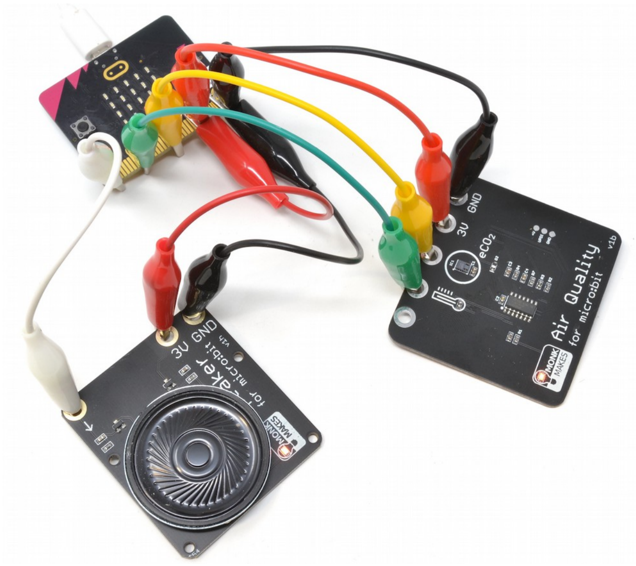
Instructions:

Air Quality Kit

For micro:bit

Works with micro:bit | V1 & V2



V1a

Table of Contents

Introduction

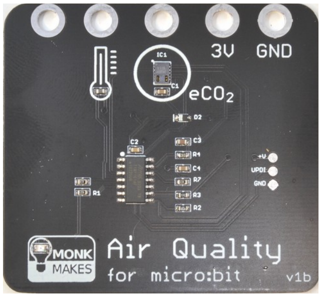
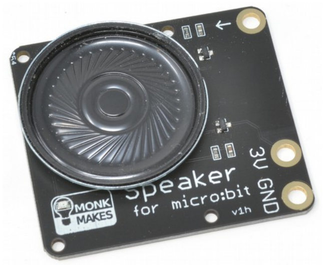
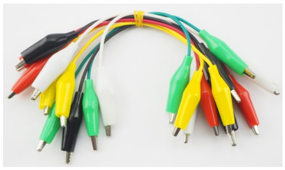
The MonkMakes Air Quality Kit for micro:bit is based around the MonkMakes Air Quality Sensor. This add-on for the BBC micro:bit measures the quality of the air in a room (how *stale* the air is) as well as the temperature. The outputs of the Air Quality Sensor board are analog (one for temperature and one for eCO2). These outputs can be read by a micro:bit and either displayed (for instance, as an air quality meter) or logged over a period of time for all sorts of interesting experiments.

As well as the Air Quality Sensor itself, the kit also includes a set of alligator clip leads to connect it to the micro:bit and also a Speaker for micro:bit that can provide a warning of low air quality.

Parts

Please note that a BBC micro:bit is NOT included in this kit.

Before you do anything else, check that your kit includes the following items.

Air Quailty Sensor for micro:bit	 3V GND eCO2 MONK MAKES Air Quality for micro:bit v1b
Speaker for micro:bit	
Set of alligator (also called crocodile) clip leads (10 leads)	

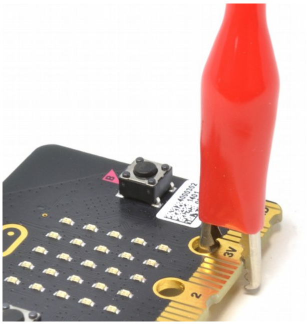
Google Chrome Browser

Please note that Makecode and the BBC micro:bit work bets with Chrome as it allows direct download onto the micro:bit and USB communication with the micro:bit. In fact, Experiment 4 will only work with Google Chrome.

Getting Started

About Alligator Clips

When using the alligator clips to connect your micro:bit to the MonkMakes boards, you have to be a bit careful how you connect the clips at the micro:bit end. The best way is to connect the clips vertically, as shown below.



Connecting the alligator clips like this prevents any accidental connections between the large ring connectors with the holes in and the much smaller connectors (gold lines in the photo).

If you have a version 2 micro:bit, this is easier because it has notches to help keep stop the clip straying.

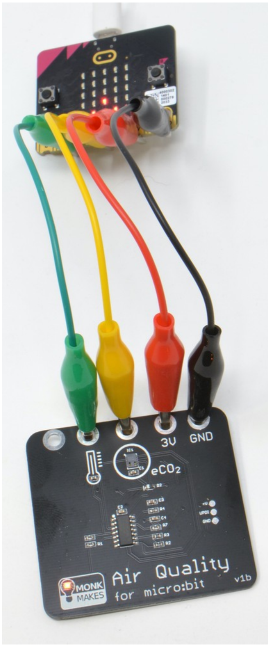
Connecting the Air Quality Sensor

To measure both temperature and air quality, the Air Quality Sensor requires four connections to the micro:bit: GND and 3V (to supply it with power) and two of the other micro:bit rings for the temperature and eCO2 readings.

Connect your micro:bit to the Air Quality Sensor as shown here.

The yellow lead is connected to micro:bit ring 2 and the green lead to ring 1.

It does not matter which colors you use for the leads, but it is a good idea to stick to black for GND, red for 3V and any other colors for the other two leads. This just makes it less likely that you will accidentally connect power the wrong way around – although if you do make that mistake, don't worry, it won't damage the board.



Air Quality and eCO2

The Air Quality Sensor board uses a sensor with a part number of CCS811. This small chip does not actually measure the level of CO2 (carbon dioxide) but instead the level of a group of gasses called volatile organic compounds (VOCs). When indoors, the level of these gasses rises at a fairly similar rate to the level of CO2 and can therefore be used to estimate the level of CO2 (called the equivalent CO2 or eCO2).

The level of CO2 in the air we breathe has a direct influence on our well-being. CO2 levels are of particular interest from a public health point of view as, to put it simply, they are a measure of how much we are breathing other people's air. We humans breathe out CO2 and so, if several people are in a poorly ventilated room, the level of CO2 will gradually increase. As will the viral aerosols that spread colds, flus and Coronavirus as people breathe both out together.

Another important impact of CO2 levels is in cognitive function – how well you can think. This study (amongst many more) have some interesting findings. The following quote is from the National Centre for Biotechnology Information in the USA:

"at 1,000 ppm CO2, moderate and statistically significant decrements occurred in six of nine scales of decision-making performance. At 2,500 ppm, large and statistically significant reductions occurred in seven scales of decision-making performance" Source: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3548274/

The table below is based on information from https://www.kane.co.uk/knowledge-centre/what-are-safe-levels-of-co-and-co2-in-rooms and shows the levels at which CO2 can become unhealthy. The CO2 readings are in ppm (parts per million).

Level of CO2 (ppm)	**Notes**
250-400	Normal concentration in ambient air.
400-1000	Concentrations typical of occupied indoor spaces with good air exchange.
1000-2000	Complaints of drowsiness and poor air.
2000-5000	Headaches, sleepiness and stagnant, stale, stuffy air. Poor concentration, loss of attention, increased heart rate and slight nausea may also be present.
5000	Workplace exposure limit in most countries.
>40000	Exposure may lead to serious oxygen deprivation resulting in permanent brain damage, coma, even death.

Experiment 1. Air Quality Meter

This first project displays the air quality as a bar graph. The more LEDs lit on the display, the lower the air quality. When all the LEDs are lit, this indicates an eCO2 (equivalent CO2) reading of 2000 parts per million. At any time, if you press button A, the micro:bit's display will show the eCO2 reading in parts per million. For more information about what these numbers mean, see the table on the previous page.

For this project, you need your Air Quality Sensor to be connected to your micro:bit as shown on page 4.

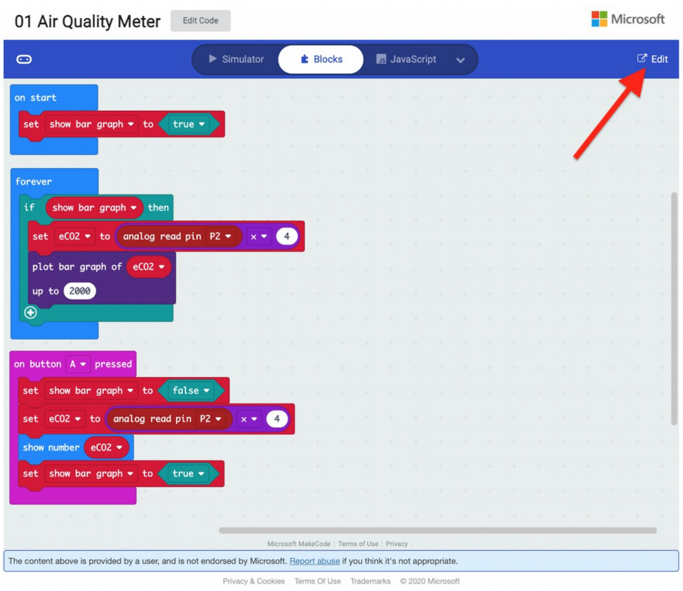
For this experiment, you can use either Makecode or MicroPython to program your micro:bit. We recommend that beginners use Makecode.

Makecode

For the Makecode version just go to this link and the code will appear in the browser.

https://makecode.microbit.org/_TcPfHbikr20T

Tip: If you download an electronic version of this instructions manual from https://monkmakes.com/mb_cc, you can click on the link above to get the code.


01 Air Quality Meter
Edit Code
Microsoft
Simulator
Blocks
JavaScript
Edit
Microsoft MakeCode | Terms of Use | Privacy
Privacy & Cookies   Terms Of Use   Trademarks   © 2020 Microsoft

```
on start
    set show bar graph to true

forever
    if show bar graph then
        set eCO2 to analog read pin P2 × 4
        plot bar graph of eCO2
        up to 2000

on button A pressed
    set show bar graph to false
    set eCO2 to analog read pin P2 × 4
    show number eCO2
    set show bar graph to true
```

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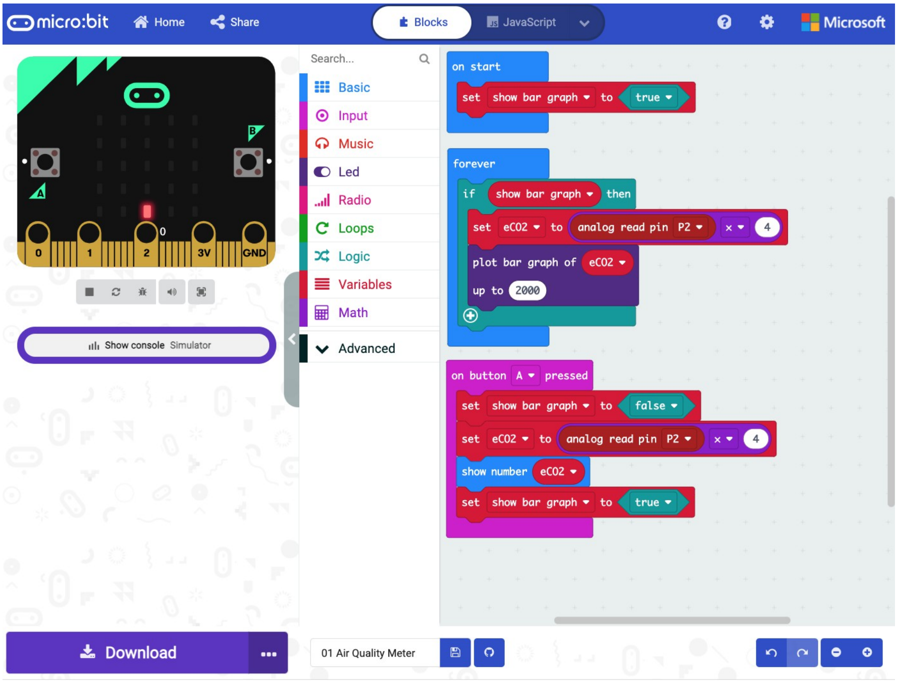
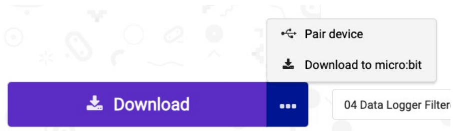
Click on the Edit button and the Makecode editor will open on the project as shown here.



```
on start
    set show bar graph to true

forever
    if show bar graph then
        set eCO2 to analog read pin P2 × 4
        plot bar graph of eCO2
        up to 2000

on button A pressed
    set show bar graph to false
    set eCO2 to analog read pin P2 × 4
    show number eCO2
    set show bar graph to true
```

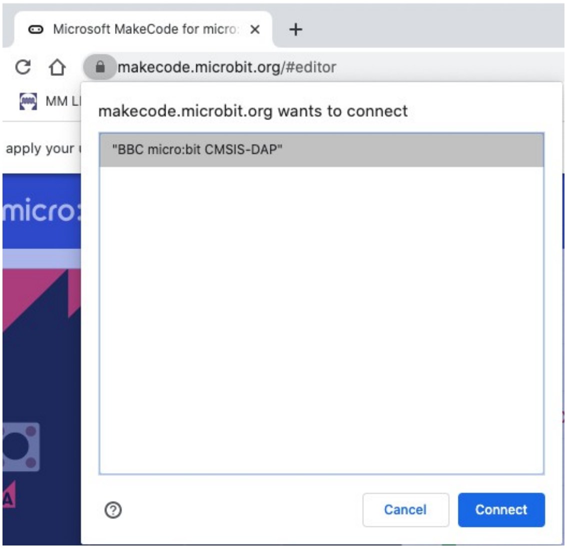
Getting the code from your computer to your micro:bit can be done a number of ways. Once set up, the most convenient way is direct from your web browser over USB by Pairing your micro:bit with the browser. This will only work if your micro:bit has a fairly new version of its built-in firmware. So, if the procedure below does not work for your micro:bit, then follow the instructions here (https://microbit.org/get-started/user-guide/firmware/) to upgrade your micro:bit to the latest version. Its actually very easy to do. You will also need to be able to pair your micro:bit to your browser for Experiment 4.

Now, to pair your micro:bit before downloading, click on the menu button (three dots) to the right of the Download button.



Then click on the Pair device option. This will lead you to a window attached to the padlock symbol on your browser, where you can identify your micro:bit to grant the

Makecode editor permission to connect to it over USB by clicking on Connect. The exact name of your micro:bit will differ.



makecode.microbit.org wants to connect

"BBC micro:bit CMSIS-DAP"

When you click on the Download button it will transfer the program onto your micro:bit and display the message *Download Completed!*. Next time you want to download a program, it should remember that your micro:bit is paired.

The m:b should now be showing a bar graph of the eCO2 level - probably just the bottom row of lights initially - and, if you breath gently near the sensor, you should see more LEDs light as the eCO2 level rises.

Lets take a quick look at the code:

The on start block initialises a variable called show bar graph to true. This variable is used so that when we press Button A to display the current reading we can stop displaying the bar graph so that is does not obscure the number being displayed.

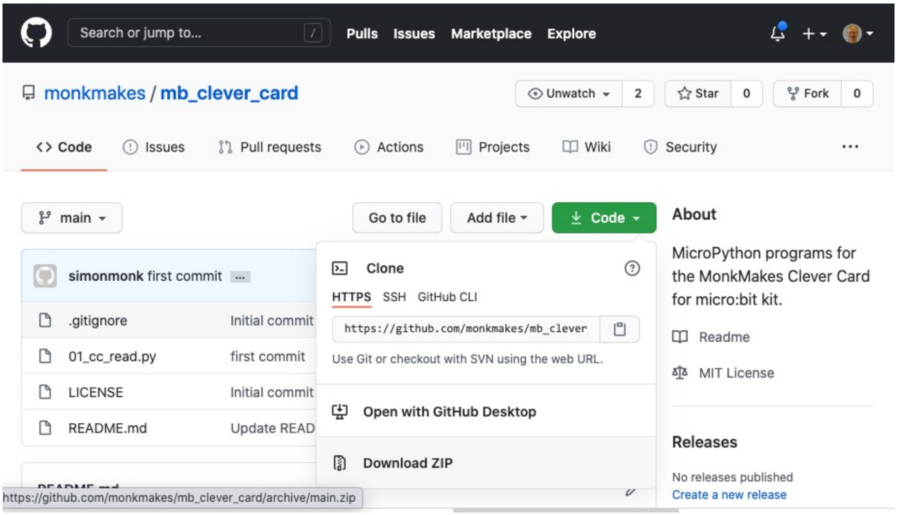
The forever block checks to see if the show bar graph variable is true, and if it is, it first sets the value of a variable called eCO2 to be the analog value read from pin P2 (which will be in the range 0 to 1023) times by 4. This gives a maximum eCO2 reading of 1023 x 4 = 4092 ppm. The plot bar graph of block is then used to display the eCO2 reading up to a maximum of 2000 ppm.

When button A is pressed, the variable show bar graph is set to false to disable the bar graph display in the forever block and then the value of eCO2 is calculated and shown on the display.

MicroPython

To fetch all the MicroPython programs for this kit, you will need to download them from the Github website where they are hosted. You will find them here:

https://github.com/monkmakes/mb_aq



simonmonk first commit

.gitignore	Initial commit
01_cc_read.py	first commit
LICENSE	Initial commit
README.md	Update READ

https://github.com/monkmakes/mb_clever

Use Git or checkout with SVN using the web URL.

MicroPython programs for the MonkMakes Clever Card for micro:bit kit.

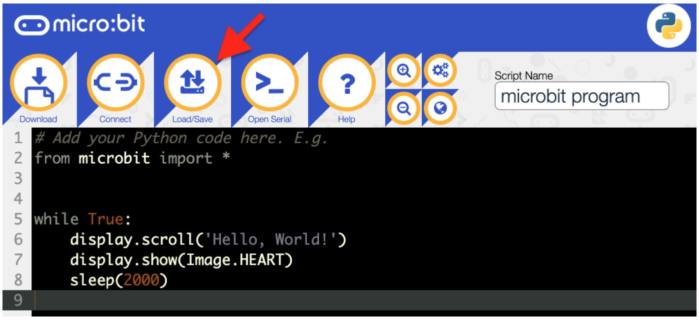
No releases published

https://github.com/monkmakes/mb_clever_card/archive/main.zip

To download them, click on the green *Code* button and select the option *Download ZIP*. Extract the ZIP archive and you will find a directory containing the python programs for Experiments 1 to 3. There is no MicroPython version of the code for Experiment 4.

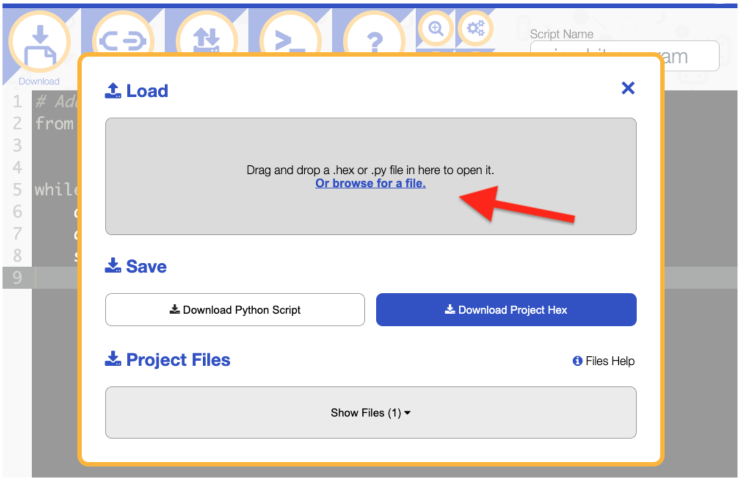
To get this code into an editor and then onto your micro:bit we recommend that you use the online Python editor for micro:bit at:

https://python.microbit.org

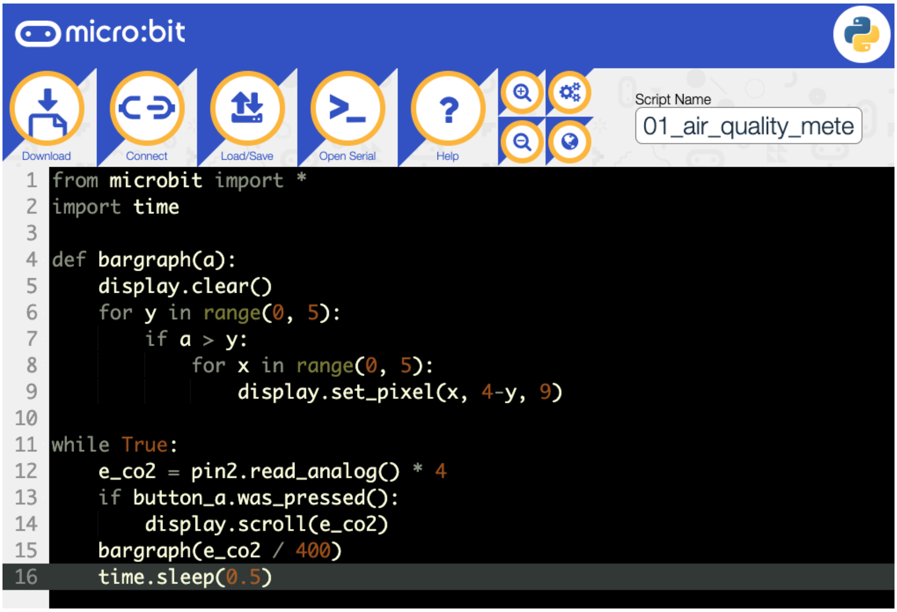


```
# Add your Python code here. E.g.
from microbit import *


while True:
    display.scroll('Hello, World!')
    display.show(Image.HEART)
    sleep(2000)
```

Click on the Load/Save button.



You can now drag one of the files you downloaded and unzipped into the Load area and it will appear in the editor. Here the file 01_air_quality_meter.py for this project has been loaded.

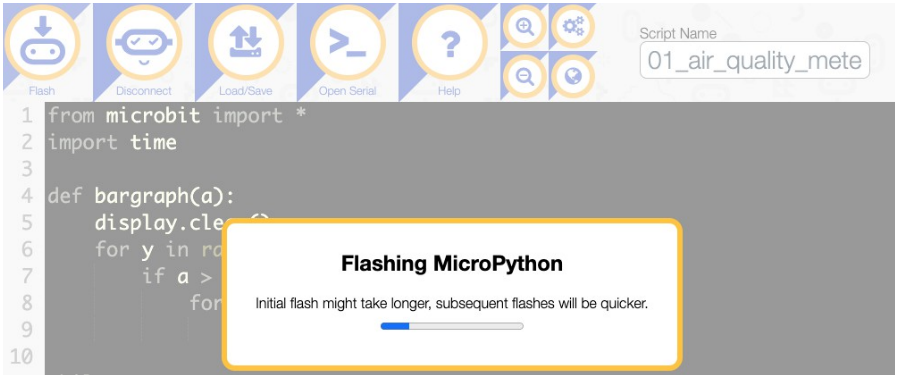


Script Name: 01_air_quality_mete

```
from microbit import *
import time

def bargraph(a):
    display.clear()
    for y in range(0, 5):
        if a > y:
            for x in range(0, 5):
                display.set_pixel(x, 4-y, 9)

while True:
    e_co2 = pin2.read_analog() * 4
    if button_a.was_pressed():
        display.scroll(e_co2)
    bargraph(e_co2 / 400)
    time.sleep(0.5)
```

Now you just need to transfer the program onto your micro:bit. This involves pairing the micro:bit with your browser just like you would when using Makecode. So click on the Connect button and then select your micro:bit.

Finally to install the program onto your micro:bit click on the Flash button.



Script Name: 01_air_quality_mete

```
from microbit import *
import time

def bargraph(a):
    display.cle
    for y in ra
        if a >
            for
```

Flashing MicroPython

Initial flash might take longer, subsequent flashes will be quicker.

Turning to the code for Experiment 1. The MicroPython version is quite similar to the Makecode version.

```
from microbit import *
import time

def bargraph(a):
    display.clear()
    for y in range(0, 5):
        if a > y:
            for x in range(0, 5):
                display.set_pixel(x, 4-y, 9)

while True:
    e_co2 = pin2.read_analog() * 4
    if button_a.was_pressed():
        display.scroll(e_co2)
    bargraph(e_co2 / 400)
    time.sleep(0.5)
```

However, the MicroPython library does not have a built in bar graph feature, so this is taken care of by the *bargraph* function that takes a number between 0 and 5 and lights that number of rows of LEDs.

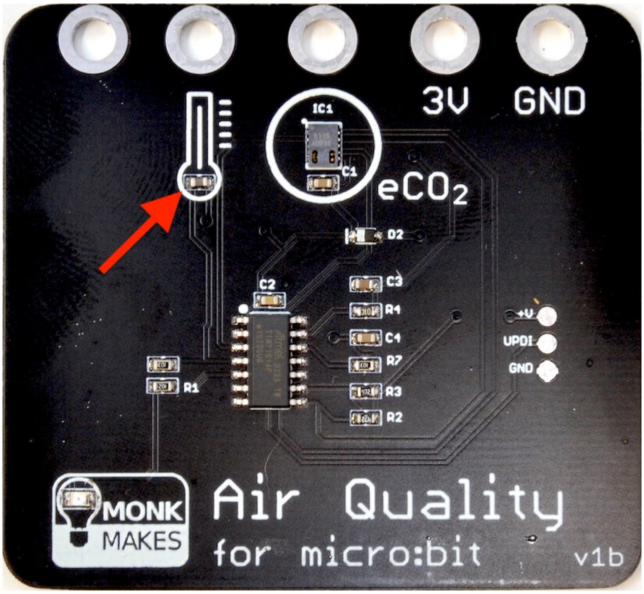
Experiment 2. Thermometer

The Air Quality Sensor board contains a temperature sensor that is mainly used to provide the eCO2 sensor with a temperature value that it requires to make its readings more accurate. This temperature reading is also available as an analog output for you to use. We can test this out using the program you will find at this link:

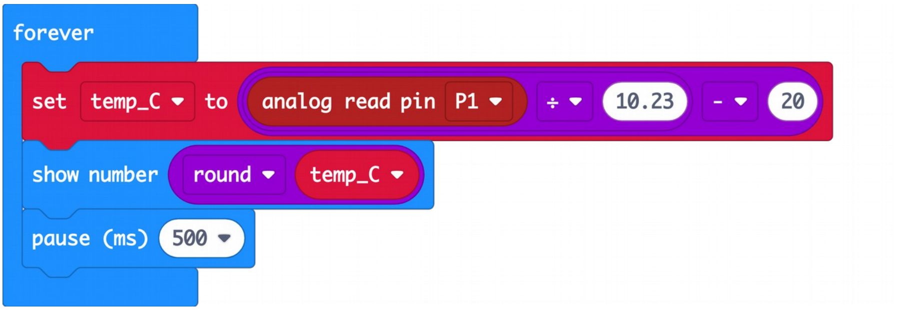
https://makecode.microbit.org/_CPqFxUcVeWFa

Open this program in the Makecode editor and install it onto your micro:bit as you did for Program 1.

This program displays the temperature, refreshing every half second. Put your finger on the temperature sensor to warm it and watch the displayed temperature increase.



The formula for converting the analog reading into a temperature in degrees C is to divide it by 10.23 and then subtract 20. This means that an analog reading of 0 equates to a temperature of -20C and a maximum reading of 1023 equates to a temperature of (1023 / 10.23) – 20 = 80 degrees C.



```
forever
    set temp_C ▾ to (analog read pin P1 ▾) ÷ ▾ 10.23 - ▾ 20
    show number round ▾ temp_C ▾
    pause (ms) 500 ▾
```

The temperature reading is only accurate to a couple of degrees C and if you prefer your temperatures in Fahrenheit, then this version of the program will do the conversion for you:

https://makecode.microbit.org/_YmwHJ8PhDbKu

WARNING: Although the temperature sensor can theoretically sense a range from -20C to + 80C, taking your micro:bit and Air Quality Sensor board outdoors may result in them getting wet, which will probably break them. So, this is a kit that is best used indoors.

MicroPython

The MicroPython version of the code is listed below. This works just the same way as its Makecode equivalent and is in the file 02_aq_thermometer_c.py.

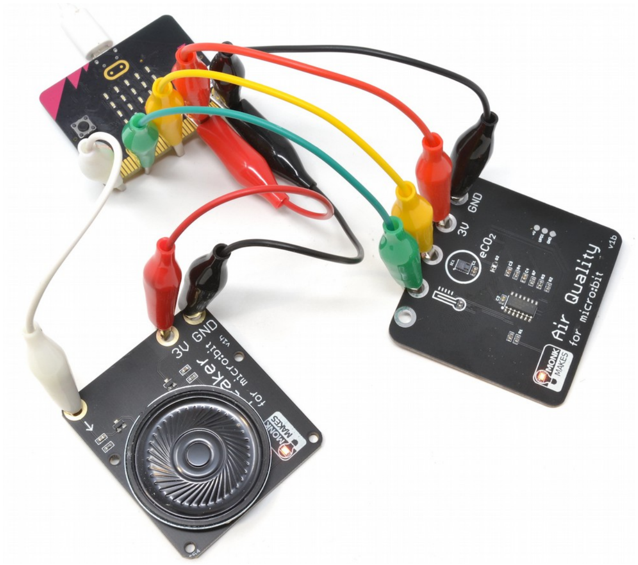
```
from microbit import *
import time

while True:
    temp_c = int(pin1.read_analog() / 10.23 - 20)
    display.scroll(temp_c)
    time.sleep(0.5)
```

There is also a Fahrenheit version of the program called 02_aq_thermometer_f.py.

Experiment 3. Air Quality Alarm

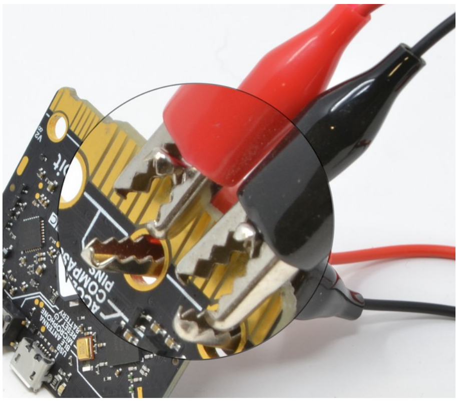
This project combines the Air Quality Sensor board with a MonkMakes Speaker for micro:bit, so that if the eCO2 reading exceeds a certain threshold then an alarm sounds and the display shows an X.

To connect both boards to your micro:bit you will need three more alligator clip leads. A second red and black lead to connect power to the Speaker and also a white lead to connect from ring 0 of the micro:bit to the input to the Speaker.



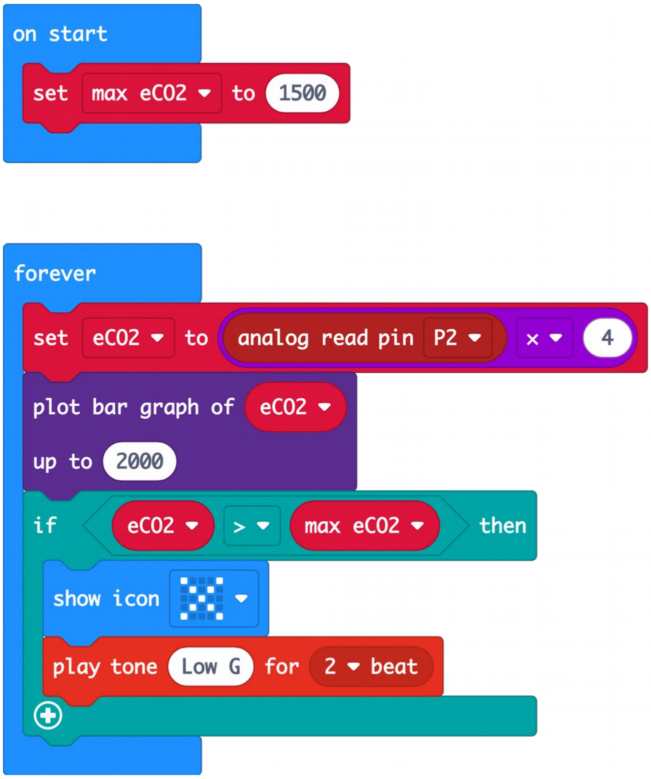
Although the micro:bit version 2 has a built-in speaker, this one's a lot louder.

To attach the second red and black leads to the micro:bit, push the original clips well into the rings on the micro:bit, so that enough alligator clip appears underneath the board to clip the new leads onto the original clips.



The Makecode block program is based on the Program 1 and you can find it here:

https://makecode.microbit.org/_JgHcLqbap8eX



```
on start
    set max eCO2 to 1500

forever
    set eCO2 to analog read pin P2 × 4
    plot bar graph of eCO2
    up to 2000
    if eCO2 > max eCO2 then
        show icon
        play tone Low G for 2 beat
```

The program uses a variable called max eCO2, which is set to 1500 ppm by default. The if block checks to see if the eCO2 level has been exceeded and, if it has, it displays an X and plays a warning tome through the speaker.

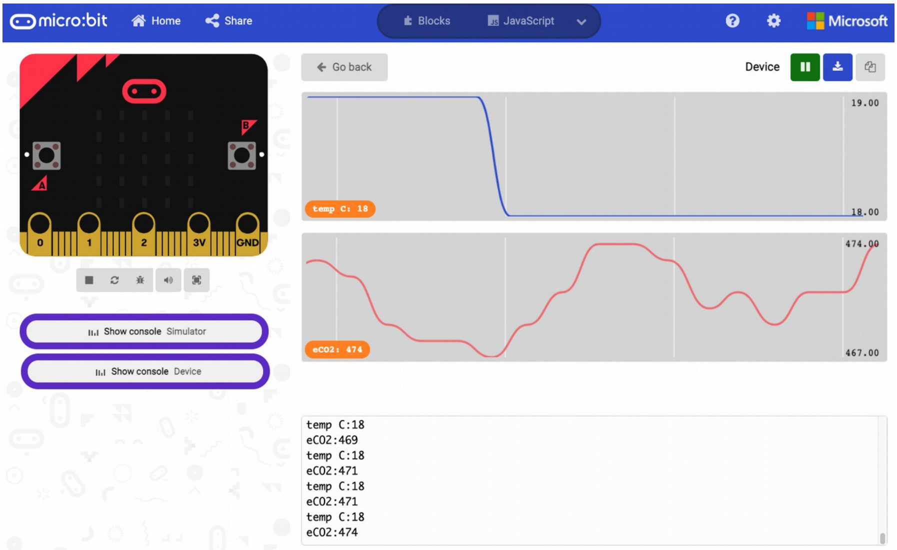
MicroPython

The MicroPython version of the program is 03_aq_alarm.py. This uses the same bargraph function as Experiment 1, but this time in the while loop, the current cCO2 reading in the variable e_co2 is compared with max_eco2 and if the limit is exceded the X (No) image is displayed and a musical note of frequency 196Hz is sounded for 500 milliseconds (half a second).

```
from microbit import *
import time
import music

max_eco2 = 1500

def bargraph(a):
    display.clear()
    for y in range(0, 5):
        if a > y:
            for x in range(0, 5):
                display.set_pixel(x, 4-y, 9)

while True:
    e_co2 = pin2.read_analog() * 4
    bargraph(e_co2 / 400)
    if e_co2 > max_eco2:
        display.show(Image.NO)
        music.pitch(196, 500)
    time.sleep(0.5)
```

Experiment 4. Air Quality Data Logger

This program uses the Makecode Console plotter feature to provide a real-time display of changes to temperature and eCO2 readings.



```
temp C:18
eCO2:469
temp C:18
eCO2:471
temp C:18
eCO2:471
temp C:18
eCO2:474
```

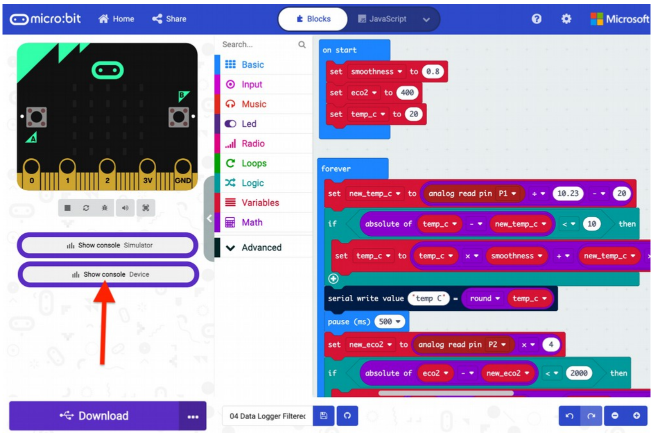
These readings can also be saved to a spreadsheet. This means that you could leave the project running overnight in your room and see how the temperature and eCO2 levels change overnight.

For this project to work, you must pair it with your browser. If you have not done this yet, please refer back to Experiment 1.

Here's the link for the Makecode program:

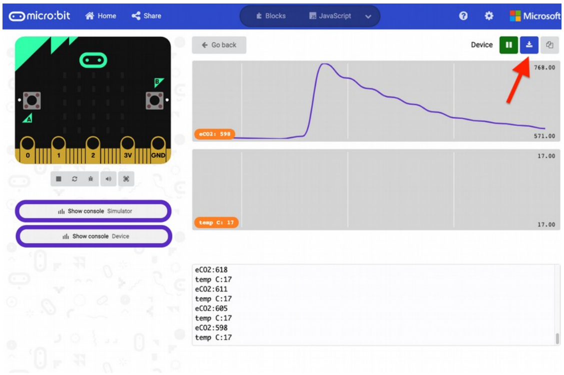
https://makecode.microbit.org/_D245rmWmg8Yw

If you are successfully paired, you should see a new button on the editor called Show Console Device. When you clock on this the real-time plot of your data should appear.



```
on start
    set smoothness to 0.8
    set eco2 to 400
    set temp_c to 20

forever
    set new_temp_c to analog read pin P1 + 10.23 - 20
    if absolute of temp_c - new_temp_c < 10 then
        set temp_c to temp_c × smoothness + new_temp_c
    serial write value "temp C" = round temp_c
    pause (ms) 500
    set new_eco2 to analog read pin P2 × 4
    if absolute of eco2 - new_eco2 < 2000 then
```

You can export the data that has been logged onto your computer by clicking on the Export Data button.

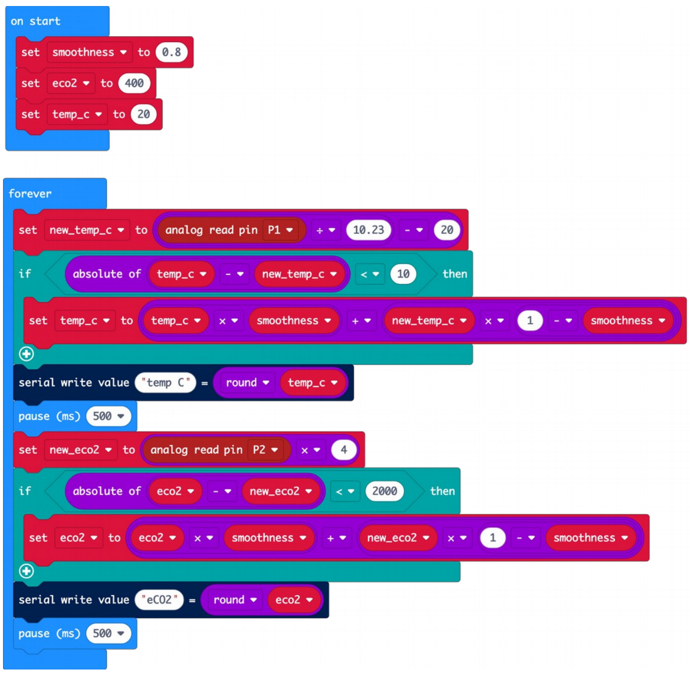


```
eCO2:618
temp C:17
eCO2:611
temp C:17
eCO2:605
temp C:17
eCO2:598
temp C:17
```

This will open the data in a spreadsheet for you.

The Code

The code takes a bit more effort with the sensor readings than the previous programs, using a software filter to smooth out the readings.



```
on start
  set smoothness to 0.8
  set eco2 to 400
  set temp_c to 20

forever
  set new_temp_c to analog read pin P1 ÷ 10.23 - 20
  if absolute of temp_c - new_temp_c < 10 then
    set temp_c to temp_c × smoothness + new_temp_c × 1 - smoothness
  serial write value "temp C" = round temp_c
  pause (ms) 500
  set new_eco2 to analog read pin P2 × 4
  if absolute of eco2 - new_eco2 < 2000 then
    set eco2 to eco2 × smoothness + new_eco2 × 1 - smoothness
  serial write value "eCO2" = round eco2
  pause (ms) 500
```

The program achieves its smoothing of the data by using a kind of rolling average of the readings controlled by a variable called smoothness. This value should always be less than 1 and typical useful values are between 0.7 and 0.95.

The way it works is that each time a reading is taken (lets say an eCO2 reading) the variable eco2 is set to be the smoothness times the old reading, plus (one minus smoothness) times the new reading. So, if smoothness is 0.8 then when the reading is updated, it will comprise 80% of its current value plus just 20% of the new reading.

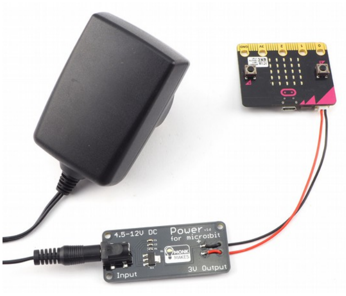
One effect of this type of filtering (called low-pass filtering) is that it will take a while for reading values to settle after a change. So, holding the temperature sensor or breathing on the CO2 sensor will take longer to have an effect on the values being logged.

The filtering also weeds out rogue readings that may occur from time to time by ignoring values that jump very suddenly. In the case of temperature sudden jumps of over 10 degrees are ignored as are changes of eCO2 reading by 2000 or more. This is called *removing outliers*.

The values are sent to the browser using the serial write value blocks.

POWERING THE AIR QUALITY SENSOR

If you want to power the project for a long period of time without an USB connection, then you can use a MonkMakes Power for micro:bit (pictured below) with an AC adaptor.



You can also use a MonkMakes Charger for micro:bit (also pictured below) that provides a steady output voltage using a rechargeable LiPo battery that charges using a USB lead.

You can find out more about these micro:bit accessories here: https://monkmakes.com/mb_power and here: https://monkmakes.com/mb_charger

TROUBLESHOOTING

Problem: I can't get any readings of Air Quality and the power LED in the MonkMakes logo isn't lit.

Solution: Make sure that you have the 3V and GND connections between the micro:bit and the Air Quality Sensor the right way around (see page 5). Also make sure that there is power to your micro:bit.

Problem: The power LED in the MonkMakes logo is blinking rapidly. What's going on?

Solution: Rapid blinking of the orange power LED in the MonkMakes logo indicates that there is an internal problem with the sensor IC. This may occasionally happen when connecting the Air Quality Sensor to your micro:bit. If you disconnect the red alligator clip lead from the Air Quality Sensor, and then connect it again, this should cure the problem and the LED should light without blinking.

Problem: I've just connected everything up, but the eCO2 readings seem wrong.

Solution: The type of sensor used in the MonkMakes Air Quality Sensor, will start producing readings from the first time you connect it. However, the readings will become more accurate with time. The datasheet for the sensor IC suggests the readings will only start to become accurate after 20 minutes of running time.

Problem: I'm comparing the readings from this sensor with a true CO2 meter and the readings are different.

Solution: That's to be expected. The Air Quality Sensor estimates the CO2 concentration (that's what the 'e' is for in eCO2). If you want true measurement of the CO2 concentration then you should use the MonkMakes CO2 Sensor for micro:bit shown here. However true CO2 measurement comes at a price.

Problem: I'm trying to run Program 4, but there is no option on the Makecode editor to Pair with my micro:bit.

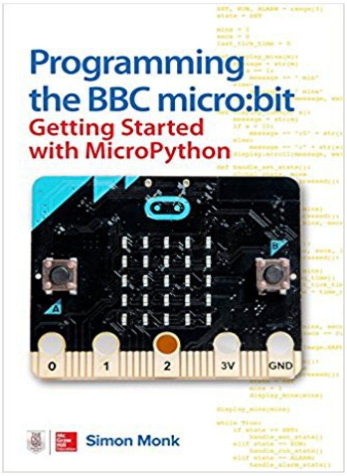
Solution: You need to update the firmware on your micro:bit by following the instructions here: https://microbit.org/get-started/user-guide/firmware/

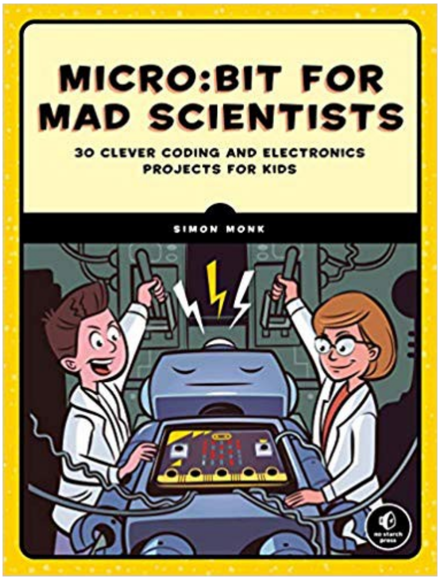
micro:bit Programming

If you want to learn more about programming the micro:bit in MicroPython, then you should consider buying Simon Monk's book *Programming micro:bit: Getting Started with MicroPython*, which is available from all major book sellers.

For some interesting project ideas, you might also like *micro:bit for the Mad Scientist* from NoStarch Press.

You can find out more about books by Simon Monk (the designer of this kit) at: http://simonmonk.org or follow him on Twitter where he is @simonmonk2





MonkMakes

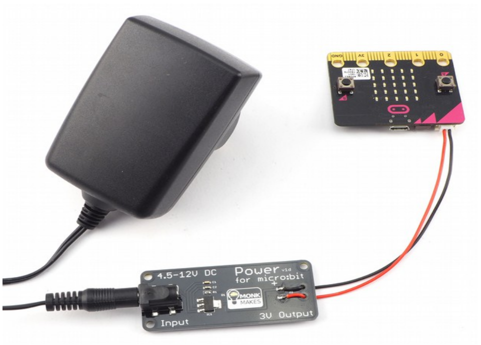
For more information on this kit, the product's home page is here: https://monkmakes.com/mb_aq

As well as this kit, MonkMakes makes all sorts of kits and gadgets to help with your maker projects. Find out more, as well as where to buy here: https://www.monkmakes.com/products

You can also follow MonkMakes on Twitter @monkmakes.

Electronics Starter Kit for micro:bit

CO2 Sensor for micro:bit



Power for micro:bit

NOTES