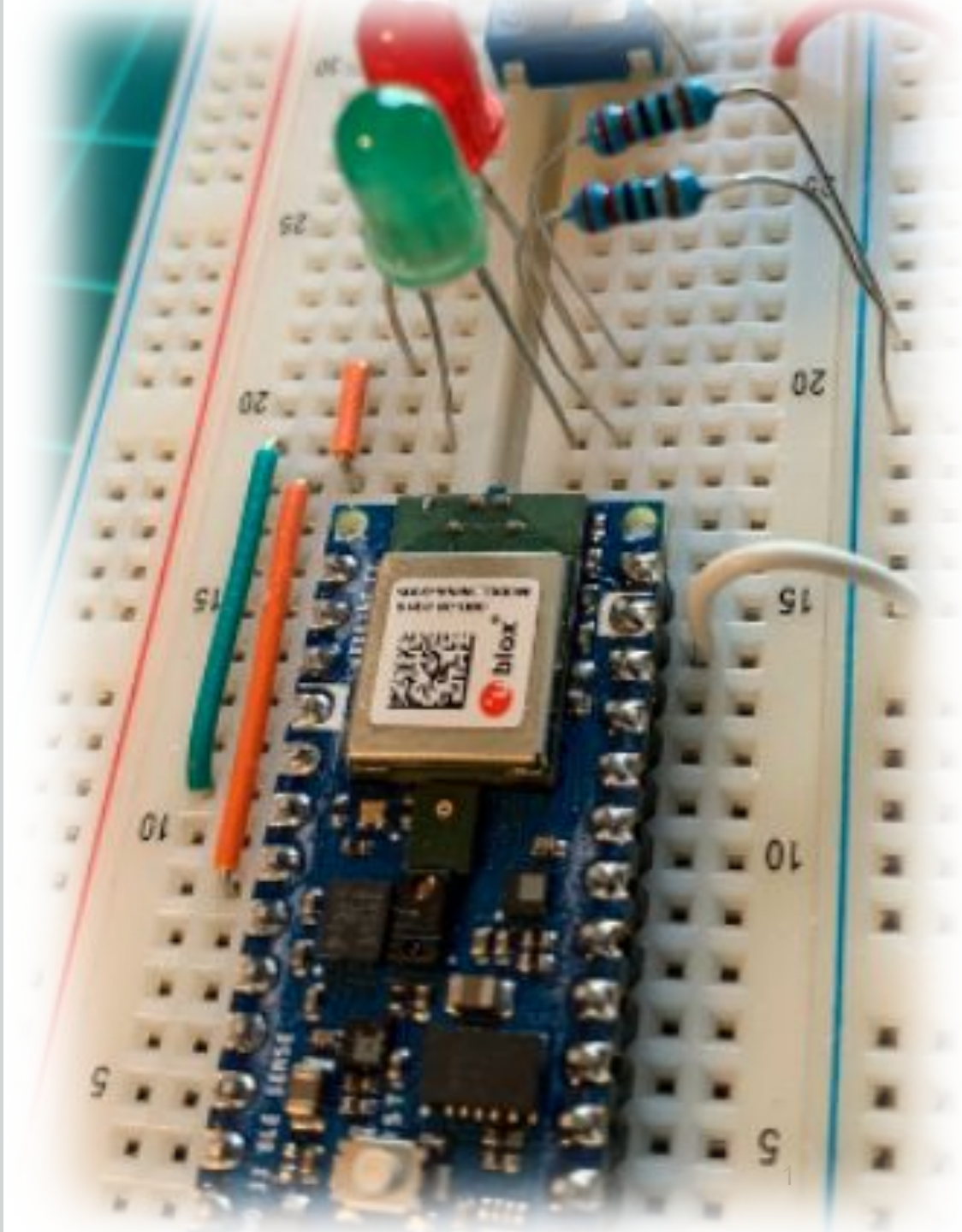
IESTI01 – TinyML

Embedded Machine Learning

17. TinyML Kit Overview - HW and SW installation & Test



Prof. Marcelo Rovai
UNIFEI

TinyML Kit Overview


ARDUINO
TINY MACHINE
LEARNING KIT
in partnership with:
edX
TensorFlow
OV7675

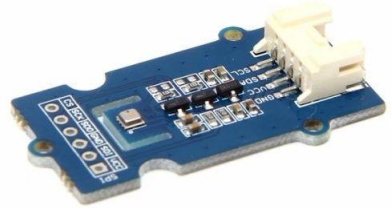
Nano 33 BLE Sense (+ USB cable)

Purpose

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

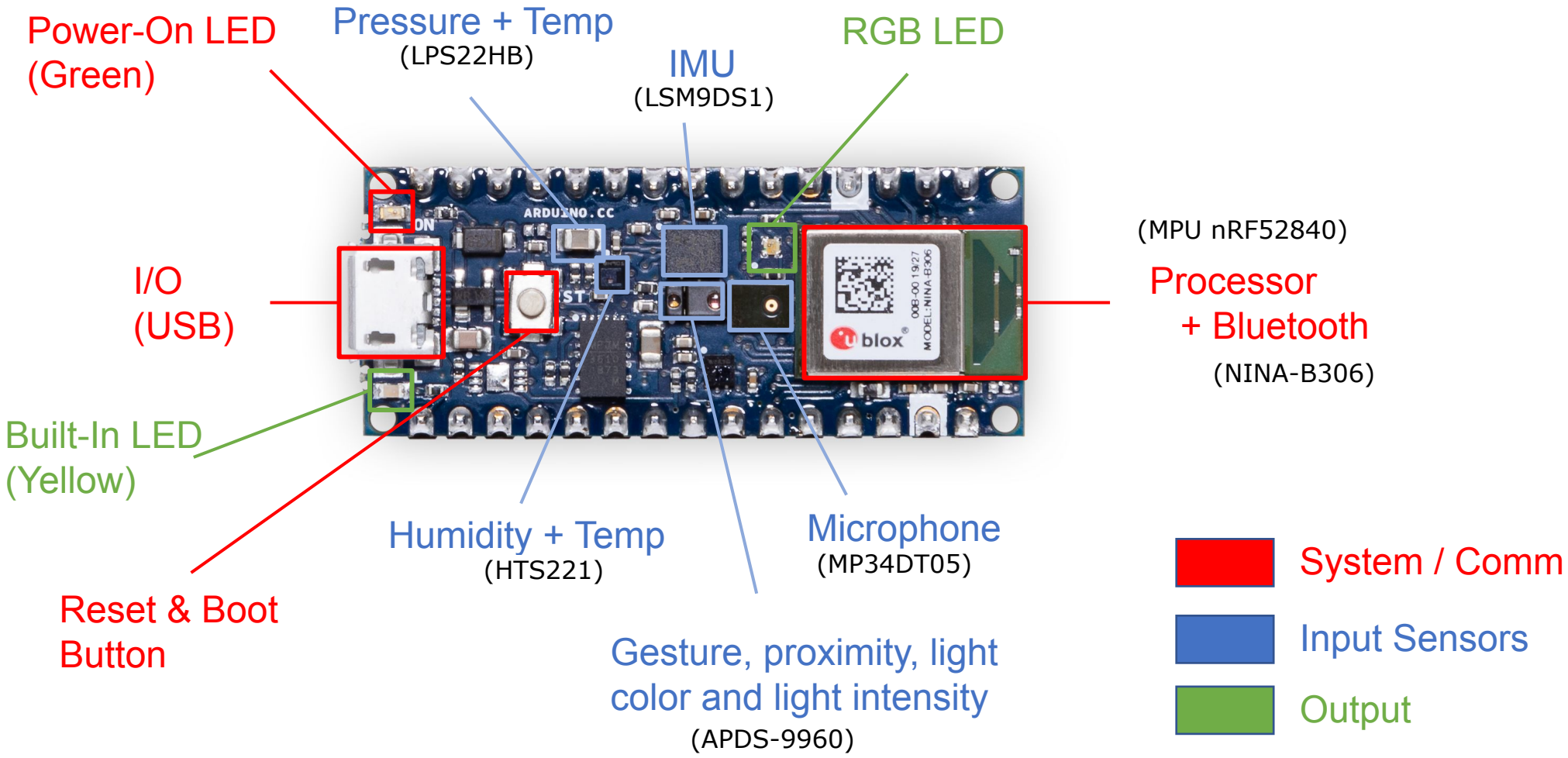
Specifications

- **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~~*, gesture, and light intensity.
- BLE module covered by ArduinoBLE library
- RGB LEDs



* Not included in some packages. For projects you can use the external Grove - Temp&Humi&Barometer Sensor (BME280)

Nano 33 BLE Sense (Development board)



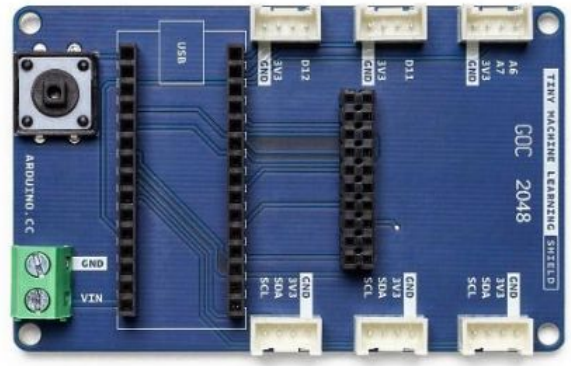
OV 7675 Camera Module

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

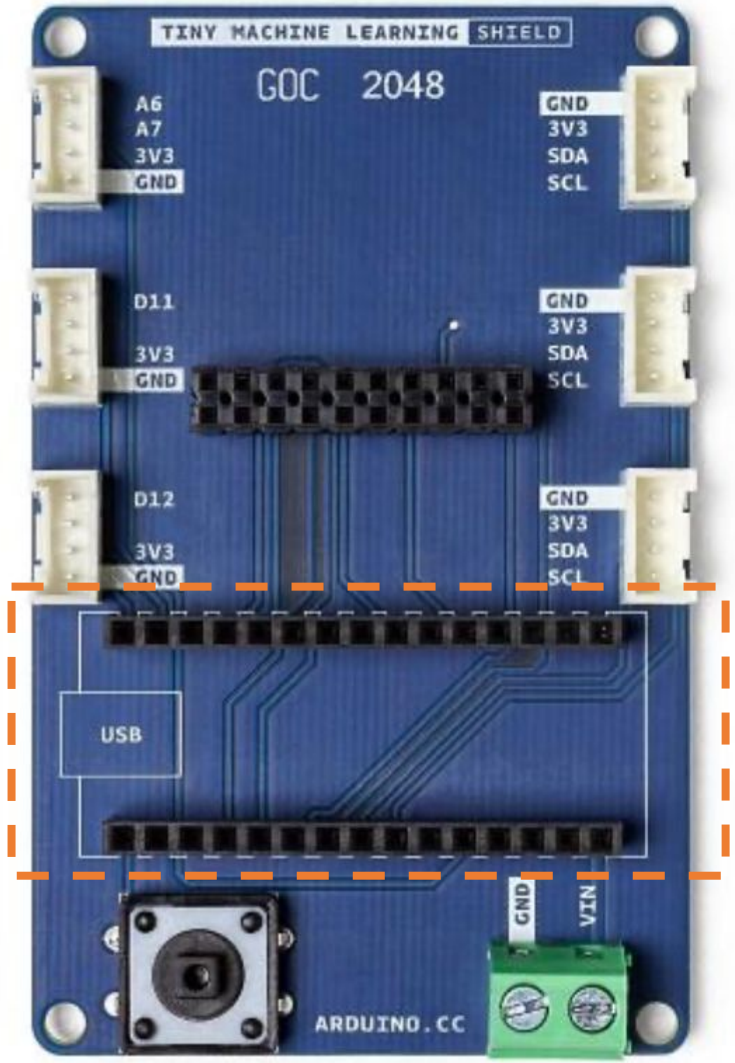
A daughter PCB designed to **breakout the I/O** from the Nano 33 BLE sense to permit easy, reliable **communication with** other local, **off-board elements**

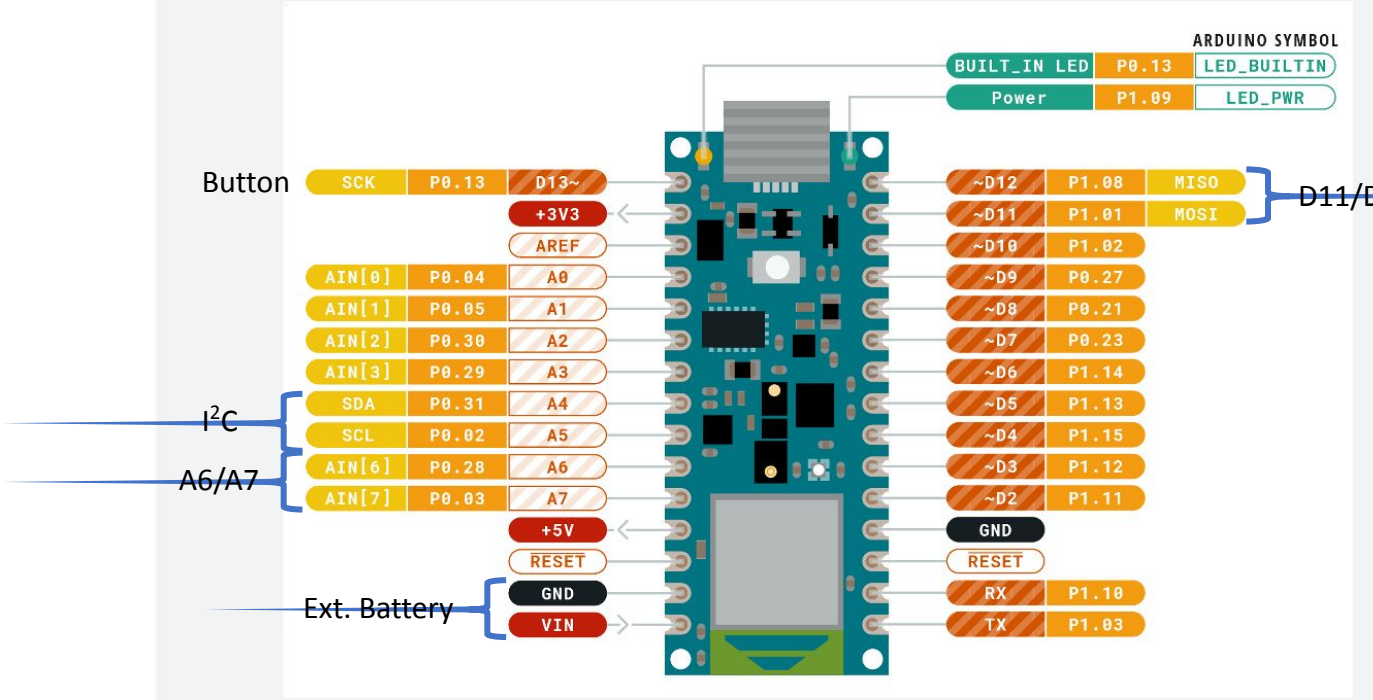
Specifications

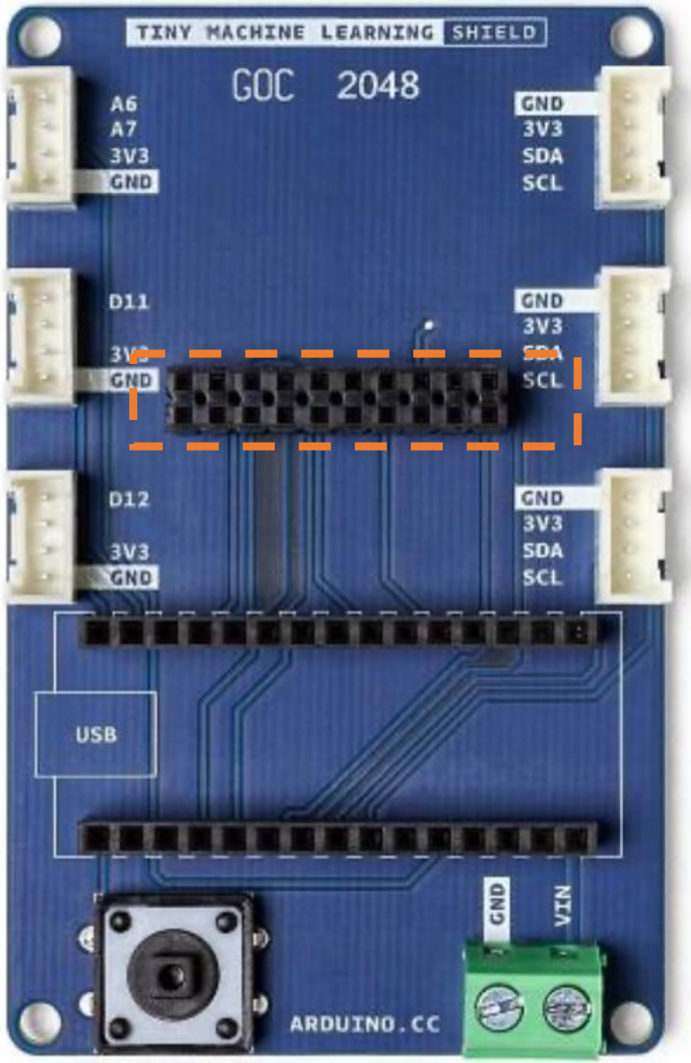
- Grove connectors (3.3V I2C and simple digital / analog - see pinouts)
- 2x10 pin array for OV7675 camera module
- Voltage input terminal block, accepts 4.5 to 21V (down regulated to 3.3V on Nano 33)

TinyML Shield

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

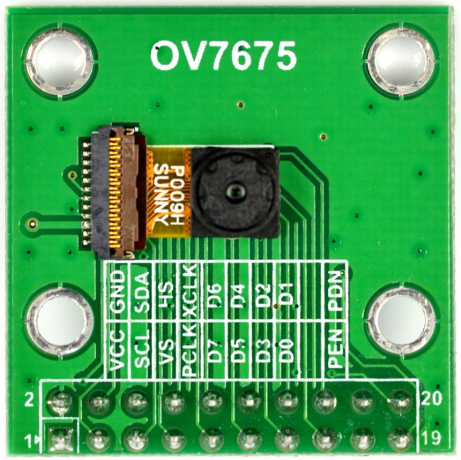




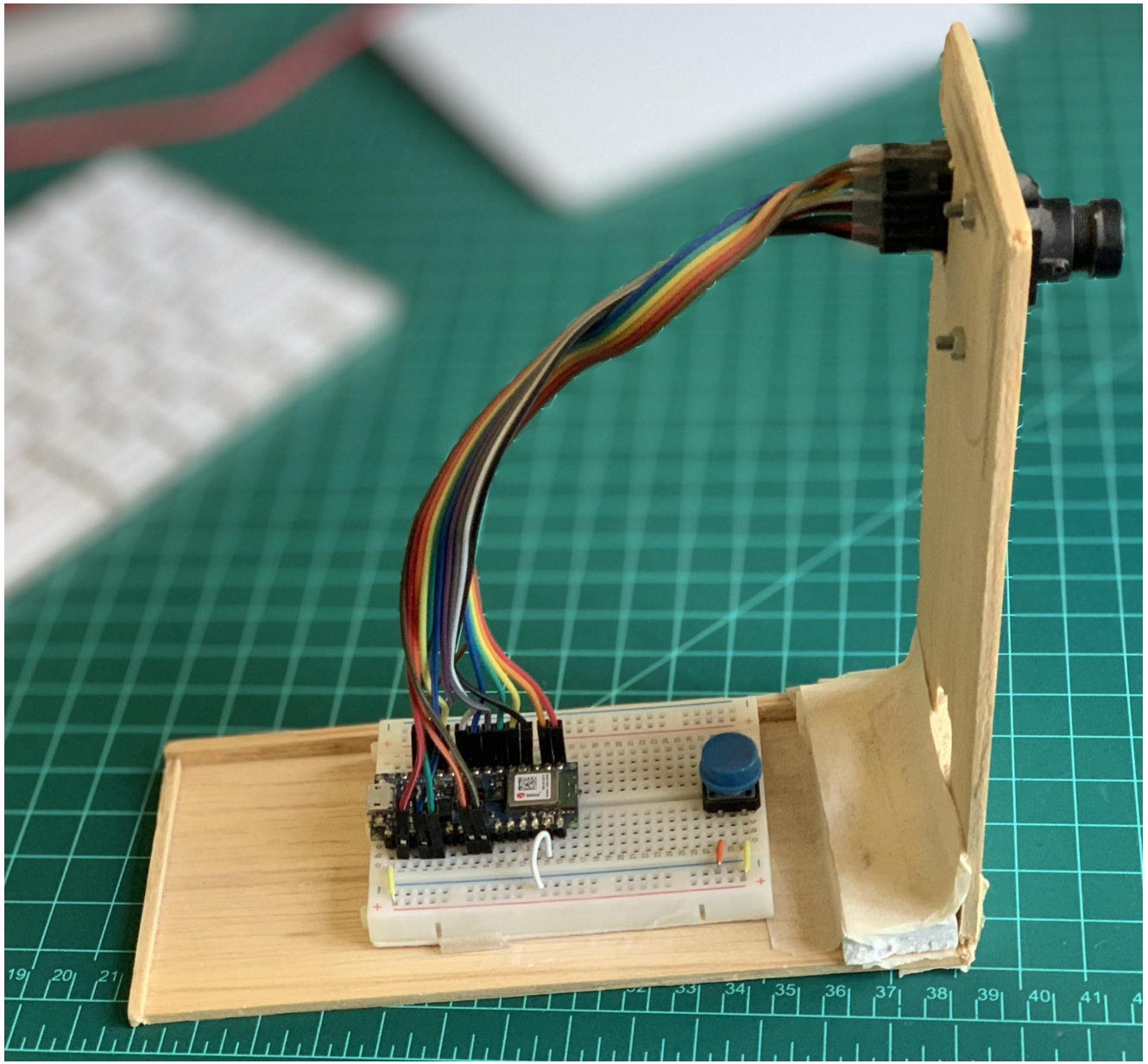


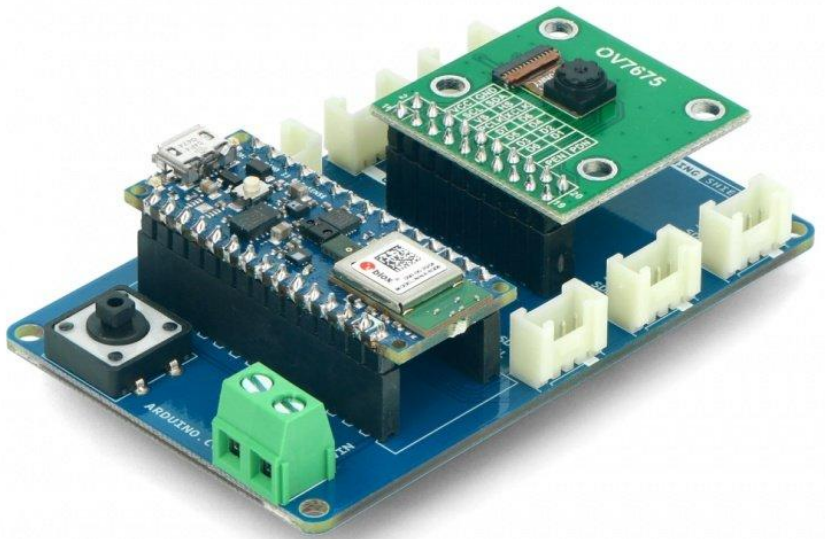
TinyML Shield

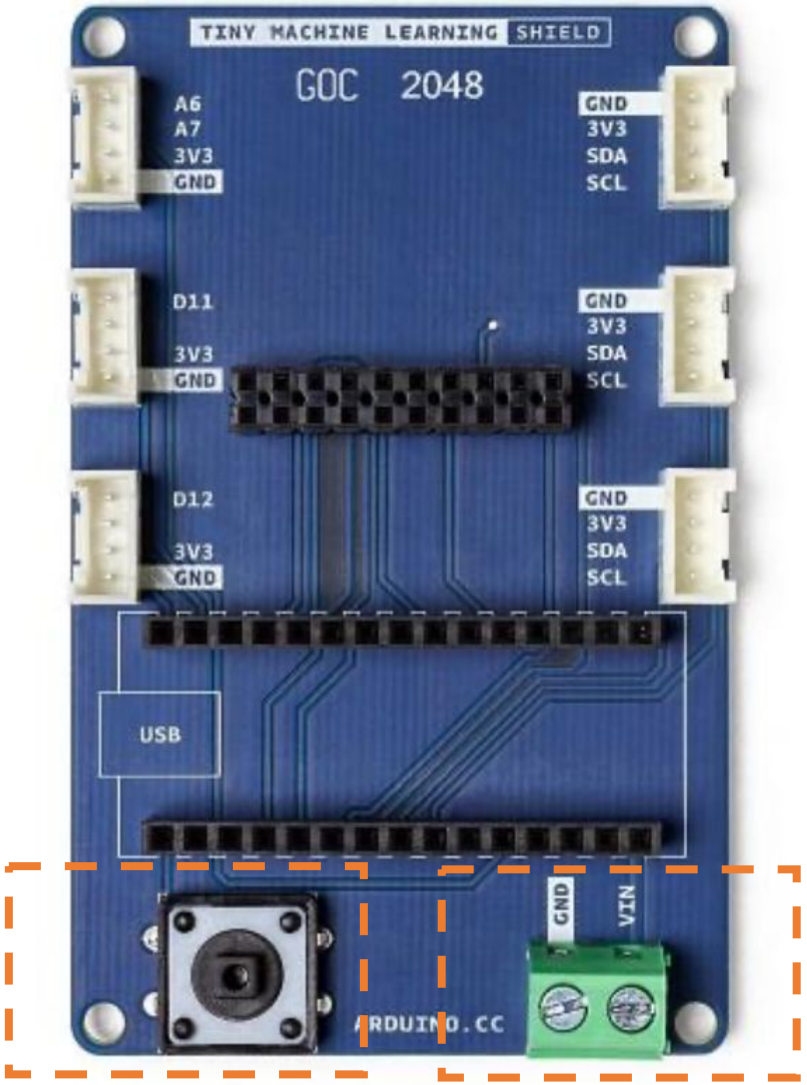
2x10 header that is intended to receive the corresponding pins of the OV7675 camera module



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

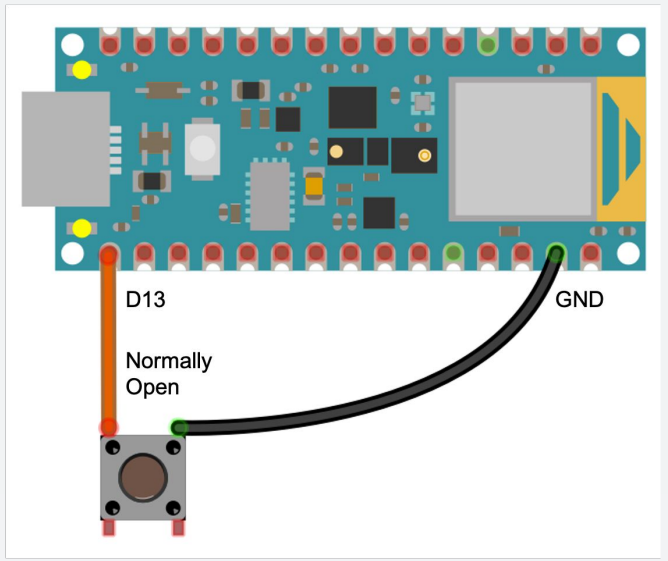



OV7675

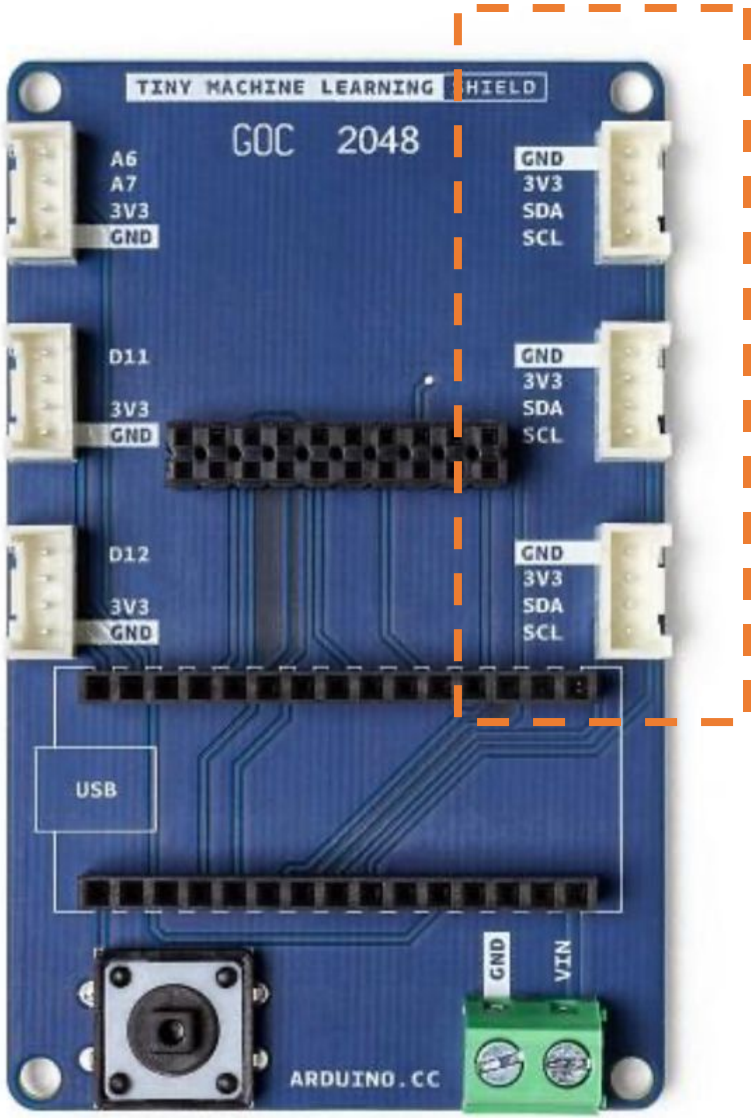


TinyML Shield

A easily programmable button on the left

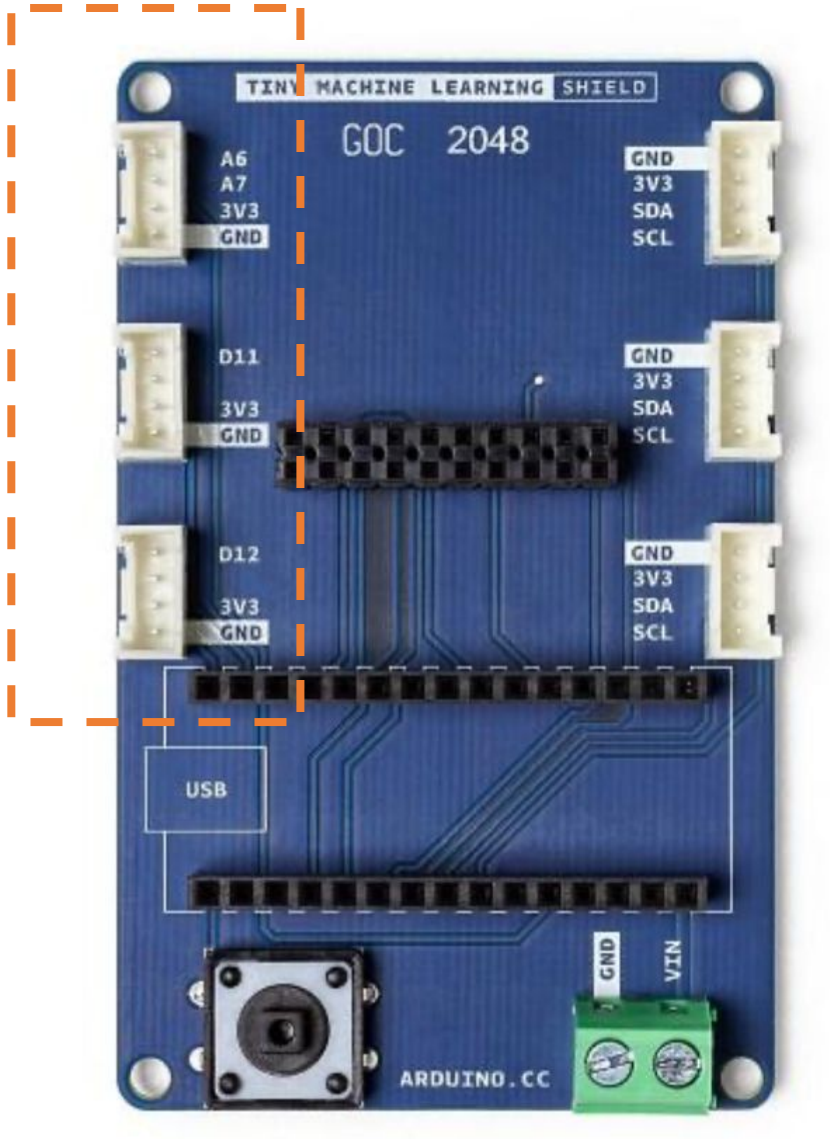


Screw-in terminal block for external (battery) power (4.5V to 21V)



TinyML Shield

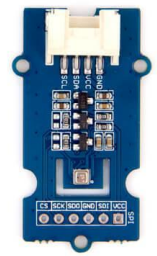
Standard Grove connectors, to permit serial communication (I2C = power + data + clock) with modules (both sensors and actuators)



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

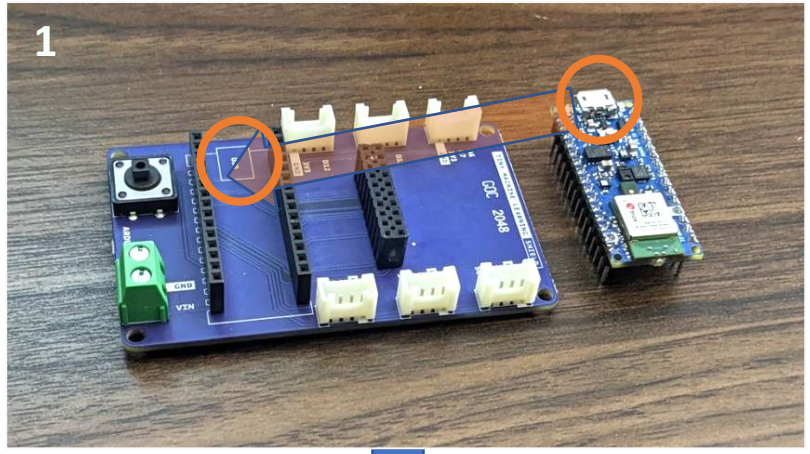
Specifications

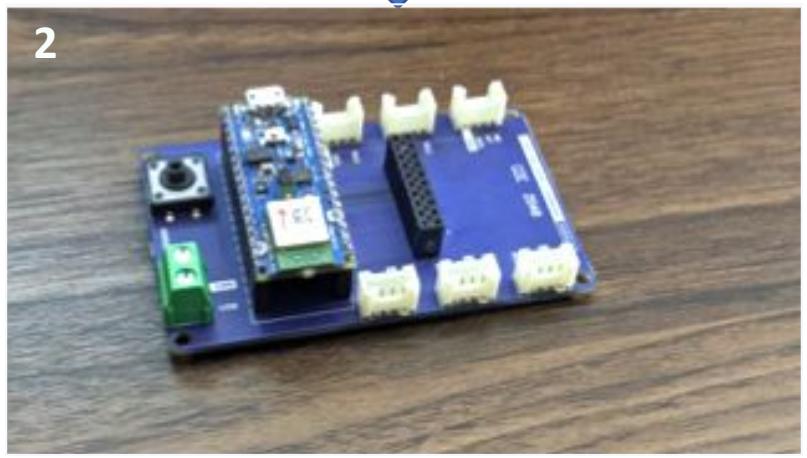
- Proprietary connection system from SeeedStudio, similar to JST PH-type connectors
- Large catalog of sensors, actuators available at seeedstudio.com
- Be sure to check the voltage requirements and pinout of any new Grove module for compatibility with this shield before purchasing or connecting said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

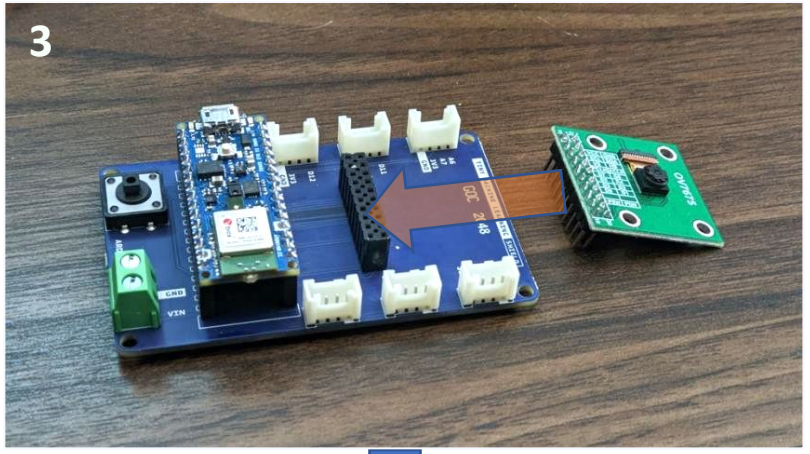
TinyML Kit Installation

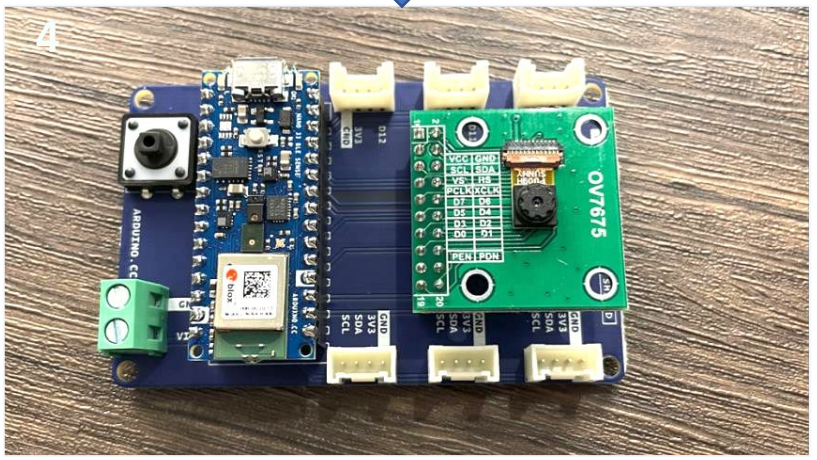
- Hardware Set-up
- Software Set-up

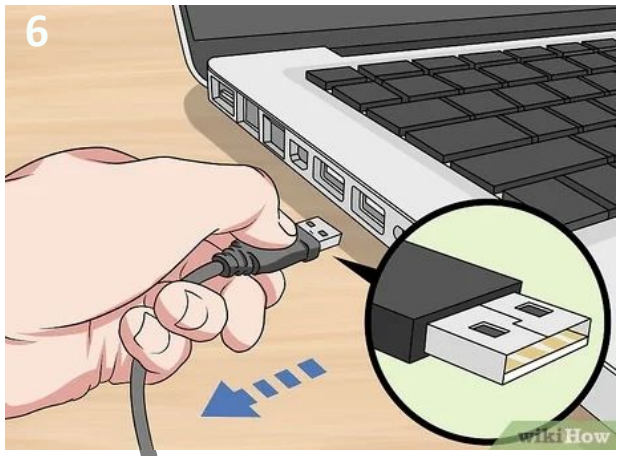
Installing the Hardware



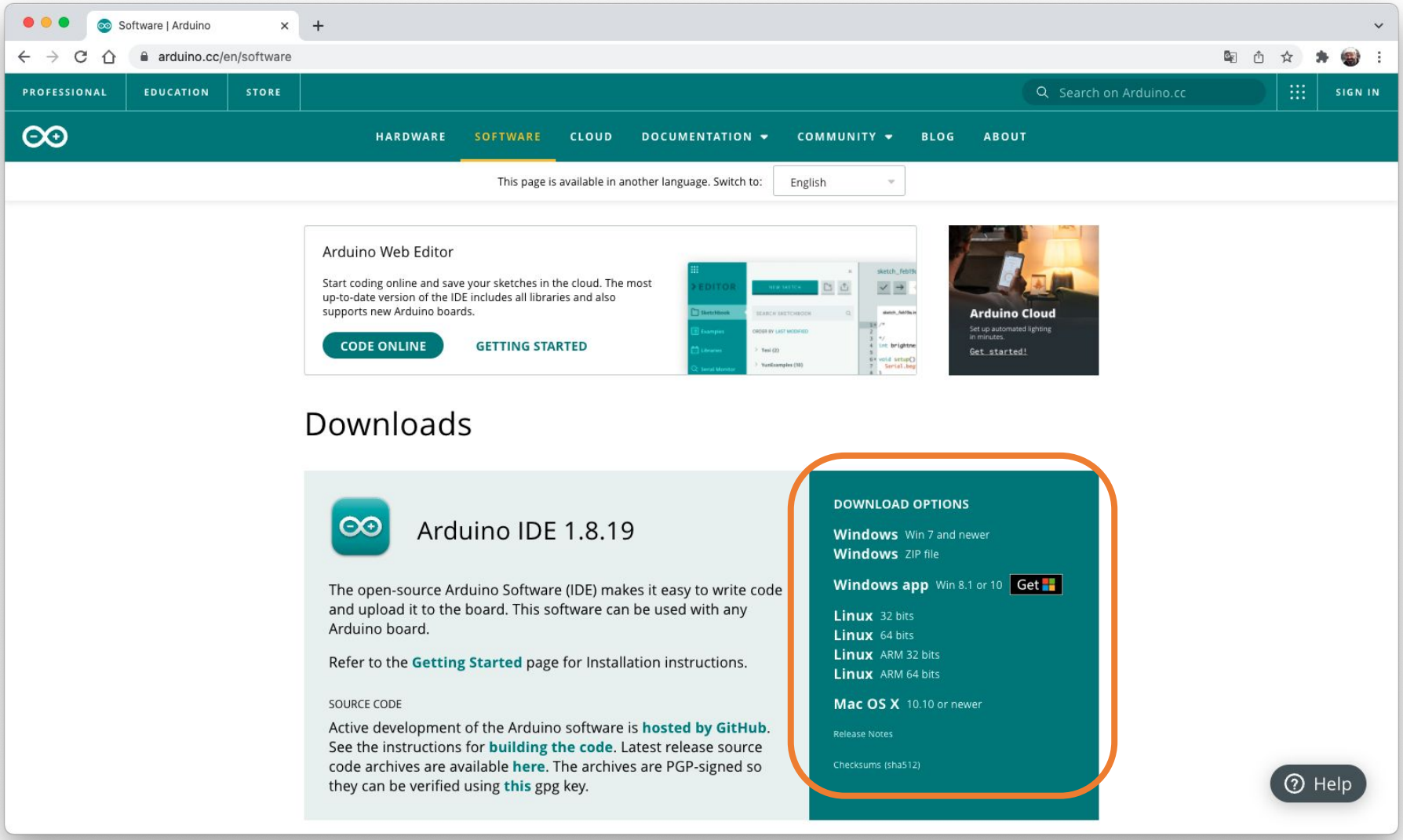








Installing the Arduino IDE

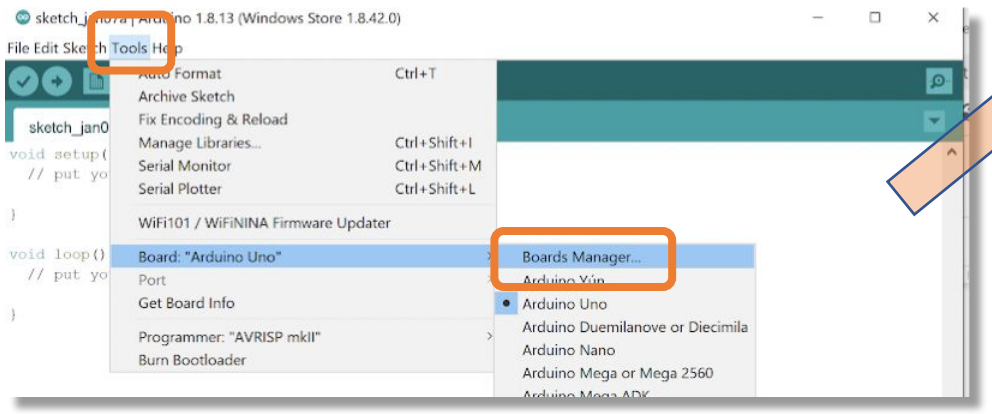


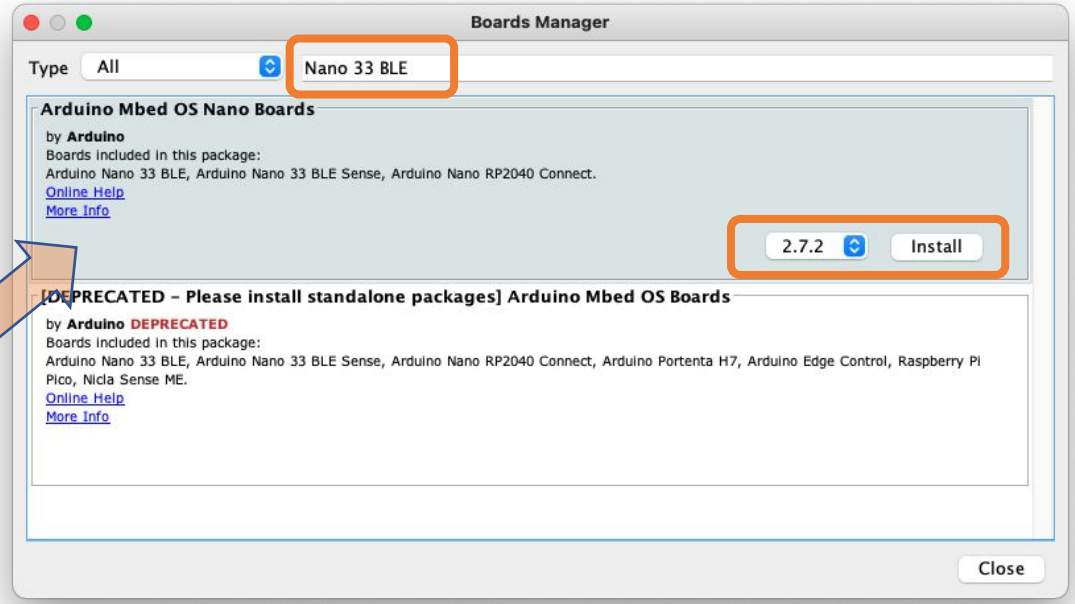
Menus and ToolBar

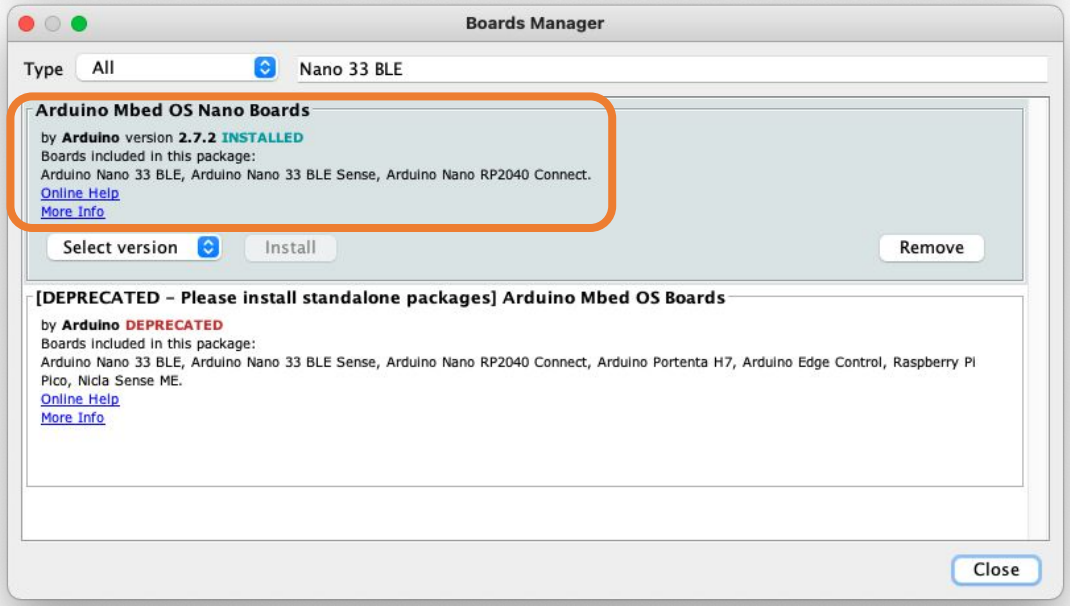
Code Area

Console

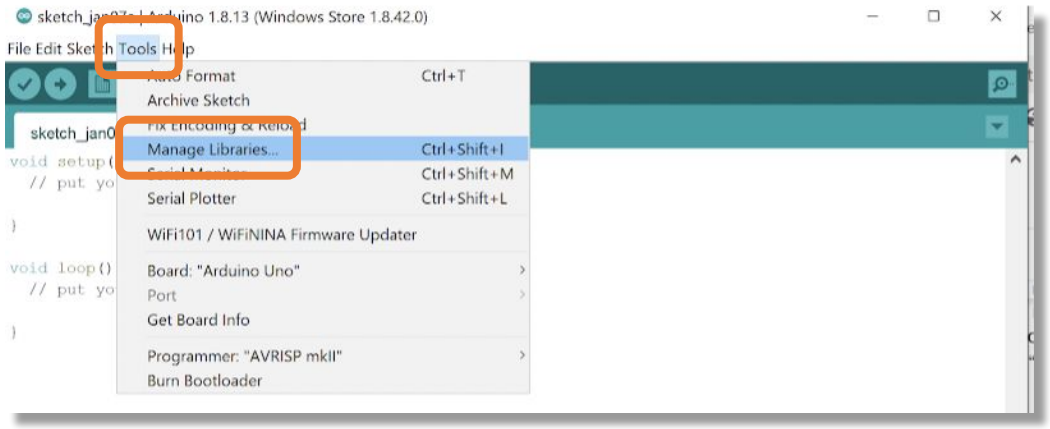
Installing the Board Files

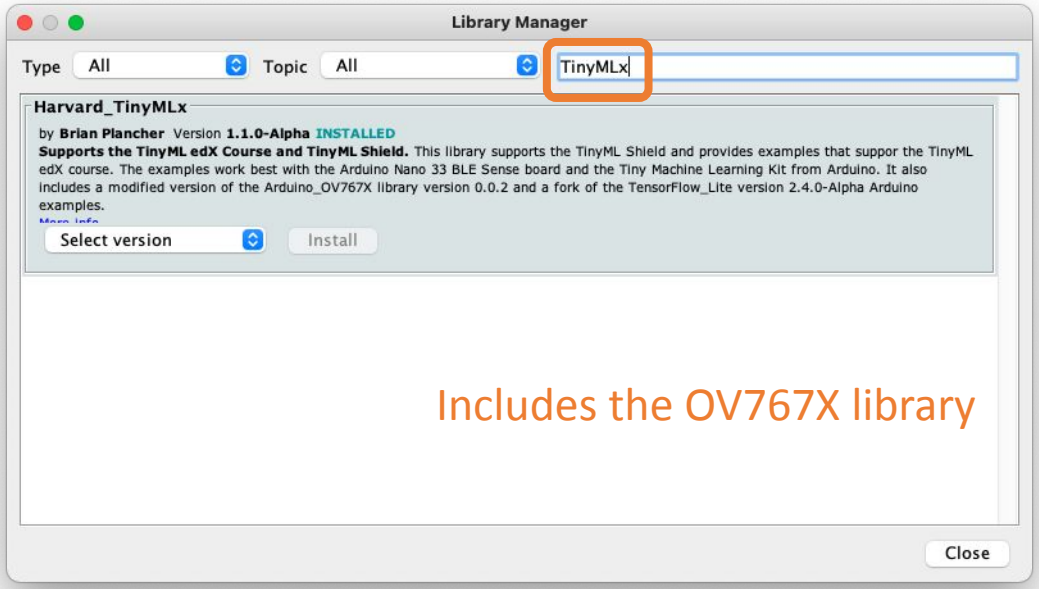




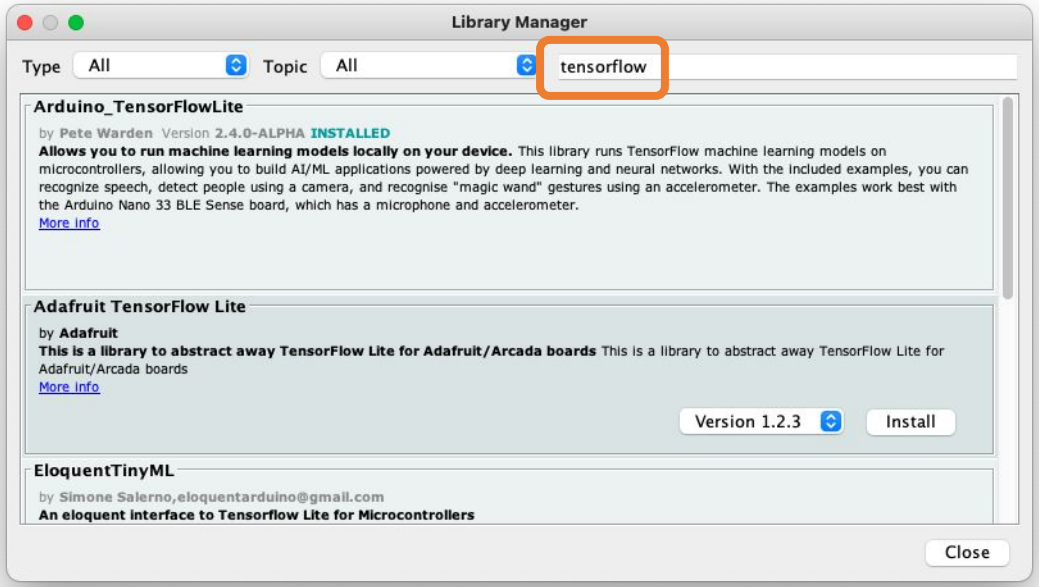


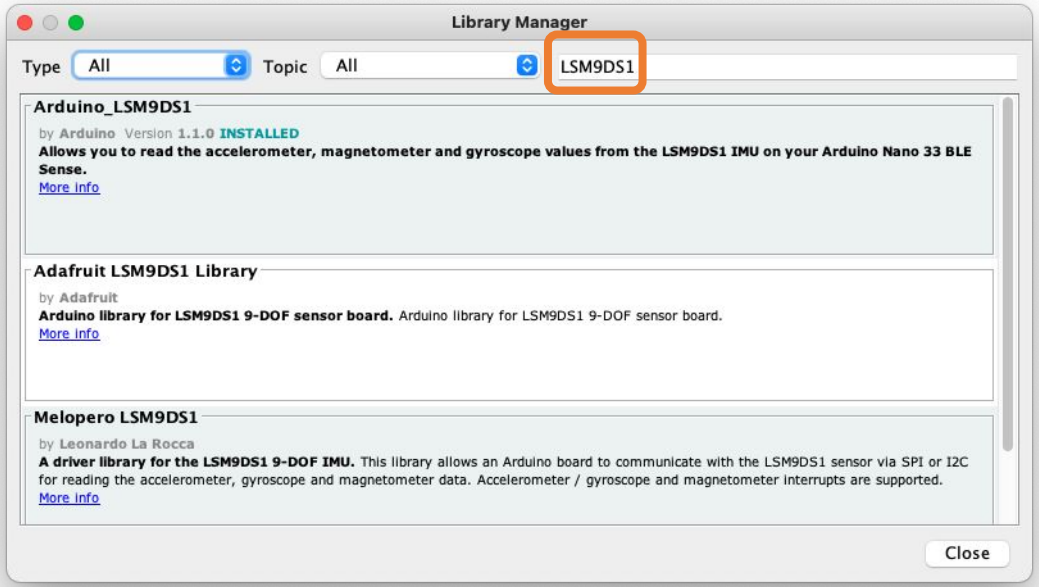
Installing the Main Libraries





Includes the OV767X library

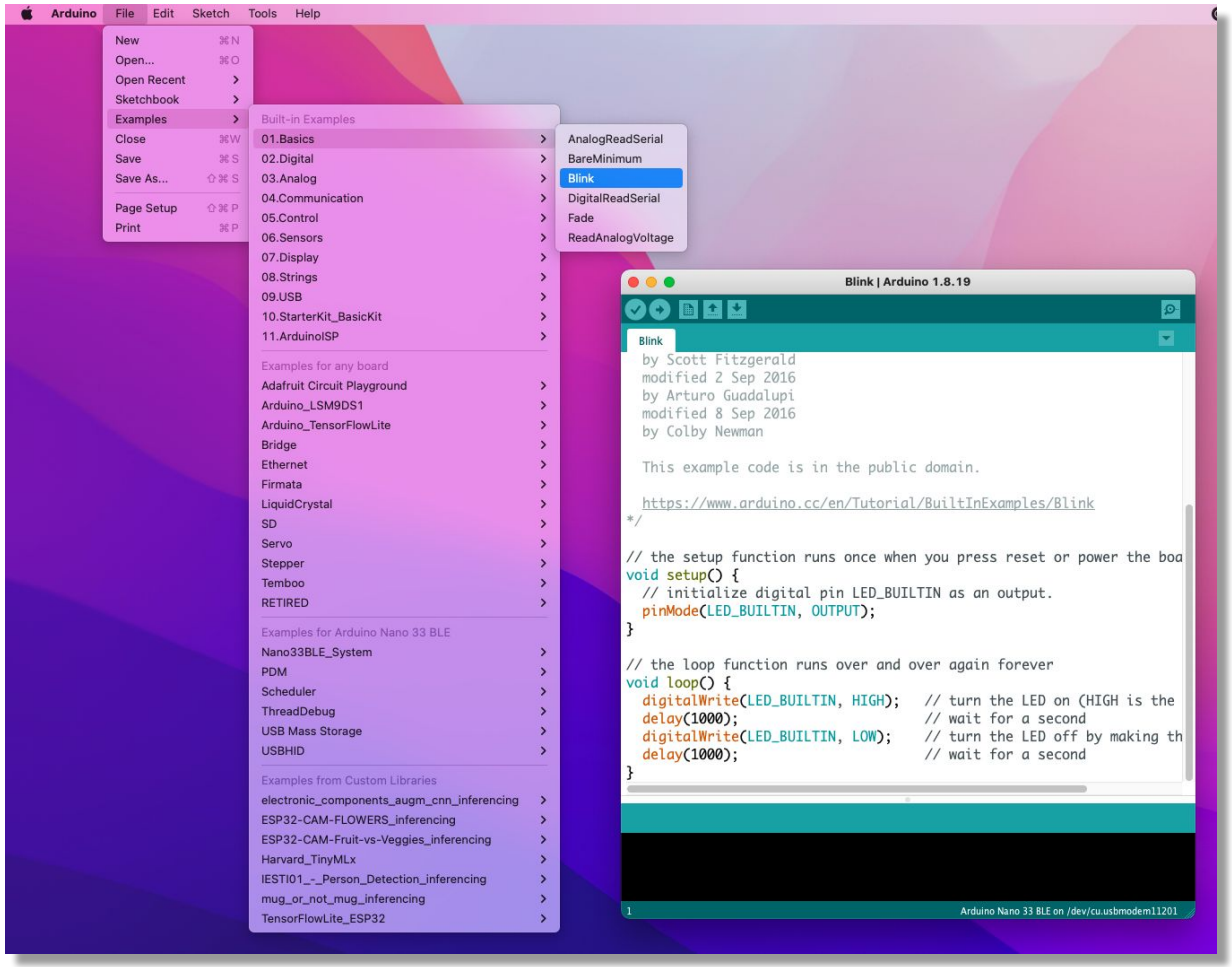


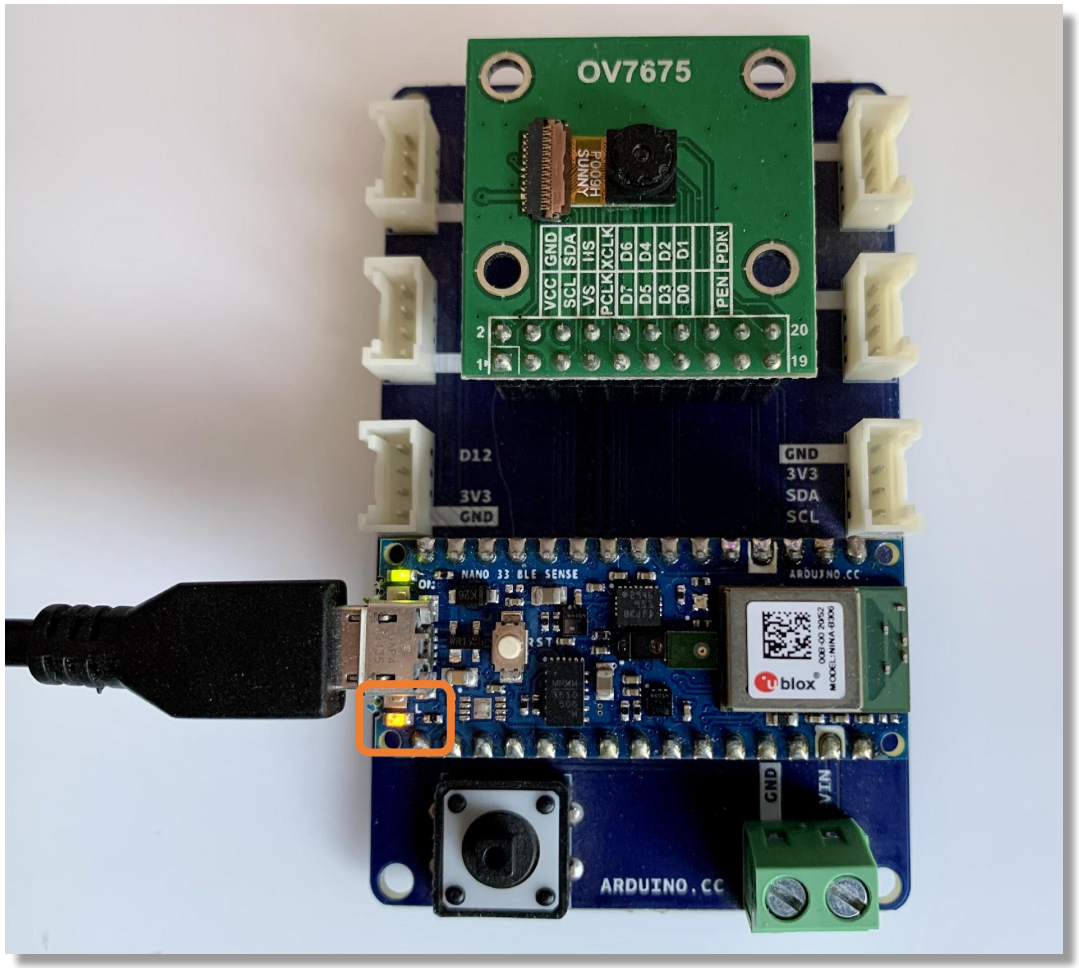


TinyML Kit Test

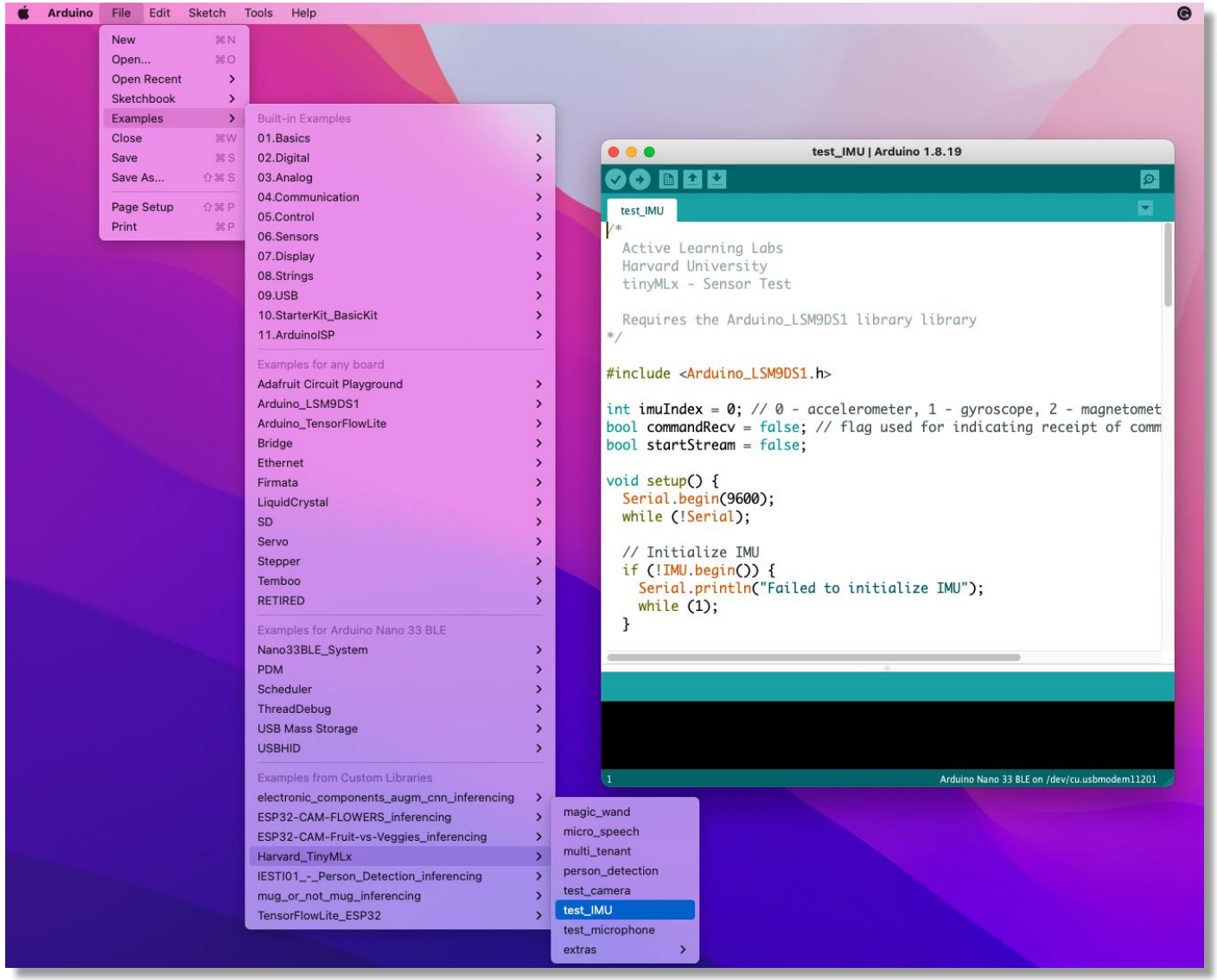
- MCU test (Blink)
- Sensors Test (IMU, MIC, CAMERA)

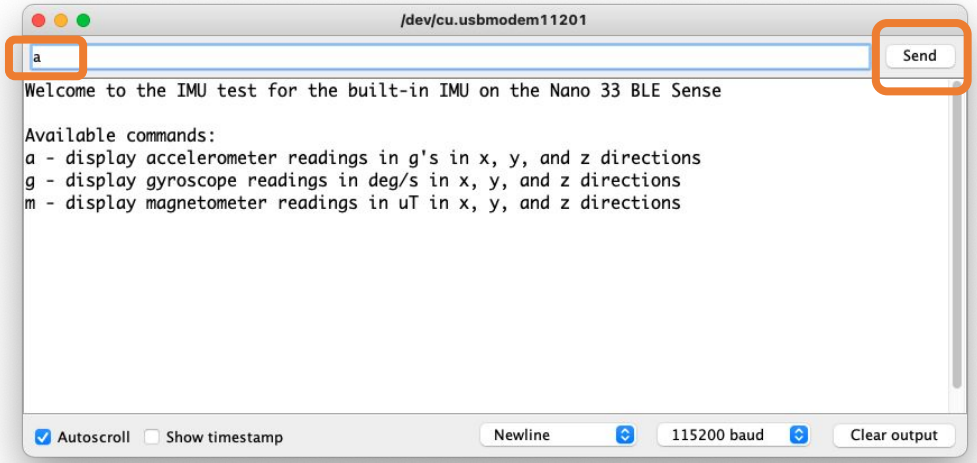
MCU installation test (Blink)

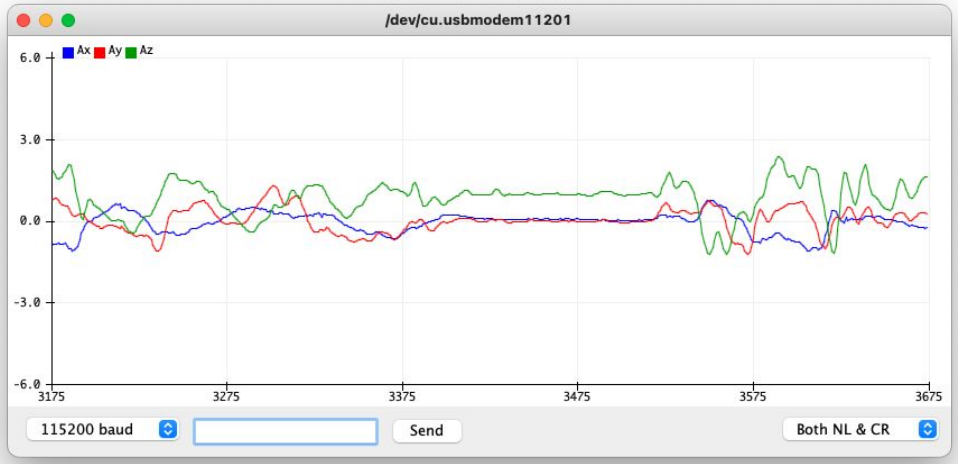




Testing IMU

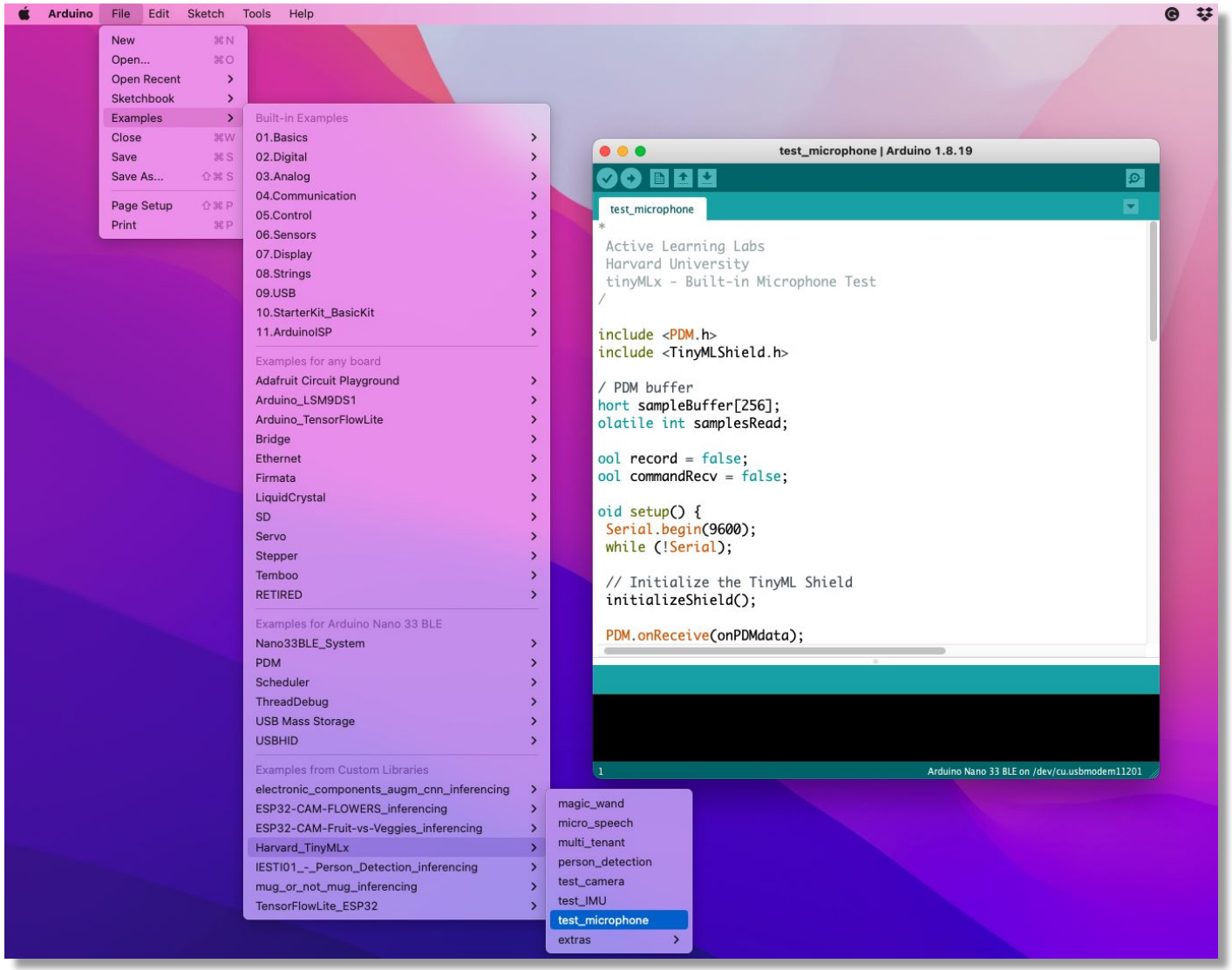


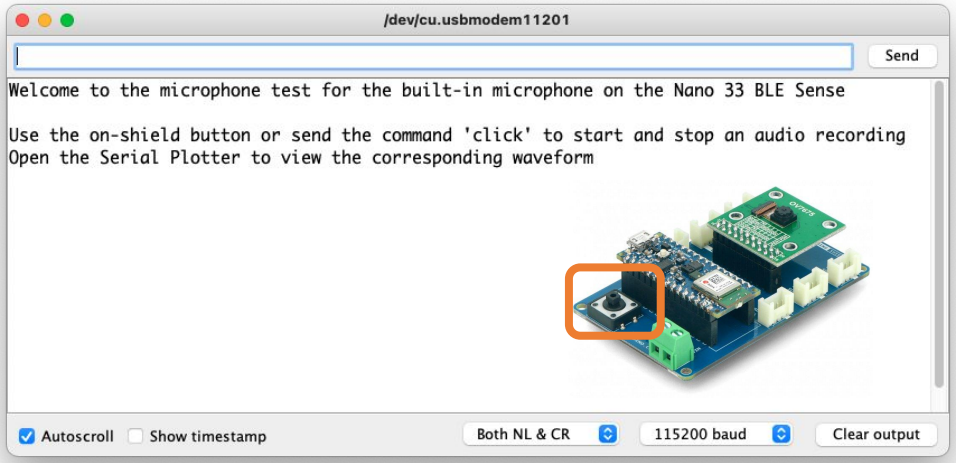


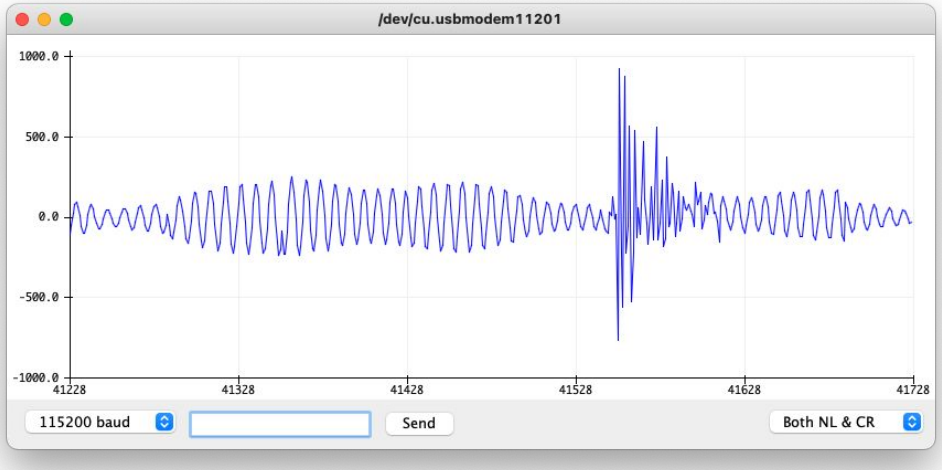


Notes: Close the Serial Monitor before open the Plotter
Repeat test for 'g' and 'm'

Testing Microphone

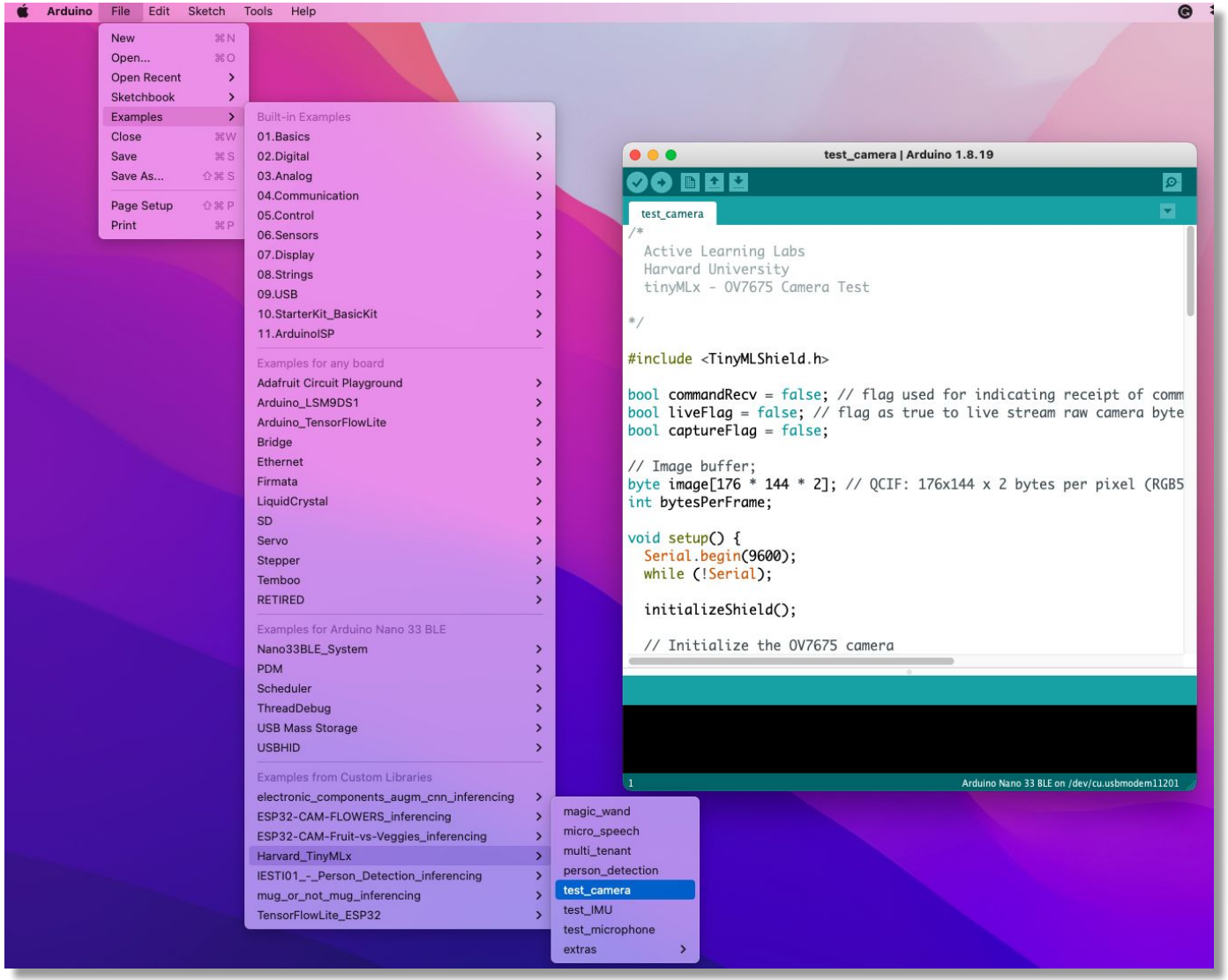


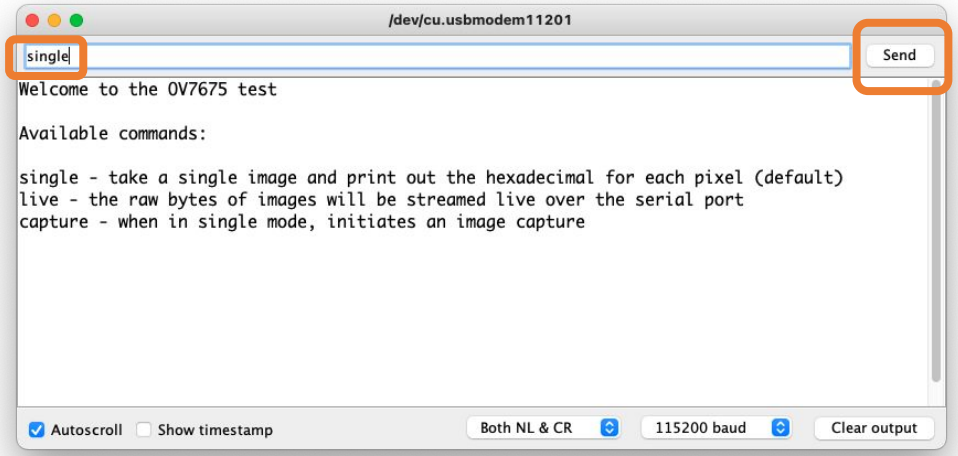


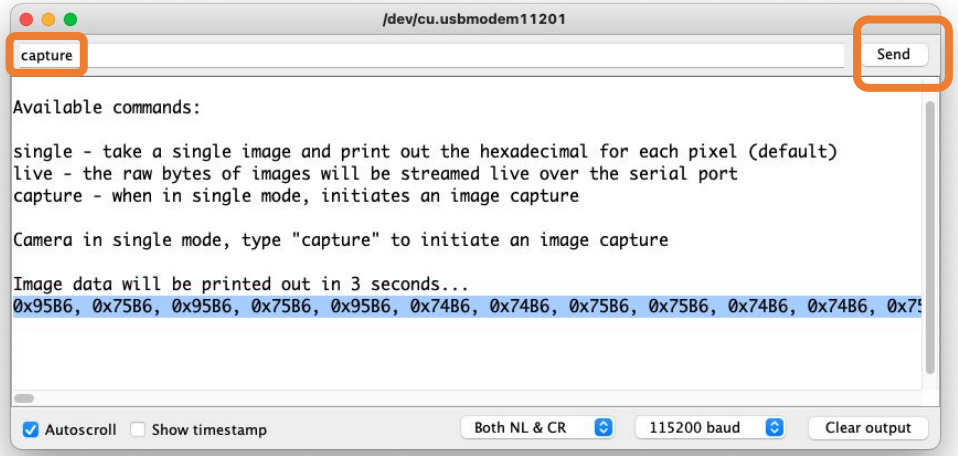


Note: Close the Serial Monitor before open the Plotter

Testing Camera

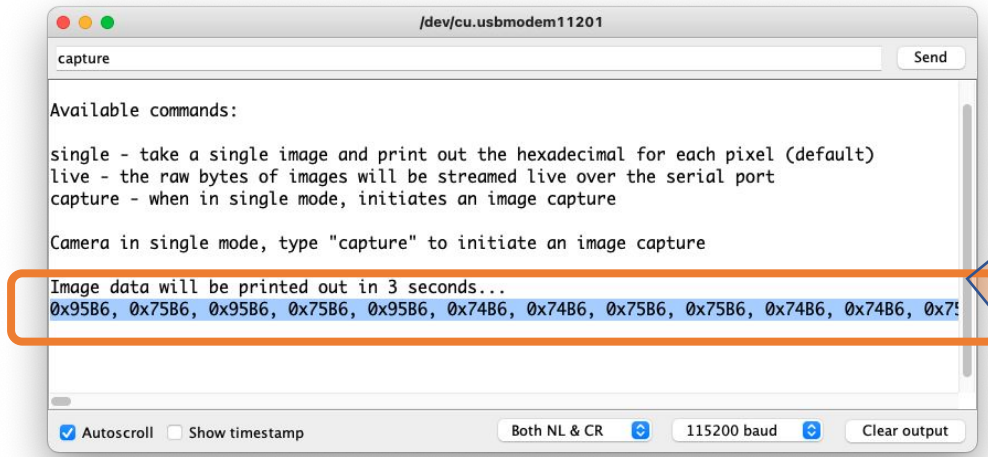


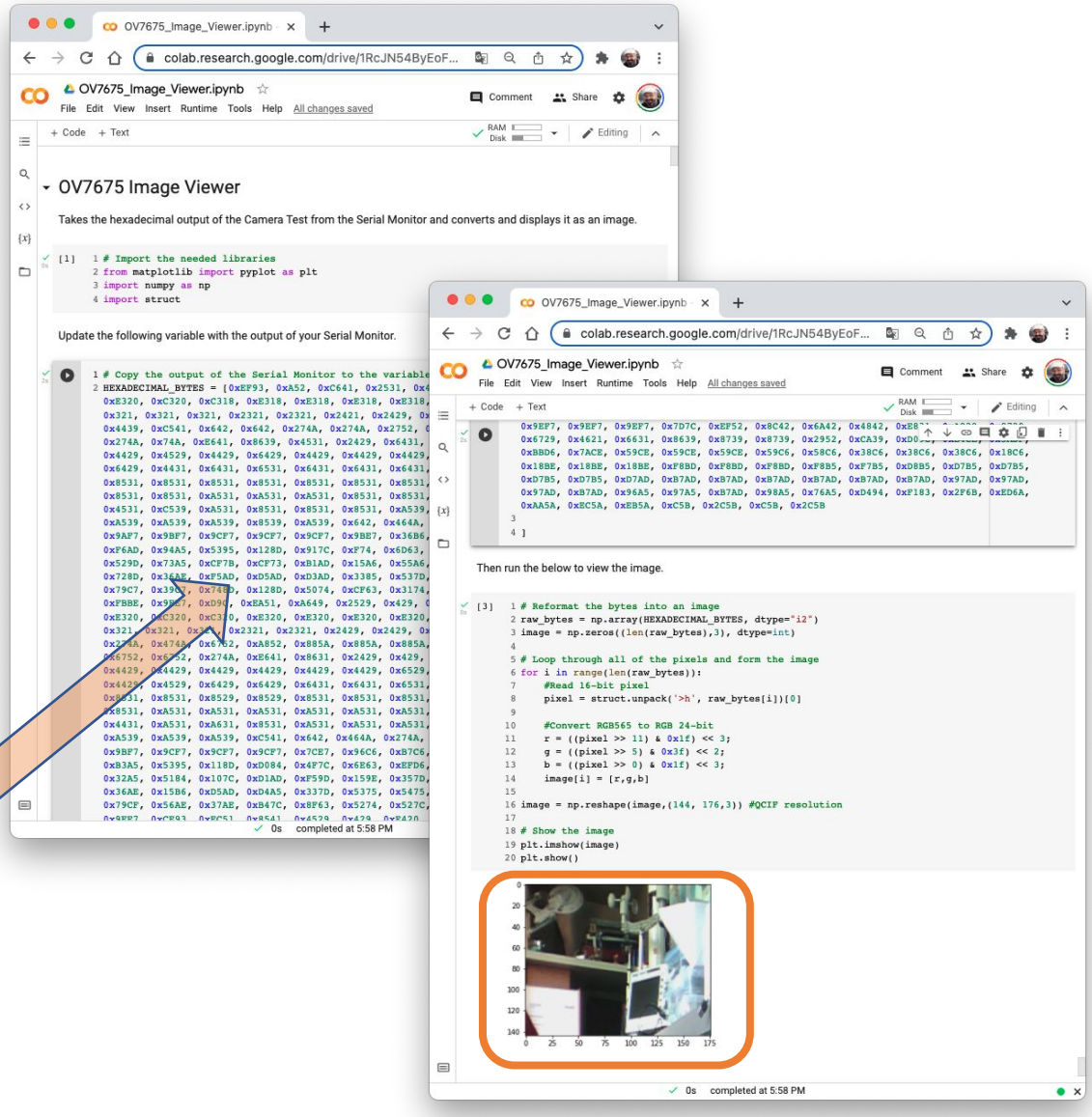




Note: You can Press Button insteady send ‘capture’

Testing Camera





Optional Tests (RGB LEDs)

bilnk_RGB | Arduino 1.8.19

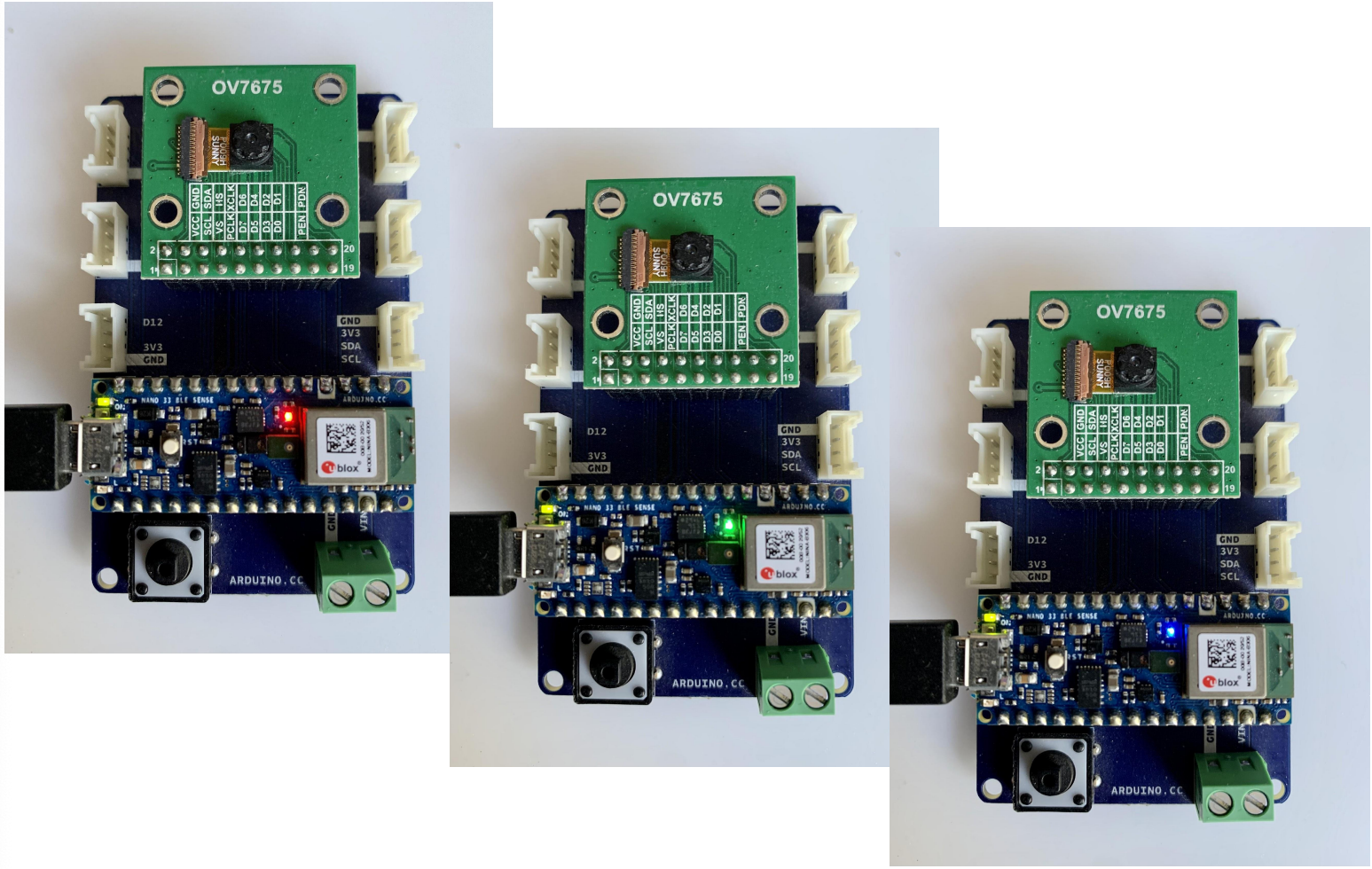
bilnk_RGB

```
void setup() {

  // Pins for the built-in RGB LEDs on the Arduino Nano 33 BLE Sense
  pinMode(LEDR, OUTPUT);
  pinMode(LEDG, OUTPUT);
  pinMode(LEDB, OUTPUT);

  // Note: The RGB LEDs are ON when the pin is LOW and off when HIGH.
  digitalWrite(LEDR, HIGH);
  digitalWrite(LEDG, HIGH);
  digitalWrite(LEDB, HIGH);
}

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

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

  digitalWrite(LEDB, LOW);
  delay(1000);
  digitalWrite(LEDB, 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)

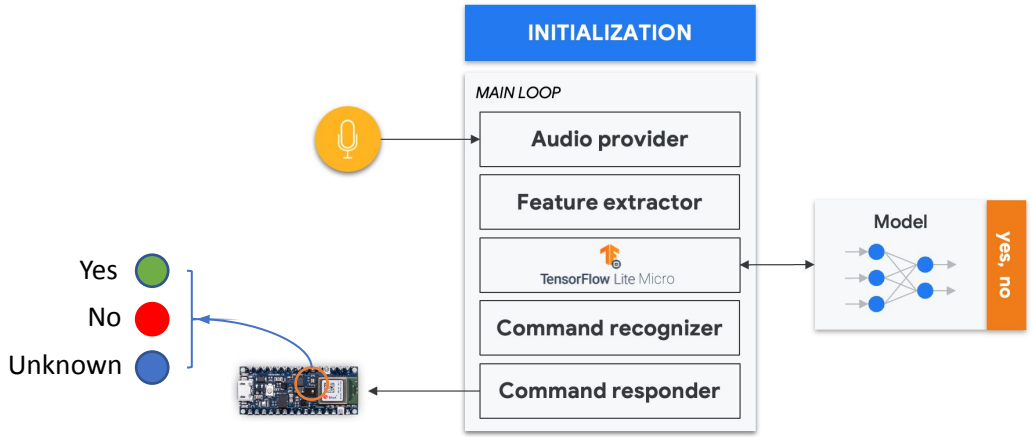
micro_speech | Arduino 1.8.19

micro_speech | arduino_audio_provider.cpp | arduino_command_responder.cpp | arduino_l...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

Send

```
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

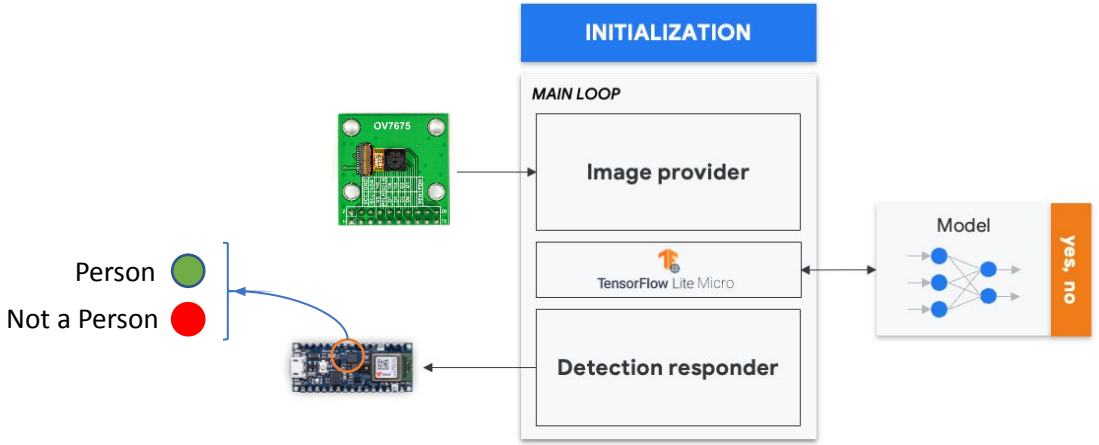
person_detection | arduino_detection_responder.cpp | arduino_image_provider.cpp | arduir ▾_mai

```
#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

Reading Material

Main references

- Harvard School of Engineering and Applied Sciences - CS249r: Tiny Machine Learning
- Professional Certificate in Tiny Machine Learning (TinyML) – edX/Harvard
- Introduction to Embedded Machine Learning - Coursera/Edge Impulse
- Computer Vision with Embedded Machine Learning - Coursera/Edge Impulse
- Fundamentals textbook: "Deep Learning with Python" by François Chollet
- Applications & Deploy textbook: "TinyML" by Pete Warden, Daniel Situnayake
- Deploy textbook "TinyML Cookbook" by Gian Marco Iodice

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Thanks

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