BBC micro:bit MicroPython Documentation

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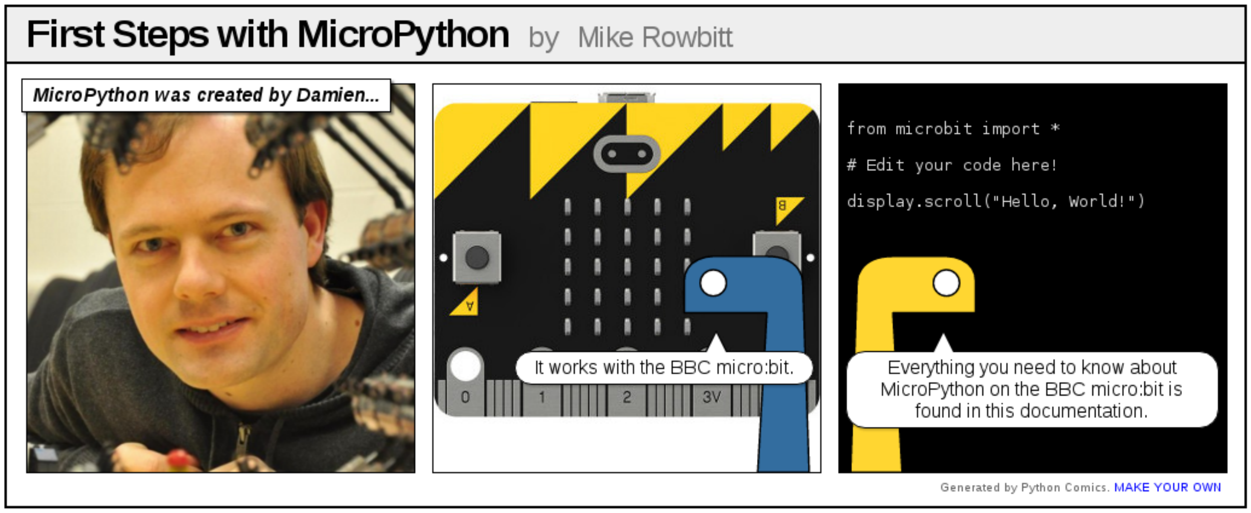
Tutorials

Welcome!

The BBC micro:bit is a small computing device for children. One of the languages it understands is the popular Python programming langauge. The version of Python that runs on the BBC micro:bit is called MicroPython.

This documentation includes lessons for teachers and API documentation for developers (check out the index on the left). We hope you enjoy developing for the BBC micro:bit using MicroPython.


First Steps with MicroPython by Mike Rowbitt
MicroPython was created by Damien...
It works with the BBC micro:bit.
Everything you need to know about MicroPython on the BBC micro:bit is found in this documentation.
Generated by Python Comics. MAKE YOUR OWN

```
from microbit import *

# Edit your code here!

display.scroll("Hello, World!")
```

To get involved with the community subscribe to the microbit@python.org mailing list (https://mail.python.org/mailman/listinfo/microbit).

Note: This project is under active development. Please help other developers by adding tips, how-tos, and Q&A to this document. Thanks!

Projects related to MicroPython on the BBC micro:bit include:

- Mu - a simple code editor for kids, teachers and beginner programmers. Probably the easiest way for people to program MicroPython on the BBC micro:bit.
- uFlash - a command line tool for flashing raw Python scripts onto a BBC micro:bit.

CHAPTER 1

Introduction

Hello, World!

The traditional way to start programming in a new language is to get your computer to say, “Hello, World!”.

This is easy with MicroPython:

```
from microbit import *
display.scroll("Hello, World!")
```

Each line does something special. The first line:

```
from microbit import *
```

...tells MicroPython to get all the stuff it needs to work with the BBC micro:bit. All this stuff is in a module called `microbit` (a module is a library of pre-existing code). When you `import` something you’re telling MicroPython that you want to use it, and `*` is Python’s way to say *everything*. So, `from microbit import *` means, in English, “I want to be able to use everything from the microbit code library”.

The second line:

```
display.scroll("Hello, World!")
```

...tells MicroPython to use the display to scroll the string of characters “Hello, World!”. The `display` part of that line is an *object* from the `microbit` module that represents the device’s physical display (we say “object” instead of “thingy”, “whatsit” or “doodah”). We can tell the display to do things with a full-stop `.` followed by what looks like a command (in fact it’s something we call a *method*). In this case we’re using the `scroll` method. Since `scroll` needs to know what characters to scroll across the physical display we specify them between double quotes (`"`) within parenthesis (`(` and `)`). These are called the *arguments*. So, `display.scroll("Hello, World!")` means, in English, “I want you to use the display to scroll the text ‘Hello, World!’”. If a method doesn’t need any arguments we make this clear by using empty parenthesis like this: `()`.

Copy the "Hello, World!" code into your editor and flash it onto the device. Can you work out how to change the message? Can you make it say hello to you? For example, I might make it say "Hello, Nicholas!". Here's a clue, you need to change the scroll method's argument.

Warning: It may not work. :-)

This is where things get fun and MicroPython tries to be helpful. If it encounters an error it will scroll a helpful message on the micro:bit's display. If it can, it will tell you the line number for where the error can be found.

Python expects you to type **EXACTLY** the right thing. So, for instance, `Microbit`, `microbit` and `microBit` are all different things to Python. If MicroPython complains about a `NameError` it's probably because you've typed something inaccurately. It's like the difference between referring to "Nicholas" and "Nicolas". They're two different people but their names look very similar.

If MicroPython complains about a `SyntaxError` you've simply typed code in a way that MicroPython can't understand. Check you're not missing any special characters like `"` or `:`. It's like putting. a full stop in the middle of a sentence. It's hard to understand exactly what you mean.

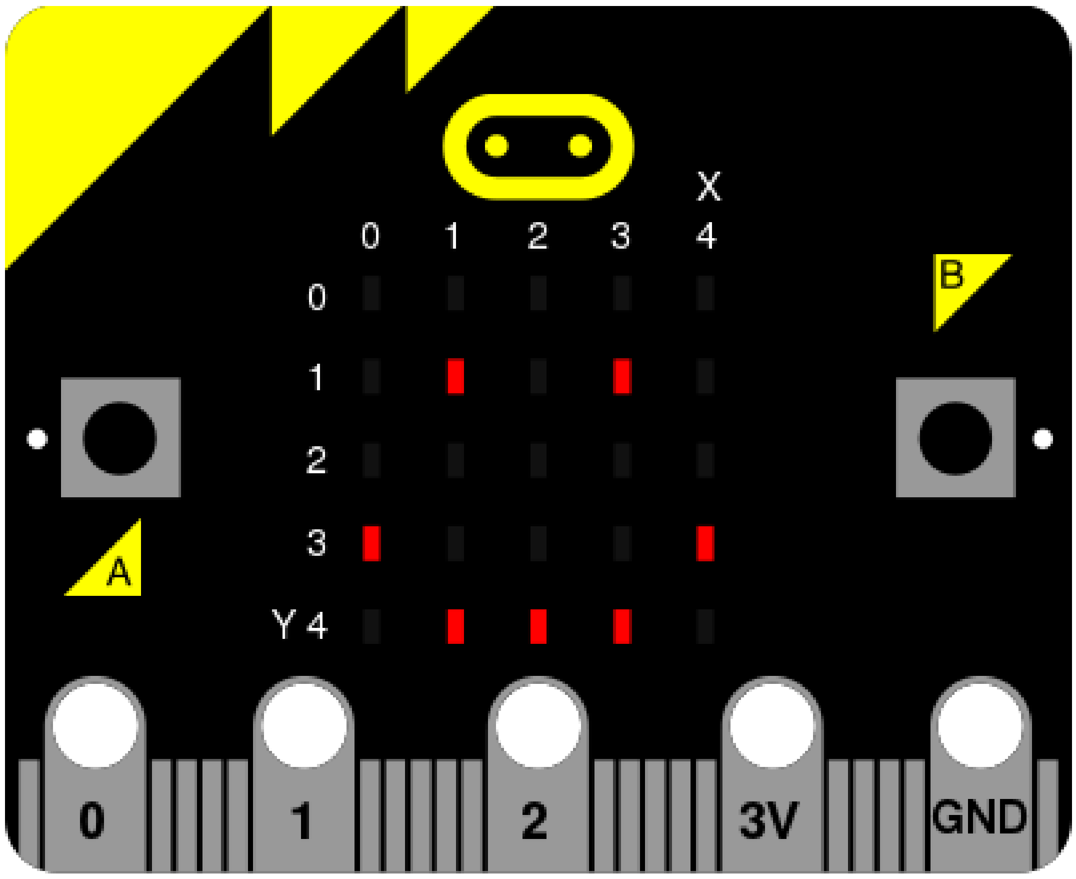
Images

MicroPython is about as good at art as you can be if the only thing you have is a 5x5 grid of red LEDs (light emitting diodes - the things that light up on the front of the device). MicroPython gives you quite a lot of control over the display so you can create all sorts of interesting effects.

MicroPython comes with lots of built-in pictures to show on the display. For example, to make the device appear happy you type:

```python
from microbit import *
display.show(Image.HAPPY)
```

I suspect you can remember what the first line does. The second line uses the `display` object to `show` a built-in image. The happy image we want to display is a part of the `Image` object and called `HAPPY`. We tell `show` to use it by putting it between the parenthesis (`(` and `)`).



Here's a list of the built-in images:

- Image.HEART
- Image.HEART_SMALL
- Image.HAPPY
- Image.SMILE
- Image.SAD
- Image.CONFUSED
- Image.ANGRY
- Image.ASLEEP
- Image.SURPRISED
- Image.SILLY
- Image.FABULOUS
- Image.MEH
- Image.YES
- Image.NO
- Image.CLOCK12, Image.CLOCK11, Image.CLOCK10, Image.CLOCK9, Image.CLOCK8, Image.CLOCK7, Image.CLOCK6, Image.CLOCK5, Image.CLOCK4, Image.CLOCK3, Image.CLOCK2,

  `Image.CLOCK1`

- `Image.ARROW_N`, `Image.ARROW_NE`, `Image.ARROW_E`, `Image.ARROW_SE`, `Image.ARROW_S`, `Image.ARROW_SW`, `Image.ARROW_W`, `Image.ARROW_NW`
- `Image.TRIANGLE`
- `Image.TRIANGLE_LEFT`
- `Image.CHESSBOARD`
- `Image.DIAMOND`
- `Image.DIAMOND_SMALL`
- `Image.SQUARE`
- `Image.SQUARE_SMALL`
- `Image.RABBIT`
- `Image.COW`
- `Image.MUSIC_CROTCHET`
- `Image.MUSIC_QUAVER`
- `Image.MUSIC_QUAVERS`
- `Image.PITCHFORK`
- `Image.XMAS`
- `Image.PACMAN`
- `Image.TARGET`
- `Image.TSHIRT`
- `Image.ROLLERSKATE`
- `Image.DUCK`
- `Image.HOUSE`
- `Image.TORTOISE`
- `Image.BUTTERFLY`
- `Image.STICKFIGURE`
- `Image.GHOST`
- `Image.SWORD`
- `Image.GIRAFFE`
- `Image.SKULL`
- `Image.UMBRELLA`
- `Image.SNAKE`

There's quite a lot! Why not modify the code that makes the micro:bit look happy to see what some of the other built-in images look like? (Just replace `Image.HAPPY` with one of the built-in images listed above.)

DIY Images

Of course, you want to make your own image to display on the micro:bit, right?

That's easy.

Each LED pixel on the physical display can be set to one of ten values. If a pixel is set to `0` (zero) then it's off. It literally has zero brightness. However, if it is set to `9` then it is at its brightest level. The values `1` to `8` represent the brightness levels between off (`0`) and full on (`9`).

Armed with this information, it's possible to create a new image like this:

```
from microbit import *

boat = Image("05050:"
             "05050:"
             "05050:"
             "99999:"
             "09990")

display.show(boat)
```

(When run, the device should display an old-fashioned "Blue Peter" sailing ship with the masts dimmer than the boat's hull.)

Have you figured out how to draw a picture? Have you noticed that each line of the physical display is represented by a line of numbers ending in `:` and enclosed between `"` double quotes? Each number specifies a brightness. There are five lines of five numbers so it's possible to specify the individual brightness for each of the five pixels on each of the five lines on the physical display. That's how to create a new image.

Simple!

In fact, you don't need to write this over several lines. If you think you can keep track of each line, you can rewrite it like this:

```
boat = Image("05050:05050:05050:99999:09990")
```

Animation

Static images are fun, but it's even more fun to make them move. This is also amazingly simple to do with MicroPython ~ just use a list of images!

Here is a shopping list:

```
Eggs
Bacon
Tomatoes
```

Here's how you'd represent this list in Python:

```
shopping = ["Eggs", "Bacon", "Tomatoes" ]
```

I've simply created a list called `shopping` and it contains three items. Python knows it's a list because it's enclosed in square brackets (`[` and `]`). Items in the list are separated by a comma (`,`) and in this instance the items are three strings of characters: `"Eggs"`, `"Bacon"` and `"Tomatoes"`. We know they are strings of characters because they're enclosed in quotation marks `"`.

You can store anything in a list with Python. Here's a list of numbers:

```
primes = [2, 3, 5, 7, 11, 13, 17, 19]
```

Note: Numbers don't need to be quoted since they represent a value (rather than a string of characters). It's the difference between `2` (the numeric value 2) and `"2"` (the character/digit representing the number 2). Don't worry if this doesn't make sense right now. You'll soon get used to it.

It's even possible to store different sorts of things in the same list:

```
mixed_up_list = ["hello!", 1.234, Image.HAPPY]
```

Notice that last item? It was an image!

We can tell MicroPython to animate a list of images. Luckily we have a couple of lists of images already built in. They're called `Image.ALL_CLOCKS` and `Image.ALL_ARROWS`:

```
from microbit import *

display.show(Image.ALL_CLOCKS, loop=True, delay=100)
```

As with a single image, we use `display.show` to show it on the device's display. However, we tell MicroPython to use `Image.ALL_CLOCKS` and it understands that it needs to show each image in the list, one after the other. We also tell MicroPython to keep looping over the list of images (so the animation lasts forever) by saying `loop=True`. Furthermore, we tell it that we want the delay between each image to be only 100 milliseconds (a tenth of a second) with the argument `delay=100`.

Can you work out how to animate over the `Image.ALL_ARROWS` list? How do you avoid looping forever (hint: the opposite of `True` is `False` although the default value for `loop` is `False`)? Can you change the speed of the animation?

Finally, here's how to create your own animation. In my example I'm going to make my boat sink into the bottom of the display:

```
from microbit import *

boat1 = Image("05050:"
              "05050:"
              "05050:"
              "99999:"
              "09990")

boat2 = Image("00000:"
              "05050:"
              "05050:"
              "05050:"
              "99999")

boat3 = Image("00000:"
              "00000:"
              "05050:"
              "05050:"
              "05050")

boat4 = Image("00000:"
              "00000:"
              "00000:"
              "05050:"
              "05050")

boat5 = Image("00000:"
              "00000:"
              "00000:"
              "00000:"
              "05050")

boat6 = Image("00000:"
              "00000:"
              "00000:"
              "00000:"
              "00000")

all_boats = [boat1, boat2, boat3, boat4, boat5, boat6]
display.show(all_boats, delay=200)
```

Here's how the code works:

- I create six `boat` images in exactly the same way I described above.
- Then, I put them all into a list that I call `all_boats`.
- Finally, I ask `display.show` to animate the list with a delay of 200 milliseconds.
- Since I've not set `loop=True` the boat will only sink once (thus making my animation scientifically accurate). :-)

What would you animate? Can you animate special effects? How would you make an image fade out and then fade in again?

Buttons

So far we have created code that makes the device do something. This is called *output*. However, we also need the device to react to things. Such things are called *inputs*.

It's easy to remember: output is what the device puts out to the world whereas input is what goes into the device for it to process.

The most obvious means of input on the micro:bit are its two buttons, labelled `A` and `B`. Somehow, we need MicroPython to react to button presses.

This is remarkably simple:

```
from microbit import *

sleep(10000)
display.scroll(str(button_a.get_presses()))
```

All this script does is sleep for ten thousand milliseconds (i.e. 10 seconds) and then scrolls the number of times you pressed button `A`. That's it!

While it's a pretty useless script, it introduces a couple of interesting new ideas:

1. The `sleep` *function* will make the micro:bit sleep for a certain number of milliseconds. If you want a pause in your program, this is how to do it. A *function* is just like a *method*, but it isn't attached by a dot to an *object*.
2. There is an object called `button_a` and it allows you to get the number of times it has been pressed with the `get_presses` *method*.

Since get_presses gives a numeric value and display.scroll only displays characters, we need to convert the numeric value into a string of characters. We do this with the str function (short for "string" ~ it converts things into strings of characters).

The third line is a bit like an onion. If the parenthesis are the onion skins then you'll notice that display.scroll contains str that itself contains button_a.get_presses. Python attempts to work out the inner-most answer first before starting on the next layer out. This is called *nesting* - the coding equivalent of a Russian Matrioshka doll.

Let's pretend you've pressed the button 10 times. Here's how Python works out what's happening on the third line:

Python sees the complete line and gets the value of get_presses:

```
display.scroll(str(button_a.get_presses()))
```

Now that Python knows how many button presses there have been, it converts the numeric value into a string of characters:

```
display.scroll(str(10))
```

Finally, Python knows what to scroll across the display:

```
display.scroll("10")
```

While this might seem like a lot of work, MicroPython makes this happen extraordinarily fast.

Event Loops

Often you need your program to hang around waiting for something to happen. To do this you make it loop around a piece of code that defines how to react to certain expected events such as a button press.

To make loops in Python you use the while keyword. It checks if something is True. If it is, it runs a *block of code* called the *body* of the loop. If it isn't, it breaks out of the loop (ignoring the body) and the rest of the program can continue.

Python makes it easy to define blocks of code. Say I have a to-do list written on a piece of paper. It probably looks something like this:

```
Shopping
Fix broken gutter
Mow the lawn
```

If I wanted to break down my to-do list a bit further, I might write something like this:

```
Shopping:
    Eggs
    Bacon
    Tomatoes
Fix broken gutter:
    Borrow ladder from next door
    Find hammer and nails
    Return ladder
Mow the lawn:
    Check lawn around pond for frogs
    Check mower fuel level
```

It's obvious that the main tasks are broken down into sub-tasks that are *indented* underneath the main task to which they are related. So `Eggs`, `Bacon` and `Tomatoes` are obviously related to `Shopping`. By indenting things we make it easy to see, at a glance, how the tasks relate to each other.

This is called *nesting*. We use nesting to define blocks of code like this:

```
from microbit import *

while running_time() < 10000:
    display.show(Image.ASLEEP)

display.show(Image.SURPRISED)
```

The `running_time` function returns the number of milliseconds since the device started.

The `while running_time() < 10000:` line checks if the running time is less than 10000 milliseconds (i.e. 10 seconds). If it is, *and this is where we can see scoping in action*, then it'll display `Image.ASLEEP`. Notice how this is indented underneath the `while` statement *just like in our to-do list*.

Obviously, if the running time is equal to or greater than 10000 milliseconds then the display will show `Image.SURPRISED`. Why? Because the `while` condition will be False (`running_time` is no longer `< 10000`). In that case the loop is finished and the program will continue after the `while` loop's block of code. It'll look like your device is asleep for 10 seconds before waking up with a surprised look on its face.

Try it!

Handling an Event

If we want MicroPython to react to button press events we should put it into an infinite loop and check if the button `is_pressed`.

An infinite loop is easy:

```
while True:
    # Do stuff
```

(Remember, `while` checks if something is `True` to work out if it should run its block of code. Since `True` is obviously `True` for all time, you get an infinite loop!)

Let's make a very simple cyber-pet. It's always sad unless you're pressing button `A`. If you press button `B` it dies. (I realise this isn't a very pleasant game, so perhaps you can figure out how to improve it.):

```
from microbit import *

while True:
    if button_a.is_pressed():
        display.show(Image.HAPPY)
    elif button_b.is_pressed():
        break
    else:
        display.show(Image.SAD)

display.clear()
```

Can you see how we check what buttons are pressed? We used `if`, `elif` (short for "else if") and `else`. These are called *conditionals* and work like this:

```
if something is True:
    # do one thing
elif some other thing is True:
    # do another thing
else:
    # do yet another thing.
```

This is remarkably similar to English!

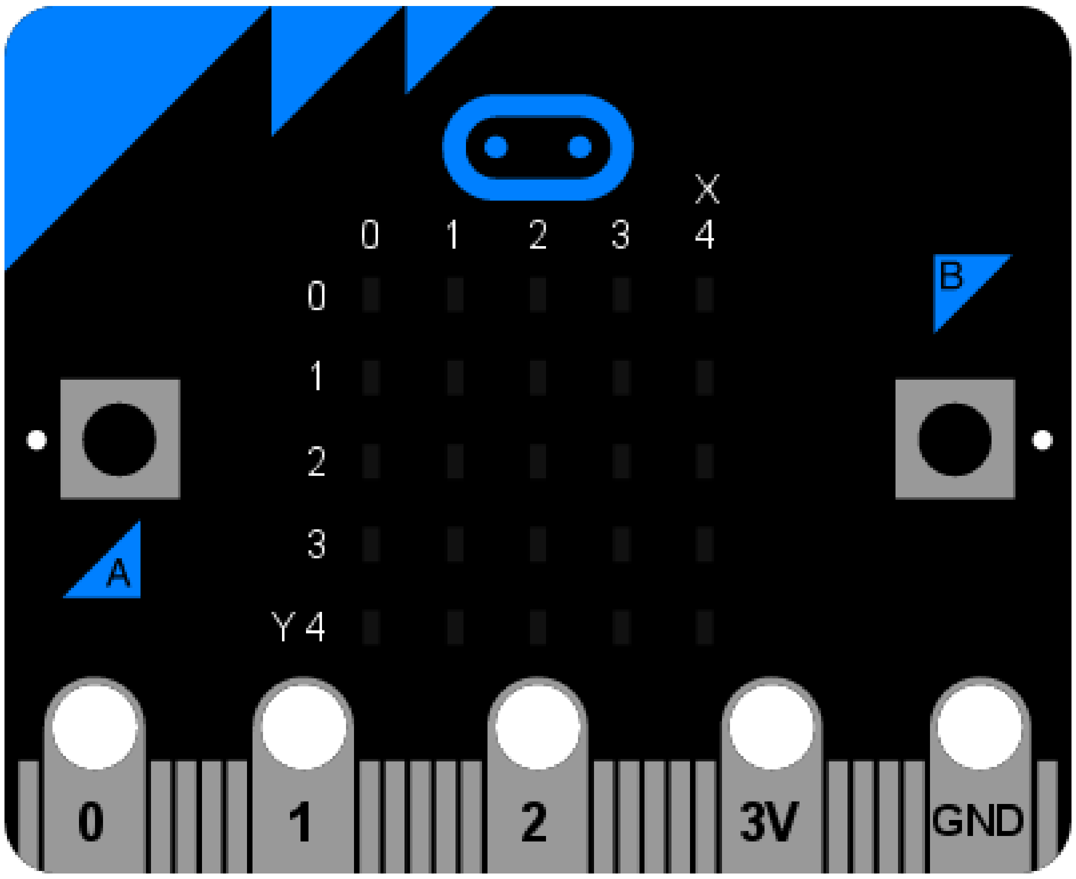
The `is_pressed` method only produces two results: `True` or `False`. If you're pressing the button it returns `True`, otherwise it returns `False`. The code above is saying, in English, "for ever and ever, if button A is pressed then show a happy face, else if button B is pressed break out of the loop, otherwise display a sad face." We break out of the loop (stop the program running for ever and ever) with the `break` statement.

At the very end, when the cyber-pet is dead, we `clear` the display.

Can you think of ways to make this game less tragic? How would you check if *both* buttons are pressed? (Hint: Python has `and`, `or` and `not` logical operators to help check multiple truth statements (things that produce either `True` or `False` results).

Input/Output

There are strips of metal along the bottom edge of the BBC micro:bit that make it look as if the device has teeth. These are the input/output pins (or I/O pins for short).



Some of the pins are bigger than others so it's possible to attach crocodile clips to them. These are the ones labelled 0, 1, 2, 3V and GND (computers always start counting from zero). If you attach an edge connector board to the device it's possible to plug in wires connected to the other (smaller) pins.

Each pin on the BBC micro:bit is represented by an *object* called `pinN` where `N` is the pin number. So, for example, to do things with the pin labelled with a 0 (zero), use the object called `pin0`.

Simple!

These objects have various *methods* associated with them depending upon what the specific pin is capable of.

Ticklish Python

The simplest example of input via the pins is a check to see if they are touched. So, you can tickle your device to make it laugh like this:

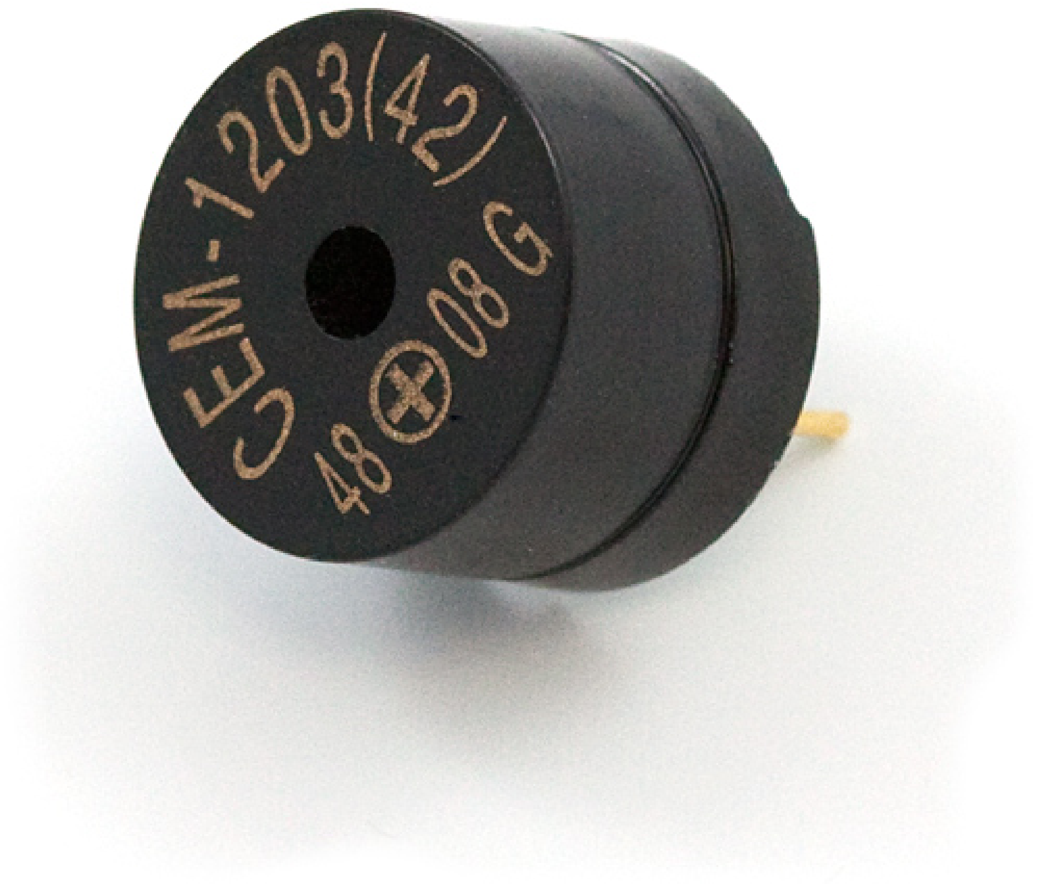
```
from microbit import *

while True:
    if pin0.is_touched():
        display.show(Image.HAPPY)
    else:
        display.show(Image.SAD)
```

With one hand, hold your device by the GND pin. Then, with your other hand, touch (or tickle) the 0 (zero) pin. You should see the display change from grumpy to happy!

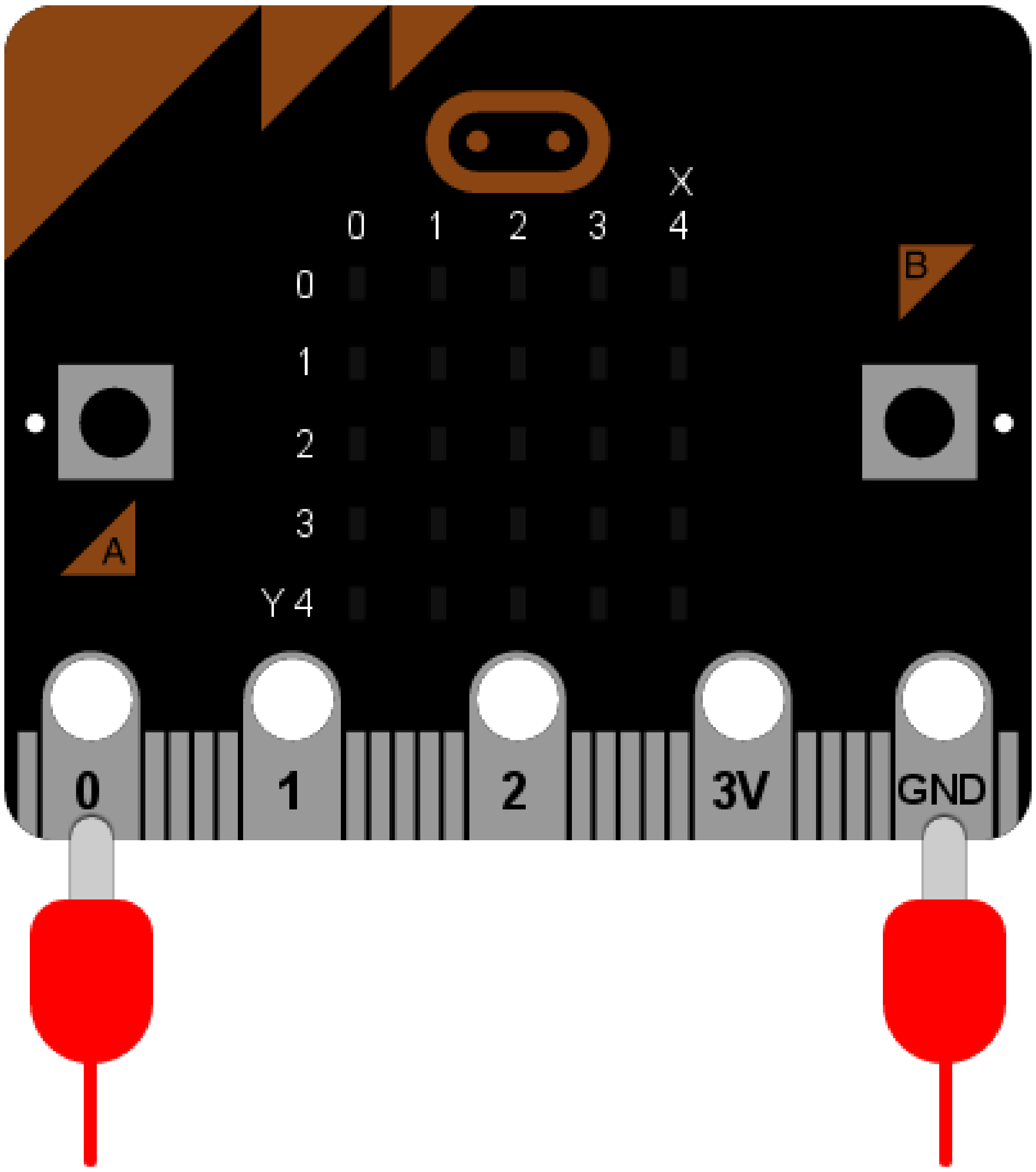
This is a form of very basic input measurement. However, the fun really starts when you plug in circuits and other devices via the pins.

Bleeps and Bloops

The simplest thing we can attach to the device is a Piezo speaker. We're going to use it for output.



These small devices play a high-pitched bleep when connected to a circuit. To attach one to your BBC micro:bit you should attach crocodile clips to pin 0 and GND (as shown below).



The wire from pin 0 should be attached to the positive connector on the speaker and the wire from GND to the negative connector.

The following program will cause the speaker to make a sound:

```
from microbit import *

pin0.write_digital(1)
```

This is fun for about 5 seconds and then you'll want to make the horrible squeaking stop. Let's improve our example and make the device bleep:

```
from microbit import *

while True:
    pin0.write_digital(1)
    sleep(20)
    pin0.write_digital(0)
    sleep(480)
```

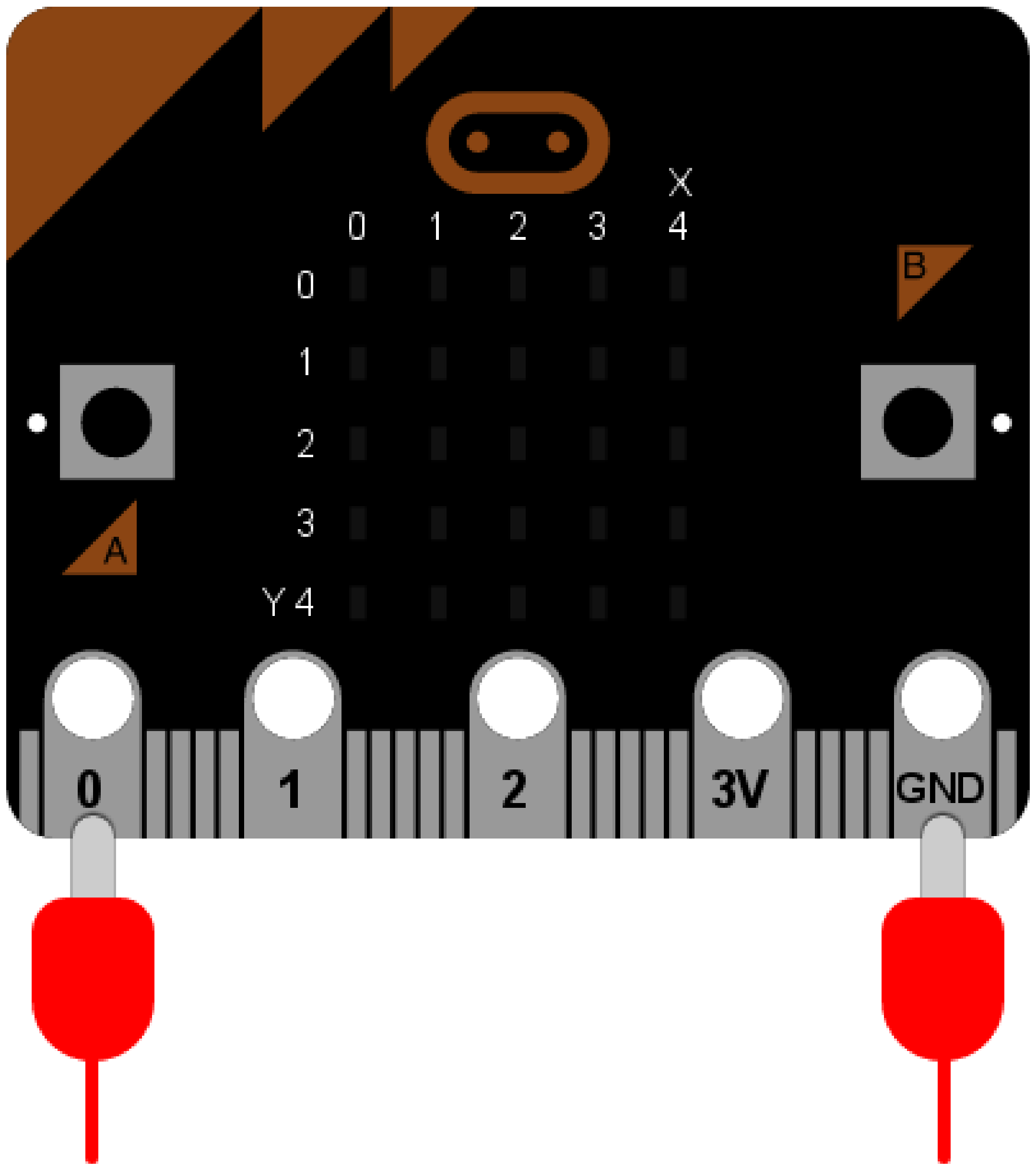
Can you work out how this script works? Remember that `1` is "on" and `0` is "off" in the digital world.

The device is put into an infinite loop and immediately switches pin 0 on. This causes the speaker to emit a beep. While the speaker is beeping, the device sleeps for twenty milliseconds and then switches pin 0 off. This gives the effect of a short bleep. Finally, the device sleeps for 480 milliseconds before looping back and starting all over again. This means you'll get two bleeps per second (one every 500 milliseconds).

We've made a very simple metronome!

Music

MicroPython on the BBC micro:bit comes with a powerful music and sound module. It's very easy to generate bleeps and bloops from the device *if you attach a speaker*. Use crocodile clips to attach pin 0 and GND to the positive and negative inputs on the speaker - it doesn't matter which way round they are connected to the speaker.



Note: Do not attempt this with a Piezo speaker - such speakers are only able to play a single tone.

Let's play some music:

```
import music

music.play(music.NYAN)
```

Notice that we import the `music` module. It contains methods used to make and control sound.

MicroPython has quite a lot of built-in melodies. Here's a complete list:

- `music.DADADADUM`
- `music.ENTERTAINER`

- `music.PRELUDE`
- `music.ODE`
- `music.NYAN`
- `music.RINGTONE`
- `music.FUNK`
- `music.BLUES`
- `music.BIRTHDAY`
- `music.WEDDING`
- `music.FUNERAL`
- `music.PUNCHLINE`
- `music.PYTHON`
- `music.BADDY`
- `music.CHASE`
- `music.BA_DING`
- `music.WAWAWAWAA`
- `music.JUMP_UP`
- `music.JUMP_DOWN`
- `music.POWER_UP`
- `music.POWER_DOWN`

Take the example code and change the melody. Which one is your favourite? How would you use such tunes as signals or cues?

Wolfgang Amadeus Microbit

Creating your own tunes is easy!

Each note has a name (like `C#` or `F`), an octave (telling MicroPython how high or low the note should be played) and a duration (how long it lasts through time). Octaves are indicated by a number ~ 0 is the lowest octave, 4 contains middle C and 8 is about as high as you'll ever need unless you're making music for dogs. Durations are also expressed as numbers. The higher the value of the duration the longer it will last. Such values are related to each other - for instance, a duration of `4` will last twice as long as a duration `2` (and so on). If you use the note name `R` then MicroPython will play a rest (i.e. silence) for the specified duration.

Each note is expressed as a string of characters like this:

```
NOTE[octave][:duration]
```

For example, `"A1:4"` refers to the note named `A` in octave number `1` to be played for a duration of `4`.

Make a list of notes to create a melody (it's equivalent to creating an animation with a list of images). For example, here's how to make MicroPython play opening of "Frere Jaques":

```
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)
```

Note: MicroPython helps you to simplify such melodies. It'll remember the octave and duration values until you next change them. As a result, the example above can be re-written as:

```
import music

tune = ["C4:4", "D", "E", "C", "C", "D", "E", "C", "E", "F", "G:8",
        "E:4", "F", "G:8"]
music.play(tune)
```

Notice how the octave and duration values only change when they have to. It's a lot less typing and simpler to read.

Sound Effects

MicroPython lets you make tones that are not musical notes. For example, here's how to create a Police siren effect:

```
import music

while True:
    for freq in range(880, 1760, 16):
        music.pitch(freq, 6)
    for freq in range(1760, 880, -16):
        music.pitch(freq, 6)
```

Notice how the `music.pitch` *method* is used in this instance. It expects a frequency. For example, the frequency of `440` is the same as a concert `A` used to tune a symphony orchestra.

In the example above the `range` function is used to generate ranges of numeric values. These numbers are used to define the pitch of the tone. The three arguments for the `range` function are the start value, end value and step size. Therefore, the first use of `range` is saying, in English, "create a range of numbers between 880 and 1760 in steps of 16". The second use of `range` is saying, "create a range of values between 1760 and 880 in steps of -16". This is how we get a range of frequencies that go up and down in pitch like a siren.

Because the siren should last forever it's wrapped in an infinite `while` loop.

Importantly, we have introduced a new sort of a loop inside the `while` loop: the `for` loop. In English it's like saying, "for each item in some collection, do some activity with it". Specifically in the example above, it's saying, "for each frequency in the specified range of frequencies, play the pitch of that frequency for 6 milliseconds". Notice how the thing to do for each item in a for loop is indented (as discussed earlier) so Python knows exactly which code to run to handle the individual items.

Random

Sometimes you want to leave things to chance, or mix it up a little: you want the device to act randomly.

MicroPython comes with a `random` module to make it easy to introduce chance and a little chaos into your code. For example, here's how to scroll a random name across the display:

```
from microbit import *
import random

```

```
names = ["Mary", "Yolanda", "Damien", "Alia", "Kushal", "Mei Xiu", "Zoltan" ]

display.scroll(random.choice(names))
```

The list (`names`) contains seven names defined as strings of characters. The final line is *nested* (the "onion" effect introduced earlier): the `random.choice` method takes the `names` list as an argument and returns an item chosen at random. This item (the randomly chosen name) is the argument for `display.scroll`.

Can you modify the list to include your own set of names?

Random Numbers

Random numbers are very useful. They're common in games. Why else do we have dice?

MicroPython comes with several useful random number methods. Here's how to make a simple dice:

```
from microbit import *
import random

display.show(str(random.randint(1, 6)))
```

Every time the device is reset it displays a number between 1 and 6. You're starting to get familiar with *nesting*, so it's important to note that `random.randint` returns a whole number between the two arguments, inclusive (a whole number is also called an integer - hence the name of the method). Notice that because `display.show` expects a character then we use the `str` function to turn the numeric value into a character (we turn, for example, `6` into `"6"`).

If you know you'll always want a number between `0` and `N` then use the `random.randrange` method. If you give it a single argument it'll return random integers up to, but not including, the value of the argument `N` (this is different to the behaviour of `random.randint`).

Sometimes you need numbers with a decimal point in them. These are called *floating point* numbers and it's possible to generate such a number with the `random.random` method. This only returns values between `0.0` and `1.0` inclusive. If you need larger random floating point numbers add the results of `random.randrange` and `random.random` like this:

```
from microbit import *
import random

answer = random.randrange(100) + random.random()
display.scroll(str(answer))
```

Seeds of Chaos

The random number generators used by computers are not truly random. They just give random like results given a starting *seed* value. The seed is often generated from random-ish values such as the current time and/or readings from sensors such as the thermometers built into chips.

Sometimes you want to have repeatable random-ish behaviour: a source of randomness that is reproducible. It's like saying that you need the same five random values each time you throw a dice.

This is easy to achieve by setting the *seed* value. Given a known seed the random number generator will create the same set of random numbers. The seed is set with `random.seed` and any whole number (integer). This version of the dice program always produces the same results:

```
from microbit import *
import random

random.seed(1337)
while True:
    if button_a.was_pressed():
        display.show(str(random.randint(1, 6)))
```

Can you work out why this program needs us to press button A instead of reset the device as in the first dice example..?

Movement

Your BBC micro:bit comes with an accelerometer. It measures movement along three axes:

- X - tilting from left to right.
- Y - tilting forwards and backwards.
- Z - moving up and down.

There is a method for each axis that returns a positive or negative number indicating a measurement in milli-g's. When the reading is 0 you are "level" along that particular axis.

For example, here's a very simple spirit-level that uses `get_x` to measure how level the device is along the X axis:

```
from microbit import *

while True:
    reading = accelerometer.get_x()
    if reading > 20:
        display.show("R")
    elif reading < -20:
        display.show("L")
    else:
        display.show("-")
```

If you hold the device flat it should display `-`; however, rotate it left or right and it'll show `L` and `R` respectively.

We want the device to constantly react to change, so we use an infinite `while` loop. The first thing to happen *within the body of the loop* is a measurement along the X axis which is called `reading`. Because the accelerometer is *so* sensitive I've made level +/-20 in range. It's why the `if` and `elif` conditionals check for `> 20` and `< -20`. The `else` statement means that if the `reading` is between -20 and 20 then we consider it level. For each of these conditions we use the display to show the appropriate character.

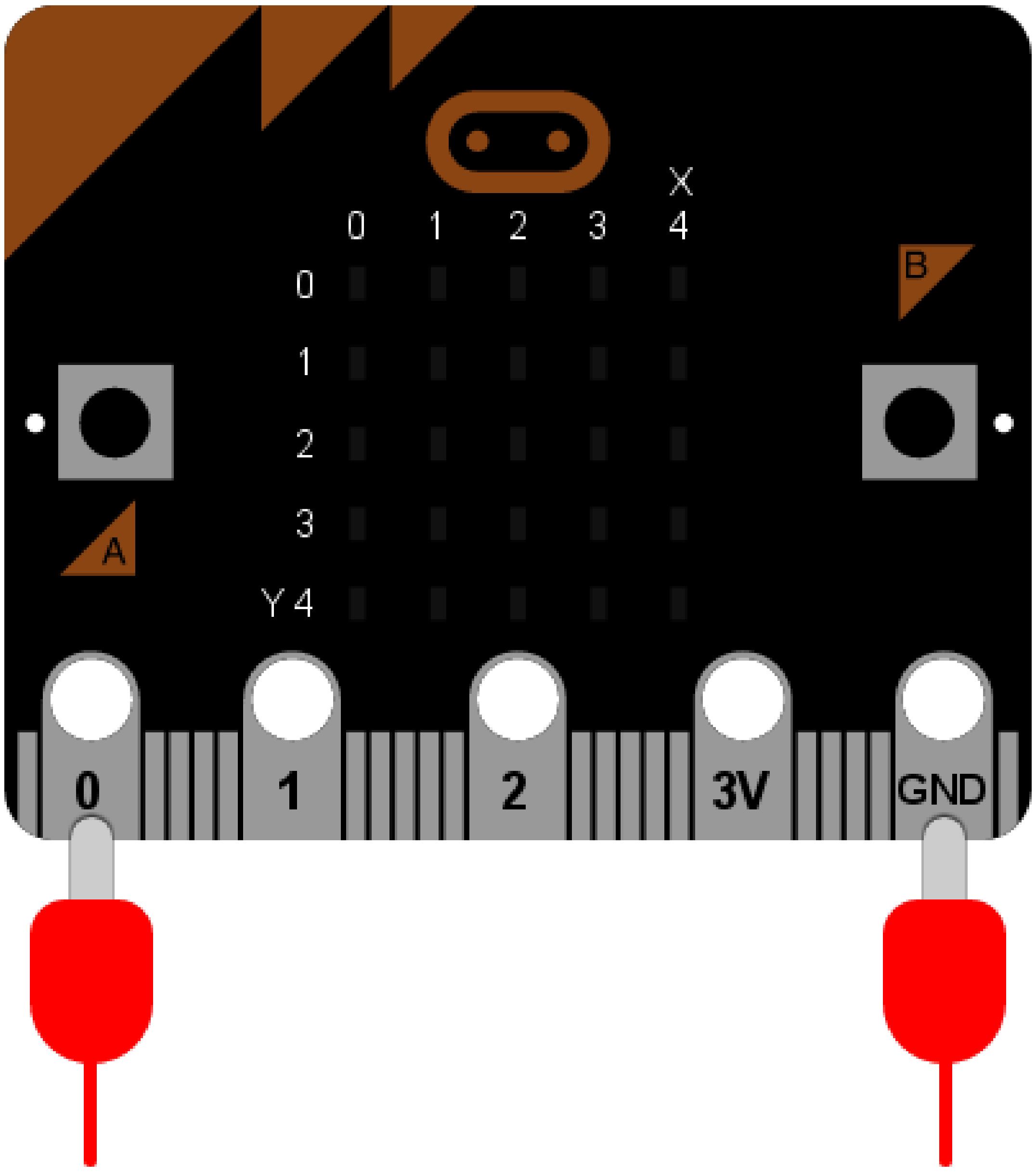
There is also a `get_y` method for the Y axis and a `get_z` method for the Z axis.

If you've ever wondered how a mobile phone knows which up to show the images on its screen, it's because it uses an accelerometer in exactly the same way as the program above. Game controllers also contain accelerometers to help you steer and move around in games.

Musical Mayhem

One of the most wonderful aspects of MicroPython on the BBC micro:bit is how it lets you easily link different capabilities of the device together. For example, let's turn it into a musical instrument (of sorts).

Connect a speaker as you did in the music tutorial. Use crocodile clips to attach pin 0 and GND to the positive and negative inputs on the speaker - it doesn't matter which way round they are connected to the speaker.



What happens if we take the readings from the accelerometer and play them as pitches? Let's find out:

```
from microbit import *
import music

while True:
    music.pitch(accelerometer.get_y(), 10)
```

The key line is at the end and remarkably simple. We *nest* the reading from the Y axis as the frequency to feed into the `music.pitch` method. We only let it play for 10 milliseconds because we want the tone to change quickly as the device is tipped. Because the device is in an infinite `while` loop it is constantly reacting to changes in the Y axis measurement.

That's it!

Tip the device forwards and backwards. If the reading along the Y axis is positive it'll change the pitch of the tone played by the micro:bit.

Imagine a whole symphony orchestra of these devices. Can you play a tune? How would you improve the program to make the micro:bit sound more musical?

Gestures

The really interesting side-effect of having an accelerometer is gesture detection. If you move your BBC micro:bit in a certain way (as a gesture) then MicroPython is able to detect this.

MicroPython is able to recognise the following gestures: `up`, `down`, `left`, `right`, `face up`, `face down`, `freefall`, `3g`, `6g`, `8g`, `shake`. Gestures are always represented as strings. While most of the names should be obvious, the `3g`, `6g` and `8g` gestures apply when the device encounters these levels of g-force (like when an astronaut is launched into space).

To get the current gesture use the `accelerometer.current_gesture` method. Its result is going to be one of the named gestures listed above. For example, this program will only make your device happy if it is face up:

```python
from microbit import *

while True:
    gesture = accelerometer.current_gesture()
    if gesture == "face up":
        display.show(Image.HAPPY)
    else:
        display.show(Image.ANGRY)
```

Once again, because we want the device to react to changing circumstances we use a `while` loop. Within the *scope* of the loop the current gesture is read and put into `gesture`. The `if` conditional checks if `gesture` is equal to `"face up"` (Python uses == to test for equality, a single equals sign = is used for assignment - just like how we assign the gesture reading to the `gesture` object). If the gesture is equal to `"face up"` then use the display to show a happy face. Otherwise, the device is made to look angry!

Magic-8

A Magic-8 ball is a toy first invented in the 1950s. The idea is to ask it a yes/no question, shake it and wait for it to reveal the truth. It's rather easy to turn into a program:

```python
from microbit import *
import random

answers = [
    "It is certain",
    "It is decidedly so",
    "Without a doubt",
    "Yes, definitely",
    "You may rely on it",
    "As I see it, yes",
    "Most likely",
    "Outlook good",
    "Yes",
    "Signs point to yes",
    "Reply hazy try again",
    "Ask again later",
    "Better not tell you now",
    "Cannot predict now",
    "Concentrate and ask again",
    "Don't count on it"
    "My reply is no",
    "My sources say no",
    "Outlook not so good",
    "Very doubtful",
]

while True:
    display.show("8")
    if accelerometer.was_gesture("shake"):
        display.clear()
        sleep(1000)
        display.scroll(random.choice(answers))
```

Most of the program is a list called `answers`. The actual game is in the `while` loop at the end.

The default state of the game is to show the character `"8"`. However, the program needs to detect if it has been shaken. The `was_gesture` method uses its argument (in this case, the string `"shake"` because we want to detect a shake) to return a `True` / `False` response. If the device was shaken the `if` conditional drops into its block of code where it clears the screen, waits for a second (so the device appears to be thinking about your question) and displays a randomly chosen answer.

Why not ask it if this is the greatest program ever written? What could you do to "cheat" and make the answer always positive or negative? (Hint: use the buttons.)

Direction

There is a compass on the BBC micro:bit. If you ever make a weather station use the device to work out the wind direction.

Compass

It can also tell you the direction of North like this:

```
from microbit import *

compass.calibrate()

while True:
    needle = ((15 - compass.heading()) // 30) % 12
    display.show(Image.ALL_CLOCKS[needle])
```

You must calibrate the compass before taking readings. Failure to do so will just produce garbage results. The `calibration` method runs a fun little game to help the device work out where it is in relation to the Earth's magnetic field.

The program takes the `compass.heading` and, using some simple yet cunning maths (floor division `//` and modulo `%` ~ look up what these mean), works out the number of the clock hand to use to display on the screen so that it is pointing roughly North.

Network

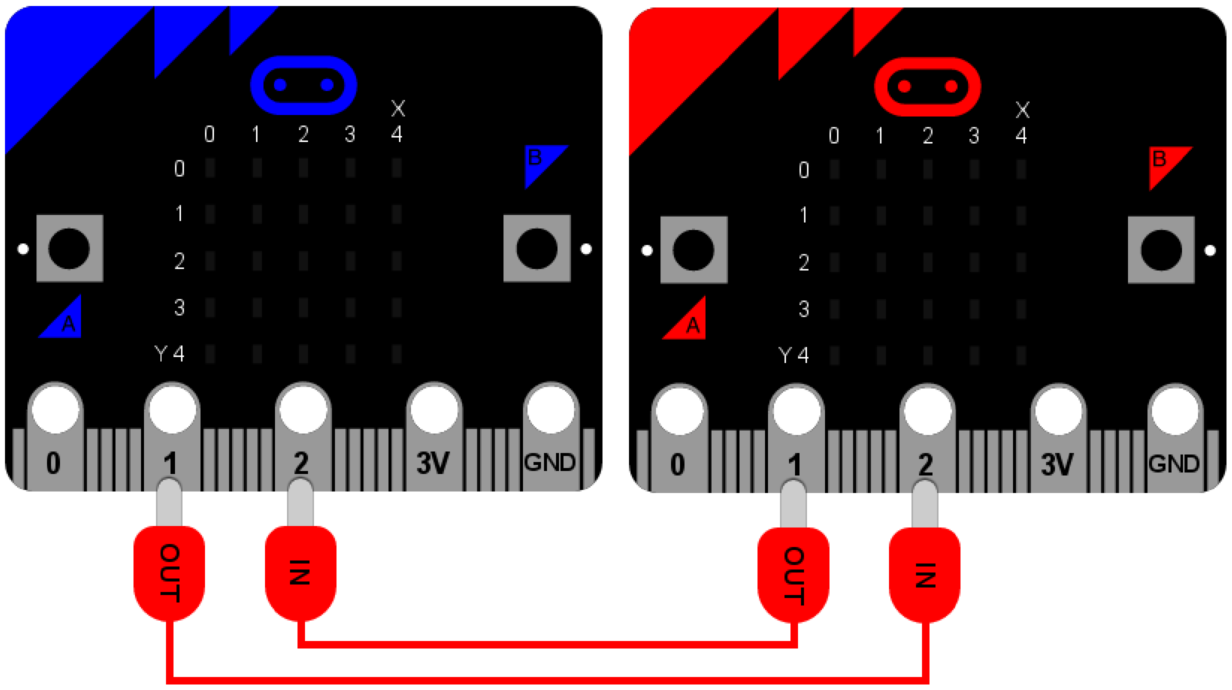
It is possible to connect devices together to send and receive messages to and from each other. This is called a network. A network of interconnected networks is called an internet. The Internet is an internet of all the internets.

Networking is hard and this is reflected in the program described below. However, the beautiful thing about this project is it contains all the common aspects of network programming you need to know about. It's also remarkably simple and fun.

But first, let's set the scene...

Connection

Imagine a network as a series of layers. At the very bottom is the most fundamental aspect of communication: there needs to be some sort of way for a signal to get from one device to the other. Sometimes this is done via a radio connection, but in this example we're simply going to use two wires.



It is upon this foundation that we can build all the other layers in the *network stack*.

As the diagram shows, blue and red micro:bits are connected via crocodile leads. Both use pin 1 for output and pin 2 for input. The output from one device is connected to the input on the other. It's a bit like knowing which way round to hold a telephone handset - one end has a microphone (the input) and the other a speaker (the output). The recording of your voice via your microphone is played out of the other person's speaker. If you hold the phone the wrong way up, you'll get strange results!

It's exactly the same in this instance: you must connect the wires properly!

Signal

The next layer in the *network stack* is the signal. Often this will depend upon the characteristics of the connection. In our example it's simply digital on and off signals sent down the wires via the IO pins.

If you remember, it's possible to use the IO pins like this:

```
pin1.write_digital(1)  # switch the signal on
pin1.write_digital(0)  # switch the signal off
input = pin2.read_digital()  # read the value of the signal (either 1 or 0)
```

The next step involves describing how to use and handle a signal. For that we need a...

Protocol

If you ever meet the Queen there are expectations about how you ought to behave. For example, when she arrives you may bow or curtsey, if she offers her hand politely shake it, refer to her as "your majesty" and thereafter as "ma'am" and so on. This set of rules is called the royal protocol. A protocol explains how to behave given a specific situation (such as meeting the Queen). A protocol is pre-defined to ensure everyone understands what's going on before a given situation arises.

It is for this reason that we define and use protocols for communicating messages via a computer network. Computers need to agree before hand how to send and receive messages. Perhaps the best known protocol is the hypertext transfer protocol (HTTP) used by the world wide web.

Another famous protocol for sending messages (that pre-dates computers) is Morse code. It defines how to send character-based messages via on/off signals of long or short durations. Often such signals are played as bleeps. Long durations are called dashes (-) whereas short durations are dots (.). By combining dashes and dots Morse defines a way to send characters. For example, here's how the standard Morse alphabet is defined:

```
.-     A      ---    J      ...    S      .----  1      ----.  9
-...   B      -.-    K      -      T      ..---  2      -----  0
-.-.   C      .-..   L      ..-    U      ...--  3
-..    D      --     M      ...-   V      ....-  4
.      E      -.     N      .--    W      .....  5
..-.   F      ---    O      -..-   X      -....  6
--.    G      .--.   P      -.--   Y      --...  7
....   H      --.-   Q      --..   Z      ---..  8
..     I      .-.    R
```

Given the chart above, to send the character "H" the signal is switched on four times for a short duration, indicating four dots (`....`). For the letter "L" the signal is also switched on four times, but the second signal has a longer duration (`.-..`).

Obviously, the timing of the signal is important: we need to tell a dot from a dash. That's another point of a protocol, to agree such things so everyone's implementation of the protocol will work with everyone elses. In this instance we'll just say that:

- A signal with a duration less than 250 milliseconds is a dot.
- A signal with a duration from 250 milliseconds to less than 500 milliseconds is a dash.
- Any other duration of signal is ignored.
- A pause / gap in the signal of greater than 500 milliseconds indicates the end of a character.

In this way, the sending of a letter "H" is defined as four "on" signals that last no longer than 250 milliseconds each, followed by a pause of greater than 500 milliseconds (indicating the end of the character).

Message

We're finally at a stage where we can build a message - a message that actually means something to us humans. This is the top-most layer of our *network stack*.

Using the protocol defined above I can send the following sequence of signals down the physical wire to the other micro:bit:

```
..../././.-../.-../---/.--/---/.-./.-../-..
```

Can you work out what it says?

Application

It's all very well having a network stack, but you also need a way to interact with it - some form of application to send and receive messages. While HTTP is interesting *most* people don't know about it and let their web-browser handle it - the underlying *network stack* of the world wide web is hidden (as it should be).

So, what sort of application should we write for the BBC micro:bit? How should it work, from the user's point of view?

Obviously, to send a message you should be able to input dots and dashes (we can use button A for that). If we want to see the message we sent or just received we should be able to trigger it to scroll across the display (we can use button B for that). Finally, this being Morse code, if a speaker is attached, we should be able to play the beeps as a form of aural feedback while the user is entering their message.

The End Result

Here's the program, in all its glory and annotated with plenty of comments so you can see what's going on:

```
from microbit import *
import music


# A lookup table of morse codes and associated characters.
MORSE_CODE_LOOKUP = {
    ".-": "A",
    "-...": "B",
    "-.-.": "C",
    "-..": "D",
    ".": "E",
    "..-.": "F",
    "--.": "G",
    "....": "H",
    "..": "I",
    ".---": "J",
    "-.-": "K",
    ".-..": "L",
    "--": "M",
    "-.": "N",
    "---": "O",
    ".--.": "P",
    "--.-": "Q",
    ".-.": "R",
    "...": "S",
    "-": "T",
    "..-": "U",
    "...-": "V",
    ".--": "W",
    "-..-": "X",
    "-.--": "Y",
    "--..": "Z",
    ".----": "1",
    "..---": "2",
    "...--": "3",
    "....-": "4",
    ".....": "5",
    "-....": "6",
    "--...": "7",
    "---..": "8",
    "----.": "9",
    "-----": "0"
}


def decode(buffer):
    # Attempts to get the buffer of Morse code data from the lookup table. If
    # it's not there, just return a full stop.
    return MORSE_CODE_LOOKUP.get(buffer, '.')


# How to display a single dot.
DOT = Image("00000:"
            "00000:"
            "00900:"
            "00000:"
            "00000:")


# How to display a single dash.
DASH = Image("00000:"
             "00000:"
             "09990:"
             "00000:"
             "00000:")


# To create a DOT you need to hold the button for less than 250ms.
DOT_THRESHOLD = 250
# To create a DASH you need to hold the button for less than 500ms.
```

```python
DASH_THRESHOLD = 500


# Holds the incoming Morse signals.
buffer = ''
# Holds the translated Morse as characters.
message = ''
# The time from which the device has been waiting for the next keypress.
started_to_wait = running_time()


# Put the device in a loop to wait for and react to key presses.
while True:
    # Work out how long the device has been waiting for a keypress.
    waiting = running_time() - started_to_wait
    # Reset the timestamp for the key_down_time.
    key_down_time = None
    # If button_a is held down, then...
    while button_a.is_pressed():
        # Play a beep - this is Morse code y'know ;-)
        music.pitch(880, 10)
        # Set pin1 (output) to "on"
        pin1.write_digital(1)
        # ...and if there's not a key_down_time then set it to now!
        if not key_down_time:
            key_down_time = running_time()
    # Alternatively, if pin2 (input) is getting a signal, pretend it's a
    # button_a key press...
    while pin2.read_digital():
        if not key_down_time:
            key_down_time = running_time()
    # Get the current time and call it key_up_time.
    key_up_time = running_time()
    # Set pin1 (output) to "off"
    pin1.write_digital(0)
    # If there's a key_down_time (created when button_a was first pressed
    # down).
    if key_down_time:
        # ... then work out for how long it was pressed.
        duration = key_up_time - key_down_time
        # If the duration is less than the max length for a "dot" press...
        if duration < DOT_THRESHOLD:
            # ... then add a dot to the buffer containing incoming Morse codes
            # and display a dot on the display.
            buffer += '.'
            display.show(DOT)
        # Else, if the duration is less than the max length for a "dash"
        # press... (but longer than that for a DOT ~ handled above)
        elif duration < DASH_THRESHOLD:
            # ... then add a dash to the buffer and display a dash.
            buffer += '-'
            display.show(DASH)
        # Otherwise, any other sort of keypress duration is ignored (this isn't
        # needed, but added for "understandability").
        else:
            pass
        # The button press has been handled, so reset the time from which the
        # device is starting to wait for a  button press.
```

```
            started_to_wait = running_time()
        # Otherwise, there hasn't been a button_a press during this cycle of the
        # loop, so check there's not been a pause to indicate an end of the
        # incoming Morse code character. The pause must be longer than a DASH
        # code's duration.
        elif len(buffer) > 0 and waiting > DASH_THRESHOLD:
            # There is a buffer and it's reached the end of a code so...
            # Decode the incoming buffer.
            character = decode(buffer)
            # Reset the buffer to empty.
            buffer = ''
            # Show the decoded character.
            display.show(character)
            # Add the character to the message.
            message += character
        # Finally, if button_b was pressed while all the above was going on...
        if button_b.was_pressed():
            # ... display the message,
            display.scroll(message)
            # then reset it to empty (ready for a new message).
            message = ''
```

How would you improve it? Can you change the definition of a dot and a dash so speedy Morse code users can use it? What happens if both devices are sending at the same time? What might you do to handle this situation?

Next Steps

These tutorials are only the first steps in using MicroPython with the BBC micro:bit. A musical analogy: you've got a basic understanding of a very simple instrument and confidently play "Three Blind Mice".

This is an achievement to build upon.

Ahead of you is an exciting journey to becoming a virtuoso coder.

You will encounter frustration, failure and foolishness. When you do please remember that you're not alone. Python has a secret weapon: the most amazing community of programmers on the planet. Connect with this community and you will make friends, find mentors, support each other and share resources.

The examples in the tutorials are simple to explain but may not be the simplest or most efficient implementations. We've left out lots of *really fun stuff* so we could concentrate on arming you with the basics. If you *really* want to know how to make MicroPython fly on the BBC micro:bit then read the API reference documentation. It contains information about *all* the capabilities available to you.

Explore, experiment and be fearless trying things out ~ for these are the attributes of a virtuoso coder. To encourage you we have hidden a number of Easter eggs in MicroPython and the code editors (both TouchDevelop and Mu). They're fun rewards for looking "under the hood" and "poking with a stick".

Such skill in Python is valuable: it's one of the world's most popular professional programming languages.

Amaze us with your code! Make things that delight us! Most of all, have fun!

Happy hacking!

Python is one of the world's most popular programming languages. Every day, without realising, you probably use software written using Python. All sorts of companies and organisations use Python for a diverse range of applications. Google, NASA, Bank of America, Disney, CERN, YouTube, Mozilla, The Guardian - the list goes on and covers all sectors of the economy, science and the arts.

For example, do you remember the announcement of the discovery of gravitational waves? The instruments used to make the measurements were controlled with Python.

Put simply, if you teach or learn Python, you are developing a highly valuable skill that applies to all areas of human endeavour.

One such area is the BBC's amazing micro:bit device. It runs a version of Python called MicroPython that's designed to run on small computers like the BBC micro:bit. It's a full implementation of Python 3 so when you move onto other things (such as programming Python on a Raspberry Pi) you'll use exactly the same language.

MicroPython does not include all the standard code libraries that come with "regular" Python. However, we have created a special `microbit` module in MicroPython that lets you control the device.

Python and MicroPython are free software. Not only does this mean you don't pay anything to use Python, but you are also free to contribute back to the Python community. This may be in the form of code, documentation, bug reports, running a community group or writing tutorials (like this one). In fact, all the Python related resources for the BBC micro:bit have been created by an international team of volunteers working in their free time.

These lessons introduce MicroPython and the BBC micro:bit in easy-to-follow steps. Feel free to adopt and adapt them for classroom based lessons, or perhaps just follow them on your own at home.

You'll have most success if you explore, experiment and play. You can't break a BBC micro:bit by writing incorrect code. Just dive in!

A word of warning: *you will fail many times*, and that is fine. **Failure is how good software developers learn**. Those of us who work as software developers have a lot of fun tracking down bugs and avoiding the repetition of mistakes.

If in doubt, remember the Zen of MicroPython:

```
Code,
Hack it,
Less is more,
Keep it simple,
Small is beautiful,

Be brave! Break things! Learn and have fun!
Express yourself with MicroPython.

Happy hacking! :-)
```

Best of luck!

CHAPTER 2

micro:bit Micropython API

Warning: As we work towards a 1.0 release, this API is subject to frequent changes. This page reflects the current micro:bit API in a developer-friendly (but not necessarily kid-friendly) way.

The microbit module

Everything directly related to interacting with the hardware lives in the *microbit* module. For ease of use it's recommended you start all scripts with:

```
from microbit import *
```

The following documentation assumes you have done this.

There are a few functions available directly:

```
# sleep for the given number of milliseconds.
sleep(ms)
# returns the number of milliseconds since the micro:bit was last switched on.
running_time()
# makes the micro:bit enter panic mode (this usually happens when the DAL runs
# out of memory, and causes a sad face to be drawn on the display). The error
# code can be any arbitrary integer value.
panic(error_code)
# resets the micro:bit.
reset()
```

The rest of the functionality is provided by objects and classes in the microbit module, as described below.

Note that the API exposes integers only (ie no floats are needed, but they may be accepted). We thus use milliseconds for the standard time unit.

Buttons

There are 2 buttons:

```
button_a
button_b
```

These are both objects and have the following methods:

```
# returns True or False to indicate if the button is pressed at the time of
# the method call.
button.is_pressed()
# returns True or False to indicate if the button was pressed since the device
# started or the last time this method was called.
button.was_pressed()
# returns the running total of button presses.
button.get_presses()
# resets the running total of button presses to zero.
button.reset_presses()
```

The LED display

The LED display is exposed via the *display* object:

```
# gets the brightness of the pixel (x,y). Brightness can be from 0 (the pixel
# is off) to 9 (the pixel is at maximum brightness).
display.get_pixel(x, y)
# sets the brightness of the pixel (x,y) to val (between 0 [off] and 9 [max
# brightness], inclusive).
display.set_pixel(x, y, val)
# clears the display.
display.clear()
# shows the image.
display.show(image, delay=0, wait=True, loop=False, clear=False)
# shows each image or letter in the iterable, with delay ms. in between each.
display.show(iterable, delay=400, wait=True, loop=False, clear=False)
# scrolls a string across the display (more exciting than display.show for
# written messages).
display.scroll(string, delay=400)
```

Pins

Provide digital and analog input and output functionality, for the pins in the connector. Some pins are connected internally to the I/O that drives the LED matrix and the buttons.

Each pin is provided as an object directly in the `microbit` module. This keeps the API relatively flat, making it very easy to use:

- pin0
- pin1
- ...
- pin15
- pin16

- *Warning: P17-P18 (inclusive) are unavailable.*
- pin19
- pin20

Each of these pins are instances of the `MicroBitPin` class, which offers the following API:

```
# value can be 0, 1, False, True
pin.write_digital(value)
# returns either 1 or 0
pin.read_digital()
# value is between 0 and 1023
pin.write_analog(value)
# returns an integer between 0 and 1023
pin.read_analog()
# sets the period of the PWM output of the pin in milliseconds
# (see https://en.wikipedia.org/wiki/Pulse-width_modulation)
pin.set_analog_period(int)
# sets the period of the PWM output of the pin in microseconds
# (see https://en.wikipedia.org/wiki/Pulse-width_modulation)
pin.set_analog_period_microseconds(int)
# returns boolean
pin.is_touched()
```

Images

Note: You don't always need to create one of these yourself - you can access the image shown on the display directly with *display.image*. *display.image* is just an instance of *Image*, so you can use all of the same methods.

Images API:

```
# creates an empty 5x5 image
image = Image()
# create an image from a string - each character in the string represents an
# LED - 0 (or space) is off and 9 is maximum brightness. The colon ":"
# indicates the end of a line.
image = Image('90009:09090:00900:09090:90009:')
# create an empty image of given size
image = Image(width, height)
# initialises an Image with the specified width and height. The buffer
# should be an array of length width * height
image = Image(width, height, buffer)

# methods
# returns the image's width (most often 5)
image.width()
# returns the image's height (most often 5)
image.height()
# sets the pixel at the specified position (between 0 and 9). May fail for
# constant images.
image.set_pixel(x, y, value)
# gets the pixel at the specified position (between 0 and 9)
image.get_pixel(x, y)
# returns a new image created by shifting the picture left 'n' times.
image.shift_left(n)
```

```
# returns a new image created by shifting the picture right 'n' times.
image.shift_right(n)
# returns a new image created by shifting the picture up 'n' times.
image.shift_up(n)
# returns a new image created by shifting the picture down 'n' times.
image.shift_down(n)
# get a compact string representation of the image
repr(image)
# get a more readable string representation of the image
str(image)

#operators
# returns a new image created by superimposing the two images
image + image
# returns a new image created by multiplying the brightness of each pixel by n
image * n

# built-in images.
Image.HEART
Image.HEART_SMALL
Image.HAPPY
Image.SMILE
Image.SAD
Image.CONFUSED
Image.ANGRY
Image.ASLEEP
Image.SURPRISED
Image.SILLY
Image.FABULOUS
Image.MEH
Image.YES
Image.NO
Image.CLOCK12 # clock at 12 o' clock
Image.CLOCK11
... # many clocks (Image.CLOCKn)
Image.CLOCK1 # clock at 1 o'clock
Image.ARROW_N
... # arrows pointing N, NE, E, SE, S, SW, W, NW (microbit.Image.ARROW_direction)
Image.ARROW_NW
Image.TRIANGLE
Image.TRIANGLE_LEFT
Image.CHESSBOARD
Image.DIAMOND
Image.DIAMOND_SMALL
Image.SQUARE
Image.SQUARE_SMALL
Image.RABBIT
Image.COW
Image.MUSIC_CROTCHET
Image.MUSIC_QUAVER
Image.MUSIC_QUAVERS
Image.PITCHFORK
Image.XMAS
Image.PACMAN
Image.TARGET
Image.TSHIRT
Image.ROLLERSKATE
Image.DUCK
Image.HOUSE
Image.TORTOISE
Image.BUTTERFLY
Image.STICKFIGURE
Image.GHOST
Image.SWORD
Image.GIRAFFE
Image.SKULL
Image.UMBRELLA
Image.SNAKE
# built-in lists - useful for animations, e.g. display.show(Image.ALL_CLOCKS)
Image.ALL_CLOCKS
Image.ALL_ARROWS
```

The accelerometer

The accelerometer is accessed via the `accelerometer` object:

```
# read the X axis of the device. Measured in milli-g.
accelerometer.get_x()
# read the Y axis of the device. Measured in milli-g.
accelerometer.get_y()
# read the Z axis of the device. Measured in milli-g.
accelerometer.get_z()
# get all three X, Y and Z readings (listed in that order).
accelerometer.get_values()
# return the name of the current gesture.
accelerometer.current_gesture()
# return True or False to indicate if the named gesture is currently active.
accelerometer.is_gesture(name)
# return True or False to indicate if the named gesture was active since the
# last call.
accelerometer.was_gesture(name)
# return a tuple of the gesture history. The most recent is listed last.
accelerometer.get_gestures()
# clears the gesture history.
accelerometer.reset_gestures()
```

The recognised gestures are: `up`, `down`, `left`, `right`, `face up`, `face down`, `freefall`, `3g`, `6g`, `8g`, `shake`.

The compass

The compass is accessed via the *compass* object:

```
# calibrate the compass (this is needed to get accurate readings).
compass.calibrate()
# return a numeric indication of degrees offset from "north".
compass.heading()
# return an numeric indication of the strength of magnetic field around
# the micro:bit.
compass.get_field_strength()
# returns True or False to indicate if the compass is calibrated.
compass.is_calibrated()
# resets the compass to a pre-calibration state.
compass.clear_calibration()
```

I2C bus

There is an I2C bus on the micro:bit that is exposed via the *i2c* object. It has the following methods:

```
# read n bytes from device with addr; repeat=True means a stop bit won't
# be sent.
i2c.read(addr, n, repeat=False)
# write buf to device with addr; repeat=True means a stop bit won't be sent.
i2c.write(addr, buf, repeat=False)
```

UART

Use `uart` to communicate with a serial device connected to the device's I/O pins:

```
# set up communication (use pins 0 [TX] and 1 [RX]) with a baud rate of 9600.
uart.init()
# return True or False to indicate if there are incoming characters waiting to
# be read.
uart.any()
# return (read) n incoming characters.
uart.read(n)
# return (read) as much incoming data as possible.
uart.readall()
# return (read) all the characters to a newline character is reached.
uart.readline()
# read bytes into the referenced buffer.
uart.readinto(buffer)
# write bytes from the buffer to the connected device.
uart.write(buffer)
```

CHAPTER 3

Microbit Module

The `microbit` module gives you access to all the hardware that is built-in into your board.

Functions

`microbit.`**`panic`**`(`*n*`)`
Enter a panic mode. Requires restart. Pass in an arbitrary integer <= 255 to indicate a status:

```
microbit.panic(404)
```

`microbit.`**`reset`**`()`
Restart the board.

`microbit.`**`sleep`**`(`*n*`)`
Wait for `n` milliseconds. One second is 1000 milliseconds, so:

```
microbit.sleep(1000)
```

will pause the execution for one second. `n` can be an integer or a floating point number.

`microbit.`**`running_time`**`()`
Return the number of milliseconds since the board was switched on or restarted.

`microbit.`**`temperature`**`()`
Return the temperature of the micro:bit in degrees Celcius.

Attributes

Buttons

There are two buttons on the board, called `button_a` and `button_b`.

Attributes

button_a
A `Button` instance (see below) representing the left button.

button_b
Represents the right button.

Classes

class **Button**
Represents a button.

Note: This class is not actually available to the user, it is only used by the two button instances, which are provided already initialized.

is_pressed()
Returns `True` if the specified button `button` is pressed, and `False` otherwise.

was_pressed()
Returns `True` or `False` to indicate if the button was pressed since the device started or the last time this method was called.

get_presses()
Returns the running total of button presses.

reset_presses()
Resets the running total of button presses to zero.

Example

```
import microbit

while True:
    if microbit.button_a.is_pressed() and microbit.button_b.is_pressed():
        microbit.display.scroll("AB")
        break
    elif microbit.button_a.is_pressed():
        microbit.display.scroll("A")
    elif microbit.button_b.is_pressed():
        microbit.display.scroll("B")
    microbit.sleep(100)
```

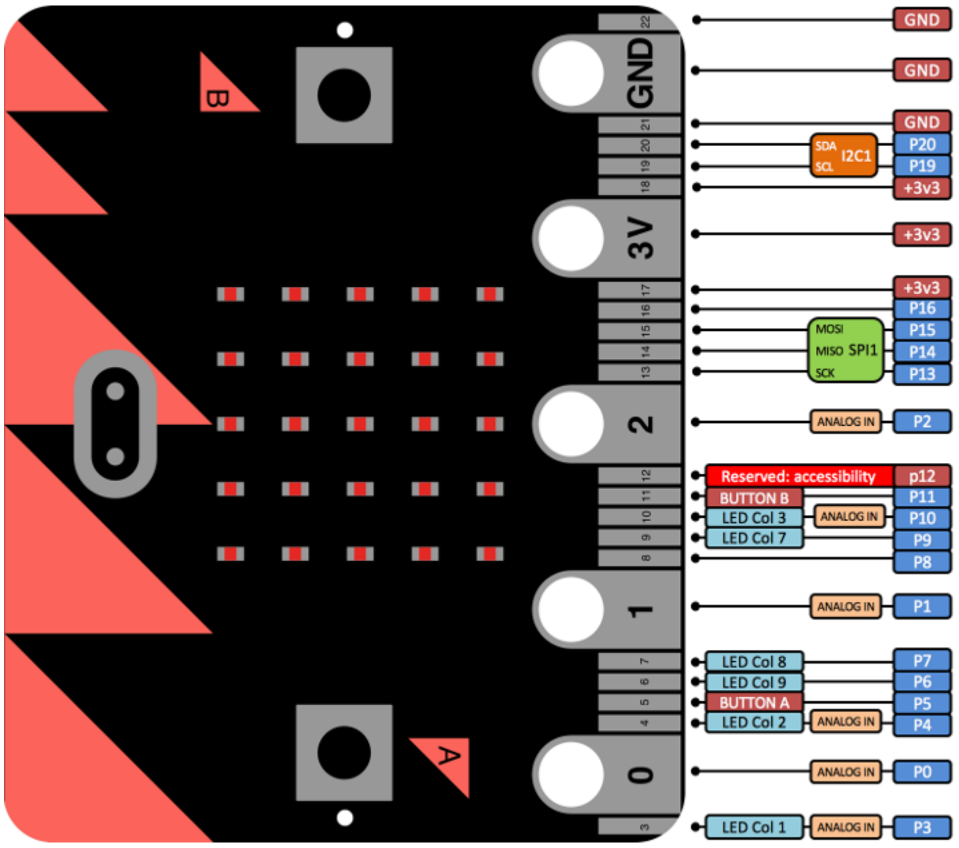
Input/Output Pins

The pins are your board's way to communicate with external devices connected to it. There are 19 pins for your disposal, numbered 0-16 and 19-20. Pins 17 and 18 are not available.

For example, the script below will change the display on the micro:bit depending upon the digital reading on pin 0:

```
from microbit import *


while True:
    if pin0.read_digital():
        display.show(Image.HAPPY)
    else:
        display.show(Image.SAD)
```

Pin Functions



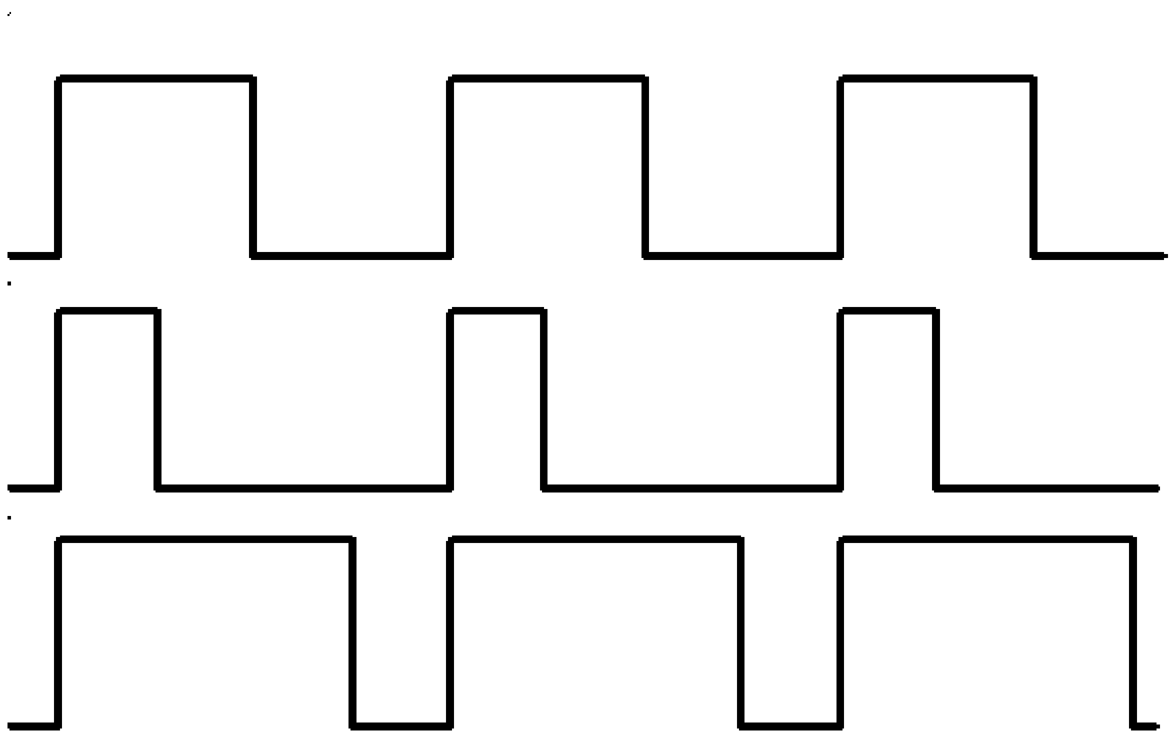
Those pins are available as attributes on the `microbit` module:`microbit.pin0` - `microbit.pin20`.

Pin	Type	Function
0	Touch	Pad 0
1	Touch	Pad 1
2	Touch	Pad 2
3	Analog	Column 1
4	Analog	Column 2
5	Digital	Button A
6	Digital	Row 2
7	Digital	Row 1
8	Digital	
9	Digital	Row 3
10	Analog	Column 3
11	Digital	Button B
12	Digital	
13	Digital	SPI MOSI
14	Digital	SPI MISO
15	Digital	SPI SCK
16	Digital	
19	Digital	I2C SCL
20	Digital	I2C SDA

The above table summarizes the pins available, their types (see below) and what they are internally connected to.

Pulse-Width Modulation

The pins of your board cannot output analog signal the way an audio amplifier can do it – by modulating the voltage on the pin. Those pins can only either enable the full 3.3V output, or pull it down to 0V. However, it is still possible to control the brightness of LEDs or speed of an electric motor, by switching that voltage on and off very fast, and controlling how long it is on and how long it is off. This technique is called Pulse-Width Modulation (PWM), and that's what the `write_analog` method below does.



Above you can see the diagrams of three different PWM signals. All of them have the same period (and thus frequency), but they have different duty cycles.

The first one would be generated by `write_analog(511)`, as it has exactly 50% duty – the power is on half of the time, and off half of the time. The result of that is that the total energy of this signal is the same, as if it was 1.65V instead of 3.3V.

The second signal has 25% duty cycle, and could be generated with `write_analog(255)`. It has similar effect as if 0.825V was being output on that pin.

The third signal has 75% duty cycle, and can be generated with `write_analog(767)`. It has three times as much energy, as the second signal, and is equivalent to outputting 2.475V on th pin.

Note that this works well with devices such as motors, which have huge inertia by themselves, or LEDs, which blink too fast for the human eye to see the difference, but will not work so good with generating sound waves. This board can only generate square wave sounds on itself, which sound pretty much like the very old computer games – mostly because those games also only could do that.

Classes

There are three kinds of pins, differing in what is available for them. They are represented by the below classes. Note that they form a hierarchy, so that each class has all the functionality of the previous class, and adds its own to that.

Note: Those classes are not actually available for the user, you can't create new instances of them. You can only use the instances already provided, representing the physical pins on your board.

class `microbit.`**`MicroBitDigitalPin`**

read_digital()
Return 1 if the pin is high, and 0 if it's low.

write_digital(*value*)
Set the pin to high if `value` is 1, or to low, if it is 0.

class `microbit.`**MicroBitAnalogDigitalPin**

read_analog()
Read the voltage applied to the pin, and return it as an integer between 0 (meaning 0V) and 1023 (meaning 3.3V).

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).

set_analog_period(*period*)
Set the period of the PWM signal being output to `period` in milliseconds. The minimum valid value is 1ms.

set_analog_period_microseconds(*period*)
Set the period of the PWM signal being output to `period` in microseconds. The minimum valid value is 35µs.

class `microbit.`**MicroBitTouchPin**

is_touched()
Return `True` if the pin is being touched with a finger, otherwise return `False`.

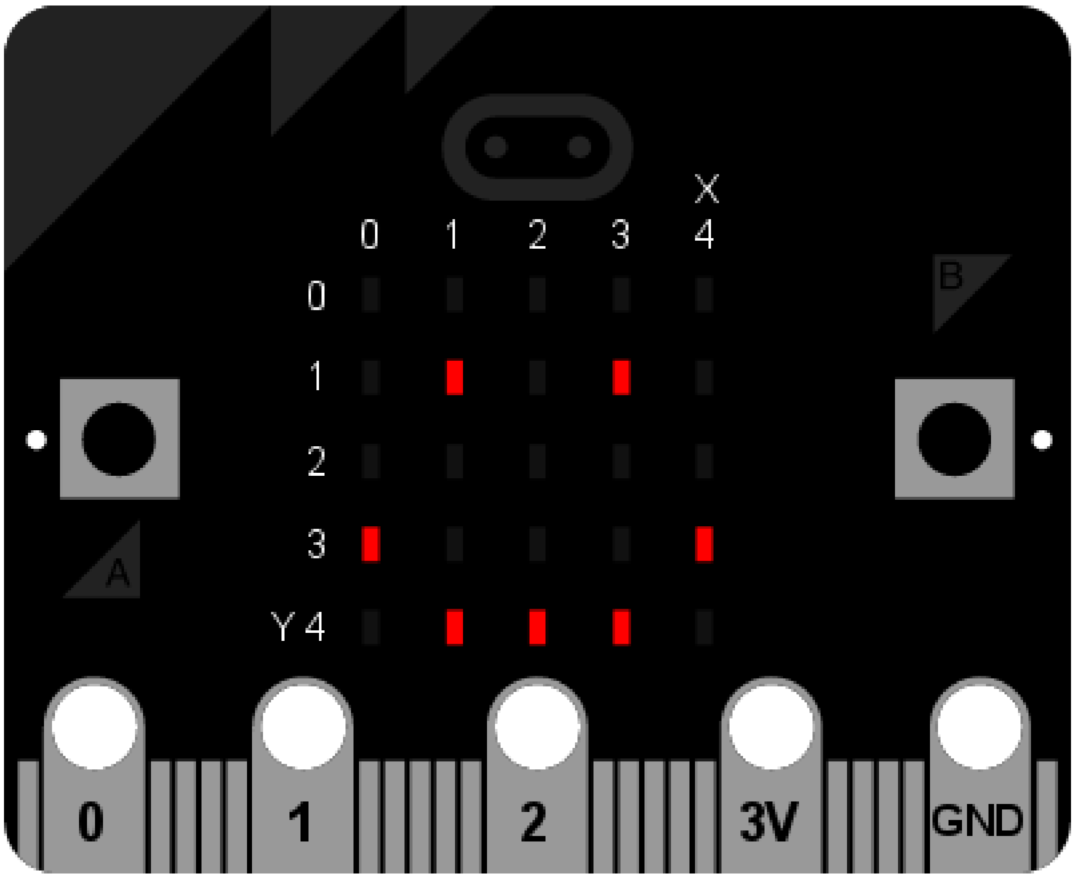
This test is done by measuring the capacitance of the pin together with whatever is connected to it. Human body has quite a large capacitance, so touching the pin gives a dramatic change in reading, which can be detected.

Classes

Image

The `Image` class is used to create images that can be displayed easily on the device's LED matrix. Given an image object it's possible to display it via the `device` API:

```
display.show(Image.HAPPY)
```



Classes

class `microbit.`**`Image`**(*string*)
class `microbit.`**`Image`**(*width=None*, *height=None*, *buffer=None*)

If `string` is used, it has to consist of digits 0-9 arranged into lines, describing the image, for example:

```
image = Image("90009:"
              "09090:"
              "00900:"
              "09090:"
              "90009")
```

will create a 5×5 image of an X. The end of a line is indicated by a colon. It's also possible to use a newline (n) to indicate the end of a line like this:

```
image = Image("90009\n"
              "09090\n"
              "00900\n"
              "09090\n"
              "90009")
```

The other form creates an empty image with `width` columns and `height` rows. Optionally `buffer` can be an array of `width``×``height` integers in range 0-9 to initialize the image.

width()
: Return the number of columns in the image.

height()
: Return the numbers of rows in the image.

set_pixel(*x*, *y*, *value*)
: Set the brightness of the pixel at column `x` and row `y` to the `value`, which has to be between 0 (dark) and 9 (bright).

  This method will raise an exception when called on any of the build-in read-only images, like `Image.HEART`.

get_pixel(*x*, *y*)
: Return the brightness of pixel at column `x` and row `y` as an integer between 0 and 9.

shift_left(*n*)
: Return a new image created by shifting the picture left by `n` columns.

shift_right(*n*)
: Same as `image.shift_left(-n)`.

shift_up(*n*)
: Return a new image created by shifting the picture up by `n` rows.

shift_down(*n*)
: Same as `image.shift_up(-n)`.

Attributes

The `Image` class also has the following built-in instances of itself included as its attributes (the attribute names indicate what the image represents):

- `Image.HEART`
- `Image.HEART_SMALL`
- `Image.HAPPY`
- `Image.SMILE`
- `Image.SAD`
- `Image.CONFUSED`
- `Image.ANGRY`
- `Image.ASLEEP`
- `Image.SURPRISED`
- `Image.SILLY`
- `Image.FABULOUS`
- `Image.MEH`
- `Image.YES`
- `Image.NO`
- `Image.CLOCK12`, `Image.CLOCK11`, `Image.CLOCK10`, `Image.CLOCK9`, `Image.CLOCK8`, `Image.CLOCK7`, `Image.CLOCK6`, `Image.CLOCK5`, `Image.CLOCK4`, `Image.CLOCK3`, `Image.CLOCK2`, `Image.CLOCK1`

- Image.ARROW_N, Image.ARROW_NE, Image.ARROW_E, Image.ARROW_SE, Image.ARROW_S, Image.ARROW_SW, Image.ARROW_W, Image.ARROW_NW
- Image.TRIANGLE
- Image.TRIANGLE_LEFT
- Image.CHESSBOARD
- Image.DIAMOND
- Image.DIAMOND_SMALL
- Image.SQUARE
- Image.SQUARE_SMALL
- Image.RABBIT
- Image.COW
- Image.MUSIC_CROTCHET
- Image.MUSIC_QUAVER
- Image.MUSIC_QUAVERS
- Image.PITCHFORK
- Image.XMAS
- Image.PACMAN
- Image.TARGET
- Image.TSHIRT
- Image.ROLLERSKATE
- Image.DUCK
- Image.HOUSE
- Image.TORTOISE
- Image.BUTTERFLY
- Image.STICKFIGURE
- Image.GHOST
- Image.SWORD
- Image.GIRAFFE
- Image.SKULL
- Image.UMBRELLA
- Image.SNAKE

Finally, related collections of images have been grouped together:

```
* ``Image.ALL_CLOCKS``
* ``Image.ALL_ARROWS``
```

Operations

```
repr(image)
```

Get a compact string representation of the image.

```
str(image)
```

Get a readable string representation of the image.

```
image1 + image2
```

Create a new image by adding the brightness values from the two images for each pixel.

```
image * n
```

Create a new image by multiplying the brightness of each pixel by `n`.

Modules

Display

This module controls the 5×5 LED display on the front of your board. It can be used to display images, animations and even text.

Functions

`microbit.display.`**`get_pixel`**`(`*x*, *y*`)`
: Return the brightness of the LED at column `x` and row `y` as an integer between 0 (off) and 9 (bright).

`microbit.display.`**`set_pixel`**`(`*x*, *y*, *value*`)`
: Set the brightness of the LED at column `x` and row `y` to `value`, which has to be an integer between 0 and 9.

`microbit.display.`**`clear`**`()`
: Set the brightness of all LEDs to 0 (off).

`microbit.display.`**`show`**`(`*image*`)`
: Display the `image`.

`microbit.display.`**`show`**`(`*iterable*, *delay*, *wait=True*, *loop=False*, *clear=False*`)`
: Display images or letters from the `iterable` in sequence, with `delay` milliseconds between them.

  If `wait` is `True`, this function will block until the animation is finished, otherwise the animation will happen in the background.

  If `loop` is `True`, the animation will repeat forever.

  If `clear` is `True`, the display will be cleared after the iterable has finished.

`microbit.display.`**`scroll`**`(`*string*, *delay=400*`)`
: Similar to `show`, but scrolls the `string` horizontally instead. The `delay` parameter controls how fast the text is scrolling. This function blocks until it is finished.

UART

The `uart` module lets you talk to a device connected to your board using a serial interface.

Functions

`microbit.uart.`**`init`**`(`*baudrate=9600, bits=8, parity=None, stop=1, pins=None*`)`

Initialize serial communication with the specified parameters on the specified `pins`. Note that for correct communication, the parameters have to be the same on both communicating devices.

> **Warning:** Initializing the UART will cause the Python console on USB to become unaccessible, as it uses the same hardware. There is currently no way to bring the console back, without restarting the module.

The `baudrate` defines the speed of communication. Common baud rates include:

- 9600
- 14400
- 19200
- 28800
- 38400
- 57600
- 115200

The `bits` defines the size of bytes being transmitted, and the board only supports 8. The `parity` parameter defines how parity is checked, and it can be `None`, `microbit.uart.ODD` or `microbit.uart.EVEN`. The `stop` parameter tells the number of stop bits, and has to be 1 for this board.

If no `pins` are specified, `microbit.pin0` is used as the TX pin, and `microbit.pin1` as the RX pin. You can also specify which pins you want by passing a tuple of two pins as `pins`, the first one being TX, and the second one, RX.

> **Note:** When connecting the device, make sure you "cross" the wires – the TX pin on your board needs to be connected with the RX pin on the device, and the RX pin – with the TX pin on the device. Also make sure the ground pins of both devices are connected.

`uart.`**`any`**`()`

Return `True` if any characters waiting, else `False`.

`uart.`**`read`**`(`[*nbytes*]`)`

Read characters. If `nbytes` is specified then read at most that many bytes.

`uart.`**`readall`**`()`

Read as much data as possible.

Return value: a bytes object or `None` on timeout.

`uart.`**`readinto`**`(`*buf*[, *nbytes*]`)`

Read bytes into the `buf`. If `nbytes` is specified then read at most that many bytes. Otherwise, read at most `len(buf)` bytes.

Return value: number of bytes read and stored into `buf` or `None` on timeout.

`uart.`**`readline`**`()`

Read a line, ending in a newline character.

Return value: the line read or `None` on timeout. The newline character is included in the returned bytes.

`uart.`**`write`**`(`*buf*`)`

Write the buffer of bytes to the bus.

Return value: number of bytes written or `None` on timeout.

SPI

The `spi` module lets you talk to a device connected to your board using a serial peripheral interface (SPI) bus. SPI uses a so-called master-slave architecture with a single master. You will need to specify the connections for three signals:

- SCLK : Serial Clock (output from master).
- MOSI : Master Output, Slave Input (output from master).
- MISO : Master Input, Slave Output (output from slave).

Functions

`microbit.spi.`**`init`**`(`*baudrate=1000000*, *bits=8*, *mode=0*, *sclk=pin13*, *mosi=pin15*, *miso=pin14*`)`

Initialize SPI communication with the specified parameters on the specified `pins`. Note that for correct communication, the parameters have to be the same on both communicating devices.

The `baudrate` defines the speed of communication.

The `bits` defines the size of bytes being transmitted. Currently only `bits=8` is supported. However, this may change in the future.

The `mode` determines the combination of clock polarity and phase according to the following convention, with polarity as the high order bit and phase as the low order bit:

SPI Mode	Polarity (CPOL)	Phase (CPHA)
0	0	0
1	0	1
2	1	0
3	1	1

Polarity (aka CPOL) 0 means that the clock is at logic value 0 when idle and goes high (logic value 1) when active; polarity 1 means the clock is at logic value 1 when idle and goes low (logic value 0) when active. Phase (aka CPHA) 0 means that data is sampled on the leading edge of the clock, and 1 means on the trailing edge (viz. https://en.wikipedia.org/wiki/Signal_edge).

The `sclk`, `mosi` and `miso` arguments specify the pins to use for each type of signal.

`spi.`**`read`**`(`*nbytes*`)`

Read at most `nbytes`. Returns what was read.

`spi.`**`write`**`(`*buffer*`)`

Write the `buffer` of bytes to the bus.

`spi.`**`write_readinto`**`(`*out*, *in*`)`

Write the `out` buffer to the bus and read any response into the `in` buffer. The length of the buffers should be the same. The buffers can be the same object.

I^{2}C

The `i2c` module lets you communicate with devices connected to your board using the I^{2}C bus protocol. There can be multiple slave devices connected at the same time, and each one has its own unique address, that is either fixed for the device or configured on it. Your board acts as the I^{2}C master.

We use 7-bit addressing for devices because of the reasons stated here.

This may be different to other micro:bit related solutions.

How exactly you should communicate with the devices, that is, what bytes to send and how to interpret the responses, depends on the device in question and should be described separately in that device's documentation.

Functions

`microbit.i2c.`**`read`**`(`*addr*, *n*, *repeat=False*`)`
    Read `n` bytes from the device with 7-bit address `addr`. If `repeat` is `True`, no stop bit will be sent.

`microbit.i2c.`**`write`**`(`*addr*, *buf*, *repeat=False*`)`
    Write bytes from `buf` to the device with 7-bit address `addr`. If `repeat` is `True`, no stop bit will be sent.

Connecting

You should connect the device's `SCL` pin to micro:bit pin 19, and the device's `SDA` pin to micro:bit pin 20. You also must connect the device's ground to the micro:bit ground (pin `GND`). You may need to power the device using an external power supply or the micro:bit.

There are internal pull-up resistors on the I^{2}C lines of the board, but with particularly long wires or large number of devices you may need to add additional pull-up resistors, to ensure noise-free communication.

Accelerometer

This object gives you access to the on-board accelerometer. The accelerometer also provides convenience functions for detecting gestures. The recognised gestures are: `up`, `down`, `left`, `right`, `face up`, `face down`, `freefall`, `3g`, `6g`, `8g`, `shake`.

Functions

`microbit.accelerometer.`**`get_x`**`()`
    Get the acceleration measurement in the `x` axis, as a positive or negative integer, depending on the direction.

`microbit.accelerometer.`**`get_y`**`()`
    Get the acceleration measurement in the `y` axis, as a positive or negative integer, depending on the direction.

`microbit.accelerometer.`**`get_z`**`()`
    Get the acceleration measurement in the `z` axis, as a positive or negative integer, depending on the direction.

`microbit.accelerometer.`**`get_values`**`()`
    Get the acceleration measurements in all axes at once, as a three-element tuple of integers ordered as X, Y, Z.

`microbit.accelerometer.`**`current_gesture`**`()`
    Return the name of the current gesture.

Note: MicroPython understands the following gesture names: `"up"`, `"down"`, `"left"`, `"right"`, `"face up"`, `"face down"`, `"freefall"`, `"3g"`, `"6g"`, `"8g"`, `"shake"`. Gestures are always represented as strings.

`microbit.accelerometer.`**`is_gesture`**`(`*name*`)`
Return True or False to indicate if the named gesture is currently active.

`microbit.accelerometer.`**`was_gesture`**`(`*name*`)`
Return True or False to indicate if the named gesture was active since the last call.

`microbit.accelerometer.`**`get_gestures`**`()`
Return a tuple of the gesture history. The most recent is listed last.

`microbit.accelerometer.`**`reset_gestures`**`()`
Clears the gesture history.

Examples

A fortune telling magic 8-ball. Ask a question then shake the device for an answer.

```
# Magic 8 ball by Nicholas Tollervey. February 2016.
#
# Ask a question then shake.
#
# This program has been placed into the public domain.
from microbit import *
import random

answers = [
    "It is certain",
    "It is decidedly so",
    "Without a doubt",
    "Yes, definitely",
    "You may rely on it",
    "As I see it, yes",
    "Most likely",
    "Outlook good",
    "Yes",
    "Signs point to yes",
    "Reply hazy try again",
    "Ask again later",
    "Better not tell you now",
    "Cannot predict now",
    "Concentrate and ask again",
    "Don't count on it"
    "My reply is no",
    "My sources say no",
    "Outlook not so good",
    "Very doubtful",
]

while True:
    display.show('8')
    if accelerometer.was_gesture('shake'):
        display.clear()
        sleep(1000)
        display.scroll(random.choice(answers))
    sleep(10)
```

Simple Slalom. Move the device to avoid the obstacles.

```
# Simple Slalom by Larry Hastings, September 2015
#
# This program has been placed into the public domain.

import microbit as m
import random

p = m.display.show

min_x = -1024
max_x = 1024
range_x = max_x - min_x

wall_min_speed = 400
player_min_speed = 200

wall_max_speed = 100
player_max_speed = 50

speed_max = 12


while True:

    i = m.Image('00000:'*5)
    s = i.set_pixel

    player_x = 2

    wall_y = -1
    hole = 0

    score = 0
    handled_this_wall = False

    wall_speed = wall_min_speed
    player_speed = player_min_speed

    wall_next = 0
    player_next = 0

    while True:
        t = m.running_time()
        player_update = t >= player_next
        wall_update = t >= wall_next
        if not (player_update or wall_update):
            next_event = min(wall_next, player_next)
            delta = next_event - t
            m.sleep(delta)
            continue

        if wall_update:
            # calculate new speeds
            speed = min(score, speed_max)
            wall_speed = wall_min_speed + int((wall_max_speed - wall_min_speed) *␣
↪speed / speed_max)
            player_speed = player_min_speed + int((player_max_speed - player_min_
↪speed) * speed / speed_max)

            wall_next = t + wall_speed
            if wall_y < 5:
                # erase old wall
                use_wall_y = max(wall_y, 0)
                for wall_x in range(5):
                    if wall_x != hole:
                        s(wall_x, use_wall_y, 0)

        wall_reached_player = (wall_y == 4)
        if player_update:
            player_next = t + player_speed
            # find new x coord
            x = m.accelerometer.get_x()
            x = min(max(min_x, x), max_x)
            # print("x accel", x)
            s(player_x, 4, 0) # turn off old pixel
            x = ((x - min_x) / range_x) * 5
            x = min(max(0, x), 4)
            x = int(x + 0.5)
            # print("have", position, "want", x)

            if not handled_this_wall:
                if player_x < x:
                    player_x += 1
                elif player_x > x:
                    player_x -= 1
            # print("new", position)
            # print()

        if wall_update:
            # update wall position
            wall_y += 1
            if wall_y == 7:
                wall_y = -1
                hole = random.randrange(5)
                handled_this_wall = False

            if wall_y < 5:
                # draw new wall
                use_wall_y = max(wall_y, 0)
                for wall_x in range(5):
                    if wall_x != hole:
                        s(wall_x, use_wall_y, 6)

        if wall_reached_player and not handled_this_wall:
            handled_this_wall = True
            if (player_x != hole):
                # collision! game over!
                break
            score += 1

        if player_update:
            s(player_x, 4, 9) # turn on new pixel

        p(i)

    p(i.SAD)
    m.sleep(1000)
    m.display.scroll("Score:" + str(score))

    while True:
        if (m.button_a.is_pressed() and m.button_a.is_pressed()):
            break
        m.sleep(100)
```

Compass

This module lets you access the built-in electronic compass. Before using, the compass should be calibrated, otherwise the readings may be wrong.

Warning: Calibrating the compass will cause your program to pause until calibration is complete. Calibration consists of a little game to draw a circle on the LED display by rotating the device.

Functions

`microbit.compass.`**`calibrate`**`()`
Starts the calibration process. An instructive message will be scrolled to the user after which they will need to rotate the device in order to draw a circle on the LED display.

`microbit.compass.`**`is_calibrated`**`()`
Returns `True` if the compass has been successfully calibrated, and returns `False` otherwise.

`microbit.compass.`**`clear_calibration`**`()`
Undoes the calibration, making the compass uncalibrated again.

`microbit.compass.`**`get_x`**`()`
Gives the reading of the magnetic force on the `x` axis, as a positive or negative integer, depending on the direction of the force.

`microbit.compass.`**`get_y`**`()`
Gives the reading of the magnetic force on the `x` axis, as a positive or negative integer, depending on the direction of the force.

`microbit.compass.`**`get_z`**`()`
Gives the reading of the magnetic force on the `x` axis, as a positive or negative integer, depending on the direction of the force.

`microbit.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.

`microbit.compass.`**`get_field_strength`**`()`
Returns an integer indication of the magnitude of the magnetic field around the device.

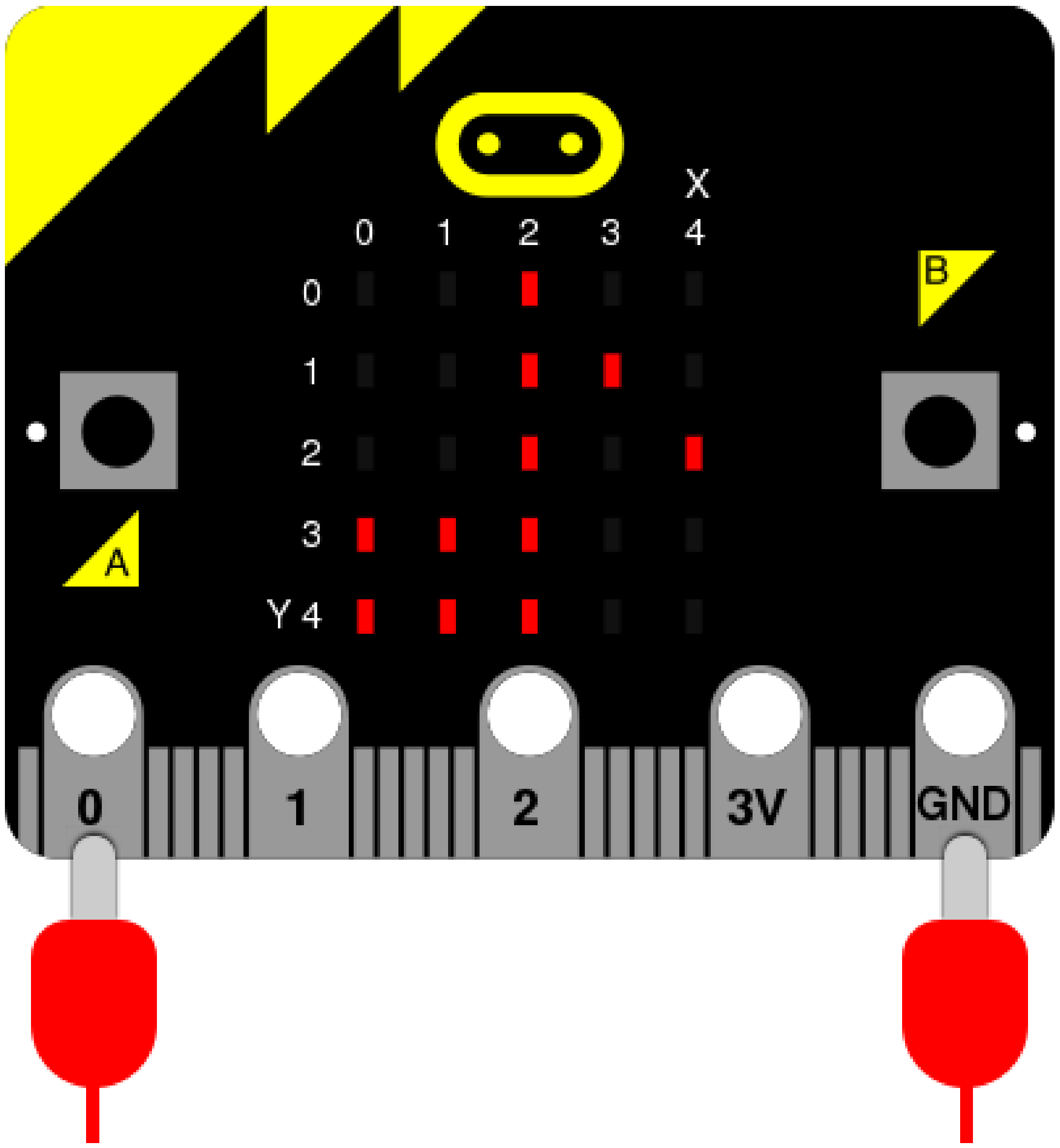
Example

```
"""
    compass.py
    ~~~~~~~~~~

    Creates a compass.

    The user will need to calibrate the compass first. The compass uses the
    built-in clock images to display the position of the needle.

"""
from microbit import *


# Start calibrating
compass.calibrate()

# Try to keep the needle pointed in (roughly) the correct direction
while True:
    sleep(100)
    needle = ((15 - compass.heading()) // 30) % 12
    display.show(Image.ALL_CLOCKS[needle])
```

CHAPTER 4

Music

This is the `music` module. You can use it to play simple tunes, provided that you connect a speaker to your board. By default the `music` module expects the speaker to be connected via pin 0:



This arrangement can be overridden (as discussed below).

To access this module you need to:

```
import music
```

We assume you have done this for the examples below.

Musical Notation

An individual note is specified thus:

```
NOTE[octave][:duration]
```

For example, `A1:4` refers to the note "A" in octave 1 that lasts for four ticks (a tick is an arbitrary length of time defined by a tempo setting function - see below). If the note name `R` is used then it is treated as a rest (silence).

Note names are case-insensitive.

The `octave` and `duration` parameters are states that carry over to subsequent notes until re-specified. The default states are `octave = 4` (containing middle C) and `duration = 4` (a crotchet, given the default tempo settings - see below).

For example, if 4 ticks is a crotchet, the following list is crotchet, quaver, quaver, crotchet based arpeggio:

```
['c1:4', 'e:2', 'g', 'c2:4']
```

The opening of Beethoven's 5th Symphony would be encoded thus:

```
['r4:2', 'g', 'g', 'g', 'eb:8', 'r:2', 'f', 'f', 'f', 'd:8']
```

The definition and scope of an octave conforms to the table listed on this page about scientific pitch notation. For example, middle "C" is `'c4'` and concert "A" (440) is `'a4'`. Octaves start on the note "C".

Functions

`music.`**`set_tempo`**`(`*ticks=4*, *bpm=120*`)`

Sets the approximate tempo for playback.

A number of ticks (expressed as an integer) constitute a beat. Each beat is to be played at a certain frequency per minute (expressed as the more familiar BPM - beats per minute - also as an integer).

Suggested default values allow the following useful behaviour:

- `music.set_tempo()` - reset the tempo to default of ticks = 4, bpm = 120
- `music.set_tempo(ticks=8)` - change the "definition" of a beat
- `music.set_tempo(bpm=180)` - just change the tempo

To work out the length of a tick in milliseconds is very simple arithmetic: `60000/bpm/ticks_per_beat` . For the default values that's `60000/120/4 = 125 milliseconds` or `1 beat = 500 milliseconds`.

`music.`**`get_tempo`**`()`

Gets the current tempo as a tuple of integers: `(ticks, bpm)`.

`music.`**`play`**`(`*music*, *pin=microbit.pin0*, *wait=True*, *loop=False*`)`

Plays `music` containing the musical DSL defined above.

If `music` is a string it is expected to be a single note such as, `'c1:4'`.

If `music` is specified as a list of notes (as defined in the section on the musical DSL, above) then they are played one after the other to perform a melody.

In both cases, the `duration` and `octave` values are reset to their defaults before the music (whatever it may be) is played.

An optional argument to specify the output pin can be used to override the default of `microbit.pin0`.

If `wait` is set to `True`, this function is blocking.

If `loop` is set to `True`, the tune repeats until `stop` is called (see below) or the blocking call is interrupted.

`music.pitch(frequency, len=-1, pin=microbit.pin0, wait=True)`

Plays a pitch at the integer frequency given for the specified number of milliseconds. For example, if the frequency is set to 440 and the length to 1000 then we hear a standard concert A for one second.

If `wait` is set to `True`, this function is blocking.

If `len` is negative the pitch is played continuously until either the blocking call is interrupted or, in the case of a background call, a new frequency is set or `stop` is called (see below).

`music.stop(pin=microbit.pin0)`

Stops all music playback on a given pin.

`music.reset()`

Resets the state of the following attributes in the following way:

- `ticks = 4`
- `bpm = 120`
- `duration = 4`
- `octave = 4`

Built in Melodies

For the purposes of education and entertainment, the module contains several example tunes that are expressed as Python lists. They can be used like this:

```
>>> import music
>>> music.play(music.NYAN)
```

All the tunes are either out of copyright, composed by Nicholas H.Tollervey and released to the public domain or have an unknown composer and are covered by a fair (educational) use provision.

They are:

- `DADADADUM` - the opening to Beethoven's 5th Symphony in C minor.
- `ENTERTAINER` - the opening fragment of Scott Joplin's Ragtime classic "The Entertainer".
- `PRELUDE` - the opening of the first Prelude in C Major of J.S.Bach's 48 Preludes and Fugues.
- `ODE` - the "Ode to Joy" theme from Beethoven's 9th Symphony in D minor.
- `NYAN` - the Nyan Cat theme (http://www.nyan.cat/). The composer is unknown. This is fair use for educational porpoises (as they say in New York).
- `RINGTONE` - something that sounds like a mobile phone ringtone. To be used to indicate an incoming message.
- `FUNK` - a funky bass line for secret agents and criminal masterminds.
- `BLUES` - a boogie-woogie 12-bar blues walking bass.
- `BIRTHDAY` - "Happy Birthday to You..." for copyright status see: http://www.bbc.co.uk/news/world-us-canada-34332853
- `WEDDING` - the bridal chorus from Wagner's opera "Lohengrin".
- `FUNERAL` - the "funeral march" otherwise known as Frédéric Chopin's Piano Sonata No. 2 in B minor, Op. 35.
- `PUNCHLINE` - a fun fragment that signifies a joke has been made.
- `PYTHON` - John Philip Sousa's march "Liberty Bell" aka, the theme for "Monty Python's Flying Circus" (after which the Python programming language is named).

- BADDY - silent movie era entrance of a baddy.
- CHASE - silent movie era chase scene.
- BA_DING - a short signal to indicate something has happened.
- WAWAWAWAA - a very sad trombone.
- JUMP_UP - for use in a game, indicating upward movement.
- JUMP_DOWN - for use in a game, indicating downward movement.
- POWER_UP - a fanfare to indicate an achievement unlocked.
- POWER_DOWN - a sad fanfare to indicate an achievement lost.

Example

```
"""
    music.py
    ~~~~~~~~

    Plays a simple tune using the Micropython music module.
    This example requires a speaker/buzzer/headphones connected to P0 and GND.
"""
from microbit import *
import music

# play Prelude in C.
notes = [
    'c4:1', 'e', 'g', 'c5', 'e5', 'g4', 'c5', 'e5', 'c4', 'e', 'g', 'c5', 'e5', 'g4',
↪'c5', 'e5',
    'c4', 'd', 'g', 'd5', 'f5', 'g4', 'd5', 'f5', 'c4', 'd', 'g', 'd5', 'f5', 'g4',
↪'d5', 'f5',
    'b3', 'd4', 'g', 'd5', 'f5', 'g4', 'd5', 'f5', 'b3', 'd4', 'g', 'd5', 'f5', 'g4',
↪'d5', 'f5',
    'c4', 'e', 'g', 'c5', 'e5', 'g4', 'c5', 'e5', 'c4', 'e', 'g', 'c5', 'e5', 'g4',
↪'c5', 'e5',
    'c4', 'e', 'a', 'e5', 'a5', 'a4', 'e5', 'a5', 'c4', 'e', 'a', 'e5', 'a5', 'a4',
↪'e5', 'a5',
    'c4', 'd', 'f#', 'a', 'd5', 'f#4', 'a', 'd5', 'c4', 'd', 'f#', 'a', 'd5', 'f#4',
↪'a', 'd5',
    'b3', 'd4', 'g', 'd5', 'g5', 'g4', 'd5', 'g5', 'b3', 'd4', 'g', 'd5', 'g5', 'g4',
↪'d5', 'g5',
    'b3', 'c4', 'e', 'g', 'c5', 'e4', 'g', 'c5', 'b3', 'c4', 'e', 'g', 'c5', 'e4', 'g
↪', 'c5',
    'b3', 'c4', 'e', 'g', 'c5', 'e4', 'g', 'c5', 'b3', 'c4', 'e', 'g', 'c5', 'e4', 'g
↪', 'c5',
    'a3', 'c4', 'e', 'g', 'c5', 'e4', 'g', 'c5', 'a3', 'c4', 'e', 'g', 'c5', 'e4', 'g
↪', 'c5',
    'd3', 'a', 'd4', 'f#', 'c5', 'd4', 'f#', 'c5', 'd3', 'a', 'd4', 'f#', 'c5', 'd4',
↪'f#', 'c5',
    'g3', 'b', 'd4', 'g', 'b', 'd', 'g', 'b', 'g3', 'b3', 'd4', 'g', 'b', 'd', 'g', 'b
↪'
]

music.play(notes)
```

CHAPTER 5

Random Number Generation

This module is based upon the `random` module in the Python standard library. It contains functions for generating random behaviour.

To access this module you need to:

```python
import random
```

We assume you have done this for the examples below.

Functions

`random.`**`getrandbits`**`(`*n*`)`

Returns an integer with `n` random bits.

Warning: Because the underlying generator function returns at most 30 bits, `n` may only be a value between 1-30 (inclusive).

`random.`**`seed`**`(`*n*`)`

Initialize the random number generator with a known integer `n`. This will give you reproducibly deterministic randomness from a given starting state (`n`).

`random.`**`randint`**`(`*a*, *b*`)`

Return a random integer `N` such that `a <= N <= b`. Alias for `randrange(a, b+1)`.

`random.`**`randrange`**`(`*stop*`)`

Return a randomly selected integer between zero and up to (but not including) `stop`.

`random.`**`randrange`**`(`*start*, *stop*`)`

Return a randomly selected integer from `range(start, stop)`.

`random.`**`randrange`**`(`*start*, *stop*, *step*`)`

Return a randomly selected element from `range(start, stop, step)`.

`random.`**`choice`**`(`*seq*`)`
Return a random element from the non-empty sequence `seq`. If `seq` is empty, raises `IndexError`.

`random.`**`random`**`()`
Return the next random floating point number in the range [0.0, 1.0)

`random.`**`uniform`**`(`*a*, *b*`)`
Return a random floating point number `N` such that `a <= N <= b` for `a <= b` and `b <= N <= a` for `b < a`.

CHAPTER 6

NeoPixel

The `neopixel` module lets you use Neopixel (WS2812) individually addressable RGB LED strips with the Microbit. Note to use the `neopixel` module, you need to import it separately with:

```
import neopixel
```

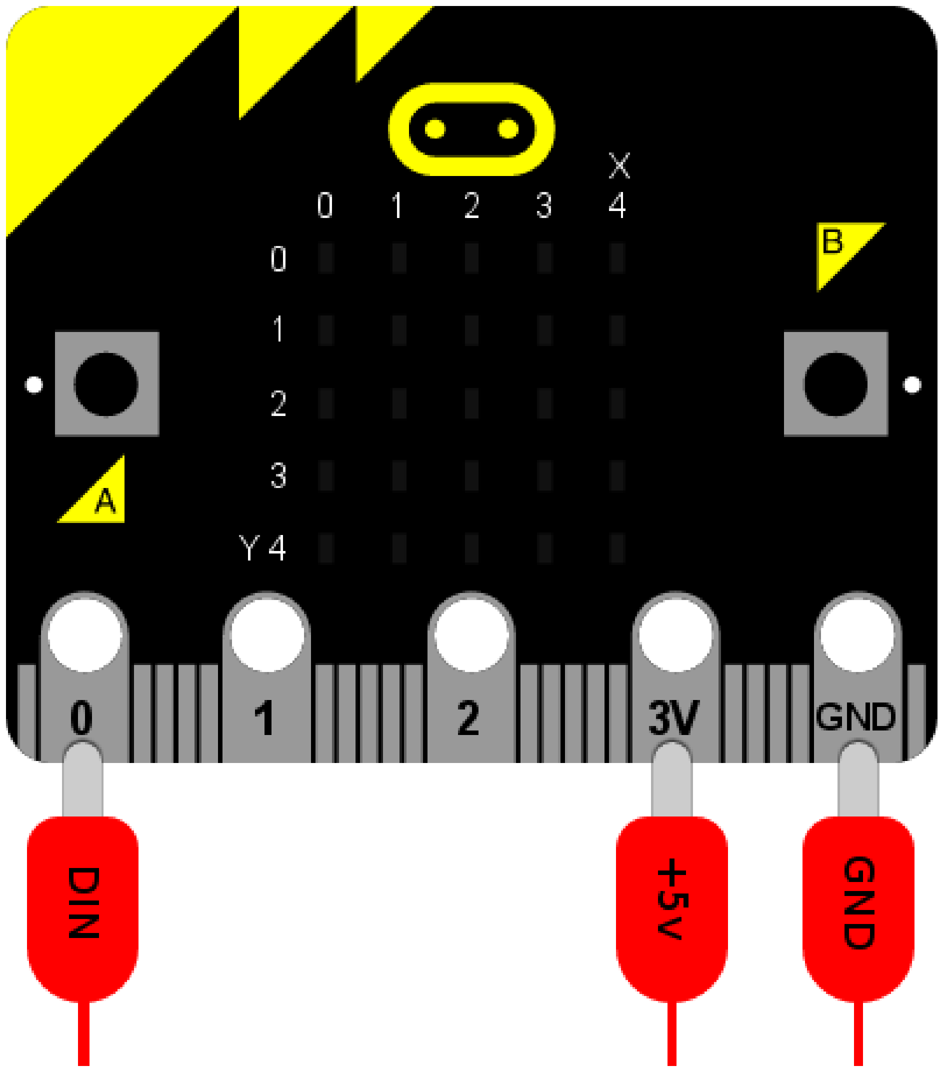
Note: From our tests, the Microbit Neopixel module can drive up to around 256 Neopixels. Anything above that and you may experience weird bugs and issues.

NeoPixels are fun strips of multi-coloured programmable LEDs. This module contains everything to plug them into a micro:bit and create funky displays, art and games such as the demo shown below.

To connect a strip of neopixels you'll need to attach the micro:bit as shown below (assuming you want to drive the pixels from pin 0 - you can connect neopixels to pins 1 and 2 too). The label on the crocodile clip tells you where to attach the other end on the neopixel strip.

Warning: Do not use the 3v connector on the Microbit to power any more than 8 Neopixels at a time.

If you wish to use more than 8 Neopixels, you must use a separate 3v-5v power supply for the Neopixel power pin.



Classes

class `neopixel.`**`NeoPixel`**`(`*pin*, *n*`)`

Initialise a new strip of `n` number of neopixel LEDs controlled via pin `pin`. Each pixel is addressed by a position (starting from 0). Neopixels are given RGB (red, green, blue) values between 0-255 as a tuple. For example, `(255,255,255)` is white.

`clear``()`

Clear all the pixels.

`show``()`

Show the pixels. Must be called for any updates to become visible.

Operations

Writing the colour doesn't update the display (use `show()` for that).

```
np[0] = (255, 0, 128)  # first element
np[-1] = (0, 255, 0)  # last element
np.show()  # only now will the updated value be shown
```

To read the colour of a specific pixel just reference it.

```
print(np[0])
```

Using Neopixels

Interact with Neopixels as if they were a list of tuples. Each tuple represents the RGB (red, green and blue) mix of colours for a specific pixel. The RGB values can range between 0 to 255.

For example, initialise a strip of 8 neopixels on a strip connected to pin0 like this:

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

Set pixels by indexing them (like with a Python list). For instance, to set the first pixel to full brightness red, you would use:

```
np[0] = (255, 0, 0)
```

Or the final pixel to purple:

```
np[-1] = (255, 0, 255)
```

Get the current colour value of a pixel by indexing it. For example, to print the first pixel's RGB value use:

```
print(np[0])
```

Finally, to push the new colour data to your Neopixel strip, use the .show() function:

```
np.show()
```

If nothing is happening, it's probably because you've forgotten this final step..!

Note: If you're not seeing anything change on your Neopixel strip, make sure you're `show()` at least somewhere otherwise your updates won't be shown.

Example

```
"""
    neopixel_random.py

    Repeatedly displays random colours onto the LED strip.
    This example requires a strip of 8 Neopixels (WS2812) connected to pin0.
```

```
"""
from microbit import *
import neopixel
from random import randint

# Setup the Neopixel strip on pin0 with a length of 8 pixels
np = neopixel.NeoPixel(pin0, 8)

while True:
    #Iterate over each LED in the strip

    for pixel_id in range(0, len(np)):
        red = randint(0, 60)
        green = randint(0, 60)
        blue = randint(0, 60)

        # Assign the current LED a random red, green and blue value between 0 and 60
        np[pixel_id] = (red, green, blue)

        # Display the current pixel data on the Neopixel strip
        np.show()
        sleep(100)
```

CHAPTER 7

Bluetooth

While the BBC micro:bit has Bluetooth Low Energy (BLE) hardware it only has 16k of RAM. The BLE stack alone takes up 12k RAM which means there's not enough room to (currently) run MicroPython.

Future versions of the device may come with 32k RAM which would be sufficient. However, until such time it's highly unlikely MicroPython will support BLE.

CHAPTER 8

Installation

This section will help you set up the tools and programs needed for developing programs and firmware to flash to the BBC micro:bit using MicroPython.

Dependencies

Development Environment

You will need:

- git
- yotta

Depending on your operating system, the installation instructions vary. Use the installation scenario that best suits your system.

Installation Scenarios

- *Windows*
- *OS X*
- *Linux*
- *Debian and Ubuntu*
- *Red Hat Fedora/CentOS*
- *Raspberry Pi*

Windows

When installing Yotta, make sure you have these components ticked to install.

- python
- gcc
- cMake
- ninja
- Yotta
- git-scm
- mbed serial driver

OS X

Linux

These steps will cover the basic flavors of Linux and working with the micro:bit and MicroPython. See also the specific sections for Raspberry Pi, Debian/Ubuntu, and Red Hat Fedora/Centos.

Debian and Ubuntu

```
sudo add-apt-repository -y ppa:terry.guo/gcc-arm-embedded
sudo add-apt-repository -y ppa:pmiller-opensource/ppa
sudo apt-get update
sudo apt-get install cmake ninja-build gcc-arm-none-eabi srecord
pip3 install yotta
```

Red Hat Fedora/CentOS

Raspberry Pi

Next steps

Congratulations. You have installed your development environment and are ready to begin *flashing firmware* to the micro:bit.

CHAPTER 9

Flashing Firmware

Building firmware

Use yotta to build.

Use target bbc-microbit-classic-gcc-nosd:

```
yt target bbc-microbit-classic-gcc-nosd
```

Run yotta update to fetch remote assets:

```
yt up
```

Start the build with either yotta:

```
yt build
```

...or use the Makefile:

```
make all
```

The result is a microbit-micropython hex file (i.e. `firmware.hex`) found in the build/bbc-microbit-classic-gcc-nosd/source from the root of the repository.

The Makefile does some extra preprocessing of the source, which is needed only if you add new interned strings to `qstrdefsport.h`. The Makefile also puts the resulting firmware at build/firmware.hex, and includes some convenience targets.

Preparing firmware and a Python program

tools/makecombined

hexlify

Flashing to the micro:bit

Installation Scenarios

- *Windows*
- *OS X*
- *Linux*
- *Debian and Ubuntu*
- *Red Hat Fedora/CentOS*
- *Raspberry Pi*

CHAPTER 10

Accessing the REPL

Accessing the REPL on the micro:bit requires:

- Using a serial communication program
- Determining the communication port identifier for the micro:bit
- Establishing communication with the correct settings for your computer

If you are a Windows user you'll need to install the correct drivers. The instructions for which are found here:

https://developer.mbed.org/handbook/Windows-serial-configuration

Serial communication

To access the REPL, you need to select a program to use for serial communication. Some common options are *picocom* and *screen*. You will need to install program and understand the basics of connecting to a device.

Determining port

The micro:bit will have a port identifier (tty, usb) that can be used by the computer for communicating. Before connecting to the micro:bit, we must determine the port identifier.

Establishing communication with the micro:bit

Depending on your operating system, environment, and serial communication program, the settings and commands will vary a bit. Here are some common settings for different systems (please suggest additions that might help others)

Settings

- *Windows*

- *OS X*
- *Linux*
- *Debian and Ubuntu*
- *Red Hat Fedora/CentOS*
- *Raspberry Pi*

CHAPTER 11

Developer FAQ

Note: This project is under active development. Please help other developers by adding tips, how-tos, and Q&A to this document. Thanks!

Where do I get a copy of the DAL? A: Ask Nicholas Tollervey for details.

CHAPTER 12

Contributing

Hey! Many thanks for wanting to improve MicroPython on the micro:bit.

Contributions are welcome without prejudice from *anyone* irrespective of age, gender, religion, race or sexuality. Good quality code and engagement with respect, humour and intelligence wins every time.

- If you're from a background which isn't well-represented in most geeky groups, get involved - *we want to help you make a difference*.
- If you're from a background which *is* well-represented in most geeky groups, get involved - *we want your help making a difference*.
- If you're worried about not being technical enough, get involved - *your fresh perspective will be invaluable*.
- If you think you're an imposter, get involved.
- If your day job isn't code, get involved.
- This isn't a group of experts, just people. Get involved!
- This is a new community, so, get involved.

We expect contributors to follow the Python Software Foundation's Code of Conduct: https://www.python.org/psf/codeofconduct/

Feedback may be given for contributions and, where necessary, changes will be politely requested and discussed with the originating author. Respectful yet robust argument is most welcome.

Checklist

- Your code should be commented in *plain English* (British spelling).
- If your contribution is for a major block of work and you've not done so already, add yourself to the AUTHORS file following the convention found therein.
- If in doubt, ask a question. The only stupid question is the one that's never asked.
- Have fun!

- genindex
- modindex
- search

Python Module Index

Index