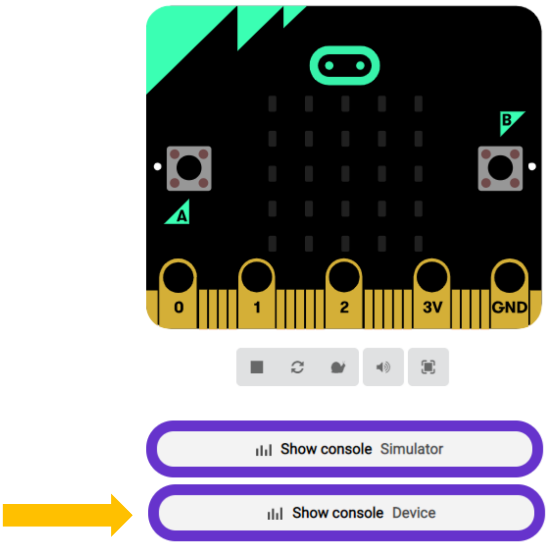
Open MakeCode first. Import the .hex file. The path is as below:
(How to import project)

| File type | Path | File name |
|---|---|---|
| HEX file | ../Projects/BlockCode/13.1_Potentiometer | Potentiometer.hex |

After importing successfully, the code is shown as below:




Check the connection of the circuit and verify it correct and then download the code into micro:bit.

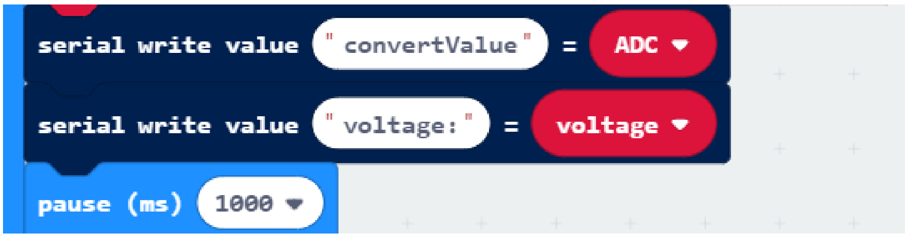



Click on the console device, rotate the potentiometer, you will see the output ADC value and voltage value.

```
voltage::2.6129032258064515
convertValue:1022
voltage::3.2967741935483867
convertValue:793
voltage::2.5580645161290318
convertValue:731
voltage::2.3580645161290321
```

Read the analog voltage value of the P0 pin, the range is 0-1023, and then convert the analog voltage value into a digital voltage value.


Print the analog voltage and digital voltage of P0 pin every 1 second.




## Reference

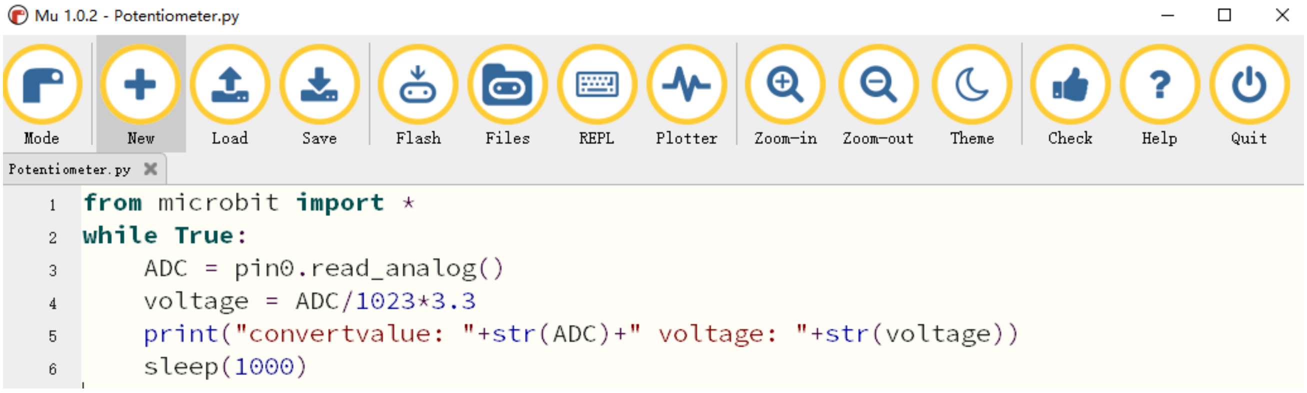
| Block | Function |
|---|---|
|   | Read an analog signal (0 to 1023) from the pin you set.) |

## Python code

Open the .py file with Mu. Code, the path is as below:

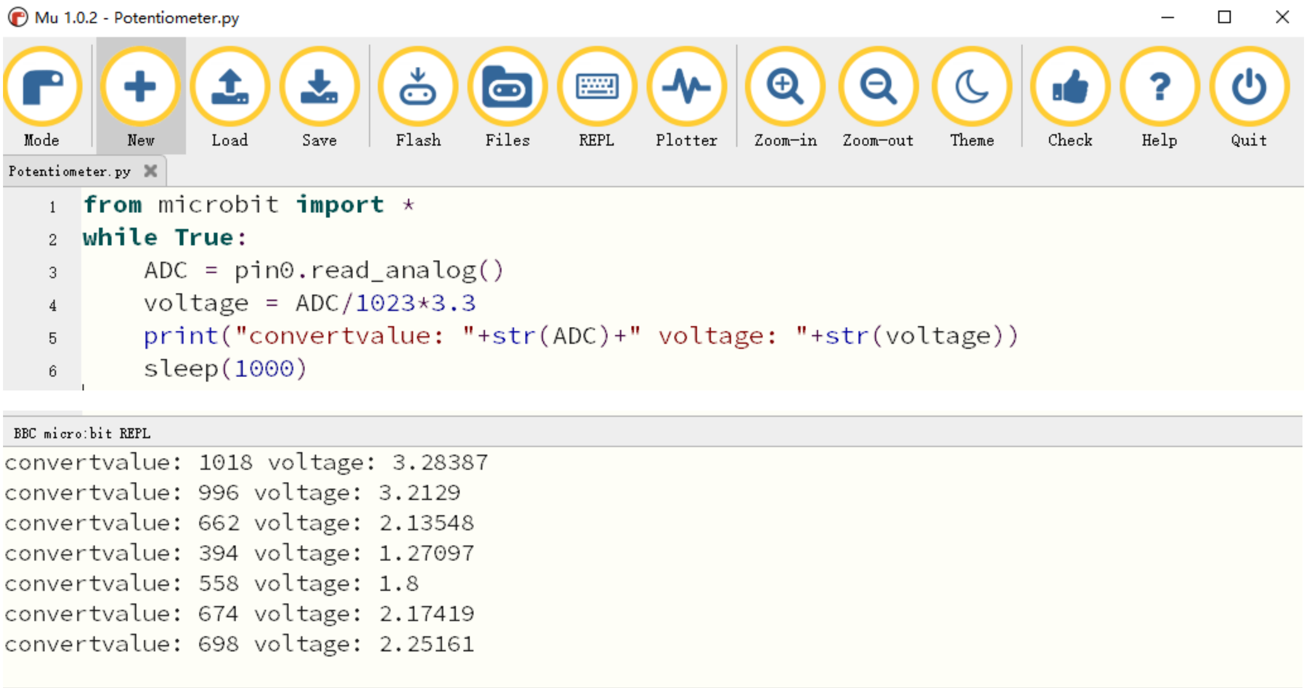
| File type | Path | File name |
|---|---|---|
| Python file | ../Projects/PythonCode/13.1_Potentiometer | Potentiometer.py |

After loading successfully, the code is shown as below:




Check the connection of the circuit and confirm that the circuit is connected correctly. Download the code into the micro:bit. (How to download?)

Click on the REPL, press the micro:bit reset button, and then rotate the potentiometer. You can see the change in the value on the software Mu, as shown below.



The following is the program code:

```
from microbit import *
while True:
    ADC = pin0.read_analog()
    voltage = ADC/1023*3.3
    print("convertvalue: "+str(ADC)+" voltage: "+str(voltage))
    sleep(1000)
```

Read the analog voltage value of the P0 pin, the range is 0-1023, and then convert the analog voltage value into a digital voltage value.

```
ADC = pin0.read_analog()
voltage = ADC/1023*3.3
```

Print the analog voltage and digital voltage of P0 pin every 1 second.

```
print("convertvalue: "+str(ADC)+" voltage: "+str(voltage))
sleep(1000)
```

## Reference

| |
|---|
| read_analog() |
| Read an analog signal (0 to 1023) from the pin you set. |
| print() |
| Print() is a Python built-in function for printing. |

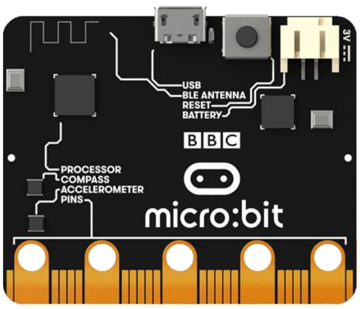
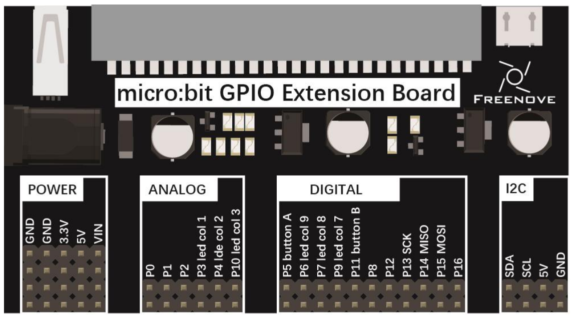
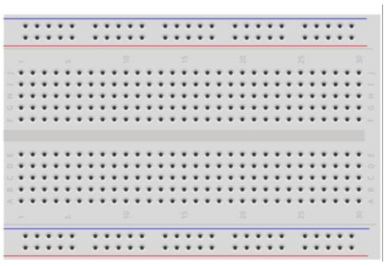
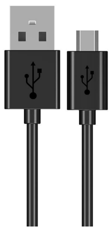
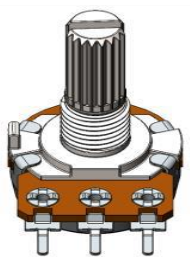
# Chapter 14 Potentiometer and LED

This chapter is a comprehensive application of potentiometer and LED.

## Project 14.1 Soft Light

In this project, we will make an LED with adjustable brightness.

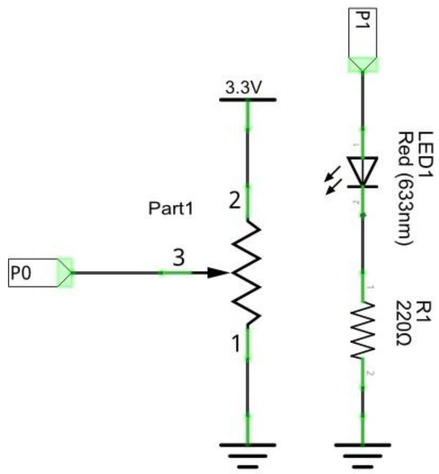
### Component list

| Microbit x1 | Extension board x1 | |
|---|---|---|
|  |  | |
| Breadboard x1 | USB cable x1 | F/M x4 M/M x1 |
|  |  |  |
| LED x1 | Resistor 220Ω x1 | Potentiometer x1 |
|  |  |  |

## Circuit

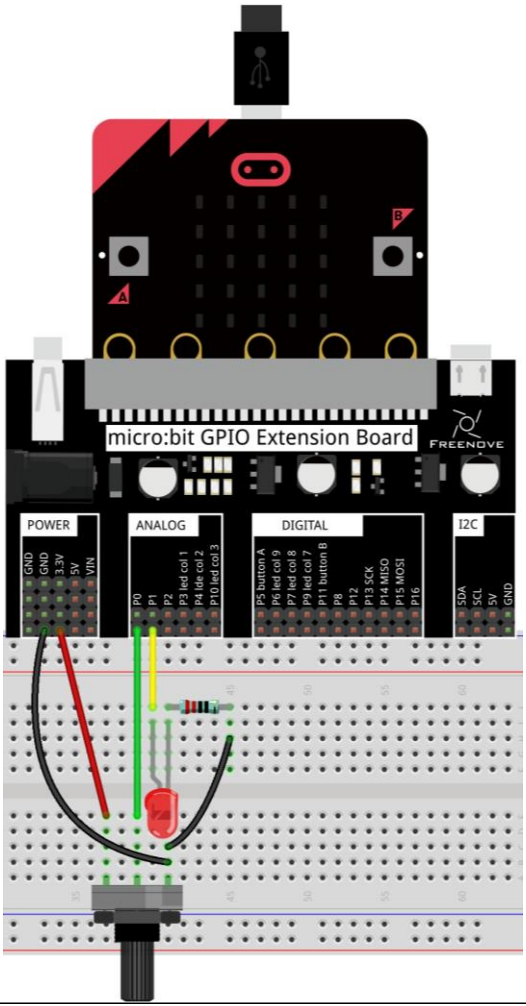
In this circuit, the port 1 and 2 of the potentiometer are respectively connected to the two ends of the power supply, and the port3 is connected to the P0 pin of the micro:bit.

Schematic diagram




Hardware connection

**P1 pin is connected to LED's long pin (positive), and its short pin (negative) is connected to resistor.**

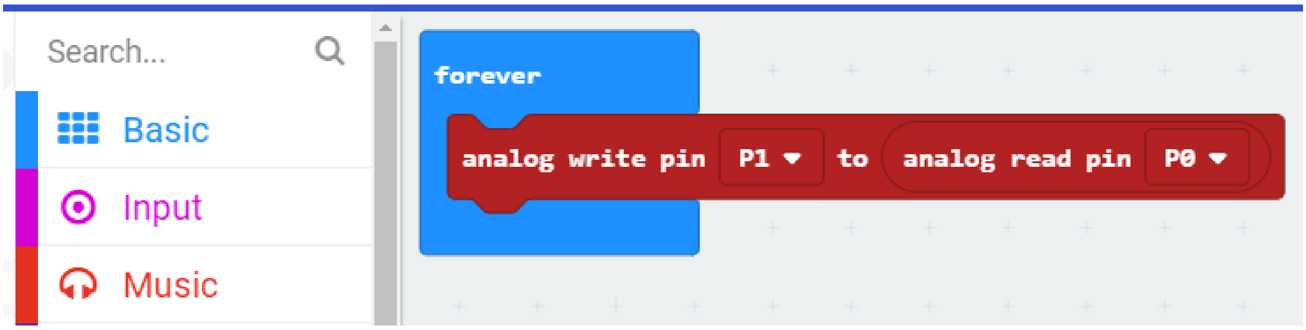


## Block code

Open MakeCode first. Import the .hex file. The path is as below:
(How to import project)

| File type | Path | File name |
|---|---|---|
| **HEX file** | ../Projects/BlockCode/14.1_SoftLight | SoftLight.hex |

After importing successfully, the code is shown as below:




Check the connection of the circuit, verify it correct,, download the code into the micro:bit, and rotate the potentiometer to see the change of the brightness.

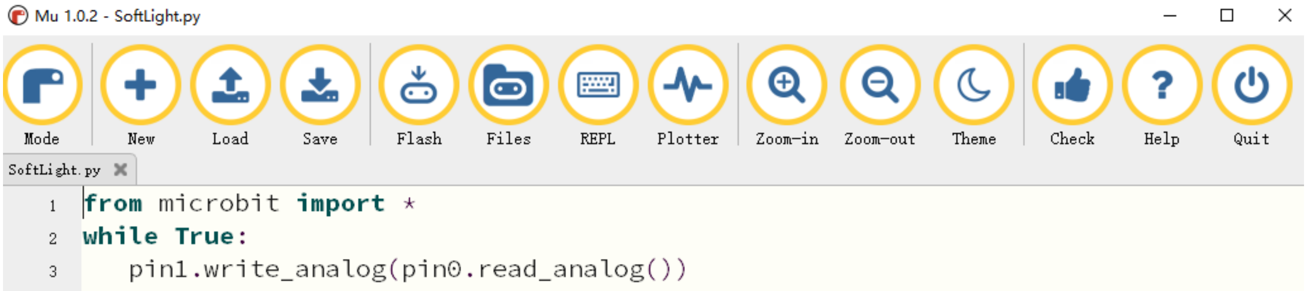
Read the analog voltage value of the P0 pin, then the P1 pin outputs the same analog voltage value.

## Python code

Open the .py file with Mu. Code, the path is as below:

| File type | Path | File name |
|---|---|---|
| **Python file** | ../Projects/PythonCode/14.1_SoftLight | SoftLight.py |

After load successfully, the code is shown as below:




Check the connection of the circuit, verify it correct, download the code into the micro:bit, and rotate the potentiometer to see the change of the brightness of the LED.

The following is the program code:

```python
from microbit import *
while True:
    pin1.write_analog(pin0.read_analog())
```

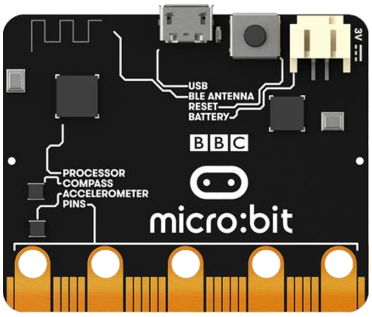
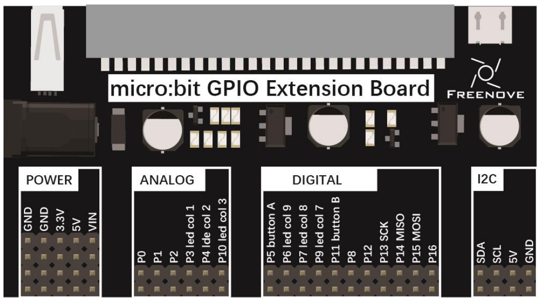
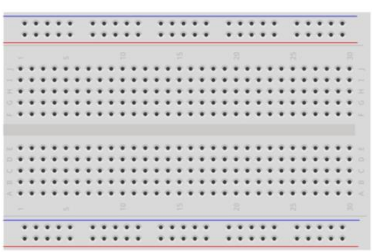
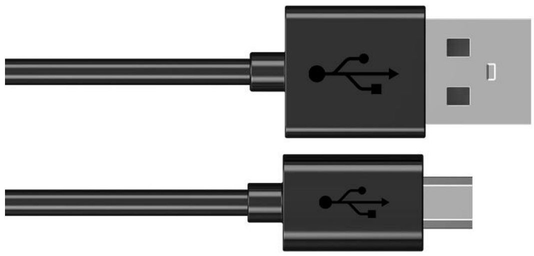
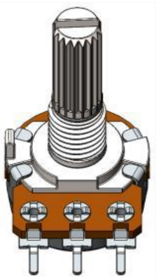
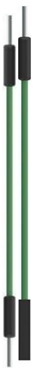
Read the analog voltage value of the P0 pin, then the P1 pin outputs the same analog voltage value.

```python
pin1.write_analog(pin0.read_analog())
```

# Project 14.2 Multicolored Soft Light

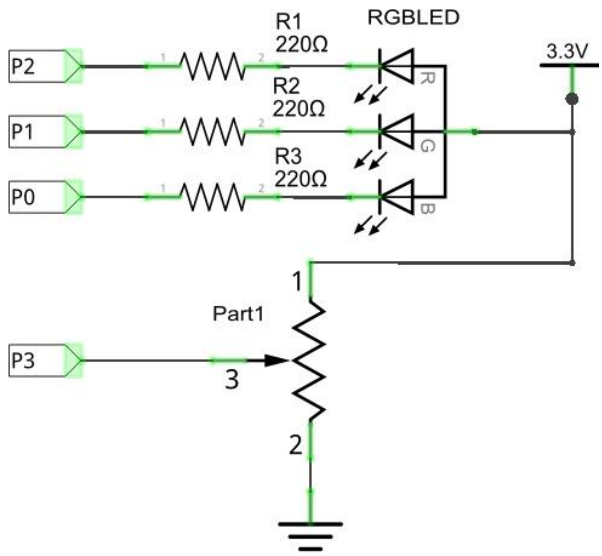
In this project, we control the color of the RGBLED with a potentiometer.

## Component list

| | |
|---|---|
| Microbit x1   | Extension board x1   |
| Breadboard x1  | USB cable x1  |
| Rotary potentionmeter x1  | RGB_LED x1  |
| F/M x6 M/M x1  | Resistor 220Ω x3  |

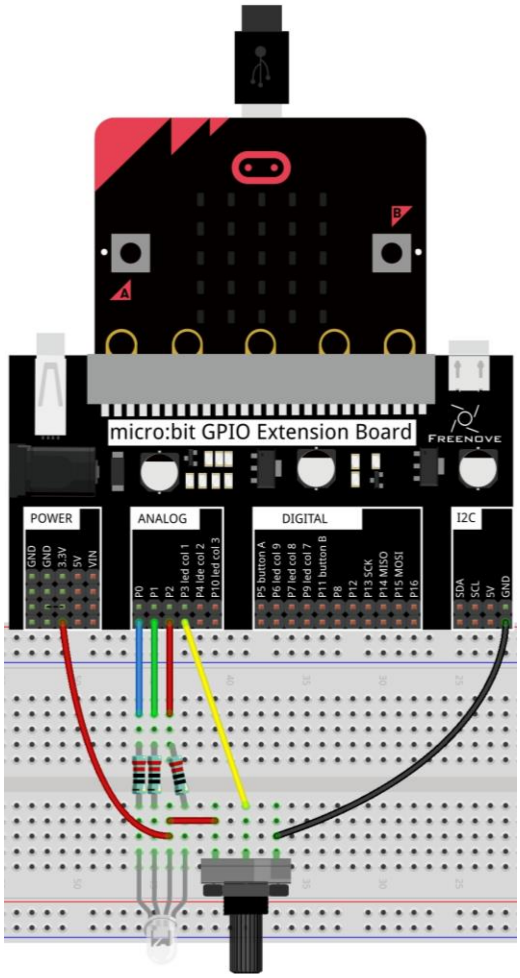
## Circuit

Schematic diagram




Hardware connection

RGBLED's long pin (anode) is connected to 3.3V power supply.



## Block code

Open MakeCode first. Import the .hex file. The path is as below:
(How to import project)

| File type | Path | File name |
| --- | --- | --- |
| **HEX file** | ../Projects/BlockCode/14.2_ColorfulSoftLight | ColorfulSoftLight.hex |

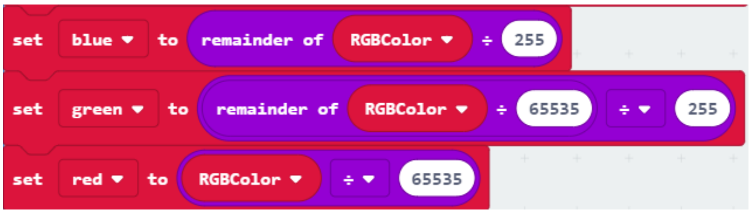
After importing successfully, the code is shown as below:


Download the code into micro:bit, rotate the potentiometer, you can see that the color of the RGBLED is changing.

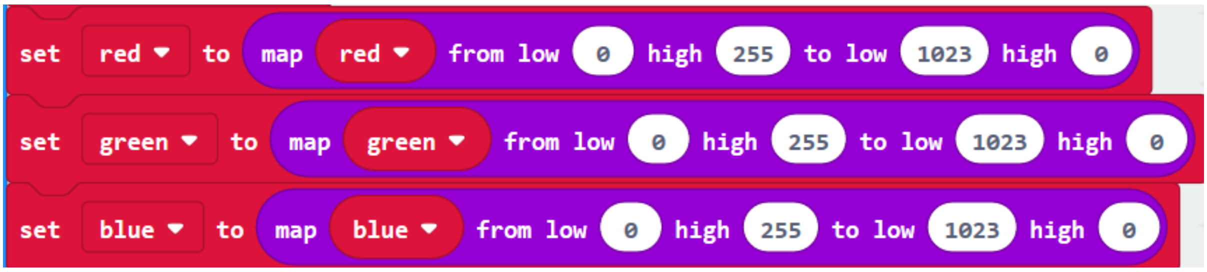
Read the potentiometer's analog voltage and map the potentiometer's analog voltage ranging 0-1023 to the hue angle ranging 0-360.


Convert the HSL color system to the RGB color system, return the RGB value corresponding to the current hue angle, and store the value in the variable RGBColor.

The value of the lower eight-bit blue channel of the variable RGBColor is assigned to the variable blue, the value of the middle eight-bit green channel is assigned to the variable green, and the value of the upper eight-bit red channel is assigned to the variable red.




RGBLED is a common anode, so the pins are set to low to turn on the RGBLED. The values of the variables 'red', 'green', and 'blue' are converted from 0-255 to analog signal values in the range of 1023-0, and then reassigned to 'red', 'green', 'blue 'variable. In this kit, three LEDs of RGB LED share a common anode(+) and their negative pins need to be set to LOW level to turn ON the RGB LED work. And the value of variables ‘red’, ‘green’, and ‘blue’ need to be converted from the value ranging from 0-255 to analog signal values ranging from 1023-0, and then reassigned to them.



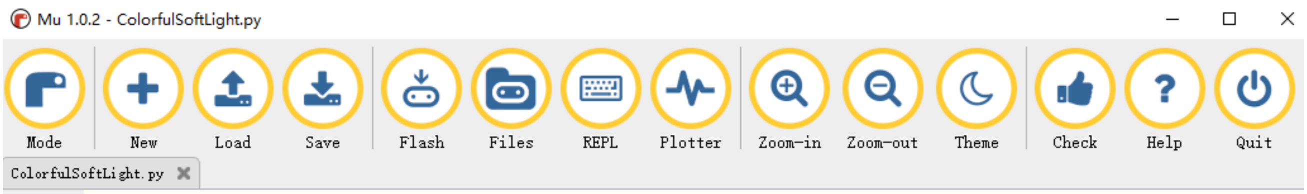

Write the analog voltage value of the red, green, and blue variables to the corresponding P0, P1, and P2 pins to change the LED color.

## Python code

Open the py file with Mu. Code, the path is as below:

| File type | Path | File name |
|---|---|---|
| Python file | ../Projects/PythonCode/14.2_ColorfulSoftLight | ColorfulSoftLight.py |

After loading successfully, the code is shown as below:




```python
from microbit import *
display.off()
def map(value,fromLow,fromHigh,toLow,toHigh):
    return (toHigh-toLow)*(value-fromLow) / (fromHigh-fromLow) + toLow
def HSL_RGB(degree):
    degree=degree/360*255
    if degree < 85:
        red = 255 - degree * 3
        green = degree * 3
        blue = 0
    elif degree < 170:
        degree = degree - 85
        red = 0
        green = 255 - degree * 3
        blue = degree * 3
    else:
        degree = degree - 170
        red = degree * 3
        green = 0
        blue = 255 - degree * 3
    return red,green,blue
while True:
    value=map(pin3.read_analog(),0,1023,0,360)
    red,green,blue=HSL_RGB(value)
    red=map(red,0,255,1023,0)
    green=map(green,0,255,1023,0)
    blue=map(blue,0,255,1023,0)
    pin2.write_analog(red)
    pin1.write_analog(green)
    pin0.write_analog(blue)
```

After checking the connection of the circuit, verify it correct, download the code into micro:bit. By rotating the potentiometer, you can see that the color of RGB LED is changing.

The following is the program code:

```
from microbit import *
display.off()
def map(value,fromLow,fromHigh,toLow,toHigh):
    return (toHigh-toLow)*(value-fromLow) / (fromHigh-fromLow) + toLow
def HSL_RGB(degree):
    degree=degree/360*255
    if degree < 85:
        red = 255 - degree * 3
        green = degree * 3
        blue = 0
    elif degree < 170:
        degree = degree - 85
        red = 0
        green = 255 - degree * 3
        blue = degree * 3
    else:
        degree = degree - 170
        red = degree * 3
        green = 0
        blue = 255 - degree * 3
    return red,green,blue
while True:
    value=map(pin3.read_analog(),0,1023,0,360)
    red,green,blue=HSL_RGB(value)
    print(red,green,blue)
    red=map(red,0,255,1023,0)
    green=map(green,0,255,1023,0)
    blue=map(blue,0,255,1023,0)
    pin2.write_analog(red)
    pin1.write_analog(green)
    pin0.write_analog(blue)
    sleep(10)
```

Turn OFF the LED screen to use the P3 pin. A custom map() function converts values in one range of numbers to values in another range of numbers.

```
display.off()
def map(value,fromLow,fromHigh,toLow,toHigh):
    return (toHigh-toLow)*(value-fromLow) / (fromHigh-fromLow) + toLow
```

The custom function HSL_RGB()is used to convert the HSL color system to the RGB color system and return the RGB value corresponding to the current hue angle.

```
def HSL_RGB(degree):
    degree=degree/360*255
    if degree < 85:
        red = 255 - degree * 3
        green = degree * 3
        blue = 0
    elif degree < 170:
        degree = degree - 85
        red = 0
        green = 255 - degree * 3
        blue = degree * 3
    else:
        degree = degree - 170
        red = degree * 3
        green = 0
        blue = 255 - degree * 3
    return red,green,blue
```

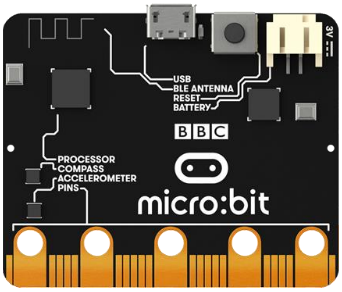
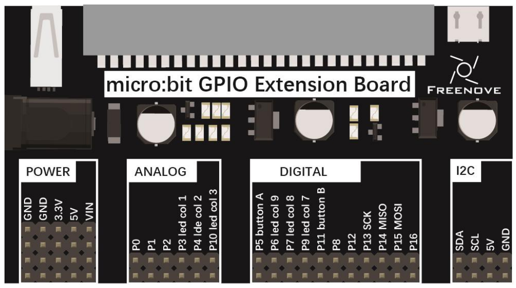
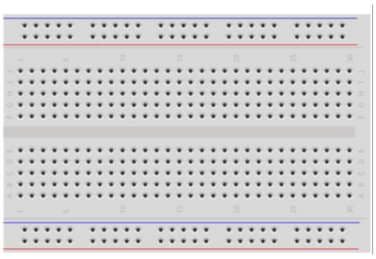
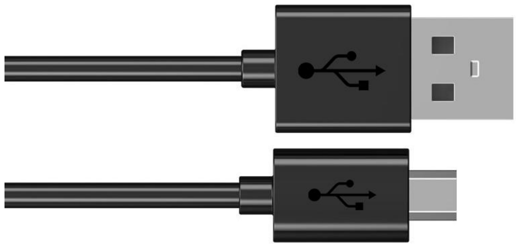
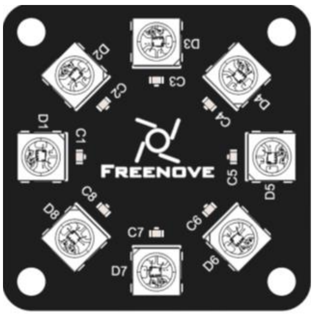
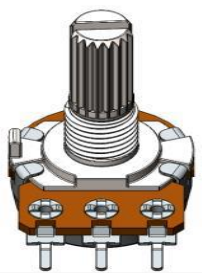
Read the analog voltage value of the P3 pin and convert it to the corresponding hue angle. Call the HSL_RGB() function to return the RGB value corresponding to the current hue angle, and then write the corresponding RGB values to the P0, P1, and P2 pins to change the LED color.

```
while True:
    value=map(pin3.read_analog(),0,1023,0,360)
    red,green,blue=HSL_RGB(value)
    print(red,green,blue)
    red=map(red,0,255,1023,0)
    green=map(green,0,255,1023,0)
    blue=map(blue,0,255,1023,0)
    pin2.write_analog(red)
    pin1.write_analog(green)
    pin0.write_analog(blue)
    sleep(10)
```

# Project 14.3 Rainbow Light

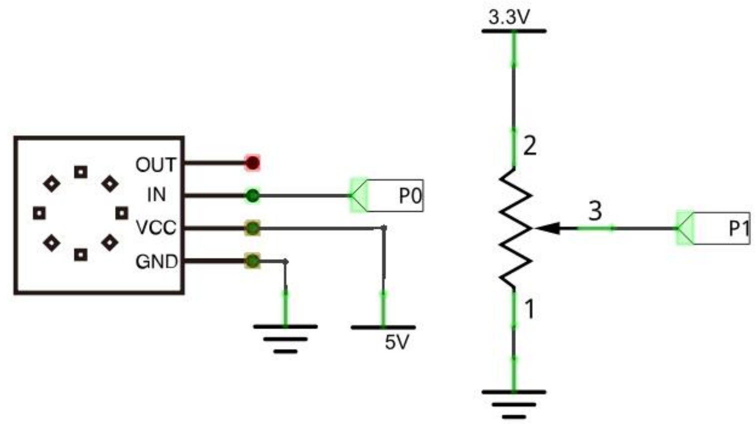
In this project, we use a potentiometer to control the RGB LED module.

## Component list

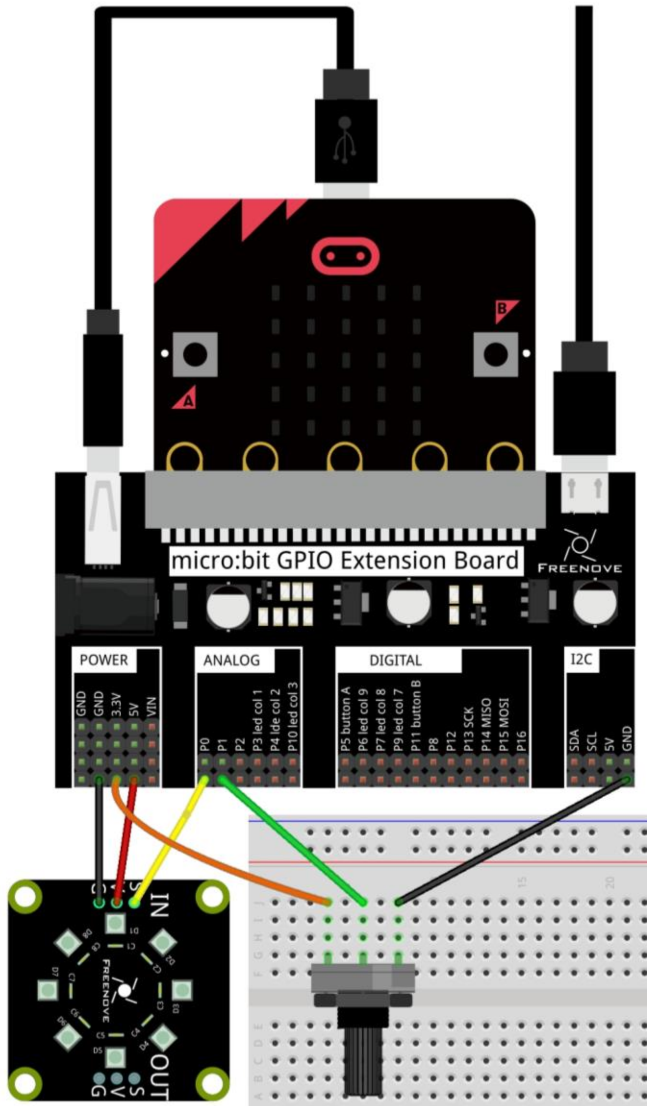
<table>
<tr><td colspan="2">Microbit x1<br>
</td><td colspan="2">Extension board x1<br>
</td></tr>
<tr><td colspan="2">Breadboard x1<br></td><td colspan="2">USB cable x2<br></td></tr>
<tr><td colspan="2">Freenove 8 RGB LED Module x1<br>
</td><td>F/M x3 F/F x3<br></td><td>Potentiometer x1<br></td></tr>
</table>

## Circuit

Schematic diagram




Hardware connection

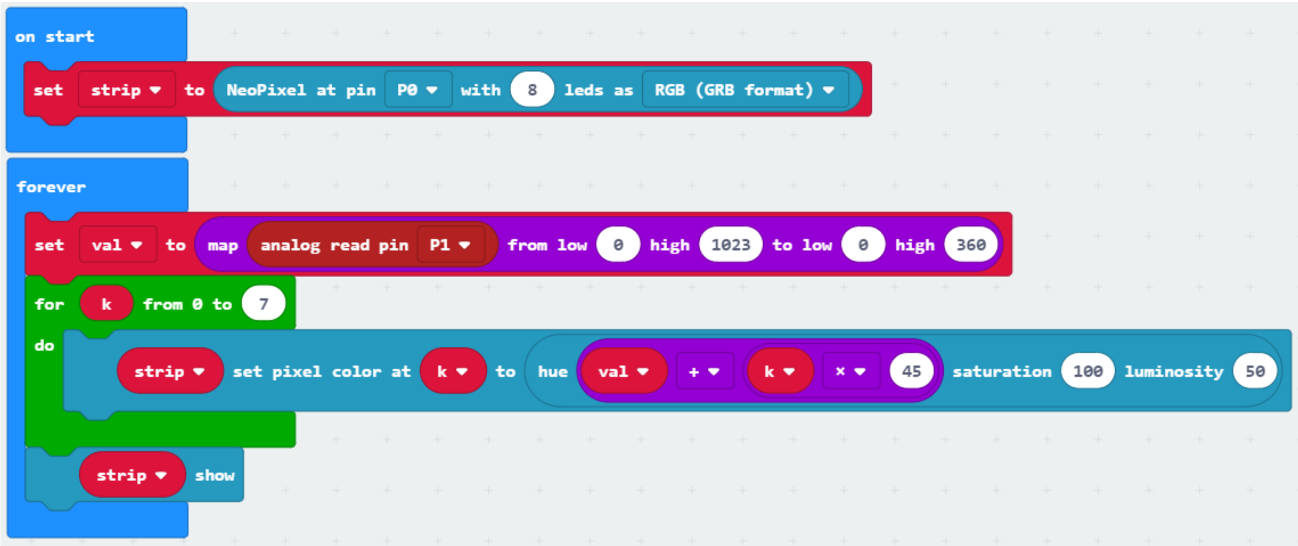


## Block code

Open MakeCode first. Import the .hex file. The path is as below:
(How to import project)

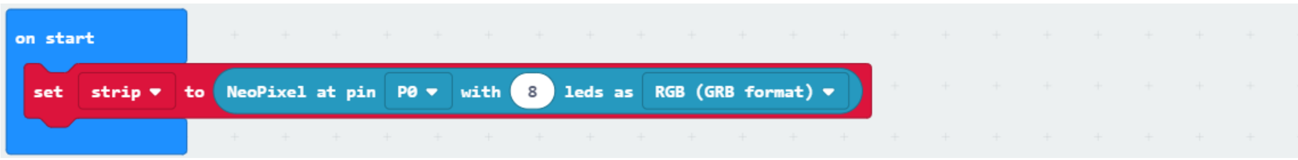
| File type | Path | File name |
|---|---|---|
| HEX file | ../Projects/BlockCode/14.3_RainbowLight | RainbowLight.hex |

After importing successfully, the code is shown as below:



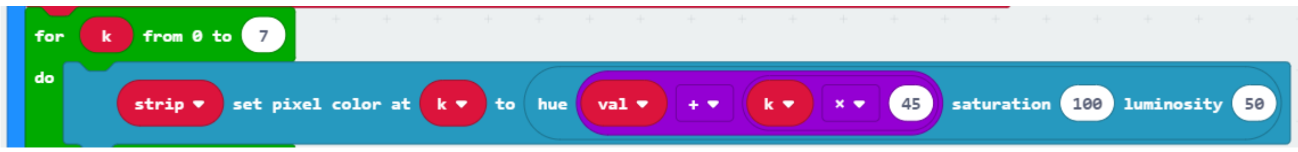

Check the connection of the circuit, verify it correct, download the code into the micro:bit, rotate the potentiometer, and the color ring of the RGB LED module also rotates.

Set the number of pins and LEDs for the RGB LED module, as well as the type of LED.




Read the voltage of the potentiometer and map the analog value of 0-1023 to an angle of 0-360.


In the for loop, the hue difference between each two LEDs is 45. When the hue changes, it ensures that the LED succeeds the hue of the previous LED. Then it converts the HSL color system to the RGB color system, and returns the RGB value corresponding to the angle, to make the LED to achieve the effect of the rainbow.



## Python code

Open the .py file with Mu. Code, the path is as below:

| File type | Path | File name |
|---|---|---|
| **Python file** | ../Projects/PythonCode/14.3_RainbowLight | RainbowLight.py |

After loading successfully, the code is shown as below:

```
from microbit import *
import neopixel
np = neopixel.NeoPixel(pin0, 8)
def HSL_RGB(degree):
    degree=degree/360*255
    if degree < 85:
        red = 255 - degree * 3
        green = degree * 3
        blue = 0
    elif degree < 170:
        degree = degree - 85
        red = 0
        green = 255 - degree * 3
        blue = degree * 3
    else:
        degree = degree - 170
        red = degree * 3
        green = 0
        blue = 255 - degree * 3
    return int(red),int(green),int(blue)
while True:

    for i in range(0, 8):
        value=pin1.read_analog()/1023*360+i*45
        if value > 360 :
            value = value-360
        red,green,blue=HSL_RGB(value)
        np[i] = (red,green,blue)
    np.show()
```

Check the connection of the circuit, verify it correct, and download the code into the micro:bit. Rotate the potentiometer, and then the color ring of the RGB LED module also rotates.

The following is the program code:

```
from microbit import *
import neopixel
np = neopixel.NeoPixel(pin0, 8)
def HSL_RGB(degree):
    degree=degree/360*255
    if degree < 85:
        red = 255 - degree * 3
        green = degree * 3
        blue = 0
    elif degree < 170:
        degree = degree - 85
        red = 0
        green = 255 - degree * 3
        blue = degree * 3
    else:
        degree = degree - 170
        red = degree * 3
        green = 0
        blue = 255 - degree * 3
    return int(red),int(green),int(blue)
while True:
    for i in range(0, 8):
        value=pin1.read_analog()/1023*360+i*45
        if value > 360 :
            value = value-360
        red,green,blue=HSL_RGB(value)
        np[i] = (red,green,blue)
    np.show()
```

Set the number of pins and LED to control the RGB LED module.

```
np = neopixel.NeoPixel(pin0, 8)
```

Custom HSL_RGB() function is used to convert HSL color to RGB color, returning the RGB value corresponding to the current hue angle.

```
def HSL_RGB(degree):
    degree=degree/360*255
    if degree < 85:
        red = 255 - degree * 3
        green = degree * 3
        blue = 0
    elif degree < 170:
        degree = degree - 85
        red = 0
        green = 255 - degree * 3
        blue = degree * 3
    else:
        degree = degree - 170
        red = degree * 3
        green = 0
        blue = 255 - degree * 3
    return int(red),int(green),int(blue)
```

In the for loop, the analog voltage of the potentiometer is read and converted to the corresponding hue angle. The hue difference between each two led is 45. The HSL_RGB() function is called to convert the HSL color system to the RGB color system, return the RGB value corresponding to the current hue angle to make the LED achieve the effect of rainbow.

```
while True:
    for i in range(0, 8):
        value=pin1.read_analog()/1023*360+i*45
        if value > 360 :
            value = value-360
        red,green,blue=HSL_RGB(value)
        np[i] = (red,green,blue)
    np.show()
```

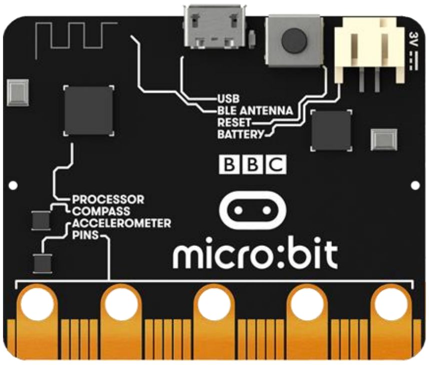
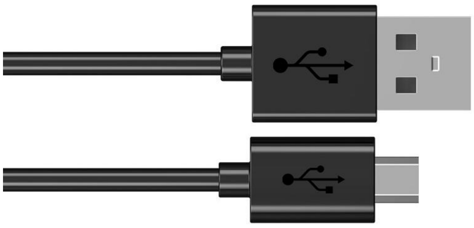
# Chapter 15 Light Sensor

In this chapter, we will learn the micro:bit built-in light sensor and photoresistor.

## Project 15.1 Built-in Light Sensor

In this project, we use the micro:bit built-in light sensor to measure the brightness of light.

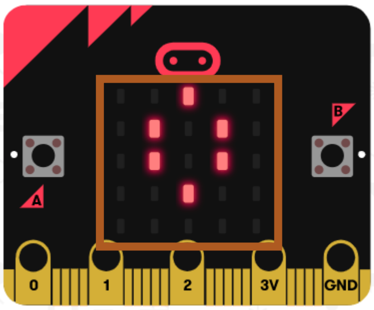
### Component list

| Microbit x1 | USB cable x1 |
|---|---|
|  |  |

### Component knowledge

#### Light sensor

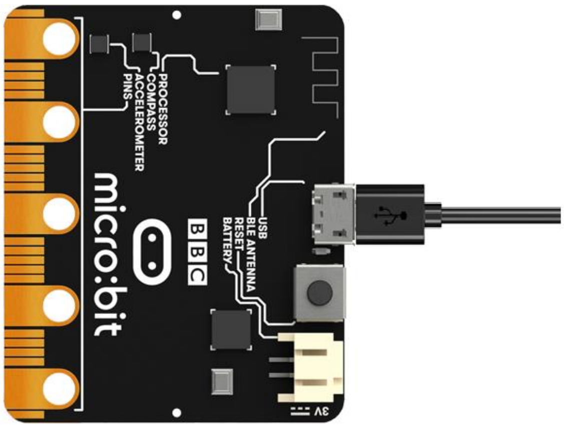
Micro:bit detects the ambient light intensity through the LED matrix. In forward bias mode, the LED screen works as a display. In reverse bias mode, the LED screen works as a basic light sensor that can be used to detect ambient light.



## Circuit

Connect micro:bit and PC via a micro USB cable.

Hardware connection




## Block code

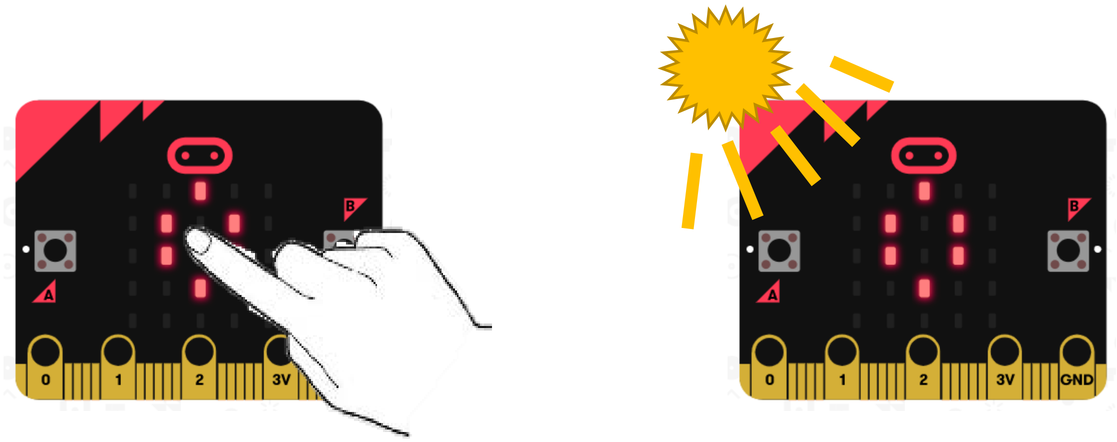
Open MakeCode first. Import the .hex file. The path is as below:

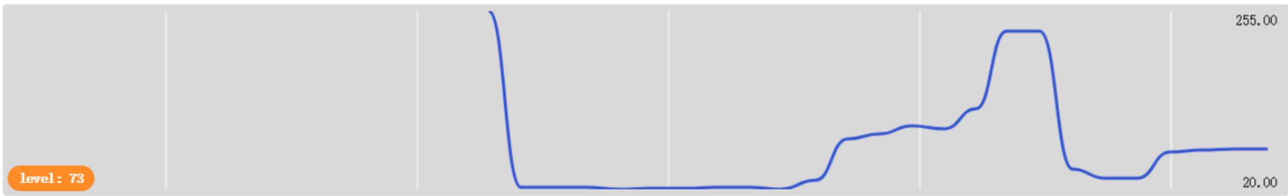
(How to import project)

| File type | Path | File name |
|---|---|---|
| **HEX file** | ../Projects/BlockCode/15.1_LightIntensityMeter | LightIntensityMeter.hex |

After importing successfully, the code is shown as below:


Check the connection of the circuit, verify it correct and download the code into the micro:bit. Open the serial port console, then you can see the reading light intensity. Cover the LED screen with your hand or increase the light shining on it, you can see the change in value, the range of values is 0-255, 0 is dark, 255 is the brightest, as shown below.




```
level:228
level:229
level:46
level:35
level:34
level:69
level:72
2 level:73
```

## Reference

| Block | Function |
|---|---|
| light level | Detect the light level (how bright or dark it is) of the environment where you are. The light level 0 means darkness and 255 means bright light. |

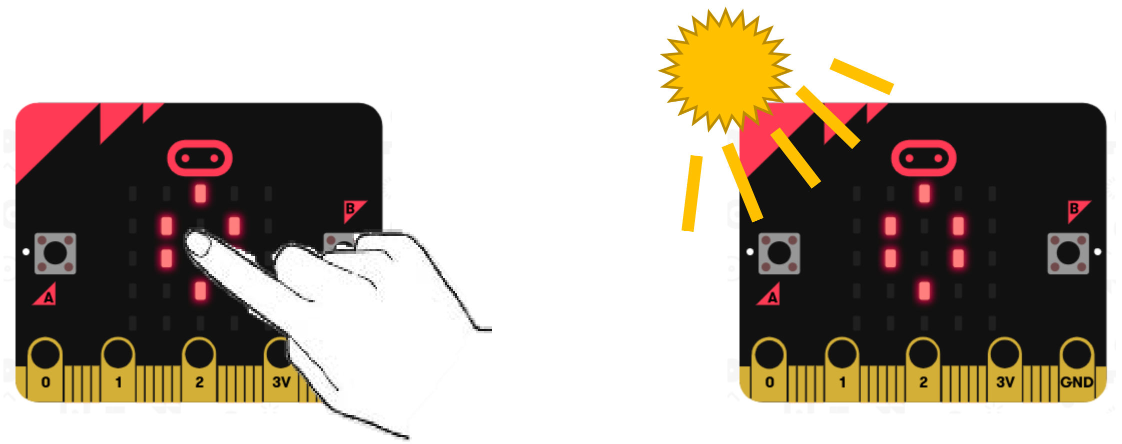
## Python code

Open the .py file with Mu. Code, the path is as below:

| File type | Path | File name |
|---|---|---|
| Python file | ../Projects/PythonCode/15.1_LightIntensityMeter | LightIntensityMeter.py |

After loading successfully, the code is shown as below:


Check the connection of the circuit, verify it correct, download the code into the micro:bit. Open the serial port console, then you can see the reading light intensity. Cover the LED screen with your hand or increase the light shining on it, you can see the change in value, the range of values is 0-255, 0 is dark, 255 is the brightest, as shown below.




The following is the program code:

```
from microbit import *
while True:
    item = display.read_light_level()
    print (item)
```

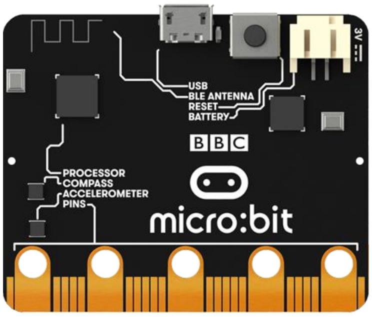
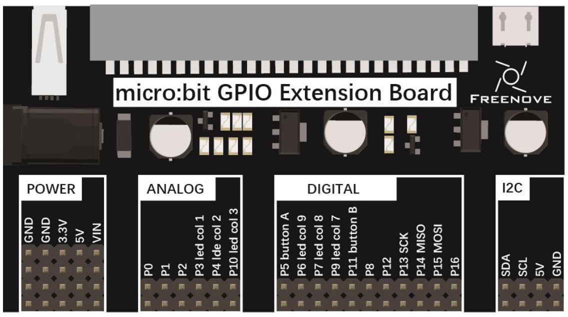
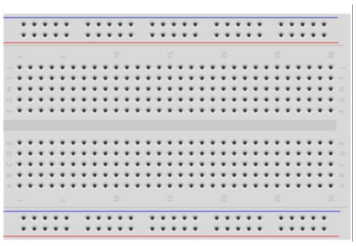
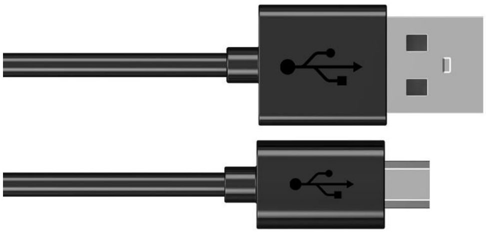
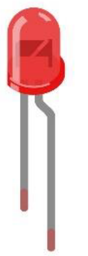
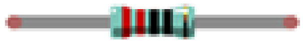
## Reference

| display.read_light_level() |
|---|
| Use the display's LEDs in reverse-bias mode to sense the amount of light falling on the display, return an integer between 0 and 255 representing the light level. The larger the value, the brighter the light.. |

# Project 15.2 Night Light

In this project, we will make a night light.

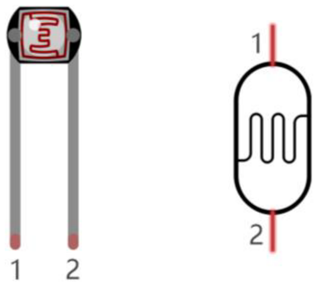
## Component list

<table>
<tr><td colspan="2">Microbit x1<br></td><td colspan="2">Extension board x1<br></td></tr>
<tr><td colspan="2">Breadboard x1<br></td><td colspan="2">USB cable x1<br></td></tr>
<tr><td rowspan="2">F/M x 4 M/M x1<br></td><td rowspan="2">Photoresistance x1<br></td><td rowspan="2">LED x1<br></td><td>Resistor 10kΩ x1<br></td></tr>
<tr><td>Resistor 220Ω x1<br></td></tr>
</table>

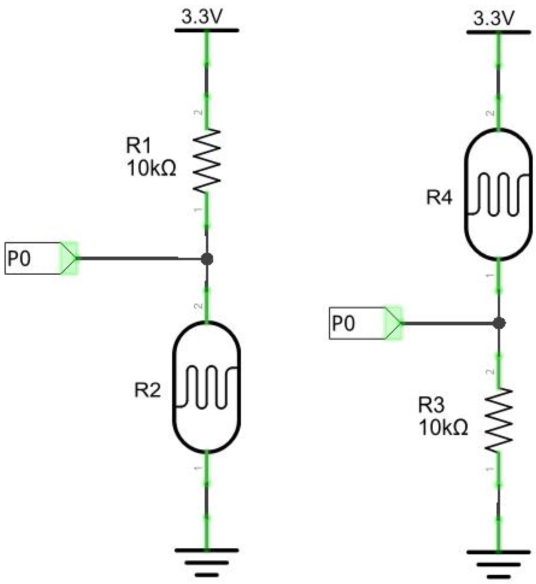
# Component knowledge

## Photoresistor

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



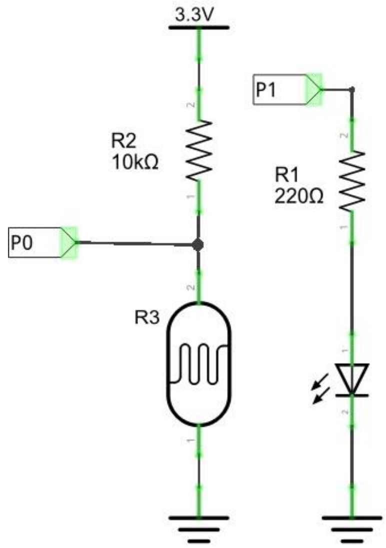

The circuit below is often used to detect the change of a photoresistor's resistance value:



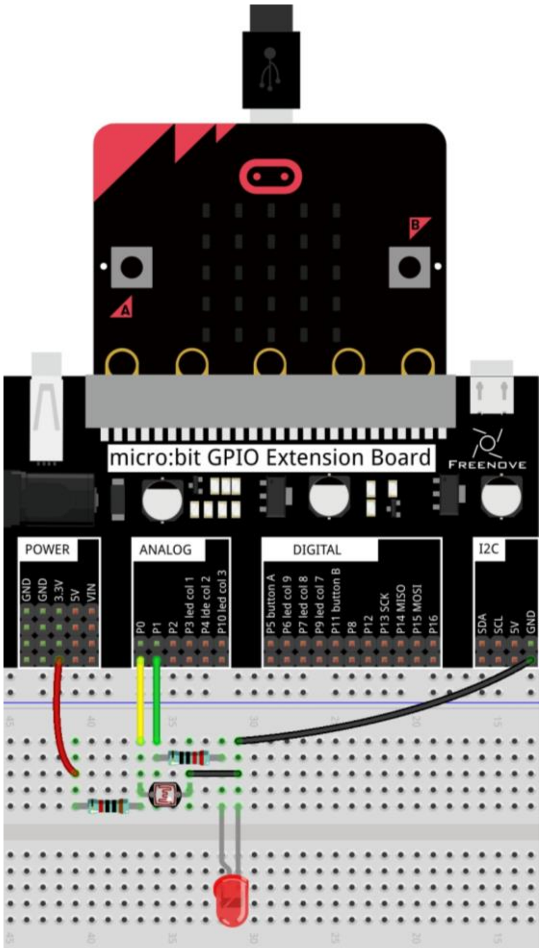

In the above circuit, when a Photoresistor's resistance vale changes due to a change in light intensity, the voltage between the Photoresistor and Resistor R1 will also change. Therefore, the intensity of the light can be obtained by measuring this voltage.

## Circuit

Schematic diagram




Hardware connection

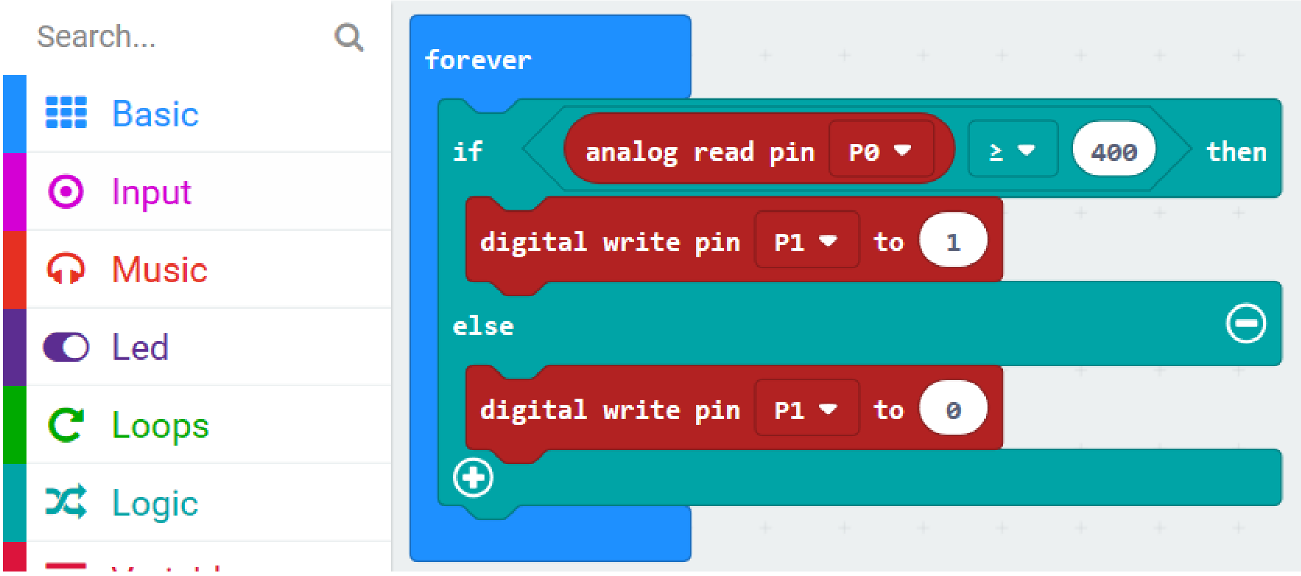


## Block code

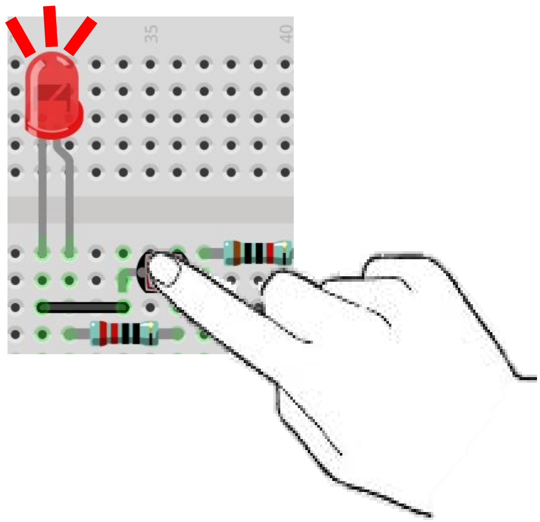
Open MakeCode first. Import the .hex file. The path is as below:
(How to import project)

| File type | Path | File name |
|---|---|---|
| HEX file | ../Projects/BlockCode/15.2_NightLight | NightLight.hex |

After importing successfully, the code is shown as below:

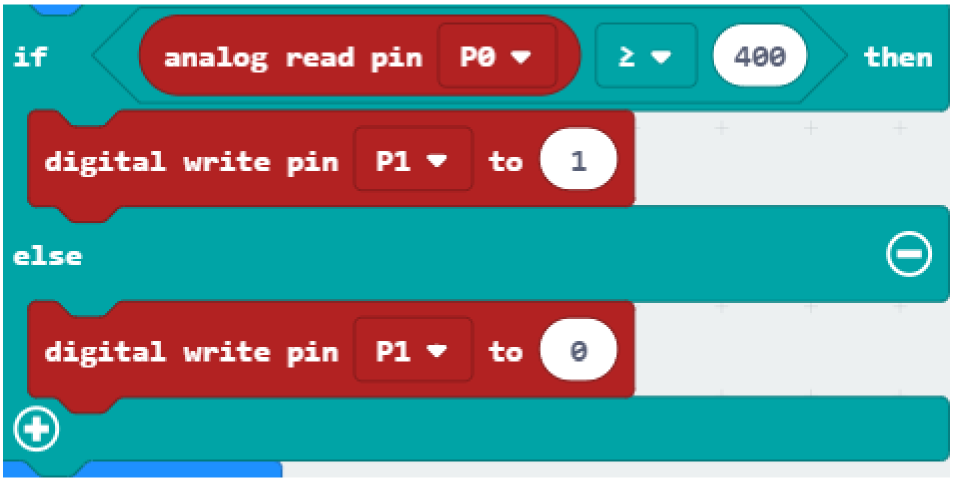



Check the connection of the circuit, verify it correct, and download the code into the micro:bit. Cover the photoresistor with your hand, the LED is turned ON. Move the hand away, the LED is turned OFF.



Read the analog voltage value of the P0 pin.


If the analog voltage read is greater than or equal to 400, it is considered to be occluded, and the LED is turned ON. Or the LED is turned OFF.

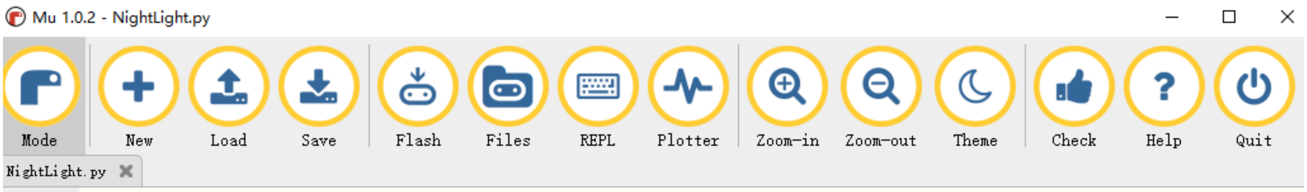


## Python code

Open the .py file with Mu. Code, the path is as below:

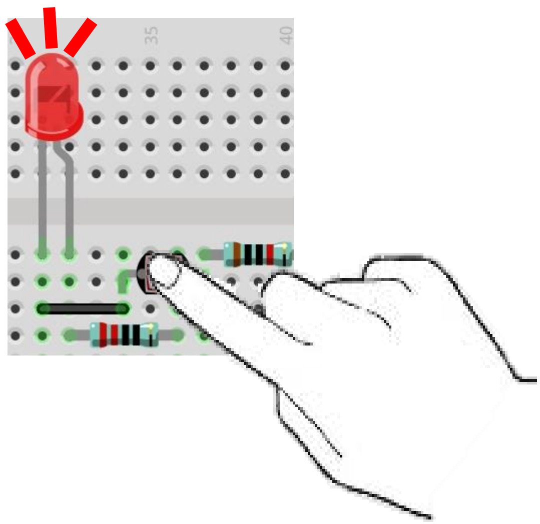
| File type | Path | File name |
|---|---|---|
| **Python file** | ../Projects/PythonCode/15.2_NightLight | NightLight.py |

After loading successfully, the code is shown as below:




```
from microbit import *
while True:
    value = pin0.read_analog()
    if value>=400:
        pin1.write_digital(1)
    else:
        pin1.write_digital(0)
```

Check the connection of the circuit, verify it correct, and download the code into the micro:bit. Cover the photoresistor with your hand, then the LED is turned ON. Move the hand away, then the LED is turned OFF.



The following is the program code:

```
from microbit import *
while True:
    value = pin0.read_analog()
        if value>=400:
        pin1.write_digital(1)
     else:
        pin1.write_digital(0)
```

Read the analog voltage value of the P0 pin.

```
value = pin0.read_analog()
```

If the analog voltage read is greater than or equal to 400, it is considered to be occluded, and the LED is turned ON. Otherwise the LED is turned OFF.

```
     if value>=400:
        pin1.write_digital(1)
     else:
        pin1.write_digital(0)
```

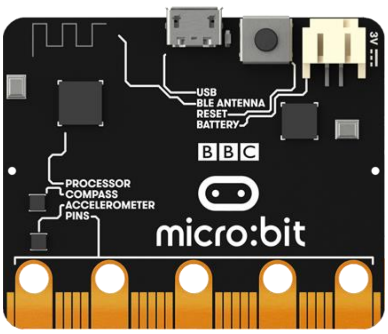
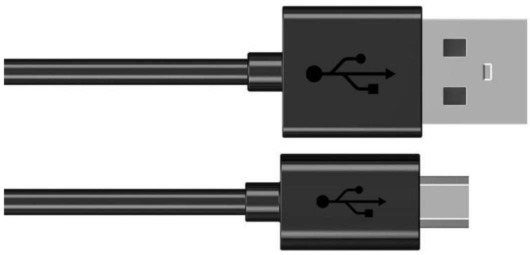
# Chapter 16 Temperature Sensor

In this chapter, we will learn the micro:bit built-in temperature sensor and thermistor.

## Project 16.1 Built-in Temperature Sensor

In this project, we measure the temperature with the micro:bit's built-in temperature sensor.

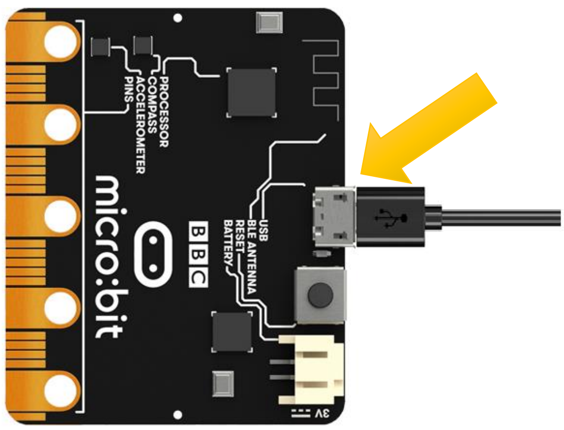
### Component list

| Microbit x1 | USB cable x1 |
|---|---|
|   |  |

### Circuit

Connect micro:bit and PC via micro the USB cable.

Hardware connection

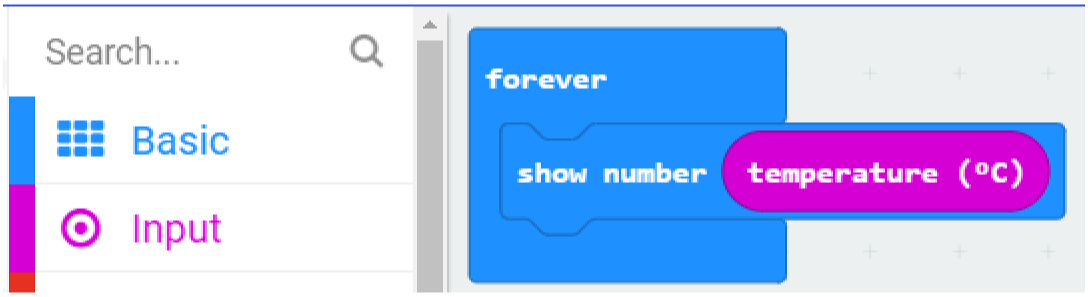


## Block code

Open MakeCode first. Import the .hex file. The path is as below:
(How to import project)

| File type | Path | File name |
|---|---|---|
| **HEX file** | ../Projects/BlockCode/16.1_BuiltInThermometer | BuiltInThermometer.hex |

After importing successfully, the code is shown as below:




Check the connection of the circuit, verify it correct, and download the code into micro:bit, and then LED dot matrix screen will display the current detected temperature.

### Reference

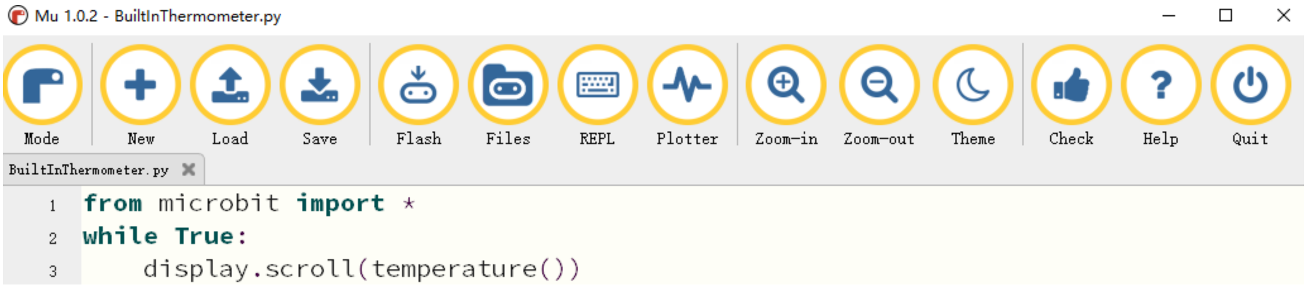
| Block | Function |
|---|---|
|   | Detect the temperature of the environment where you are. The temperature is measured in Celsius (metric). |

## Python code

Open the .py file with Mu. Code, the path is as below:

| File type | Path | File name |
|---|---|---|
| **Python file** | ../Projects/PythonCode/16.1_BuiltInThermometer | BuiltInThermometer.py |

After loading successfully, the code is shown as below:




Check the connection of the circuit, verify it correct, and download the code into micro:bit, and then LED dot matrix screen will display the current detected temperature.

The following is the program code:

```
from microbit import *
while True:
    display.scroll(temperature())
```

Display the detected temperature on the LED dot matrix.

```
display.scroll(temperature())
```

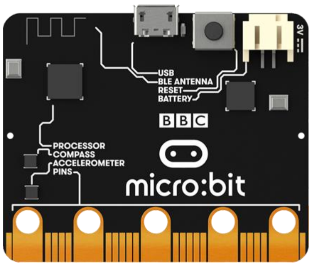
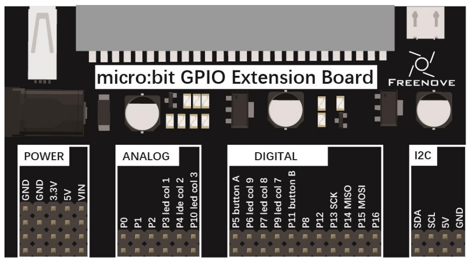
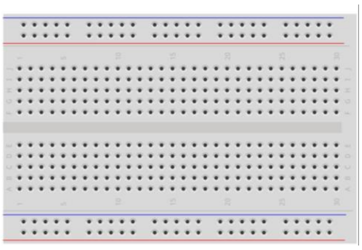
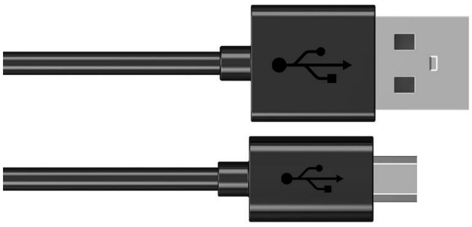
## Reference

| |
|---|
| `temperature()` |
| Return the temperature of the micro:bit in Celcius. |
| `display.scroll()` |
| scrolls a string across the display |

# Project 16.2 Thermistor

In this project, we will use a thermistor to detect the ambient temperature.

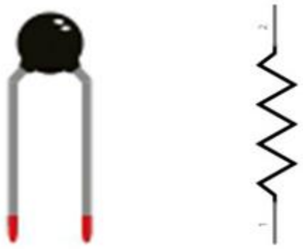
## Component list

<table>
<tr><td colspan="2">Microbit x1<br>
</td><td colspan="2">Extension board x1<br>
</td></tr>
<tr><td colspan="2">Breadboard x1<br></td><td colspan="2">USB cable x1<br></td></tr>
<tr><td>Jumper F/M x3<br></td><td colspan="2">Thermistor x1<br></td><td>Resistor 10kΩ x1<br></td></tr>
</table>

# Component knowledge

### Thermistor

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*(1/T2-1/T1)]

Where:

**Rt** is the thermistor resistance under T2 temperature;

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

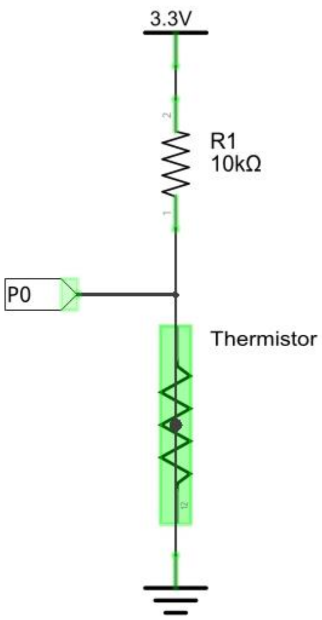
**EXP[n]** is nth power of e;

**B** is for thermal index;

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

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

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



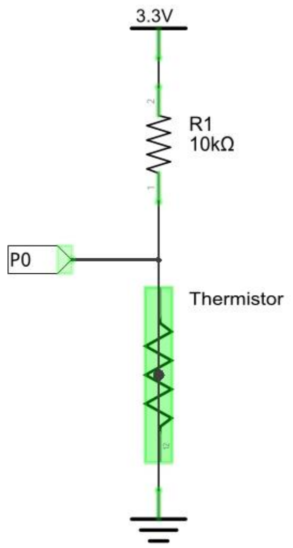

We can use the value measured by the analog pin of micro:bit to obtain resistance value of thermistor, and then we can use the formula to obtain the temperature value.

Therefore, the temperature formula can be derived as:

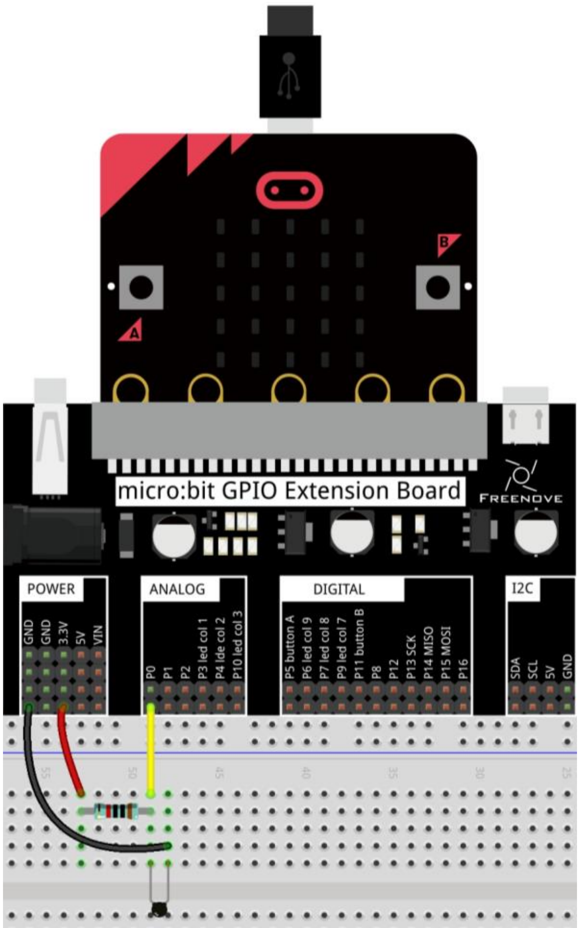
T2 = 1/(1/T1 + ln(Rt/R)/B)

## Circuit

Schematic diagram




Hardware connection

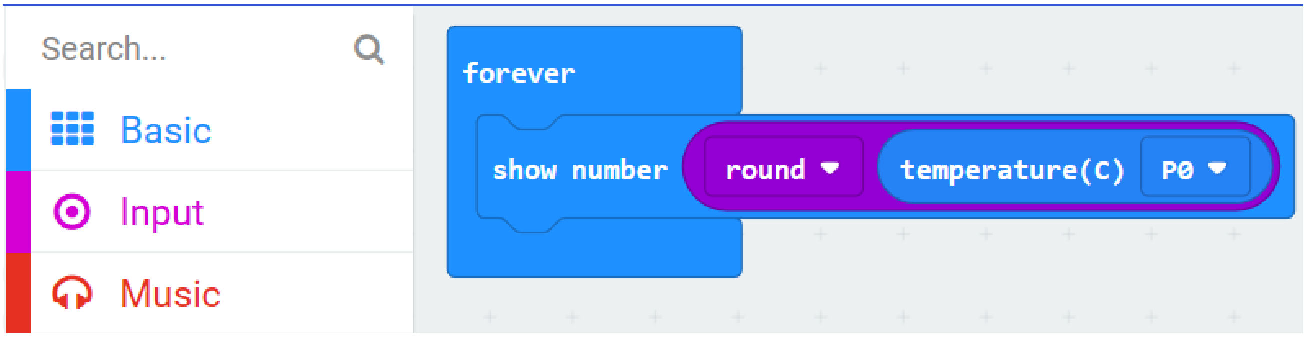


## Block code

Open MakeCode first. Import the .hex file. The path is as below:
(How to import project)

| File type | Path | File name |
|---|---|---|
| **HEX file** | ../Projects/BlockCode/16.2_ExternalThermometer | ExternalThermometer.hex |

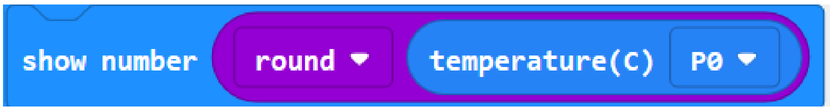
After importing successfully, the code is shown as below:



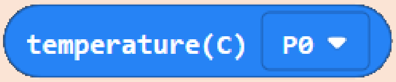

Check the connection of the circuit, verify it correct, download the code into the micro:bit, and the LED dot matrix will display the detected temperature.

The temperature measured by the thermistor and the temperature measured by the micro:bit's built-in temperature sensor may have slight difference. This is because the hardware used is different, and there are certain differences in the manufacturing of the components. It is within a reasonable range and can be ignored.

Obtain the temperature data measured by the thermistor, and then round up and display on the LED display.



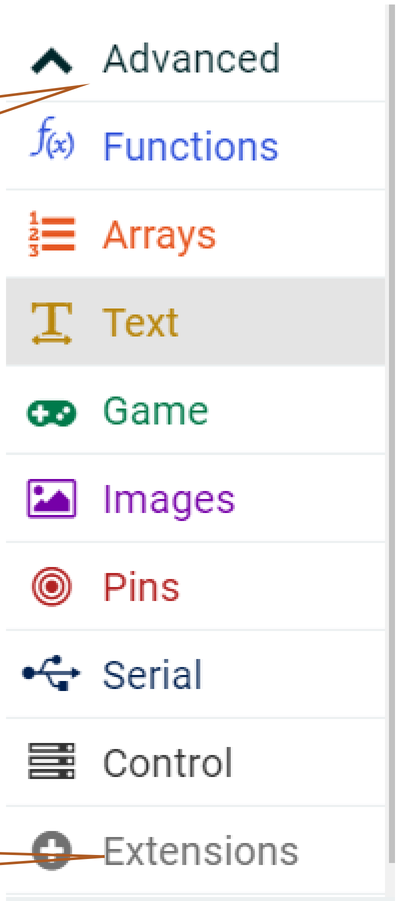

### Reference

| Block | Function |
|---|---|
|   | Belongs to the Freenove extension block. Get the temperature data measured by the thermistor. |

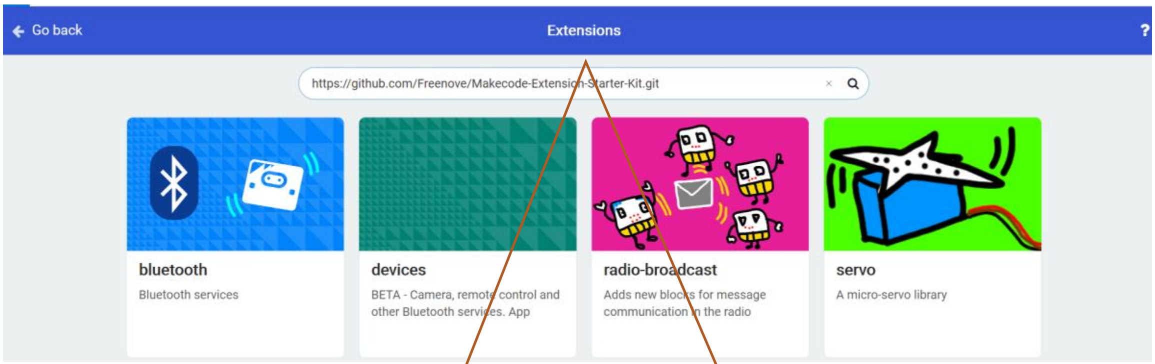
## Extensions

If you want to import Freenove extensions in a new project, follow the steps below to add them.

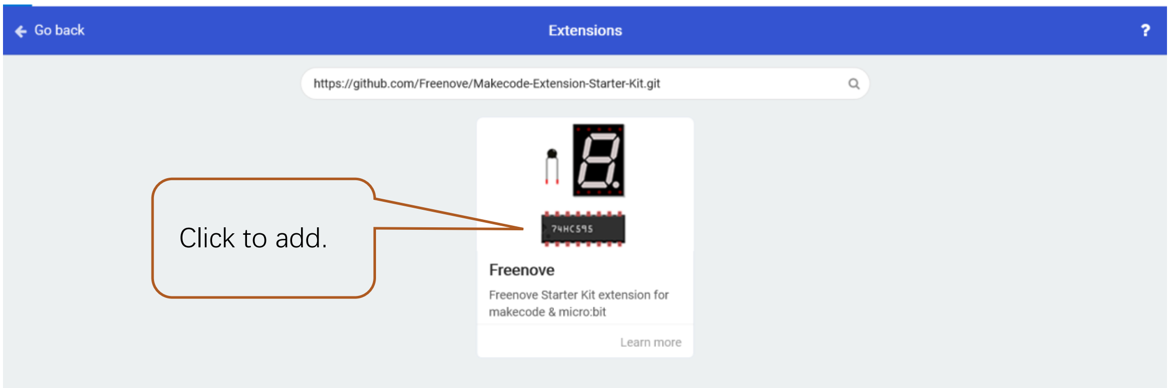
Click "Advanced" to expand the list.

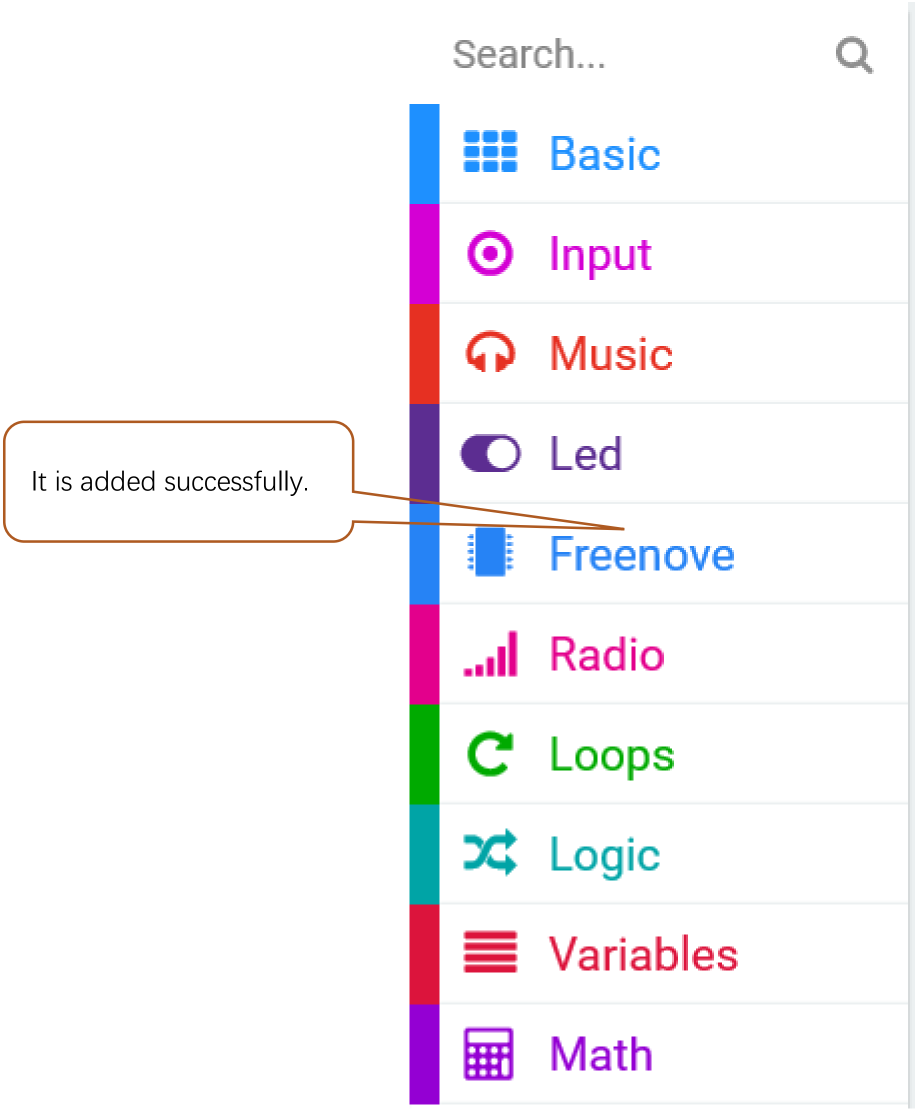



Click"Extension".




Enter " https://github.com/Freenove/Makecode-Extension-Starter-Kit.git" to search.


Go back
Extensions
?
https://github.com/Freenove/Makecode-Extension-Starter-Kit.git
74HC595
Freenove
Freenove Starter Kit extension for makecode & micro:bit
Learn more
Click to add.

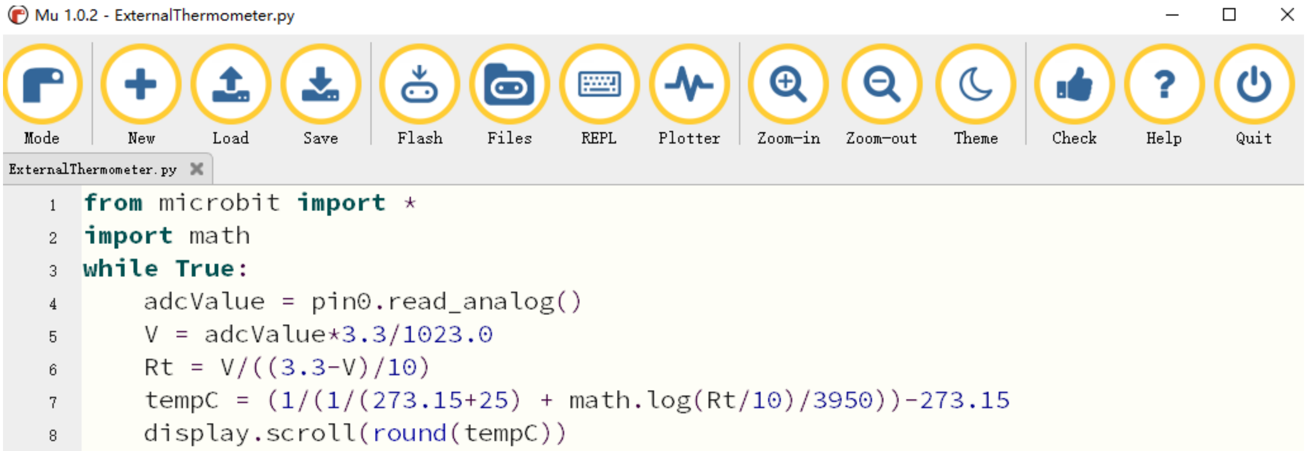

Search...
Basic
Input
Music
Led
Freenove
Radio
Loops
Logic
Variables
Math
It is added successfully.

## Python code

Open the .py file with Mu. Code, the path is as below:

| File type | Path | File name |
|---|---|---|
| **Python file** | ../Projects/PythonCode/16.2_ExternalThermometer | ExternalThermometer.py |

After loading successfully, the code is shown as below:




Check the connection of the circuit, verify it correct, download the code into the micro:bit, and the LED dot matrix will display the detected temperature.

The following is the program code:

```
from microbit import *
import math
while True:
    adcValue = pin0.read_analog()
    V = adcValue*3.3/1023.0
    Rt = V/((3.3-V)/10)
    tempC = (1/(1/(273.15+25) + math.log(Rt/10)/3950))-273.15
    display.scroll(round(tempC))
```

Read the analog voltage of the thermistor and calculate the resistance of the thermistor.

```
    adcValue = pin0.read_analog()
    V = adcValue*3.3/1023.0
    Rt = V/((3.3-V)/10)
```

Calculate the current temperature according to the resistance value of the thermistor and then display it on the LED dot matrix screen. For the formula, please refer to the component knowledge.,.

```
    tempC = (1/(1/(273.15+25) + math.log(Rt/10)/3950))-273.15
    display.scroll(round(tempC))
```

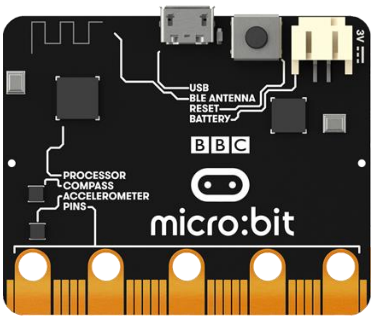
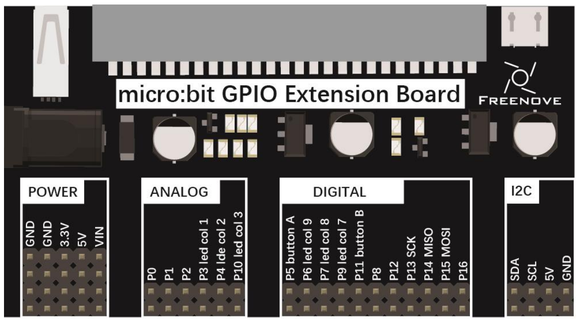
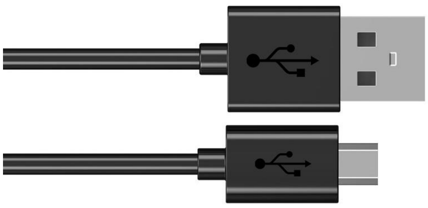
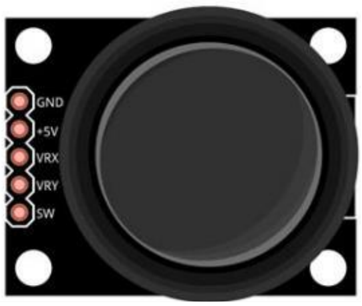
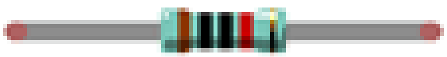
# Chapter 17 Joystick

In an earlier chapter, we learned how to use Rotary Potentiometer. We will now learn about joysticks, which are electronic modules that work on the same principle as the Rotary Potentiometer.

## Project 17.1 Displaying Joystick Data

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

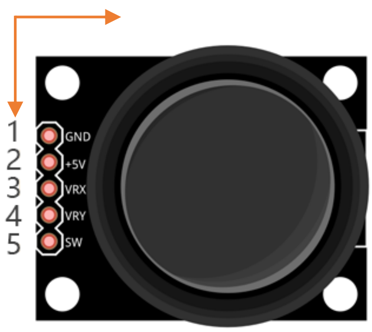
### Component list

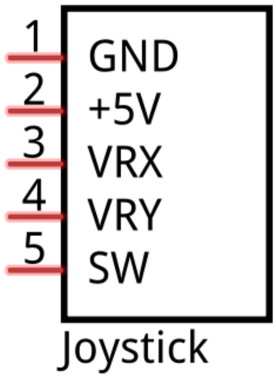
| | |
|---|---|
| Microbit x1   | Extetnsion board x1   |
| USB cable x2  | Joystick x1   |
| F/F x4 F/M x3  | Resistor 10kΩ x1  |

# Component knowledge

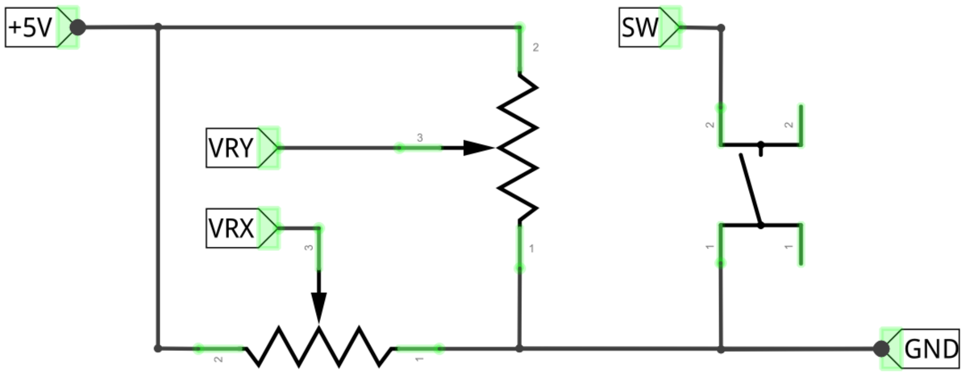
## Joystick

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



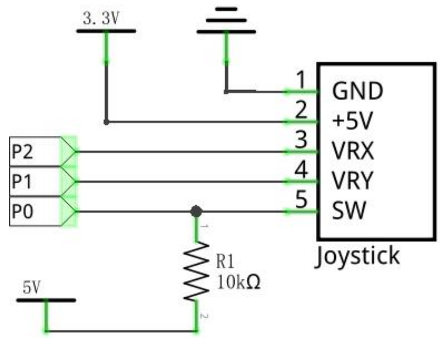




This is accomplished by incorporating two rotary potentiometers inside the Joystick Module at 90 degrees of each other, placed in such a manner as to detect shifts in direction in two directions simultaneously and with a Push Button Switch in the "vertical" axis, which can detect when a User presses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

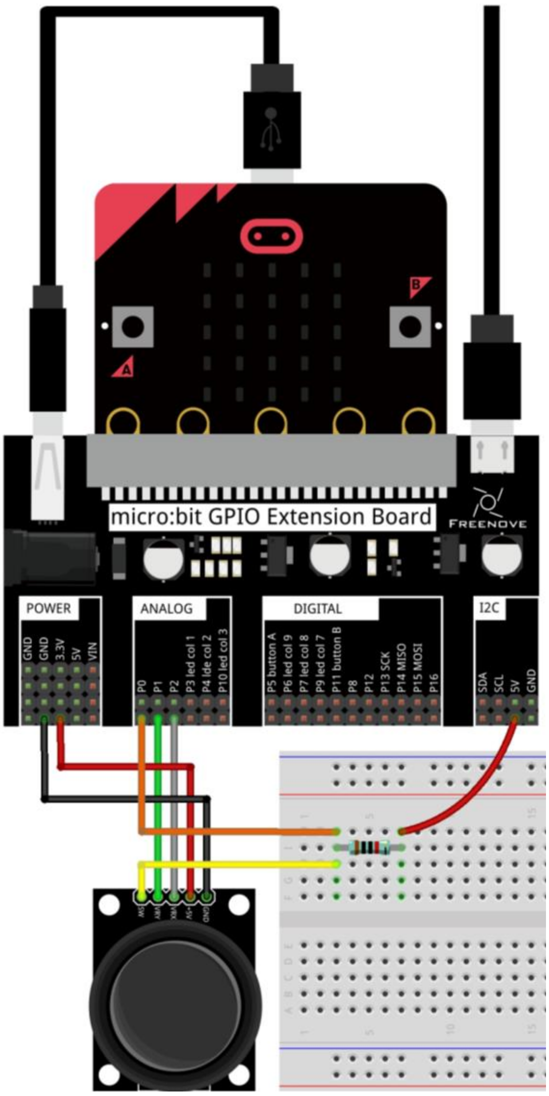


## Circuit

Schematic diagram




Hardware connection

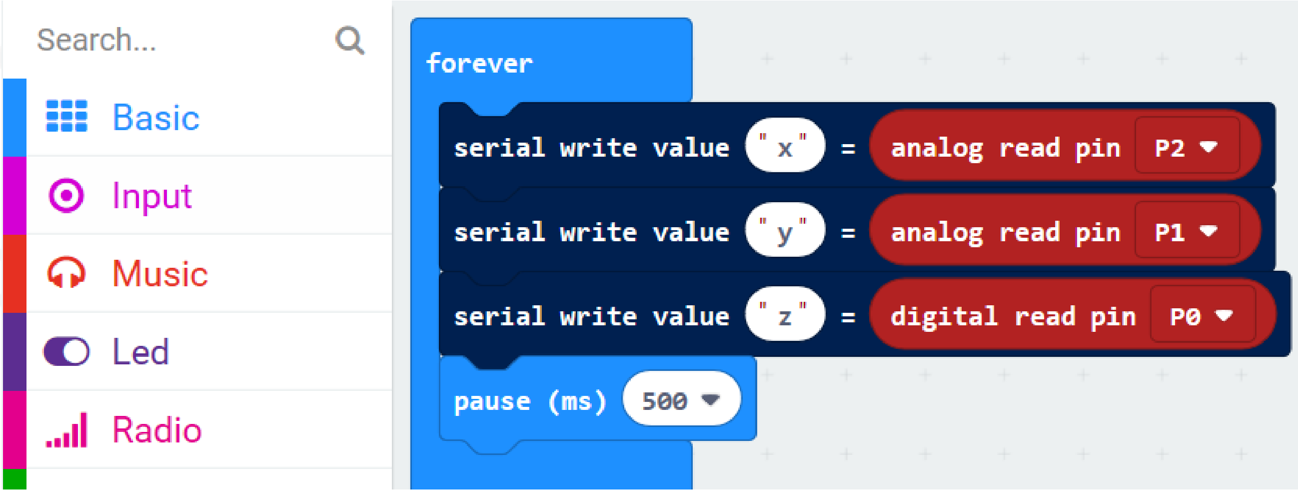


## Block code

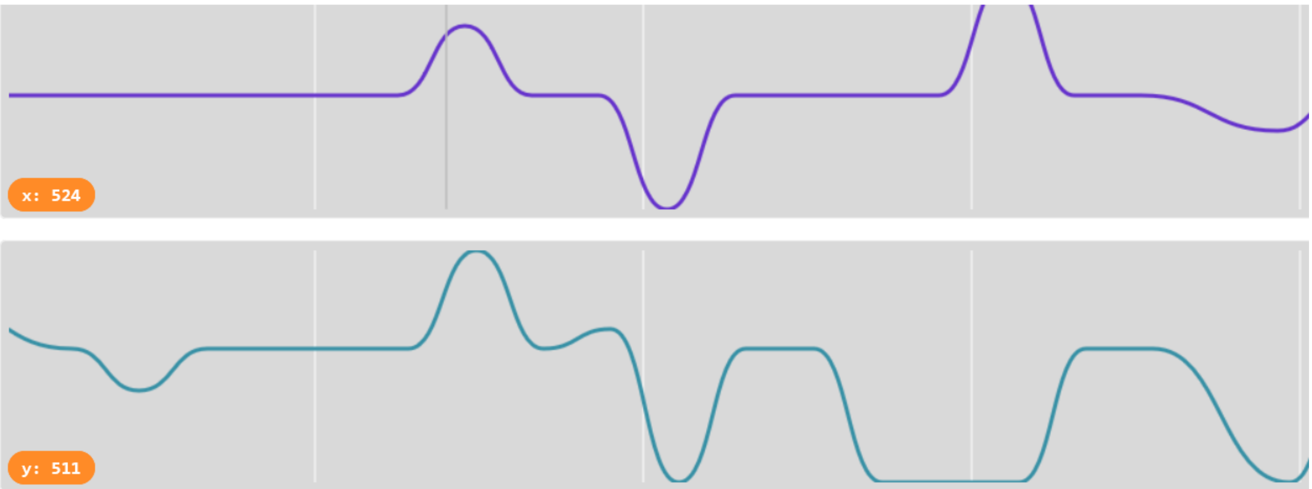
Open MakeCode first. Import the .hex file. The path is as below:
(How to import project)

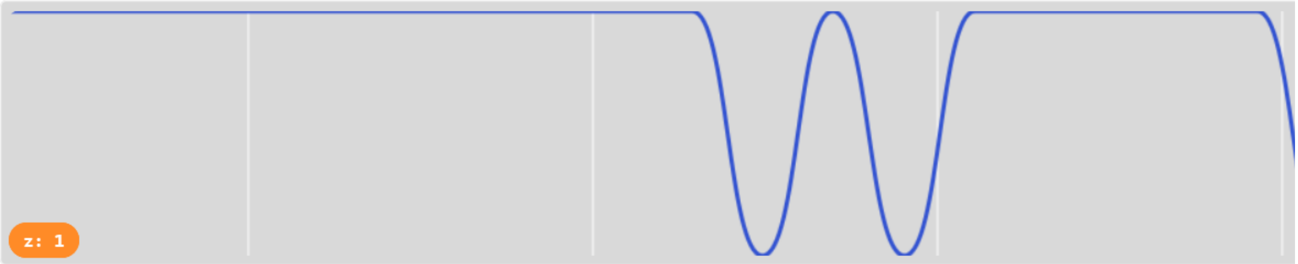
| File type | Path | File name |
|---|---|---|
| HEX file | ../Projects/BlockCode/17.1_DisplayJoystickData | DisplayJoystickData.hex |

After importing successfully, the code is shown as below:



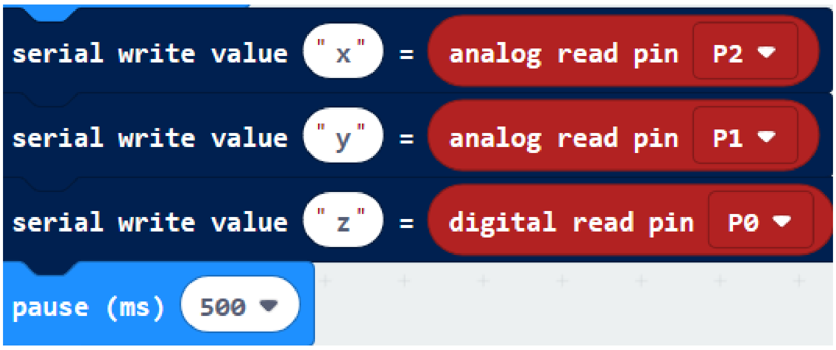

Check the connection of the circuit, verify it correct, and download the code into the micro:bit. Open the serial console, then you can see the Joystick data, as shown below.






```
x:524
y:511
z:0
x:524
y:512
z:1
x:524
y:512
```

Read the analog voltage value of P1 and P2 pins and the digital voltage value of P0 pin, and print the values every 500ms.

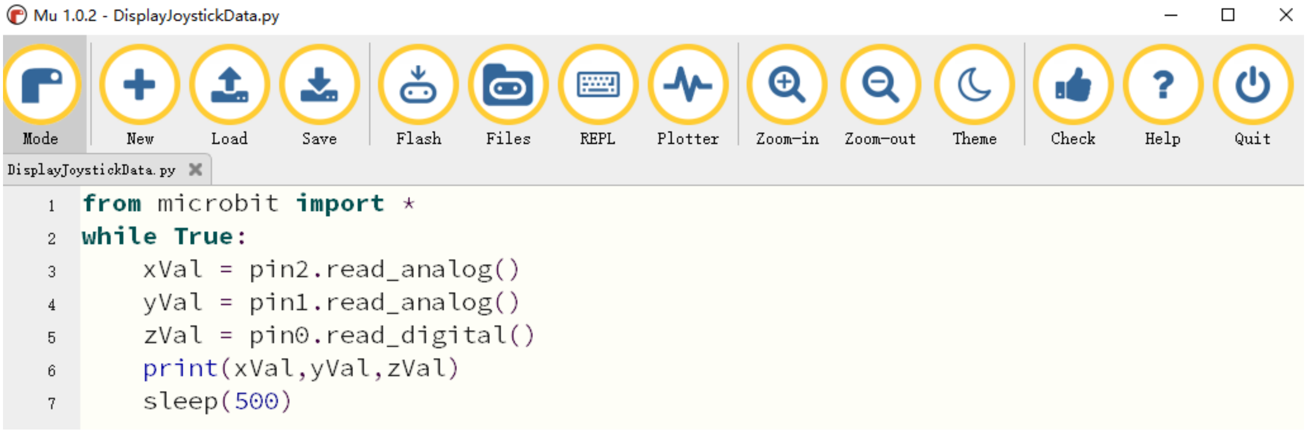


## Python code

Open the .py file with Mu. Code, the path is as below:

| File type | Path | File name |
| --- | --- | --- |
| **Python file** | ../Projects/PythonCode/17.1_DisplayJoystickData | DisplayJoystickData.py |

After loading successfully, the code is shown as below:




Check the connection of the circuit, verify it correct, and download the code into the micro:bit. Click on the REPL, and then press the micro:bit reset button to see the Joystick data.


The following is the program code:

```
from microbit import *
while True:
    xVal = pin2.read_analog()
    yVal = pin1.read_analog()
    zVal = pin0.read_digital()
    print(xVal, yVal, zVal)
    sleep(500)
```

Read the analog voltage value of P0, P1, P2 pins.

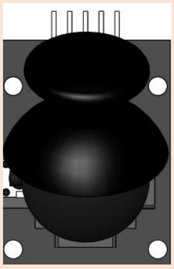
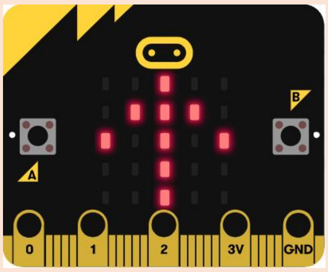
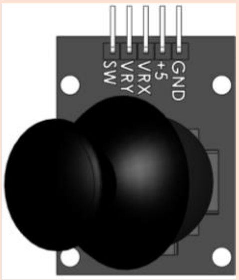
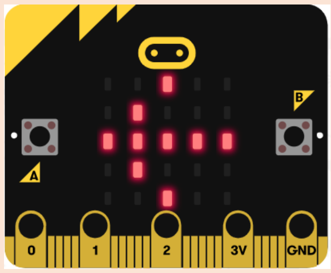
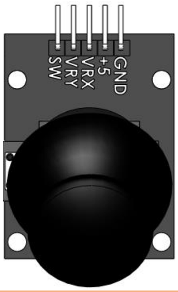
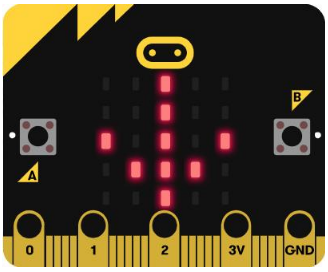
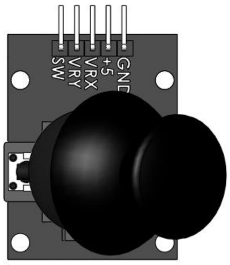
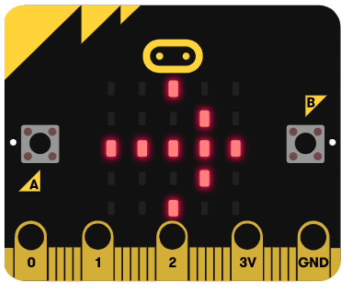
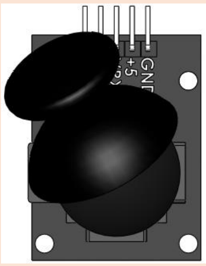
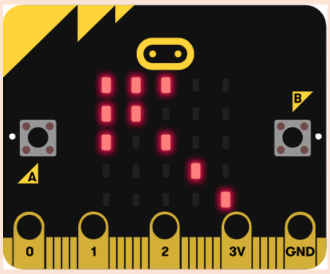
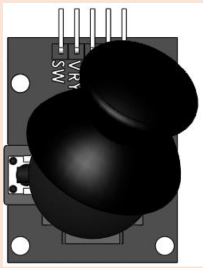
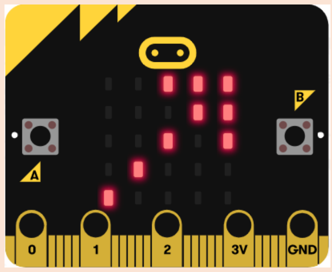
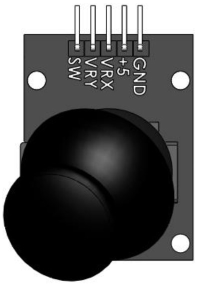
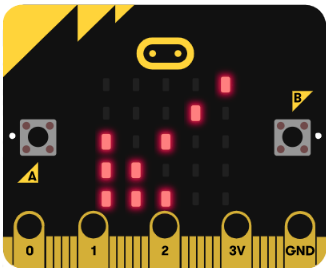
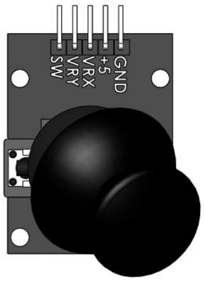
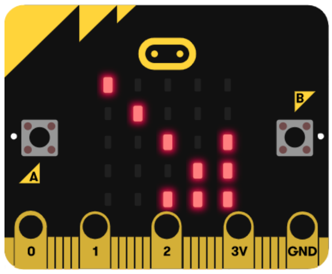
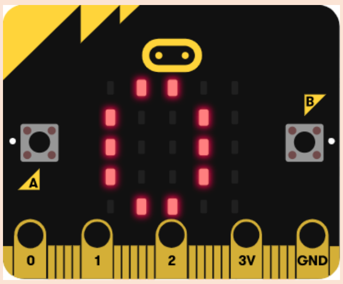
```
    xVal = pin2.read_analog()
    yVal = pin1.read_analog()
    zVal = pin0.read_digital()
```

Print data every 500ms.

```
    print(xVal, yVal, zVal)
    sleep(500)
```

# Project 17.2 Showing Direction

This project shows the direction of the Joystick with arrows on the dot matrix.

| Joystick direction | Arrow direction | Joystick Direction | Arrow Direction |
|---|---|---|---|
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  | | |

## Component list

It is same as the previous project.

## Circuit

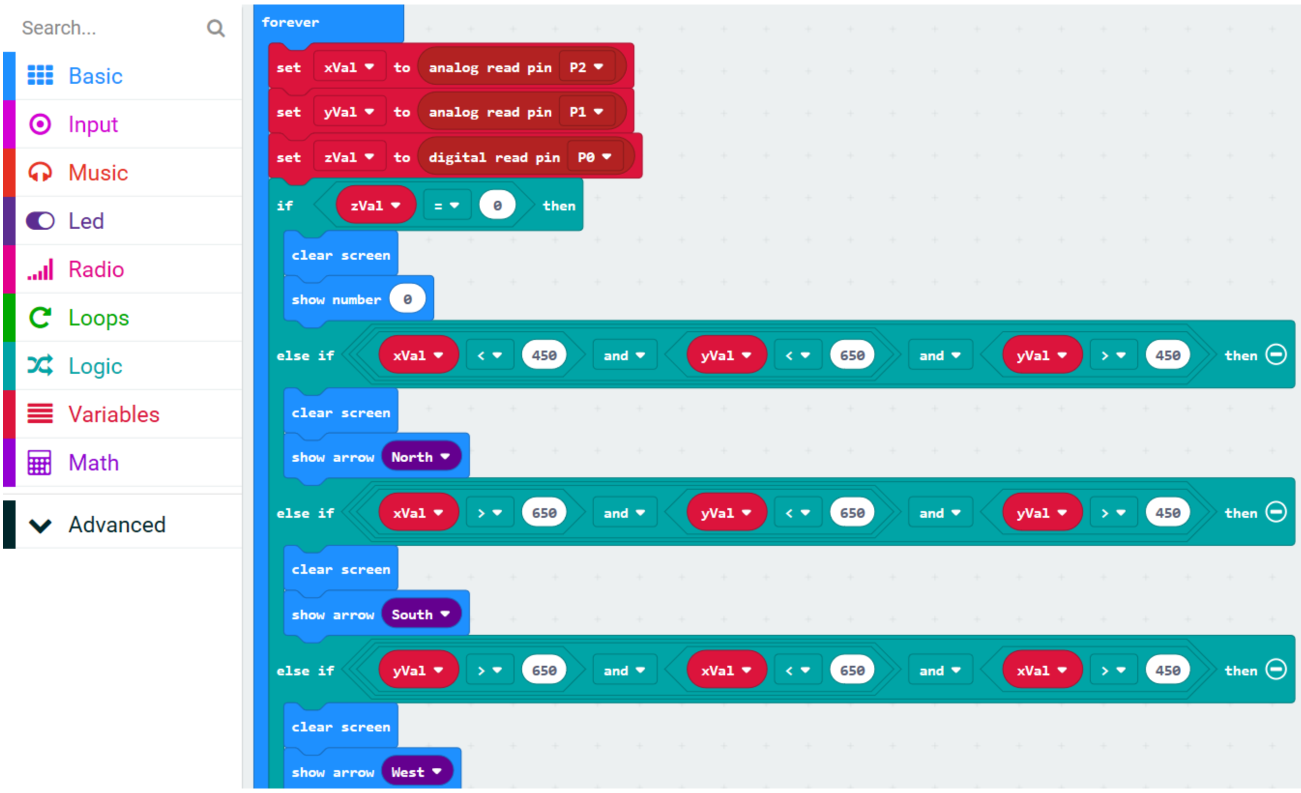
It is same as the previous project.

## Block code

Open MakeCode first. Import the .hex file. The path is as below:
(How to import project)

| File type | Path | File name |
|---|---|---|
| HEX file | ../Projects/BlockCode/17.2_Joystick | Joystick.hex |

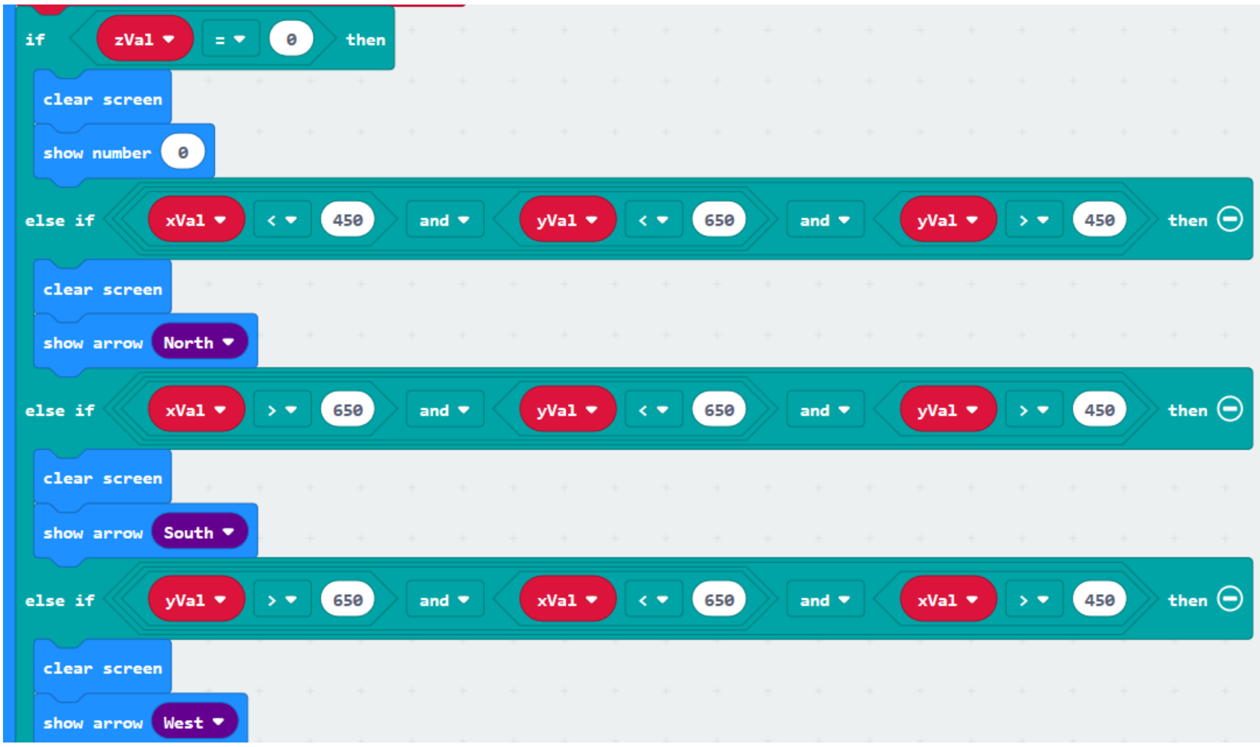
After importing successfully, the code is shown as below:




Check the connection of the circuit and verify it correct. Download the code into the micro:bit, and then the direction of the Joystick will be displayed on the dot matrix.

Get the values in the X, Y, and Z directions.

Display the corresponding arrow image according to the values of the X, Y, and Z directions.

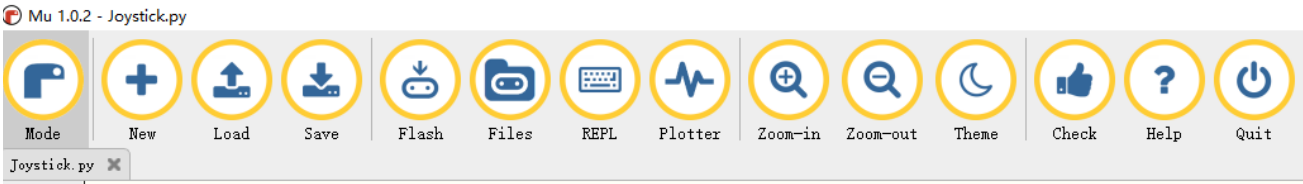



# Python code

Open the .py file with Mu. Code, the path is as below:

| File type | Path | File name |
|---|---|---|
| **Python file** | ../Projects/PythonCode/17.2_Joystick | Joystick.py |

After loading successfully, the code is shown as below:




```python
from microbit import *
circle = Image("09900:"
               "90090:"
               "90090:"
               "90090:"
               "09900")
while True:
    xVal = pin2.read_analog()
    yVal = pin1.read_analog()
    zVal = pin0.read_digital()
    if zVal == 0:
        display.clear()
        display.show(circle)
    elif xVal <450  and yVal < 650 and yVal >450:
        display.clear()
        display.show(Image.ARROW_N)
    elif xVal >650  and yVal < 650 and yVal >450:
        display.clear()
        display.show(Image.ARROW_S)
    elif yVal >650  and xVal < 650 and xVal >450:
        display.clear()
        display.show(Image.ARROW_W)
    elif yVal < 450  and xVal < 650 and xVal >450:
        display.clear()
        display.show(Image.ARROW_E)
    elif xVal <450  and yVal > 650:
        display.clear()
        display.show(Image.ARROW_NW)
    elif xVal <450  and yVal < 450:
        display.clear()
        display.show(Image.ARROW_NE)
    elif xVal > 650  and yVal > 650:
        display.clear()
        display.show(Image.ARROW_SW)
    elif xVal > 650  and yVal < 450:
        display.clear()
        display.show(Image.ARROW_SE)
    else:
        display.clear()
```

Check the connection of the circuit and verify it correct. Download the code into the micro:bit and then the direction of the Joystick will be displayed on the dot matrix.

The following is the program code:

```
from microbit import *
circle = Image("09900:"
               "90090:"
               "90090:"
               "90090:"
               "09900")
while True:
    xVal = pin2.read_analog()
    yVal = pin1.read_analog()
    zVal = pin0.read_digital()
    if zVal == 0:
        display.clear()
        display.show(circle)
    elif xVal <450  and yVal < 650 and yVal >450:
        display.clear()
        display.show(Image.ARROW_N)
    elif xVal >650  and yVal < 650 and yVal >450:
        display.clear()
        display.show(Image.ARROW_S)
    elif yVal >650  and xVal < 650 and xVal >450:
        display.clear()
        display.show(Image.ARROW_W)
    elif yVal < 450  and xVal < 650 and xVal >450:
        display.clear()
        display.show(Image.ARROW_E)
    elif xVal <450  and yVal > 650:
        display.clear()
        display.show(Image.ARROW_NW)
    elif xVal <450  and yVal < 450:
        display.clear()
        display.show(Image.ARROW_NE)
    elif xVal > 650  and yVal > 650:
        display.clear()
        display.show(Image.ARROW_SW)
    elif xVal > 650  and yVal < 450:
        display.clear()
        display.show(Image.ARROW_SE)
    else:
        display.clear()
```

Custom image number "0" will be displayed when pressing the Joystick.

```
circle = Image("09900:"
               "90090:"
               "90090:"
               "90090:"
               "09900")
```

Get the values in the X, Y, and Z directions.

```
    xVal = pin2.read_analog()
    yVal = pin1.read_analog()
    zVal = pin0.read_analog()
```

Display the corresponding arrow image according to the value of X, Y, Z in three directions

```
    if zVal == 1:
        display.clear()
        display.show(circle)
    elif xVal <450  and yVal < 650 and yVal >450:
        display.clear()
        display.show(Image.ARROW_N)
    elif xVal >650  and yVal < 650 and yVal >450:
        display.clear()
        display.show(Image.ARROW_S)
    elif yVal >650  and xVal < 650 and xVal >450:
        display.clear()
        display.show(Image.ARROW_W)
    elif yVal < 450  and xVal < 650 and xVal >450:
        display.clear()
        display.show(Image.ARROW_E)
    elif xVal <450  and yVal > 650:
        display.clear()
        display.show(Image.ARROW_NW)
    elif xVal <450  and yVal < 450:
        display.clear()
        display.show(Image.ARROW_NE)
    elif xVal > 650  and yVal > 650:
        display.clear()
        display.show(Image.ARROW_SW)
    elif xVal > 650  and yVal < 450:
        display.clear()
        display.show(Image.ARROW_SE)
    else:
        display.clear()
```

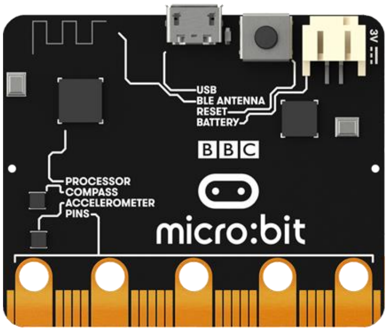
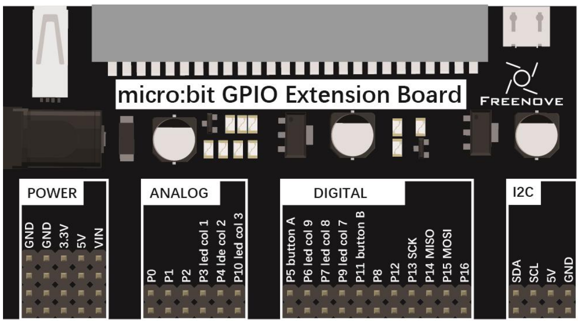
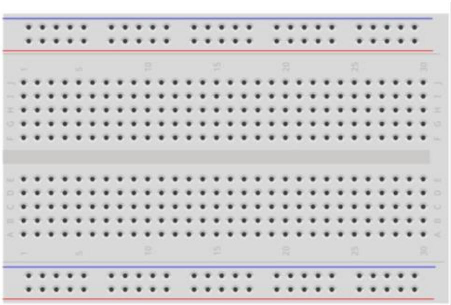
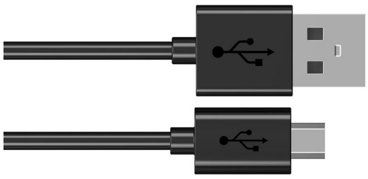
# Chapter 18 74HC595 and LED Bar Graph

In this chapter, we will learn a new component: 74HC595

## Project 18.1 Flowing Water Light

In this project, we will use a 74HC595 chip and LED Bar Graph to make a flowing water light.

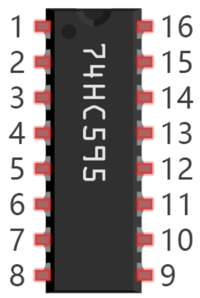
### Component list

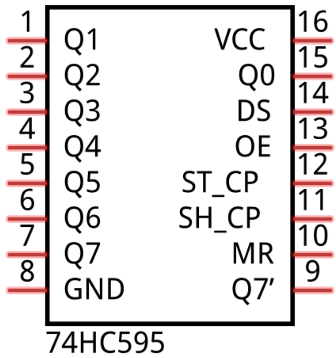
| | | |
|---|---|---|
| Microbit x1<br> | Extension board x1<br> | |
| Breadboard x1<br> | USB cable x1<br> | F/M x5 M/M x11<br> |
| LED Bar Graph x1<br> | 74HC595 x1<br> | Resistor 220Ω x8<br> |

## Component knowledge

### 74HC595

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



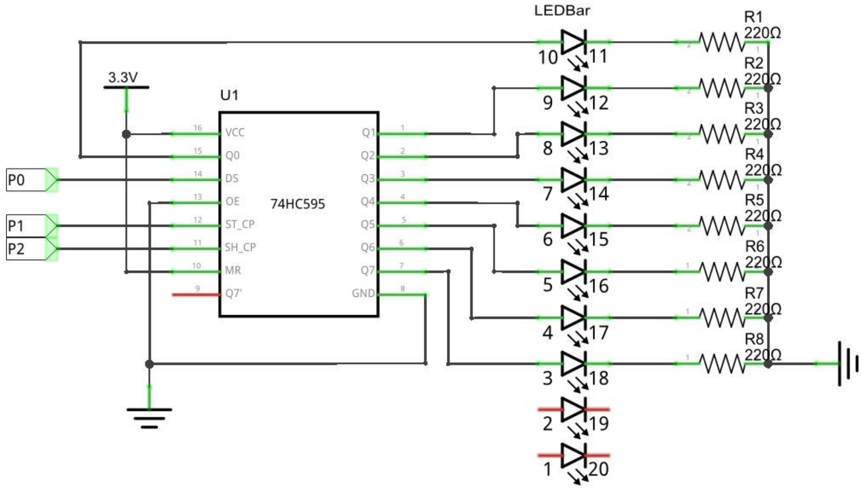

The ports of 74HC595 are described as follows:

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

For more detail, please refer to the datasheet.

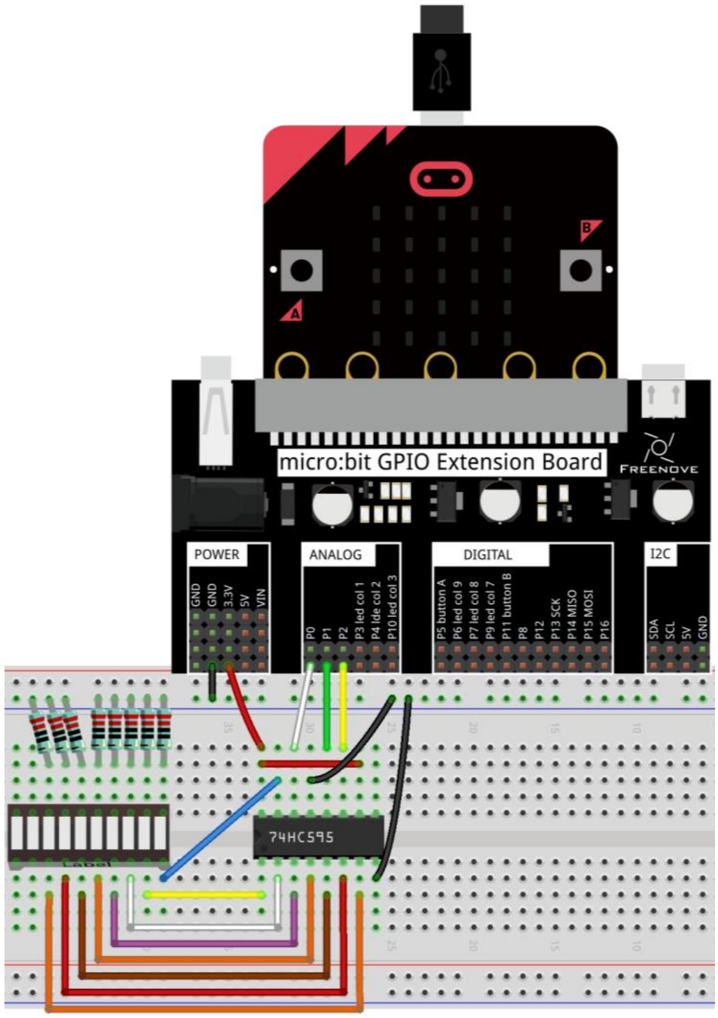
## Circuit

Schematic diagram




Hardware connection

**If LED bar doesn't work, try rotating the LED bar 180°.**

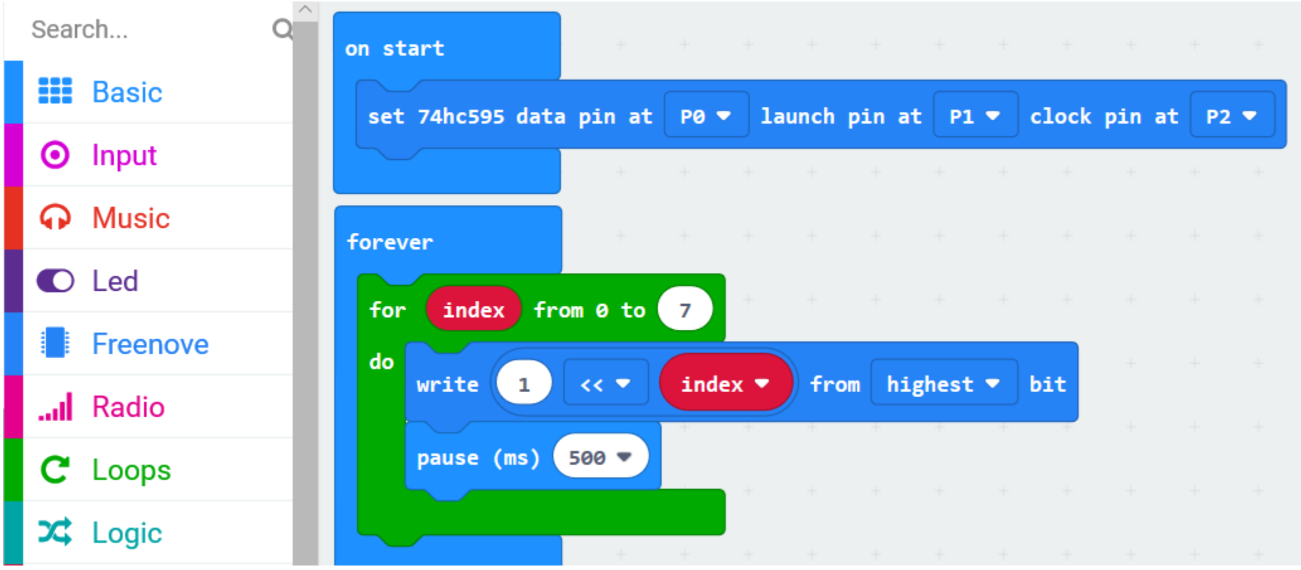


## Block code

Open MakeCode first. Import the .hex file. The path is as below:
(How to import project)

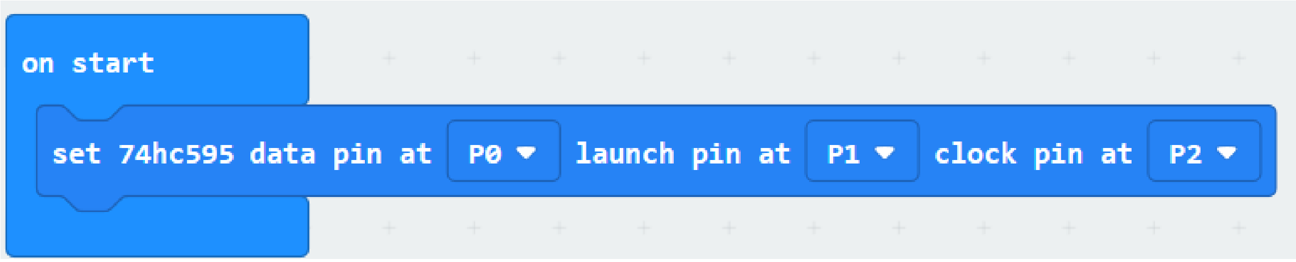
| File type | Path | File name |
|---|---|---|
| **HEX file** | ../Projects/BlockCode/18.1_FlowingLight02 | FlowingLight02.hex |

After importing successfully, the code is shown as below:

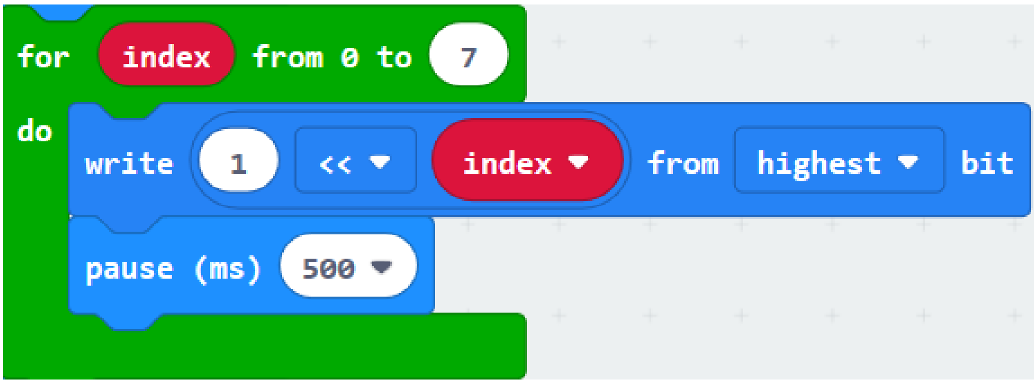



After checking the connection of the circuit and verify it correct, download the code into micro:bit, and you can see that the LED flow from left to right in turn circularly.

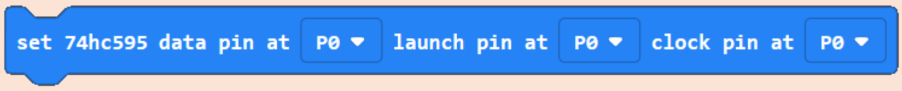
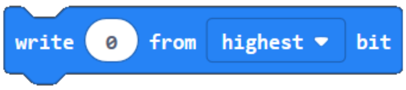
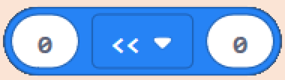
Set 74HC595's data pin as P0, launch pin as P1, and clock pin as P2.




In the for loop, the number '1' moves index bit to the left, writes the shifted value to 74HC595 serially, and then turn ON the LED through parallel output of Q0-Q7 to realize flowing water light.




## Reference

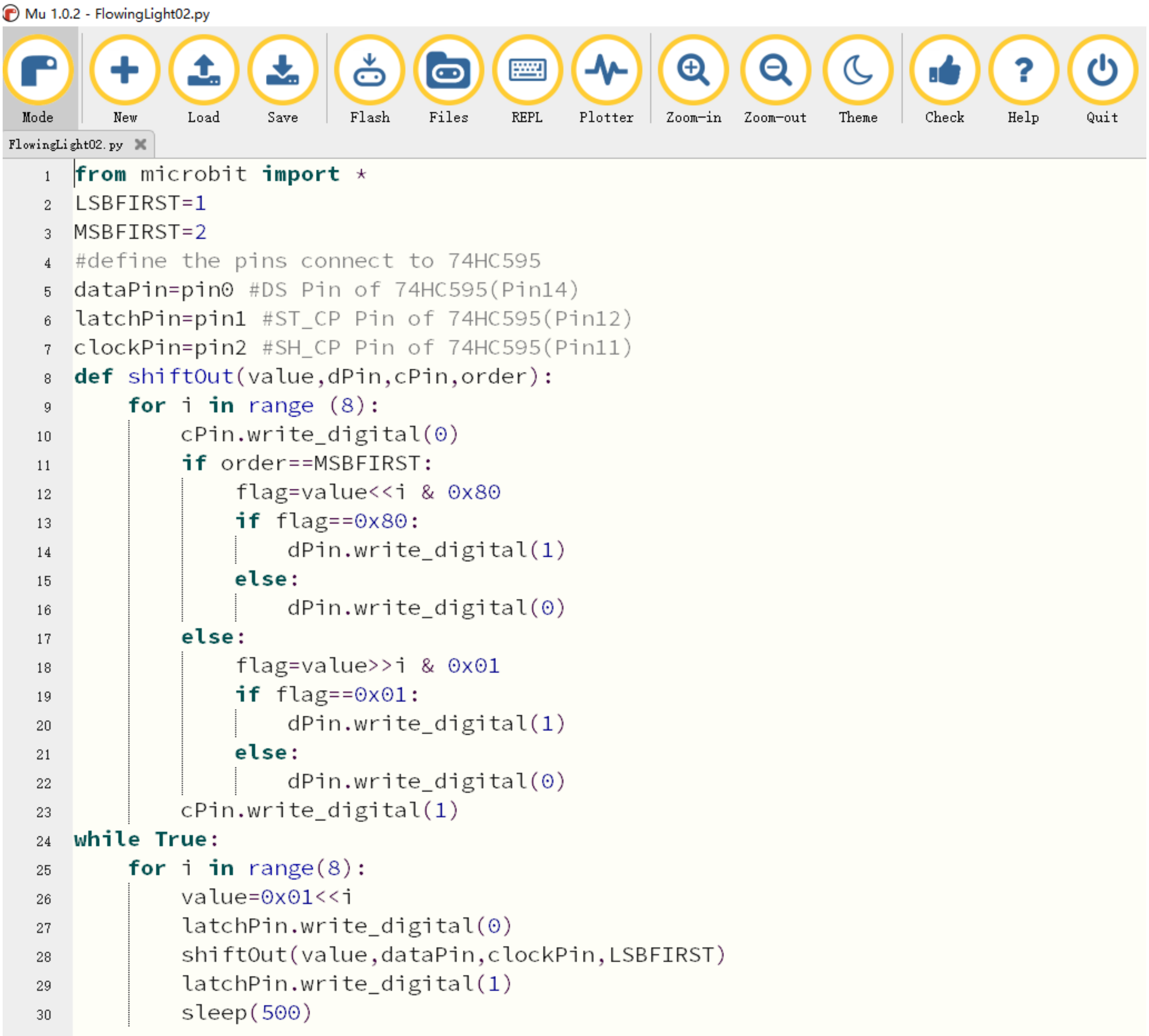
| Block | Function |
|---|---|
|  | It belongs to Freenove Extension Block. It is used to set data pin, launch pin, clock pin for 74HC595. |
|  | It belongs to Freenove Extension Block. The data of 0-255 is serially written to 74HC595, and then output in parallel through Q0-Q7. The order of data writing is either from the highest bit or from the least bit. |
|  | It belongs to Freenove Extension Block. Move data to the left (x) bit or to the right (x) bit. |

## python code

Open the .py file with Mu. Code, the path is as below:

| File type | Path | File name |
|---|---|---|
| Python file | ../Projects/PythonCode/18.1_FlowingLight02 | FlowingLight02.py |

After loading successfully, the code is shown as below:




After checking the connection of the circuit and verify it correct, download the code into micro:bit, and you can see that the LED flow from left to right in turn circularly.

The following is the program code:

```
from microbit import *
LSBFIRST=1
MSBFIRST=2
#define the pins connect to 74HC595
```

```
dataPin=pin0 #DS Pin of 74HC595(Pin14)
latchPin=pin1 #ST_CP Pin of 74HC595(Pin12)
clockPin=pin2 #SH_CP Pin of 74HC595(Pin11)
def shiftOut(value,dPin,cPin,order):
    for i in range (8):
        cPin.write_digital(0)
        if order==MSBFIRST:
            flag=value<<i & 0x80
            if flag==0x80:
                dPin.write_digital(1)
            else:
                dPin.write_digital(0)
        else:
            flag=value>>i & 0x01
            if flag==0x01:
                dPin.write_digital(1)
            else:
                dPin.write_digital(0)
        cPin.write_digital(1)
while True:
    for i in range(8):
        value=0x01<<i
        latchPin.write_digital(0)
        shiftOut(value,dataPin,clockPin,LSBFIRST)
        latchPin.write_digital(1)
        sleep(500)
```

Define pins P0, P1, P2 for 74HC595.

```
from microbit import *
LSBFIRST=1
MSBFIRST=2
#define the pins connect to 74HC595
dataPin=pin0 #DS Pin of 74HC595(Pin14)
latchPin=pin1 #ST_CP Pin of 74HC595(Pin12)
clockPin=pin2 #SH_CP Pin of 74HC595(Pin11)
```

Custom shiftOut() function is used to write data to 74HC595 serially.

```
def shiftOut(value,dPin,cPin,order):
    for i in range (8):
        cPin.write_digital(0)
        if order==MSBFIRST:
            flag=value<<i & 0x80
            if flag==0x80:
                dPin.write_digital(1)
```

```
            else:
                dPin.write_digital(0)
        else:
            flag=value>>i & 0x01
            if flag==0x01:
                dPin.write_digital(1)
            else:
                dPin.write_digital(0)
        cPin.write_digital(1)
```

In the for loop, the value of the variable value shifts to the left i-bit, then the value of the variable value is written to 74HC595, and then turn ON the LED one by one through parallel output of Q0-Q7 to realize flowing water light.

```
while True:
    for i in range(8):
        value=0x01<<i
        latchPin.write_digital(0)
        shiftOut(value,dataPin,clockPin,LSBFIRST)
        latchPin.write_digital(1)
        sleep(500)
```

## Reference

`shiftOut(value,dPin,cPin,order)`

This function is used to serially write 8 bits of data to 74HC595. Value represents data to be written to 74HC595 registers, dPin represents data pins, cPin represents clock pins, and order represents priority bit flags (high or low). About order, LSBFIRST starts writing from low data, MSBFIRST starts writing from high data.

`<< operator`

"<<" is a left shift operator that moves all bits of byte data to the left (high) direction by a few bits and add 0 on the right (low). For example, shift binary 0001 1110 to the left by 1 bit to get 0011 1100. If you shift 1 bit to the right, it is 0000 1111.

">>" is the right shift operator, as opposed to the left shift operator, which moves all bits of byte data to the right (low) direction by a few bits and add 0 on the left(high).

`& operator`

& is a bitwise AND operation, which performs an AND operation on binary bit. Operation rules:

0&0=0;
0&1=0;
1&0=0;
1&1=1

For example:

```
        A=0011 1100
        B=0000 1101
    ---------------
    A&B=0000 1100
```

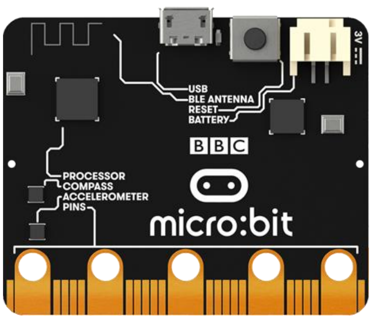
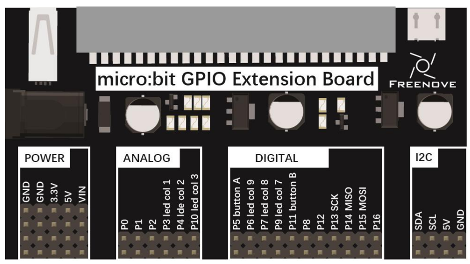
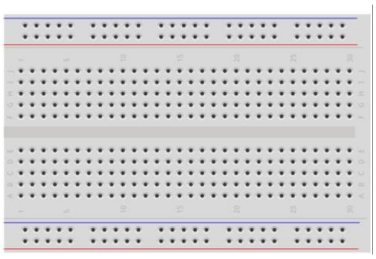
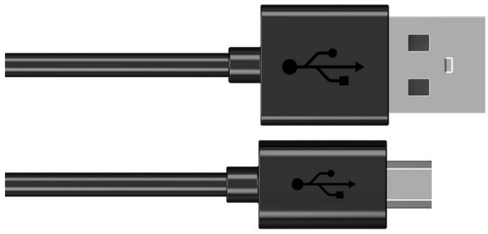
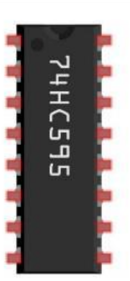
# Chapter 19 74HC595 and 7-segment display

In this chapter, we will learn a new component: 7-segment display.

## Project 19.1 7-segment display

In this project, we will use the 74HC595 chip and a 7-segment digital tube display to display the numbers 0 to 9.

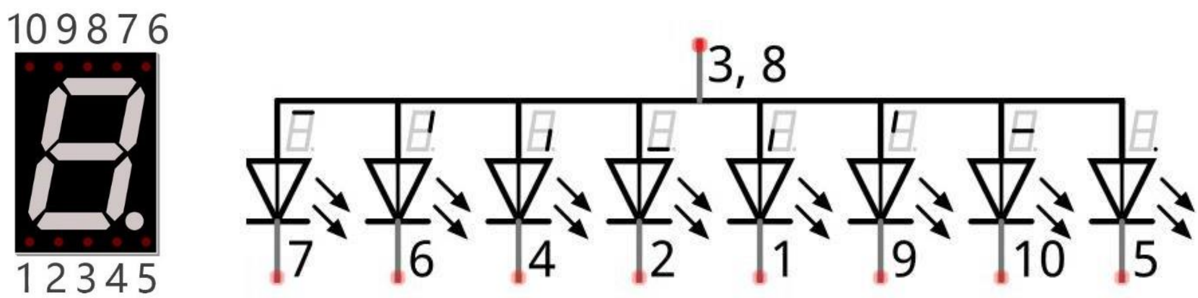
### Component list

<table>
<tr><td colspan="2">Microbit x1<br>
</td><td>Extension board x1<br>
</td></tr>
<tr><td colspan="2">Breadboard x1<br></td><td>USB cable x1<br></td></tr>
<tr><td rowspan="2">1-digit 7-segment-display x1<br></td><td rowspan="2">74HC595 x1<br>
</td><td>M/M x12 F/M x5<br></td></tr>
<tr><td>Resistor 220Ω x8<br></td></tr>
</table>

# Component knowledge

## 1-digit 7-segment display

A 7-Segment Display is a digital electronic display device. There is a figure "8" and a decimal point represented, which consists of 8 LEDs. There are two kinds of 1-digit 7-segment display: Common Anode and Common Cathode. The one we use is that have a Common Anode(+) and individual Cathodes. Its internal structure and pin designation diagram is shown below:




As we can see in the above circuit diagram, we can control the state of each LED separately. Also, by combining LEDs with different states of ON and OFF, we can display different characters (Numbers and Letters). For example, to display a “0”: we need to turn ON LED segments 7,6,4,2,1 and 9, and turn OFF LED segments 10 and 5.

If we use a byte to show the state of the LEDs that connected to pin 5, 10, 9, 1, 2, 4, 6, 7, we can use 0 to represent the state of on and 1 for off. Then the number 0 can be expressed as a binary number 11000000, namely hex 0xc0.

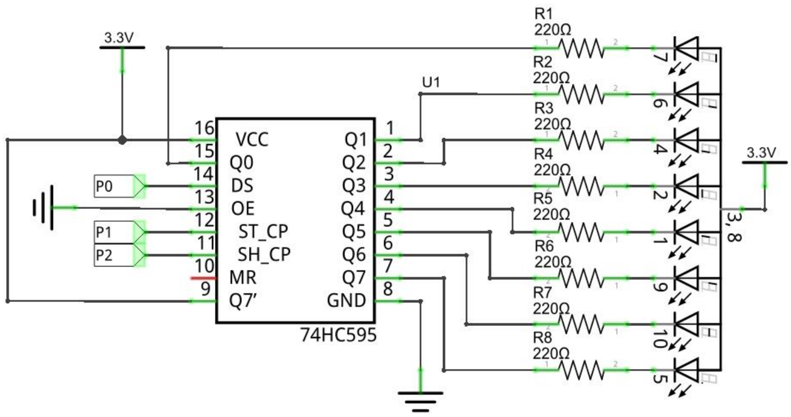
The numbers and letters that can be display are shown below:

| Number/Letter | Binary number | Hexadecimal number | Decimal number |
|---|---|---|---|
| 0 | 11000000 | 0xc0 | 192 |
| 1 | 11111001 | 0xf9 | 249 |
| 2 | 10100100 | 0xa4 | 164 |
| 3 | 10110000 | 0xb0 | 176 |
| 4 | 10011001 | 0x99 | 153 |
| 5 | 10010010 | 0x92 | 146 |
| 6 | 10000010 | 0x82 | 130 |
| 7 | 11111000 | 0xf8 | 248 |

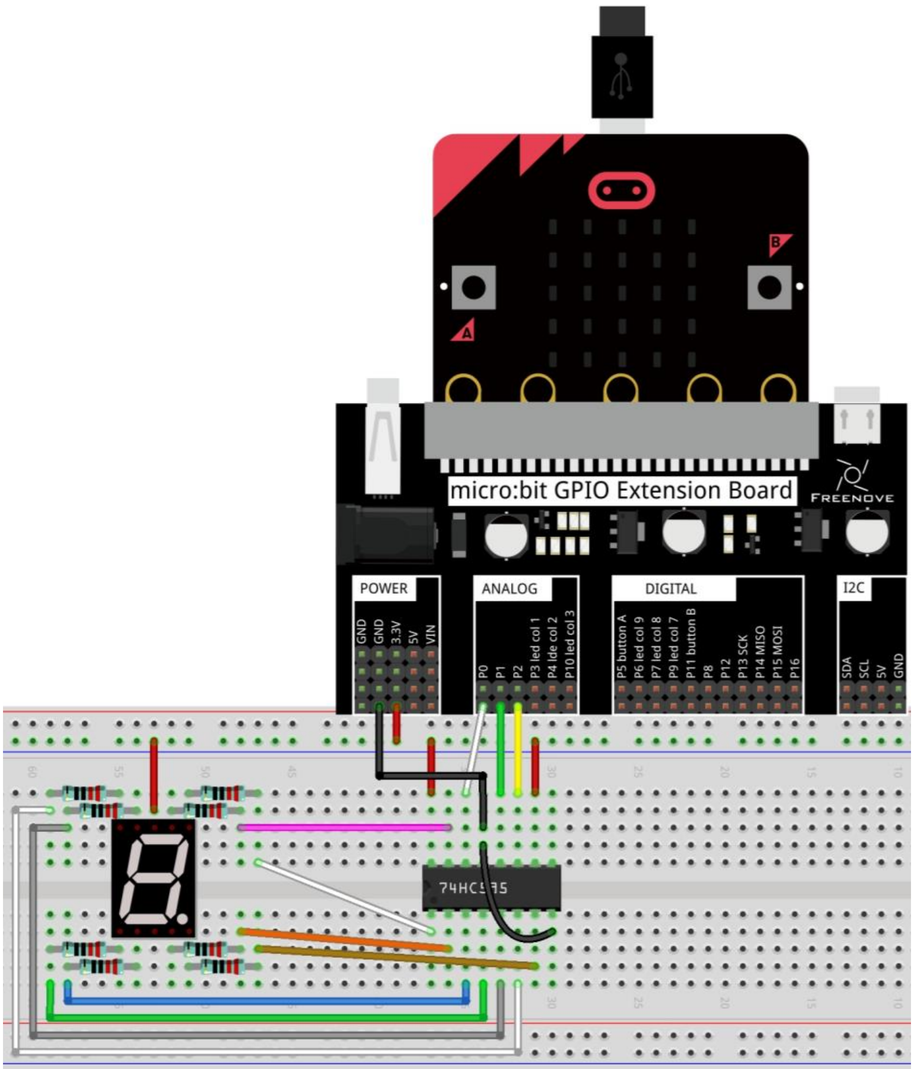
| | | | |
|---|---|---|---|
| 8 | 10000000 | 0x80 | 128 |
| 9 | 10010000 | 0x90 | 144 |
| A | 10001000 | 0x88 | 136 |
| b | 10000011 | 0x83 | 131 |
| C | 11000110 | 0xc6 | 198 |
| d | 10100001 | 0xa1 | 161 |
| E | 10000110 | 0x86 | 134 |
| F | 10001110 | 0x8e | 142 |

## Circuit

Schematic diagram




Hardware connection

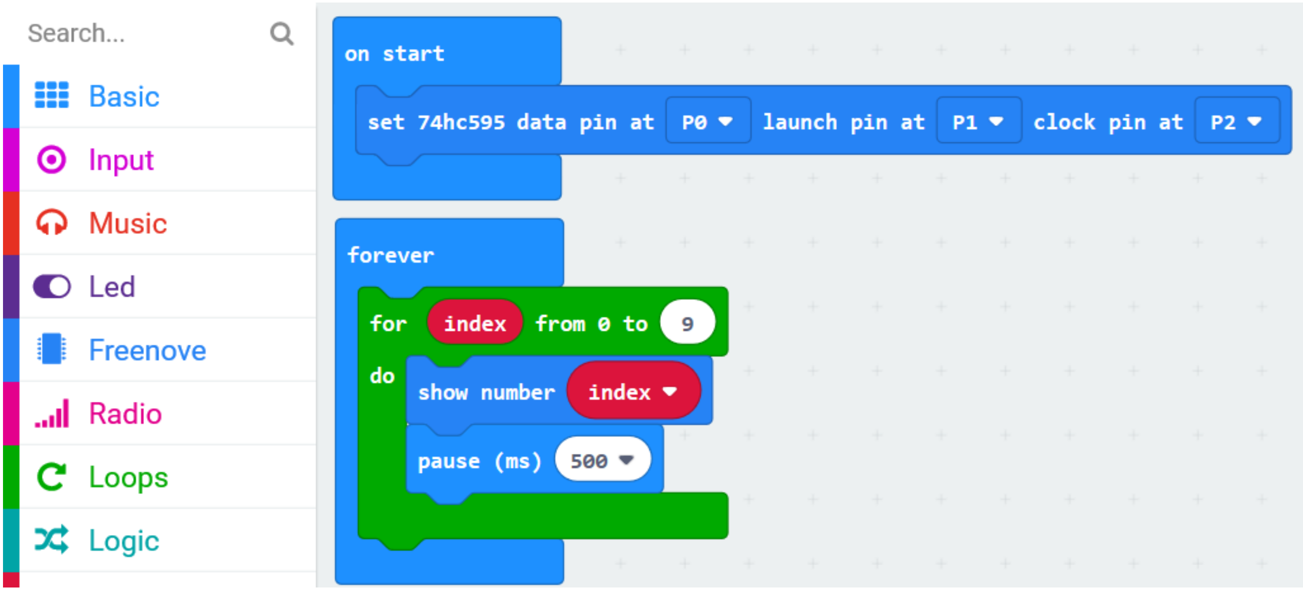


## Block code

Open MakeCode first. Import the .hex file. The path is as below:
(How to import project)

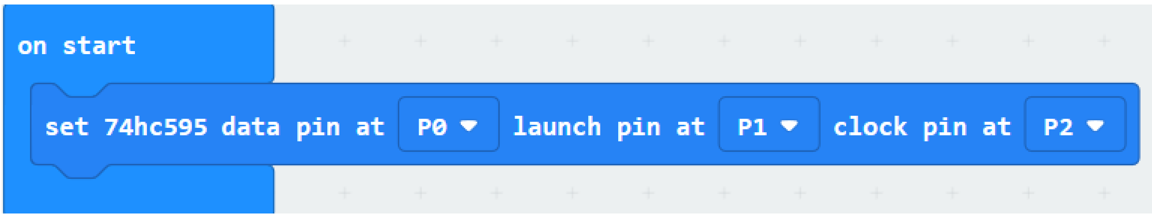
| File type | Path | File name |
|---|---|---|
| HEX file | ../Projects/BlockCode/19.1_SevenSegmentDisplay | SevenSegmentDisplay.hex |

After importing successfully, the code is shown as below:



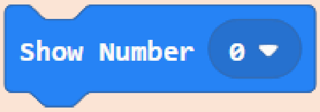

After checking the connection of the circuit and verifying it correct, the code is downloaded into micro:bit. You can see that the 7-segment display shows 0, 1... 9 in turn.

Set 74HC595 data pin as P0, launch pin as P1, and clock pin as P2.




In the for loop, the digital tube displays the numbers 0 to 9 in turn, and change the number every 500ms.


## Reference

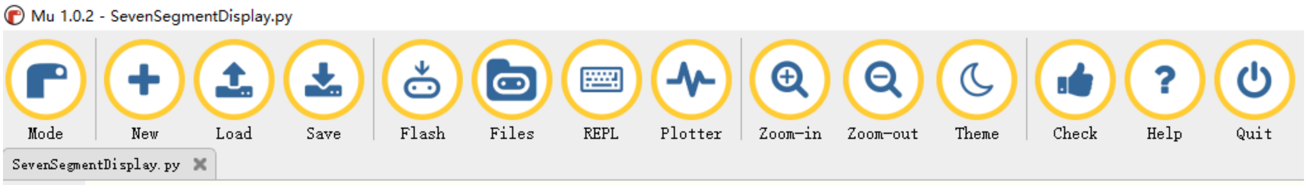
| Block | Function |
| --- | --- |
|   | It belongs to Freenove Extension Block. It is used to control digital tube to display number and character 0-F by using 74HC595. |

## Python code

Open the .py file with Mu. Code, the path is as below:

| File type | Path | File name |
|---|---|---|
| Python file | ../Projects/PythonCode/19.1_SevenSegmentDisplay | SevenSegmentDisplay.py |

After loading successfully, the code is shown as below:




```
from microbit import *
number =[0xc0,0xf9,0xa4,0xb0,0x99,0x92,0x82,0xf8,0x80,0x90]
LSBFIRST=1
MSBFIRST=2
#define the pins connect to 74HC595
dataPin=pin0 #DS Pin of 74HC595(Pin14)
latchPin=pin1 #ST_CP Pin of 74HC595(Pin12)
clockPin=pin2 #SH_CP Pin of 74HC595(Pin11)
def shiftOut(value,dPin,cPin,order):
    for i in range (8):
        cPin.write_digital(0)
        if order==MSBFIRST:
            flag=value<<i & 0x80
            if flag==0x80:
                dPin.write_digital(1)
            else:
                dPin.write_digital(0)
        else:
            flag=value>>i & 0x01
            if flag==0x01:
                dPin.write_digital(1)
            else:
                dPin.write_digital(0)
        cPin.write_digital(1)
while True:
    for Num in number:
        latchPin.write_digital(0)
        shiftOut(Num,dataPin,clockPin,MSBFIRST)
        latchPin.write_digital(1)
        sleep(500)
```

After checking the connection of the circuit and verifying it correct, the code is downloaded into micro:bit. You can see that the 7-segment display shows 0, 1... 9 in turn.

The following is the program code:

```
from microbit import *
number =[0xc0,0xf9,0xa4,0xb0,0x99,0x92,0x82,0xf8,0x80,0x90]
LSBFIRST=1
MSBFIRST=2
#define the pins connect to 74HC595
dataPin=pin0 #DS Pin of 74HC595(Pin14)
latchPin=pin1 #ST_CP Pin of 74HC595(Pin12)
clockPin=pin2 #SH_CP Pin of 74HC595(Pin11)
def shiftOut(value,dPin,cPin,order):
    for i in range (8):
        cPin.write_digital(0)
        if order==MSBFIRST:
            flag=value<<i & 0x80
            if flag==0x80:
                dPin.write_digital(1)
            else:
                dPin.write_digital(0)
        else:
            flag=value>>i & 0x01
            if flag==0x01:
                dPin.write_digital(1)
            else:
                dPin.write_digital(0)
        cPin.write_digital(1)
while True:
    for Num in number:
        latchPin.write_digital(0)
        shiftOut(Num,dataPin,clockPin,MSBFIRST)
        latchPin.write_digital(1)
        sleep(500)
```

Define variable number to store numbers 0, 1, 2...9 in Hexadecimal.
Define pins P0, P1, P2 for 74HC595.

```
number =[0xc0,0xf9,0xa4,0xb0,0x99,0x92,0x82,0xf8,0x80,0x90]
LSBFIRST=1
MSBFIRST=2
#define the pins connect to 74HC595
dataPin=pin0 #DS Pin of 74HC595(Pin14)
latchPin=pin1 #ST_CP Pin of 74HC595(Pin12)
clockPin=pin2 #SH_CP Pin of 74HC595(Pin11)
```

Custom shiftOut () function is used for writing data to 74HC595 serially.

```
def shiftOut(value,dPin,cPin,order):
    for i in range (8):
        cPin.write_digital(0)
        if order==MSBFIRST:
            flag=value<<i & 0x80
            if flag==0x80:
                dPin.write_digital(1)
            else:
                dPin.write_digital(0)
        else:
            flag=value>>i & 0x01
            if flag==0x01:
                dPin.write_digital(1)
            else:
                dPin.write_digital(0)
        cPin.write_digital(1)
```

Call the shiftOut() function, and write the hexadecimal number stored in the number variable to 74HC595 serially, then turn ON the LEDs through parallel output of Q0 ~ Q7.

```
while True:
    for Num in number:
        latchPin.write_digital(0)
        shiftOut(Num,dataPin,clockPin,MSBFIRST)
        latchPin.write_digital(1)
        sleep(500)
```

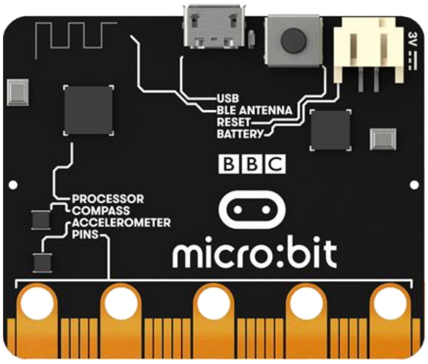
# Chapter 20 LCD1602

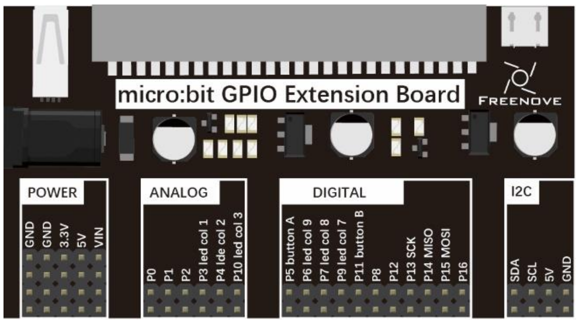
In this chapter, we will learn the LCD1602 display.

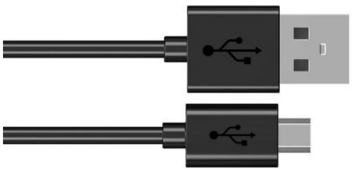
## Project 20.1 I2C LCD1602

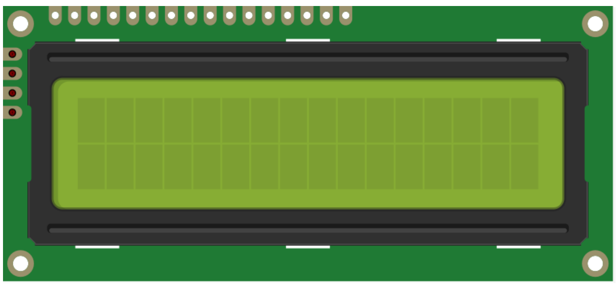
This project realizes the display of the current ambient temperature on the LCD1602 display.

### Component list

<table>
<tr>
<td>Microbit x1<br>


</td>
<td>Extension board x1<br>


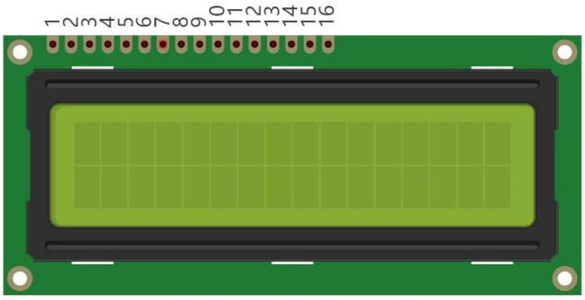
</td>
</tr>
<tr>
<td>USB cable x2<br>

</td>
<td>F/F x4<br>

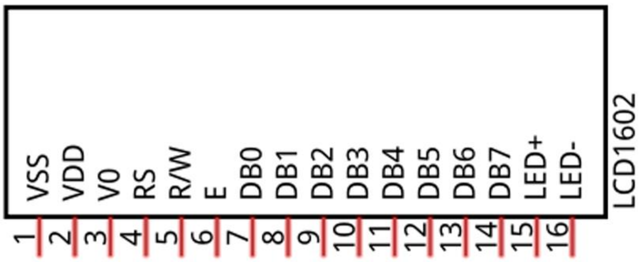
</td>
</tr>
<tr>
<td colspan="2">LCD1602<br>

</td>
</tr>
</table>

# Component knowledge

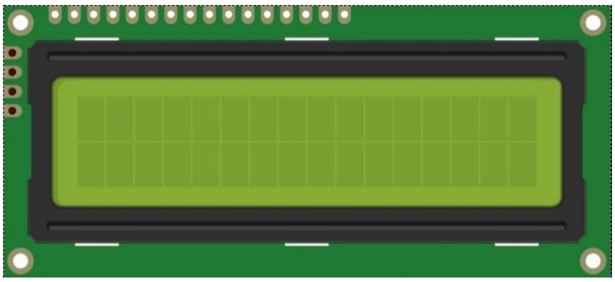
## LCD1602

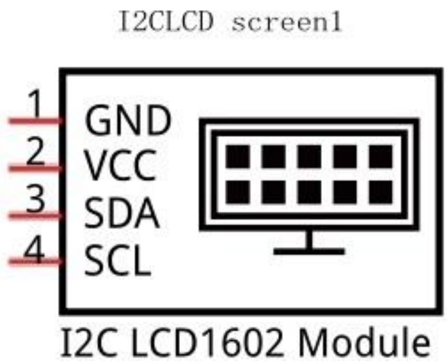
The LCD1602 Display Screen can display 2 lines of characters in 16 columns. It is capable of displaying numbers, letters, symbols, ASCII code and so on. As shown below is a monochrome LCD1602 Display Screen along with its circuit pin diagram




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

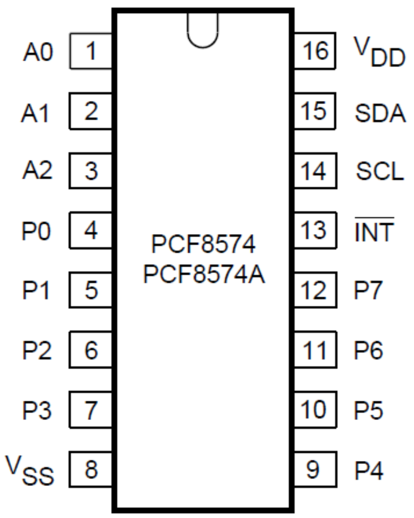




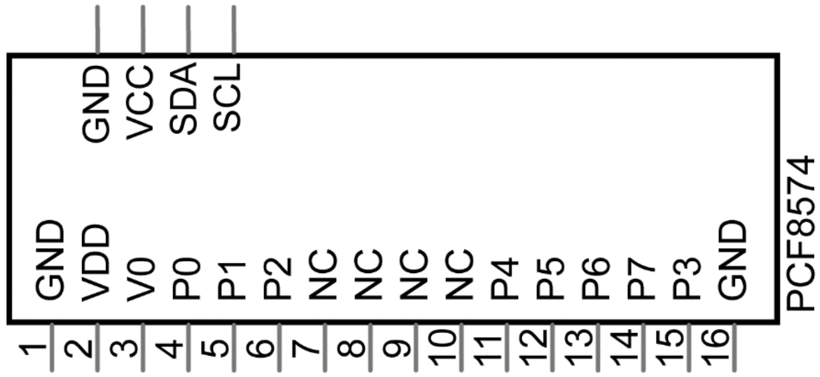

The serial-to-parallel IC chip used in this module is PCF8574T (PCF8574AT), and its default I2C address is 0x27(0x3F).

PCF8574 pin diagram:

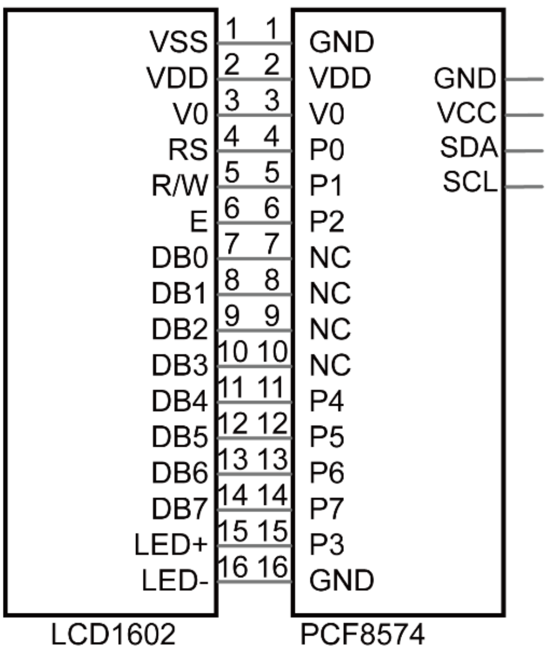
PCF8574 chip pin diagram:




PCF8574 module pin diagram




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

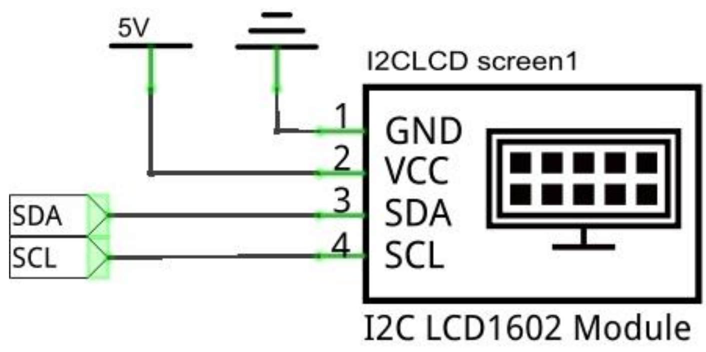



Because of this, as stated earlier, we only need 4 pins to control the 16 pins of the LCD1602 Display Screen through the I2C interface.

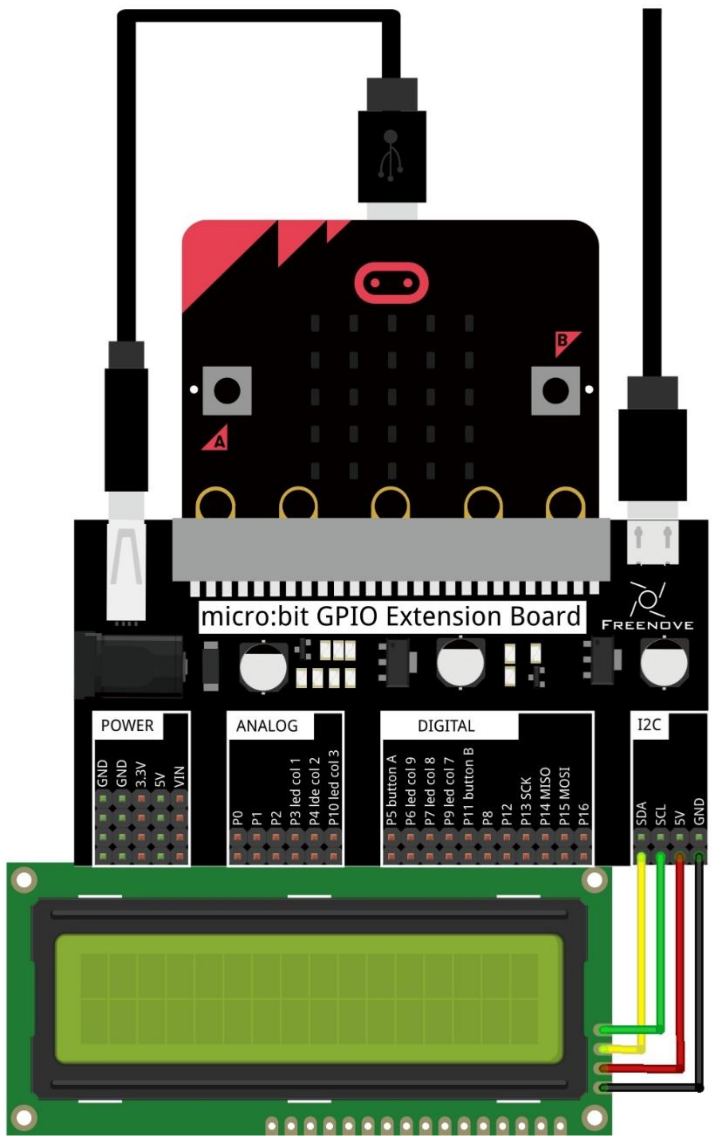
In this project, we will use I2CLCD1602 to display some static characters and dynamic variables.

# Circuit

Schematic diagram




Hardware connection

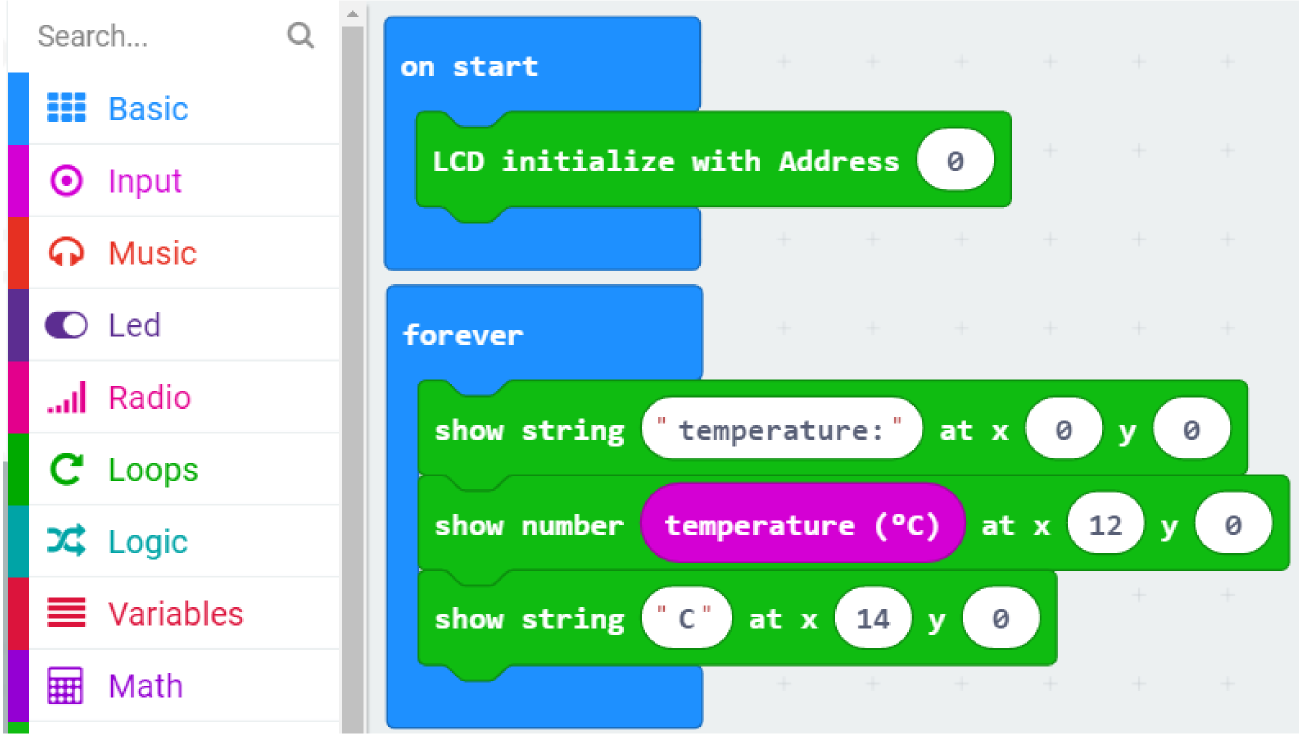


## Block code

Open MakeCode first. Import the .hex file. The path is as below:
(How to import project)

| File type | Path | File name |
|---|---|---|
| HEX file | ../Projects/BlockCode/20.1_LCD1602 | LCD1602.hex |

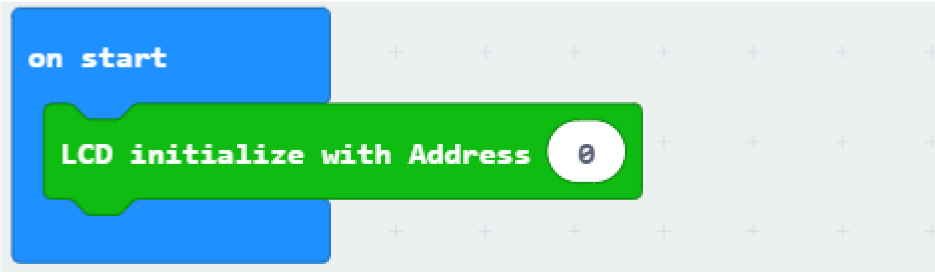
After importing successfully, the code is shown as below:



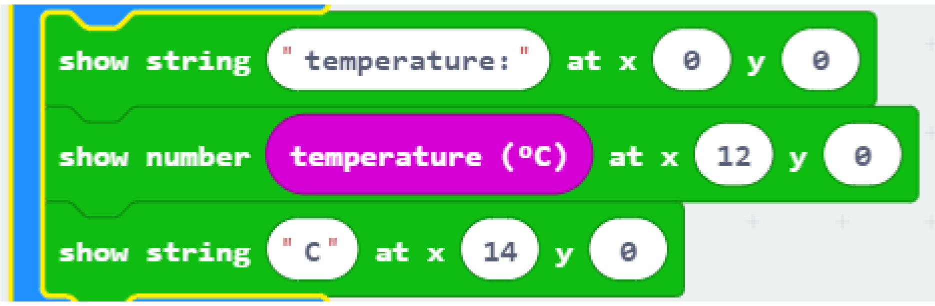

Check the connection of the circuit, verify it correct, and download the code into the micro:bit, and then the LCD screen will display the current ambient temperature.

**NOTE: After the program is executed, if you cannot see anything on the display or the display is not clear, try rotating the white knob on back of LCD1602 slowly, which adjusts the contrast, until the screen can display the Temperature clearly.**

LCD initialization, we provide two kinds of LCD screen, you can write I2C address (0x27 or 0x3F) according to the LCD screen you receive. If you enter 0, it will automatically search for the correct I2C address and connect.




Display the temperature of the current environment on the LCD display.

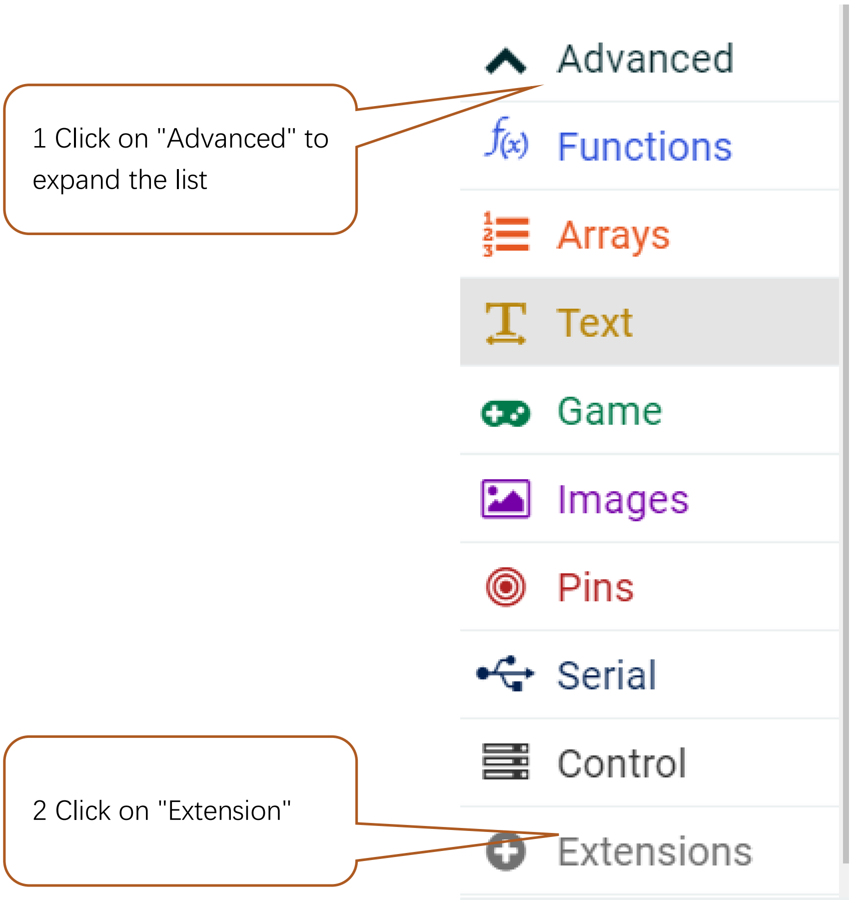


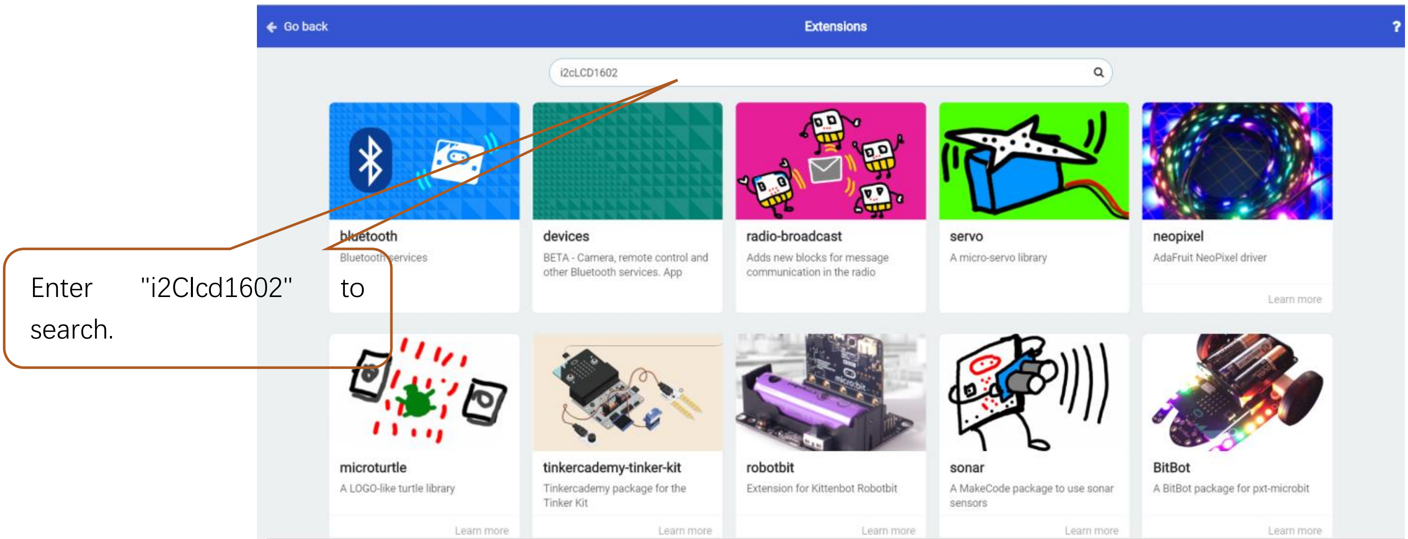

## Reference

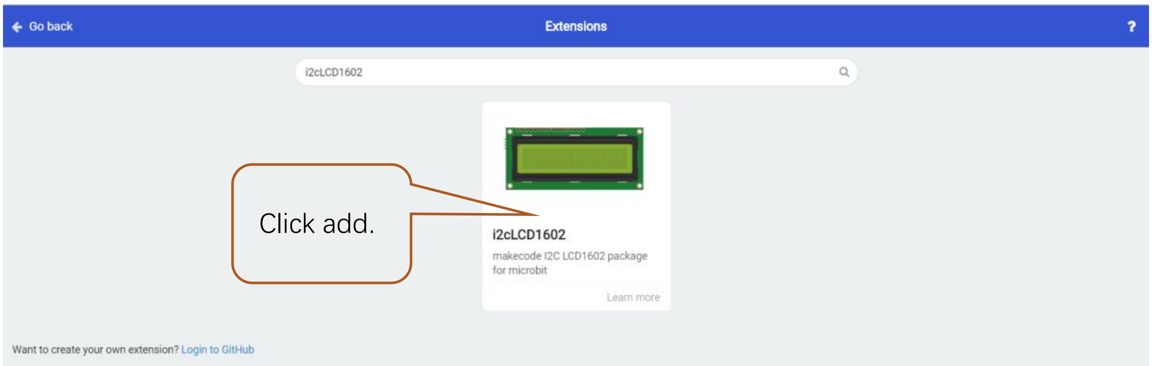
| Block | Function |
| --- | --- |
|   | LCD initialization, input LCD I2C address (0x27 or 0x3F). If you enter 0, it will automatically find the correct address and connect. |
|   | The LCD screen displays the number in the x column, y column of the screen. |
|   | The LCD screen displays the string in the x column, the y column of the screen |

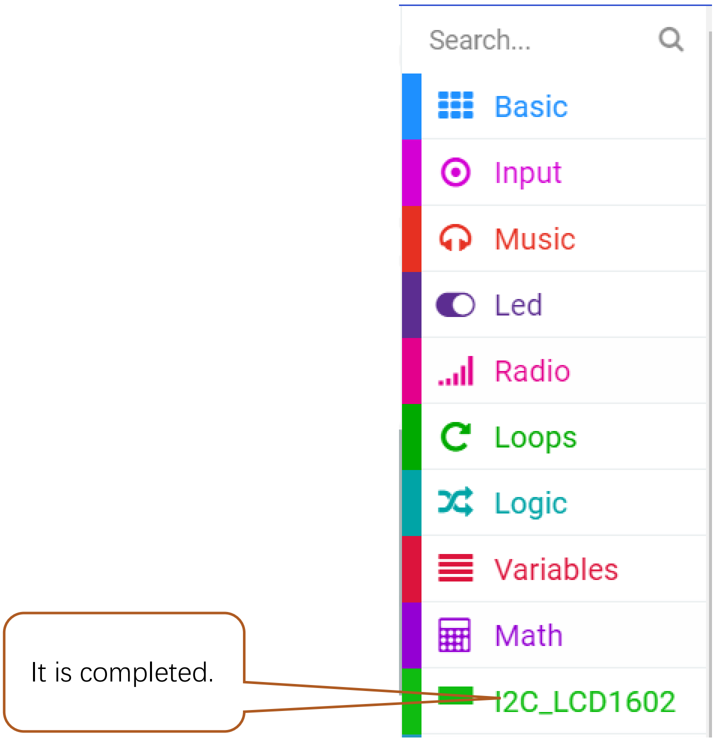
## Extensions

If you want to import the LCD1602 expansion block in a new project, follow the steps below to add it.




Go back
Extensions
?
i2cLCD1602
Click add.
i2cLCD1602
makecode I2C LCD1602 package for microbit
Learn more
Want to create your own extension? Login to GitHub

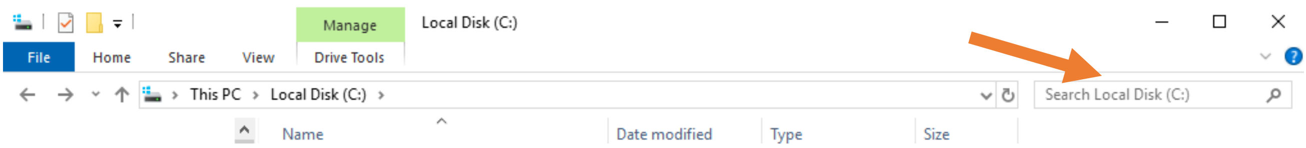

Search...
Basic
Input
Music
Led
Radio
Loops
Logic
Variables
Math
I2C_LCD1602
It is completed.

# Python code

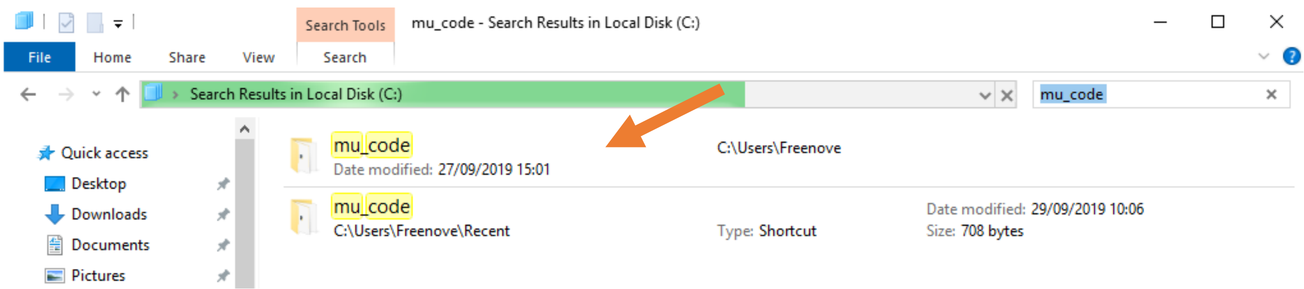
## Import necessary Python file into micro:bit

In the code of this tutorial, the LCD1602 module and DHT11 module are used, so it is necessary to import "I2C_LCD1602_Class.py" and "DHT11_RW.py" into the micro:bit. You can skip this section if you don't use them. When you need, you can come back to import them.

The import method is as follows:
Search on the C drive and find the "mu_code" folder.



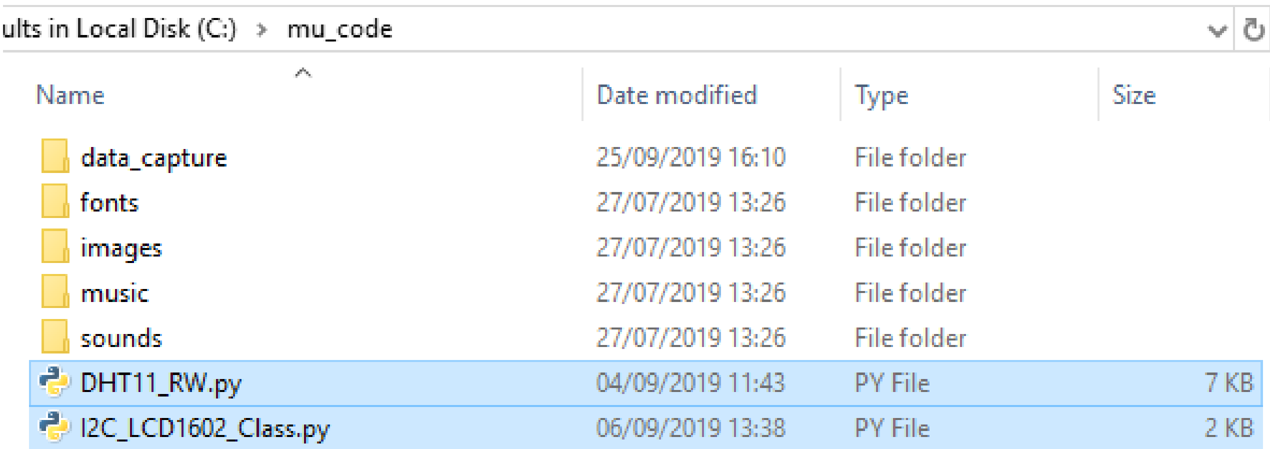

Double click on "mu_code" to enter the folder.



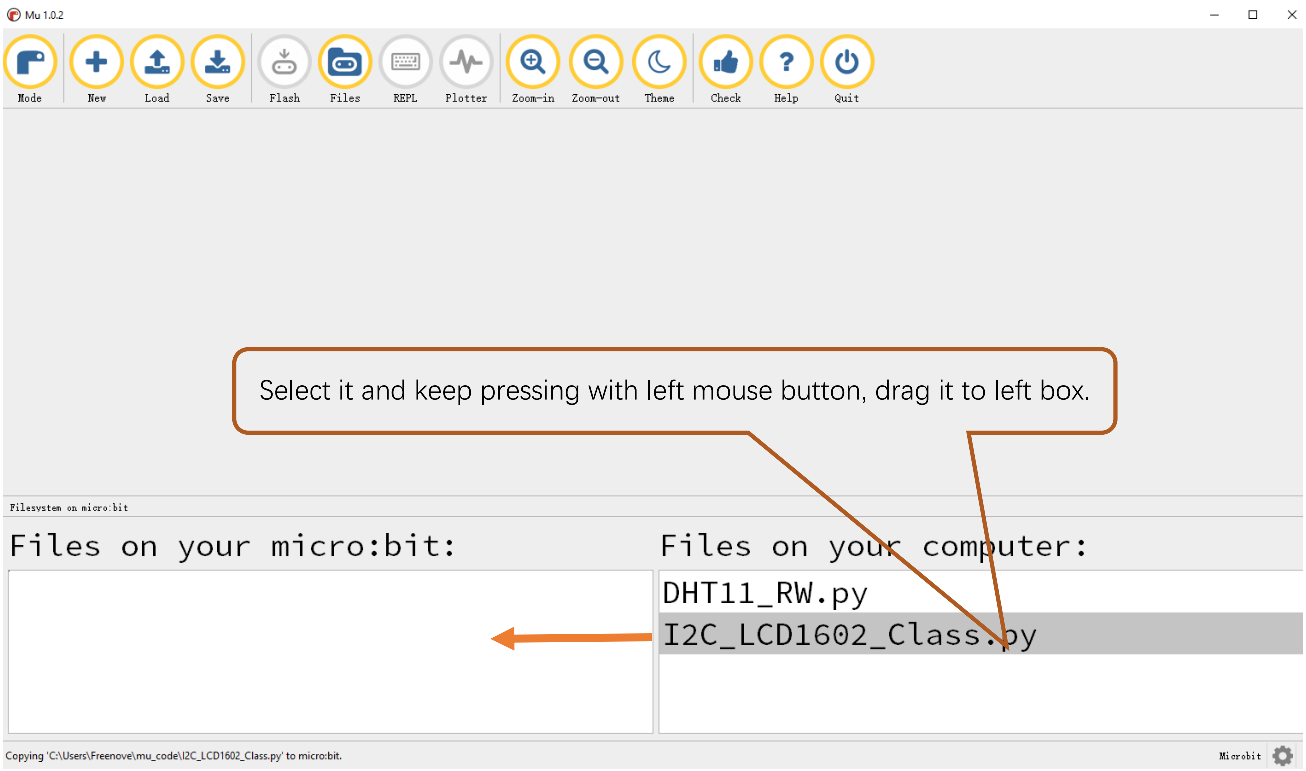

Copy "I2C_LCD1602_Class.py" and "DHT11_RW.py" from following path into "mu_code" directory.

| File type | Path | File name | |
|---|---|---|---|
| **Python file** | .. /Projects/PythonLibrary | I2C_LCD1602_Class.py | DHT11_RW.py |

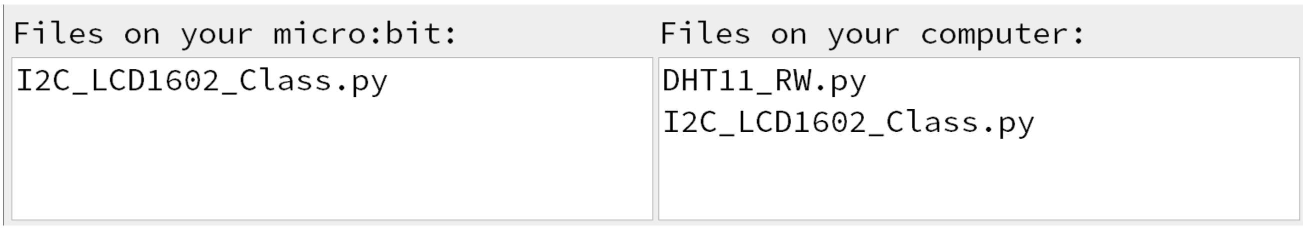
After pasting successfully, you can see them as below:



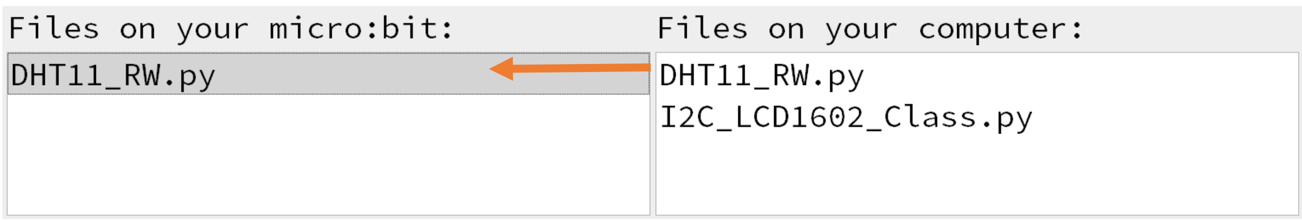
Open the Mu software, click "Files". Here we take "I2C_LCD1602_Class.py" as an example, drag "I2C_LCD1602_Class.py" into micro:bit.




After importing successfully, you will see it on the left.




The import method of "DHT11_RW.py" is the same as described above. You just need to import the one you need to use.



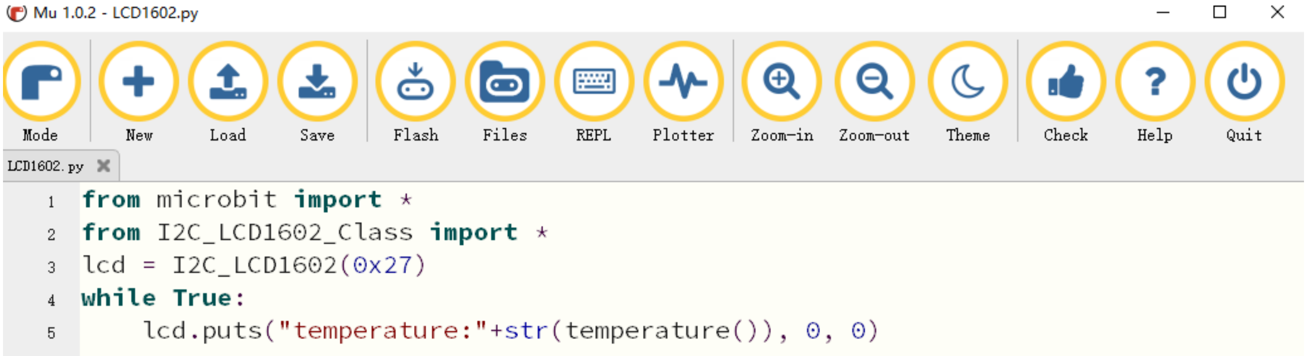

**Note, after you upload other file into micro:bit, the original content will be covered. You need to import it next time you use it.**

Open the .py file with Mu. Code, the path is as below:

| File type | Path | File name |
|---|---|---|
| **Python file** | ../Projects/PythonCode/20.1_LCD1602 | LCD1602.py |

After the code is loaded, as shown below, import the "I2C_LCD1602_Class.py" file to micro:bit before downloading the code.

(How to import?)




```
from microbit import *
from I2C_LCD1602_Class import *
lcd = I2C_LCD1602(0x27)
while True:
    lcd.puts("temperature:"+str(temperature()), 0, 0)
```

After the "I2C_LCD1602_Class.py" file is imported, check the connection of the circuit and verify it correct. Download the code into the micro:bit and the LCD screen will display the current ambient temperature.

**NOTE: After the program is executed, if you cannot see anything on the display or the display is not clear, try rotating the white knob on back of LCD1602 slowly, which adjusts the contrast, until the screen can display the Temperature clearly.**

The following is the program code:

```
from microbit import *
from I2C_LCD1602_Class import *
lcd = I2C_LCD1602(0x27)
while True:
    lcd.puts("temperature:"+str(temperature()), 0, 0)
```

Export everything from the I2C_LCD1602_Class module, create the object lcd of the I2C_LCD1602 class, and enter the I2C address of the LCD screen. Change the I2C address according to the LCD type.

If the chip of LCD is PCF8574 T, the i2c address is 0x27.

If the chip of LCD is PCF8574A T, the i2c address is 0x3F.

```
from I2C_LCD1602_Class import *
lcd = I2C_LCD1602(0x27)
```

Read the temperature data, and then call the puts function in the I2C_LCD1602 class to display the temperature on the LCD screen.

```
lcd.puts("temperature:"+str(temperature()), 0, 0)
```

## Reference

| puts(String, x, y) |
|---|
| This function is defined in the I2C_LCD1602 class. The function is to display the string on the LCD screen x column, y row, x range is 0-15, y range is 0-1. |

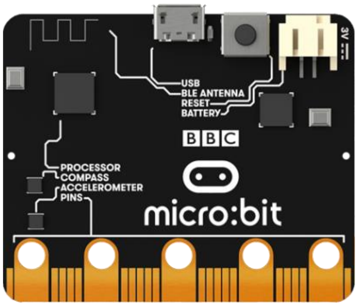
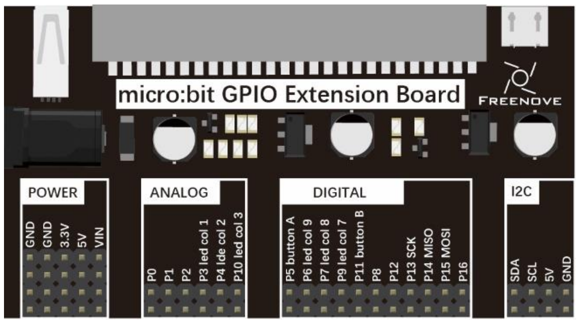
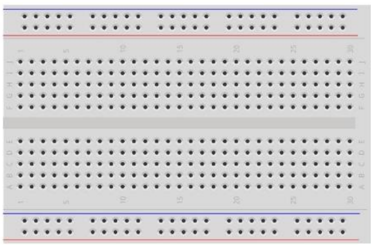
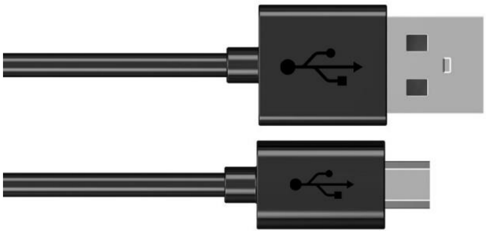
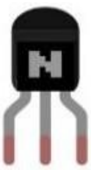
# Chapter 21 Motor

In this chapter, we will learn the comprehensive application of motor.

## Project 21.1 Relay & Motor

In this project, we will control a relay to drive a motor.

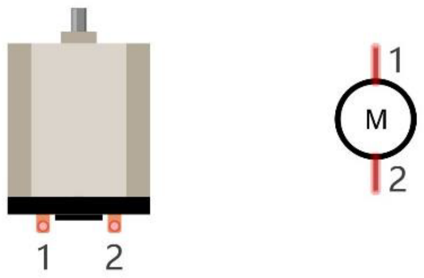
### Component list

<table>
<tr><td colspan="2">Microbit x1<br>
</td><td colspan="2">Extension board x1<br>
</td></tr>
<tr><td colspan="2">Breadboard x1<br></td><td colspan="2">USB cable x2<br></td></tr>
<tr><td>NPN(8050)transistor x 1<br></td><td>Motor x1<br></td><td>1kΩ x1<br><br>220Ω x1<br></td><td rowspan="2">Jumper M/M x4<br><br>Jumper F/M x5<br><br>Jumper F/F x1<br></td></tr>
<tr><td>Relay x1<br>
</td><td>LED x1<br></td><td>Diode x1<br></td></tr>
</table>

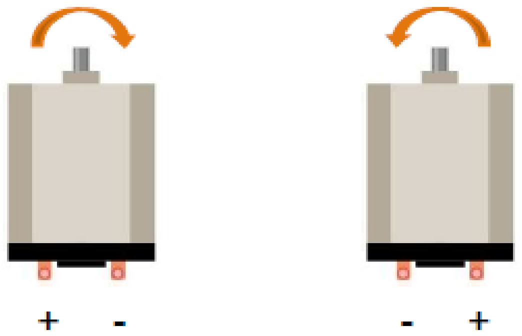
## Component knowledge

### DC Motor

DC Motor is a device that converts electrical energy into mechanical energy. DC Motors consist of two major parts, a Stator and the Rotor. The stationary part of a DC Motor is the Stator and the part that Rotates is the Rotor. The Stator is usually part of the outer case of motor (if it is simply a pair of permanent magnets), and it has terminals to connect to the power if it is made up of electromagnet coils. Most Hobby DC Motors only use Permanent Magnets for the Stator Field. The Rotor is usually the shaft of motor with 3 or more electromagnets connected to a commutator where the brushes (via the terminals 1 & 2 below) supply electrical power, which can drive other mechanical devices. The diagram below shows a small DC Motor with two terminal pins.

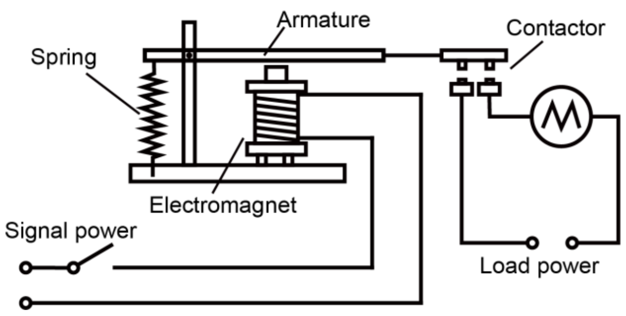



When a DC Motor is connected to a power supply, it will rotate in one direction. If you reverse the polarity of the power supply, the DC Motor will rotate in opposite direction. This is important to note.

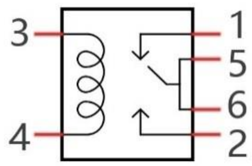


## Relay

Relays are a type of Switch that open and close circuits electromechanically or electronically. Relays control one electrical circuit by opening and closing contacts in another circuit using an electromagnet to initiate the Switch action. When the electromagnet is energized (powered), it will attract internal contacts completing a circuit, which act as a Switch. Many times Relays are used to allow a low powered circuit (and a small low amperage switch) to safely turn ON a larger more powerful circuit. They are commonly found in automobiles, especially from the ignition to the starter motor.
The following is a basic diagram of a common relay and the image and circuit symbol diagram of the 5V relay used in this project:

<table>
<tr><td>Diagram</td><td>Feature:</td><td>Symbol</td></tr>
<tr><td>


</td><td>


</td><td>


</td></tr>
</table>

Pin 5 and pin 6 are internally connected to each other. When the coil pin3 and pin 4 are connected to a 5V power supply, pin 1 will be disconnected from pins 5 & 6 and pin 2 will be connected to pins 5 & 6. Pin 1 is called Closed End and pin 2 is called the Open End.

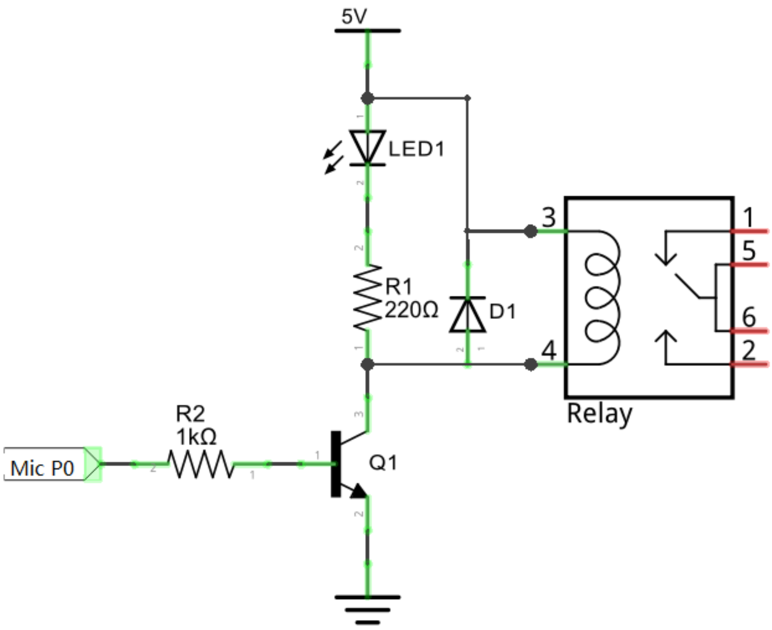
## Inductor

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

An Inductor is a passive device that stores energy in its Magnetic Field and returns energy to the circuit whenever required. An Inductor is formed by a Cylindrical Core with many Turns of conducting wire (usually copper wire). Inductors will hinder the changing current passing through it. When the current passing through the Inductor increases, it will attempt to hinder the increasing movement of current; and when the current passing through the inductor decreases, it will attempt to hinder the decreasing movement of current. So the current passing through an Inductor is not transient.

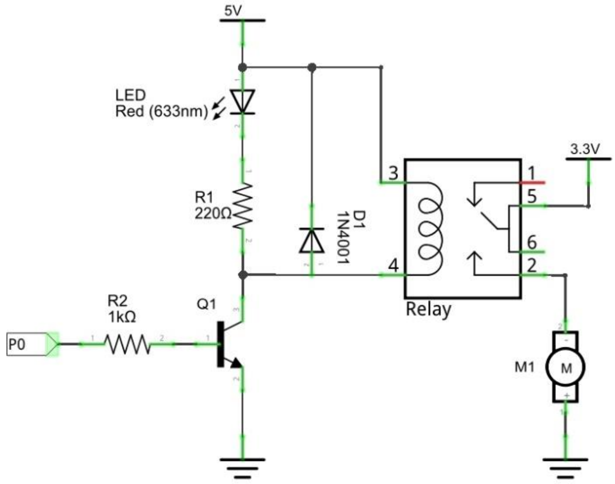


The circuit for a Relay is as follows: The coil of Relay can be equivalent to an Inductor, when a Transistor is present in this coil circuit it can disconnect the power to the relay, the current in the Relay’s coil does not stop immediately, which affects the power supply adversely. To remedy this, diodes in parallel are placed on both ends of the Relay coil pins in opposite polar direction. Having the current pass through the diodes will avoid any adverse effect on the power supply.

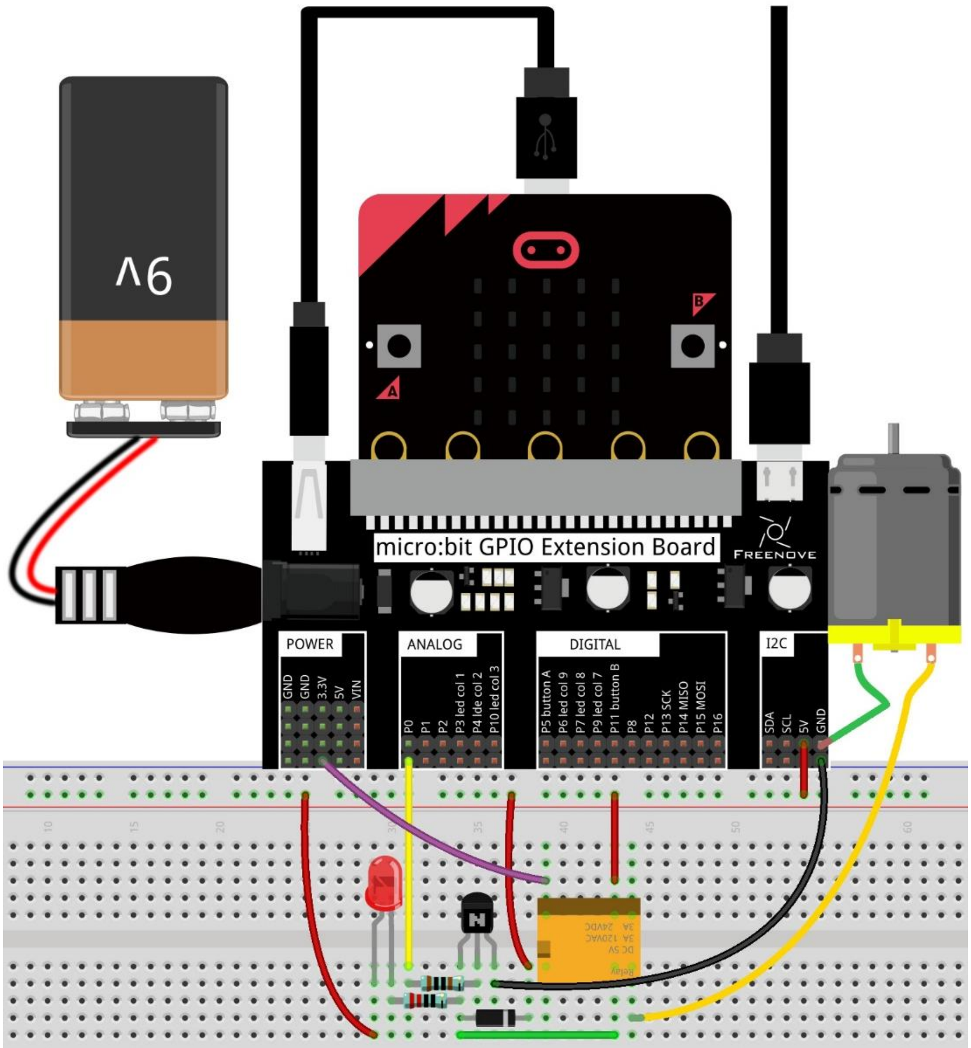


## Circuit

Schematic diagram




Hardware connection

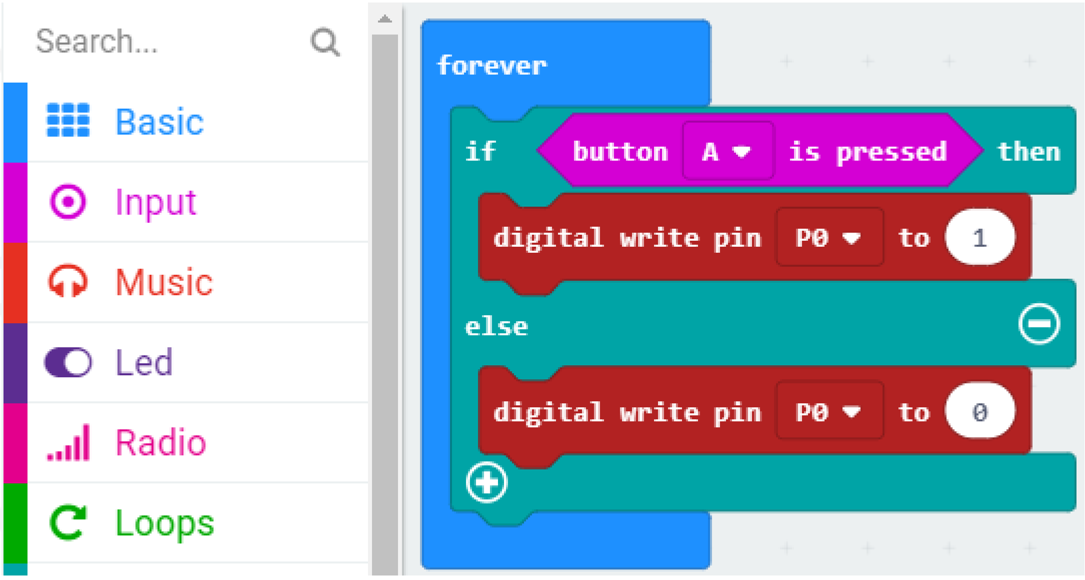


## Block code

Open MakeCode first. Import the .hex file. The path is as below:
(How to import project)

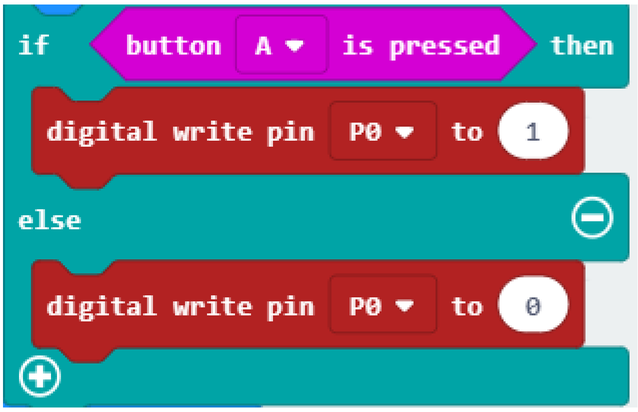
| File type | Path | File name |
|---|---|---|
| **HEX file** | ../Projects/BlockCode/21.1_Relay | Relay.hex |

After importing successfully, the code is shown as below:




Check the connection of the circuit, verify it correct, and download the code into micro:bit. Press button A, then the motor starts to rotate. Release the button, then the motor stops.

It is to determine whether the button A is pressed. If pressed, P0 outputs a high level, the relay is turned on, and the motor is running; if it is not pressed, P0 outputs a low level, and the motor does not run.

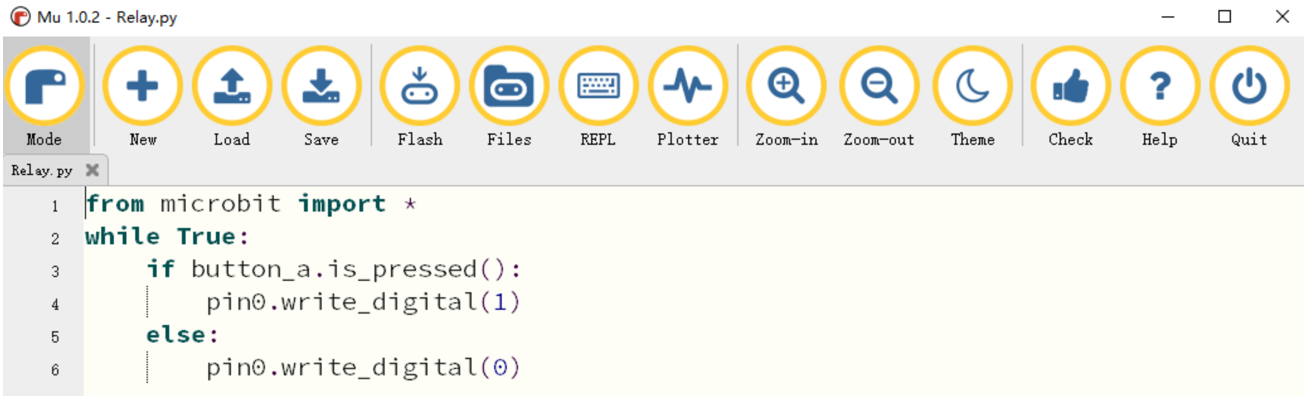


## Python code

Open the .py file with Mu. Code, the path is as below:

| File type | Path | File name |
|---|---|---|
| **Python file** | ../Projects/PythonCode/21.1_Relay | Relay.py |

After loading successfully, the code is shown as below:




Check the connection of the circuit, verify it correct, and download the code into micro:bit. Press button A, then the motor starts to rotate. Release the button, then the motor stops.

The following is the program code:

```
from microbit import *
while True:
    if button_a.is_pressed():
        pin0.write_digital(1)
    else:
        pin0.write_digital(0)
```

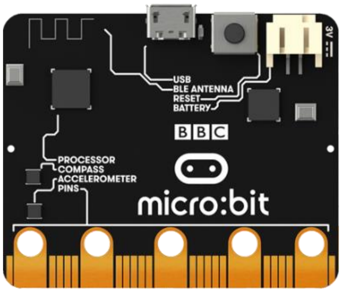
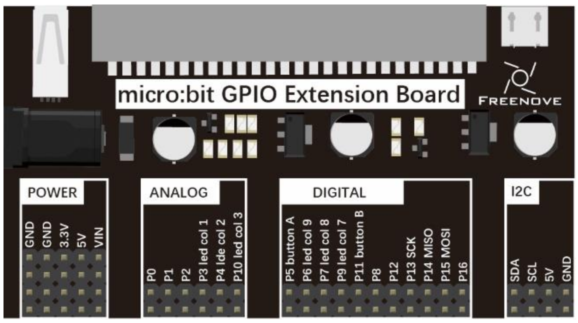
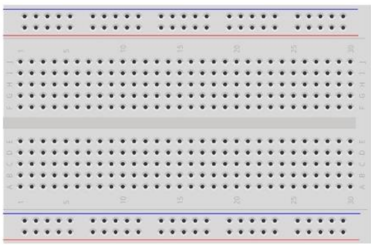
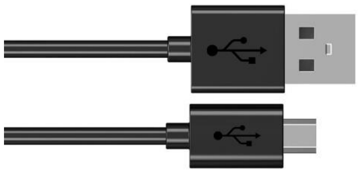
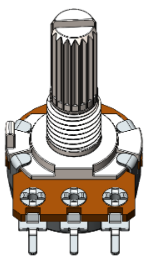
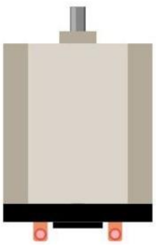
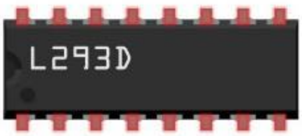
If A is pressed, P0 outputs a high level, the relay is turned on, and the motor is running. If it is not pressed, P0 outputs a low level, and the motor does not run.

```
    if button_a.is_pressed():
        pin0.write_digital(1)
    else:
        pin0.write_digital(0)
```

# Project 21.2 Potentiometer & Motor

In this project, a rotary potentiometer is used to control a motor.

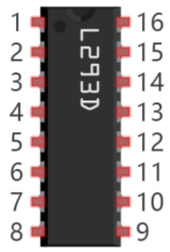
## Component list

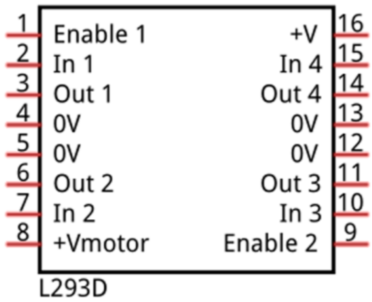
| | |
|---|---|
| Microbit x1   | Extension board x1   |
| Breadboard x1  | USB cable x2  |
| F/M x9 M/M x3  | Rotary potentionmeter x1  |
| Motor x1  | L293D x1   |

# Component knowledge

### L293D

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

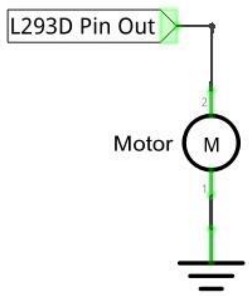


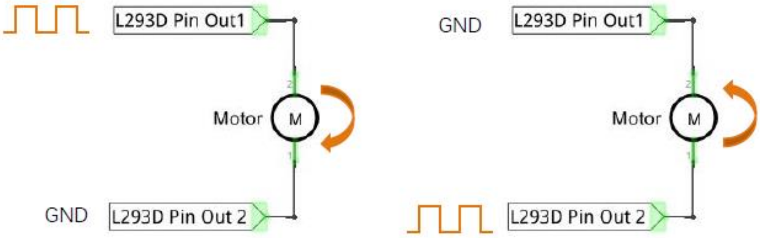

Port description of L293D module is as follows:

| Pin name | Pin number | Description |
|---|---|---|
| In x | 2, 7, 10, 15 | Channel x digital signal input pin |
| Out x | 3, 6, 11, 14 | Channel x output pin, input high or low level according to In x pin, get connected to +Vmotor or 0V |
| Enable1 | 1 | Channel 1 and channel 2 enable pin, high level enable |
| Enable2 | 9 | Channel 3 and channel 4 enable pin, high level enable |
| 0V | 4, 5, 12, 13 | Power cathode (GND) |
| +V | 16 | Positive electrode (VCC) of power supply, supply voltage 4.5~36V |
| +Vmotor | 8 | Positive electrode of load power supply, provide power supply for the Out pin x, the supply voltage is +V~36V |

For more details, please see datasheet.
When using the L293D to drive a DC Motor, there are usually two connection options.
The following connection option uses one channel of the L239D, which can control motor speed through the PWM, However the motor then can only rotate in one direction.



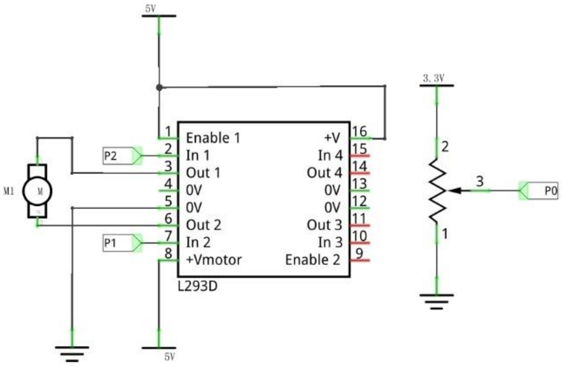

The following connection uses two channels of the L239D: one channel outputs the PWM wave, and the other channel connects to GND. Therefore, you can control the speed of the motor. When these two channel signals are exchanged, not only controls the speed of motor, but also can control the speed of the motor.



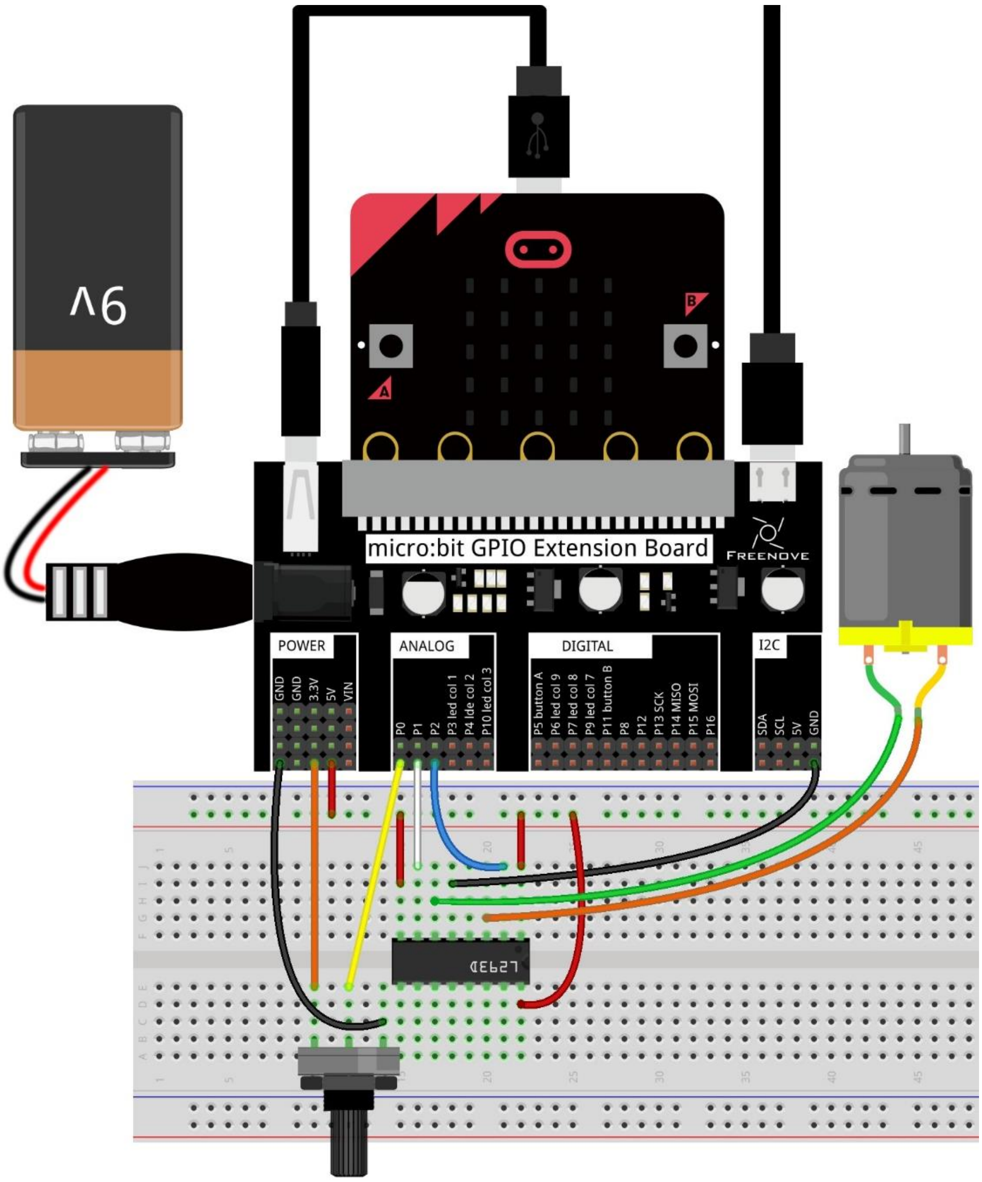

In practical use the motor is usually connected to channel 1 and by outputting different levels to in1 and in2 to control the rotational direction of the motor, and output to the PWM wave to Enable1 port to control the motor’s rotational speed. If the motor is connected to channel 3 and 4 by outputting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

# Circuit

Schematic diagram




Hardware connection

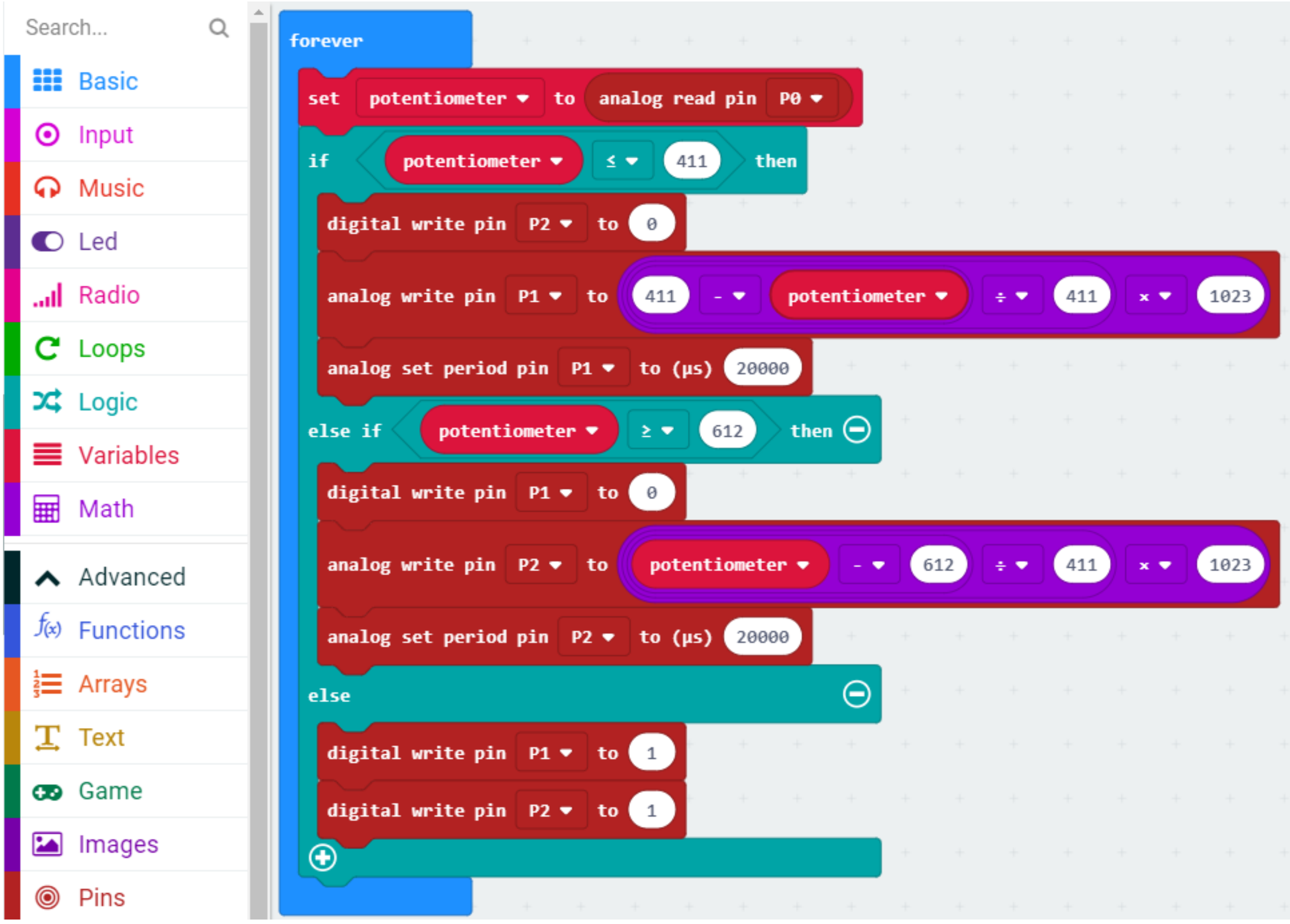


## Block code

Open MakeCode first. Import the .hex file. The path is as below:
(How to import project)

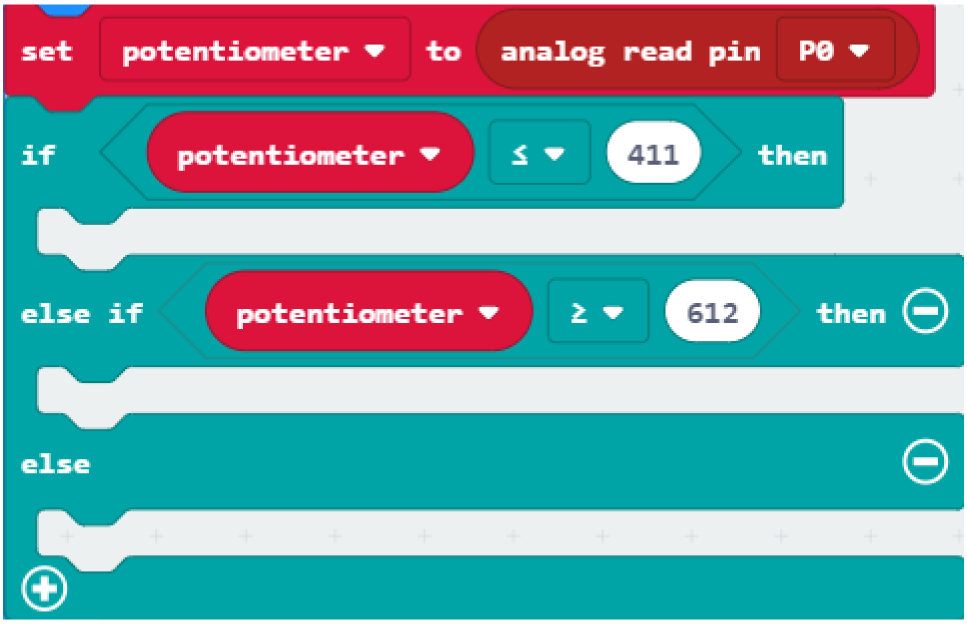
| File type | Path | File name |
|---|---|---|
| **HEX file** | ../Projects/BlockCode/21.2_Motor | Motor.hex |

After importing successfully, the code is shown as below:

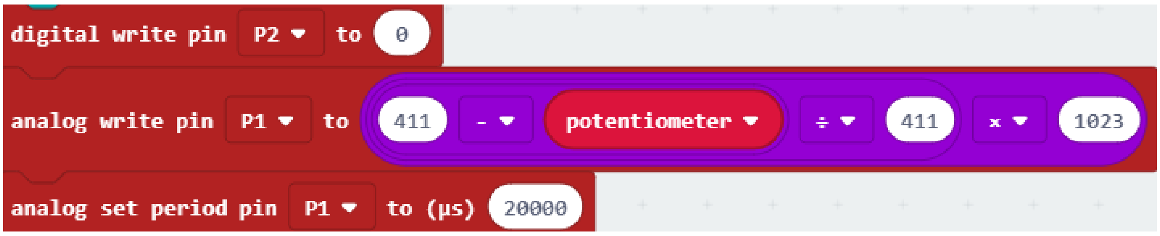



Check the connection of the circuit and verify it correct. Download the code into the micro:bit and rotate the potentiometer. When the potentiometer is in the middle position, the motor stops rotating. When the potentiometer gets away from middle position, the motor speed increases. The potentiometer moves to the limit and the motor speed reaches its maximum value. When the potentiometer is on a different side, the rotating direction of motor is different.

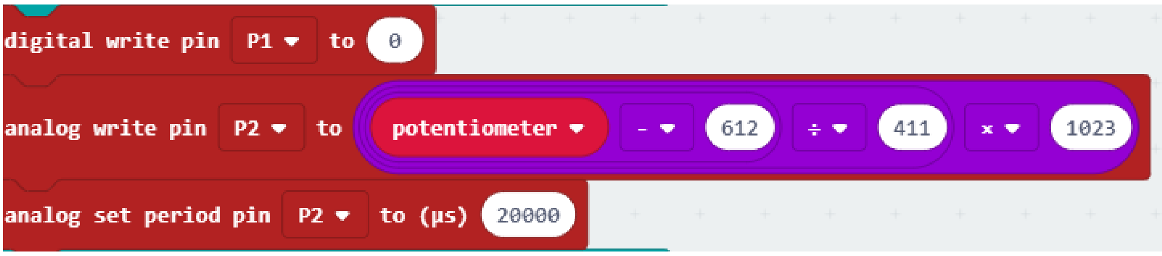
Read the analog value of the P0 pin of the potentiometer. When the analog value is less than 411, the motor rotates forward. When the analog value is greater than 612, the motor reverses. When the analog value is between 411 and 612, the motor does not rotate.




Set P2 to low level. P1 outputs PWM signal with an interval of 20ms and duty cycle changes with the change of potentiometer variable, then motor rotates forward.




Set P1 to low level, P2 output PWM signal with an interval of 20ms, duty cycle changes with the change of potentiometer variable, then motor rotates in a reverse direction.




When P1, P2 pin output high level, motor does not rotate.

## Reference

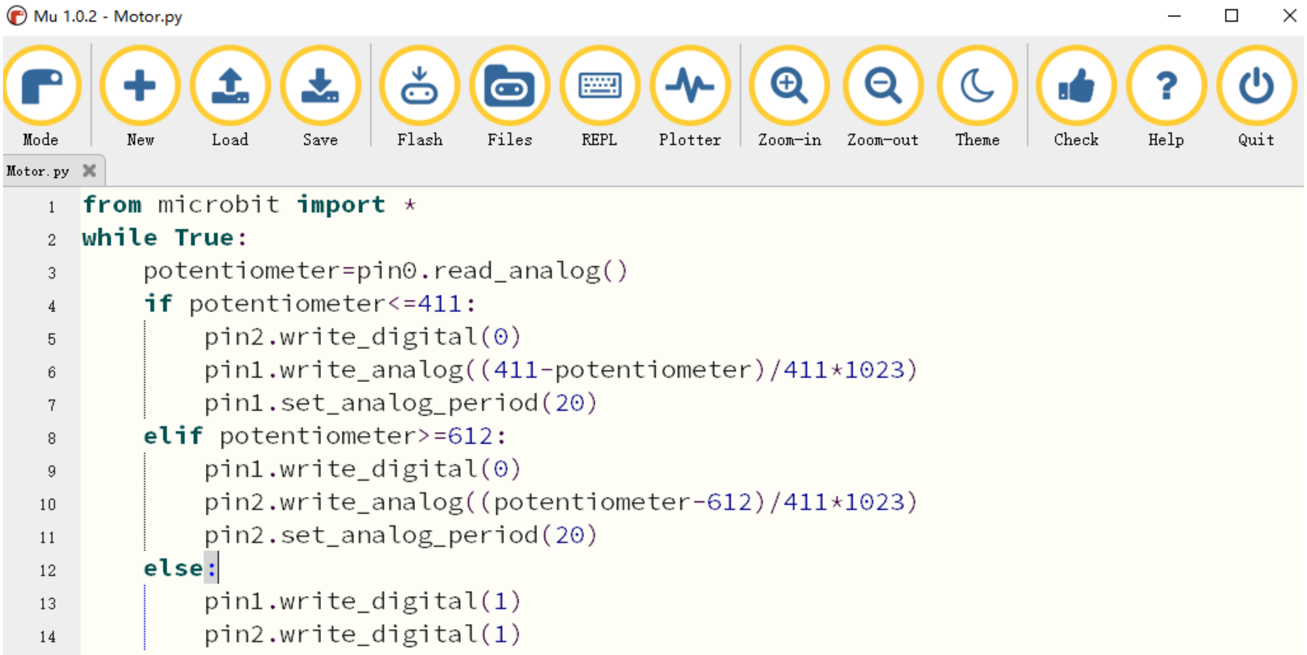
| Block | Function |
|---|---|
| analog write pin P0 ▾ to 1023 | Write an analog signal (0 through 1023) to the pin you set. |
| analog set period pin P0 ▾ to (µs) 20000 | Configure the period of Pulse Width Modulation (PWM) on the specified analog pin. Before you call this function, you should set the specified pin as analog. |

## Python code

Open the .py file with Mu. Code, the path is as below:

| File type | Path | File name |
|---|---|---|
| **Python file** | ../Projects/PythonCode/21.2_Motor | Motor.py |

After loading successfully, the code is shown as below:




Check the connection of the circuit and verify it correct. Download the code into the micro:bit and rotate the potentiometer. When the potentiometer is in the middle position, the motor stops rotating. When the potentiometer gets away from middle position, the motor speed increases. The potentiometer moves to the limit and the motor speed reaches its maximum value. When the potentiometer is on a different side, the rotating direction of motor is different.

The following is the program code:

```
from microbit import *
while True:
    potentiometer=pin0.read_analog()
    if potentiometer<=411:
        pin2.write_digital(0)
        pin1.write_analog((411-potentiometer)/411*1023)
        pin1.set_analog_period(20)
    elif potentiometer>=612:
        pin1.write_digital(0)
        pin2.write_analog((potentiometer-612)/411*1023)
        pin2.set_analog_period(20)
    else:
        pin1.write_digital(1)
        pin2.write_digital(1)
```

Read the analog value of the P0 pin of the potentiometer. When the analog value is less than 411, the motor rotates forward. When the analog value is greater than 612, the motor reverses. When the analog value is between 411 and 612, the motor does not rotate.

```
potentiometer=pin0.read_analog()
if potentiometer<=411:

elif potentiometer>=612:

else:
```

Set P2 to low level. P1 outputs PWM signal with an interval of 20ms, duty cycle changes with potentiometer variable, then motor rotates forward.

```
pin2.write_digital(0)
pin1.write_analog((411-potentiometer)/411*1023)
pin1.set_analog_period(20)
```

Set P1 to low level. P2 outputs PWM signal with an interval of 20ms, duty cycle changes with the change of potentiometer variable, then motor rotates in a reverse direction.

```
pin1.write_digital(0)
pin2.write_analog((potentiometer-612)/411*1023)
pin2.set_analog_period(20)
```

When P1, P2 pins output high level, motor does not rotate.

```
pin1.write_digital(1)
pin2.write_digital(1)
```

## Reference

| |
|---|
| `pin.set_analog_period(int)` |
| sets the interval; of the PWM output of the pin in milliseconds<br>see https://en.wikipedia.org/wiki/Pulse-width_modulation |
| `pin.write_analog(value)` |
| value is between 0 and 1023 |

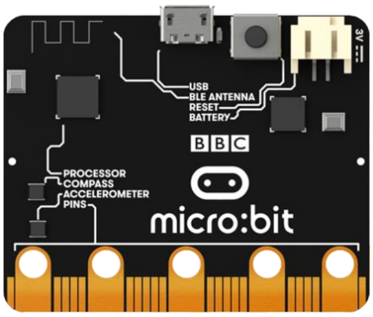
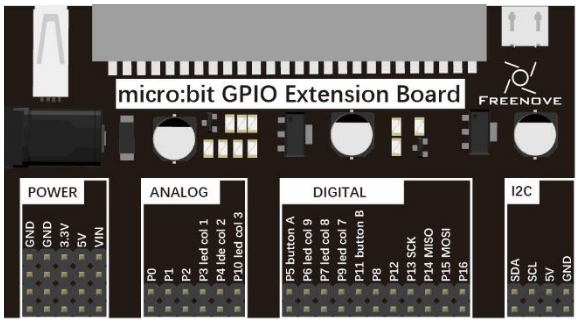
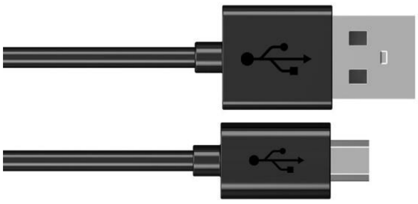
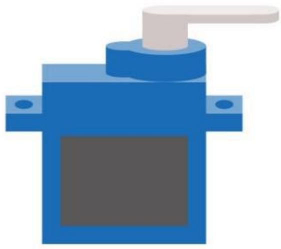
# Chapter 22 Servo

In this chapter, we will learn about Servos which are a rotary actuator type motor that can be controlled rotate to specific angles.

## Project 22.1 Sweep

In this project, we will use a servo.

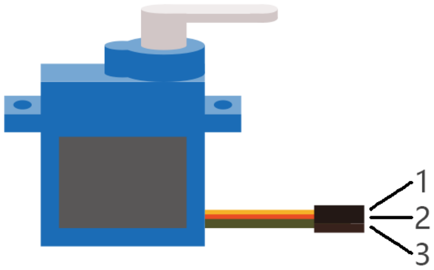
### Component list

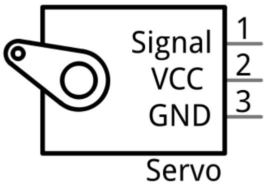
| | |
|---|---|
| Microbit x1<br><br> | Extension board x1<br><br> |
| USB cable x2<br> | Servo x1<br> |
| Jumper F/M x3<br> | |

# Component knowledge

## Servo

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



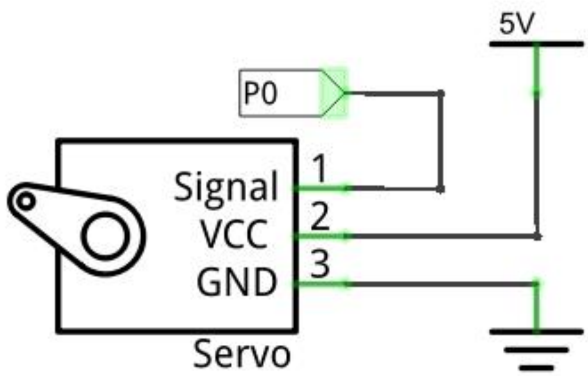
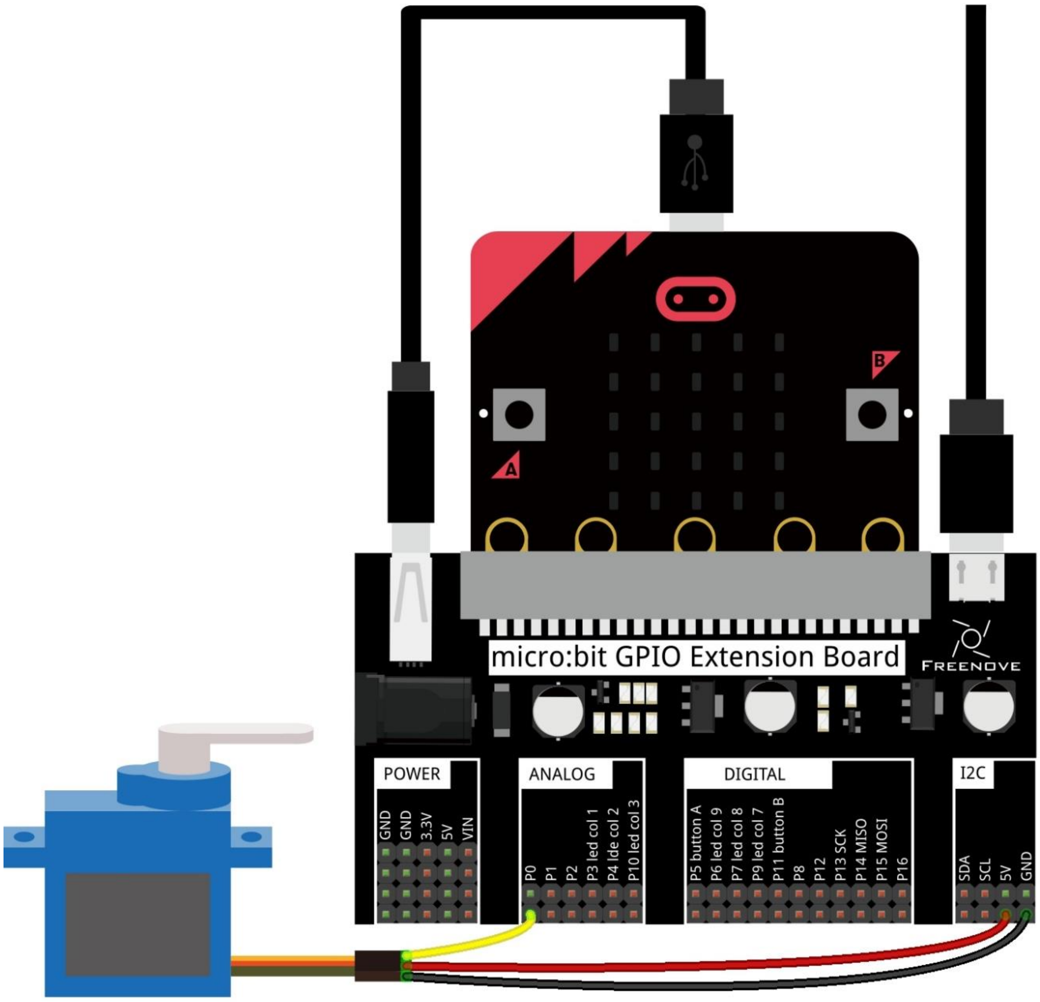

We will use a 50Hz PWM signal with a duty cycle in a certain range to drive the Servo. The lasting time 0.5ms-2.5ms of PWM single cycle high level corresponds to the Servo angle 0 degrees - 180 degree linearly. Part of the corresponding values are as follows:

| High level time | Servo angle |
|---|---|
| 0.5ms | 0 degree |
| 1ms | 45 degree |
| 1.5ms | 90 degree |
| 2ms | 135 degree |
| 2.5ms | 180 degree |

As can be seen from the above table, the servo rotates from 0 to 180 degrees, and the corresponding pulse width is 0.5-2.5ms. Then the analog voltage value is written to the micro:bit pin ranging from 25.6 to 128.

# Circuit

This circuit Servo is powered by 5V, and the Micro:bit P0 pin controls the Servo rotation angle.

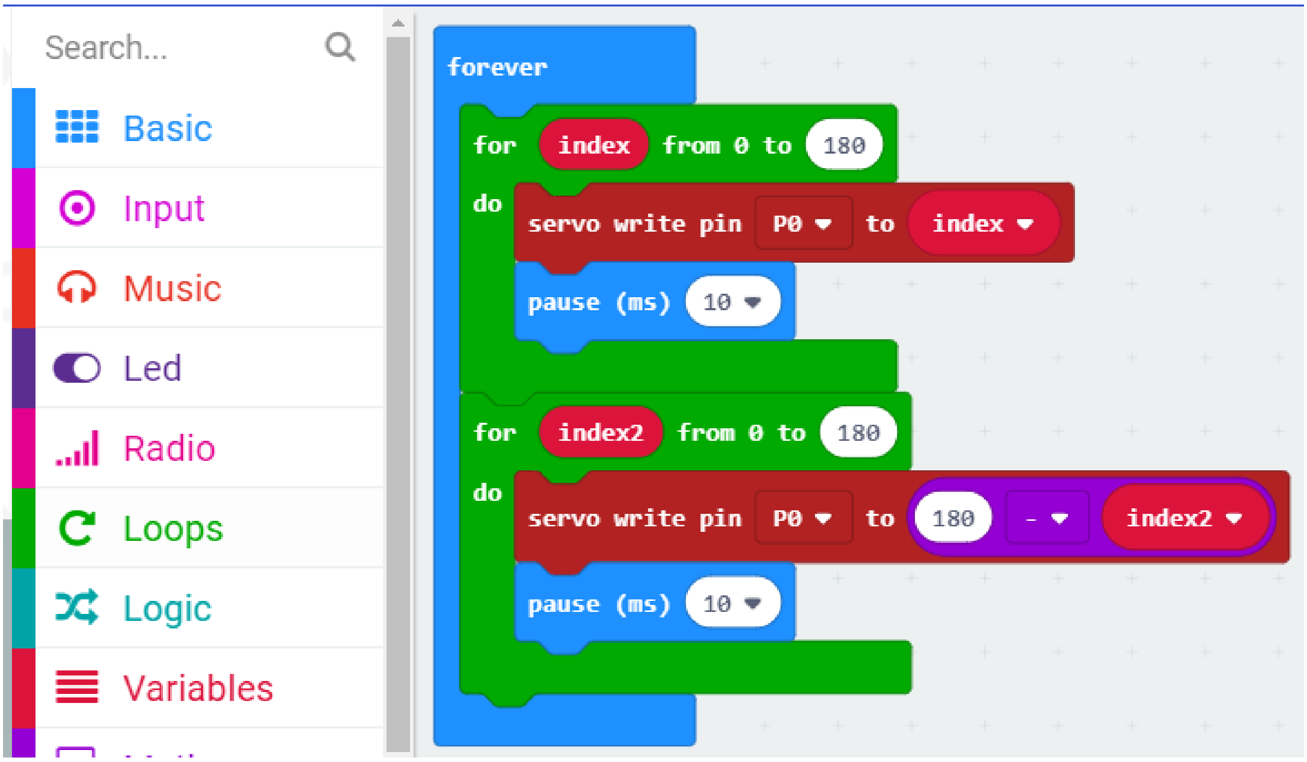
| Diagram schematic |
|---|
|  |
| Hardware connection |
|  |

## Block code

Open MakeCode first. Import the .hex file. The path is as below:
(How to import project)

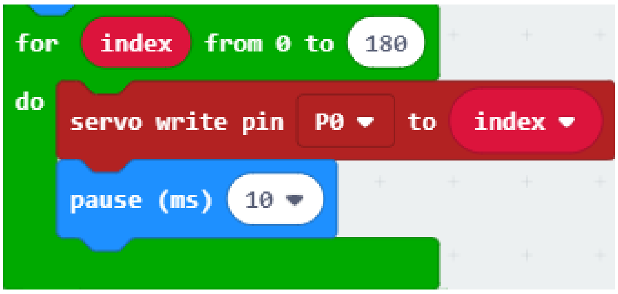
| File type | Path | File name |
|---|---|---|
| HEX file | ../Projects/BlockCode/22.1_Sweep | Sweep.hex |

After importing successfully, the code is shown as below:

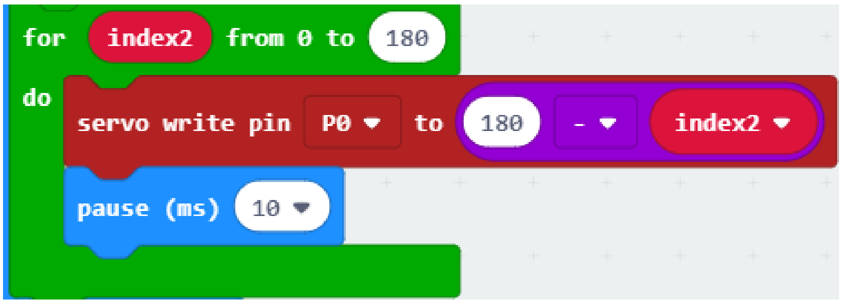



Check the connection of the circuit, verify it correct, and download the code into micro:bit. The servo rotates from 0 degrees to 180 degrees, then from 180 degrees to 0 degrees, and repeats in an endless loop.

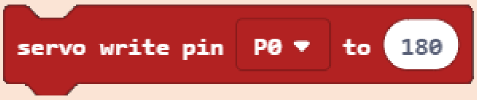
In the for loop of 0-180, let the servo change from 0 to 180 degrees.



In the for loop of 0-180, take the difference between 180 and index2, and let the servo rotate from 180 degrees to 0 degrees.




## Reference

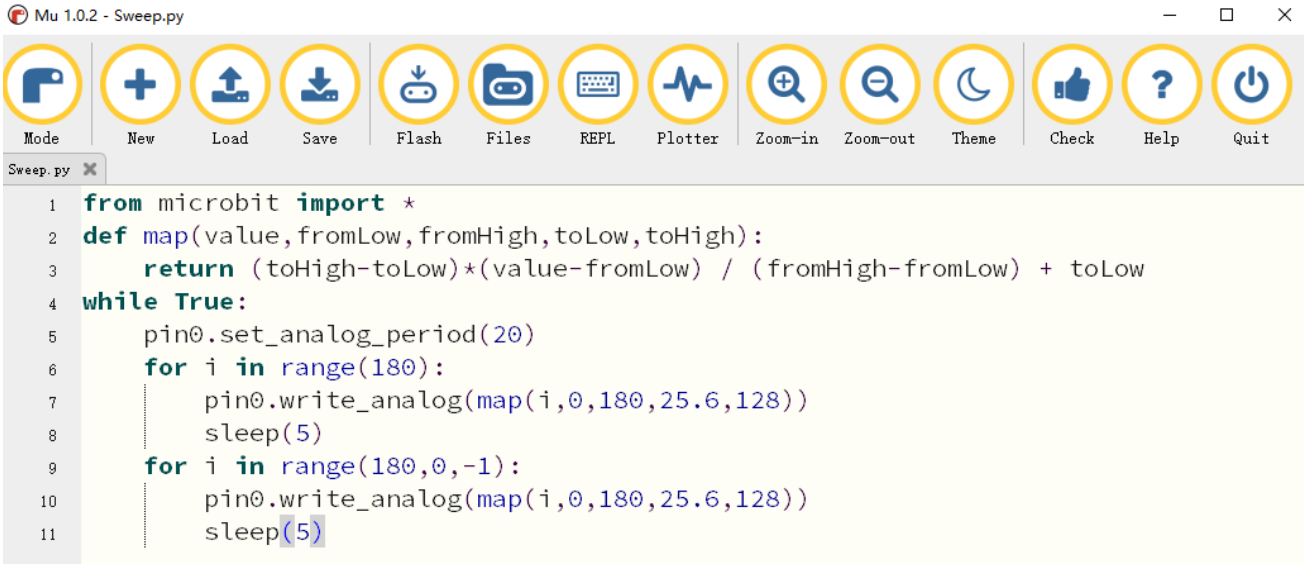
| Block | Function |
| --- | --- |
|  | Write a value to the servo on the specified pin and control the shaft. |

# python code

Open the .py file with Mu. Code, the path is as below:

| File type | Path | File name |
|---|---|---|
| Python file | ../Projects/PythonCode/22.1_Sweep | Sweep.py |

After loading successfully, the code is shown as below:




After checking the connection of the circuit and verifying it correct, download the code into micro:bit, and then the servo will from 0 degree to 180 degree, and then from 180 degree to 0 degree, which repeats in an endless loop.

The following is the program code:

```
from microbit import *
def map(value, fromLow, fromHigh, toLow, toHigh):
    return (toHigh-toLow)*(value-fromLow) / (fromHigh-fromLow) + toLow
while True:
    pin0.set_analog_period(20)
    for i in range(180):
        pin0.write_analog(map(i, 0, 180, 25.6, 128))
        sleep(5)
    for i in range(180, 0, -1):
        pin0.write_analog(map(i, 0, 180, 25.6, 128))
        sleep(5)
```

Define map functions to convert values in one range to values in another range.

```
def map(value,fromLow,fromHigh,toLow,toHigh):
    return (toHigh-toLow)*(value-fromLow) / (fromHigh-fromLow) + toLow
```

Set the interval of the PWM signal to 20ms. In a 0-180 for loop, convert the value in the range 0-180 to an analog voltage value in the range of 25.6~128, and then output the corresponding PWM signal to turn the servo from 0 degrees to 180 degrees.

```
pin0.set_analog_period(20)
for i in range(180):
    pin0.write_analog(map(i,0,180,25.6,128))
    sleep(5)
```

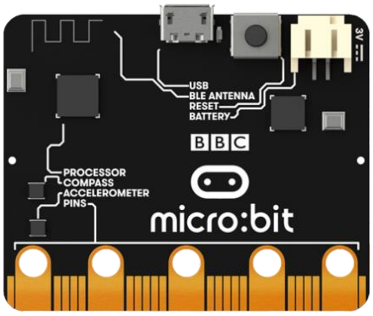
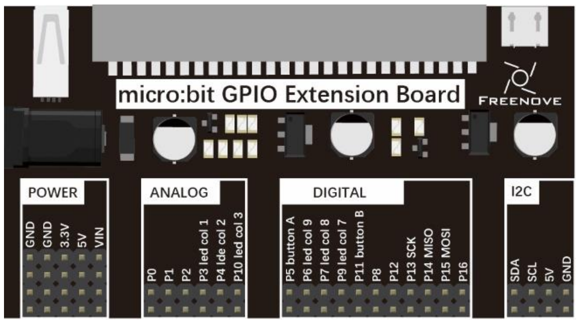
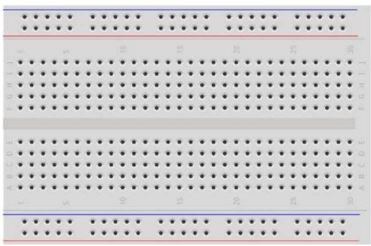
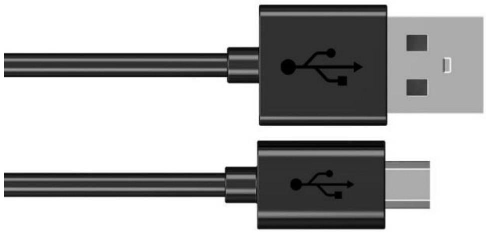
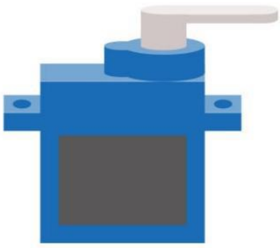
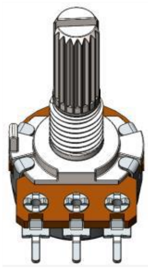
In a 180-0 for loop, convert the value in the range 0-180 to the analog voltage value in the range of 25.6~128, and then output the corresponding PWM signal to rotate the servo from 180 degrees to 0 degrees.

```
for i in range(180,0,-1):
    pin0.write_analog(map(i,0,180,25.6,128))
    sleep(5)
```

# Project 22.2 Knob

In this project, we will use a potentiometer to control the rotation angle of the Servo.

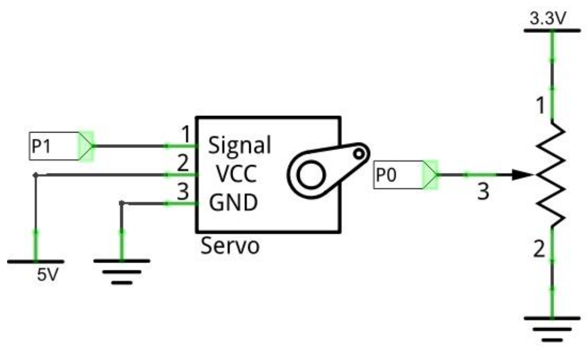
## Component list

<table>
<tr><td colspan="3">Microbit x1<br>
</td><td colspan="3">Extension board x1<br>
</td></tr>
<tr><td colspan="3">Breadboard x1<br></td><td colspan="3">USB cable x2<br></td></tr>
<tr><td colspan="2">Servo x1<br></td><td colspan="2">Rotary potentiometer x1<br></td><td colspan="2">F/M x6<br></td></tr>
</table>

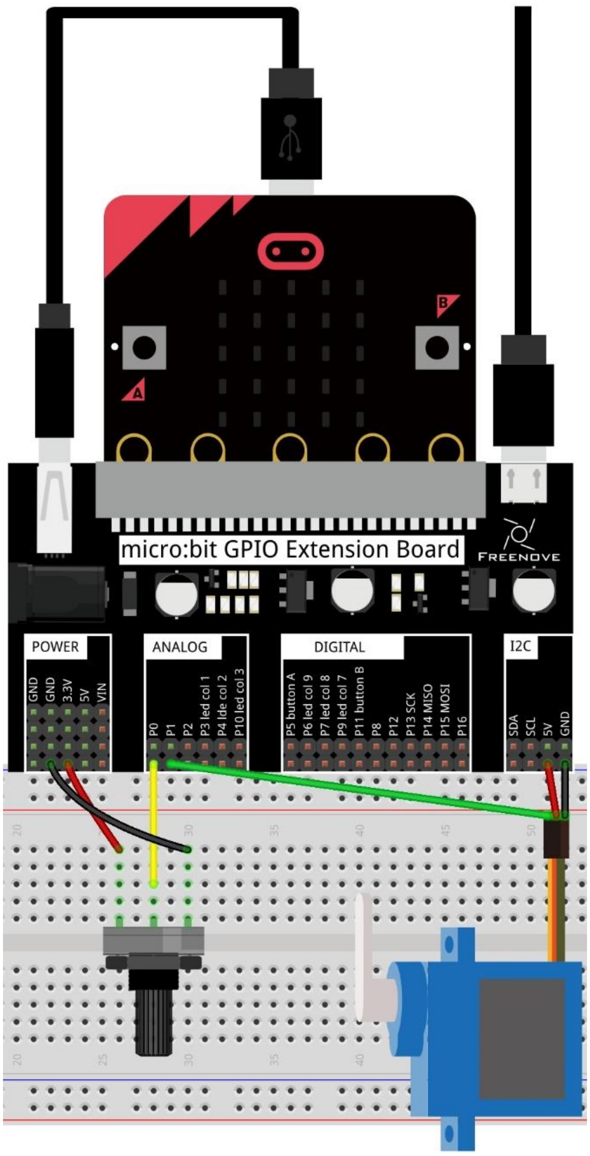
# Circuit

The P0 pin of this circuit microbit reads the voltage of the potentiometer, and the P1 pin drives the servo.

Schematic diagram




Hardware connection



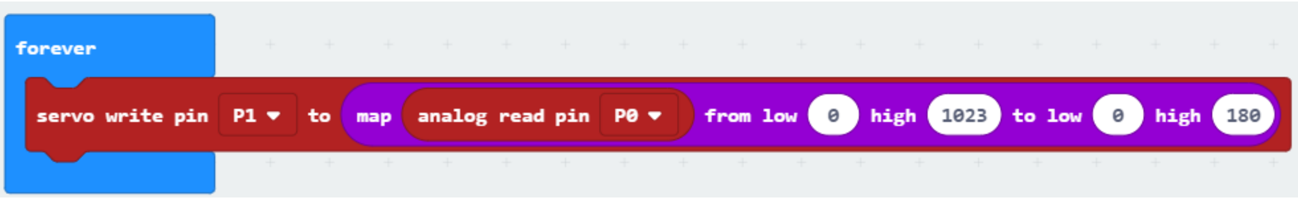
# Block code

Open MakeCode first. Import the .hex file. The path is as below:

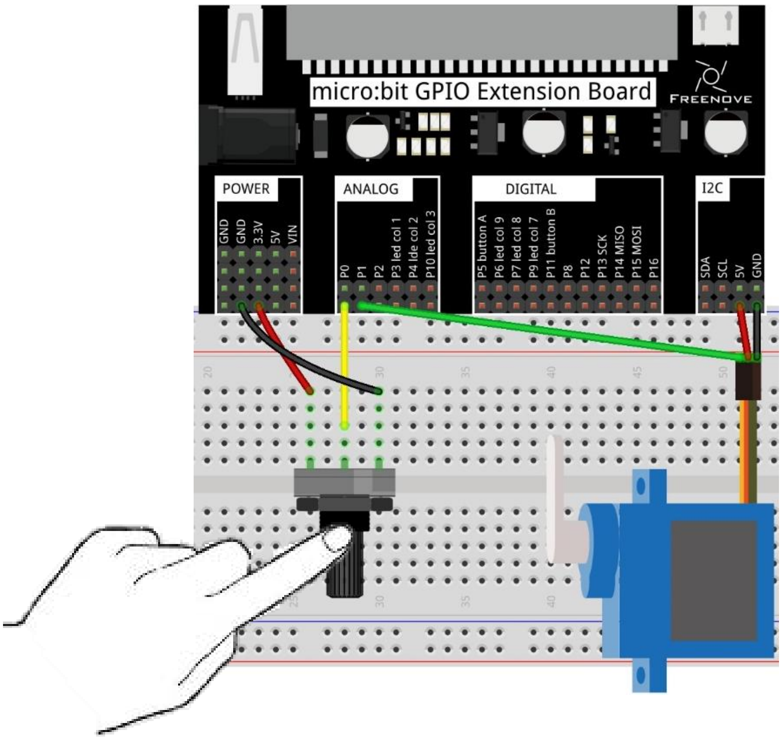
(How to import project)

| File type | Path | File name |
|---|---|---|
| HEX file | ../Projects/BlockCode/22.2_Knob | Knob.hex |

After importing successfully, the code is shown as below:




Check the connection of the circuit and verify it correct, download the code into the micro:bit, rotate the potentiometer, and the servo will follow the rotation.



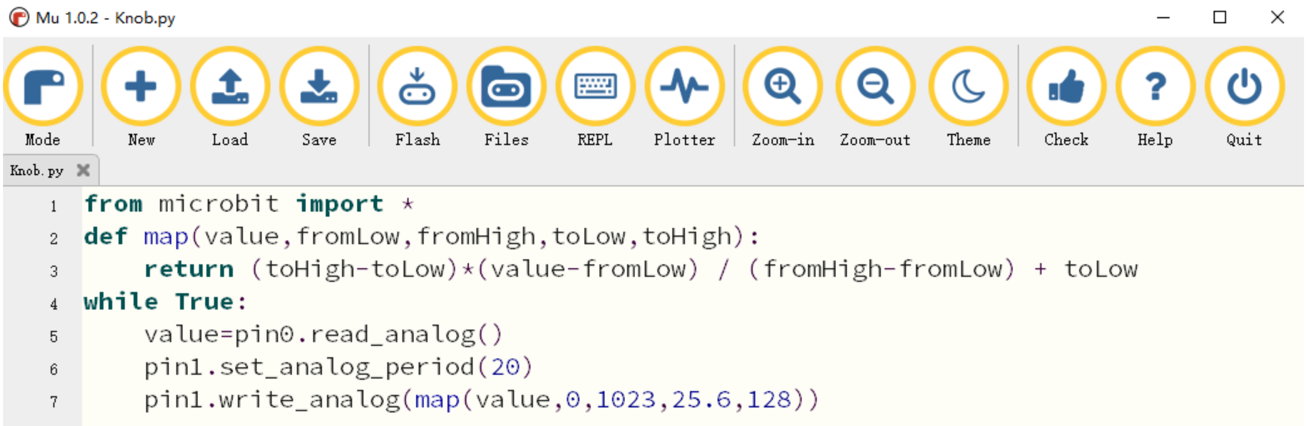

Read the analog voltage value of the P0 pin, map the analog voltage value in the range of 0-1023 to the angle of the servo in the range of 0-180, and then drive the servo to rotate the corresponding angle through the P1 pin.

# Python code

Open the .py file with Mu. Code, the path is as below:

| File type | Path | File name |
|---|---|---|
| **Python file** | ../Projects/PythonCode/22.2_Knob | Knob.py |

After loading successfully, the code is shown as below:




Check the connection of the circuit and verify it correct, download the code into the micro:bit, rotate the potentiometer, and the servo will follow the rotation.

The following is the program code:

```
from microbit import *
def map(value, fromLow, fromHigh, toLow, toHigh):
    return (toHigh-toLow)*(value-fromLow) / (fromHigh-fromLow) + toLow
while True:
    value=pin0.read_analog()
    pin1.set_analog_period(20)
    pin1.write_analog(map(value, 0, 1023, 25.6, 128))
```

Define map functions to convert values in one range to values in another range.

```
def map(value, fromLow, fromHigh, toLow, toHigh):
    return (toHigh-toLow)*(value-fromLow) / (fromHigh-fromLow) + toLow
```

Set the period of PWM signal to 20 ms. Read the analog voltage value of P0 foot, convert the analog voltage value in the range of 0-1023 to the analog voltage value in the range of 25.6-128, and then output the corresponding PWM signal to rotate the servo at the corresponding angle.

```
value=pin0.read_analog()
pin1.set_analog_period(20)
pin1.write_analog(map(value, 0, 1023, 25.6, 128))
```

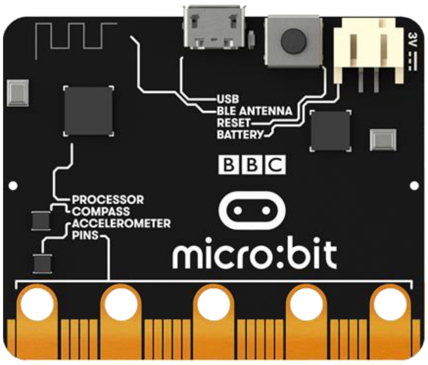
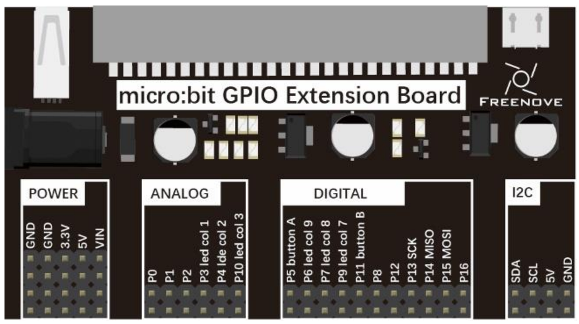
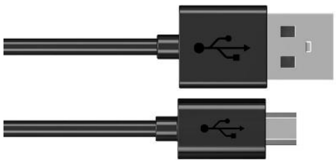
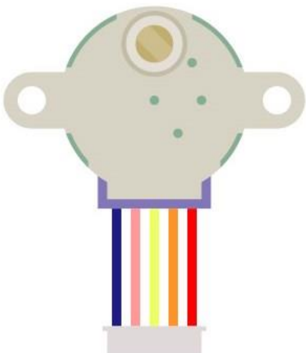
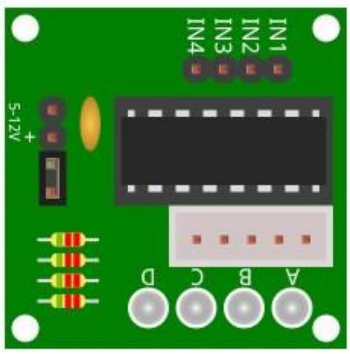
# Chapter 23 Stepper Motor

In this chapter, we will learn how to drive a Stepper Motor, and understand its working principle.

## Project 23.1 Stepper Motor

In this project, we will use micro:bit to control a stepper motor.

### Component list

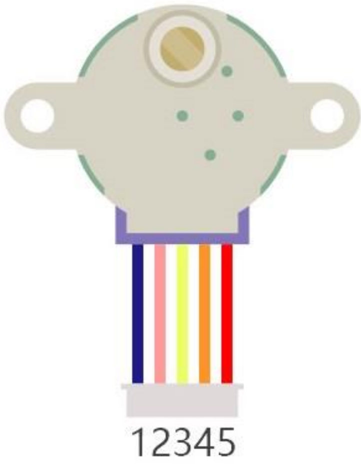
| | |
|---|---|
| Microbit x1   | Extension board x1   |
| USB cable x2  | Jumper F/F x6  |
| Stepper Motor x1  | ULN2003 Stepper Motor Driver x1   |

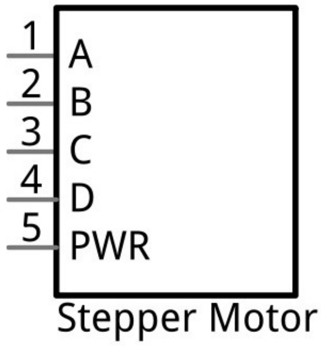
# Component knowledge

## Stepper Motor

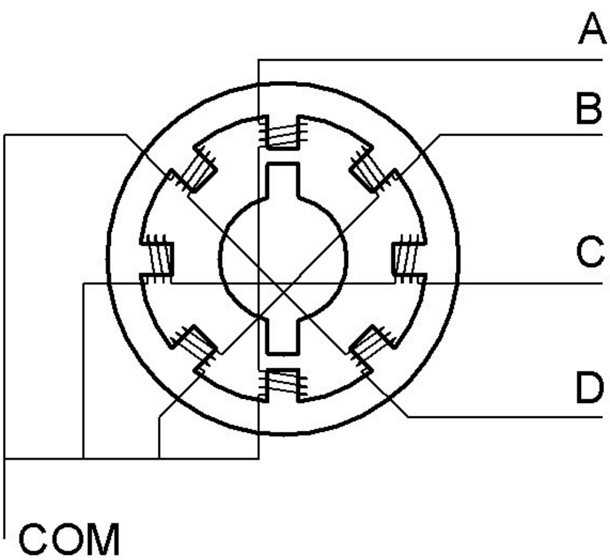
Stepper Motors are an open-loop control device, which converts an electronic pulse signal into angular displacement or linear displacement. In a non-overload condition, the speed of the motor and the location of the stops depends only on the pulse signal frequency and number of pulses and is not affected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

A small Four-Phase Deceleration Stepper Motor is shown here:



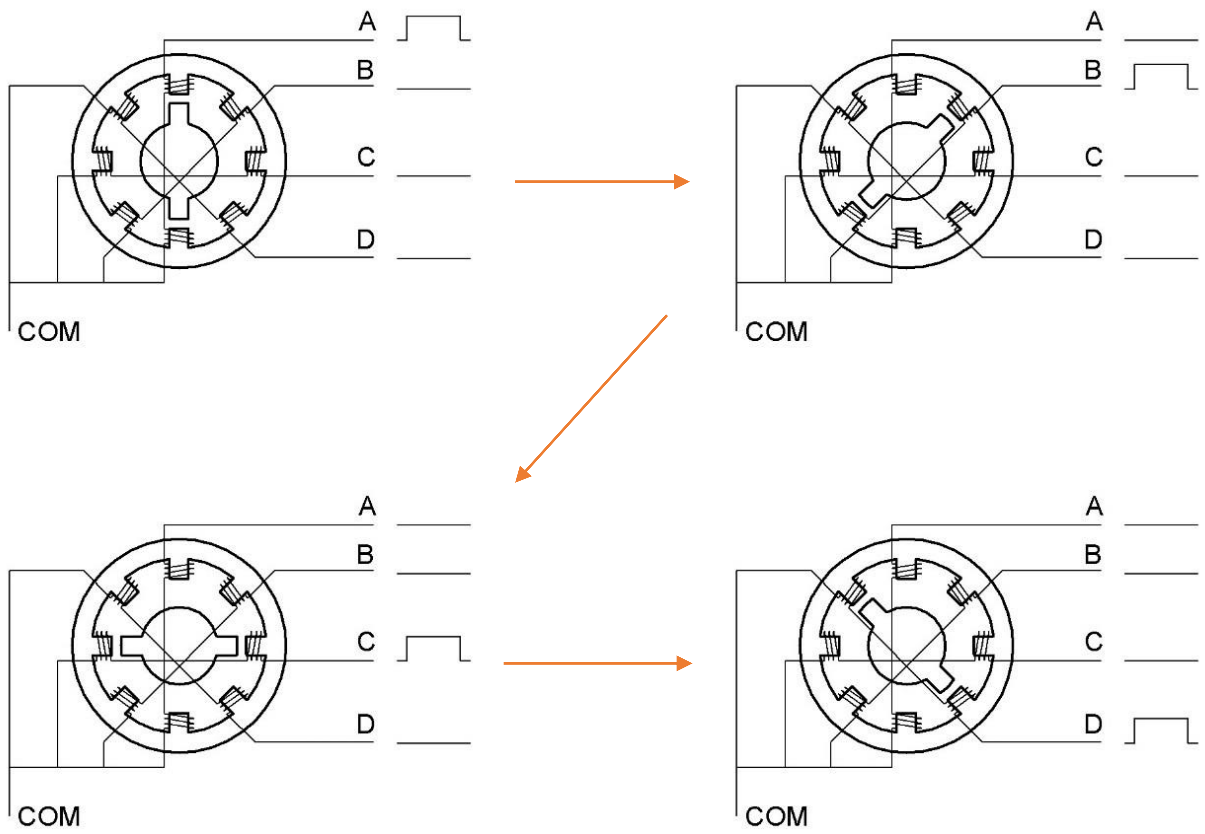




The schematic diagram of a four-phase stepping motor is shown below:




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

A common driving process is as follows:



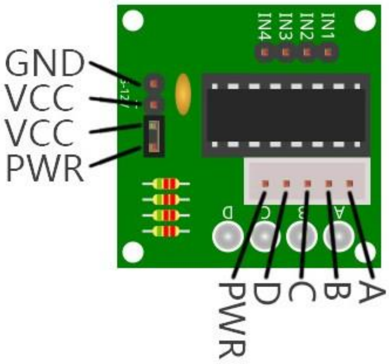

In the sequence above, the Stepper Motor rotates once at a certain angle, which is called a “step”. By controlling the number of rotational steps, you can then control the Stepper Motor’s rotation angle. By defining the time between two steps, you can control the Stepper Motor’s rotation speed. When rotating clockwise, the order of coil powered on is: A → B → C → D → A →······ . And the rotor will rotate in accordance with this order, step by step, called four-steps, four-part. If the coils is powered ON in the reverse order, D → C → B → A → D →··· , the rotor will rotate in counter-clockwise direction.

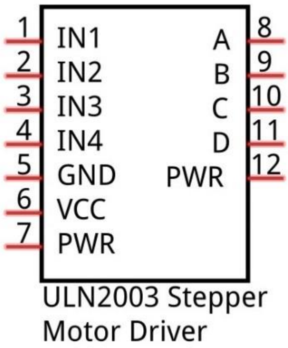
There are other methods to control Stepper Motors, such as: connect A phase, then connect A B phase, the stator will be located in the center of A B, which is called a half-step. This method can improve the stability of the Stepper Motor and reduces noise. Tise sequence of powering the coils looks like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

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

## ULN2003 Stepping motor driver

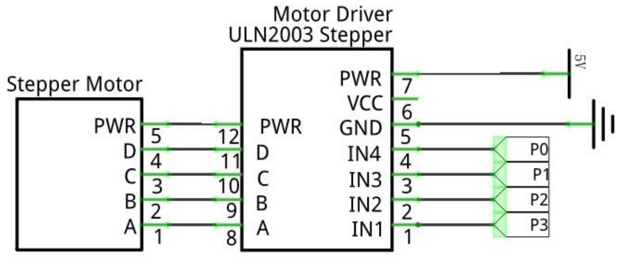
A ULN2003 Stepper Motor Driver is used to convert weak signals into more powerful control signals in order to drive the Stepper Motor. In the illustration below, the input signal IN1-IN4 corresponds to the output signal A-D, and 4 LEDs are integrated into the board to indicate the state of these signals.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



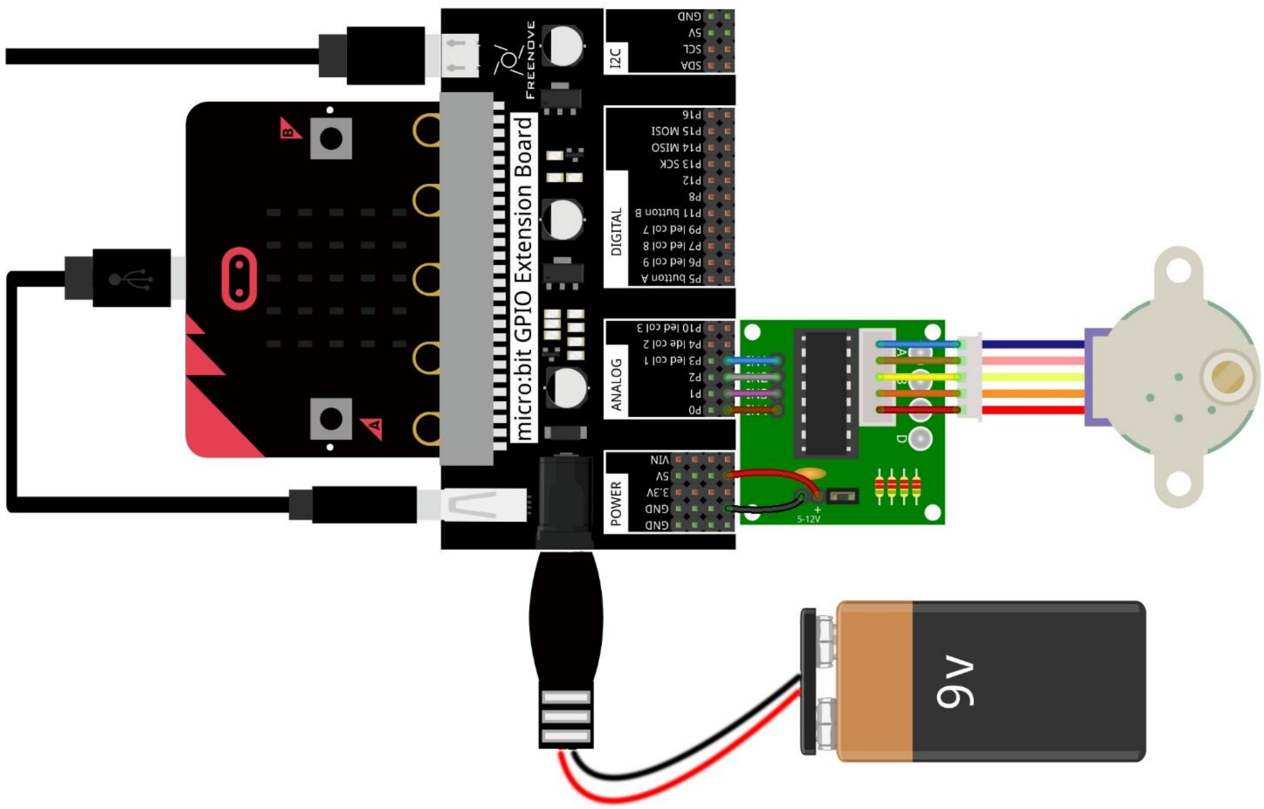



## Circuit

Schematic diagram




Hardware connection

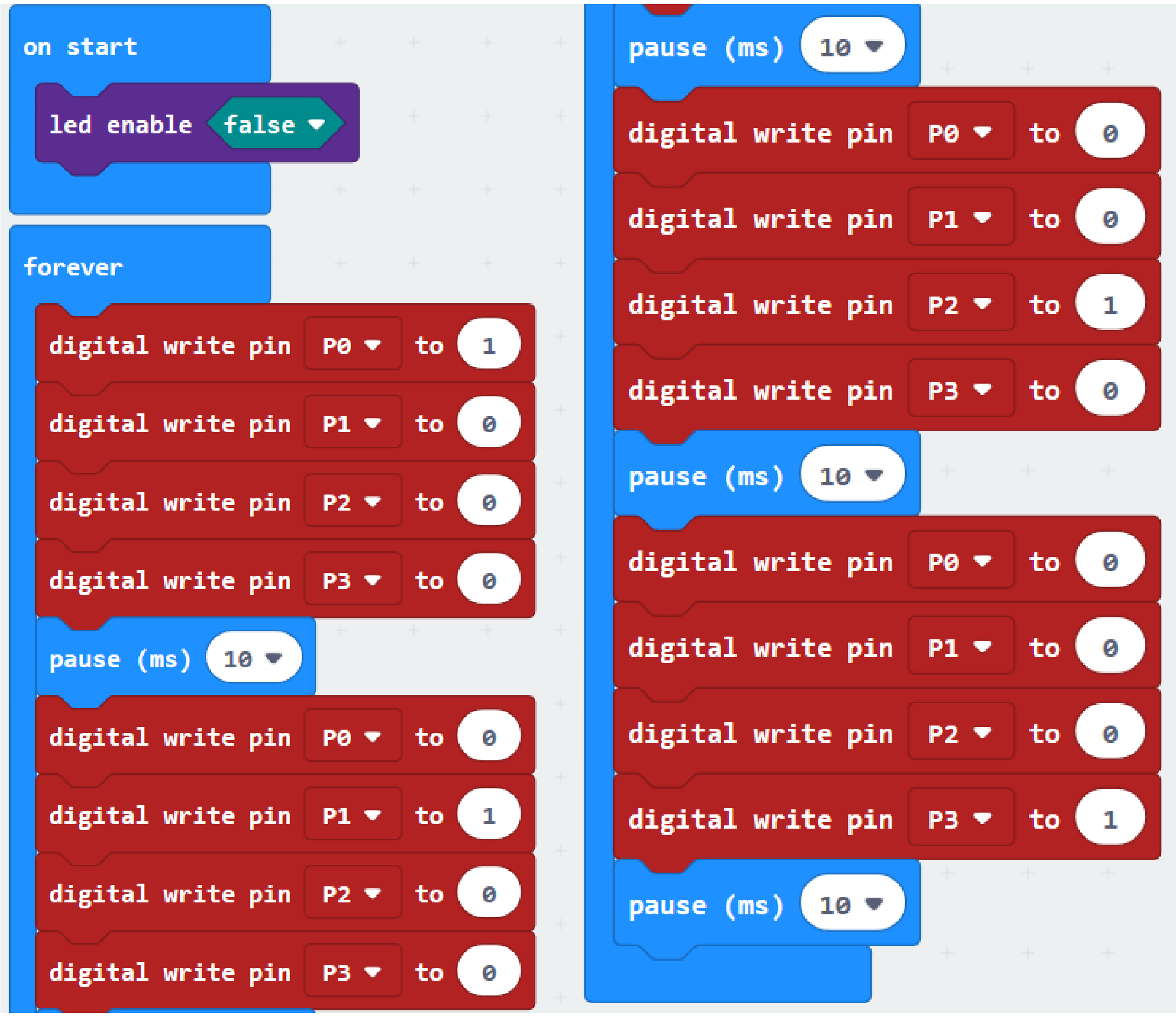


## Block code

Open MakeCode first. Import the .hex file. The path is as below:
(How to import project)

| File type | Path | File name |
|---|---|---|
| HEX file | ../Projects/BlockCode/23.1_StepperMotor | StepperMotor.hex |

After importing successfully, the code is shown as below:




After checking the connection of the circuit and verifying it correct, download the code into micro:bit, and then the stepper motor will rotate slowly.

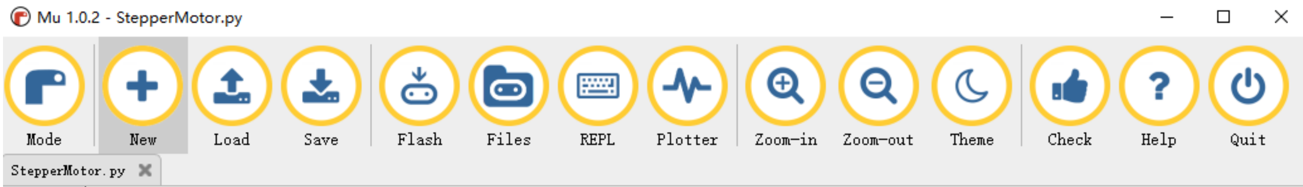
In the code, the pins of P0, P1, P2 and P3 is set to high level in turn. When one pin is at a high level, set the other three pins to low level. So the coil is energized as follows: A_B_C_D_A... A_B_C_D_A_C_D... to make the stepper motor rotate.

## Python code

Open the .py file with Mu. Code, the path is as below:

| File type | Path | File name |
|---|---|---|
| Python file | ../Projects/PythonCode/23.1_StepperMotor | StepperMotor.py |

After loading successfully, the code is shown as below:




```
from microbit import *
display.off()
Pin = [pin0, pin1, pin2, pin3]
while True:
    for i in Pin:
        for j in Pin:
            if i == j:
                j.write_digital(1)
            else:
                j.write_digital(0)
        sleep(10)
```

After checking the connection of the circuit and verifying it correct, download the code into micro:bit, and the stepper motor rotates slowly.

The following is the program code:

```
from microbit import *
display.off()
Pin = [pin0, pin1, pin2, pin3]
while True:
    for i in Pin:
        for j in Pin:
            if i == j:
                j.write_digital(1)
            else:
                j.write_digital(0)
         sleep(10)
```

Close the LED dot matrix screen to allow the GPIO pins associated with the LED dot matrix screen to be reused for other purposes. Define Pin list to store P0, P1, P2, P3 pin variables.

```
display.off()
Pin = [pin0, pin1, pin2, pin3]
```

In the for loop, the pin order with output high level is P0, P1, P3 P0.... When one pin outputs high level, make the other three pins output low levels. Make the coil electrified as follows: A_B_C_D_A_... to make stepper motor rotate.

```
for i in Pin:
    for j in Pin:
        if i == j:
            j.write_digital(1)
        else:
            j.write_digital(0)
     sleep(10)
```

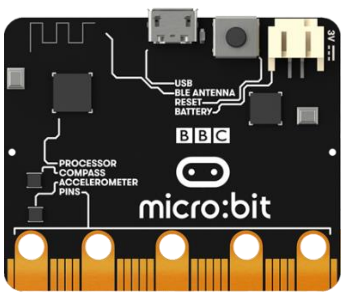
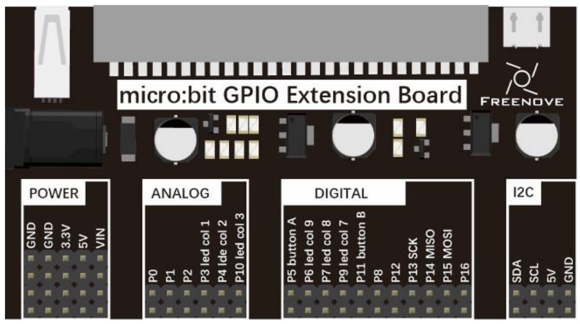
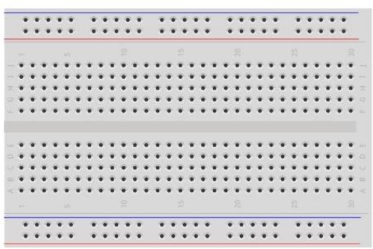
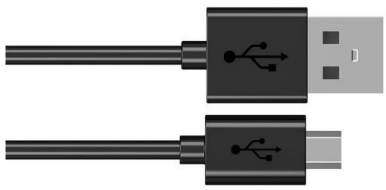
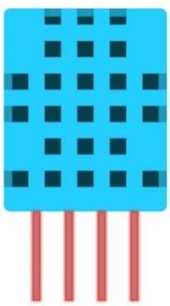
# Chapter 24 Hygrothermograph

In this chapter, we will learn a commonly used sensor - Thermohygrometer DHT11.

## Project 24.1 Hygrothermograph

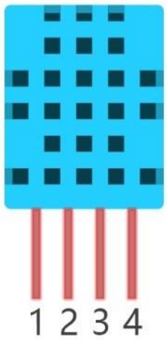
In this project, we will use the micro:bit to read and print the temperature and humidity data of DHT11.

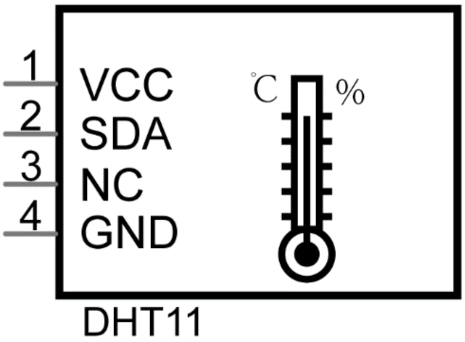
### Component list

<table>
<tr><td colspan="3">Microbit x1<br>
</td><td colspan="3">Extension board x1<br>
</td></tr>
<tr><td colspan="3">Breadboard x1<br></td><td colspan="3">USB cable x2<br></td></tr>
<tr><td colspan="2">DHT11 x1<br></td><td colspan="2">Resistor 10kΩ x1<br></td><td colspan="2">Jumper M/M x1 F/M x3<br></td></tr>
</table>

## Component knowledge

The Temperature & Humidity Sensor DHT11 is a compound temperature & humidity sensor, and the output digital signal has been calibrated by its manufacturer.

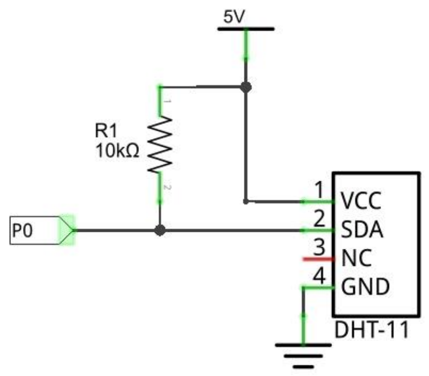


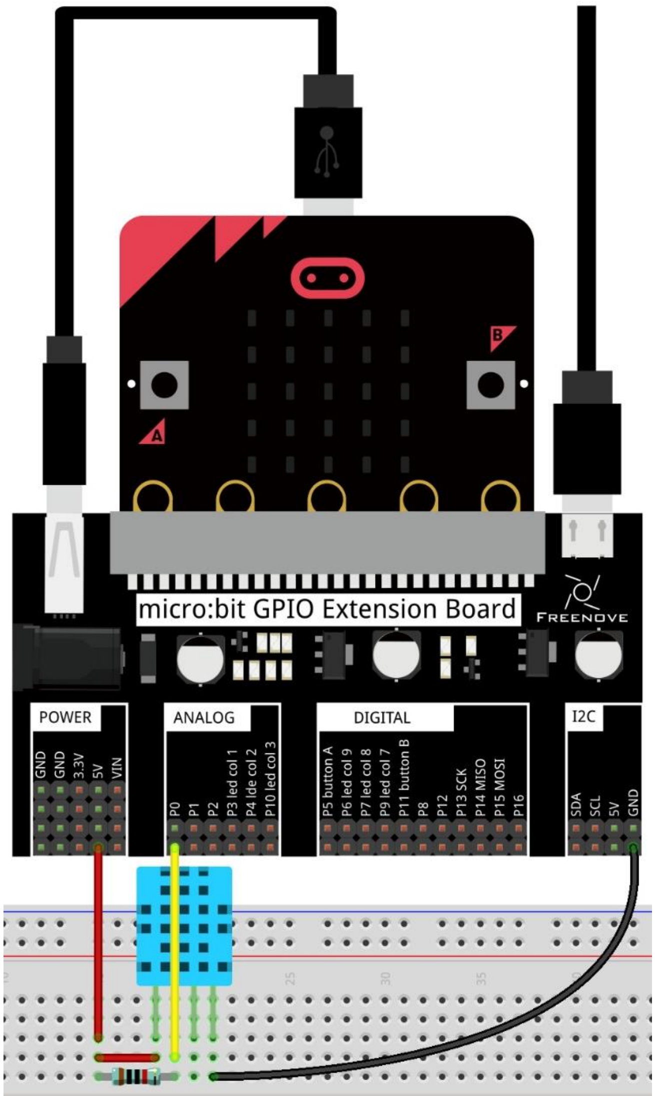

After being powered up, it will initialize in 1S's time. Its operating voltage is within the range of 3.3V-5.5V.
The SDA pin is a data pin, which is used to communicate with other devices.
The NC pin (Not Connected Pin) are a type of pin found on various integrated circuit packages. Those pins have no functional purpose to the outside circuit (but may have an unknown functionality during manufacture and test). Those pins should not be connected to any of the circuit connections.

## Circuit

Schematic diagram




Hardware connection

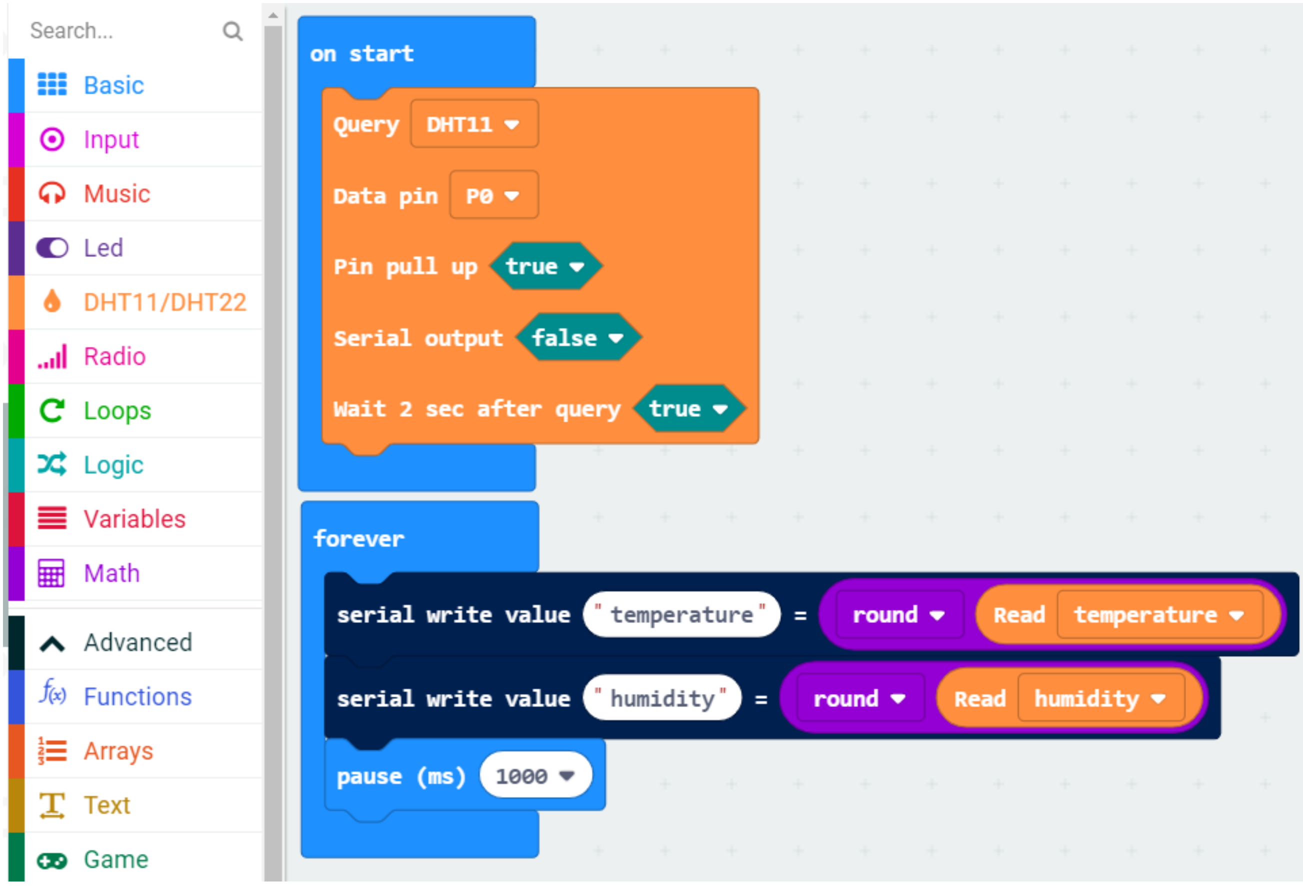


# Block code

Open MakeCode first. Import the .hex file. The path is as below:
(How to import project)

| File type | Path | File name |
|---|---|---|
| HEX file | ../Projects/BlockCode/24.1_DHT11 | DHT11.hex |

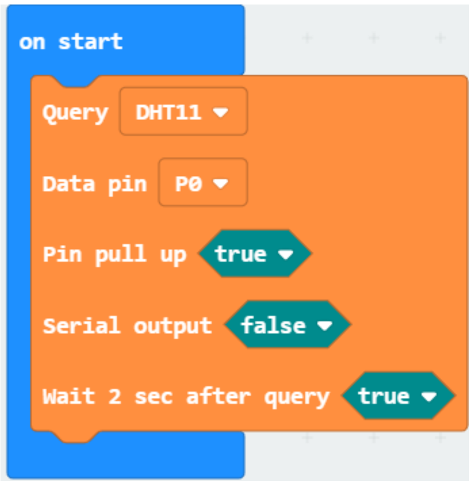
After importing successfully, the code is shown as below:



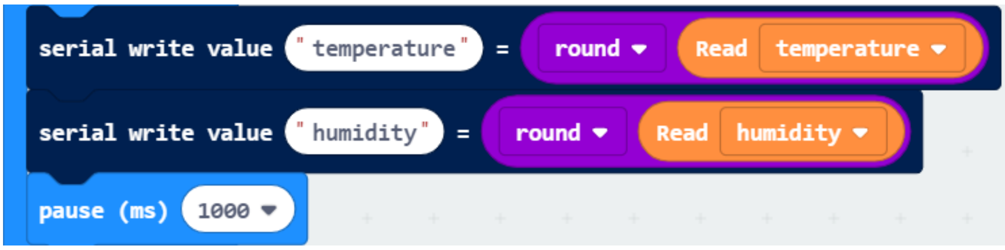

After checking the connection of the circuit and verifying it correct, download the code into micro:bit and open the serial port controller, you can see the temperature and humidity of the current environment, as shown in the following figure:

```
temperature:27
humidity:56
temperature:27
humidity:56
temperature:27
```

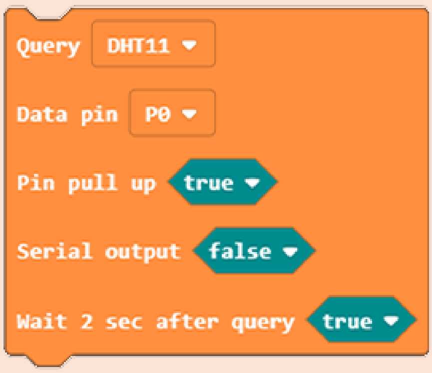
Set sensor type to DHT11, data pin to P0, initialize DHT11 module, wait for 2 seconds




Every 1 s, the temperature and humidity data read will be printed out by serial port controller.

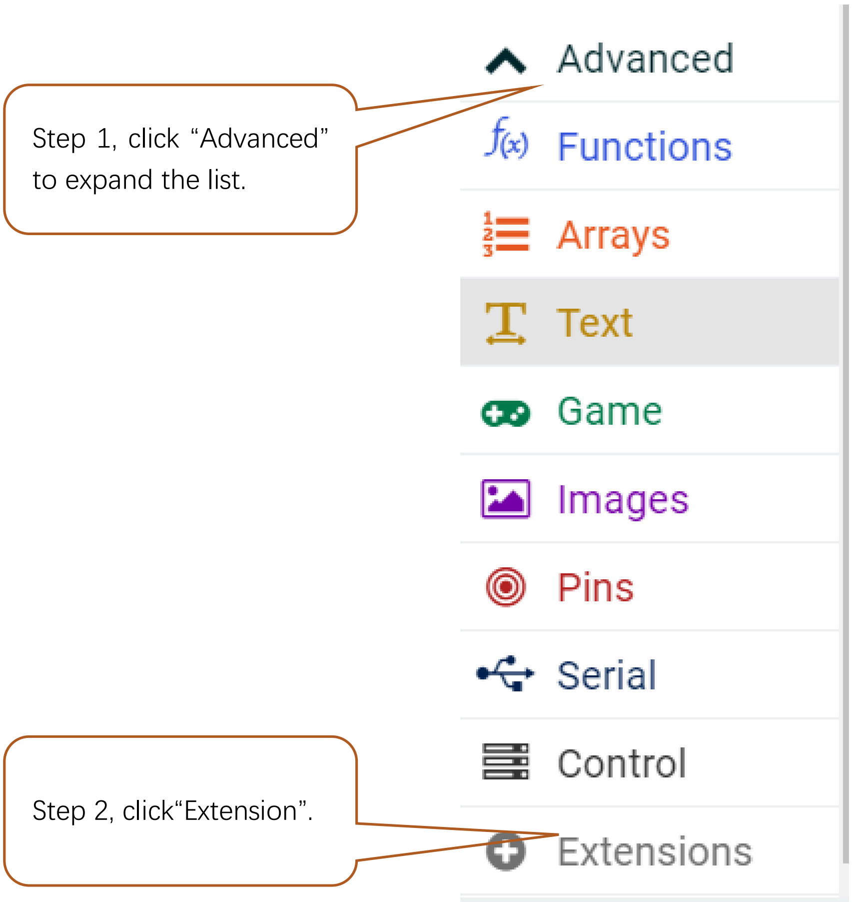


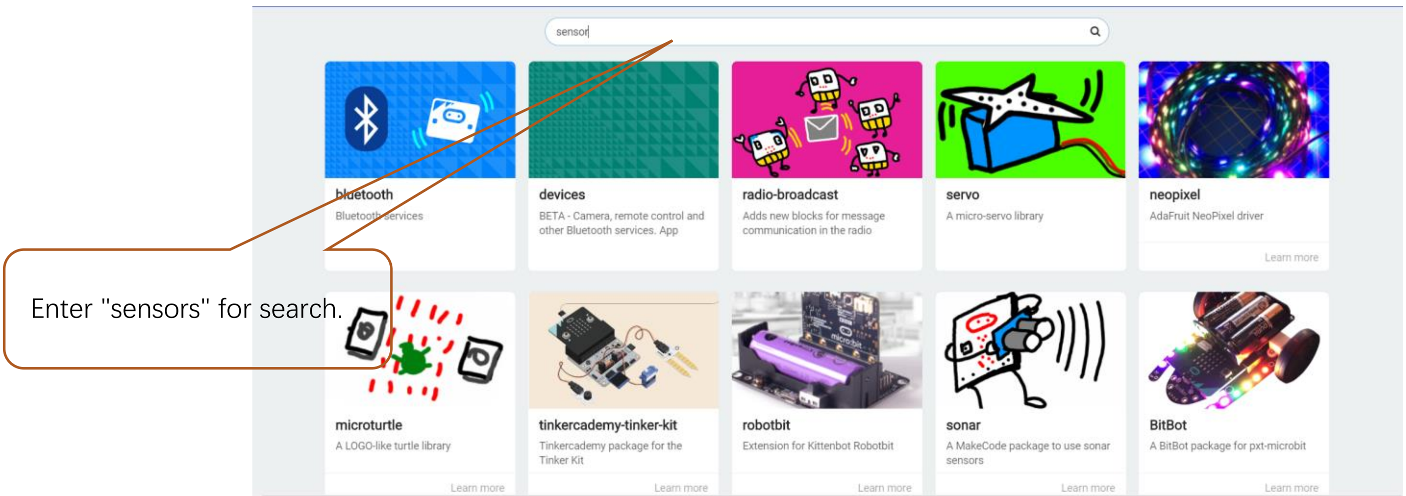

## Reference

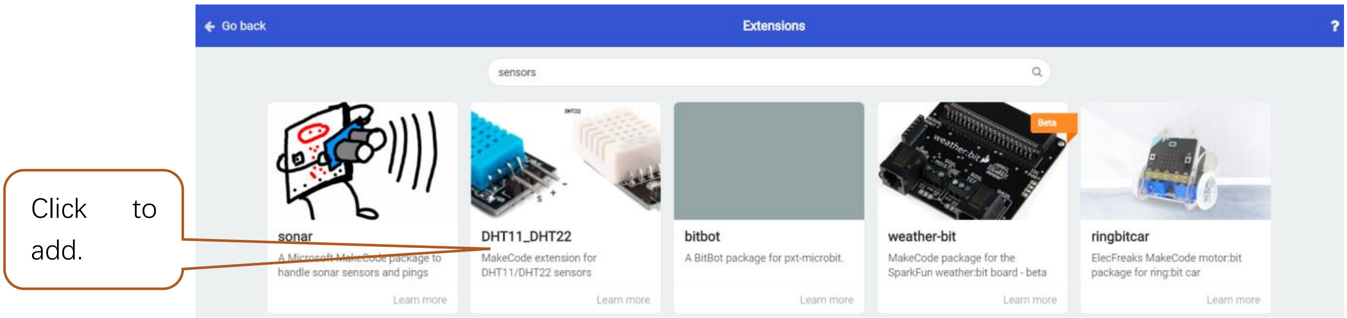
| Block | Function |
|---|---|
|   | Set sensor type DHT11 or DHT22, select data pin and initialize DHT module. |
|   | Read humidity level (%) or temperature (Celsius). |

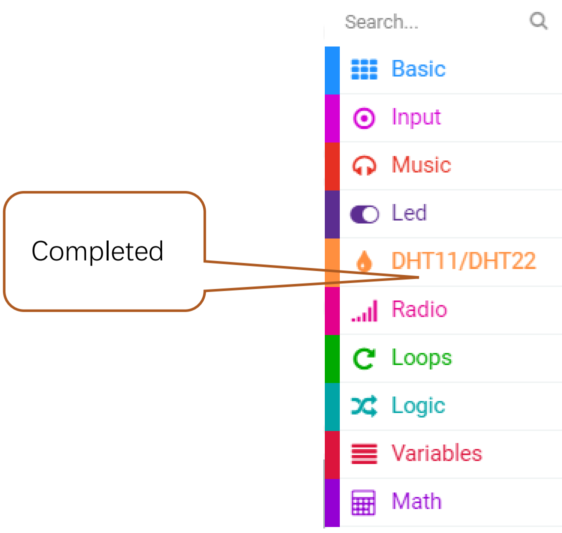
## Extensions

If you want to import the DHT Sensor Extension Block into your new project, follow these steps to add it.




Go back
Extensions
sensors
sonar
A Microsoft MakeCode package to handle sonar sensors and pings
DHT11_DHT22
MakeCode extension for DHT11/DHT22 sensors
bitbot
A BitBot package for pxt-microbit.
weather-bit
MakeCode package for the SparkFun weather:bit board - beta
ringbitcar
ElecFreaks MakeCode motor:bit package for ring:bit car
Learn more
Click to add.

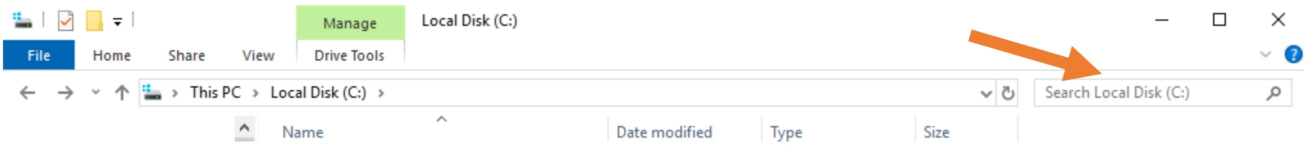

Search...
Basic
Input
Music
Led
DHT11/DHT22
Radio
Loops
Logic
Variables
Math
Completed

# Python code

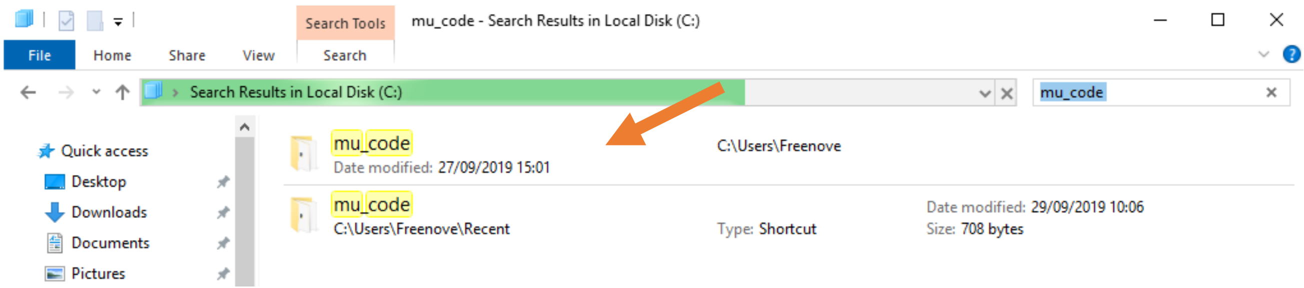
## Import necessary Python file into micro:bit

In the code of this tutorial, the LCD1602 module and DHT11 module are used, so it is necessary to import "I2C_LCD1602_Class.py" and "DHT11_RW.py" into the micro:bit. You can skip this section if you don't use them. When you need, you can come back to import them.

The import method is as follows:
Search on the C drive and find the "mu_code" folder.



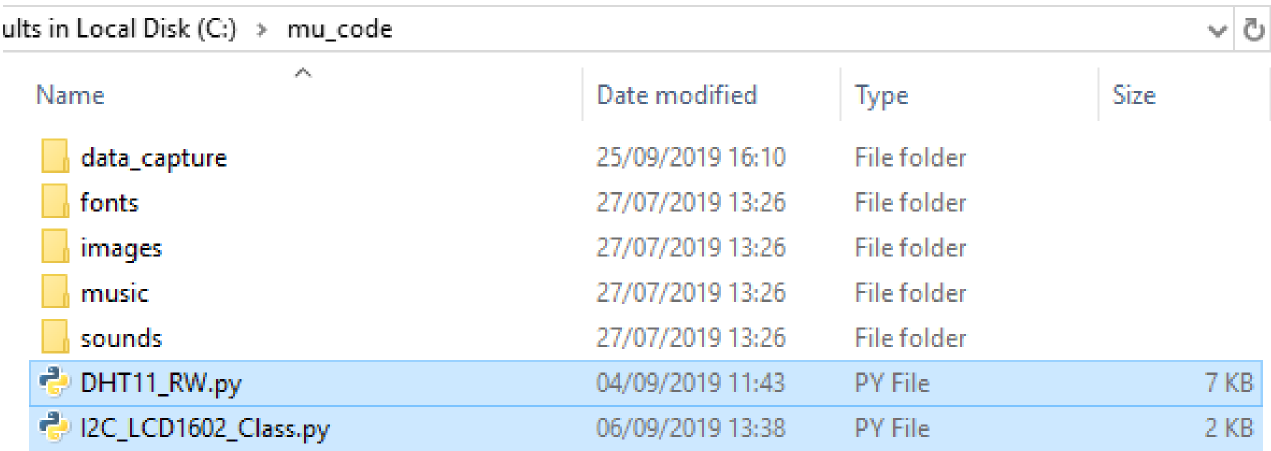

Double click on "mu_code" to enter the folder.



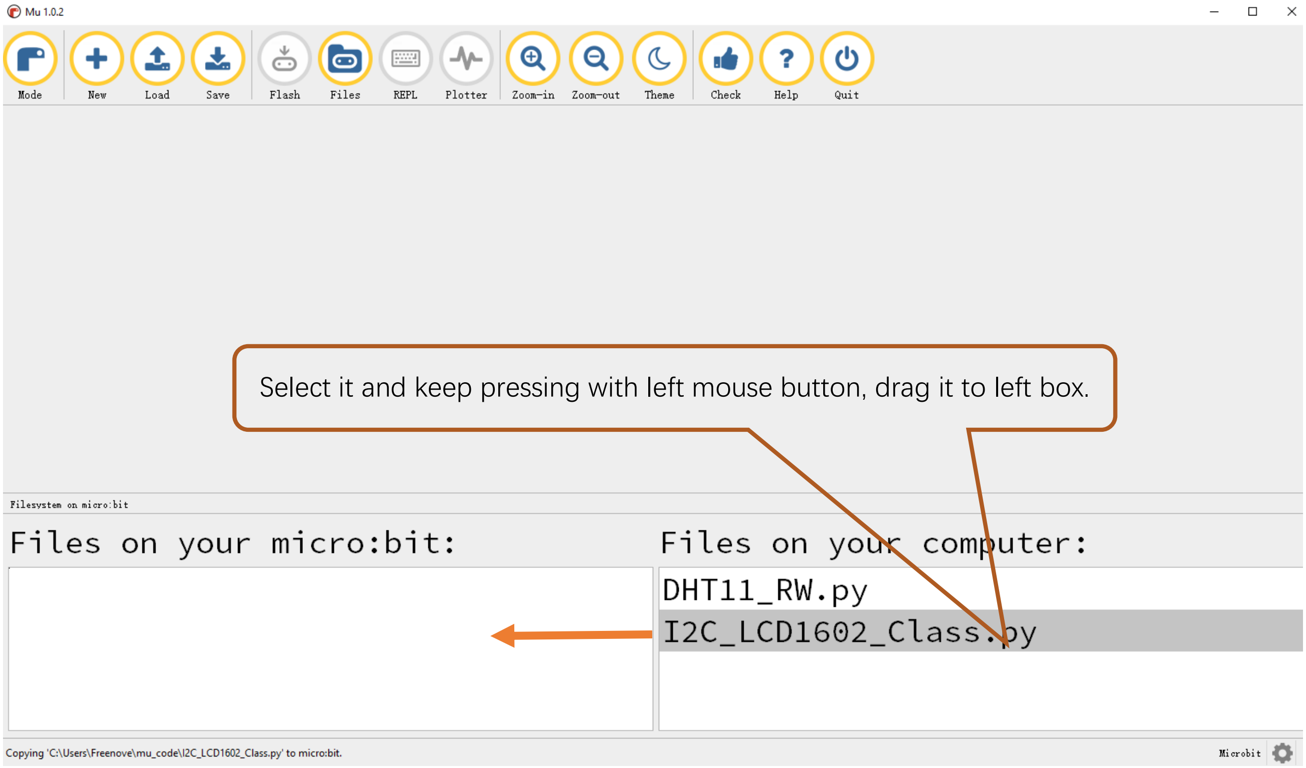

Copy "I2C_LCD1602_Class.py" and "DHT11_RW.py" from following path into "mu_code" directory.

| File type | Path | File name | |
|---|---|---|---|
| **Python file** | .. /Projects/PythonLibrary | I2C_LCD1602_Class.py | DHT11_RW.py |

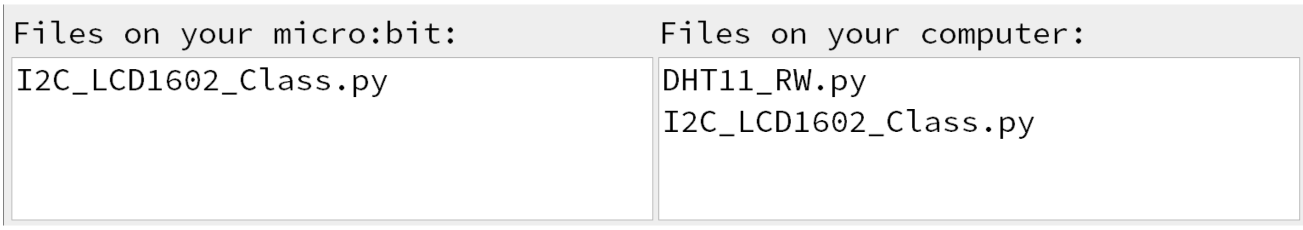
After pasting successfully, you can see them as below:



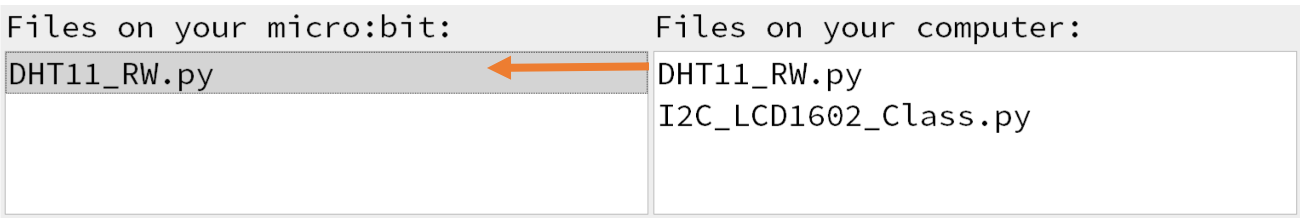
Open the Mu software, click "Files". Here we take "I2C_LCD1602_Class.py" as an example, drag "I2C_LCD1602_Class.py" into micro:bit.




After importing successfully, you will see it on the left.




The import method of "DHT11_RW.py" is the same as described above. You just need to import the one you need to use.

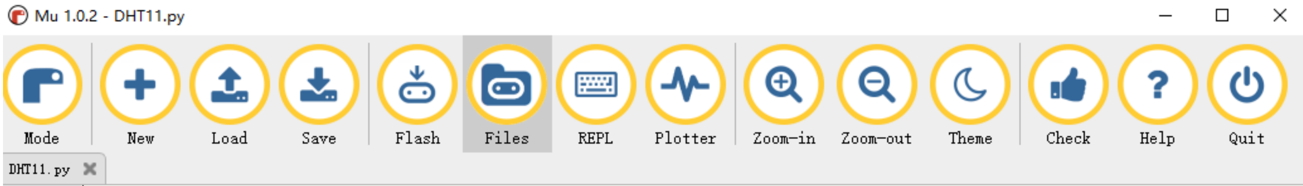



**Note, after you upload other file into micro:bit, the original content will be covered. You need to import it next time you use it.**

Open the .py file with Mu. Code, the path is as below:

| File type | Path | File name |
|---|---|---|
| **Python file** | ../Projects/PythonCode/24.1_DHT11 | DHT11.py |

After loading the code, as shown below. Before downloading the code, import the "DHT11_RW.py" file into micro:bit first.(How to import?)




```python
from microbit import *
from DHT11_RW import *
if __name__ == '__main__':
    sensor = DHT11(pin0)
    while True:
        try:
            temperature , humidity = sensor.read()
            print("temperature:"+str(temperature)+" C")
            print("humidity:"+str(humidity)+"%")
        except Exception as e:
            print("Error : " + str(e))
        time.sleep(1)
```

After importing the DHT11_RW.py file, check the connection of the circuit, verify it correct. And then download the code into micro:bit, click "REPL", press the micro:bit reset button, you can see the temperature and humidity of the current environment, as shown below:

BBC micro:bit REPL

```
humidity:46.0%
temperature:28.0 C
humidity:46.0%
temperature:28.0 C
humidity:46.0%
temperature:28.0 C
humidity:46.0%
temperature:28.0 C
humidity:46.0%
```

The following is the program code:

```
from microbit import *
from DHT11_RW import *
if __name__ == '__main__':
    sensor = DHT11(pin0)
    while True:
        try:
            temperature , humidity = sensor.read()
            print("temperature:"+str(temperature)+" C")
            print("humidity:"+str(humidity)+"%")
        except Exception as e:
            print("Error : " + str(e))
        time.sleep(1)
```

Export everything of DHT11_RW module, create object of DHT class, and set data pin to P0

```
from DHT11_RW import *
sensor = DHT11(pin0)
```

Every 1 second, call the read() function in DHT11 class, get the temperature and humidity data, and print them out separately.

```
while True:
        try:
            temperature , humidity = sensor.read()
            print("temperature:"+str(temperature)+" C")
            print("humidity:"+str(humidity)+"%")
        except Exception as e:
            print("Error : " + str(e))
        time.sleep(1)
```

## Reference

| sensor.read() |
|---|
| The read() function is defined in DHT11 to obtain temperature and humidity data. |

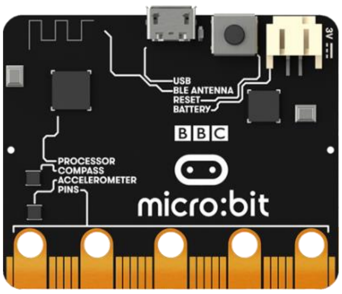
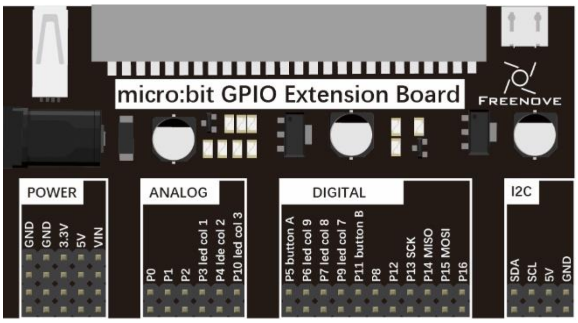
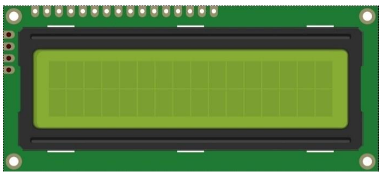
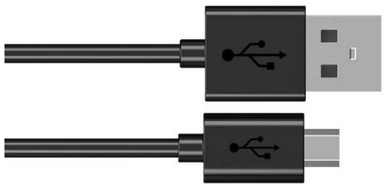
# Chapter 25 Matrix Keypad

Earlier we learned about a single Push Button Switch. In this chapter, we will learn about Matrix Keyboards, which integrates a number of Push Button Switches as Keys for the purposes of Input.

## Project 25.1 Matrix Keypad

In this project, we will make LCD screen display number and character pressed on matrix keyboard.

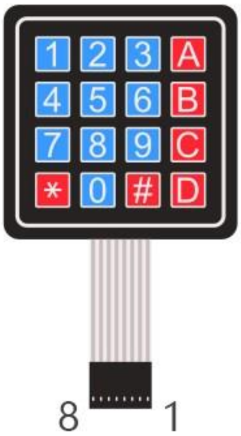
### Component list

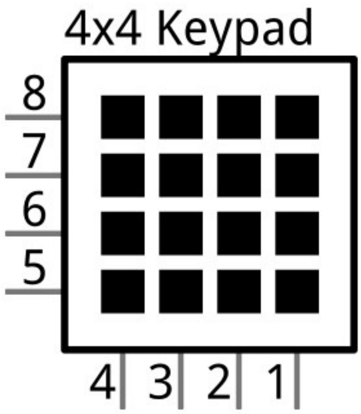
| | |
|---|---|
| Microbit x1<br> | Extension board x1<br> |
| I2C LCD1602 Module x1<br> | USB cable x2<br> |
| F/M x8 F/F x4<br> | 4x4 Matrix Keypad x1<br> |

## Component knowledge

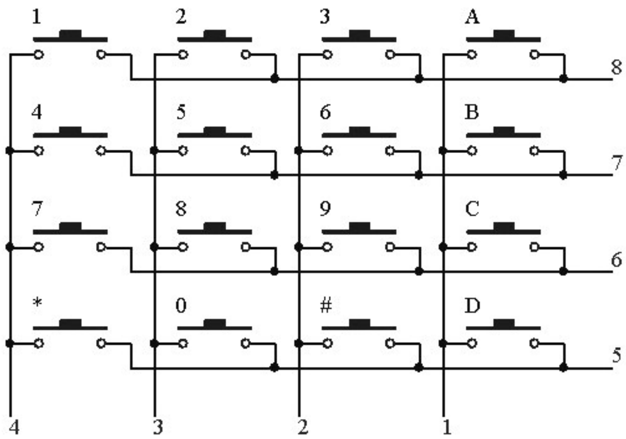
### 4x4 Matrix Keypad

A Keypad Matrix is a device that integrates a number of keys in one package. As is shown below, a 4x4 Keypad Matrix integrates 16 keys (think of this as 16 Push Button Switches in one module):



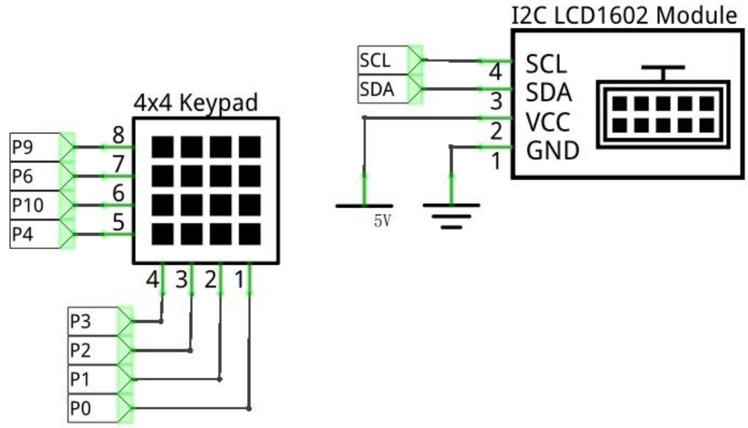

Similar to the integration of an LED Matrix, the 4x4 Keypad Matrix has each row of keys connected with one pin and this is the same for the columns. Such efficient connections reduce the number of processor ports required. The internal circuit of the Keypad Matrix is shown below.



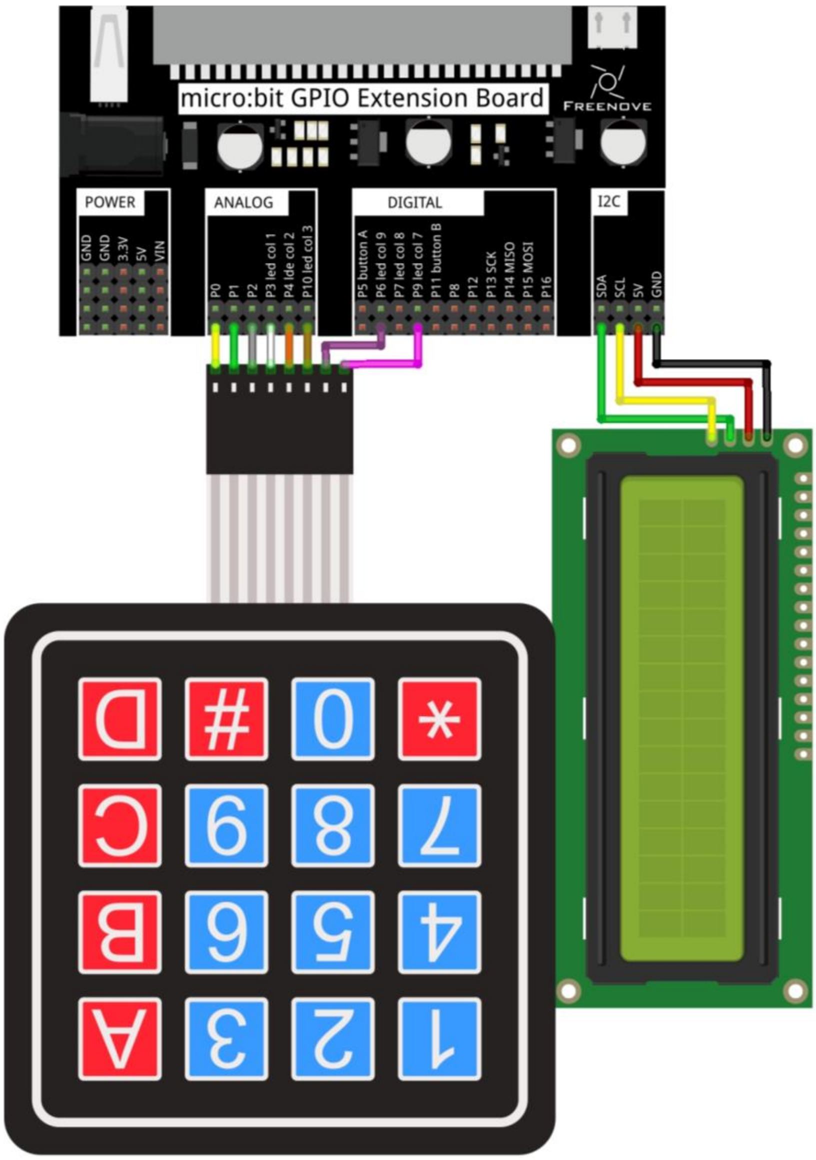

The method of usage is similar to the Matrix LED, by using a row or column scanning method to detect the state of each key's position by column and row. Take column scanning method as an example, send low level to the first 1 column (Pin1), detect level state of row 5, 6, 7, 8 to judge whether the key A, B, C, D are pressed. Then send low level to column 2, 3, 4 in turn to detect whether other keys are pressed. Therefore, you can get the state of all of the keys.

## Circuit

Schematic diagram




Hardware connection

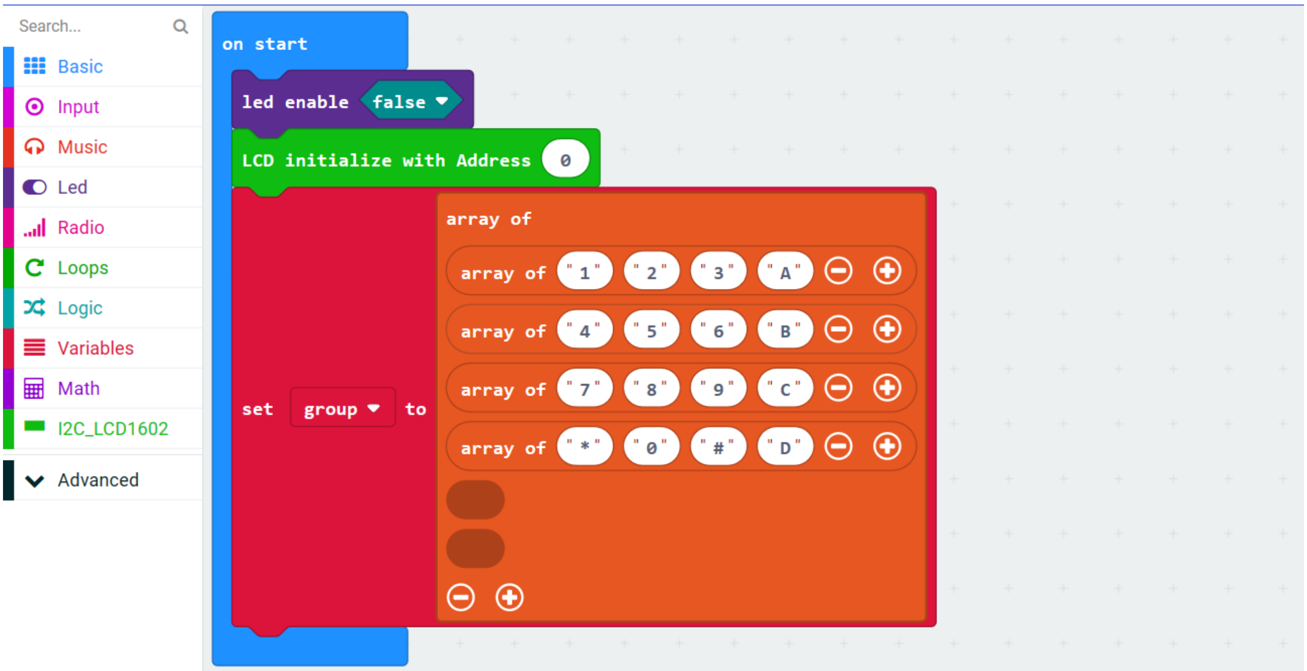


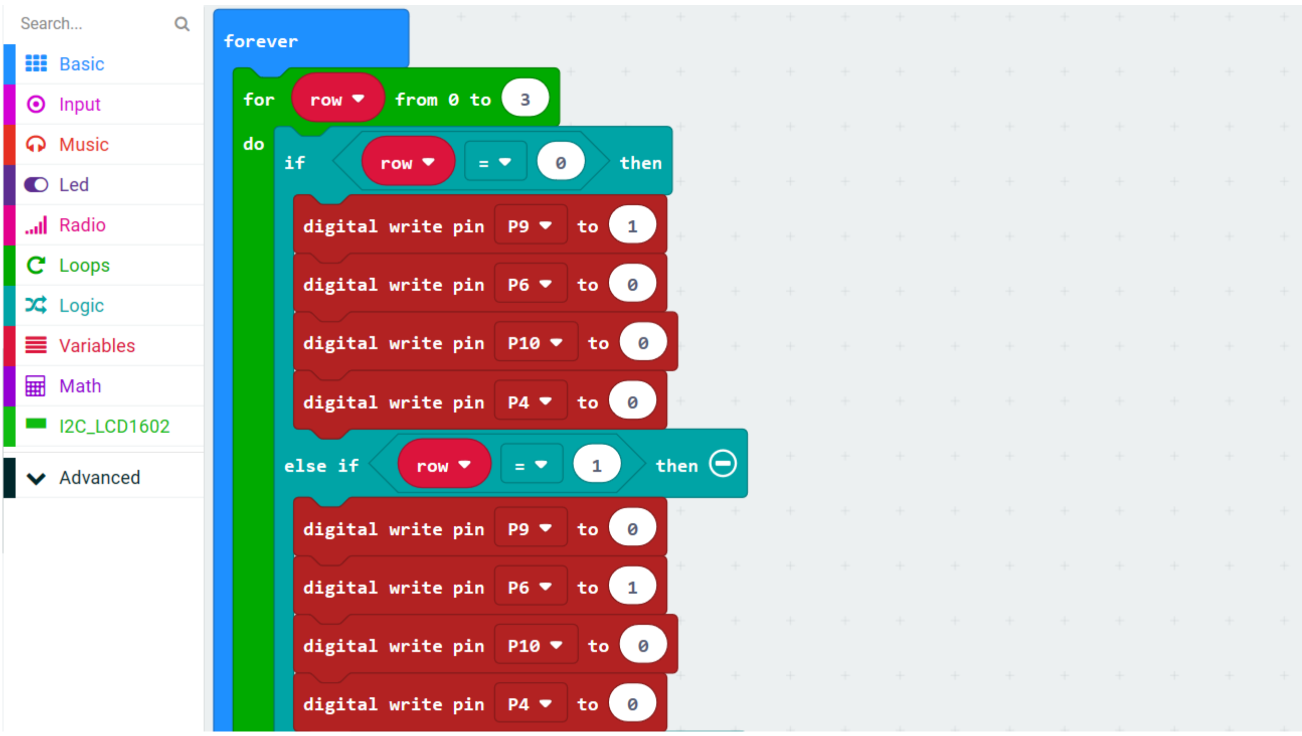
# Block code

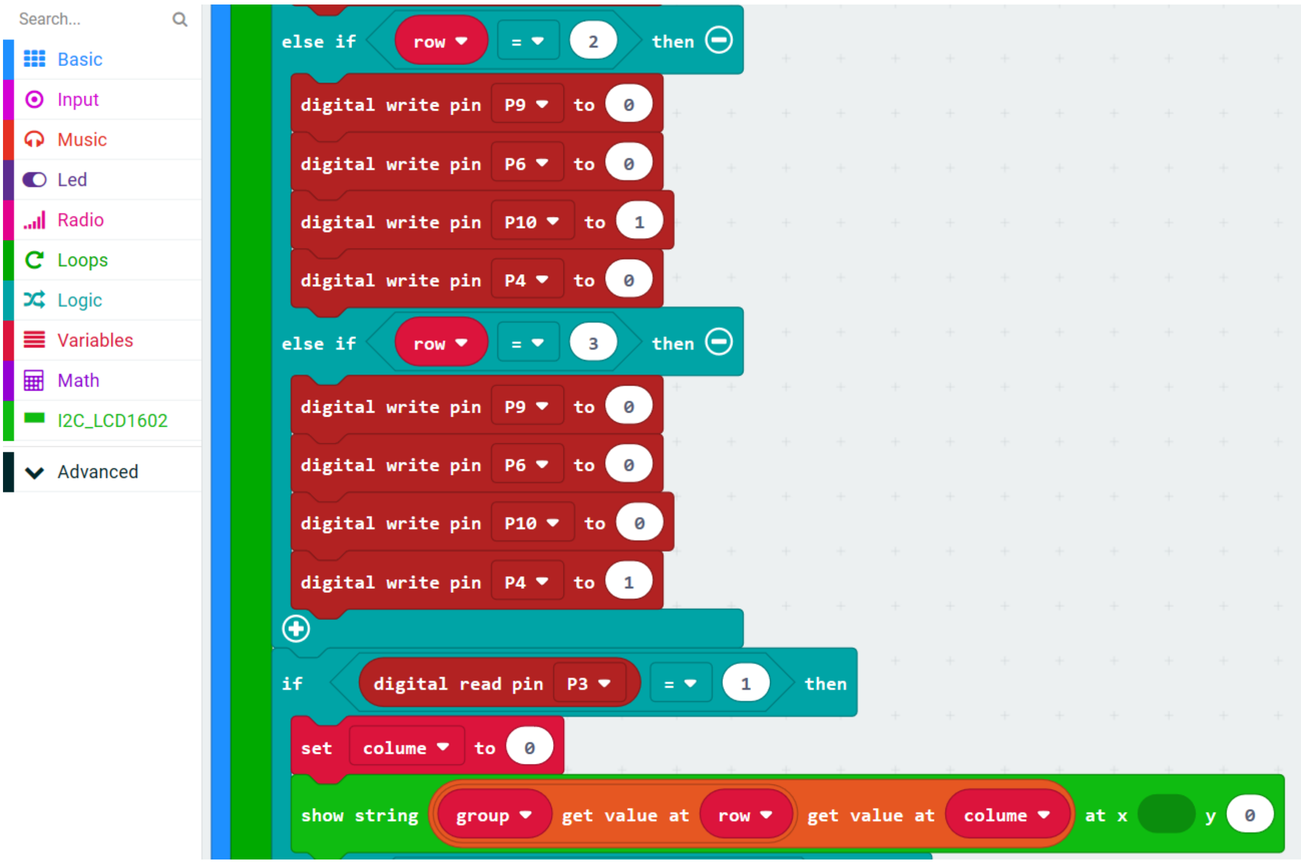
Open MakeCode first. Import the .hex file. The path is as below:
(How to import project)

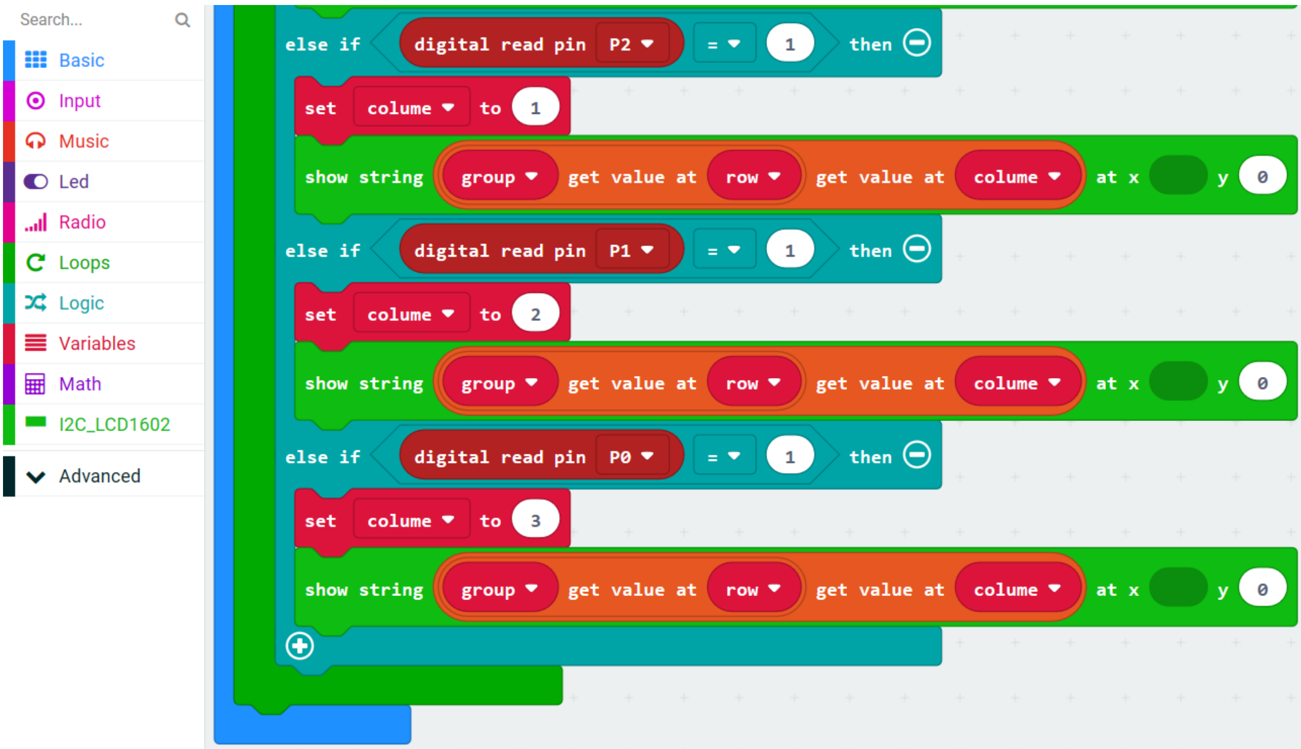
| File type | Path | File name |
|---|---|---|
| HEX file | ../Projects/BlockCode/25.1_Keypad | Keypad.hex |

After importing successfully, the code is shown as below:



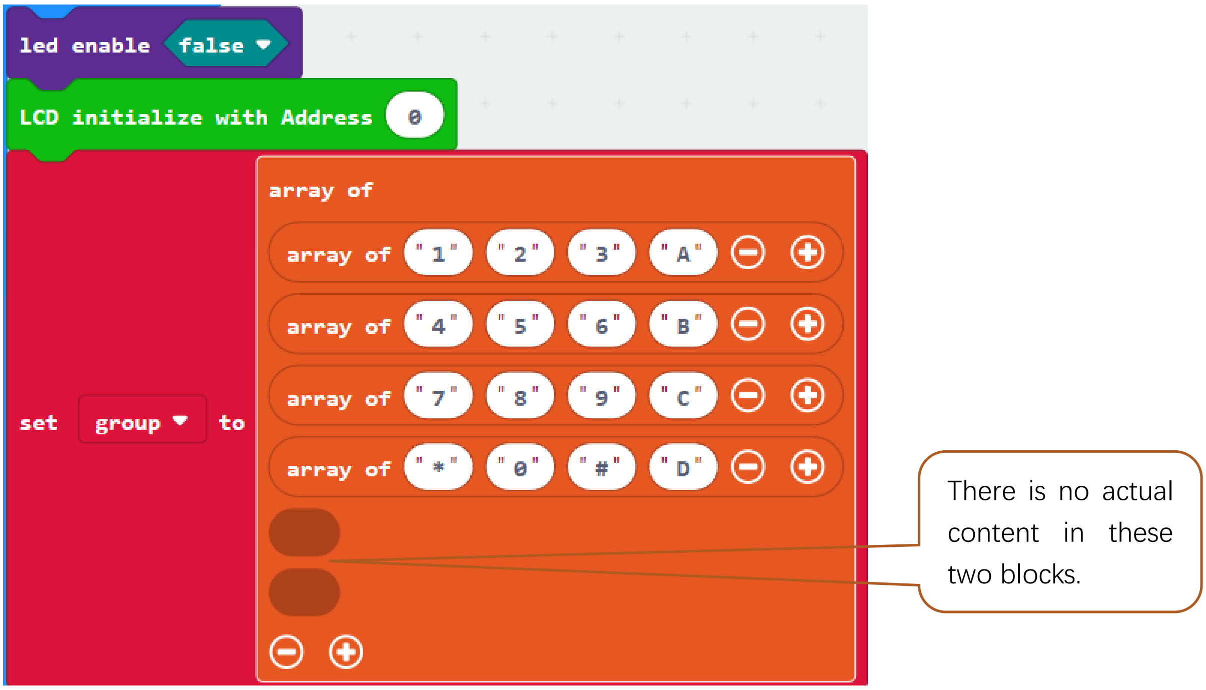





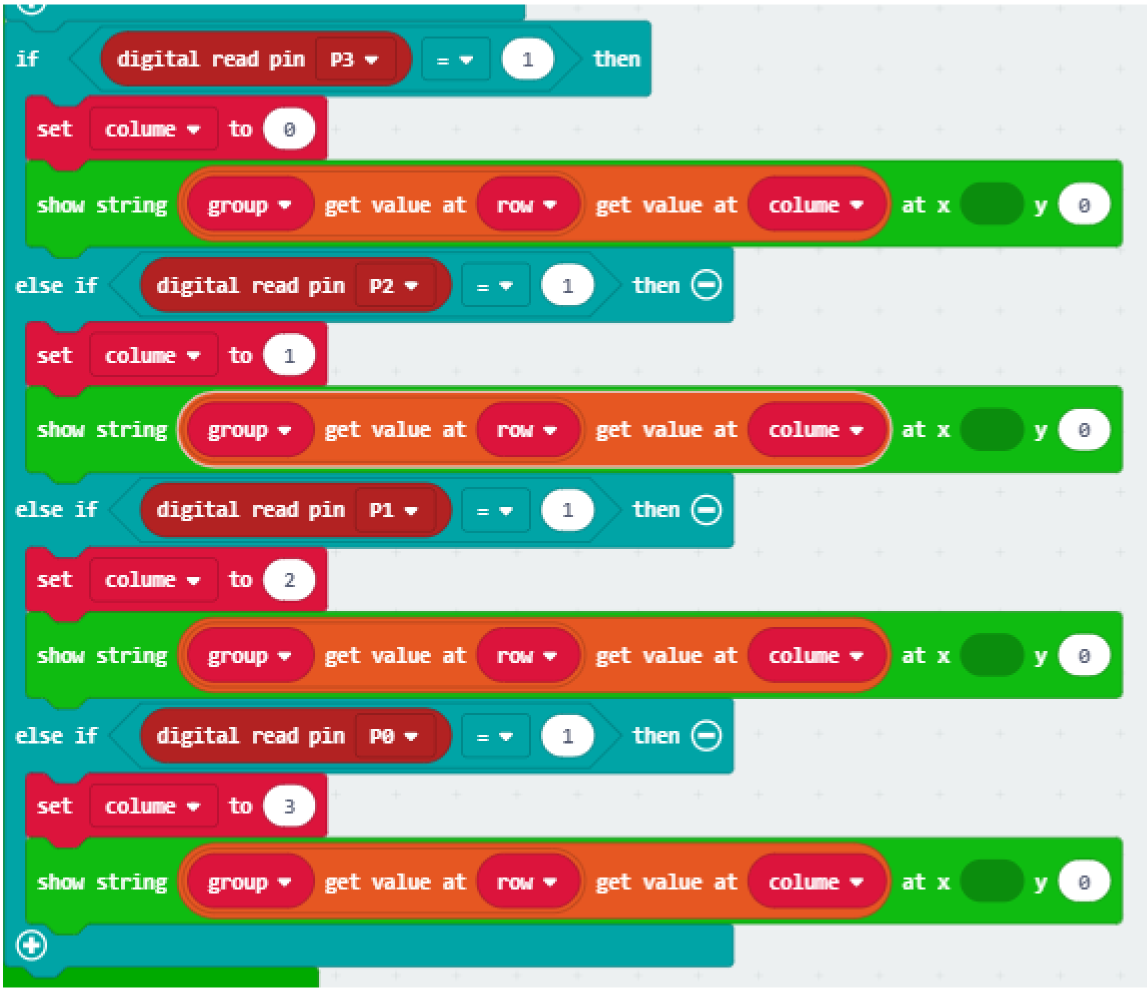

After checking the connection of the circuit and verifying it correct, the code is downloaded into micro:bit. When the key of the matrix keyboard is pressed, the LCD will display the corresponding numbers or characters.

Close the LED dot matrix screen, initialize the LCD, and store the values of the matrix keyboard 1, 2, 3, 4, 5, 6, 7, 8, 9, 0, A, B, C, D, #, *, in the array group variable.



Row scanning. Pins P9, P6, P10, P4 corresponds to the first, second, third and fourth rows. Make the pins output high level in turn, the other pins output low level.

Column scanning. Pins P3, P2, P1, P0 corresponds to the first, second, third and fourth columns. Reading high level means the key of current line and column is pressed. And the corresponding number or character in the group array will be displayed on the LCD.

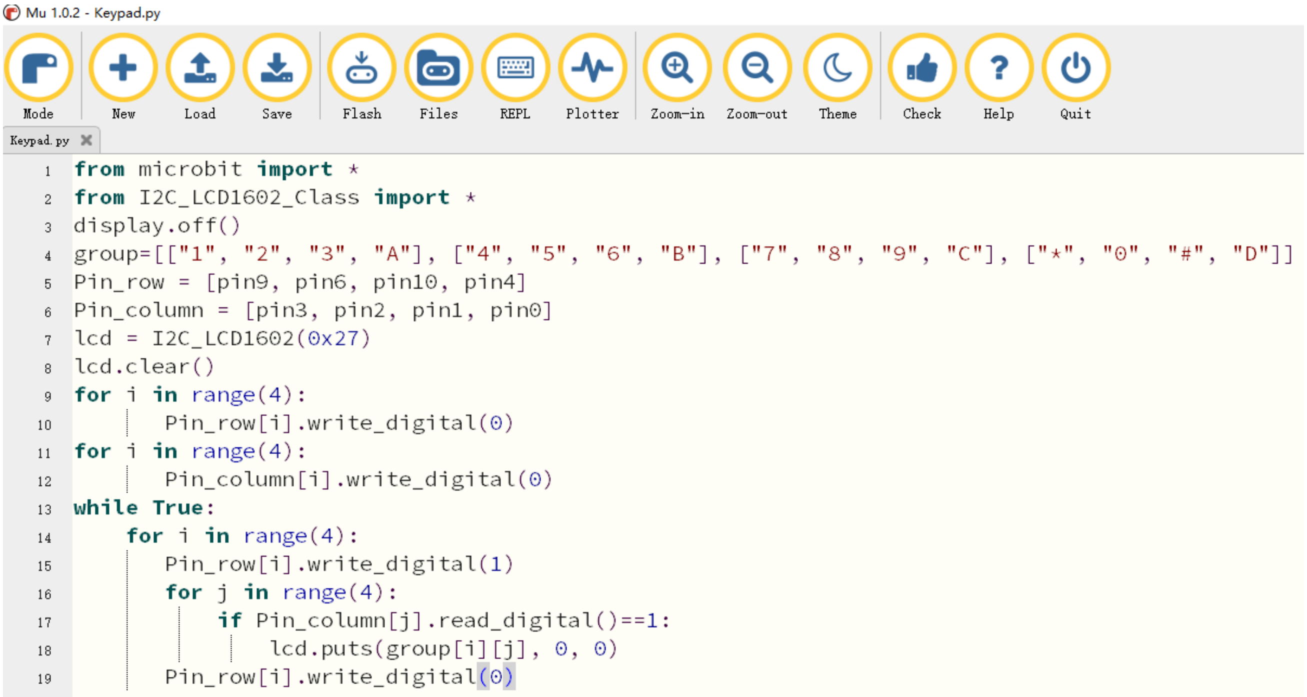


# Python code

Open the .py file with Mu. Code, the path is as below:

| File type | Path | File name |
| --- | --- | --- |
| **Python file** | ../Projects/PythonCode/25.1_Keypad | Keypad.py |

After the code is loaded, as shown below, import the "I2C_LCD1602_Class.py" file to micro:bit before downloading the code. (How to import?)




After importing the I2C_LCD1602_Class.py file, check the connection of the circuit and verify it correct, and then download the code into micro:bit, and press the key of the matrix keyboard, LCD will display the corresponding number or character.

The following is the program code:

```
from microbit import *
from I2C_LCD1602_Class import *
display.off()
group=[["1", "2", "3", "A"], ["4", "5", "6", "B"], ["7", "8", "9", "C"], ["*", "0", "#", "D"]]
Pin_row = [pin9, pin6, pin10, pin4]
Pin_column = [pin3, pin2, pin1, pin0]
lcd = I2C_LCD1602(0x27)
lcd.clear()
for i in range(4):
        Pin_row[i].write_digital(0)
for i in range(4):
        Pin_column[i].write_digital(0)
while True:
    for i in range(4):
```

```
        Pin_row[i].write_digital(1)
        for j in range(4):
            if Pin_column[j].read_digital()==1:
                lcd.puts(group[i][j], 0, 0)
        Pin_row[i].write_digital(0)
```

Close the LED dot matrix screen, store the values of matrix keyboard 1, 2, 3, 4, 5, 6, 7, 8, 9, 0, A, B, C, D,, *, in the array group. Store the pin variables of the control keyboard row to Pin_row, and store the pin variables of the control keyboard column to Pin_column. Create the I2C_LCD1602 object lcd, enter the I2C address and clear the screen. Set the pins connecting the matrix keyboard to low level.

```
display.off()
group=[["1", "2", "3", "A"], ["4", "5", "6", "B"], ["7", "8", "9", "C"], ["*", "0", "#", "D"]]
Pin_row = [pin9, pin6, pin10, pin4]
Pin_column = [pin3, pin2, pin1, pin0]
lcd = I2C_LCD1602(0x27)
lcd.clear()
for i in range(4):
        Pin_row[i].write_digital(0)
for i in range(4):
        Pin_column[i].write_digital(0)
```

Scan rows and columns. If the key in certain row and column is pressed, the corresponding number or character in the group array will be displayed on the LCD.

```
while True:
    for i in range(4):
        Pin_row[i].write_digital(1)
        for j in range(4):
            if Pin_column[j].read_digital()==1:
                lcd.puts(group[i][j], 0, 0)
        Pin_row[i].write_digital(0)
```

# Project 25.2 Countdown Timer

This project makes a countdown timer.

## Component list

It is same as the previous project.

## Circuit

It is same as the previous project.

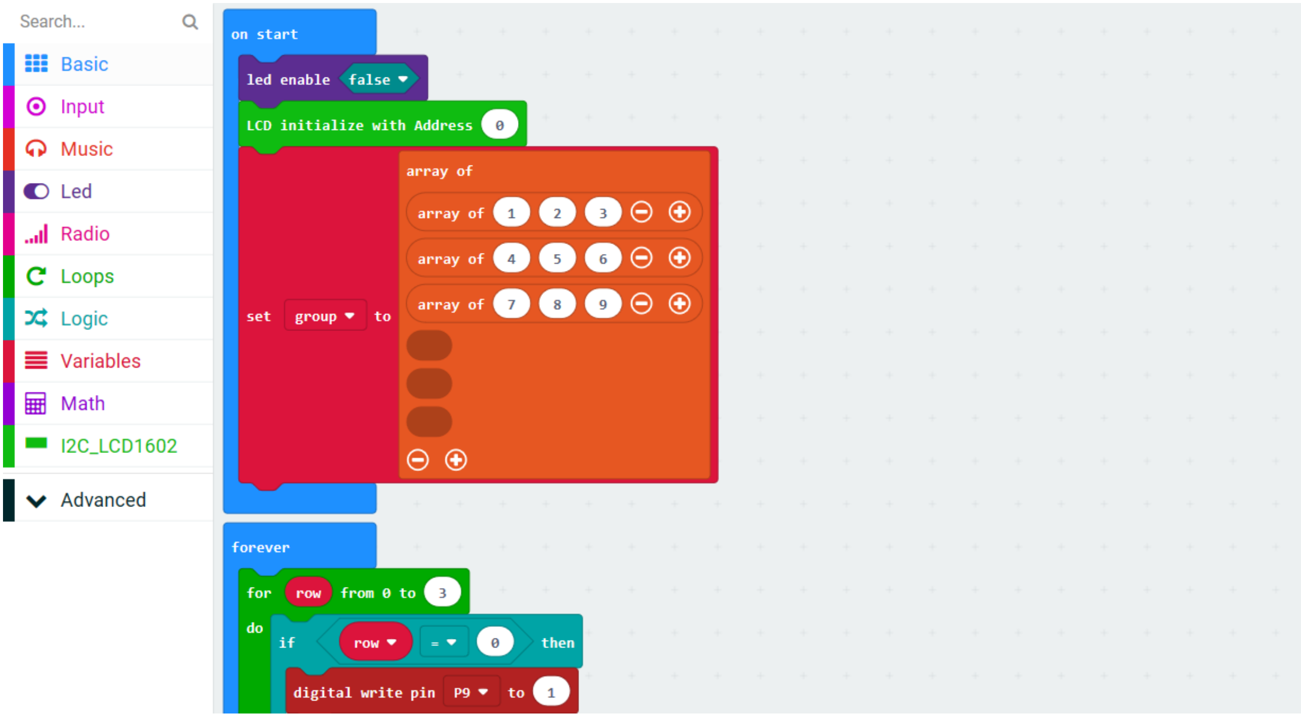
## Block code

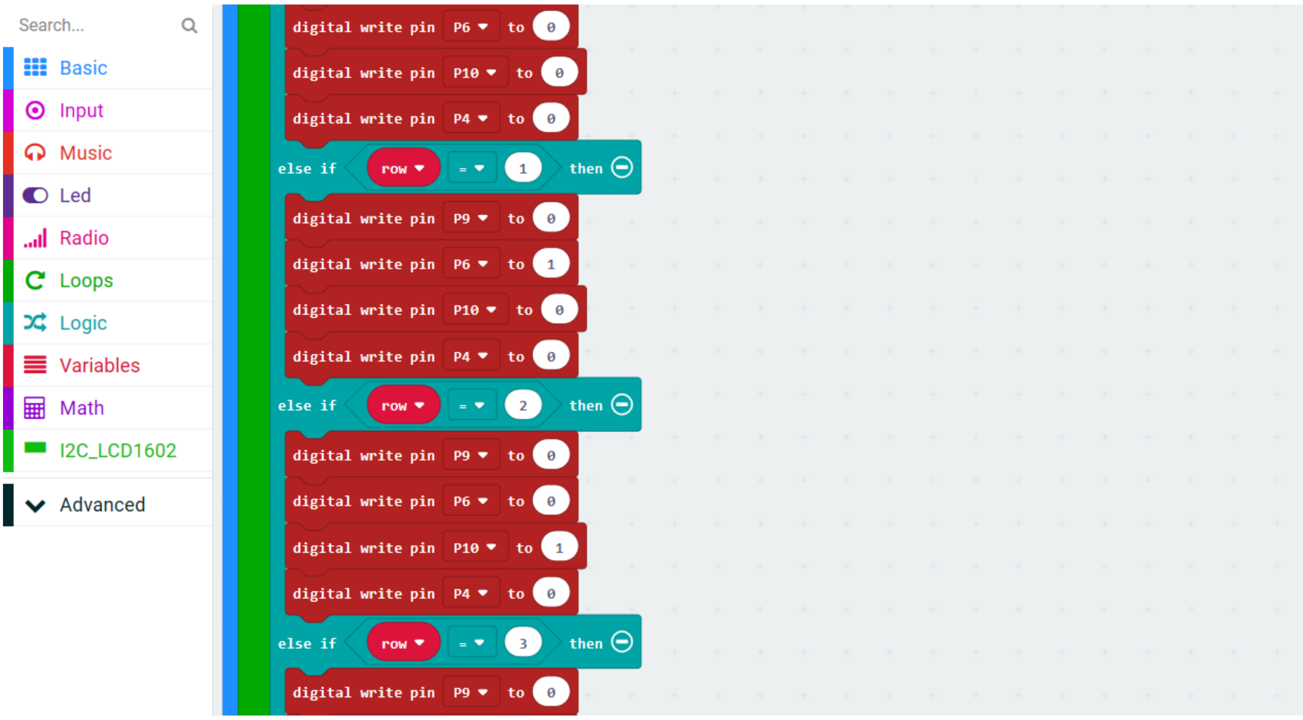
Open MakeCode first. Import the .hex file. The path is as below:

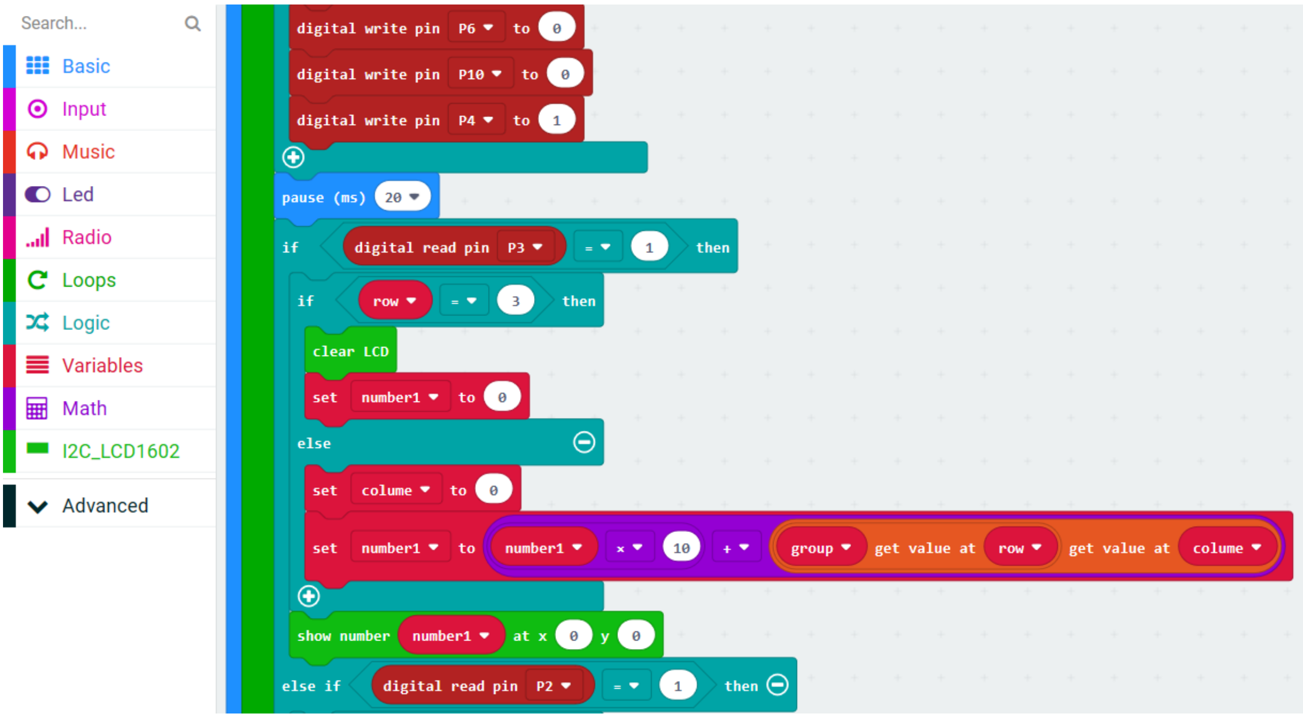
(How to import project)

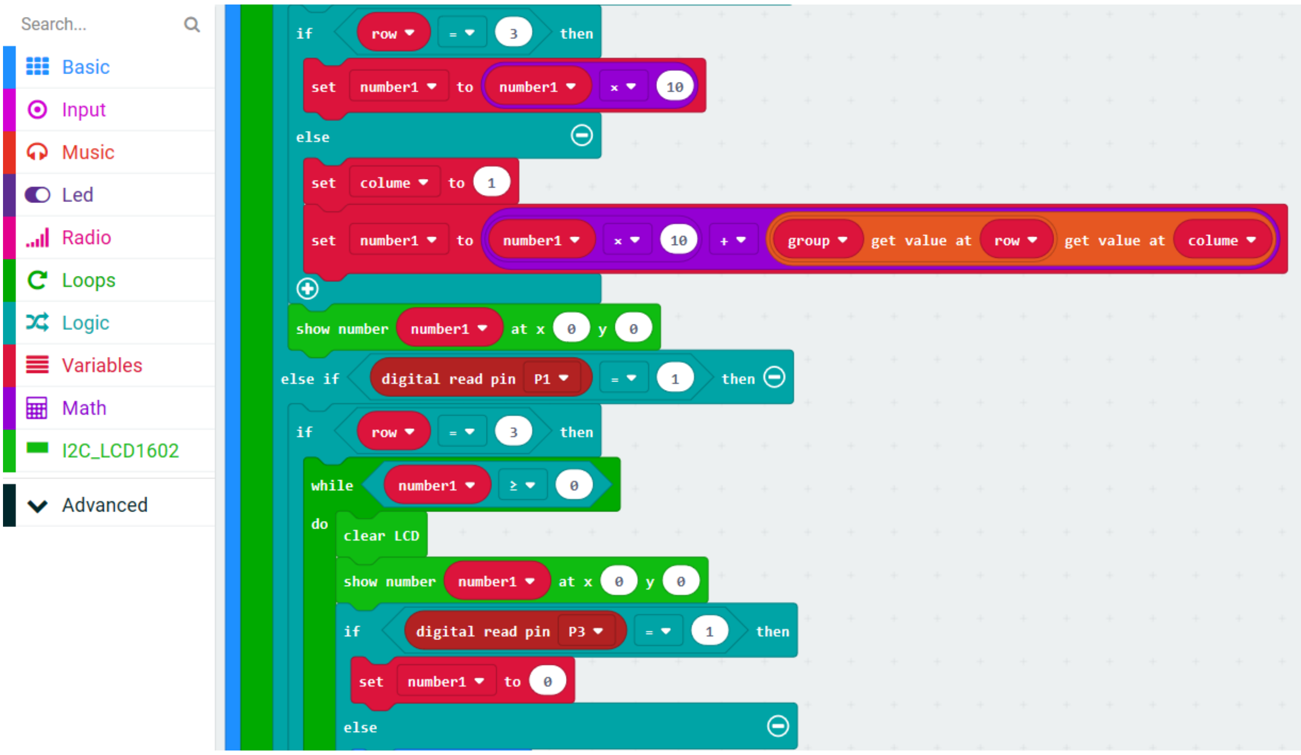
| File type | Path | File name |
|---|---|---|
| **HEX file** | ../Projects/BlockCode/25.2_CountdownTimer | CountdownTimer.hex |

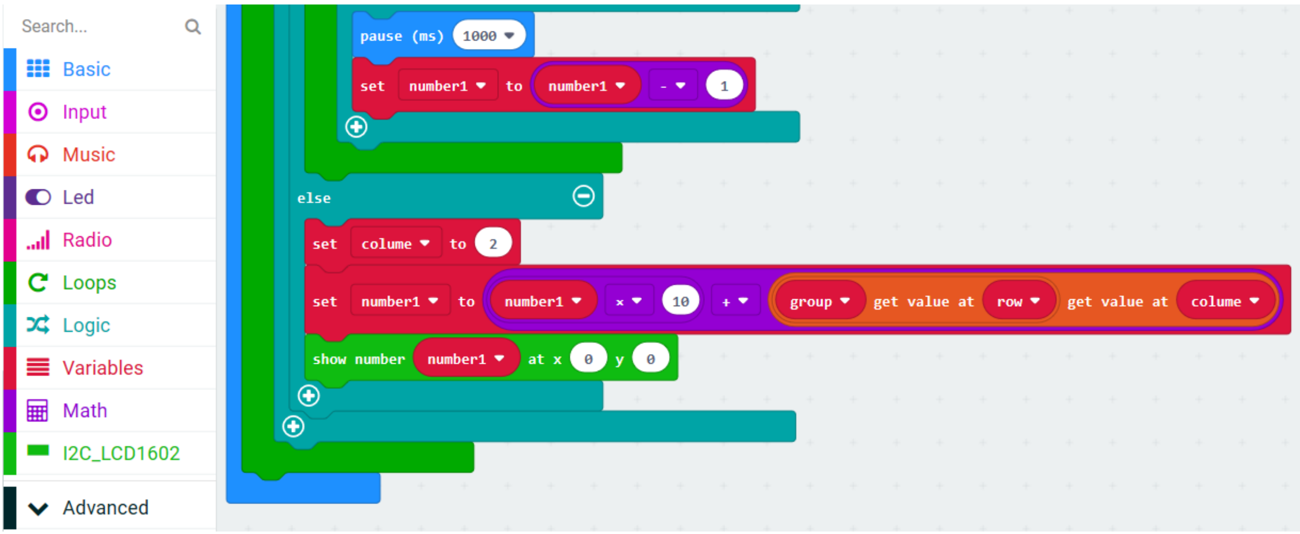
After importing successfully, the code is shown as below:




Search...
Basic
Input
Music
Led
Radio
Loops
Logic
Variables
Math
I2C_LCD1602
Advanced
digital write pin P6 to 0
digital write pin P10 to 0
digital write pin P4 to 0
else if row = 1 then
digital write pin P9 to 0
digital write pin P6 to 1
digital write pin P10 to 0
digital write pin P4 to 0
else if row = 2 then
digital write pin P9 to 0
digital write pin P6 to 0
digital write pin P10 to 1
digital write pin P4 to 0
else if row = 3 then
digital write pin P9 to 0

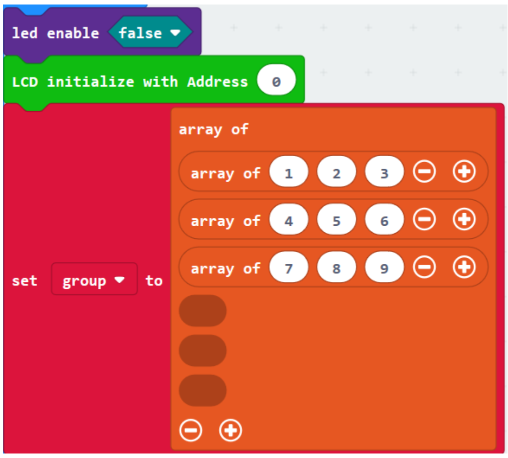

Search...
Basic
Input
Music
Led
Radio
Loops
Logic
Variables
Math
I2C_LCD1602
Advanced
digital write pin P6 to 0
digital write pin P10 to 0
digital write pin P4 to 1
pause (ms) 20
if digital read pin P3 = 1 then
if row = 3 then
clear LCD
set number1 to 0
else
set colume to 0
set number1 to number1 × 10 + group get value at row get value at colume
show number number1 at x 0 y 0
else if digital read pin P2 = 1 then



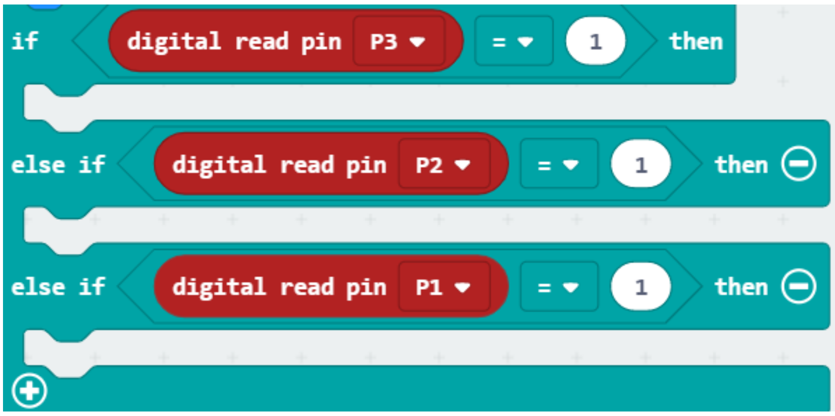

After checking the connection of the circuit and verifying it correct, download the code into micro:bit, type in the value, press the'#'key, start countdown, the key '*' is reset.

Close the LED dot matrix screen, initialize the LCD and store the values of matrix keyboard 1, 2, 3, 4, 5, 6, 7, 8, 9 in the array group.

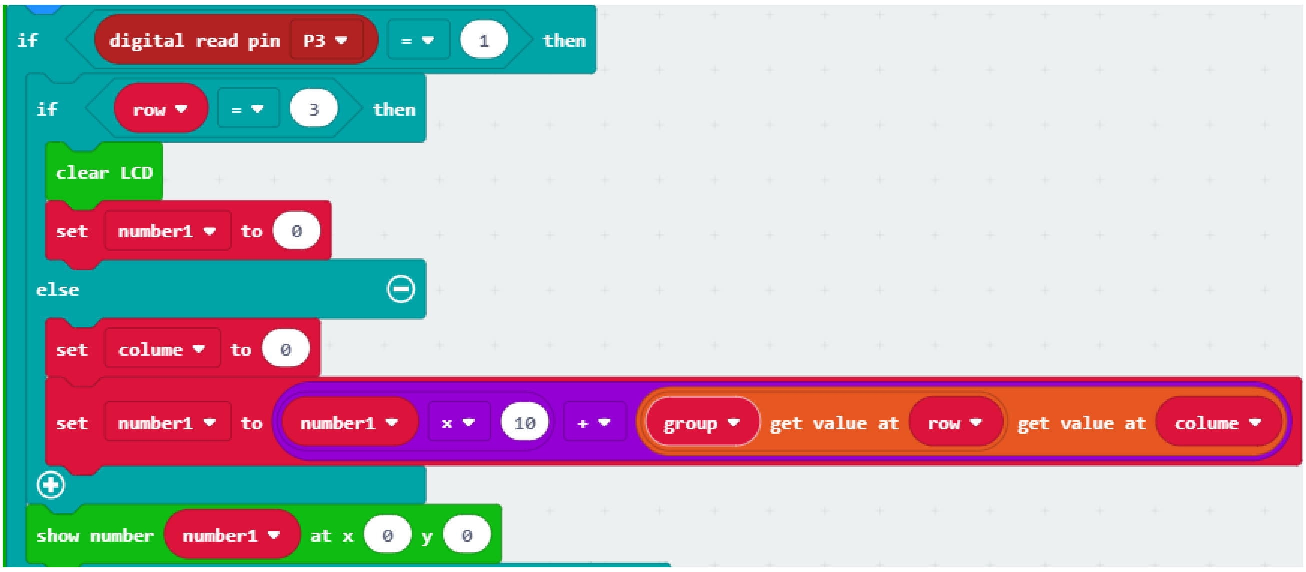



Row scanning. Pins P9, P6, P10, P4 corresponds to the first, second, third and fourth rows. Make the pins output high level in turn, the other pins output low level.

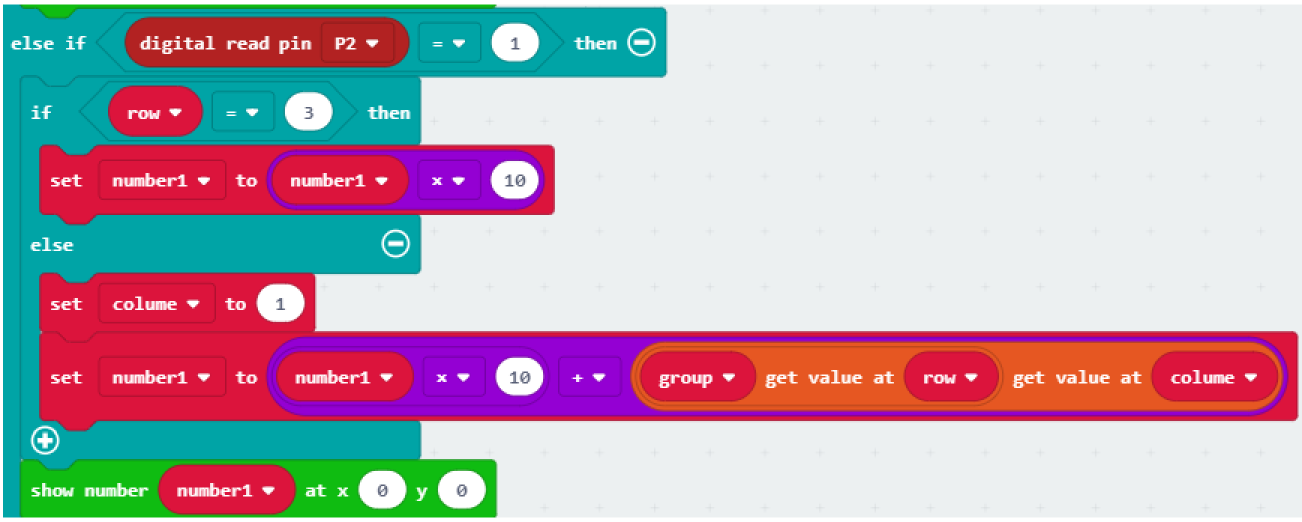

Column scanning. Pins P3, P2, P1 corresponds to the first, second and third columns. When reading high level, the corresponding reaction will be executed.



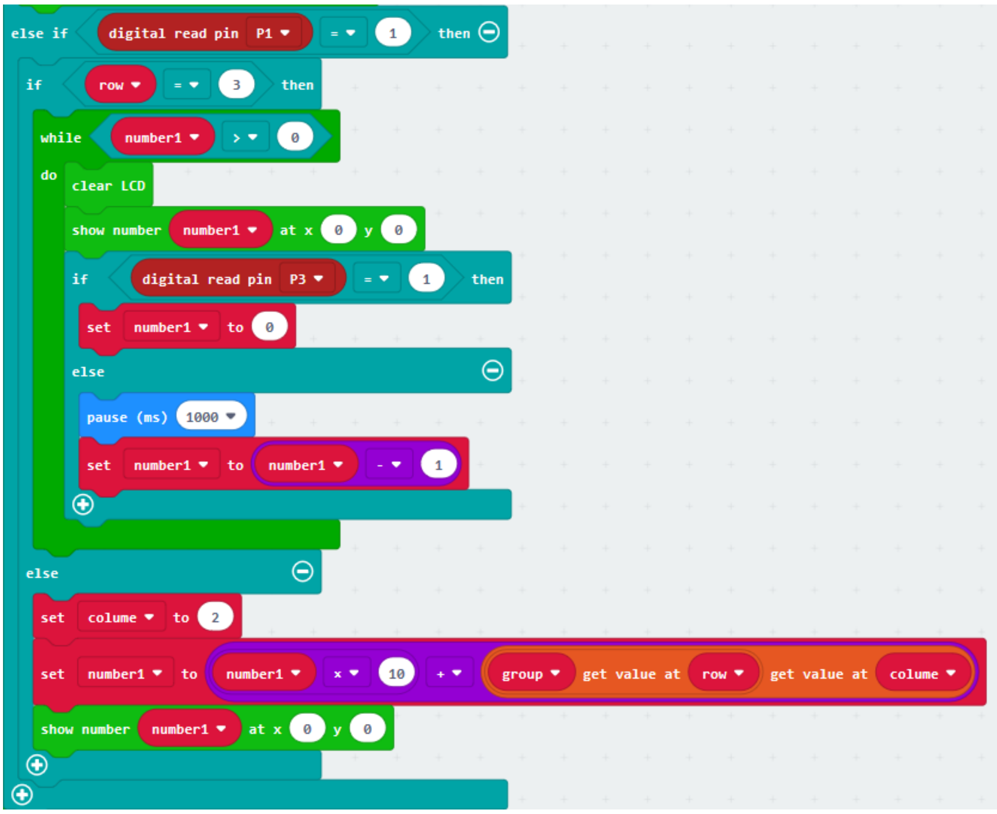

Determine whether the first column on the left is pressed, and then determine which row of the column is pressed. If the "*" key of the fourth row and first column is pressed, clear the LCD screen content, and the Number1 variable is assigned 0; if the other keys 1, 4 or 7 is pressed, the Number1 variable is multiplied by 10 and the corresponding key value is added, and then reassigned to Number1 to achieve carry effect.



Determine whether the second column on the left is pressed, and then determine which row of the column is pressed. If the "0" key of the fourth row and second column is pressed, the value of Number1 is multiplied by 10, and then reassigned to Number1 variable. If the other keys 2, 5 or 8 is pressed, the value of Number1 is multiplied by 10 and the corresponding key value is added, and then reassigned to Number1 to achieve carry effect.




Determine whether the third column on the left is pressed, and then determine which row of the column is pressed. If the "#" key of the fourth row and the third column is pressed, the countdown is performed by the while loop. If the other keys 3, 6, 9 is pressed, the value of Number1 will be multiplied by 10 and the corresponding key value is reassigned to the Number1 variable to achieve carry effect. The Number1 variable will decrease by 1 every 1s. During the cycle, if the "*" key is pressed or the value of Number1 variable is less than or equal to 0, the loop will jumper out.

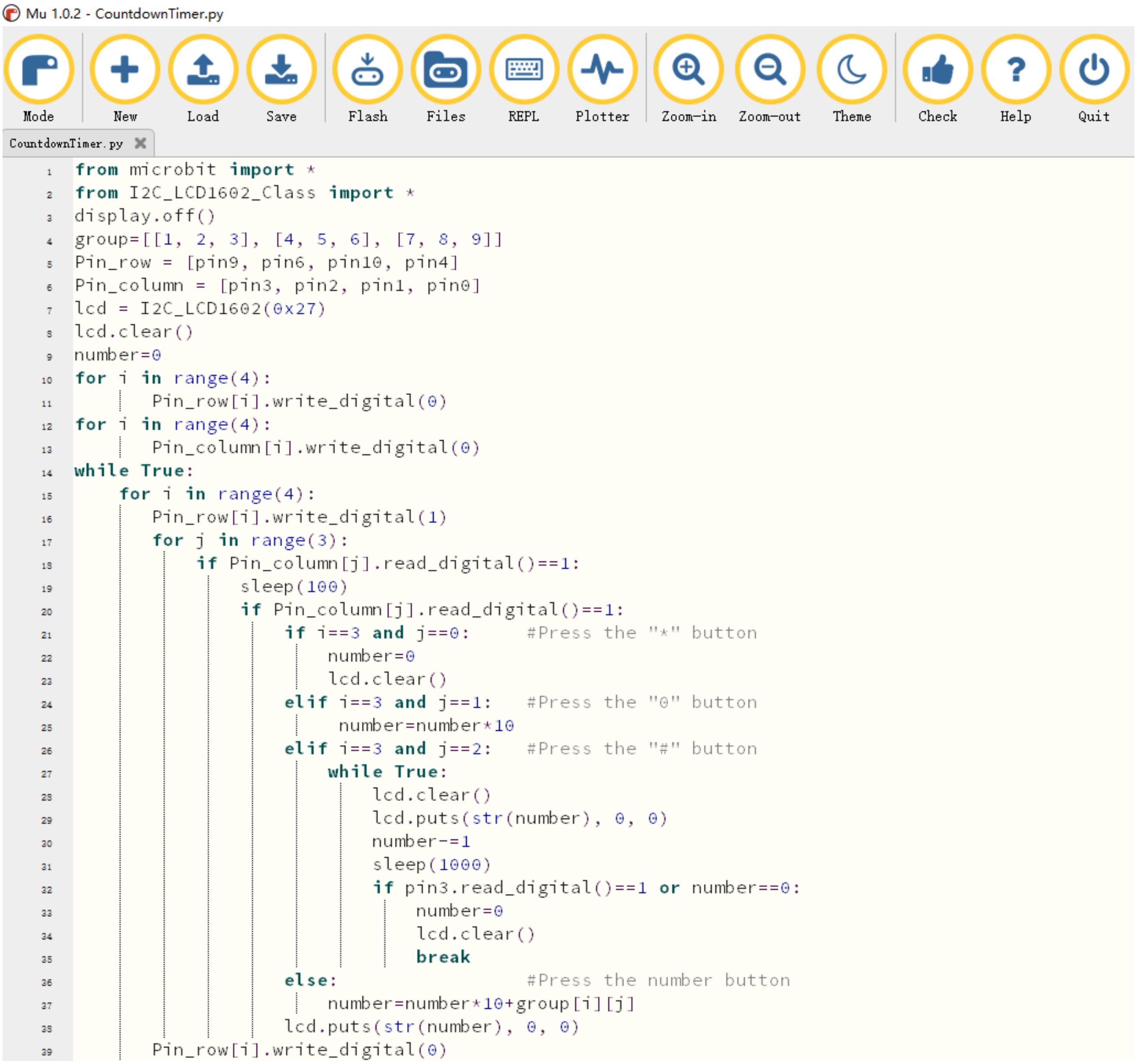


## Python code

Open the .py file with Mu. Code, the path is as below:

| File type | Path | File name |
|---|---|---|
| **Python file** | ../Projects/PythonCode/25.2_CountdownTimer | CountdownTimer.py |

After the code is loaded, as shown below, import the "I2C_LCD1602_Class.py" file to micro:bit before downloading the code.(How to import?)




After importing the I2C_LCD1602_Class.py file, check the connection of the circuit and verify it correct, and download the code into micro:bit, type in the value, press the '#' key, start countdown, the key'*' is reset.

The following is the program code:

```
from microbit import *
from I2C_LCD1602_Class import *
```

```
display.off()
group=[[1, 2, 3], [4, 5, 6], [7, 8, 9]]
Pin_row = [pin9, pin6, pin10, pin4]
Pin_column = [pin3, pin2, pin1, pin0]
lcd = I2C_LCD1602(0x27)
lcd.clear()
number=0
for i in range(4):
        Pin_row[i].write_digital(0)
for i in range(4):
        Pin_column[i].write_digital(0)
while True:
    for i in range(4):
        Pin_row[i].write_digital(1)
        for j in range(3):
            if Pin_column[j].read_digital()==1:
                sleep(100)
                if Pin_column[j].read_digital()==1:
                    if i==3 and j==0:     #Press the "*" button
                        number=0
                        lcd.clear()
                    elif i==3 and j==1:   #Press the "0" button
                         number=number*10
                    elif i==3 and j==2:   #Press the "#" button
                        while True:
                            lcd.clear()
                            lcd.puts(str(number), 0, 0)
                            number-=1
                            sleep(1000)
                            if pin3.read_digital()==1 or number==0:
                                number=0
                                lcd.clear()
                                break
                    else:                 #Press the number button
                        number=number*10+group[i][j]
                    lcd.puts(str(number), 0, 0)
        Pin_row[i].write_digital(0)
```

Close the LED dot matrix screen, store the values of matrix keyboard 1, 2, 3, 4, 5, 6, 7, 8, 9 in the array group, store the pin variables of the control keyboard row in Pin_row, and store the pin variables of the control keyboard column in Pin_column. Create the object lcd of class I2C_LCD1602, enter the I2C address and clear the screen, and set the pins connecting the matrix keyboard to low level.

```
display.off()
group=[[1, 2, 3], [4, 5, 6], [7, 8, 9]]
```

```
Pin_row = [pin9, pin6, pin10, pin4]
Pin_column = [pin3, pin2, pin1, pin0]
lcd = I2C_LCD1602(0x27)
lcd.clear()
number=0
for i in range(4):
        Pin_row[i].write_digital(0)
for i in range(4):
        Pin_column[i].write_digital(0)
```

Scan the rows and columns to check if the key is pressed.
If the "*" key is pressed, the number variable is assigned 0
If the "#" key is pressed, then the content of the while loop is executed. Number variable decreases by 1 every 1s to achieve the countdown effect. During the period, if the "*" key is pressed or the value of number variable is 0, the while loop jumper out and the number variable is assigned with 0.
If the number key is pressed, the number variable is multiplied by 10 and add the corresponding key value, then reassigned to the number variable.

```
while True:
    for i in range(4):
        Pin_row[i].write_digital(1)
        for j in range(3):
            if Pin_column[j].read_digital()==1:
                sleep(100)
                if Pin_column[j].read_digital()==1:
                    if i==3 and j==0:      #Press the "*" button
                        number=0
                        lcd.clear()
                    elif i==3 and j==1:    #Press the "0" button
                         number=number*10
                    elif i==3 and j==2:    #Press the "#" button
                        while True:
                            lcd.clear()
                            lcd.puts(str(number), 0, 0)
                            number-=1
                            sleep(1000)
                            if pin3.read_digital()==1 or number==0:
                                number=0
                                lcd.clear()
                                break
                    else:                  #Press the number button
                        number=number*10+group[i][j]
                    lcd.puts(str(number), 0, 0)
        Pin_row[i].write_digital(0)
```

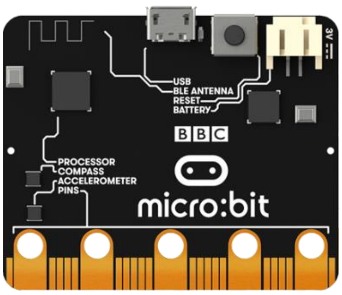
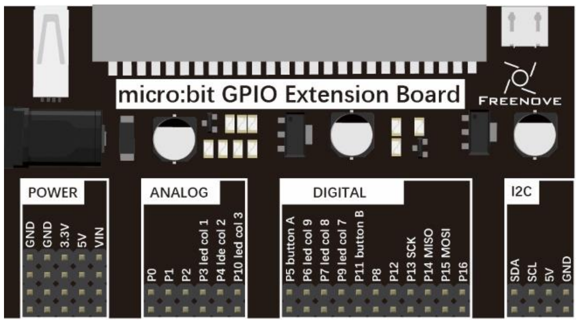
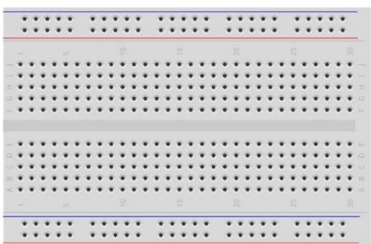
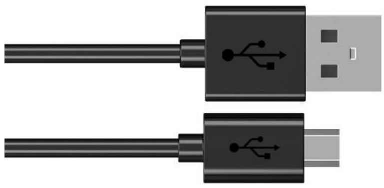
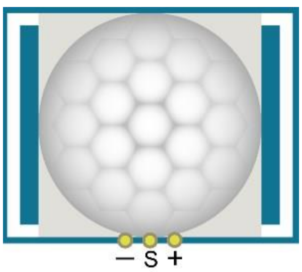
# Chapter 26 Infrared Motion Sensor

In this chapter, we will learn a widely used sensor, Infrared Motion Sensor.

## Project 26.1 Sense Light

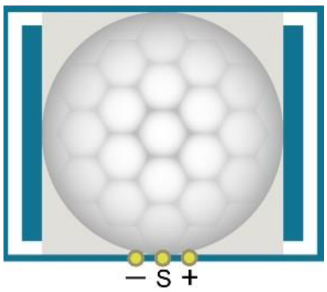
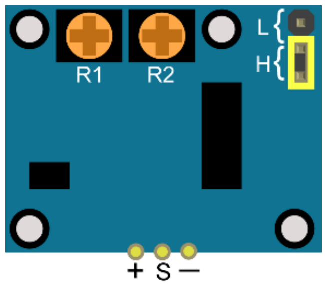
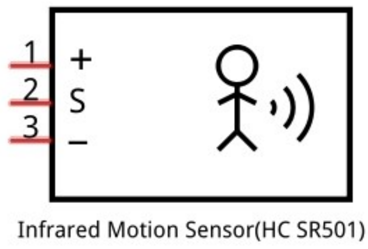
In this project, we will make a Motion Detector, with the human body infrared pyroelectric sensors.
When someone is in close proximity to the Motion Detector, it will automatically light up and when there is no one close by, it will be out.
This Infrared Motion Sensor can detect the infrared spectrum (heat signatures) emitted by living humans and animals.

## Component list

<table>
<tr><td colspan="2">Microbit x1<br>
</td><td colspan="2">Extension board x1<br>
</td></tr>
<tr><td colspan="2">Breadboard x1<br></td><td colspan="2">USB cable x2<br></td></tr>
<tr><td>HC-SR501 x1<br>
</td><td>LED x1<br></td><td>Resistor 220Ω x1<br></td><td>F/M x4 M/M x1<br></td></tr>
</table>

## Component knowledge

The following is the diagram of infrared Motion sensor(HC SR-501):

| Top | Bottom | Schematic |
|---|---|---|
|   |   |   |

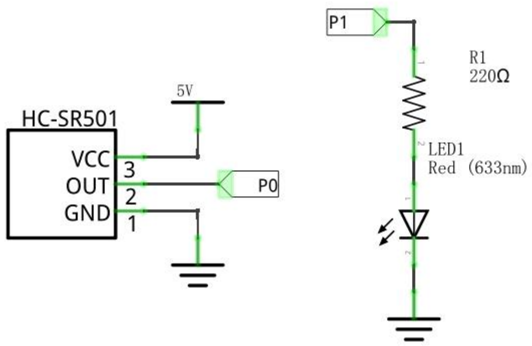
Description:

1. Working voltage: 5v-20v(DC) Static current: 65uA.
2. Automatic Trigger. When a living body enters into the active area of sensor, the module will output high level (3.3V). When the body leaves the sensor's active detection area, it will output high level lasting for time period T, then output low level(0V). Delay time T can be adjusted by the potentiometer R1.
3. According to the position of Fresnel lenses dome, you can choose non-repeatable trigger modes or repeatable modes.
   L: non-repeatable trigger mode. The module output high level after sensing a body, then when the delay time is over, the module will output low level. During high level time, the sensor no longer actively senses bodies.
   H: repeatable trigger mode. The distinction from the L mode is that it can sense a body until that body leaves during the period of high level output. After this, it starts to time and output low level after delaying T time.
4. Induction block time: the induction will stay in block condition and does not induce external signal at lesser time intervals (less than delay time) after outputting high level or low level
5. Initialization time: the module needs about 1 minute to initialize after being powered ON. During this period, it will alternately output high or low level.
6. One characteristic of this sensor is when a body moves close to or moves away from the sensor's dome edge, the sensor will work at high sensitively. When a body moves close to or moves away from the sensor's dome in a vertical direction (perpendicular to the dome), the sensor cannot detect well (please take note of this deficiency). Actually this makes sense when you consider that this sensor is usually placed on a celling as part of a security product. Note: The Sensing Range (distance before a body is detected) is adjusted by the potentiometer.

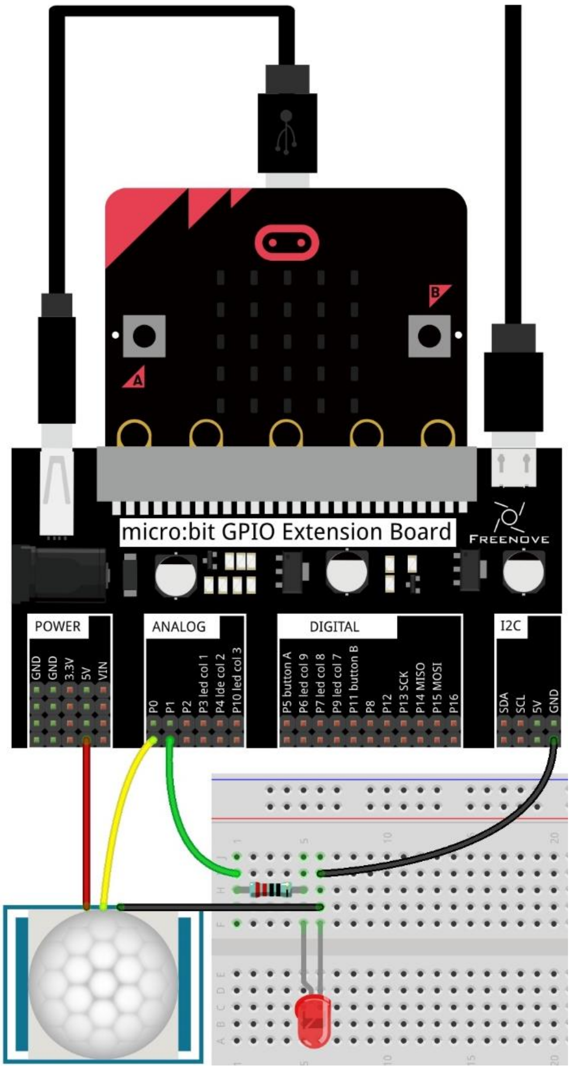
We can regard this sensor as a simple inductive switch when in use.

## Circuit

Schematic diagram




Hardware connection

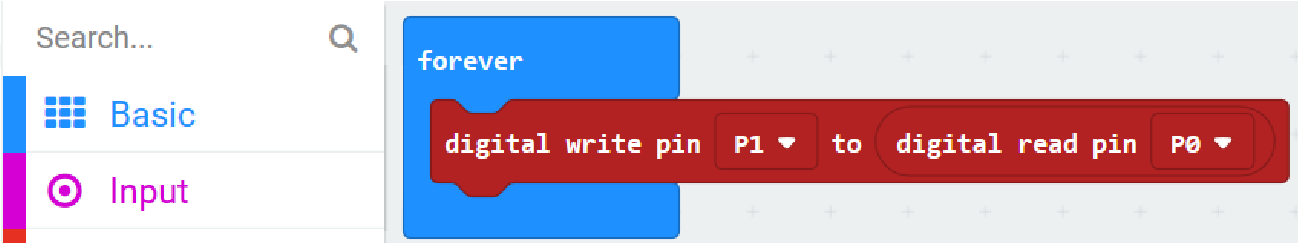


## Block code

Open MakeCode first. Import the .hex file. The path is as below:
(How to import project)

| File type | Path | File name |
|---|---|---|
| HEX file | ../Projects/BlockCode/26.1_SenseLight | SenseLight.hex |

After import successfully, the code is shown as below:




After checking the connection of the circuit and verifying it correct, download the code into micro:bit, then HC-SR501 module is initialized for about one minute. After initialization, when someone is moving in its detection range, the LED will light up; otherwise it will not respond. Two potentiometers can adjust the detection distance and Induction block time.

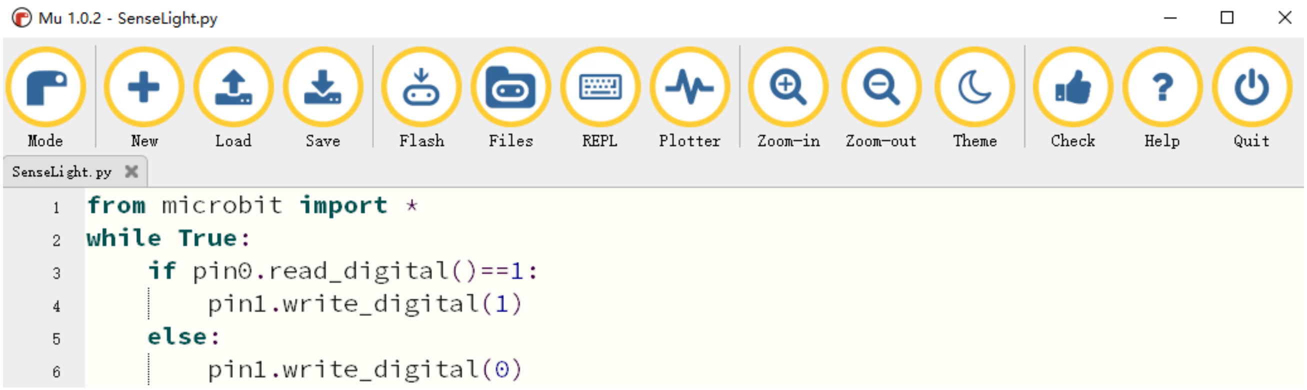
If human movement is detected, the module will output high level. If not, the module will always output low level. The level read from P0 pin is written to the P1 pin, so that the level of P0 and P1 pin will be consistent to control the LED.

# Python code

Open the .py file with Mu. Code, the path is as below:

| File type | Path | File name |
|---|---|---|
| **Python file** | ../Projects/PythonCode/26.1_SenseLight | SenseLight.py |

After loading successfully, the code is shown as below:




After checking the connection of the circuit and verifying it correct, download the code into micro:bit, then HC-SR501 module is initialized for about one minute. After initialization, when someone is moving in its detection range, the LED will light up; Otherwise it will not respond. Two potentiometers can adjust the detection distance and Induction block time.

The following is the program code:

```
from microbit import *
while True:
    if pin0.read_digital()==1:
        pin1.write_digital(1)
    else:
        pin1.write_digital(0)
```

If human movement is detected, the module will output high level. If not, the module will always output low level. According to the read level of the P1 pin, the P0 pin also outputs the same level to control the LED.

```
    if pin0.read_digital()==1:
        pin1.write_digital(1)
    else:
        pin1.write_digital(0)
```

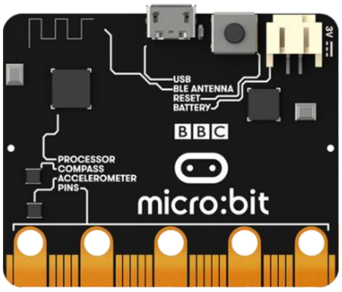
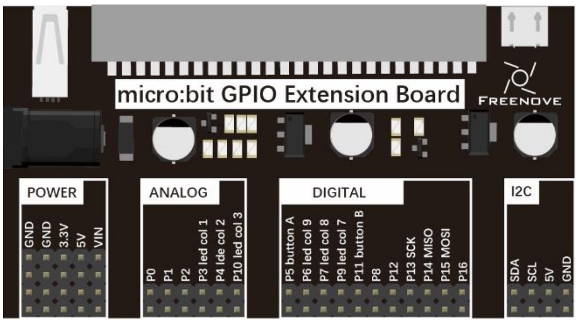
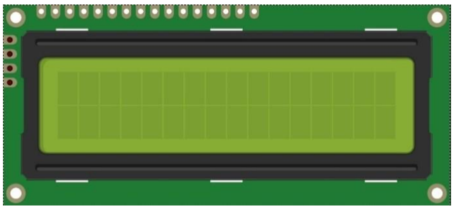
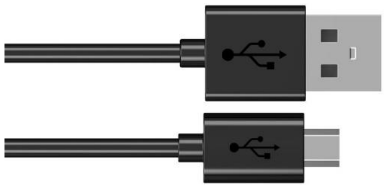
# Chapter 27 Ultrasonic Ranging

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

## Project 27.1 Ultrasonic Ranging

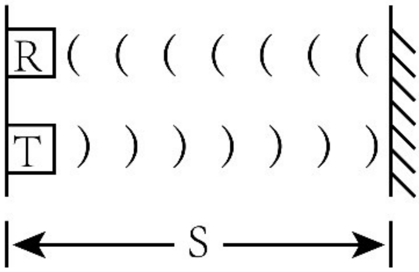
In this project, we use HC-SR04 ultrasonic module to measure the distance between the module and the obstacle in front of it and display it on LCD screen.

### Component list

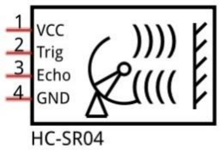
| | |
|---|---|
| Microbit x1  | Extension board x1  |
| I2C LCD1602 Module x1  | USB cable x2  |
| F/F x8  | HC-SR04 x1  |

## Component Knowledge

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




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

| | |
|---|---|
|   |   |

Pin description:

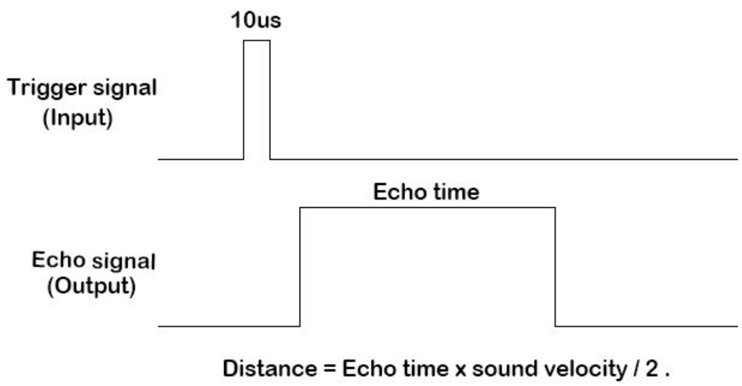
| | |
|---|---|
| VCC | power supply pin |
| Trig | trigger pin |
| Echo | Echo pin |
| GND | GND |

**Technical specs:**

Working voltage: 5V Working current: 12mA

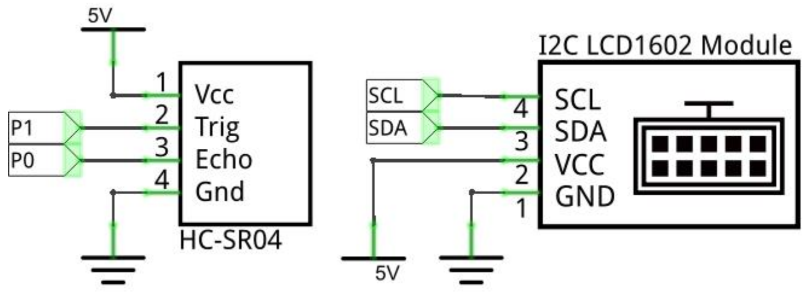
Minimum measured distance: 2cm Maximum measured distance: 200cm

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

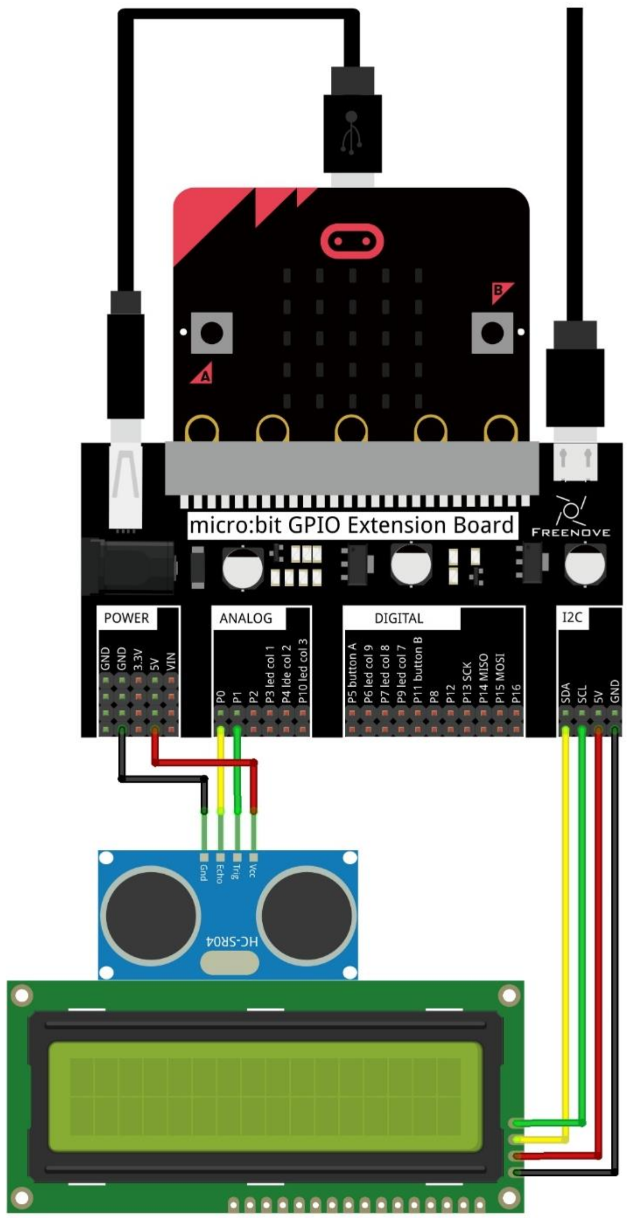


## Circuit

Schematic diagram




Hardware connection

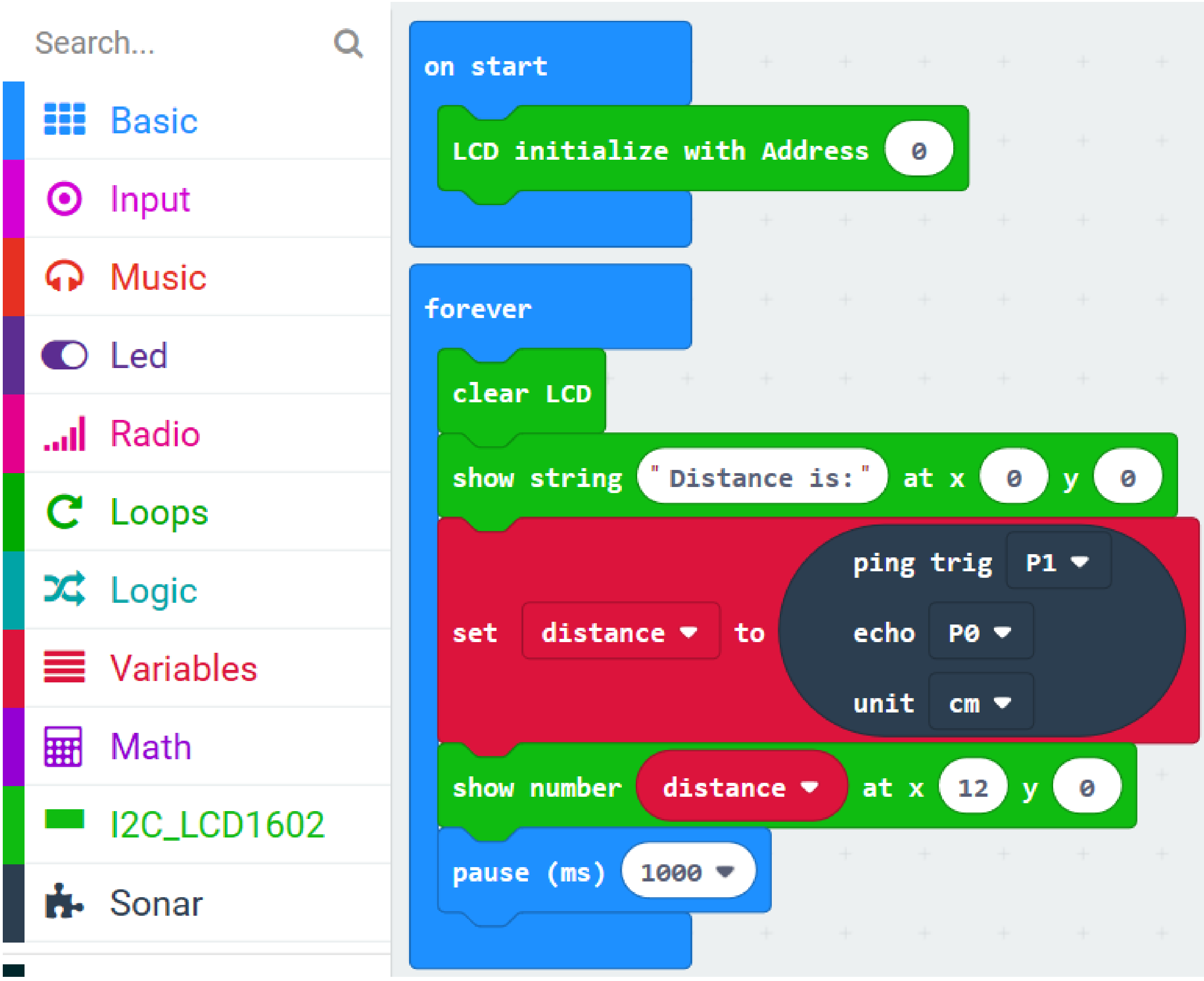


## Block code

Open MakeCode first. Import the .hex file. The path is as below:
(How to import project)

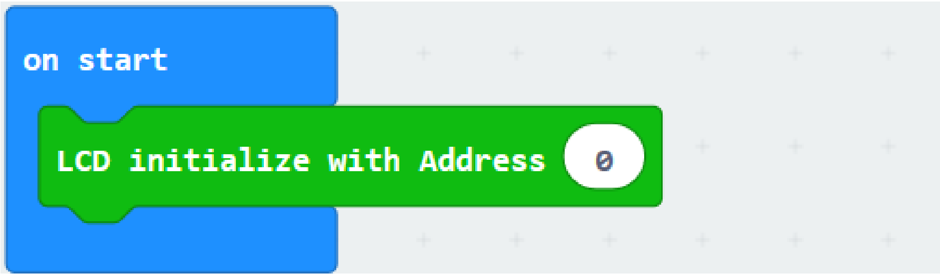
| File type | Path | File name |
|---|---|---|
| HEX file | ../Projects/BlockCode/27.1_UltrasonicRanging | UltrasonicRanging.hex |

After importing successfully, the code is shown as below:

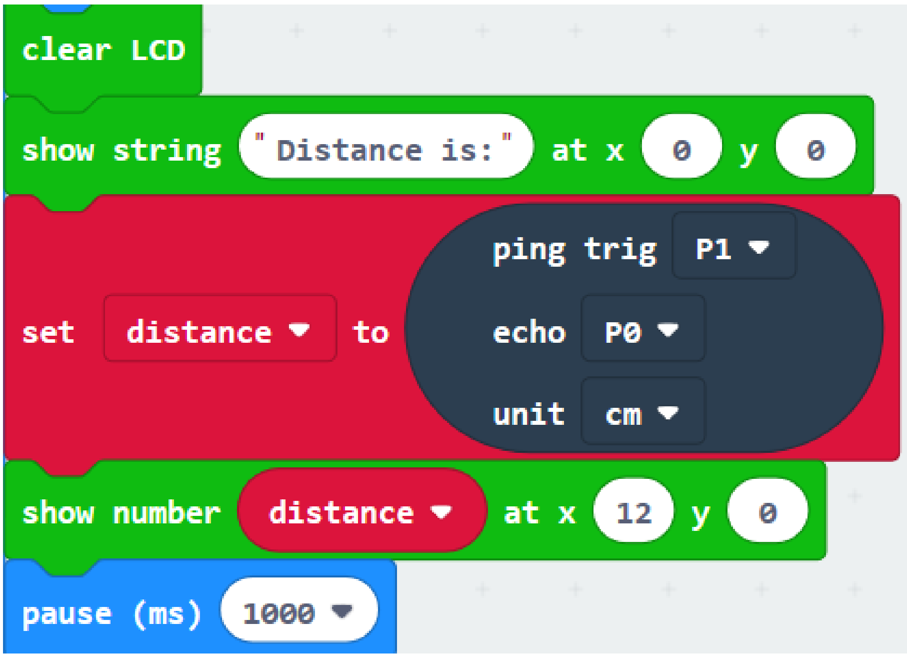



After checking the connection of the circuit and verifying it correct, download the code into micro:bit. The LCD screen will show the distance between the obstacle and the ultrasonic module in CM.

Initialize LCD.




The distance of obstacles measured by the ultrasonic module will be assigned to the variable distance, and then displayed on LCD. LCD refreshes every 1 second.

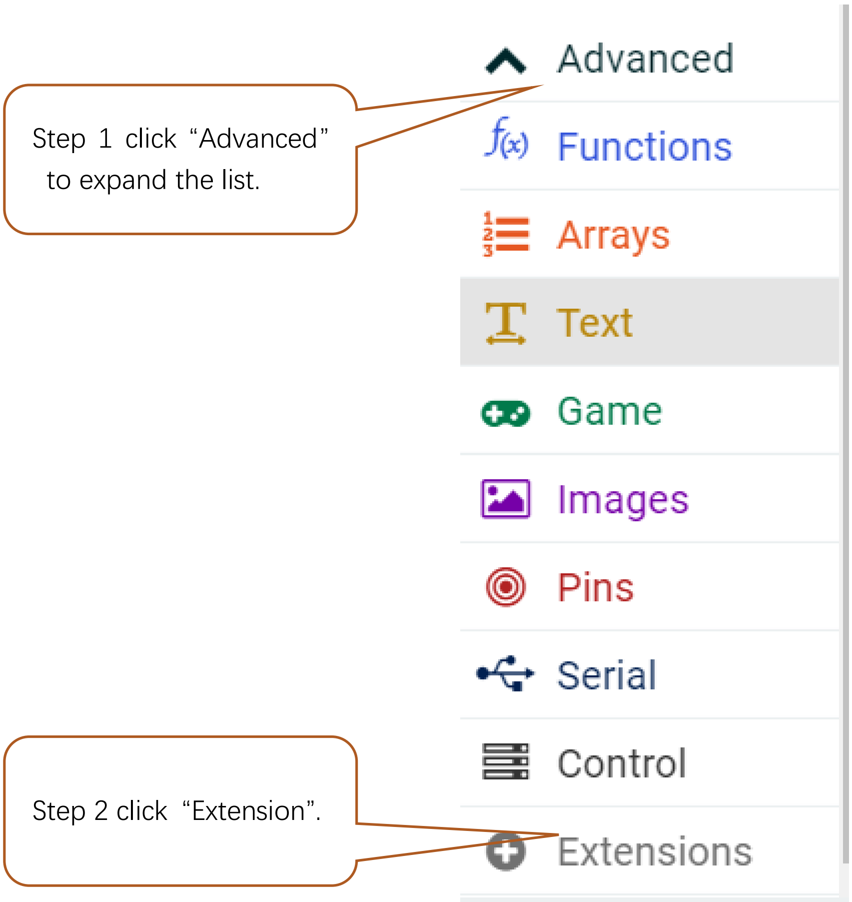


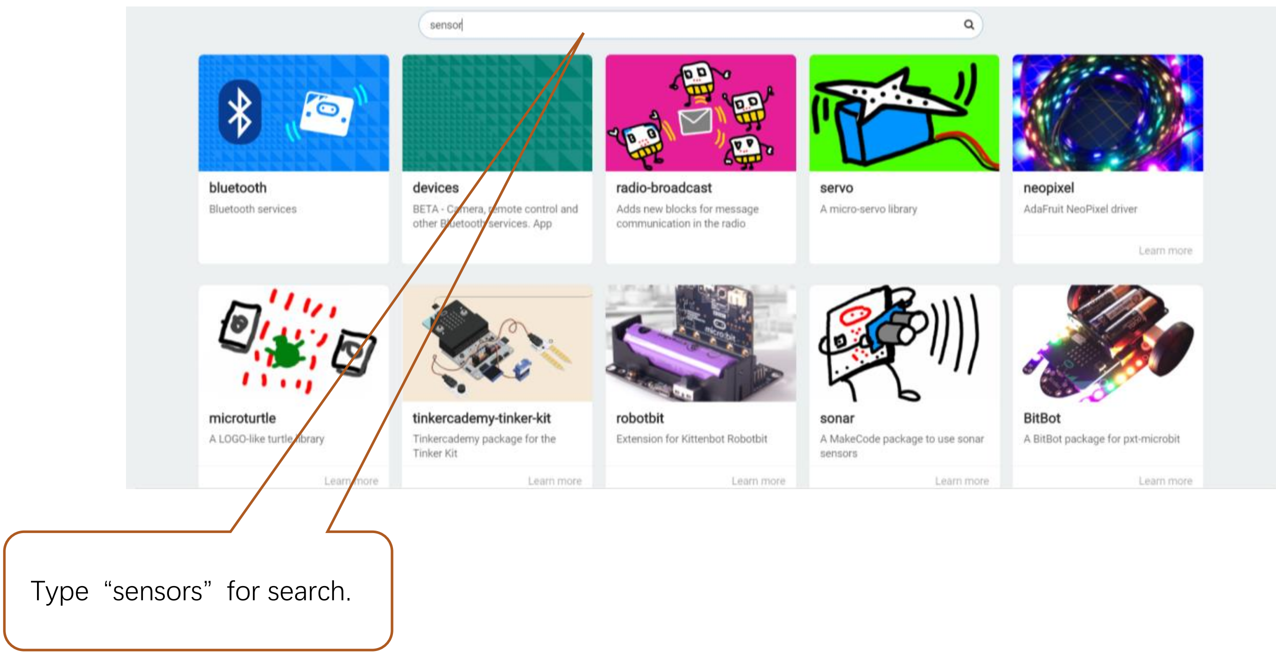

## Reference

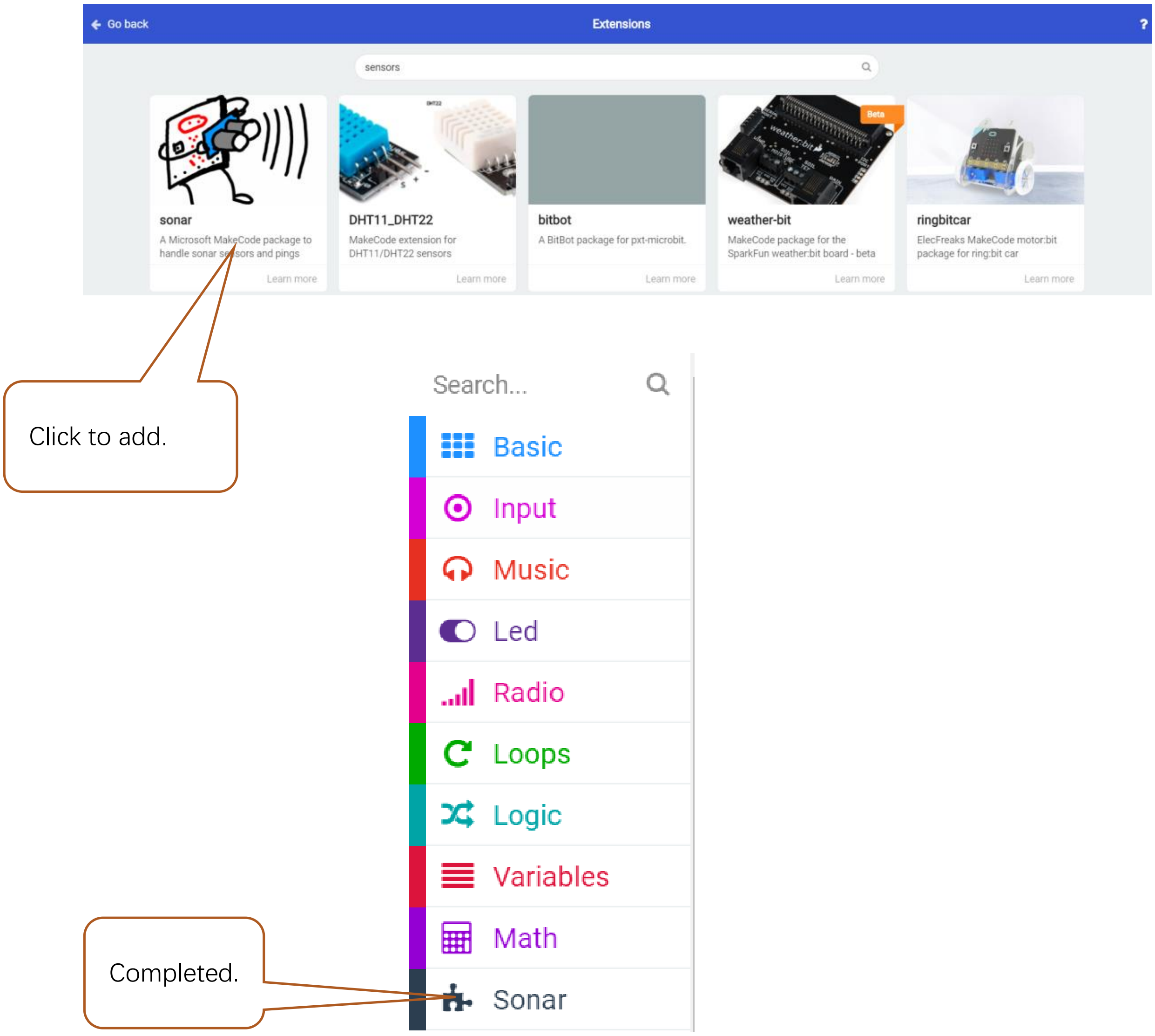
| Block | Function |
|---|---|
|   | It can return the distance of obstacles detected by sensor. |

## Extensions

If you want to import the ultrasonic module expansion block into the new project, follow the steps below to add it.



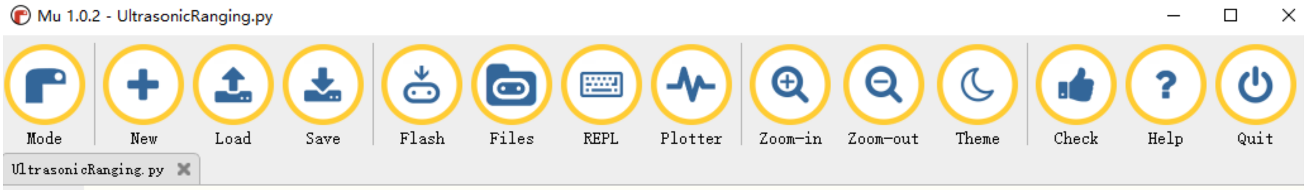

Go back
Extensions
sensors
sonar
A Microsoft MakeCode package to handle sonar sensors and pings
DHT11_DHT22
MakeCode extension for DHT11/DHT22 sensors
bitbot
A BitBot package for pxt-microbit.
weather-bit
MakeCode package for the SparkFun weather:bit board - beta
ringbitcar
ElecFreaks MakeCode motor:bit package for ring:bit car
Learn more
Click to add.
Search...
Basic
Input
Music
Led
Radio
Loops
Logic
Variables
Math
Sonar
Completed.

# Python code

Open the .py file with Mu. Code, the path is as below:

| File type | Path | File name |
|---|---|---|
| Python file | ../Projects/PythonCode/27.1_UltrasonicRanging | UltrasonicRanging.py |

After the code is loaded, as shown below, import the "I2C_LCD1602_Class.py" file to micro:bit before downloading the code. (How to import?)




```
from microbit import *
from I2C_LCD1602_Class import *
from time import sleep_us,ticks_us
def getdistance():
    distance=0
    pin1.write_digital(1)
    sleep_us(15)
    pin1.write_digital(0)
    while pin0.read_digital() == 0:
        pass
    if pin0.read_digital() == 1:
        ts = ticks_us()
        while pin0.read_digital() == 1:
            pass
        te = ticks_us()
        tc = te - ts
        print(te,ts)
        distance = (tc*170)*0.0001
    return distance

lcd = I2C_LCD1602(0x27)
while True:
  distance=round(getdistance())
  lcd.clear()
  lcd.puts("Distance is:",0,0)
  lcd.puts(str(distance),12,0)
  sleep(1000)
```

After importing the I2C_LCD1602_Class.py file, check the connection of the circuit and verify it correct. After downloading the code into micro:bit, you can see that the LCD screen will show the distance between the obstacle and the ultrasonic module. The unit is CM.

The following is the program code:

```
from microbit import *
from I2C_LCD1602_Class import *
from time import sleep_us,ticks_us
def getdistance():
    distance=0
    pin1.write_digital(1)
    sleep_us(15)
    pin1.write_digital(0)
    while pin0.read_digital() == 0:
        pass
    if pin0.read_digital() == 1:
        ts = ticks_us()
        while pin0.read_digital() == 1:
            pass
        te = ticks_us()
        tc = te - ts
        print(te,ts)
        distance = (tc*170)*0.0001
    return distance

lcd = I2C_LCD1602(0x27)
while True:
  distance=round(getdistance())
  lcd.clear()
  lcd.puts("Distance is:",0,0)
  lcd.puts(str(distance),12,0)
  sleep(1000)
```

The custom getdistance() function is used to get the distance between the obstacle and the ultrasonic module. The unit of return value is CM.

```
def getdistance():
    distance=0
    pin1.write_digital(1)
    sleep_us(15)
    pin1.write_digital(0)
    while pin0.read_digital() == 0:
        pass
    if pin0.read_digital() == 1:
        ts = ticks_us()
        while pin0.read_digital() == 1:
            pass
        te = ticks_us()
        tc = te - ts
        print(te,ts)
        distance = (tc*170)*0.0001
    return distance
```

Create the object lcd of I2C_LCD1602 class, input I2C address 0x27, call getdistance() function, get the distance of the obstacle to the ultrasonic module, assign it to the distance variable, and then display the value of the distance variable on the LCD.

```
lcd = I2C_LCD1602(0x27)
while True:
  distance=round(getdistance())
  lcd.clear()
  lcd.puts("Distance is:",0,0)
  lcd.puts(str(distance),12,0)
  sleep(1000)
```

## Reference

| getdistance() |
|---|
| Get the distance from the ultrasonic module to the obstacle. The unit is CM. |

# 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 you have suggestions and/or questions about the Tutorial or component contents of this Kit, please feel free to contact us: support@freenove.com
We will make every effort to make changes and correct errors as soon as feasibly possible and publish a revised version.
If you want to learn more about micro:bit, we have a smart Car named Micro:bit Rover. You can visit our website to purchase. http://www.freenove.com/store.html

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