

# SciTinyML

Scientific Use of Machine Learning on Low Power Devices

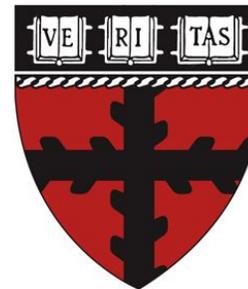
## Regional Workshops

TinyML Kit Overview - HW and SW Installation & Test



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*Harvard John A. Paulson School of Engineering and Applied Sciences*

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*UNIFEI - Federal University of Itajubá, Brazil*



# TinyML Kit Overview



ARDUINO

TINY MACHINE  
LEARNING KIT

In partnership with:

edX

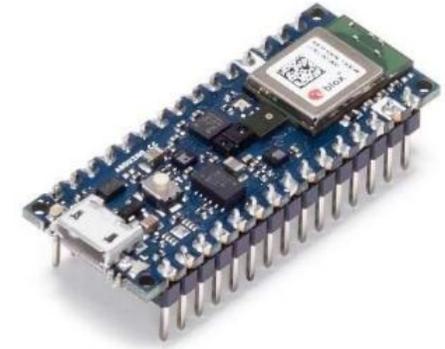
TensorFlow

ARDUINO

ARDUINO

OV7675

# Nano 33 BLE Sense (+ USB cable)

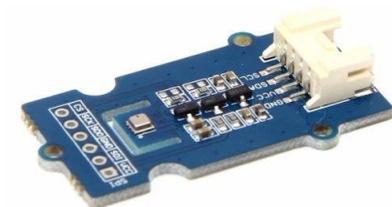


## Purpose

AI-enabled developmental **microcontroller board** with USB-A to microB cable

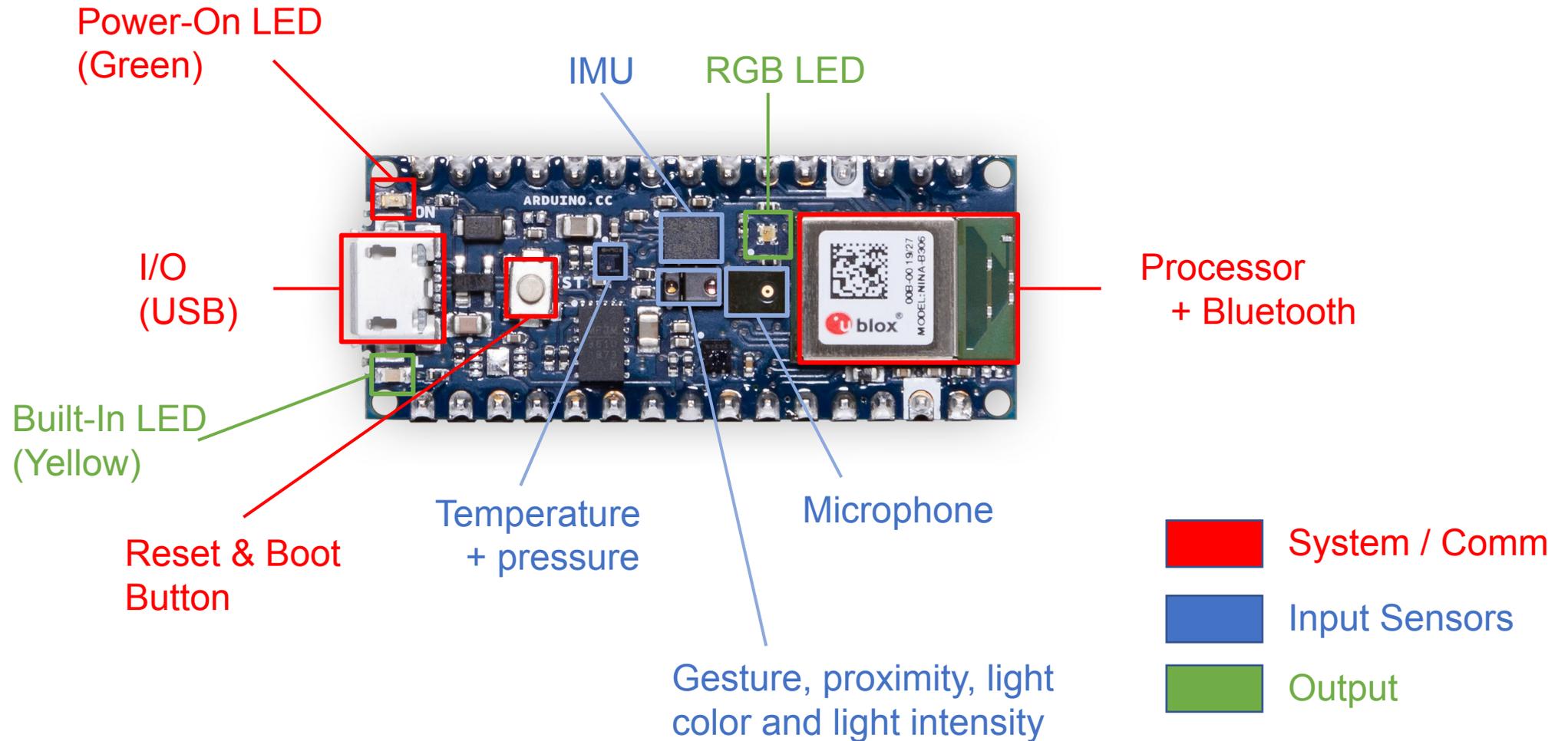
## Specifications

- **MPU:** Nordic nRF52840 (ARM Cortex-M4 w/FPU): **3.3V**, 64MHz, 1MB flash, **256 kB RAM**
- **Sensors on board:** microphone, IMU (9 axis), color, light, proximity, barometric, temperature, ~~humidity~~<sup>\*</sup>, gesture, and light intensity.
- BLE module covered by ArduinoBLE library
- RGB LEDs

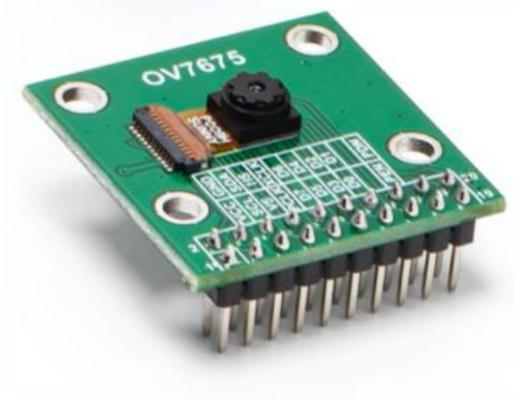


\* **Not included in the package.** For projects we will use the external Grove - Temp&Humi&Barometer Sensor (BME280)

# Nano 33 BLE Sense (Development board)



# OV 7675 Camera Module



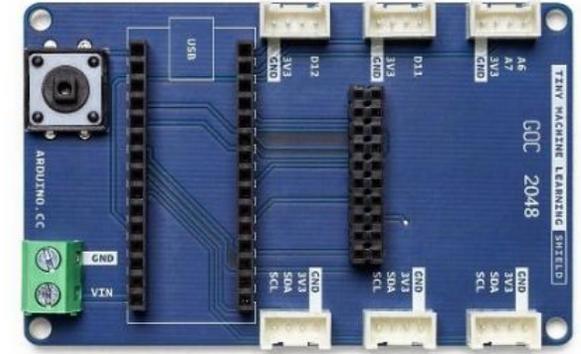
## Purpose

Breakout PCB for *tiny* camera.

## Specifications

- Low-cost, Low-voltage, **0.3 MP** CMOS VGA (can step down to **QVGA**, QQVGA) image sensor
- Serial Camera Control Bus (SCCB) + Camera Parallel Interface (CPI) / Digital Video Port (DVP) interface
- Breaks ribbon cable out to 2x10 pin array
- **1 or 5 fps** (Frames per Second)

# Tiny Machine Learning Shield

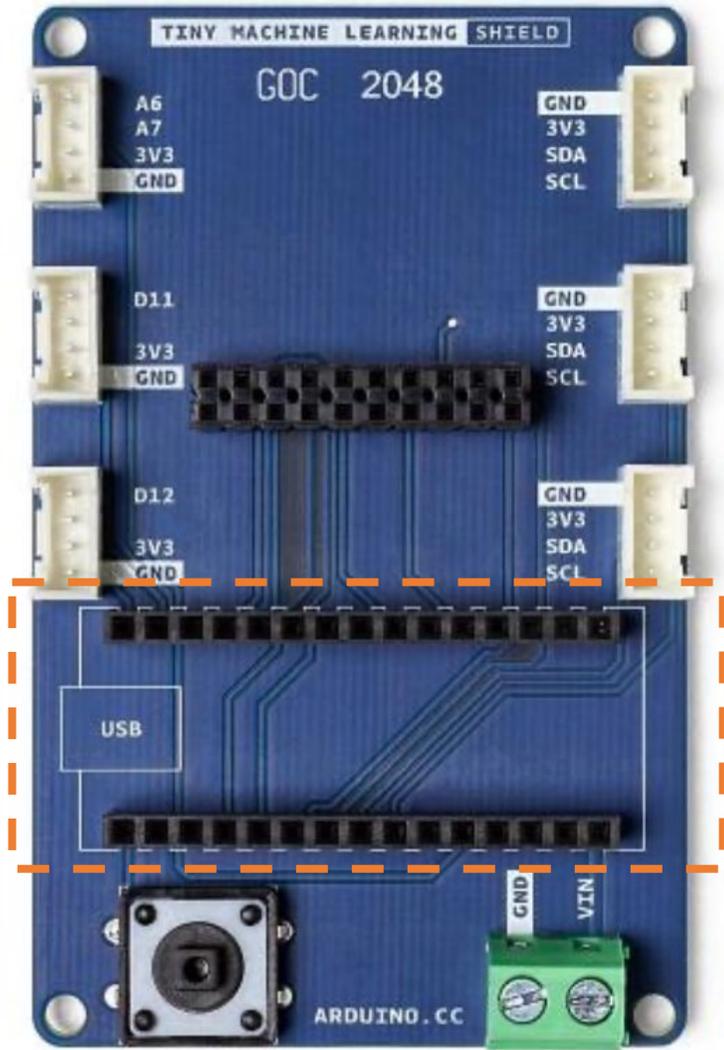


## Purpose

A daughter PCB designed to **breakout the I/O** from the Nano 33 BLE sense to permit easy, reliable **communication with** other local, **off-board elements**

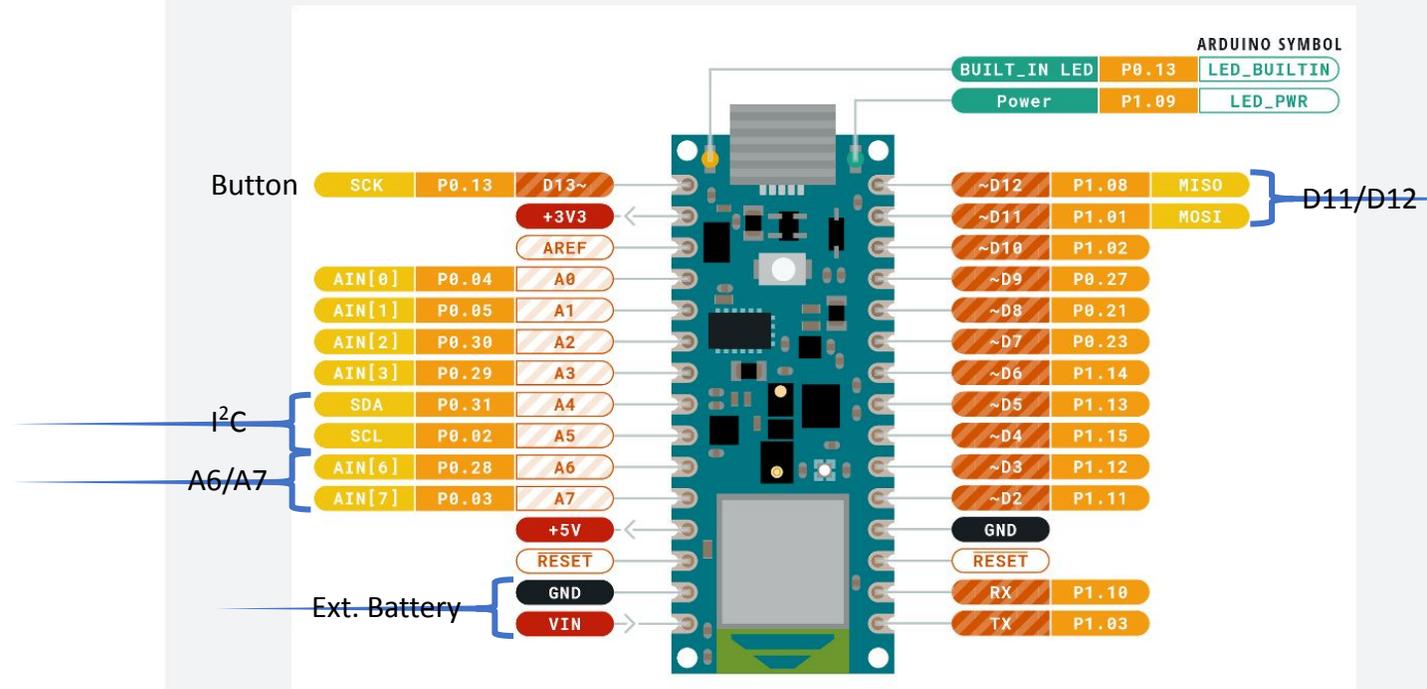
## Specifications

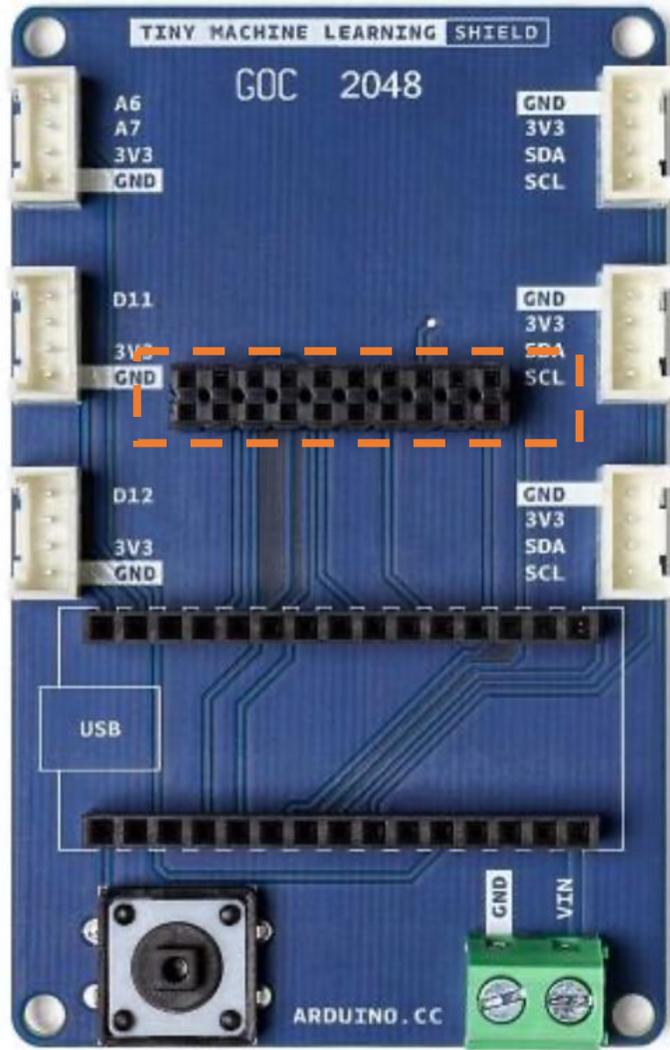
- Grove connectors (3.3V I2C and simple digital / analog - see pinouts)
- 2x10 pin array for OV7675 camera module
- Voltage input terminal block, accepts 4.5 to 21V (down regulated to 3.3V on Nano 33)



# TinyML Shield

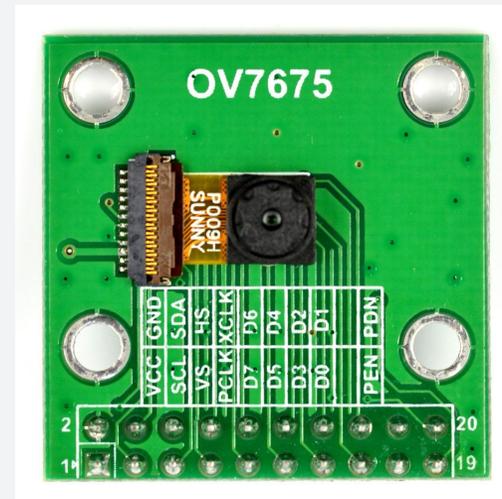
Two rows of 1x15 headers that you can slot the Nano 33 BLE sense into



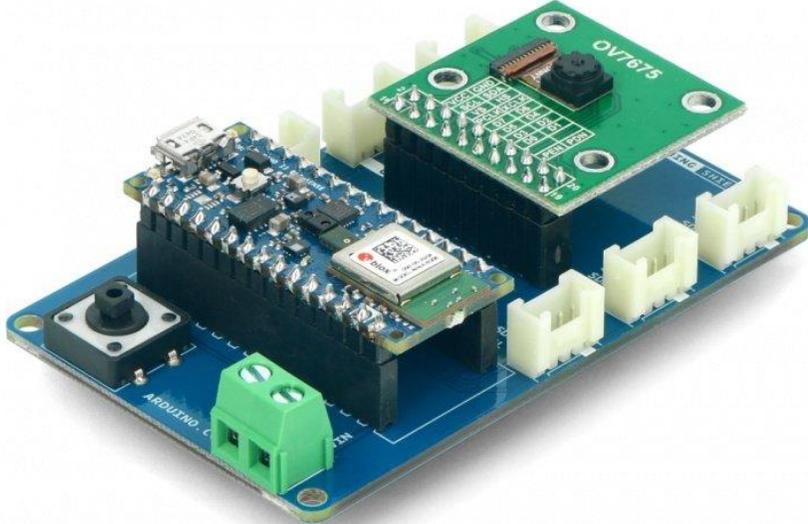
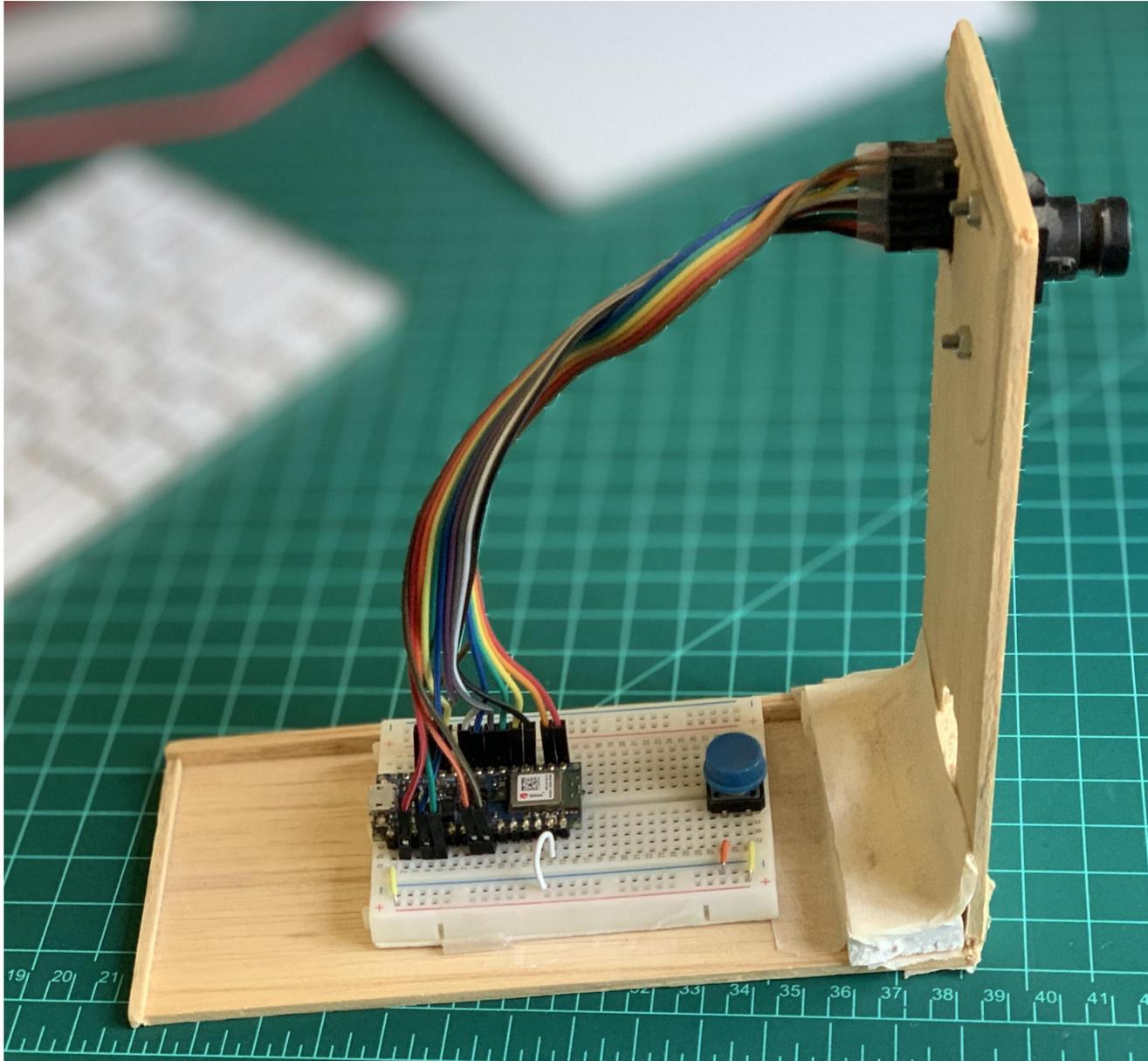


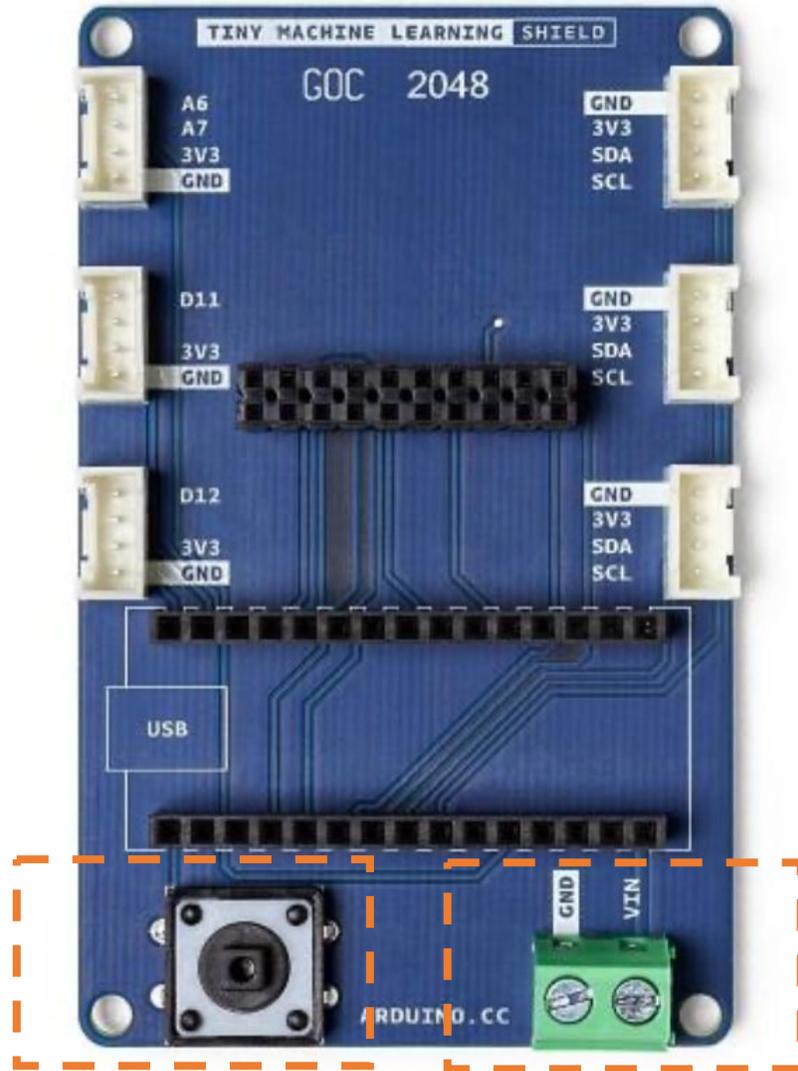
# TinyML Shield

2x10 header that is intended to receive the corresponding pins of the OV7675 camera module



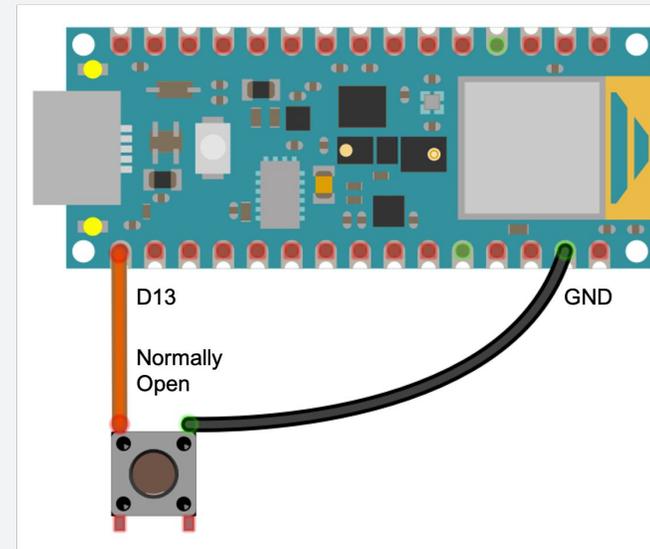
OV7670_VSYNC	8
OV7670_HREF	A1
OV7670_PLK	A0
OV7670_XCLK	9
OV7670_D0	10
OV7670_D1	1
OV7670_D2	0
OV7670_D3	2
OV7670_D4	3
OV7670_D5	5
OV7670_D6	6
OV7670_D7	4



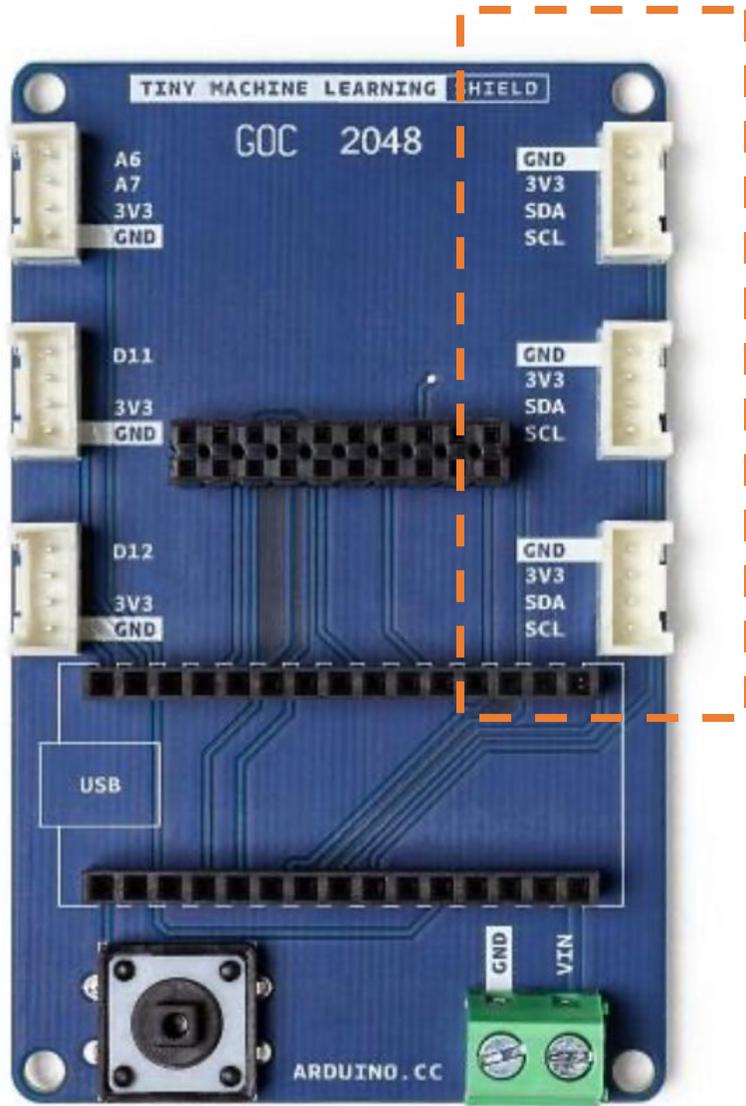


# TinyML Shield

A easily programmable button on the left

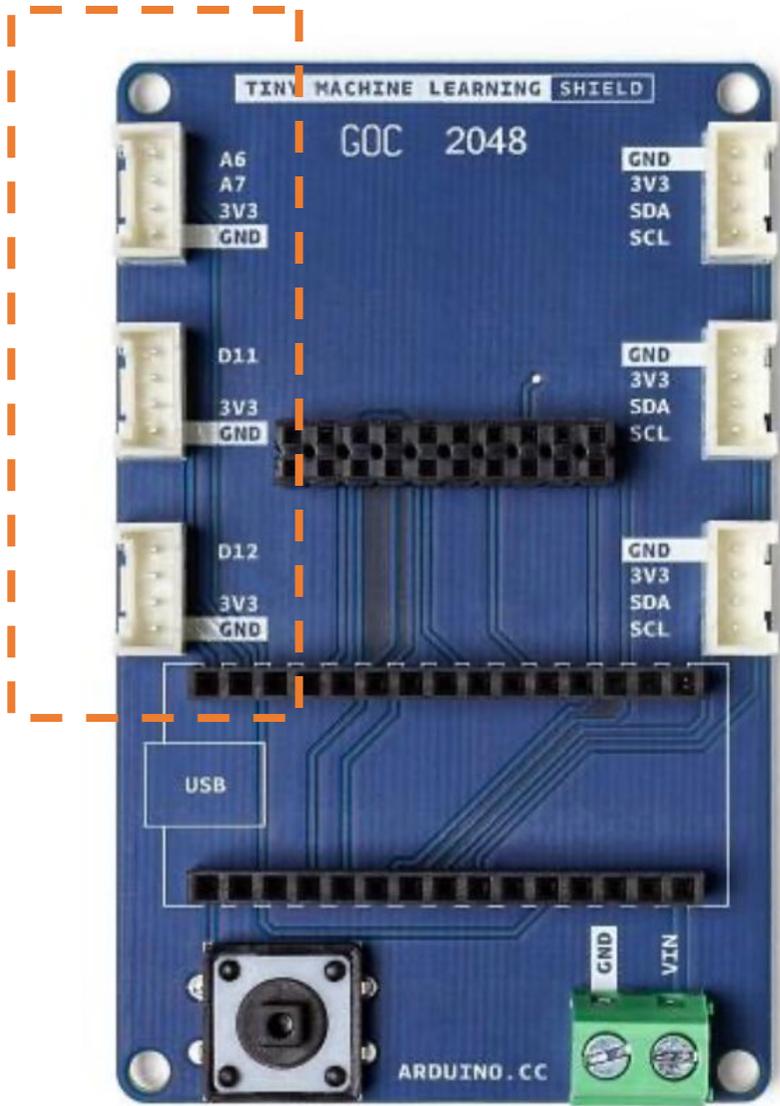


Screw-in terminal block for external (battery) power (4.5V to 21V)



# TinyML Shield

Standard Grove connectors, to permit serial communication (I2C = power + data + clock) with modules (both sensors and actuators)



# TinyML Shield

Grove connectors that break out analog and digital GPIO

# Grove Connectors



## Purpose

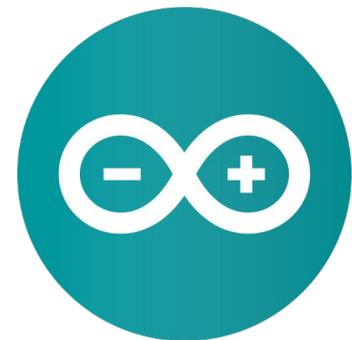
Facilitate **plug-and-play connections** to off-board modules to extend the possible scope of functionality to new **TinyML** applications

## Specifications

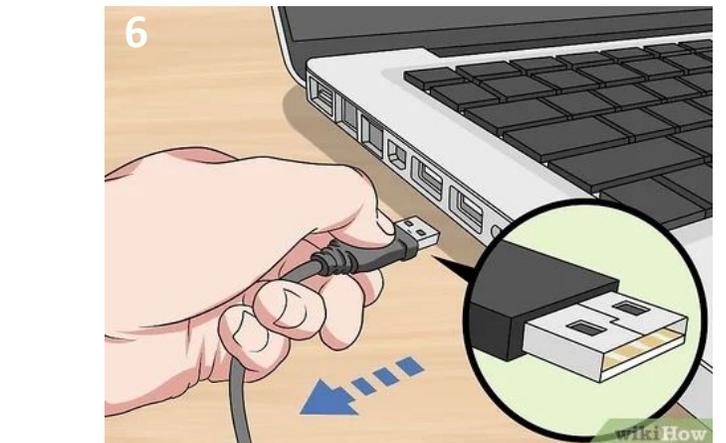
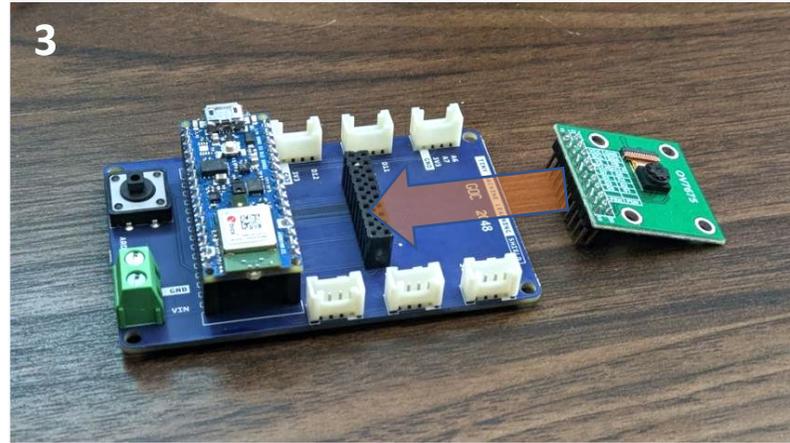
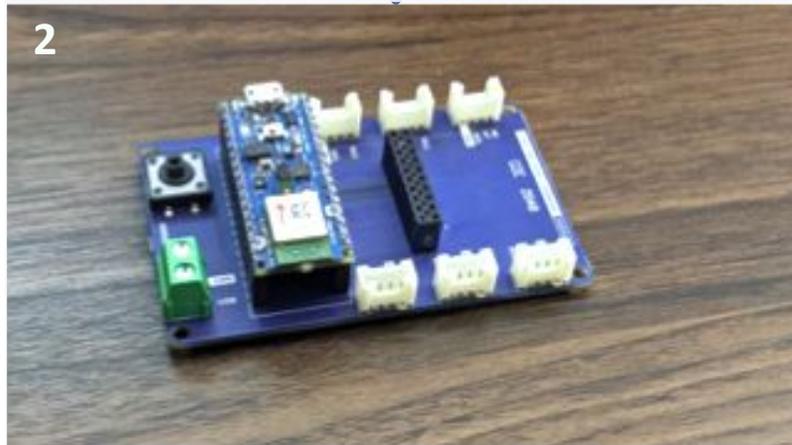
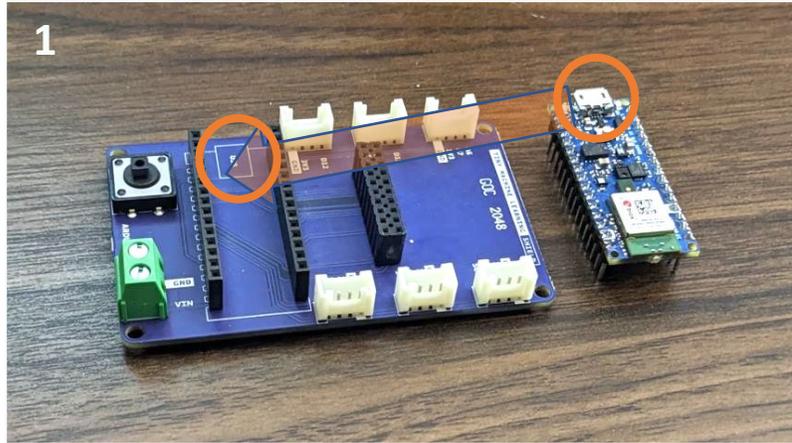
- Proprietary connection system from SeeedStudio, similar to JST PH-type connectors
- Large catalog of sensors, actuators available at [seeedstudio.com](https://www.seeedstudio.com)
- Be sure to check the voltage requirements and pinout of any new Grove module for compatibility with this shield before purchasing or connecting said module

# TinyML Kit Installation

- Hardware Set-up
- Software Set-up



# Installing the Hardware



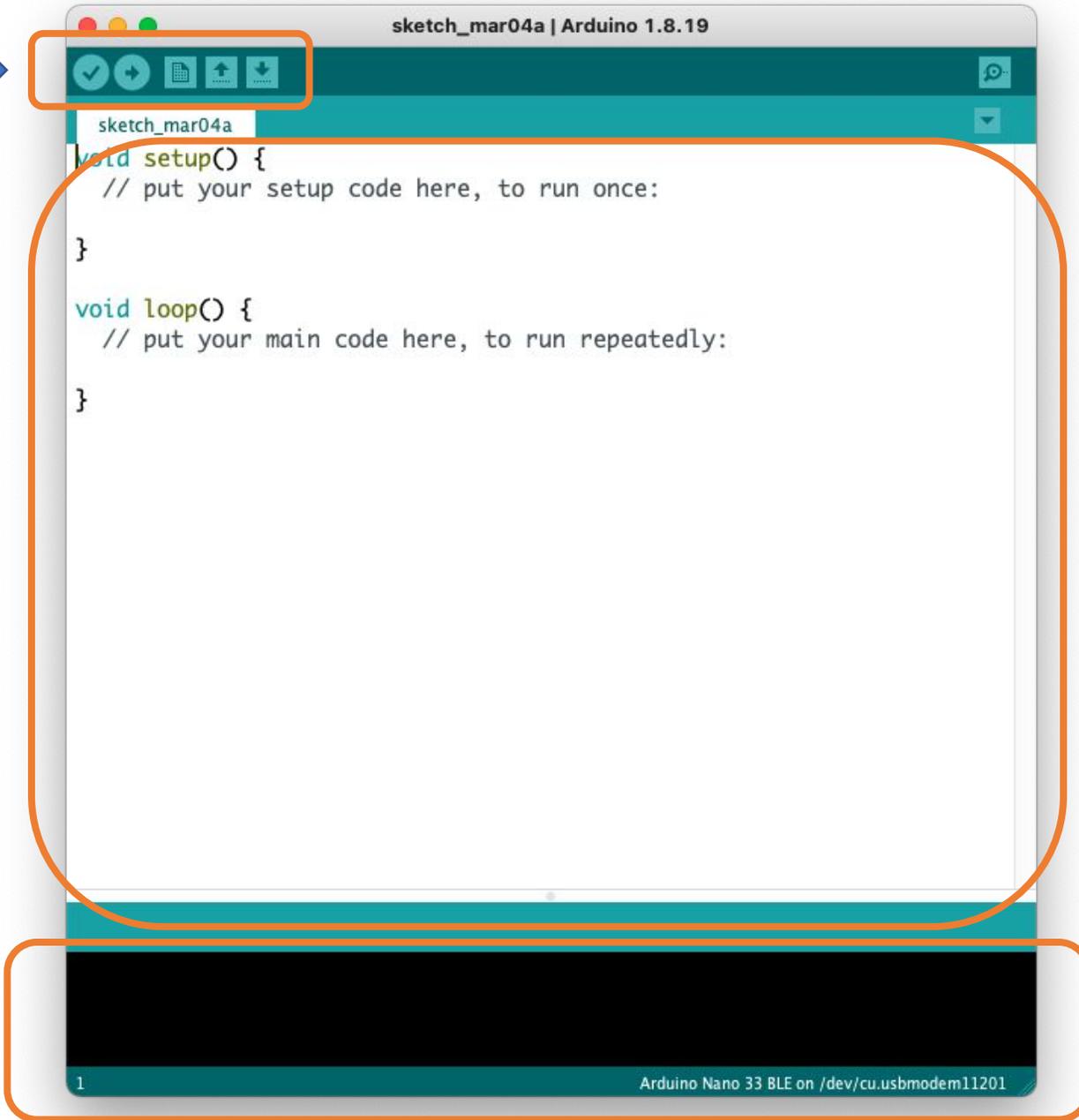
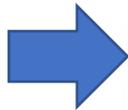
# Installing the Arduino IDE

The screenshot shows the Arduino website's software page. The main navigation bar includes links for Professional, Education, Store, Hardware, Software (highlighted), Cloud, Documentation, Community, Blog, and About. A search bar and a 'SIGN IN' button are also present. Below the navigation, there is a language switcher set to 'English'. The main content area features a section for 'Arduino Web Editor' with a 'CODE ONLINE' button and a 'GETTING STARTED' link. Below this is a 'Downloads' section for 'Arduino IDE 1.8.19'. The download options are listed in a teal box with an orange border:

- DOWNLOAD OPTIONS**
- Windows** Win 7 and newer
- Windows** ZIP file
- Windows app** Win 8.1 or 10 [Get](#)
- Linux** 32 bits
- Linux** 64 bits
- Linux** ARM 32 bits
- Linux** ARM 64 bits
- Mac OS X** 10.10 or newer

Additional links for 'Release Notes' and 'Checksums (sha512)' are provided. A 'Help' button is located at the bottom right of the download options box.

Menus  
and  
ToolBar

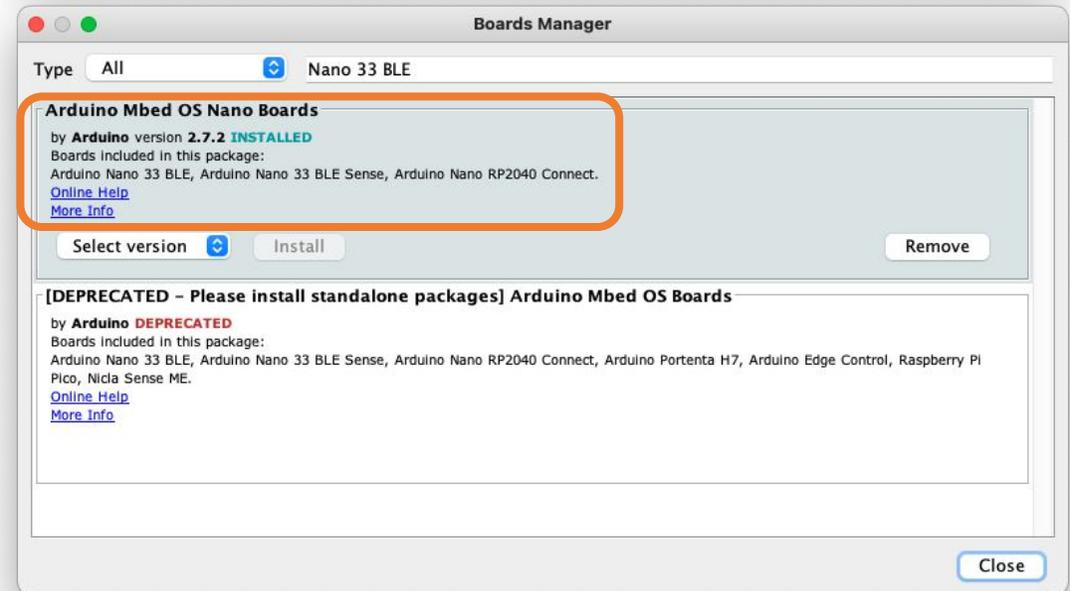
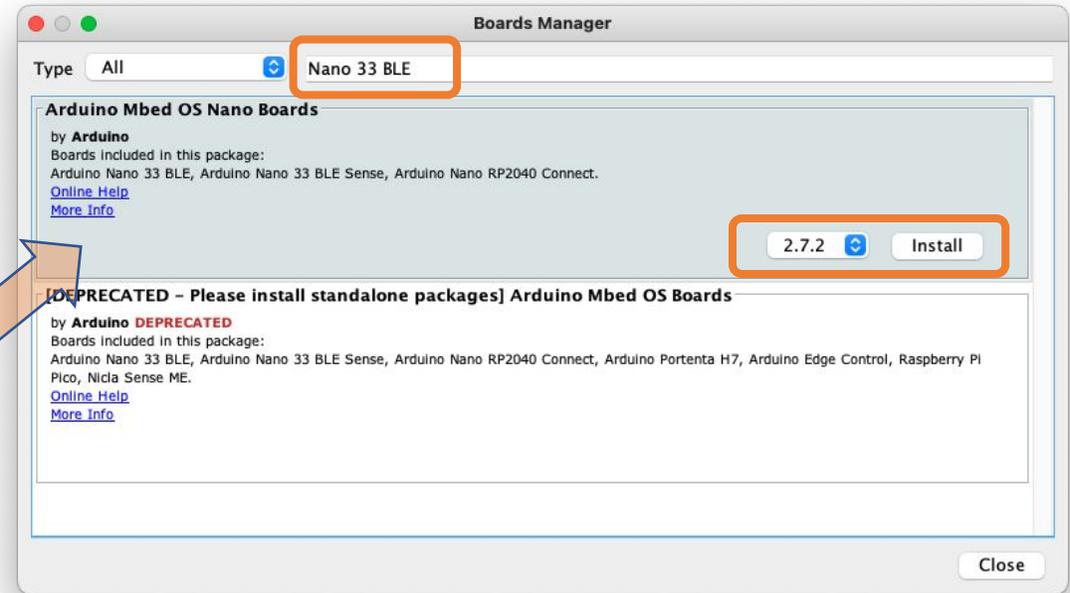
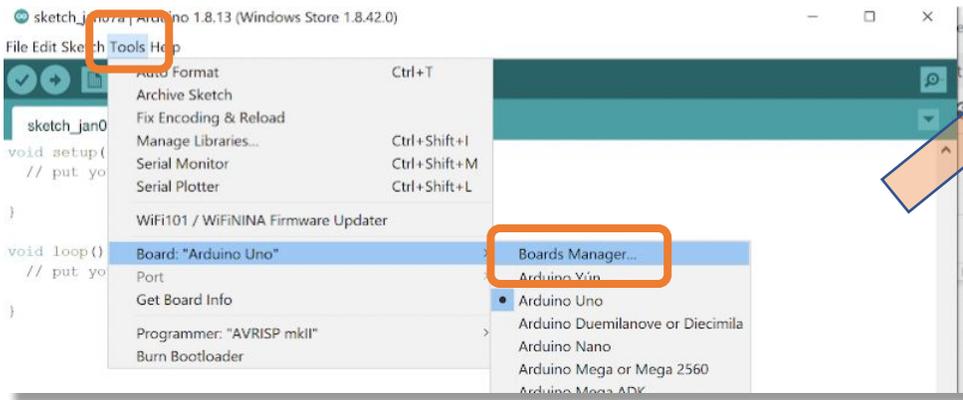


Code Area

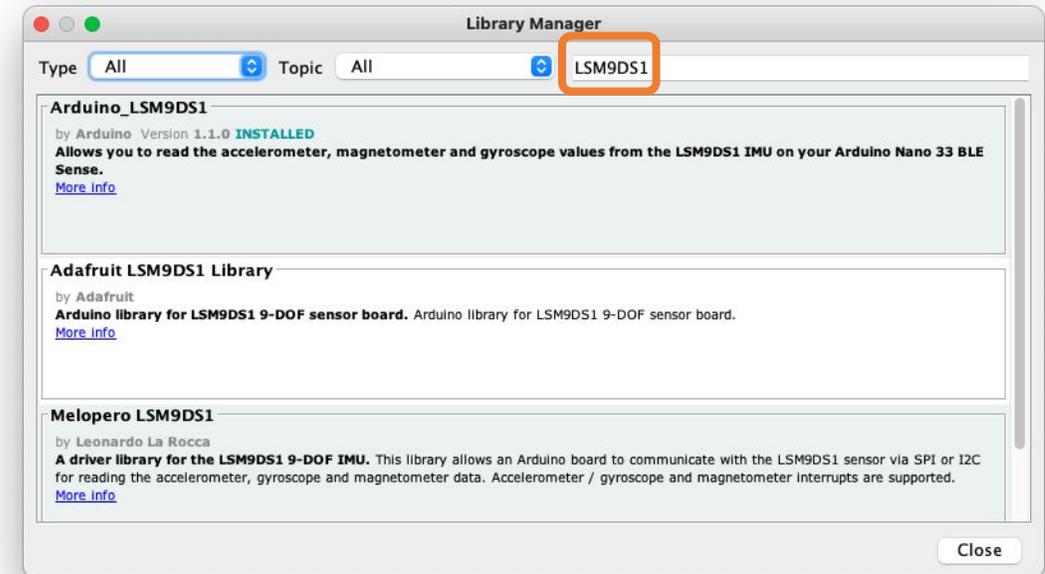
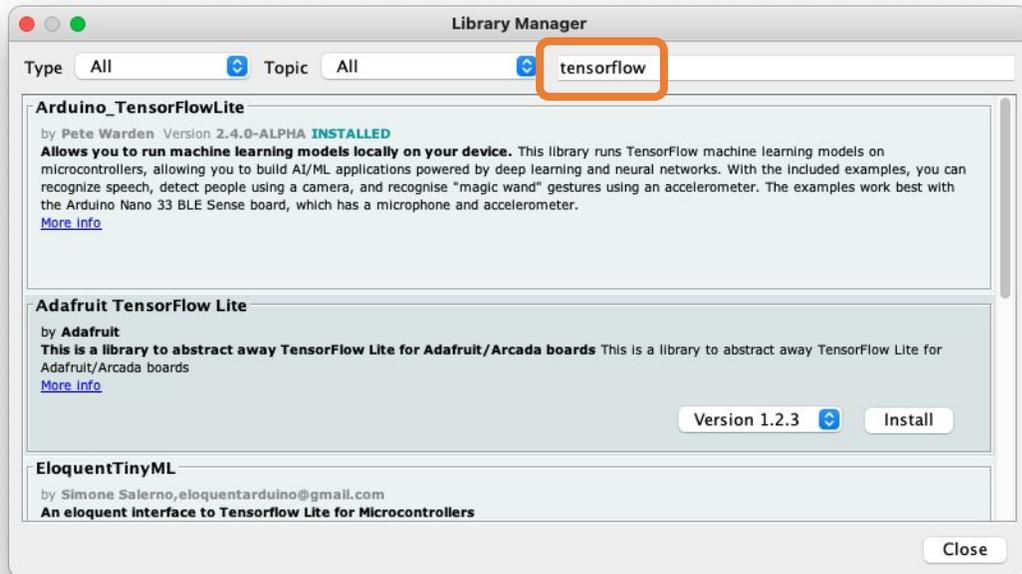
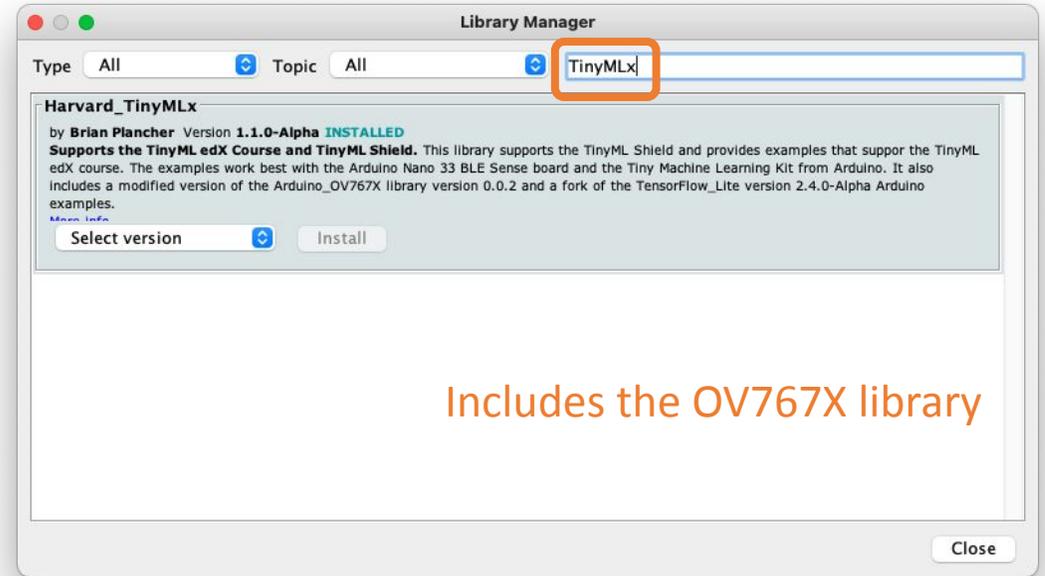
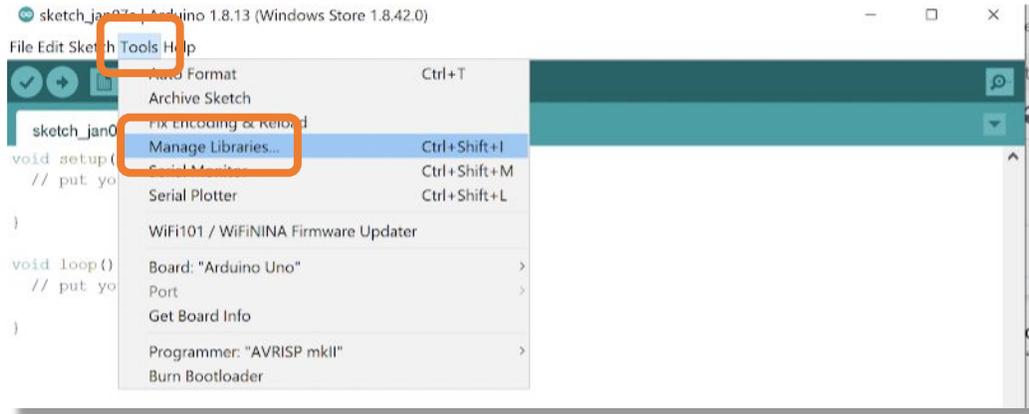


Console

# Installing the Board Files

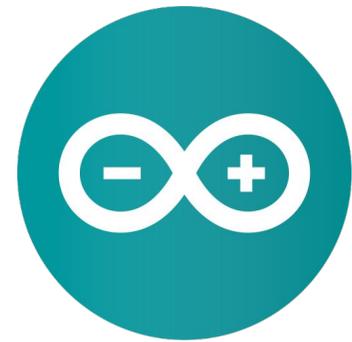


# Installing the Main Libraries

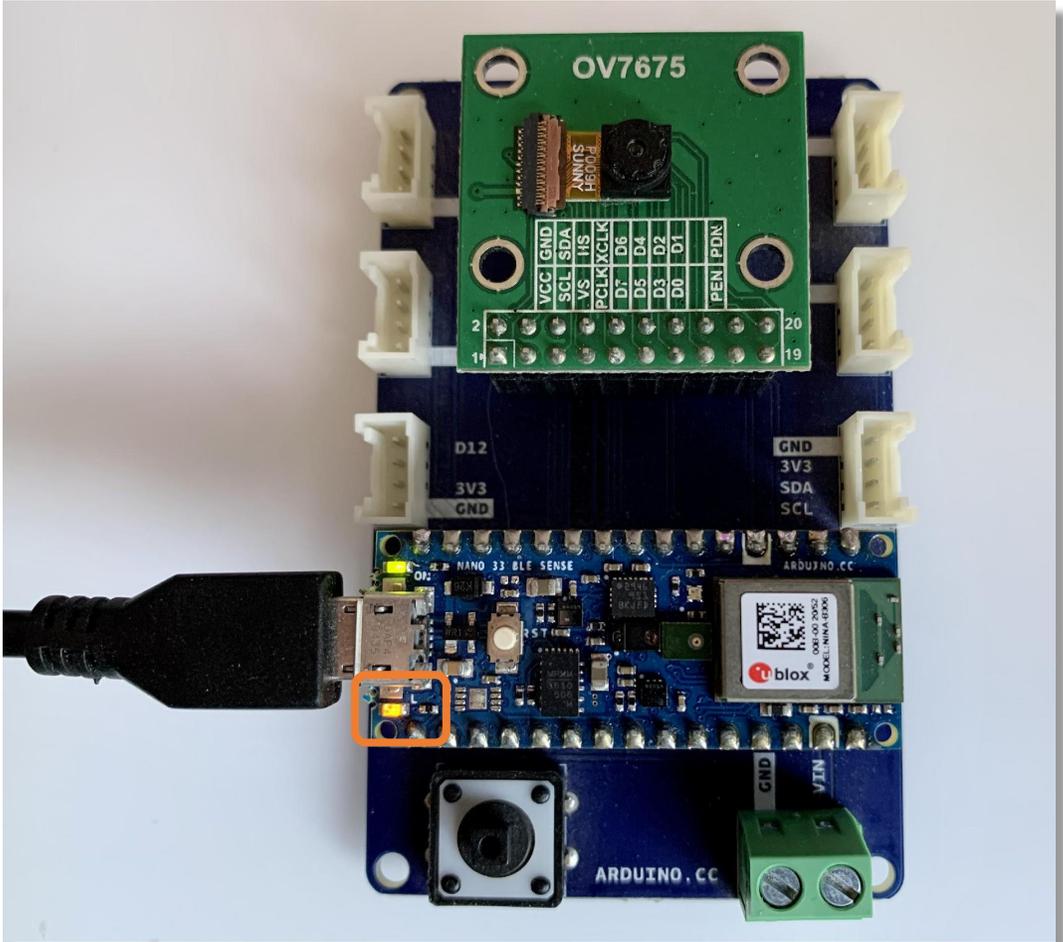
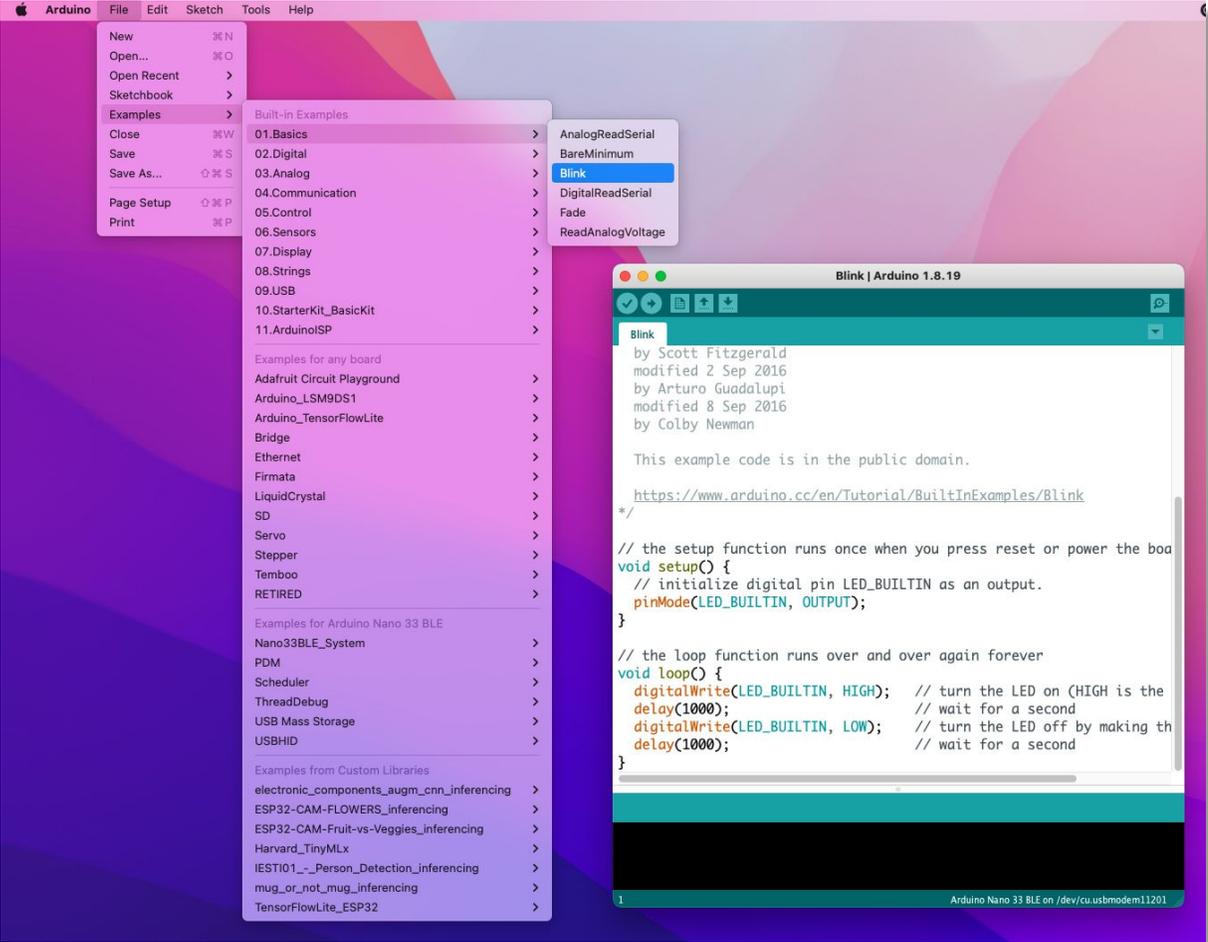


# TinyML Kit Test

- MCU test (Blink)
- Sensors Test (IMU, MIC, CAMERA)



# MCU installation test (Blink)



# Testing Microphone

The screenshot shows the Arduino IDE interface. The 'Examples' menu is open, displaying a list of examples categorized by board and library. The 'test\_microphone' example is selected. The code editor shows the following code:

```
test_microphone
Active Learning Labs
Harvard University
tinyMLx - Built-in Microphone Test
/

include <PDM.h>
include <TinyMLShield.h>

/ PDM buffer
const sampleBuffer[256];
volatile int samplesRead;

bool record = false;
bool commandRecv = false;

void setup() {
  Serial.begin(9600);
  while (!Serial);

  // Initialize the TinyML Shield
  initializeShield();

  PDM.onReceive(onPDMdata);
}
```

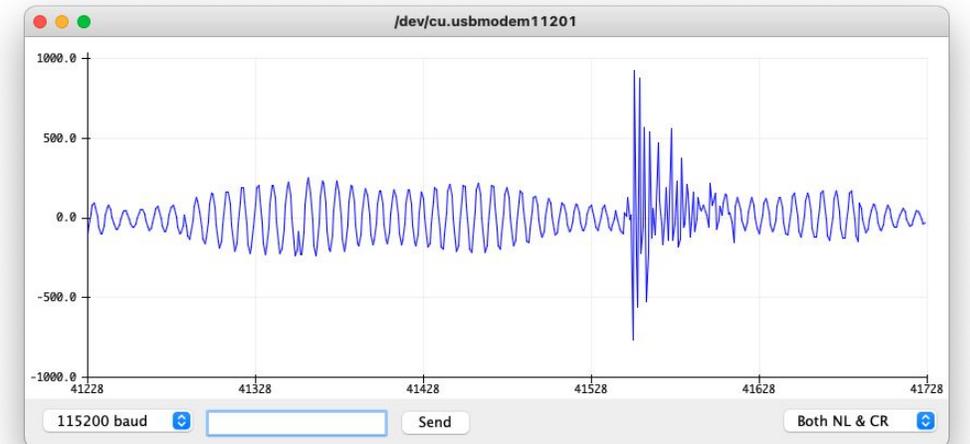
The Serial Monitor window displays the following text:

Welcome to the microphone test for the built-in microphone on the Nano 33 BLE Sense

Use the on-shield button or send the command 'click' to start and stop an audio recording

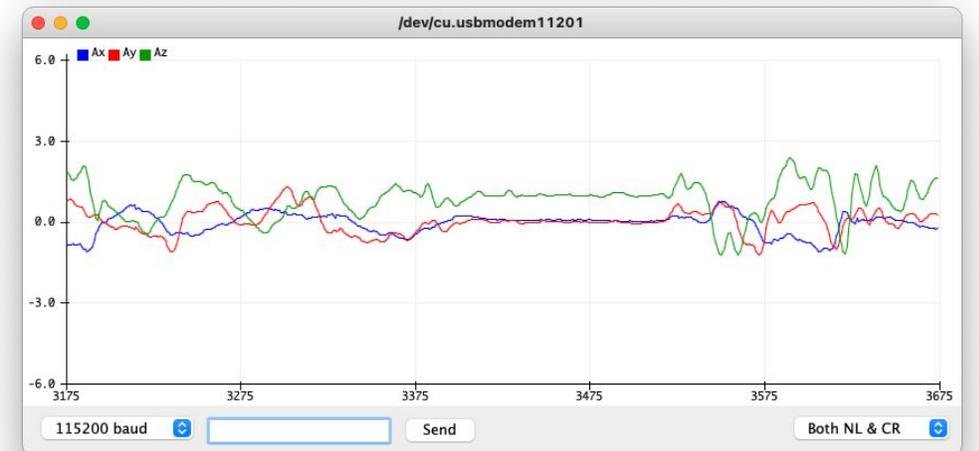
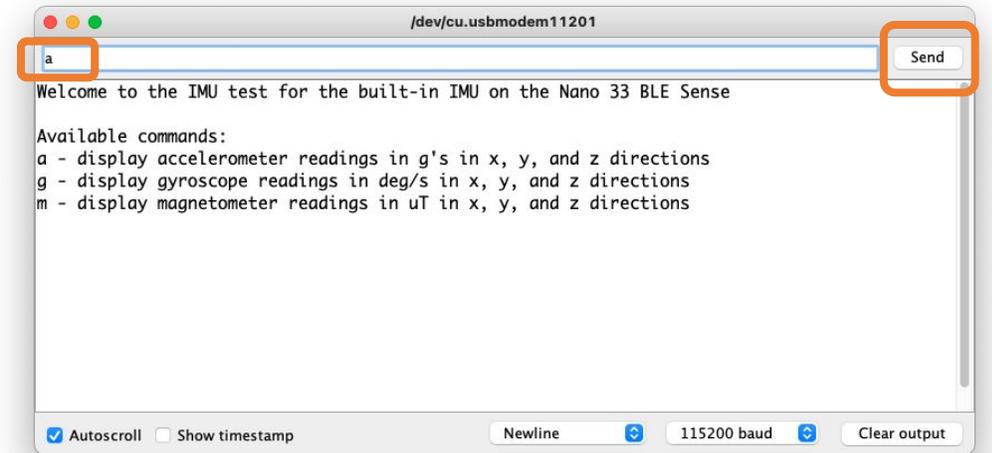
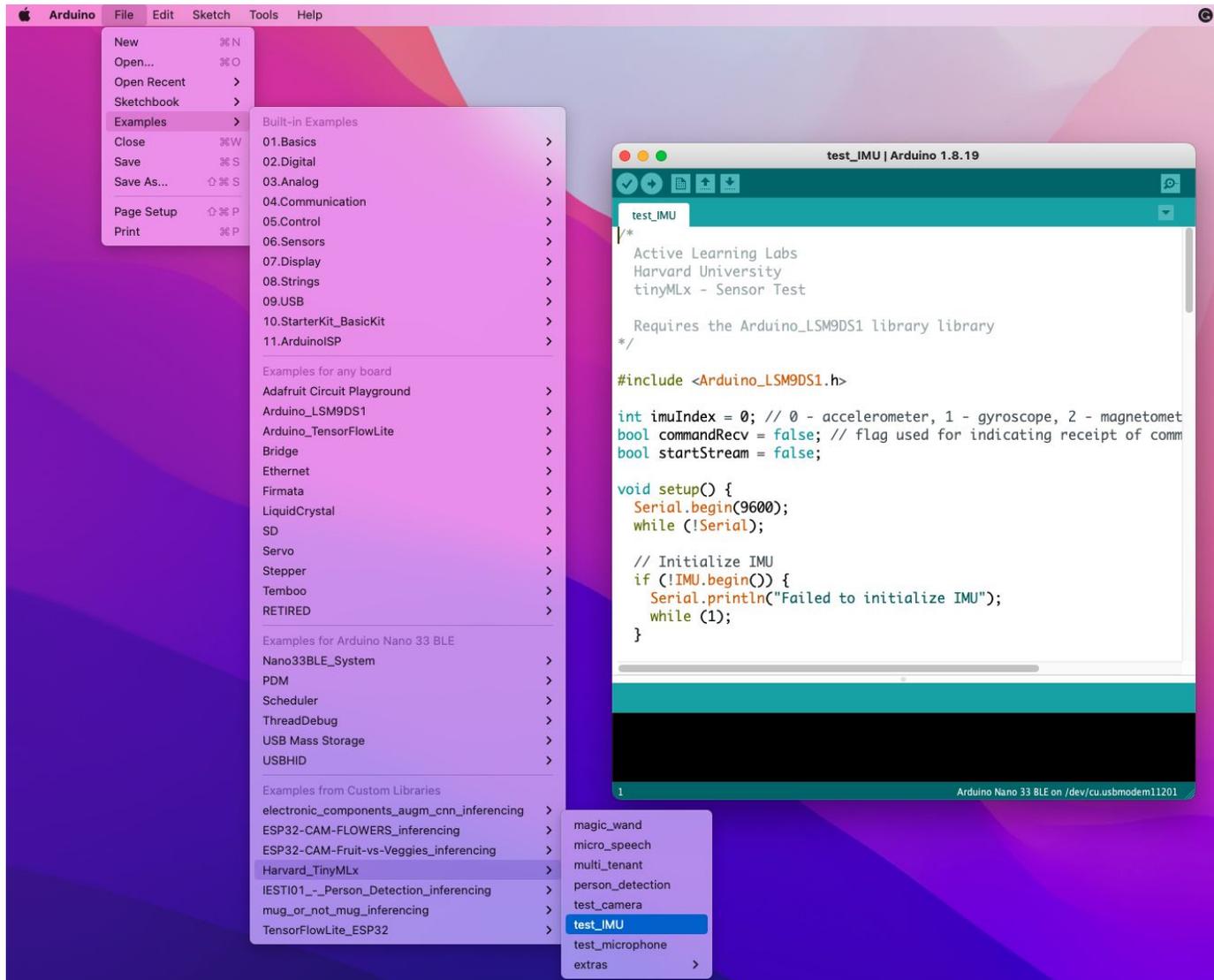
Open the Serial Plotter to view the corresponding waveform

The image shows the Arduino Nano 33 BLE Sense board with a red box highlighting the microphone component.



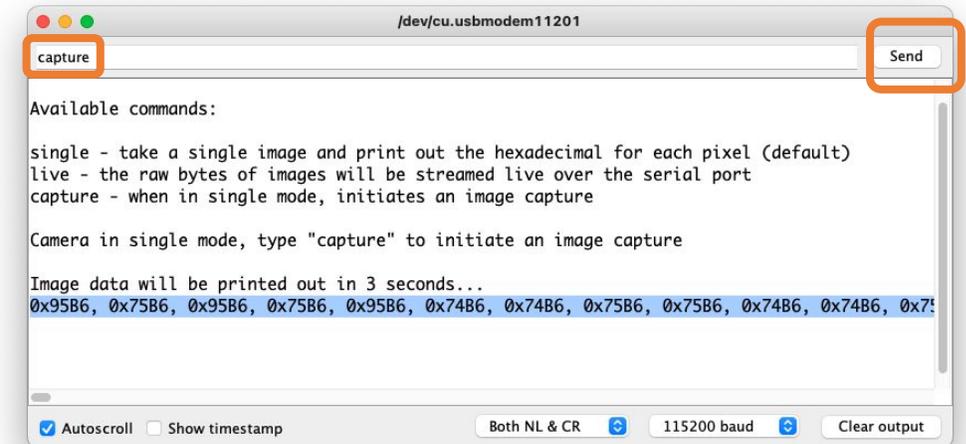
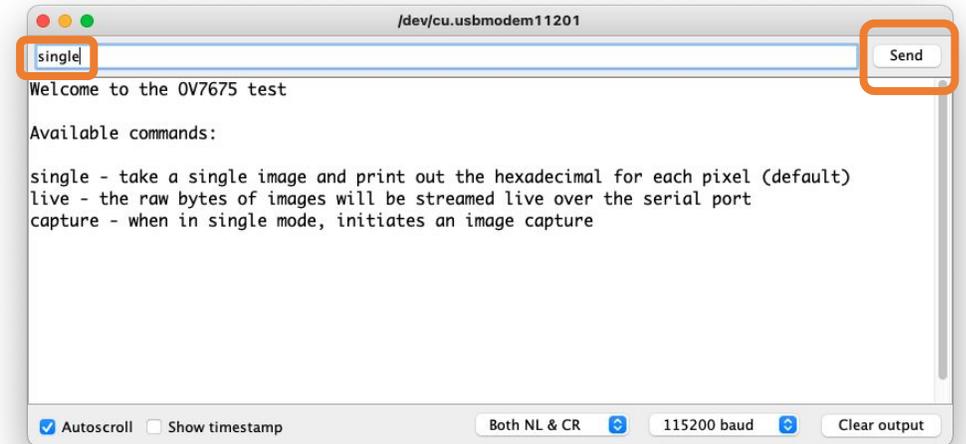
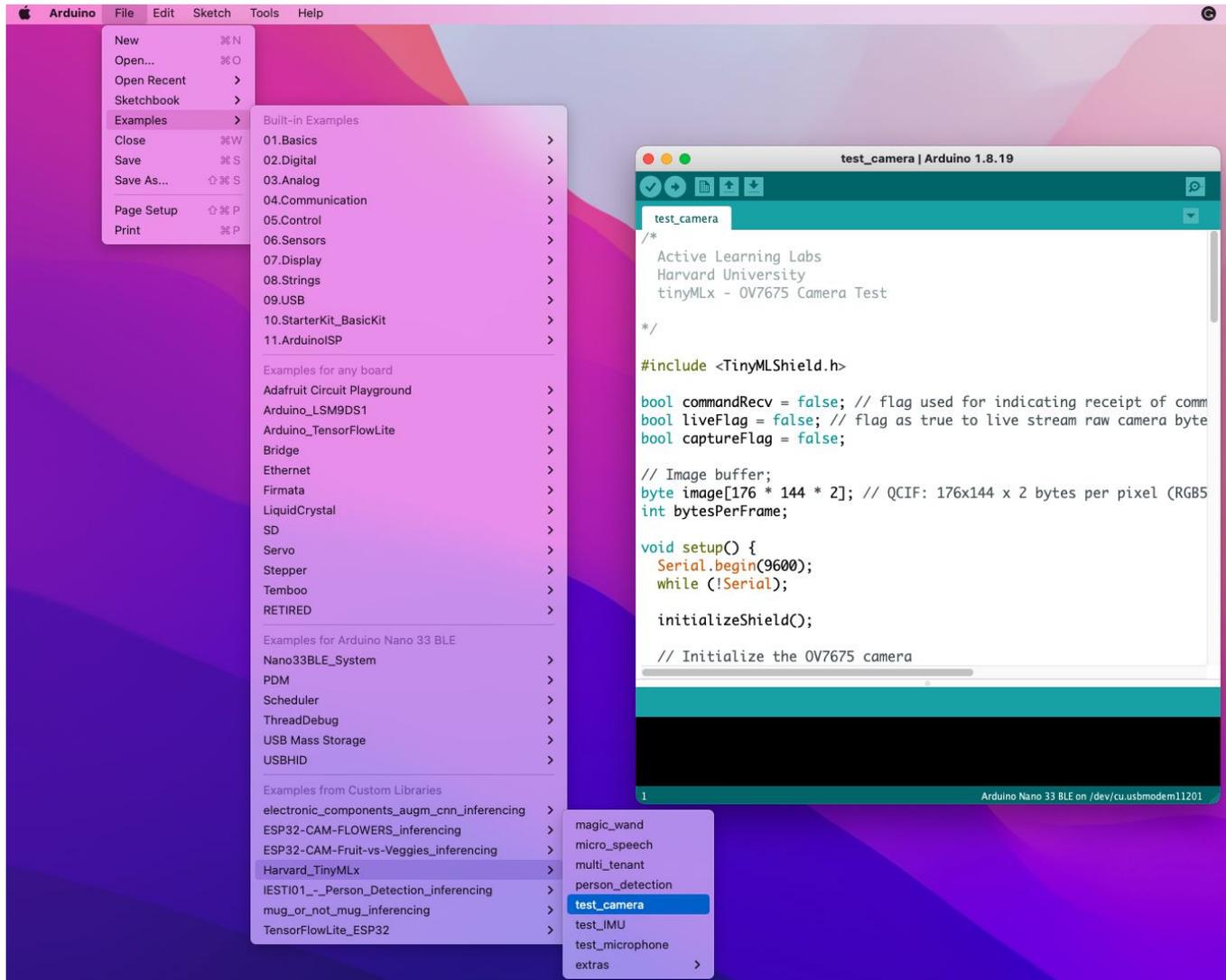
Note: Close the Serial Monitor before open the Plotter

# Testing IMU



Notes: Close the Serial Monitor before open the Plotter  
Repeat test for 'g' and 'm'

# Testing Camera



Note: You can Press Button instead send 'capture'



# Optional Tests (RGB LEDs)

```
bilnk_RGB | Arduino 1.8.19
bilnk_RGB

void setup() {
  // Pins for the built-in RGB LEDs on the Arduino Nano 33 BLE Sense
  pinMode(LED_R, OUTPUT);
  pinMode(LED_G, OUTPUT);
  pinMode(LED_B, OUTPUT);

  // Note: The RGB LEDs are ON when the pin is LOW and off when HIGH.
  digitalWrite(LED_R, HIGH);
  digitalWrite(LED_G, HIGH);
  digitalWrite(LED_B, HIGH);
}

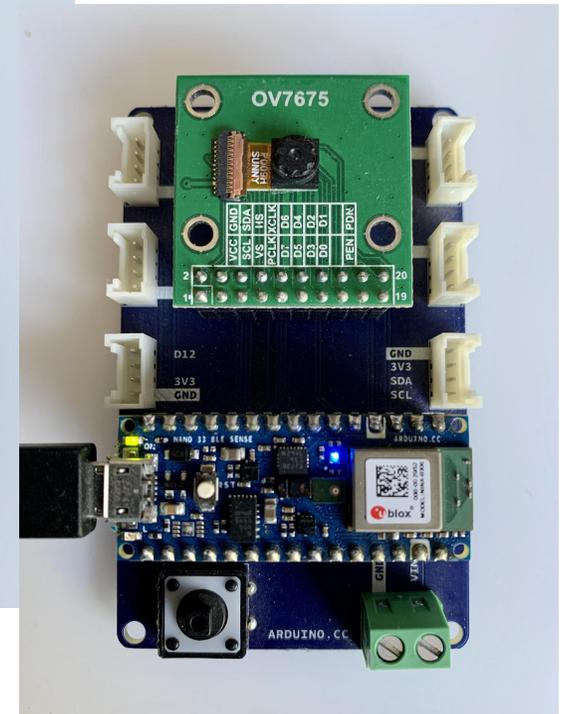
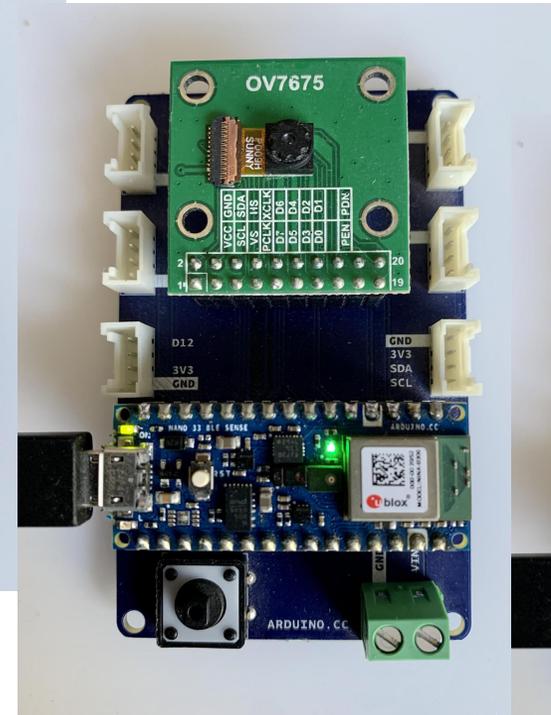
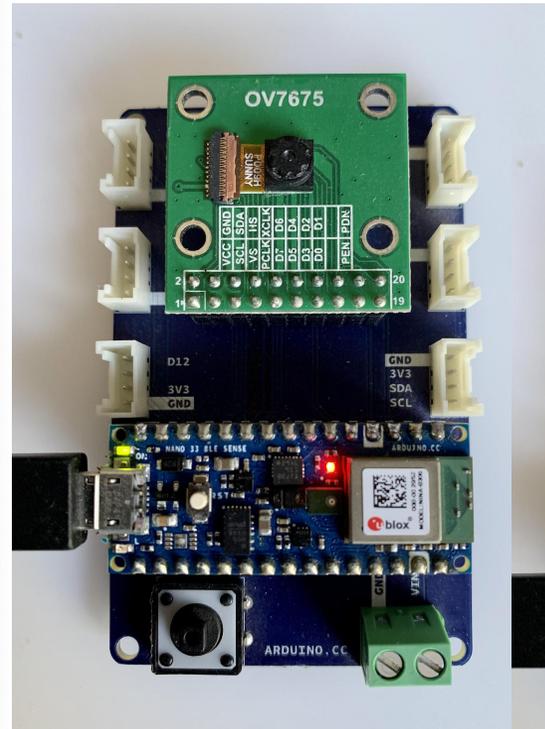
void loop() {
  digitalWrite(LED_R, LOW);
  delay(1000);
  digitalWrite(LED_R, HIGH);
  delay(1000);

  digitalWrite(LED_G, LOW);
  delay(1000);
  digitalWrite(LED_G, HIGH);
  delay(1000);

  digitalWrite(LED_B, LOW);
  delay(1000);
  digitalWrite(LED_B, HIGH);
  delay(1000);
}

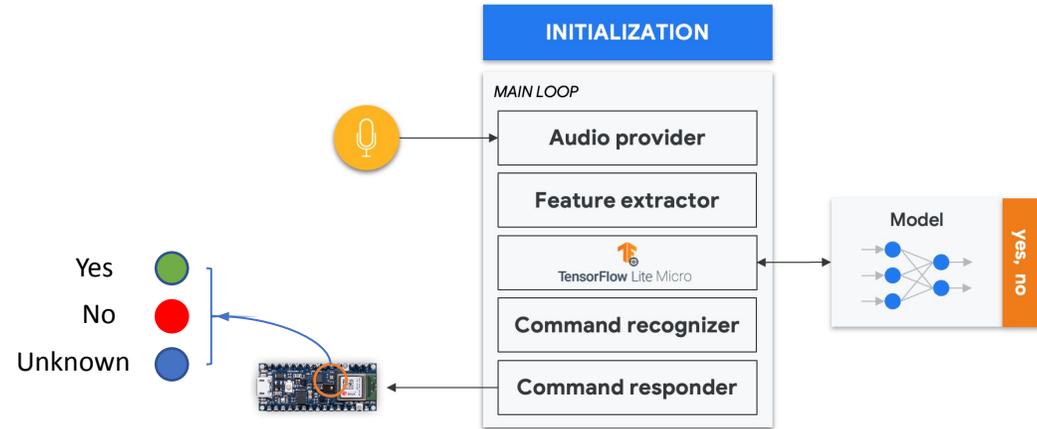
Done uploading.
Done in 0.001 seconds
Write 83944 bytes to flash (21 pages)
[=====] 100% (21/21 pages)
Done in 3.378 seconds

28 Arduino Nano 33 BLE on /dev/cu.usbmodem11201
```



# Optional Tests (KeyWord Spotting)

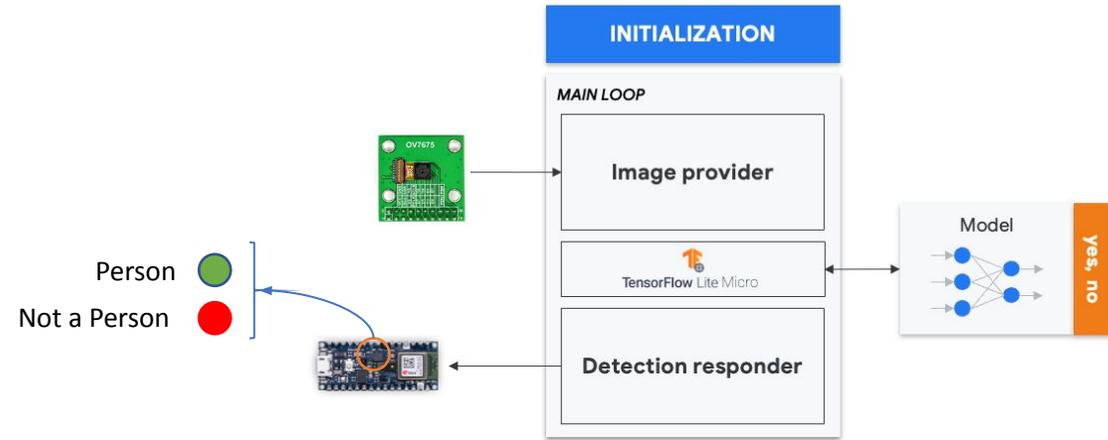
```
micro_speech | Arduino 1.8.19  
micro_speech  arduino_audio_provider.cpp  arduino_command_responder.cpp  arduino_r n.cp  
#include <TensorFlowLite.h>  
#include "main_functions.h"  
#include "audio_provider.h"  
#include "command_responder.h"  
#include "feature_provider.h"  
#include "micro_features_micro_model_settings.h"  
#include "micro_features_model.h"  
#include "recognize_commands.h"  
#include "tensorflow/lite/micro/micro_error_reporter.h"  
#include "tensorflow/lite/micro/micro_interpreter.h"  
#include "tensorflow/lite/micro/micro_mutable_op_resolver.h"  
#include "tensorflow/lite/schema/schema_generated.h"  
#include "tensorflow/lite/version.h"  
  
// Globals, used for compatibility with Arduino-style sketches.  
namespace {  
  tflite::ErrorReporter* error_reporter = nullptr;  
  
Done in 0.001 seconds  
Write 171992 bytes to flash (42 pages)  
[=====] 100% (42/42 pages)  
Done in 6.733 seconds  
1  
Arduino Nano 33 BLE on /dev/cu.usbmodem11201
```



```
/dev/cu.usbmodem11201  
Heard silence (204) @1408ms  
Heard yes (204) @6416ms  
Heard yes (201) @8784ms  
Heard unknown (207) @11280ms  
Heard yes (209) @16656ms  
Heard no (201) @25312ms  
Heard no (201) @28608ms  
Heard unknown (202) @35552ms  
Autoscroll Show timestamp Both NL & CR 115200 baud Clear output
```

# Optional Tests (Person Detection)

```
person_detection | Arduino 1.8.19  
person_detection  arduino_detection_responder.cpp  arduino_image_provider.cpp  ardui...mai  
  
#include <TensorFlowLite.h>  
#include "main_functions.h"  
  
#include "detection_responder.h"  
#include "image_provider.h"  
#include "model_settings.h"  
#include "person_detect_model_data.h"  
#include "tensorflow/lite/micro/micro_error_reporter.h"  
#include "tensorflow/lite/micro/micro_interpreter.h"  
#include "tensorflow/lite/micro/micro_mutable_op_resolver.h"  
#include "tensorflow/lite/schema/schema_generated.h"  
#include "tensorflow/lite/version.h"  
  
// Globals, used for compatibility with Arduino-style sketches.  
namespace {  
  tflite::ErrorReporter* error_reporter = nullptr;  
  const tflite::Model* model = nullptr;  
  tflite::MicroInterpreter* interpreter = nullptr;  
  
  Done uploading.  
  
  Done in 0.001 seconds  
  Write 451984 bytes to flash (111 pages)  
  [=====] 100% (111/111 pages)  
  Done in 17.863 seconds  
  
  1  
  Arduino Nano 33 BLE on /dev/cu.usbmodem11201
```



```
/dev/cu.usbmodem11201  
Send  
  
Person score: -37 No person score: 37  
Person score: -39 No person score: 39  
Person score: 10 No person score: -10  
Person score: 2 No person score: -2  
Person score: 0 No person score: 0  
Person score: 22 No person score: -22  
Person score: 22 No person score: -22  
Person score: 21 No person score: -21  
Person score: 9 No person score: -9  
Person score: -1 No person score: 1  
Person score: 14 No person score: -14  
Person score: 12 No person score: -12  
Person score: -40 No person score: 40  
Person score: -34 No person score: 34  
  
Autoscroll Show timestamp Both NL & CR 115200 baud Clear output
```

**Thanks**  
**And stay safe!**



**UNIFEI**

