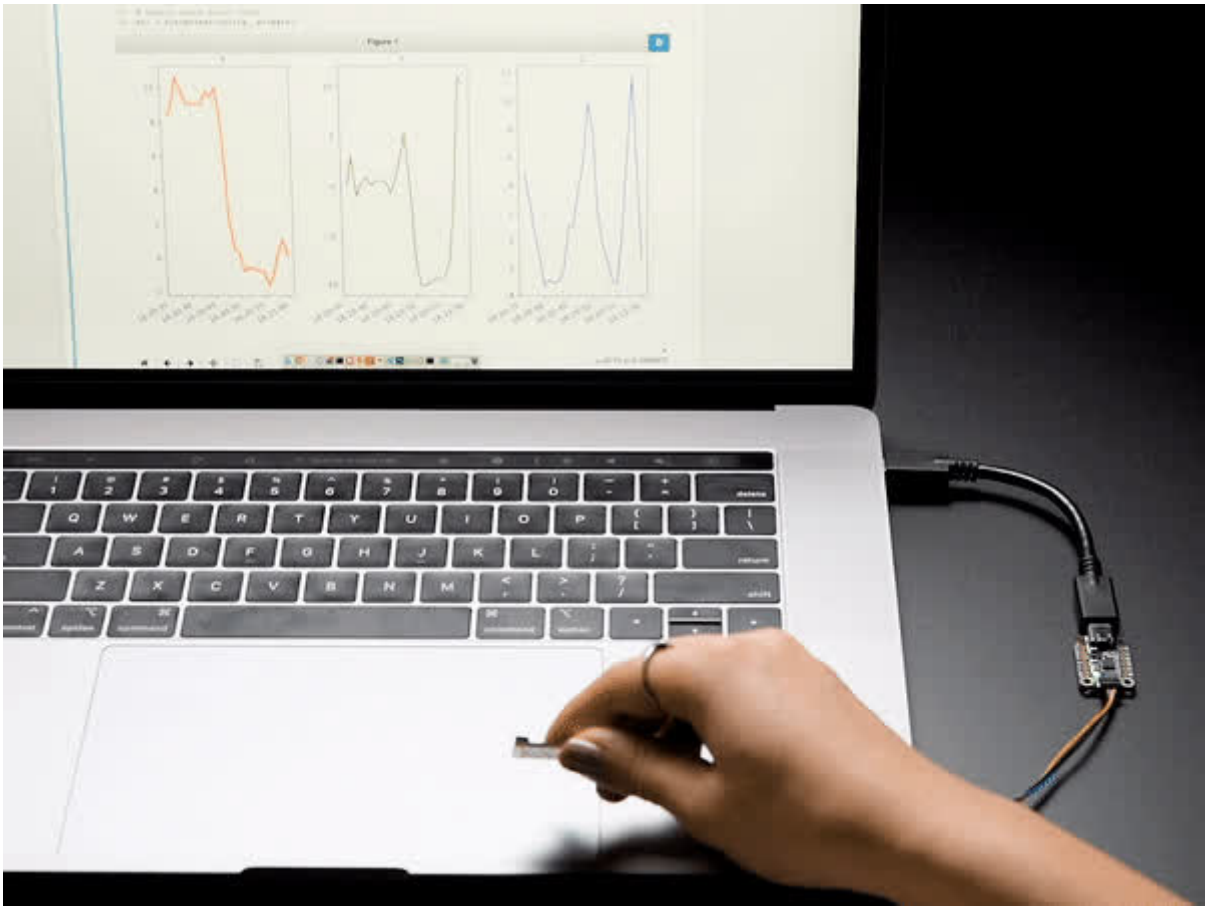
CircuitPython Libraries and Jupyter Notebook on any Computer with MCP2221

Created by Brent Rubell



https://learn.adafruit.com/jupyter-on-any-computer-with-circuitpython-libraries-and-mcp2221

Last updated on 2024-03-08 03:39:46 PM EST

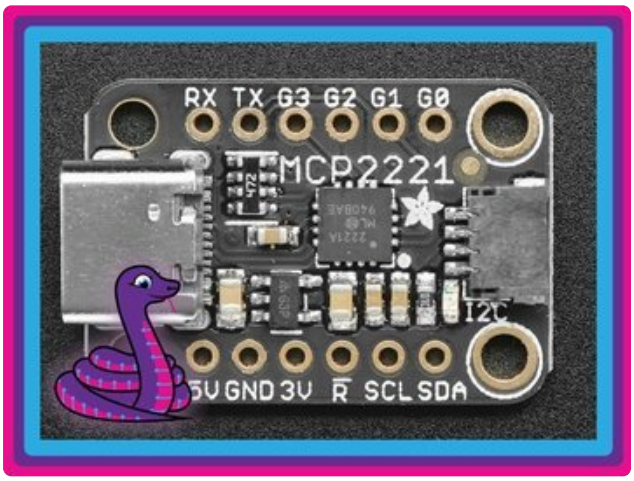
Table of Contents

Overview

This guide will show you **how to use Jupyter Notebook with the MCP2221(A) to connect I2C sensors from your desktop PC running Windows, macOS or Linux**. You can use any CircuitPython library for any of our I2C sensors to stream data into your computer's USB port.

We've written three interactive Jupyter Notebooks for three different types of sensors - a temperature sensor, an accelerometer and a thermal camera. All of these notebooks have animated graphs so you can see data streaming into your computer in real-time.

This guide is also compatible with the Adafruit FT232H breakout **(http://adafru.it/2264) (EXCEPT for the MLX thermal camera example).** You'll need to make a small adjustment to the code. See the Jupyter Notebook Examples page for more information (https://adafru.it/HMf).



MCP2221

Our MCP2221A breakout board (http://adafru.it/4471) allows your computer to talk to sensors or devices that use I2C or analog/digital GPIO.

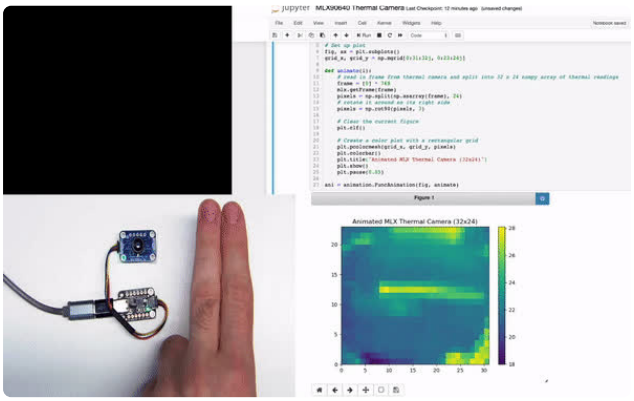
There's no firmware to deal with, so you don't have to deal with how to "send data to and from an Arduino which is then sent to and from" an electronic sensor or display or part.

This board is plug & play compatible with with all of our Stemma QT/Qwiic connector sensors with no soldering required (https://adafru.it/HMB).

CircuitPython Libraries on your Computer

In this guide we will **not** be using the actual CircuitPython firmware. But we will be installing and using **CircuitPython Libraries on your Computer.** This allows us to interface with a growing collection of 200+ libraries and drivers.

For more information about how this works, check out the CircuitPython Libraries on MCP2221 Guide here... (https://adafru.it/HMC)



Jupyter Notebook

> **Jupyter Notebook is an open-source web application that allows you to create and share documents that contain live code, equations, visualizations and narrative text.**

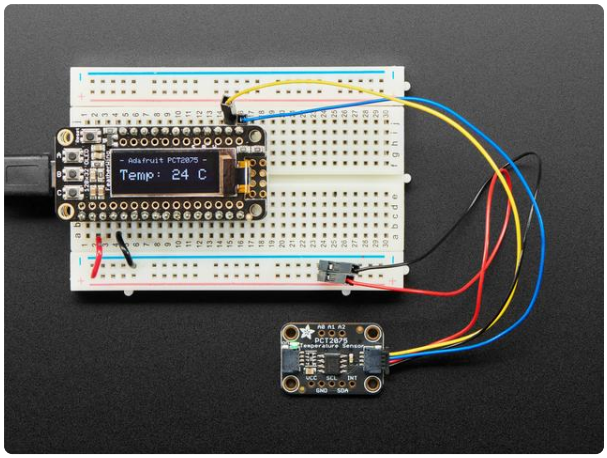
You'll use Jupyter to create interactive notebooks containing live code which interfaces with your MCP2221 and sensors.

Parts

Adafruit MCP2221A Breakout - General Purpose USB to GPIO ADC I2C

Wouldn't it be cool to drive a tiny OLED display, read a

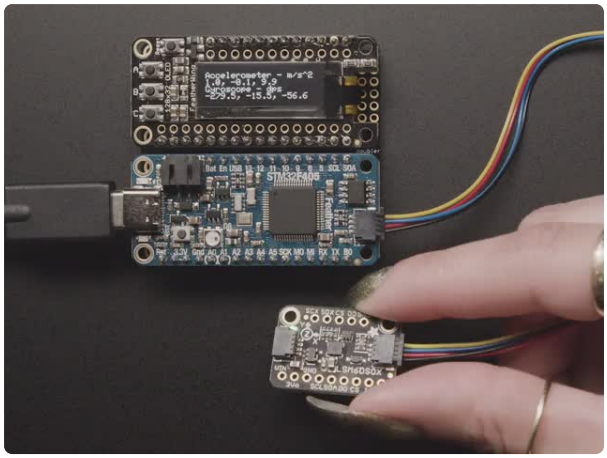
https://www.adafruit.com/product/4471



Adafruit PCT2075 Temperature Sensor - STEMMA QT / Qwiic

The Adafruit PCT2075 Temperature Sensor is a 'code compatible' drop-in replacement for a very...

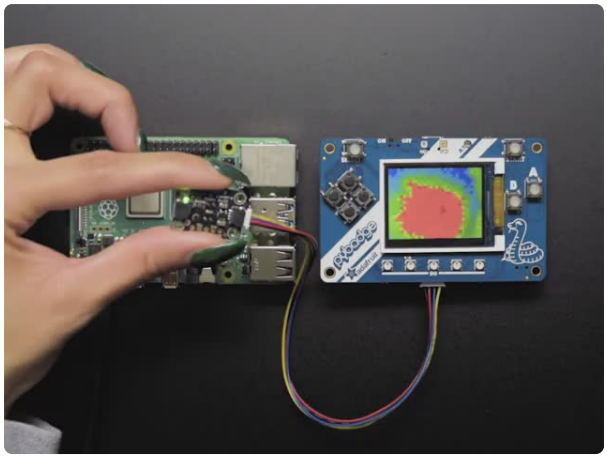
https://www.adafruit.com/product/4369



Adafruit LSM6DSOX 6 DoF Accelerometer and Gyroscope

Behold, the ST LSM6DSOX: The latest in a long line of quality Accelerometer+Gyroscope 6-DOF IMUs from ST.This IMU sensor has 6 degrees of freedom - 3 degrees each of linear...

https://www.adafruit.com/product/4438



Adafruit MLX90640 24x32 IR Thermal Camera Breakout

You can now add affordable heat-vision to your project and with an Adafruit MLX90640 Thermal Camera Breakout. This sensor contains a 24x32 array of IR thermal sensors. When connected...

https://www.adafruit.com/product/4469

Materials

The MCP2221A has a **USB-C** connector, make sure you pick up the correct cable or adapter for your computer.

1 x USB C to USB C Cable, 1 meter — https://www.adafruit.com/product/4199

USB C to USB C Cable - USB 3.1 Gen 4 with E-Mark - 1 meter long

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1 x Micro B USB to USB C Adapter — https://www.adafruit.com/product/4299

Micro B USB to USB C Adapter

The sensors we selected for this guide can be used with a STEMMA QT cable so you can plug-and-play with the MCP2221's STEMMA QT port.

1 x STEMMA QT Cable, 50mm — https://www.adafruit.com/product/4399

STEMMA QT / Qwiic JST SH 4-Pin Cable - 50mm Long

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1 x STEMMA QT Cable, 100mm — https://www.adafruit.com/product/4210

STEMMA QT / Qwiic JST SH 4-pin Cable - 100mm Long

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1 x STEMMA QT Cable, 200mm — https://www.adafruit.com/product/4401

STEMMA QT / Qwiic JST SH 4-Pin Cable - 200mm Long

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1 x STEMMA QT to Male Headers Cable, 150mm — https://www.adafruit.com/product/4209

STEMMA QT / Qwiic JST SH 4-pin to Premium Male Headers Cable - 150mm Long

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Running CircuitPython Code without CircuitPython

There are two parts to the CircuitPython ecosystem:

- **CircuitPython firmware**, written in C and built to run on various microcontroller boards (not PCs). The firmware includes the CircuitPython interpreter, which reads and executes CircuitPython programs, and chip-specific code that controls the hardware peripherals on the microcontroller, including things like USB, I2C, SPI, GPIO pins, and all the rest of the hardware features the chip provides.
- **CircuitPython libraries,** written in Python to use the native (built into the firmware) modules provided by CircuitPython to control the microcontroller peripherals and interact with various breakout boards.

But suppose you'd like to use CircuitPython **libraries** on a board or computer that does not have a native CircuitPython **firmware** build. For example, on a PC running Windows or macOS. Can that be done? The answer is yes, via a separate piece of software called **Blinka**. Details about Blinka follow, however it is important to realize that the **CircuitPython firmware is never used**.

CircuitPython firmware is NOT used when using Blinka.

Adafruit Blinka: a CircuitPython Compatibility Library

Enter **Adafruit Blinka**. Blinka is a software library that emulates the parts of CircuitPython that control hardware. Blinka provides non-CircuitPython implementations for `board`, `busio`, `digitalio`, and other native CircuitPython modules. You can then write Python code that looks like CircuitPython and uses CircuitPython libraries, without having CircuitPython underneath.

There are multiple ways to use Blinka:

- Linux based Single Board Computers, for example a Raspberry Pi
- Desktop Computers + specialized USB adapters
- Boards running MicroPython

More details on these options follow.

Raspberry Pi and Other Single-Board Linux Computers

On a Raspberry Pi or other single-board Linux computer, you can use Blinka with the regular version of Python supplied with the Linux distribution. Blinka can control the hardware pins these boards provide.

Desktop Computers

On Windows, macOS, or Linux desktop or laptop ("host") computers, you can use special USB adapter boards that that provide hardware pins you can control. These boards include MCP221A (https://adafru.it/IfV) and FT232H (https://adafru.it/xia) breakout boards, and Raspberry Pi Pico boards running the **u2if** software (https://adafru.it/Sje). These boards connect via regular USB to your host computer, and let you do GPIO, I2C, SPI, and other hardware operations.

MicroPython

You can also use Blinka with MicroPython, on MicroPython-supported boards (https://adafru.it/SBi). Blinka will allow you to import and use CircuitPython libraries in your MicroPython program, so you don't have to rewrite libraries into native MicroPython code. Fun fact - this is actually the original use case for Blinka.

Installing Blinka

Installing Blinka on your particular platform is covered elsewhere in this guide. The process is different for each platform. Follow the guide section specific to your platform and make sure Blinka is properly installed before attempting to install any libraries.

Be sure to install Blinka before proceeding.

Installing CircuitPython Libraries

Once Blinka is installed the next step is to install the CircuitPython libraries of interest. How this is down is different for each platform. Here are the details.

Linux Single-Board Computers

On Linux single-board computers, such as Raspberry Pi, you'll use the Python `pip3` program (sometimes named just `pip`) to install a library. The library will be downloaded from pypi.org (https://adafru.it/19ff) automatically by `pip3`.

How to install a particular library using `pip3` is covered in the guide page for that library. For example, here is the `pip3` installation information (https://adafru.it/OkF) for the library for the LIS3DH accelerometer.

The library name you give to `pip3` is usually of the form `adafruit-circuitpython-libraryname`. This is not the name you use with `import`. For example, the LIS3DH sensor library is known by several names:

- The GitHub library repository is Adafruit_CircuitPython_LIS3DH (https://adafru.it/uBs).
- When you import the library, you write `import adafruit_lis3dh`.
- The name you use with `pip3` is `adafruit-circuitpython-lis3dh`. This the name used on pypi.org (https://adafru.it/19ff).

Libraries often depend on other libraries. When you install a library with `pip3`, it will automatically install other needed libraries.

Desktop Computers using a USB Adapter

When you use a desktop computer with a USB adapter, like the MCP2221A, FT232H, or u2if firmware on an RP2040, you will also use pip3. However, **do not install the library with `sudo pip3`**, as mentioned in some guides. Instead, just install with `pip3`.

MicroPython

For MicroPython, you will not use `pip3`. Instead you can get the library from the CircuitPython bundles. See this guide page (https://adafru.it/ABU) for more information about the bundles, and also see the Libraries page on circuitPython.org (https://adafru.it/ENC).

Installing Anaconda

Set up MCP2221

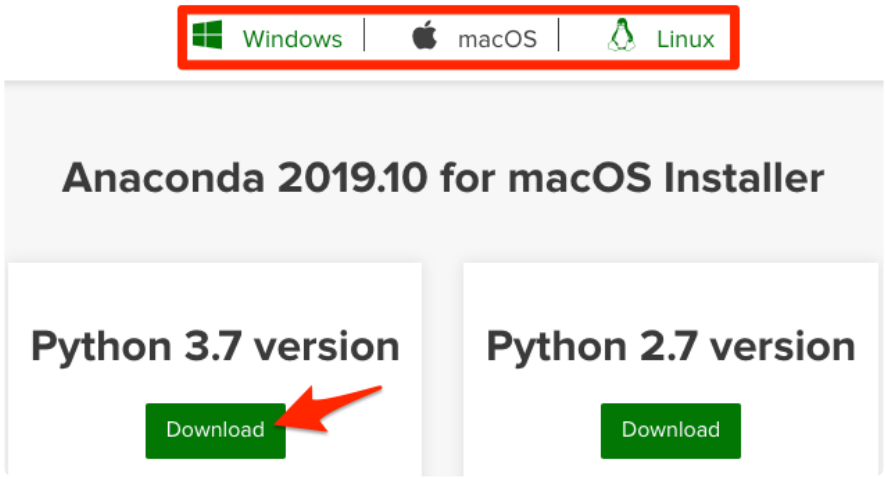
This guide assumes you've set up your computer to interface with the MCP2221. If you have not yet set up the MCP2221 for your computer, **click the link below and come back to this page once you have everything set up**.

- MCP2221 Setup Page (https://adafru.it/HMD)

Install Anaconda

If you're new to all this, the Jupyter Project recommends installing Anaconda (https://adafru.it/HME). This package installs the latest stable version of Python, Jupyter Notebook, and other commonly used packages for scientific computing and data science.

Navigate to the Anaconda downloads page (https://adafru.it/FrB), **select your operating system**, and **download the installer including Python 3.7+**.



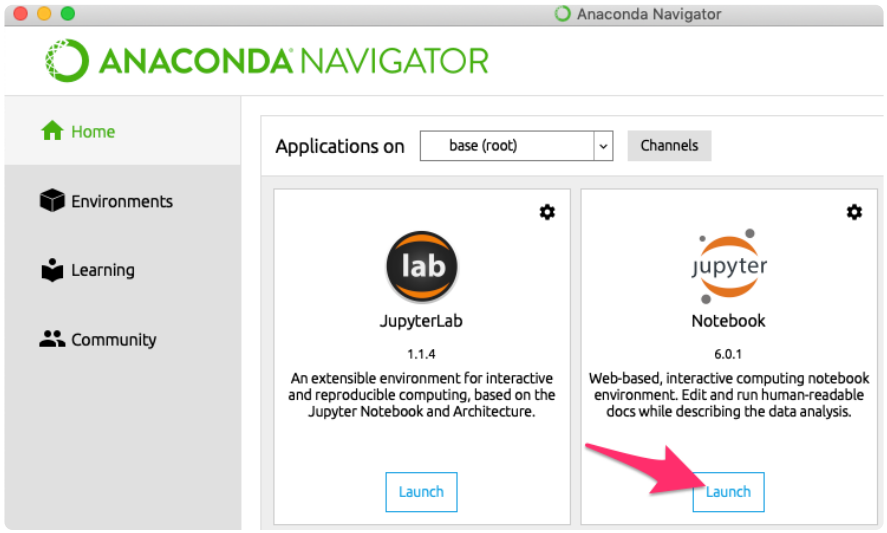
Install the version of Anaconda you downloaded by following the executable's instructions.

Launching Jupyter Notebook

Once Anaconda is installed, **open** the Anaconda Navigator Application.

Under Jupyter Notebook, **click Launch**

We are using Jupyter Notebook for this guide. At the time of writing, Jupyter Lab has problems with displaying Matplotlib's interactive elements and real-time data animations and is not recommended for this guide.



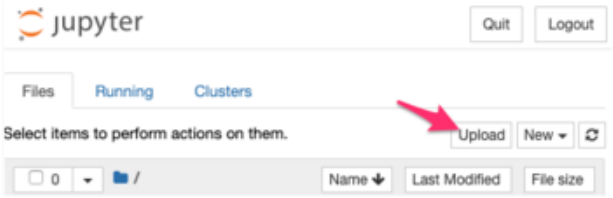
Jupyter Notebook should open in a new web browser at the URL http://localhost:8888/notebooks (). To ensure you set up the MCP2221 correctly, we created a Jupyter Notebook.

Download all the notebooks required for this project by clicking Download: Project ZIP on the upper left hand side of the embedded preview below.

Once downloaded, **unzip the file** and keep it somewhere safe like on your desktop.

```
{
 "cells": [
  {
   "cell_type": "code",
   "execution_count": null,
   "metadata": {},
   "outputs": [],
   "source": [
    "# Python Software Package Installation\n",
    "import sys\n",
    "!{sys.executable} -m pip install adafruit-blinka adafruit-circuitpython-msa301
hidapi"
   ]
  },
  {
   "cell_type": "code",
   "execution_count": null,
   "metadata": {},
   "outputs": [],
   "source": [
    "# Set an Environment Variable so Adafruit Blinka knows we're using the
MCP2221\n",
    "import os\n",
    "os.environ[\"BLINKA_MCP2221\"] = \"1\""
   ]
  },
```

```
  {
   "cell_type": "code",
   "execution_count": null,
   "metadata": {},
   "outputs": [],
   "source": [
    "# Attempt to import a CircuitPython Module\n",
    "import board"
   ]
  }
 ],
 "metadata": {
  "kernelspec": {
   "display_name": "Python 3",
   "language": "python",
   "name": "python3"
  },
  "language_info": {
   "codemirror_mode": {
    "name": "ipython",
    "version": 3
   },
   "file_extension": ".py",
   "mimetype": "text/x-python",
   "name": "python",
   "nbconvert_exporter": "python",
   "pygments_lexer": "ipython3",
   "version": "3.7.4"
  }
 },
 "nbformat": 4,
 "nbformat_minor": 2
}
```

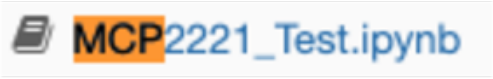


From Jupyter, **click the Upload** button.

From your file browser, **navigate to and select the MCP2221_Test.ipynb file.**

The Jupyter notebook should appear in the file browser. **Click upload**.

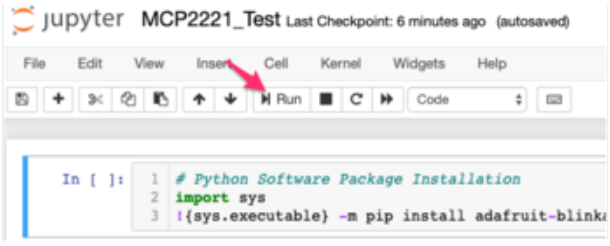
Once the Jupyter Notebook has been successfully uploaded, it will show up in the file browser. **Click MCP2221_Test.ipynb** to launch the notebook.



Code Usage

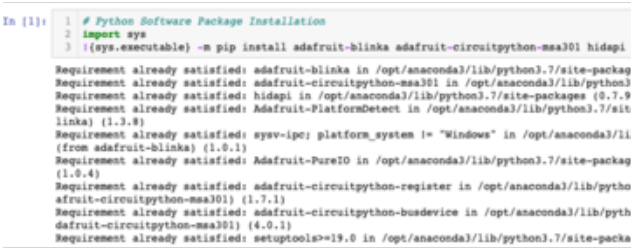
Jupyter Notebooks are split into cells. Cells may contain code, images, equations or text. This example notebook only contains code cells.

The first code cell contains two lines. The first imports the `sys` module which imports functions that interact with the Python interpreter. The second line installs all the dependencies we need to use this notebook with the MCP2221, including adafruit-blinka and hardware support packages.



To execute this cell, **click the first "cell" containing code**. **Click the run button** to execute the code within the cell.

You should observe the output from the Python interpreter print out underneath the cell. Once complete, the cell should display a [1] next to it, indicating the interpreter has completed executing the cell.



The next cell will set an Environment Variable (`BLINKA_MCP2221`) so Adafruit Blinka knows we're using the MCP2221 board. **Click the cell to highlight it**, then **click the run button or press ctrl/cmd+enter to execute the code within the cell**.

You should get no errors at all, in which case you can continue onto the examples!

Error: Board not supported None

If you get `NotImplementedError: Board not supported None`,

That could mean you did not set the MCP2221 environmental variable or you don't have the latest Python libraries installed or the MCP2221 is not plugged in to USB.

```
[3]: # Attempt to import a CircuitPython Module
     import board

---------------------------------------------------------------------------
NotImplementedError                       Traceback (most recent call last)
<ipython-input-3-a8ce227b5022> in <module>()
      1 # Attempt to import a CircuitPython Module
----> 2 import board

~/anaconda3/lib/python3.7/site-packages/board.py in <module>()
    117
    118 else:
--> 119     raise NotImplementedError("Board not supported {}".format(board_id))
    120
    121 def I2C():

NotImplementedError: Board not supported None
```

Error: BLINKA_MCP2221 environment variable set, but no MCP2221 device found

If you get this error, check your USB cable - it could be that you have a charge-only not charge+sync cable. Your board may also be unplugged from USB.

```
[8]: # Attempt to import a CircuitPython Module
     import board

---------------------------------------------------------------------------
RuntimeError                              Traceback (most recent call last)
<ipython-input-8-a8ce227b5022> in <module>()
      1 # Attempt to import a CircuitPython Module
----> 2 import board

~/anaconda3/lib/python3.7/site-packages/board.py in <module>()
     44     from adafruit_blinka.board.pyboard import *
     45
---> 46 elif detector.board.any_raspberry_pi_40_pin:
     47     from adafruit_blinka.board.raspi_40pin import *
     48

~/anaconda3/lib/python3.7/site-packages/adafruit_platformdetect/board.py in any_raspberry_pi_40_pin(self)
    448     def any_raspberry_pi_40_pin(self):
    449         """Check whether the current board is any 40-pin Raspberry Pi."""
--> 450         return self.id in _RASPBERRY_PI_40_PIN_IDS
    451
    452     @property

~/anaconda3/lib/python3.7/site-packages/adafruit_platformdetect/board.py in id(self)
    305             pass
    306
--> 307         chip_id = self.detector.chip.id
    308         board_id = None
    309

~/anaconda3/lib/python3.7/site-packages/adafruit_platformdetect/chip.py in id(self)
     54                 if dev['vendor_id'] == 0x04D8 and dev['product_id'] == 0x00DD:
     55                     return MCP2221
---> 56             raise RuntimeError('BLINKA_MCP2221 environment variable ' + \
     57                                'set, but no MCP2221 device found')
     58         if os.environ.get('BLINKA_NOVA'):

RuntimeError: BLINKA_MCP2221 environment variable set, but no MCP2221 device found
```

Jupyter Notebook Examples

Now that you have Jupyter installed and Blinka set up on your computer, let's play around!

The following pages contain code examples as downloadable Jupyter notebooks. The examples use some popular sensors we have and should serve as a jumping off point for your experimentation.

If you're looking for more sensors - check out our growing range of plug-and-play STEMMA sensors here (https://adafru.it/HMF). Most of these have CircuitPython libraries available and are compatible with this guide.

Make sure you've set the BLINKA_MCP2221 environment variable at the top of your Jupyter Notebooks!

Compatibility with FT232H

The notebooks in this guide are also compatible with the Adafruit FT232H breakout (http://adafru.it/2264) and CircuitPython Libraries.

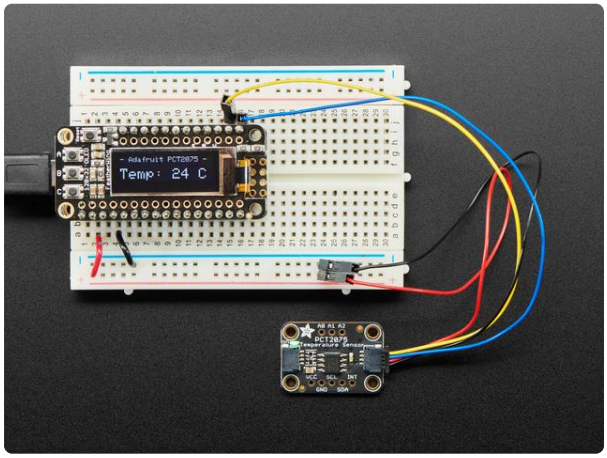
If you're using a FT232H breakout, make sure you change the BLINKA_MCP2221 environment variable to BLINKA_FT232H.

- Read the learning system guide here to get set up with the FT232H and CircuitPython Libraries... (https://adafru.it/FWD)

Temperature

This example is a Jupyter notebook which graphs the current temperature using a PCT2075 (http://adafru.it/4369) temperature sensor. The graph is updated in real-time with temperature values and we've added horizontal lines across the X-axis to show temperature maximum and minimum thresholds.

While this notebook is designed for the PCT2075 sensor, you can easily implement one of the many temperature sensors available on the Adafruit website. Be sure to check if it has a CircuitPython library first!



Adafruit PCT2075 Temperature Sensor - STEMMA QT / Qwiic
The Adafruit PCT2075 Temperature Sensor is a 'code compatible' drop-in replacement for a very...
https://www.adafruit.com/product/4369

STEMMA QT / Qwiic JST SH 4-pin Cable - 100mm Long

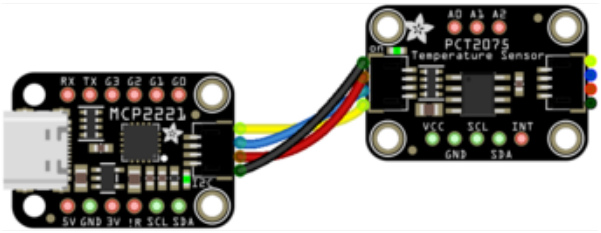
This 4-wire cable is a little over 100mm / 4" long and fitted with JST-SH female 4-pin connectors on both ends. Compared with the chunkier JST-PH these are 1mm pitch instead of...

https://www.adafruit.com/product/4210

Wiring

We'll be using the PCT2075 (http://adafru.it/4369) sensor to precisely measure temperature. The MCP2221 and PCT2075 both have STEMMA QT connectors, so you can either wire it up on a breadboard or use a STEMMA QT cable.

Try to avoid hot plugging I2C sensors. The MCP2221 doesn't seem to like that. Remove USB power first.



Make the following connections between the MCP2221 and the PCT2075:

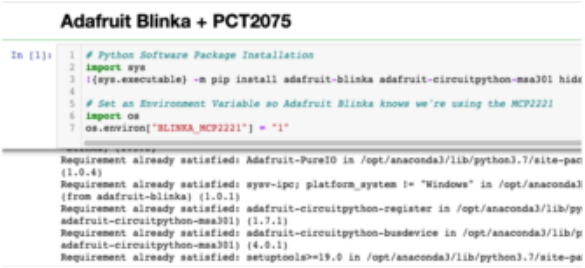
Board 3V to **sensor VCC (red wire)**
Board GND to **sensor GND (black wire)**
Board SCL to **sensor SCL (blue wire)**
Board SDA to **sensor SDA (yellow wire)**

Then, download the example notebook:

Download PCT2075 Notebook

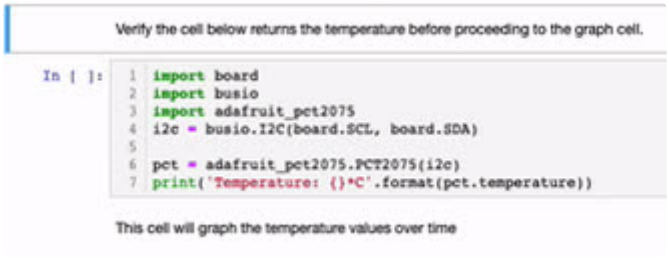
https://adafru.it/RnD

In the Jupyter file browser, **click Upload**. From the file browser, **select the PCT2075.ipynb example.**

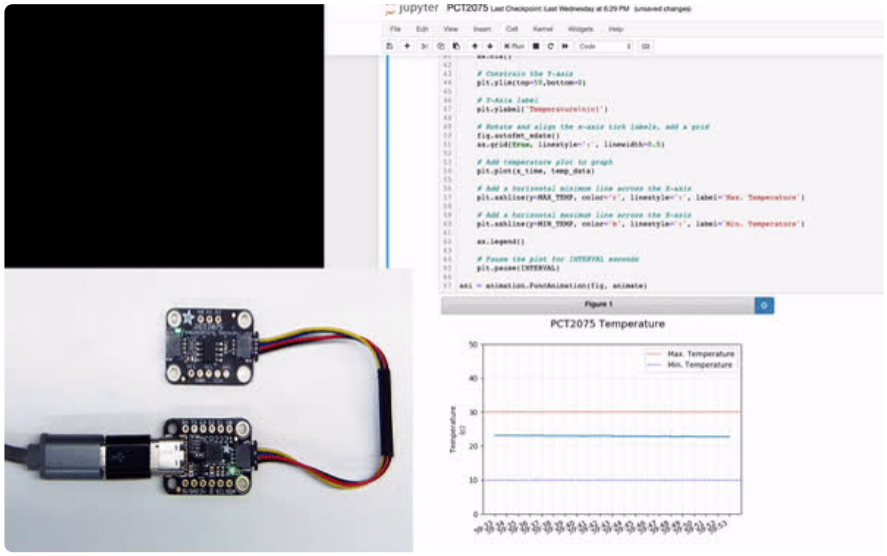


Click the Run button to execute the first cell. This cell will install the `adafruit-circuitpython-pct2075` library required for this example and set an environment variable so Blinka knows we're using the MCP2221

The next cell imports CircuitPython modules (such as `board` and `busio`) and initializes the I2C connection with the sensor. To verify that your board is properly initialized, it will also print a temperature reading from the PCT2075.



Click the cell containing the code to graph the temperature sensor. The graph should update every 5 seconds with a new reading.



Code Walkthrough

Let's walk through this notebook, cell-by-cell, to understand how this code works.

First, we import all the required libraries for the notebook. We'll be using matplotlib to plot the temperature data from our sensor. We'll also invoke the special `%matplotlib notebook` magic to tell matplotlib we're using a Jupyter notebook.

```
%matplotlib notebook
from datetime import datetime
import matplotlib.pyplot as plt
from collections import deque
from matplotlib.animation import FuncAnimation
```

Next we declare some constants like `HISTORY_SIZE` (how many sensor samples we're displaying on the graph), and `INTERVAL` (the graph's update interval, in seconds). We'll also declare `MAX_TEMP` and `MIN_TEMP` which are used to generate horizontal lines across the x-axis for displaying the maximum and minimum temperature values.

```
# How many sensor samples we want to store
HISTORY_SIZE = 100

# Graph update interval (in seconds)
INTERVAL = 5

# Maximum Temperature (in degrees C)
MAX_TEMP = 30

# Minimum Temperature (in degrees C)
MIN_TEMP = 10
```

Our code plots and displays 100 sensor readings at a time. We store these readings in a list-like object called a `deque` container datatype (https://adafru.it/HNa). If you've never seen this datatype before, don't worry - it's very similar to a `list` object except it's "optimized for fast fixed-length operations" and support a `maxlen` argument which sets the maximum possible size of a deque. When the deque grows beyond its `maxlen` size, it pops objects off of its opposite end (like a FIFO stack).

We use one deque to store sensor readings (`temp_data`) and another deque to store time-stamps (`x_time`)

```
# Global x-axis array
x_time = deque(maxlen=HISTORY_SIZE)

# Temperature data
temp_data = deque(maxlen=HISTORY_SIZE)
```

Next up, let's make a new plot and give it a title.

```
# Create new plot
fig, ax = plt.subplots()
```

```
# Global title
fig.suptitle("PCT2075 Temperature", fontsize=14)
```

In the animate method, we'll poll the temperature sensor and store it in the `temp_data` deque. Using the CPython datetime module, the code takes the current time and formats it using `strftime` for display on the x-axis as ticks.

```
# Read the temperature sensor and add the value to the temp_data array
temp_data.append(pct.temperature)

# Grab the datetime, auto-range based on length of accel_x array
x_time.append(datetime.now().strftime('%M:%S'))
```

The next chunk of code clears the axis, constrains the y-axis to display a maximum value of 50 degrees celsius and 0 degrees celsius. It also adds a descriptive label to the Y-Axis.

```
# Clear axis prior to plotting
ax.cla()

# Constrain the Y-axis
plt.ylim(top=50,bottom=0)

# Y-Axis label
plt.ylabel('Temperature\n(c)')
```

We'll use the `autofmt_date` method to rotate and align the x-axis tick labels. Then, let's add a grid so we can see our data better.

```
fig.autofmt_xdate()
ax.grid(True, linestyle=':', linewidth=0.5)
```

Next up, plot the temperature graph and two dotted horizontal lines across the x-axis to represent maximum and minimum temperature values.

```
# Add a horizontal minimum line across the X-axis
plt.axhline(y=MAX_TEMP, color='r', linestyle=':', label='Max. Temperature')

# Add a horizontal maximum line across the X-axis
plt.axhline(y=MIN_TEMP, color='b', linestyle=':', label='Min. Temperature')
```

Let's add a legend to the graph. This will make it easy to discern which line is which if we look back at it later, or if the notebook is shared with a colleague or friend.

Matplotlib's `ax.legend()` method automatically creates a legend for your graph, provided each plot has a label attached to it.

```
# Add a legend to the graph
ax.legend()
```

We'll pause the plot's output for `INTERVAL` seconds

```
# Pause the plot for INTERVAL seconds
plt.pause(INTERVAL)
```

Finally, this method "makes an animation by repeatedly calling a function", `animate`. We provide it the `fig` we generated earlier and the function we'd like to animate.

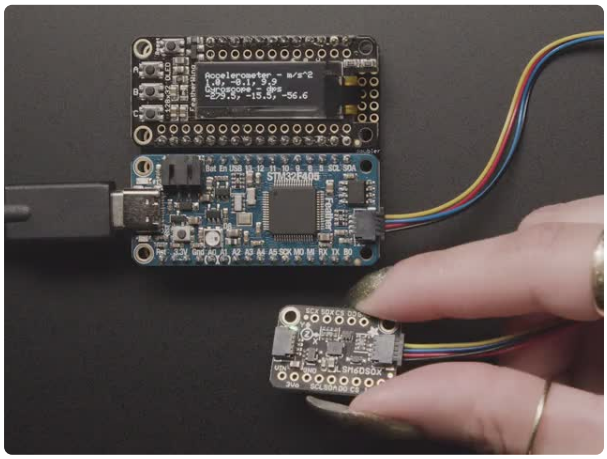
```
ani = animation.FuncAnimation(fig, animate)
```

Accelerometer

Wiring

We'll be using the LSM6DSOX sensor to precisely measure acceleration data (http://adafru.it/4438). The MCP2221 and LSM6DSOX both have STEMMA QT connectors, so you can either wire it up on a breadboard or use a STEMMA QT cable.

Try to avoid hot plugging I2C sensors. The MCP2221 doesn't seem to like that. Remove USB power first.

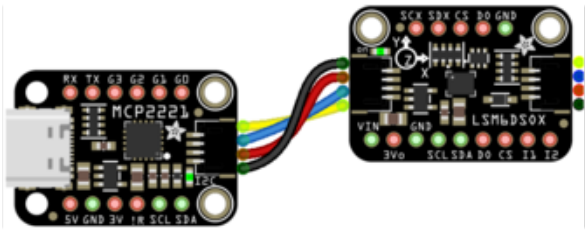


Adafruit LSM6DSOX 6 DoF Accelerometer and Gyroscope
Behold, the ST LSM6DSOX: The latest in a long line of quality Accelerometer+Gyroscope 6-DOF IMUs from ST.This IMU sensor has 6 degrees of freedom - 3 degrees each of linear...
https://www.adafruit.com/product/4438

STEMMA QT / Qwiic JST SH 4-pin Cable - 100mm Long

This 4-wire cable is a little over 100mm / 4" long and fitted with JST-SH female 4-pin connectors on both ends. Compared with the chunkier JST-PH these are 1mm pitch instead of...

https://www.adafruit.com/product/4210



Make the following connections between the MCP2221 and the LSM6DSOX:

Board 3V to **sensor VIN (red wire)**
Board GND to **sensor GND (black wire)**
Board SCL to **sensor SCL (yellow wire)**
Board SDA to **sensor SDA (blue wire)**

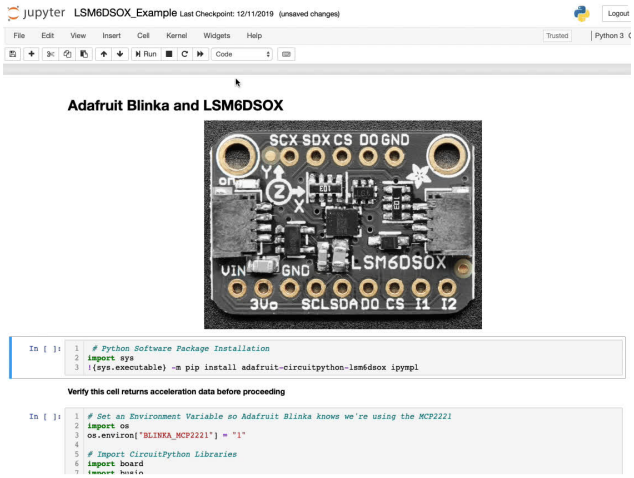
Then, download the example notebook:

Download LSM6DSOX Notebook

https://adafru.it/RnE

Code Usage

In the Jupyter file browser, **click Upload**. From the file browser, **select the LSM6DSOX_Accel.ipynb example.**



Click the Run button to execute the first cell. This cell installs the required libraries for using this notebook.

This cell installs the `adafruit-circuitpython-lsm6dsox` library for interfacing with the LSM303 sensor .

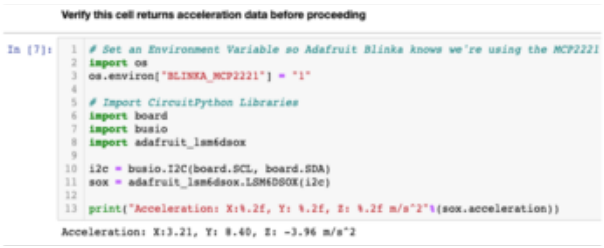
This cell also installs a Jupyter Extension, `ipympl`. This extension makes it possible for us to create interactive Matplotlib graphs from within a Jupyter notebook.

The next cell sets an environment variable so Blinka knows we're using the MCP2221.

Then, it imports CircuitPython libraries and initializes the I2C connection with the sensor.

The next cell imports CircuitPython modules (such as `board` and `busio`) and initializes the i2c connection with the sensor. To verify that your board is properly initialized, it should also values form the LSM6DSOX's acceleration sensor.

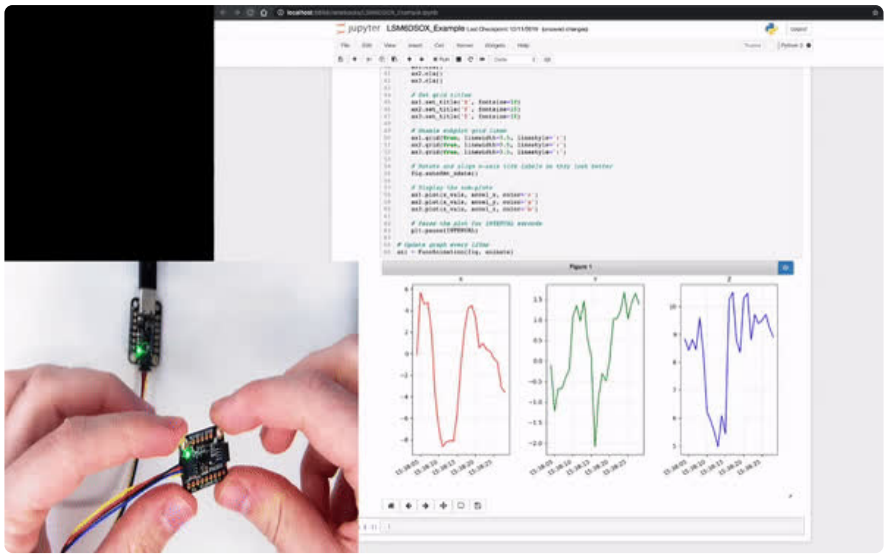
The next cell sets an environment variable so Blinka knows we're using the MCP2221.



Then, it imports CircuitPython modules (such as `board` and `busio`) and initializes the i2c connection with the sensor. To verify that your board is properly initialized, it should also print values from the LSM6DSOX acceleration sensor.

If you receive an error with the `board` module, make sure your MCP2221 is plugged into a usb port on your computer.

The third code cell uses Matplotlib to generate a graph for the LSM6DSOX's acceleration data. We used three side-by-side subplots to visualize the X, Y, and Z axis.



Increasing the Number of Sensor Readings

By default, this code cell only displays 20 sensor readings. If you want to display more sensor readings on your graph, simply change the value of the `HISTORY_SIZE` variable in the code cell and re-run it.

For more information about how this code cell works, read on!

Code Walkthrough

First, we import all required libraries for this code cell. Most of the libraries come from the Matplotlib library. We use this library to plot the data obtained by our sensor.

```
%matplotlib notebook
import matplotlib.pyplot as plt
from matplotlib.animation import FuncAnimation
import datetime
import matplotlib.dates as mdates
from collections import deque
```

Our code only plots and displays 20 sensor readings at a time. We store these readings in a list-like object called a `deque` container datatype (https://adafru.it/HNa). If you've never seen this datatype before, don't worry - it's very similar to a `list` object except it's "optimized for fast fixed-length operations" and support a `maxlen` argument which sets the maximum possible size of a deque. When the deque grows beyond its `maxlen` size, it pops objects off of its opposite end (like a FIFO stack).

We'll be using four deque objects to represent the x-axis, the first graph's y-axis (accelerometer's x-axis data), the second graph's y-axis (accelerometer's y-axis data), and the third graph's y-axis (accelerometer's y-axis data). These deque objects use

`HISTORY_SIZE` as the deque's `maxlen`. You may increase the amount of data to display on the graph by increasing `HISTORY_SIZE`.

```
# Deque for X-Axis (time)
x_vals = deque(maxlen=HISTORY_SIZE)

# Deque for Y-Axis (accelerometer readings)
accel_x = deque(maxlen=HISTORY_SIZE)
accel_y = deque(maxlen=HISTORY_SIZE)
accel_z = deque(maxlen=HISTORY_SIZE)
```

Next, we'll create three side-by-side sub-plots and call `tight_layout` to adjust the subplot parameters to give nicer padding between examples.

- For more information about spacing matplotlib subplots, check out this guide... (https://adafru.it/HNc)

```
# Create 3 side-by-side subplots
fig, (ax1, ax2, ax3) = plt.subplots(1,3)

# Automatically adjust subplot parameters for nicer padding between plots
plt.tight_layout()
```

Let's now take a look at the `animate` method. This method polls the LSM303's acceleration values and stores them in a tuple named `accel_data`. Next, the code appends the values from the tuple to `deque` objects, `accel_x`, `accel_y`, `accel_z`.

```
def animate(i):
    # Poll the LSM303AGR
    accel_data = accel.acceleration
    # Add the X/Y/Z values to the accel arrays
    accel_x.append(accel_data[0])
    accel_y.append(accel_data[1])
    accel_z.append(accel_data[2])
```

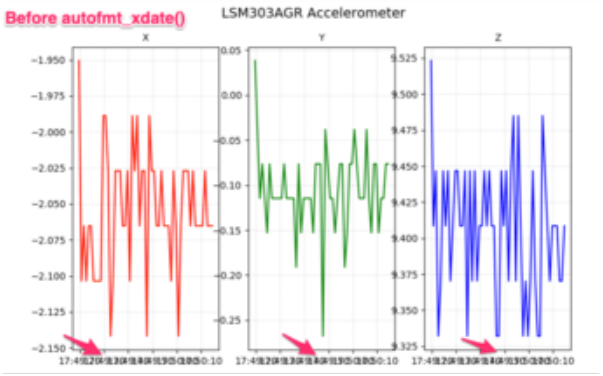
We grab the current time (in seconds using CPython's `datetime` module) and store it in a deque, `x_vals`.

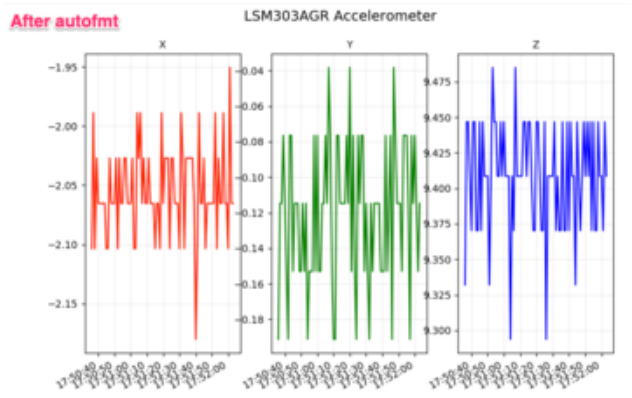
```
# Grab the datetime, auto-range based on length of accel_x array
x_vals = [datetime.datetime.now() + datetime.timedelta(seconds=i) for i in
range(len(accel_x))]
```

Now we're up to the fun part of this code walkthrough - displaying the graphs. Since we're "animating" the graph, the axis will need to be cleared and re-drawn each time the `animate` method runs. Let's clear the three axis, set up grid titles and enable grid lines.

```
# Clear all axis
ax1.cla()
ax2.cla()
```

```
ax3.cla()

# Set grid titles
ax1.set_title('X', fontsize=10)
ax2.set_title('Y', fontsize=10)
ax3.set_title('Z', fontsize=10)

# Enable subplot grid lines
ax1.grid(True, linewidth=0.5, linestyle=':')
ax2.grid(True, linewidth=0.5, linestyle=':')
ax3.grid(True, linewidth=0.5, linestyle=':')
```





Since we are displaying a large amount of data on the x-axis, we'll use Matplotlib's `autofmt_xdate()` method (https://adafru.it/HNd) to automatically align and roate the x-axis labels.

The first image on the left shows this code without a call to `autofmt_xdate` while the second image shows a nicely formatted graph. Pretty neat, right

Finally, we'll display the sub-plots on the figure by calling `ax.plot` and specifying the x-axis and y-axis deques. We'll also specify different colors for each graphs to help us visually identify the sub-graphs.

```
# Display the sub-plots
ax1.plot(x_vals, accel_x, color='r')
ax2.plot(x_vals, accel_y, color='g')
ax3.plot(x_vals, accel_z, color='b')
```

Finally, we'll pause the plot's drawing for `INTERVAL` seconds.

```
# Pause the plot for INTERVAL seconds
plt.pause(INTERVAL)
```

About Notebook Performance

Computers with less available resources will render choppy graphs. For reference, all GIFs in this guide were rendered on a computer with a 2.6GHz i7 and 32GB of RAM.

We can increase the `INTERVAL`, keeping in mind two things:

1. USB is limited to one transaction per millisecond
2. We are displaying `HISTORY_SIZE` samples at a time. You may want to decrease the number of samples displayed on the graph for better performance.

This method "makes an animation by repeatedly calling a function", `animate`. We provide it the figure we generated earlier and the function we'd like to animate.

```
# Update graph every 125ms
ani = FuncAnimation(fig, animate)
```

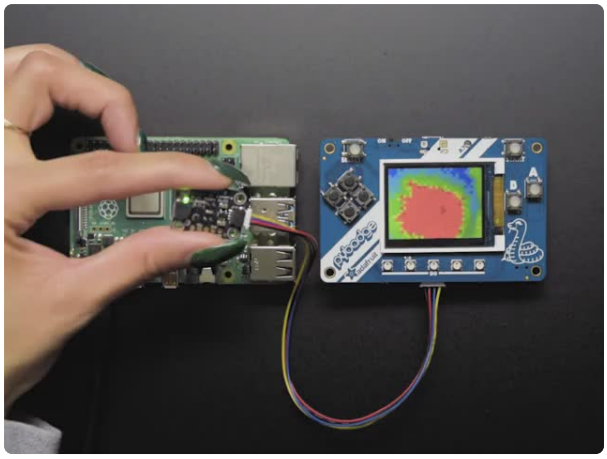
Thermal Camera

Wiring

We'll be using the MLX90640 IR Thermal Camera Breakout (http://adafru.it/4407) to display an animated image comprised of thermal data to our notebook.

This breakout contains a 24x32 array of IR thermal sensors. When it's connected to the MCP2221, it returns an array of 768 individual infrared temperature readings over I2C. We'll read these values, manipulate, and display them in our Jupyter Notebook.

The MCP2221 and MLX90640 (http://adafru.it/4407) both have STEMMA QT connectors, so you can either wire it up on a breadboard or use a STEMMA QT cable.



Adafruit MLX90640 24x32 IR Thermal Camera Breakout

You can now add affordable heat-vision to your project and with an Adafruit MLX90640 Thermal Camera Breakout. This sensor contains a 24x32 array of IR thermal sensors. When connected...

https://www.adafruit.com/product/4469

STEMMA QT / Qwiic JST SH 4-pin Cable - 100mm Long

This 4-wire cable is a little over 100mm / 4" long and fitted with JST-SH female 4-pin connectors on both ends. Compared with the chunkier JST-PH these are 1mm pitch instead of...

https://www.adafruit.com/product/4210

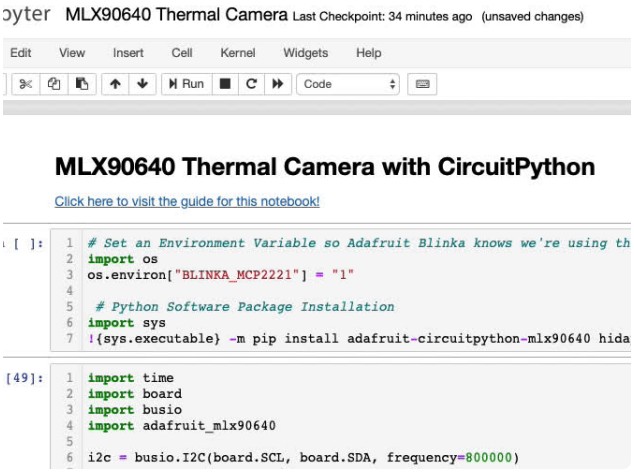
Then, download the example Jupyter notebook:

Download MLX90640 Thermal Camera Notebook

https://adafru.it/19Ar

Code Usage

In the Jupyter file browser, **click Upload**. From the file browser, **select the MLX90640 Thermal Camera.ipynb example.**



Click the Run button to execute the first cell. This cell first sets an environment variable so Blinka knows we're using the MCP2221 sensor.

Then, it installs the `adafruit-circuitpython-mlx90640` library for interfacing with the thermal camera breakout .

```
import time
import board
import busio
import adafruit_mlx90640

i2c = busio.I2C(board.SCL, board.SDA, frequency

mlx = adafruit_mlx90640.MLX90640(i2c)
print("MLX addr detected on I2C!")

# Set refresh rate
mlx.refresh_rate = adafruit_mlx90640.RefreshRat
print("MLX refresh rate: ", pow(2, (mlx.refresh
```

The next code cell imports CircuitPython libraries such as `board`, `busio`, and `adafruit_mlx90640`. Then, it initializes an I2C connection with the sensor and creates a `mlx` object.

We also set the refresh rate to 1HZ for this notebook.

Before continuing, **make sure your code prints the MLX was found on I2C.**

If it the MCP2221 was unable to detect the MLX breakout, unplug the sensor and plug it back in. Then, restart the Jupyter kernel by clicking Kernel->Restart.

```
import numpy as np

# read in frame from thermal camera and split i
frame = [0] * 768
```

Click run on the next cell. This cell reads data from the thermal camera and splits it into a 32x24 array of thermal readings. We're using the numpy package (https://adafru.it/HNf) so we can do perform fast manipulations to the data within the array.

```
import numpy as np

# read in frame from thermal camera and split into 32 x 24 numpy array of thermal readings
frame = [0] * 768
mlx.getFrame(frame)
pixels = np.split(np.asarray(frame), 24)
# rotate it around so its right side
pixels = np.rot90(pixels, 3)
print(len(pixels[0]), "x", len(pixels))
```

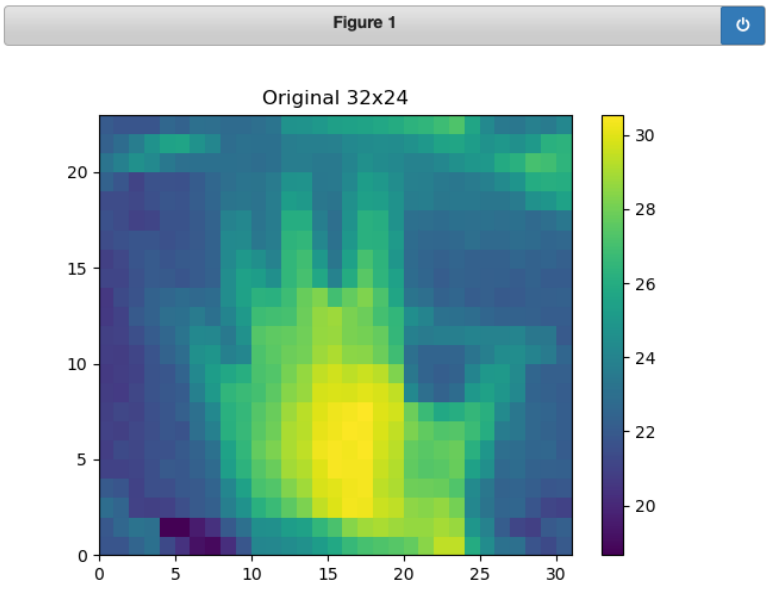
```
24 x 32
```

The next cell plots the data read from the previous cell. **Click run to see a heatmap of your data**.

This sensor reads the data twice per frame, in a checker-board pattern, so it's normal to see a checker-board dither effect when moving the sensor around - the effect isn't noticable when things move slowly.

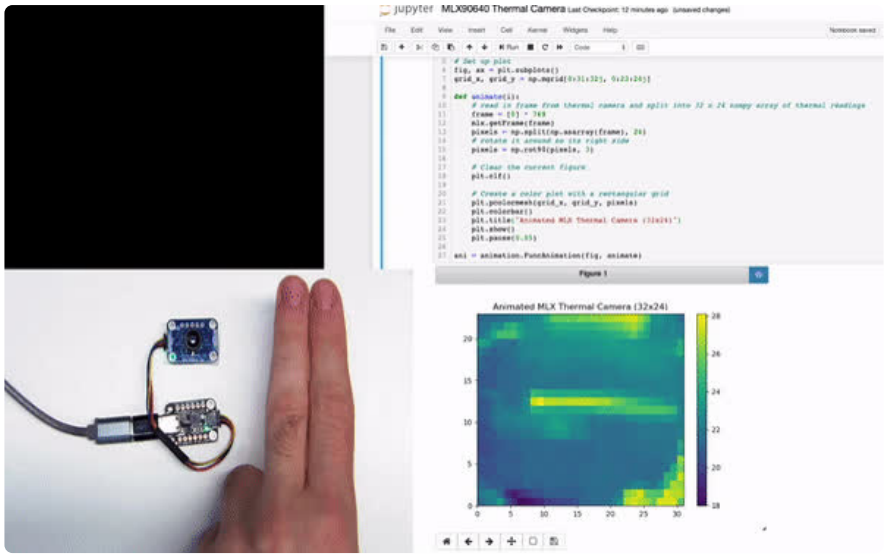
```
In [26]:
```

```
#%matplotlib notebook
import math
import time

from scipy.interpolate import griddata
import matplotlib.pyplot as plt
import matplotlib.animation as animation

grid_x, grid_y = np.mgrid[0:31:32j, 0:23:24j]

plt.figure()
plt.pcolormesh(grid_x, grid_y, pixels)
plt.colorbar()
plt.title("Original 32x24")

plt.show()
```



The final cell in this notebook produces a live heat-map from your thermal camera. Point the camera towards yourself and click run.

Note: This GIF has been sped up (2x), we suggest moving very slowly to avoid a dithering effect.


jupyter MLX90640 Thermal Camera
Animated MLX Thermal Camera (32x24)