

August 27, 2021

Current

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1 Target Audience

This tutorial is intended for users of the Syntiant TinyML board who are:

- Subject matter experts with limited knowledge of Artificial Intelligence (AI) system design
- Professional firmware developers getting into AI system design
- Professors, students, AI enthusiasts and hobbyists

2 Prerequisites and Materials

Experience with the following is recommended for this tutorial:

- Basic knowledge of Artificial Intelligence, Neural Networks and TensorFlow
- Windows 10 compatible laptop
- A Chrome web browser is recommended
- Account with Edge Impulse
- Syntiant TinyML board
- Micro-USB cable to connect your Laptop/PC to the TinyML board

3 Tutorial Coverage

What is covered in this tutorial:

- Collecting data for testing
- Training a neural network
- Testing a neural network in a software flow
- Creating a voice controlled remote car controller which responds to two speech commands: “Go” and “Stop”, using the Syntiant TinyML board

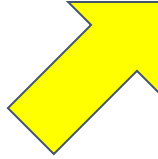
What is not covered in this tutorial:

- Collecting data for training
- Data alignment and annotation
- Automatic posterior parameter search
- Testing for False Rejection Rate (FRR) or False Acceptance Rate (FAR) within the software flow
- Optimization for FRR
- Optimization for FAR

4 Tips for this Tutorial

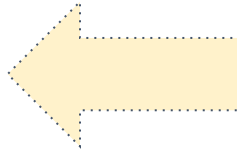
Through the course of this tutorial, you will need to click on multiple GUI buttons:

- An arrow with a solid line which you click the mouse on the application:



Sign for clicking

- An arrow with a dotted line is used to indicate verification of a step:



Sign for verification

Text color and font usage

- Warning text is written in **red** color
- Blue *text* in italics font is used to represent text used “as is” in other documentation, software etc.

Please note that the screenshots might differ from what is published in this tutorial, based on the specific operating system revision loaded on your computer. In the unusual case where you run into issues completing this tutorial, please contact tinymml@syntiant.com for help. There is also a [FAQ](#) published which might provide additional support as well

5 Syntiant TinyML board Block Diagram

The block diagram of the Syntiant TinyML board is shown in the figure below

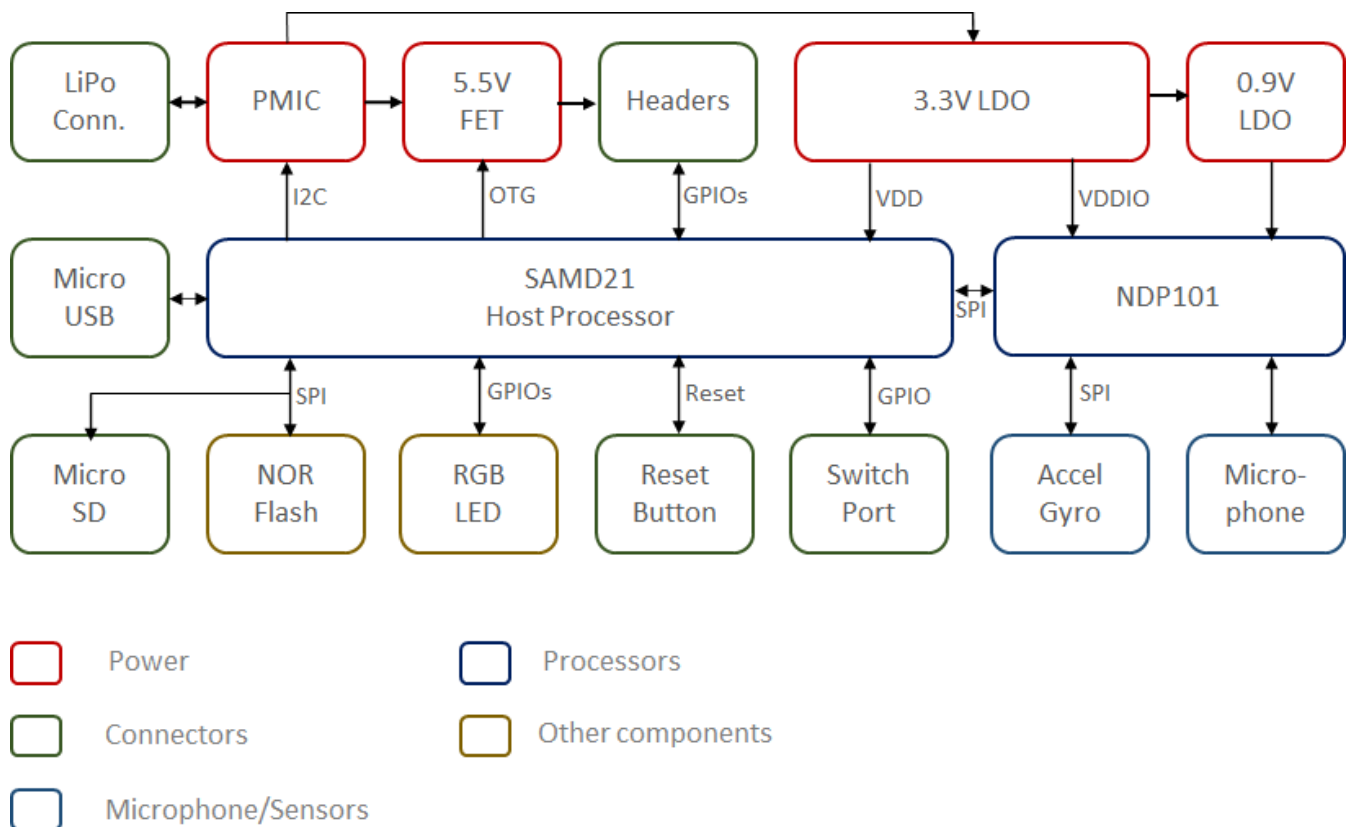


Figure 1 Syntiant TinyML Board Block Diagram

Key features of the Syntiant TinyML board include:

- Neural Decision Processor: NDP101
- Host processor: SAMD21 Cortex-M0+ 32bit low power ARM MCU, including
 - 256KB flash memory
 - 32KB host processor SRAM
- Board power supply: 5V micro-USB or 3.7V LiPo battery
- Digital I/Os compatible with Arduino MKR series boards
- 1 UART interface (included in the digital I/O Pins)
- 1 I2C interface (included in the digital I/O Pins)
- 2MB on-board serial flash
- 48MHz system clock
- One user defined RGB LED
- µSD card slot (µSD card not included)

TinyML Tutorial

- BMI160 6 axis motion sensor
- SPH0641LM4H microphone

6 Syntiant TinyML board Annotation

The annotation of the Syntiant TinyML board is illustrated in the figure below

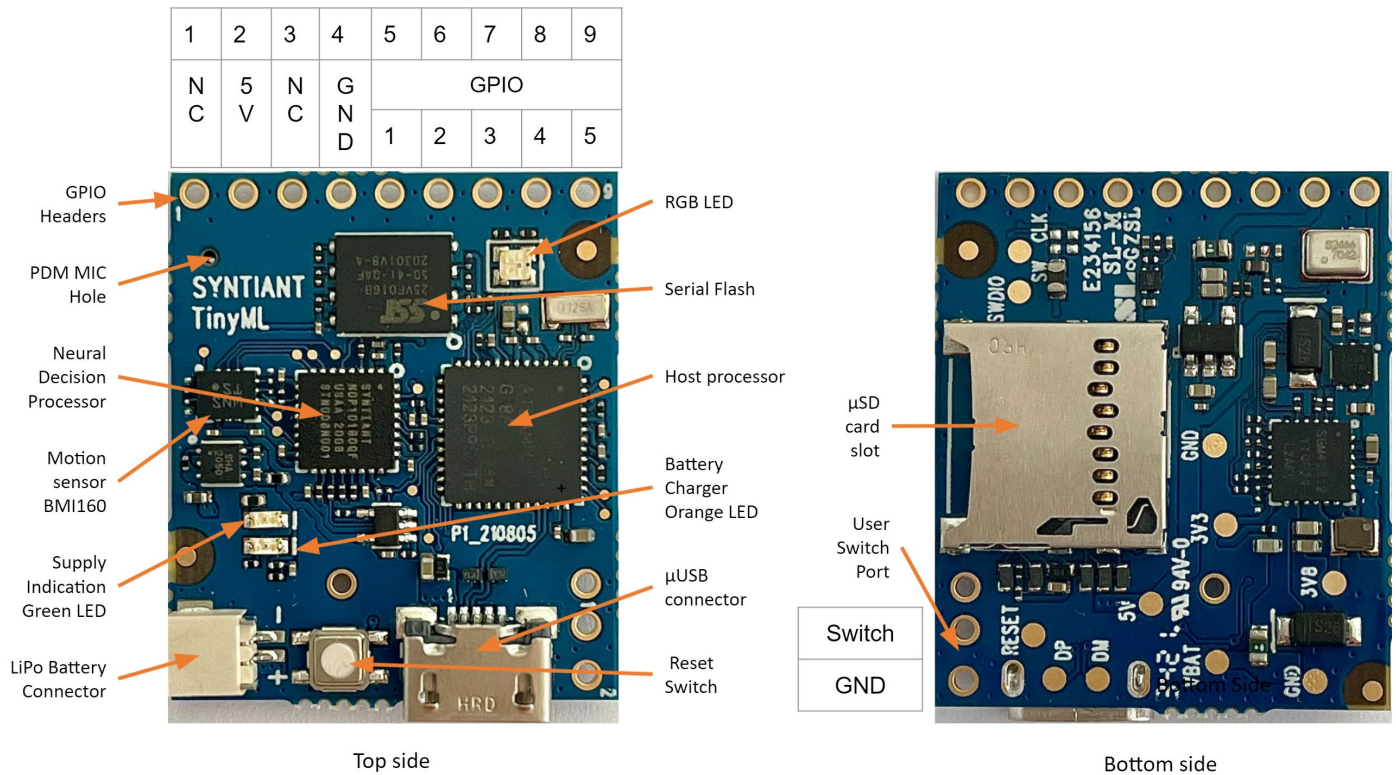


Figure 2 Syntiant TinyML Board Annotation

7 Tutorial Overview

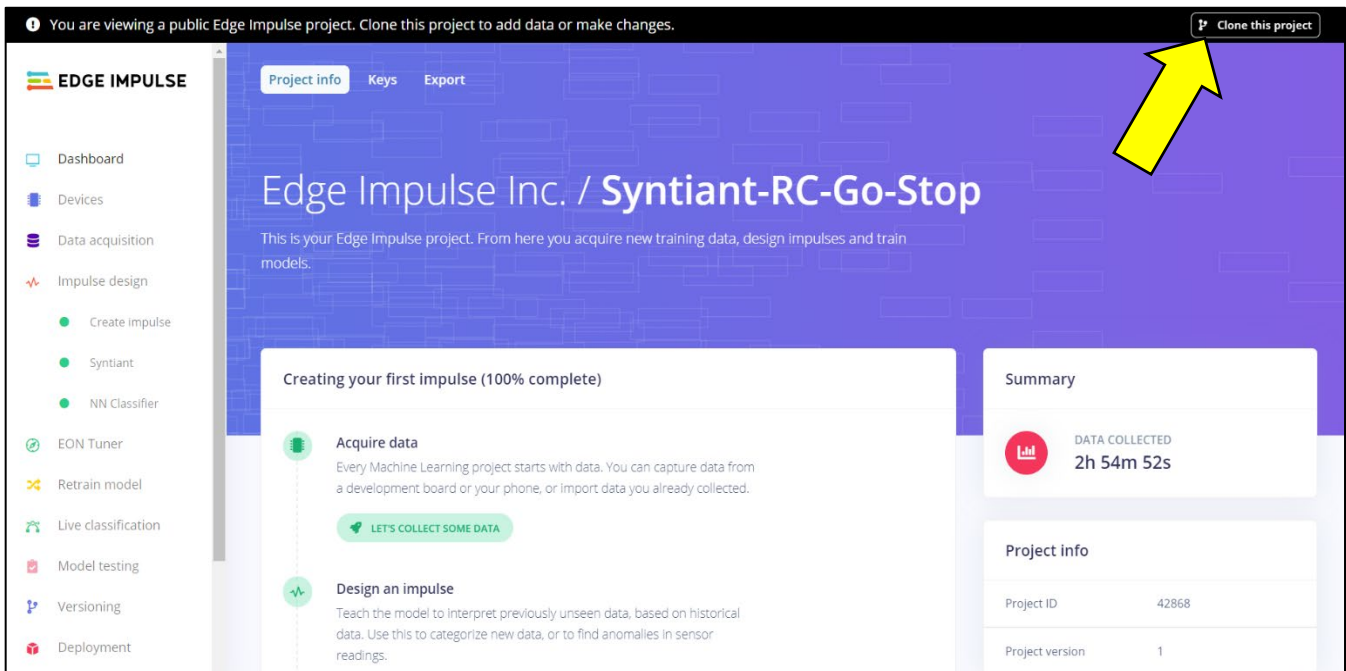
There are 3 sections to completing this tutorial:

1. Machine Learning
This section is common for all operating systems
2. Deployment
3. Real-Time Testing

8 Section 1 – Machine Learning

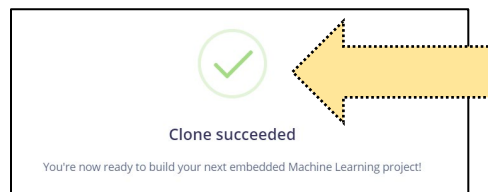
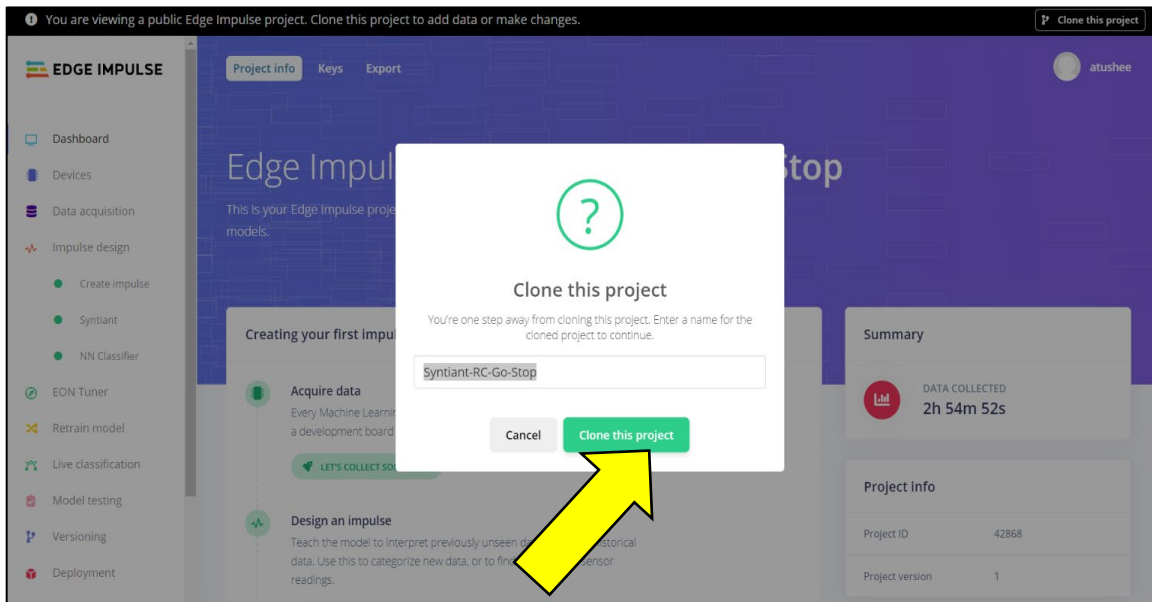
In this section you will learn to how to generate a neural network model which will work the Syntiant TinyML board. Start by cloning the Go/Stop Project from the Edge Impulse website by following these steps

- Click on this link: [Tutorial: Syntiant-RC](#). A new browser window will open as shown below.
- Click on [Clone this project](#). If you have not logged in to your already existing Edge Impulse account, it will ask you to create a new account.



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- On the next screen, click on [Clone this project](#). Allow 5-10 minutes to clone the project into your user account. Confirm [Clone succeeded](#).



Review of the Cloned Project

The cloned project is ready and can be downloaded on the [Syntiant TinyML](#) board. However, we will redo some of the steps so that you can get familiar with the process. We will start with exploring the [Data acquisition](#) by following these steps

- Select the [Data acquisition](#) option in the left menu. You will see the right panel change. Click the [filter your data](#) button.

EDGE IMPULSE

DATA ACQUISITION (SYNTIANT-RC-GO-STOP)

Training data Test data

Did you know? You can capture data from any device or development board, or

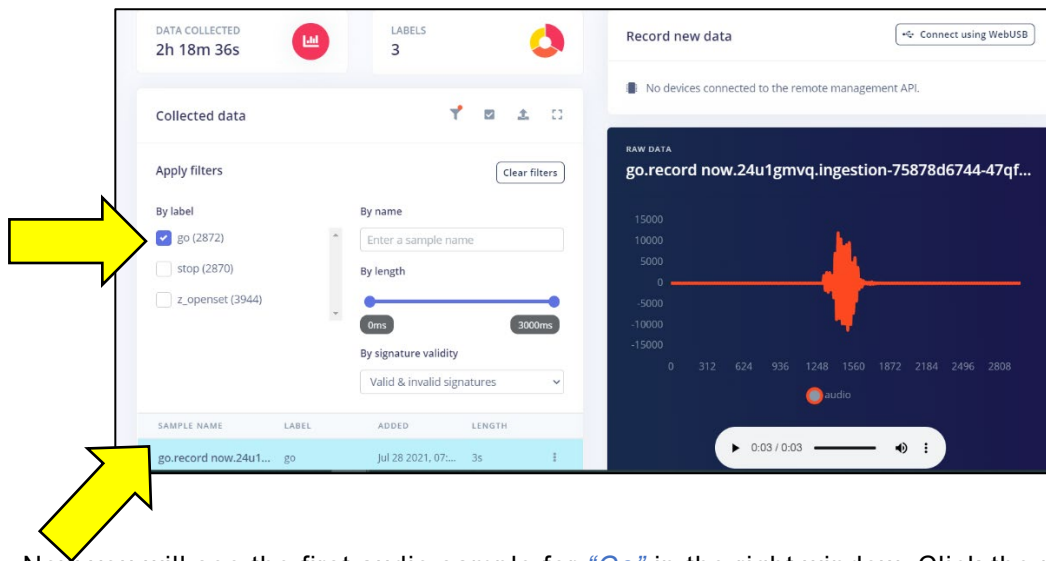
DATA COLLECTED 2h 18m 36s

LABELS 3

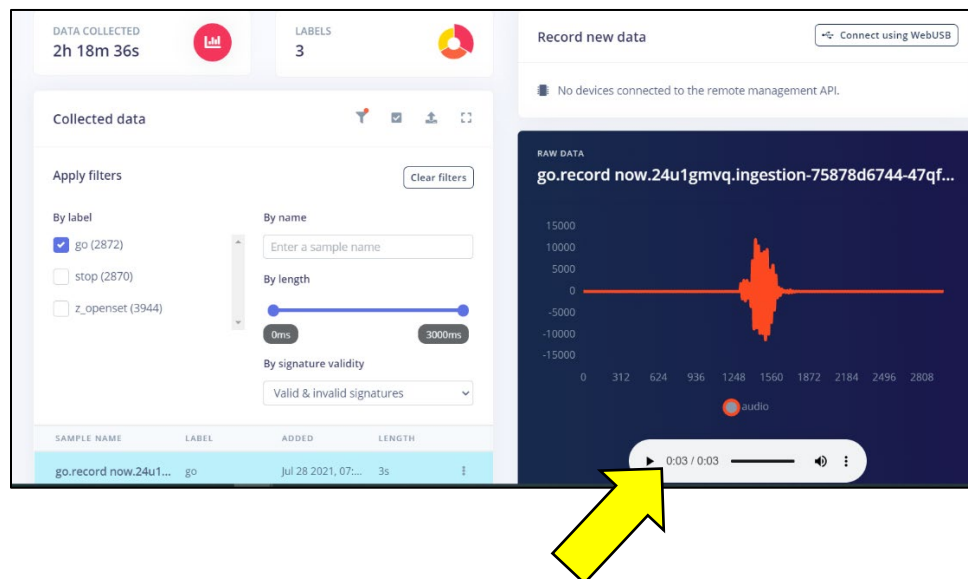
Collected data

SAMPLE NAME	LABEL	DATE	LENGTH
z_openset.helloworl...	z_openset	Jul 28 2021, 07:...	1s
z_openset.helloworl...	z_openset	Jul 28 2021, 07:...	1s
z_openset.helloworl...	z_openset	Jul 28 2021, 07:...	1s
z_openset.helloworl...	z_openset	Jul 28 2021, 07:...	1s
z_openset.helloworl...	z_openset	Jul 28 2021, 07:...	1s
z_openset.helloworl...	z_openset	Jul 28 2021, 07:...	1s

- Now you should see data in the right panel, filtered by label. Unselect *stop* and *z_openset*. Click on the first sample name, which is a sample of the “Go” classifier.



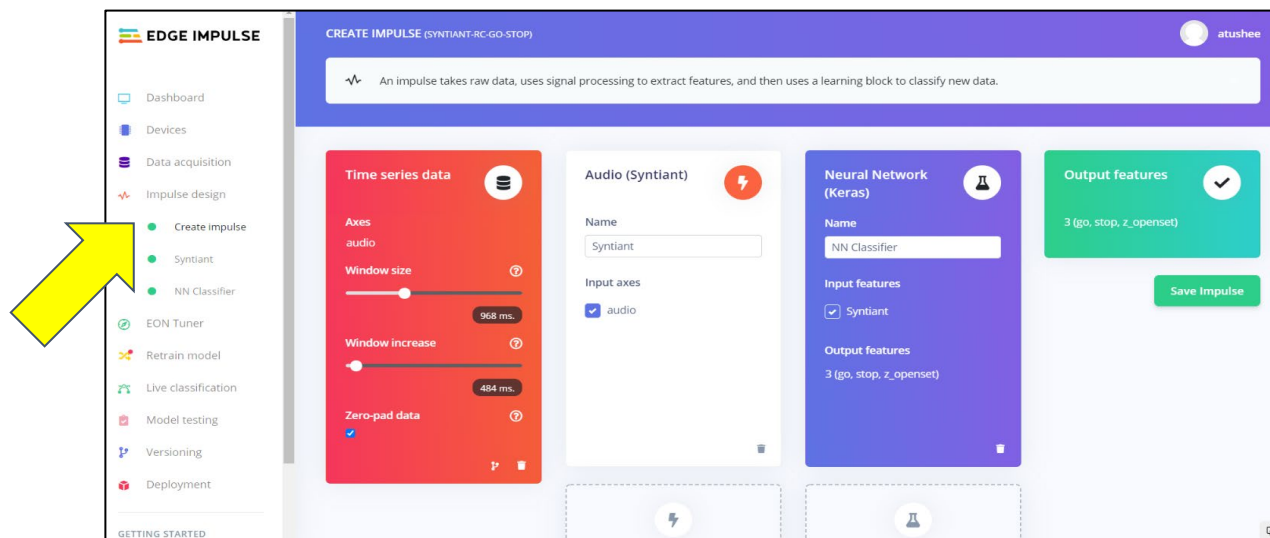
- Now you will see the first audio sample for “Go” in the right window. Click the play button. You will hear the “Go” sound.



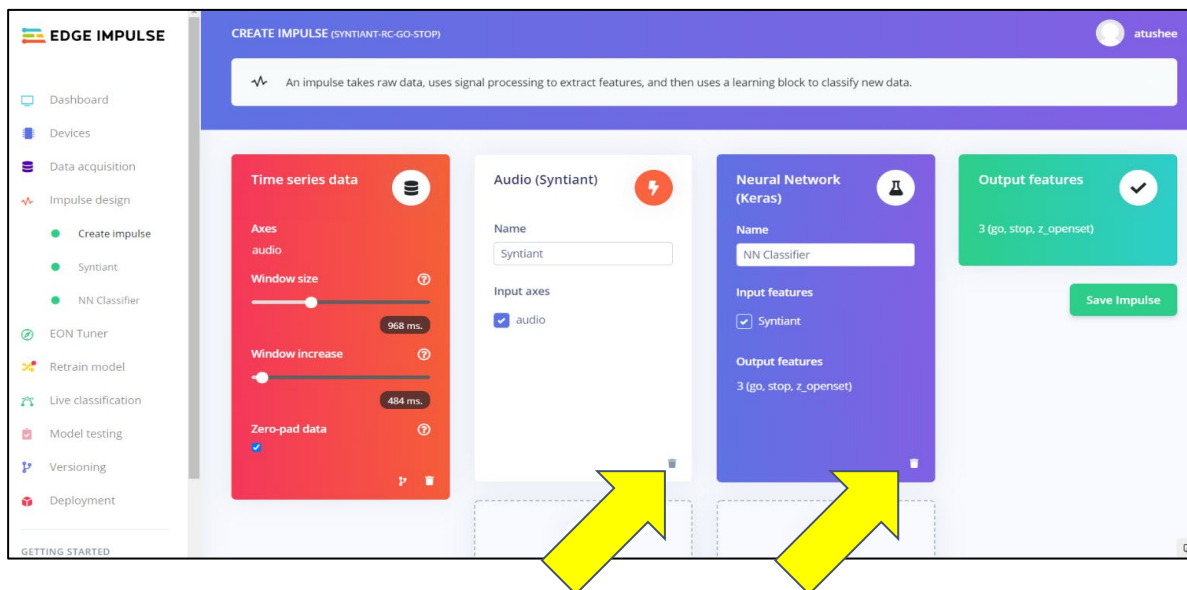
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Next, start the impulse design:

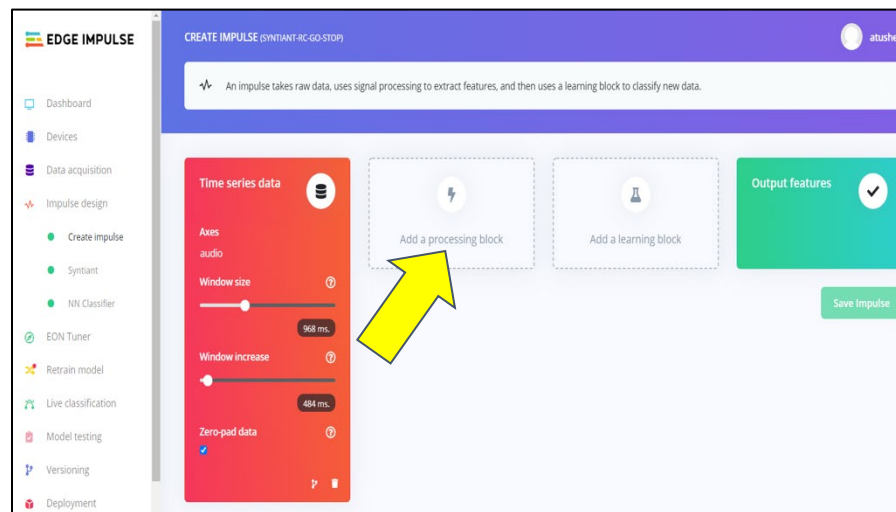
- Click on [Create impulse](#). The right panel will change to what is shown below.



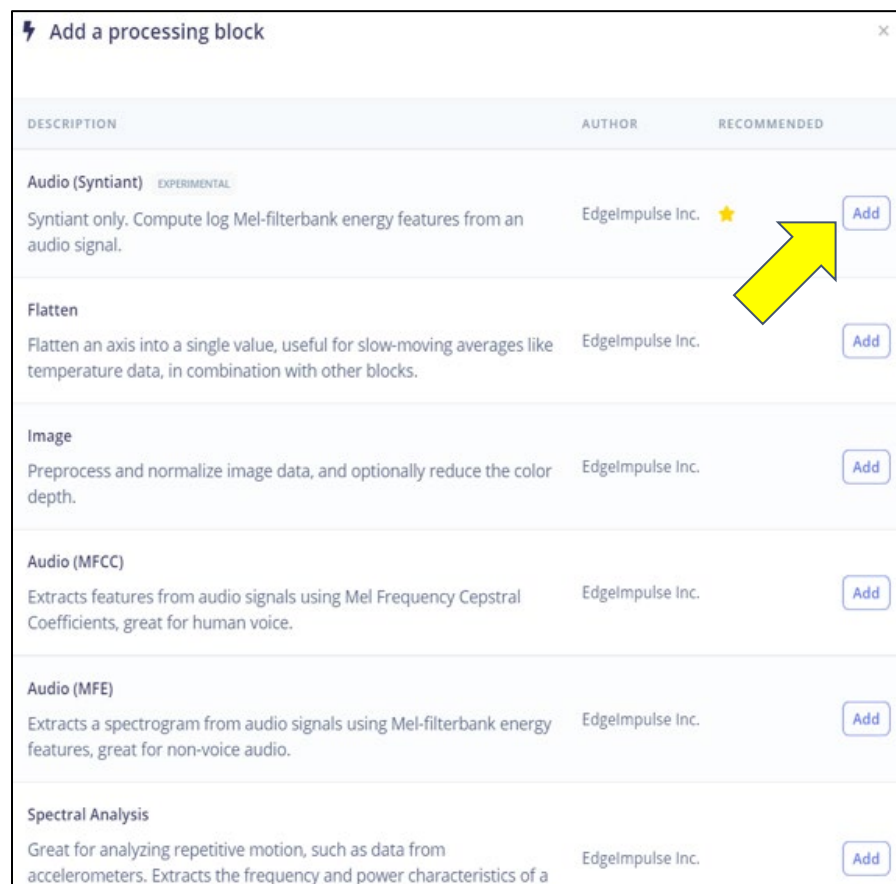
- Delete the [Audio \(Syntiant\)](#) and [Neural Network \(Keras\)](#) blocks by clicking on the trash icon in the bottom right corner of each.



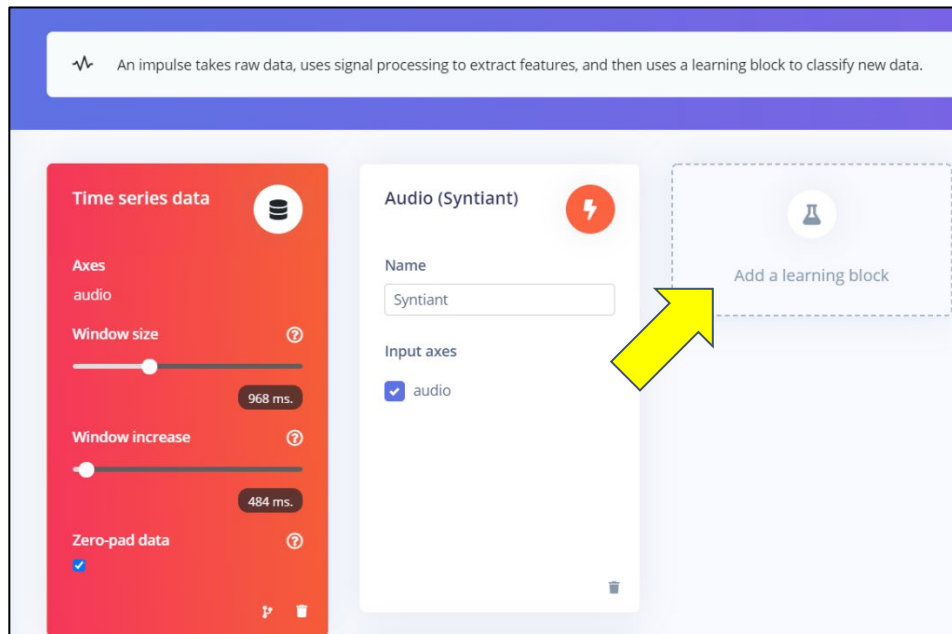
- Next, click on [Add a processing block](#). A new window will pop up.



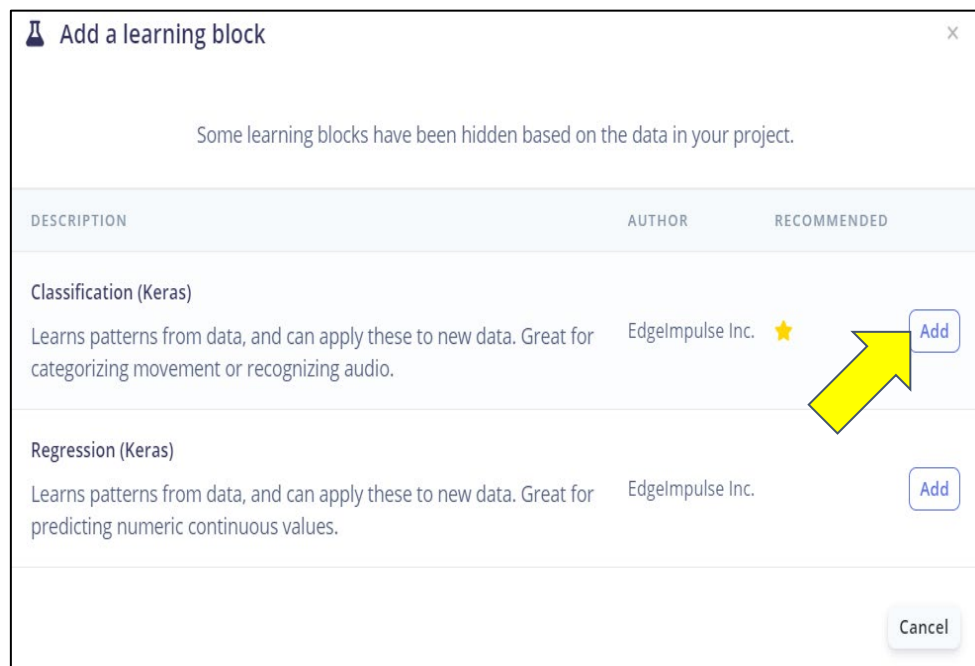
- Scroll and select [Audio \(Syntiant\)](#), then click [Add](#).



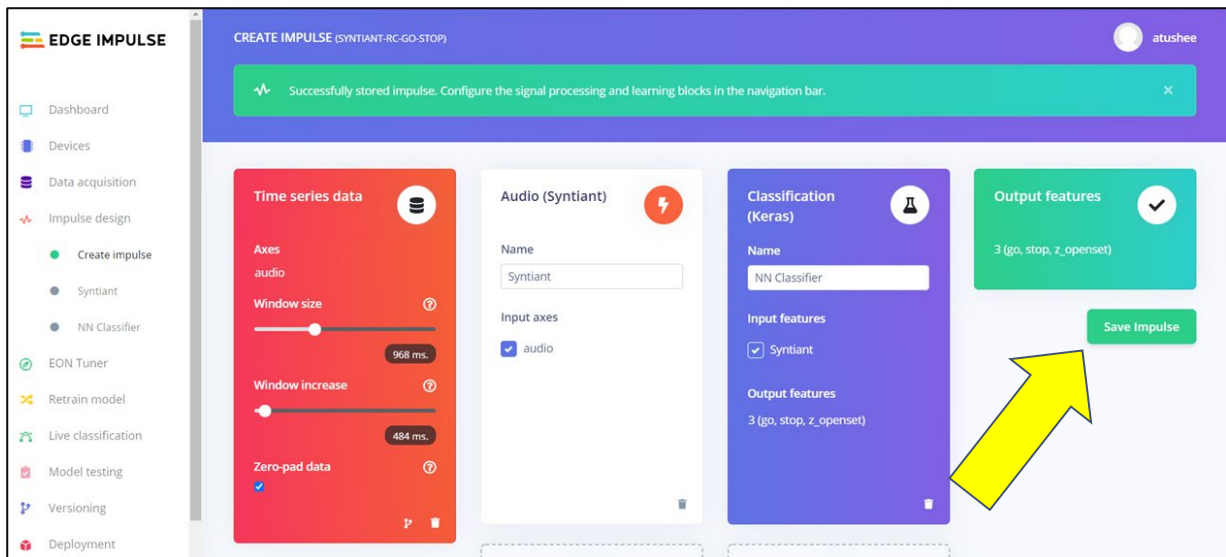
- Click [Add a learning block](#).



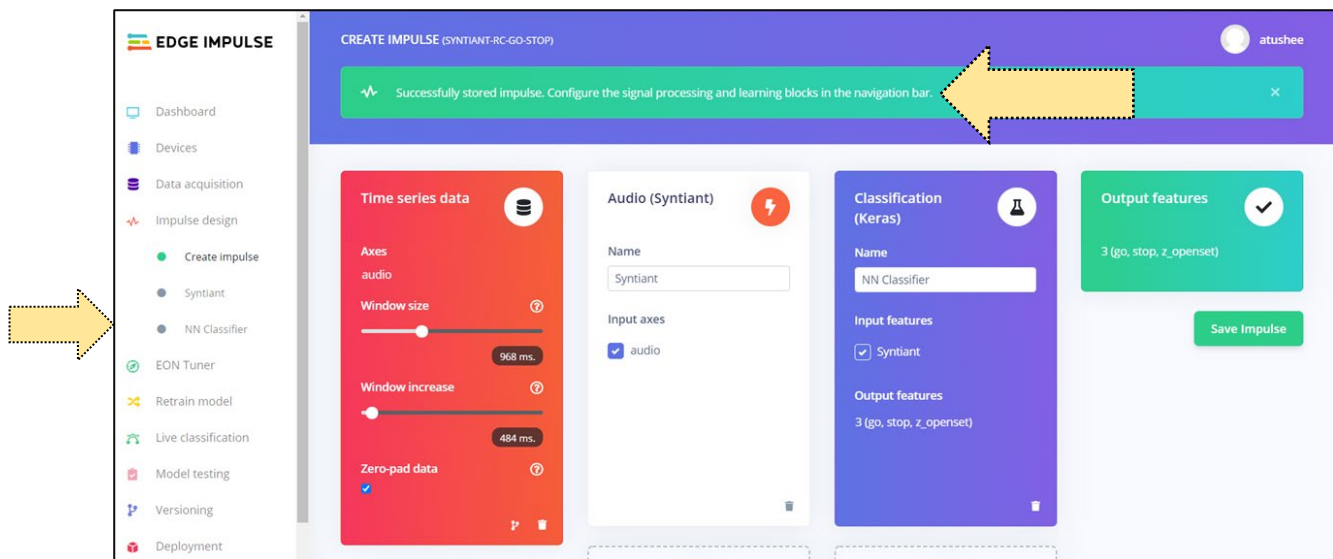
- Choose [Classification \(Keras\)](#) from another popped-out window. Click [Add](#).



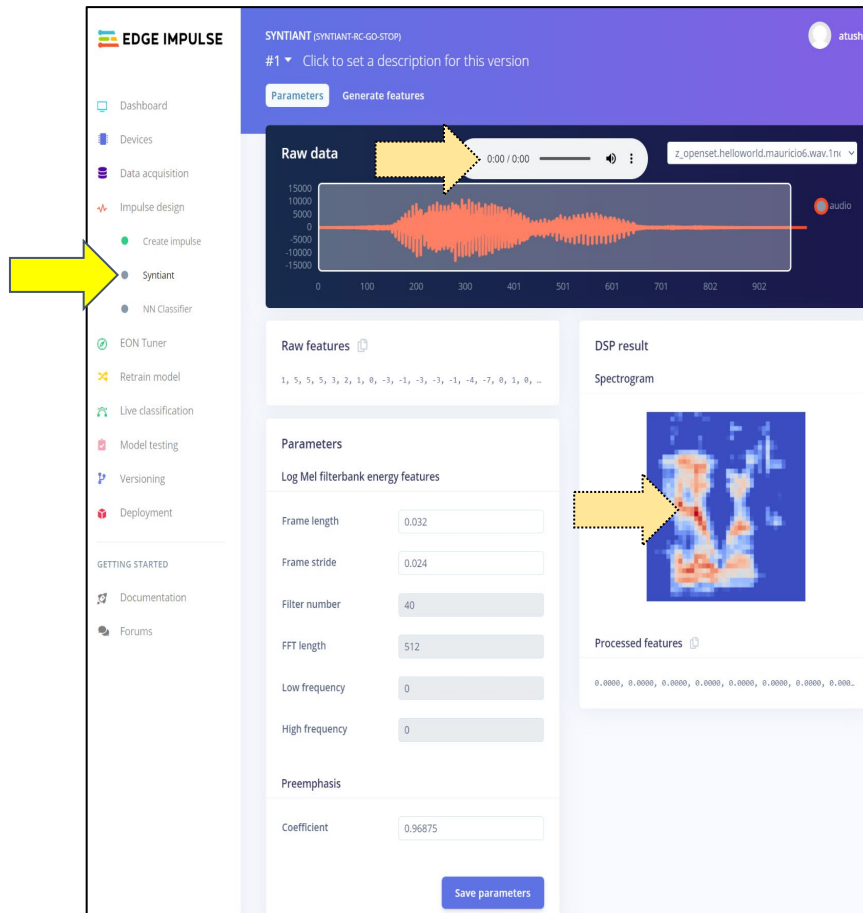
- Click on *Save Impulse*



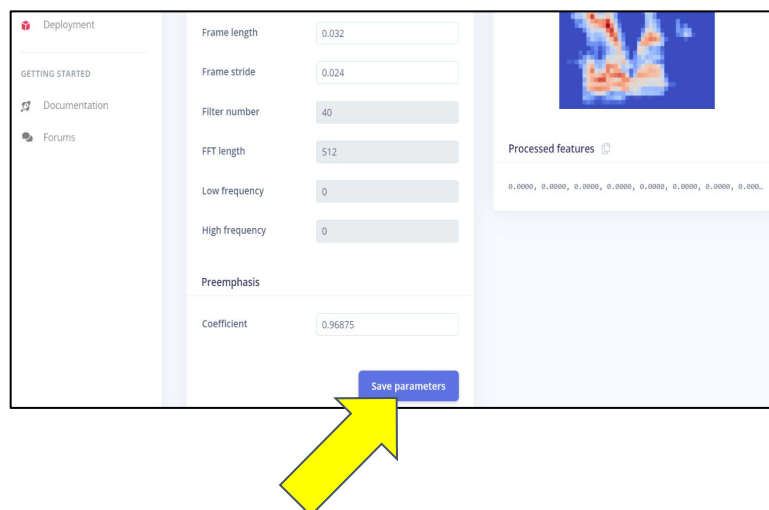
- Confirm “*Successfully stored impulse. Configure the signal processing and learning blocks in the navigation bar*”. before proceeding. You will notice that the bullets in front of *Syntiant* and *NN Classifier* turned from green to gray



- Select [Syntiant](#) in the left panel. Note the spectrogram of the sample on the right side. By clicking on the play button, you will hear “Hello world”, which is an open set sample.

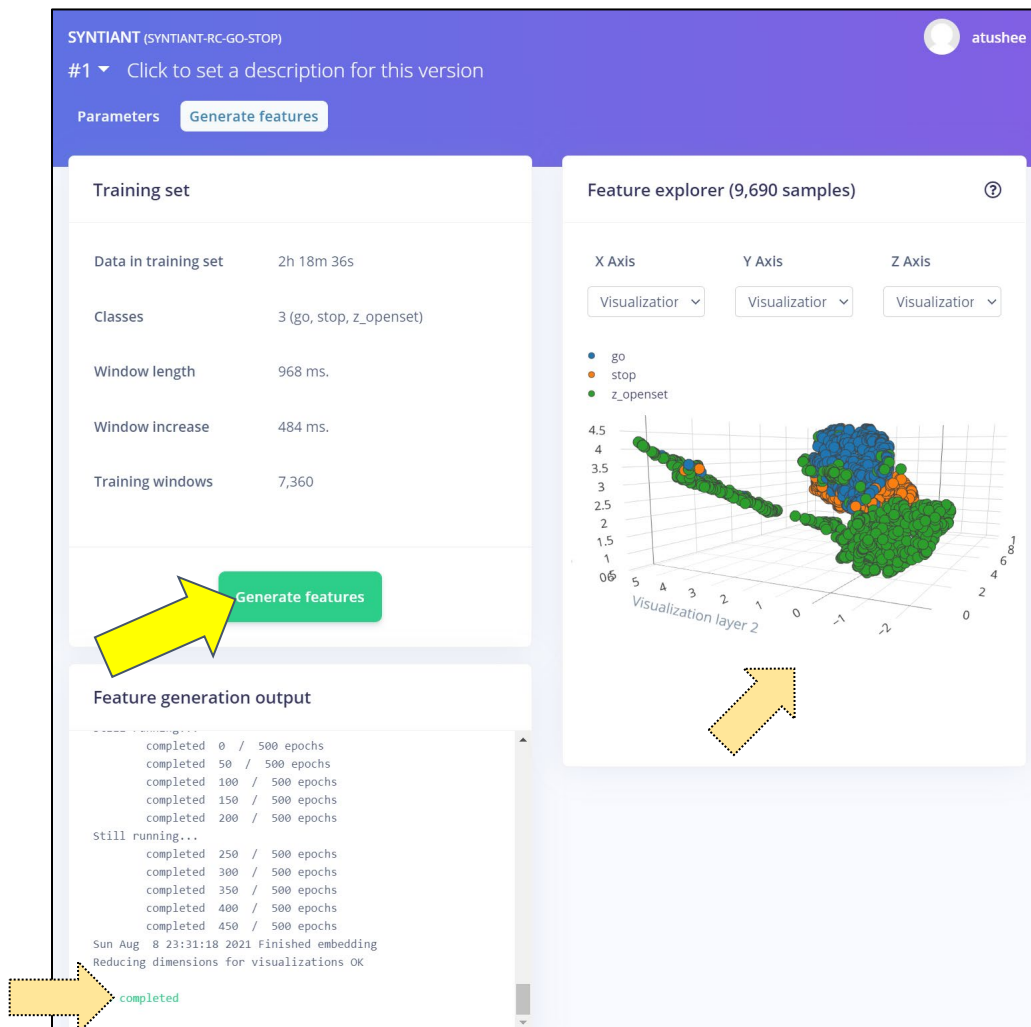


- Scroll down and click on [Save parameters](#).



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- Click on [Generate features](#). Allow 5-10 minutes for this computing-intensive step to finish. Confirm [job completed](#). A three-dimensional database should have been generated. It shows the clusters and their separation by classifiers.

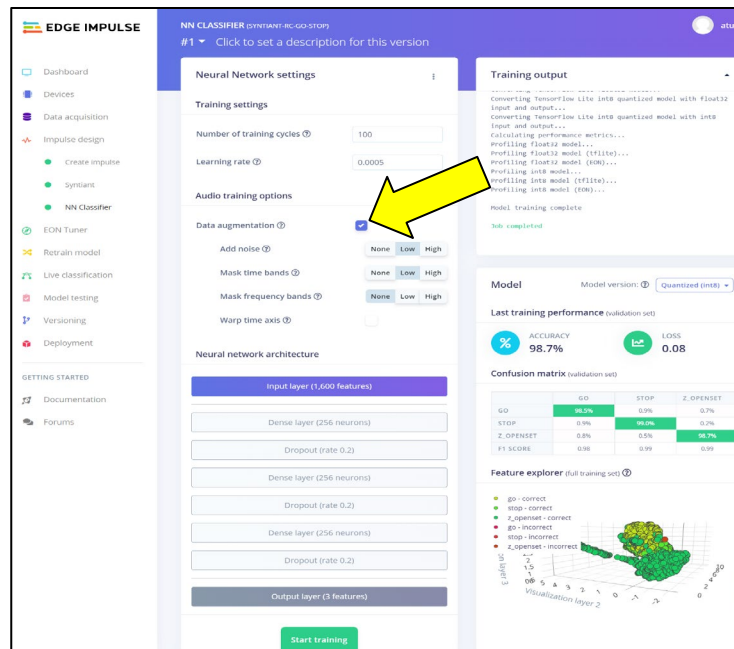


- Select **NN Classifier**. The right panel will change.

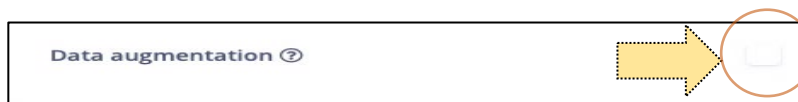
The screenshot shows the Syntiant Edge Impulse web interface for the NN Classifier. The left sidebar has a yellow arrow pointing to the 'NN Classifier' option. The main panel is titled 'NN CLASSIFIER (SYNTIANT-RC-GO-STOP)' and includes a description field. The 'Neural Network settings' section contains 'Training settings' (Number of training cycles: 100, Learning rate: 0.0005) and 'Audio training options' (Data augmentation: checked, Add noise: Low, Mask time bands: Low, Mask frequency bands: None, Warp time axis: unchecked). The 'Neural network architecture' section shows a sequence of layers: Input layer (1,600 features), Dense layer (256 neurons), Dropout (rate 0.2), Dense layer (256 neurons), Dropout (rate 0.2), Dense layer (256 neurons), Dropout (rate 0.2), and Output layer (3 features). A 'Start training' button is at the bottom. The right panel shows 'Training output' with a log of training steps, 'Model' version (Quantized (int8)), 'Last training performance' (Accuracy: 98.7%, Loss: 0.08), a 'Confusion matrix' table, and a 'Feature explorer' 3D scatter plot.

	GO	STOP	Z_OPENSET
GO	96.5%	0.9%	0.7%
STOP	0.9%	99.0%	0.2%
Z_OPENSET	0.8%	0.5%	98.7%
F1 SCORE	0.98	0.99	0.99

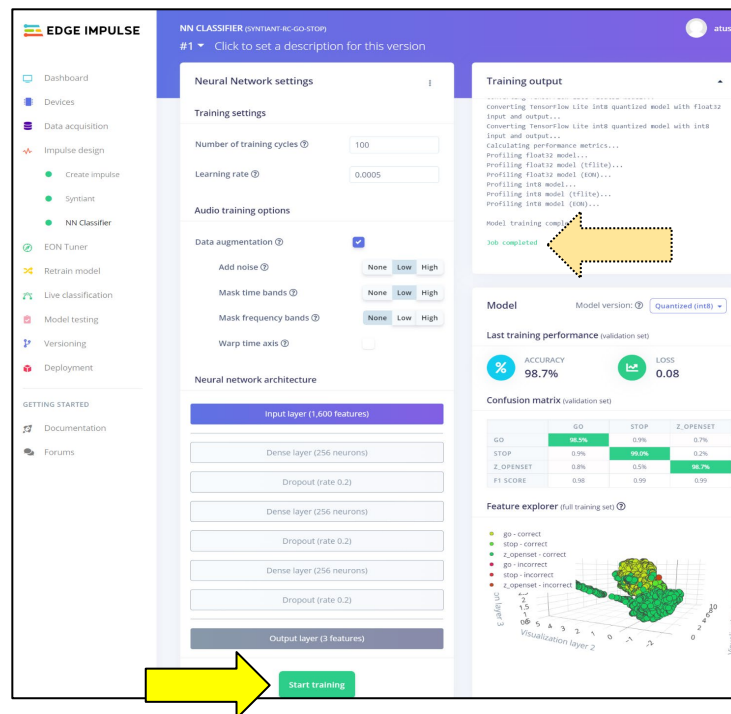
- Check the box for **Data augmentation**, then choose the **Low** setting under both **Add Noise** and **Mask time bands**. Choose **None** for **Mask frequency bands**. Do not check **Wrap time axis**



Hint: The checkmark for step 2 is very faint, as shown in the image directly below. It is aligned with the boxes to get values for Number of training cycles and learning rate. You may have to look from different angles to locate it (it helps to look for the slight shadow around the bottom and sides).



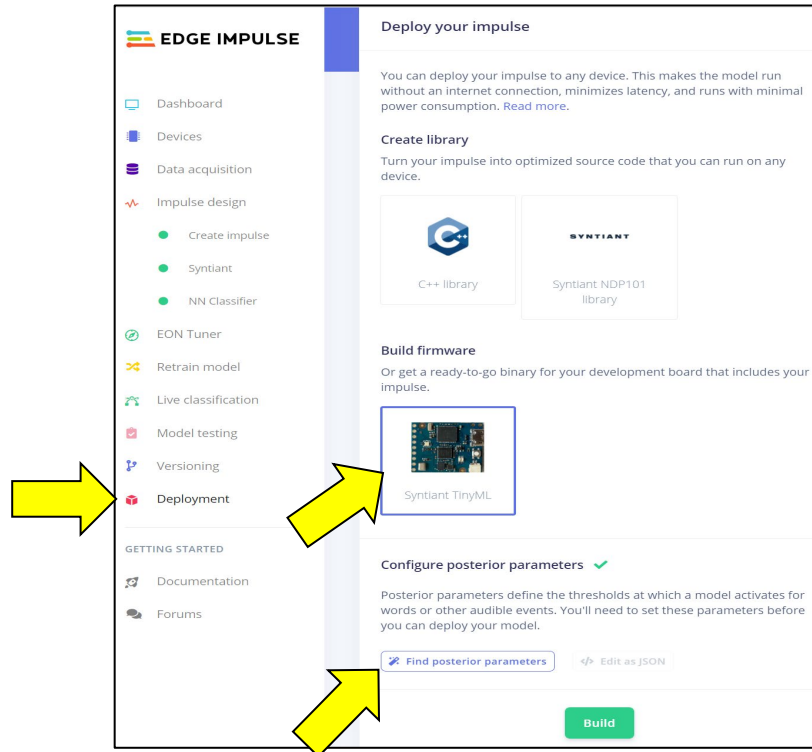
- Click on [Start training](#). Allow 10-15 minutes for this computing-intensive job. Confirm that it says *Job completed* before proceeding. Review [Accuracy](#) and [Confusion matrix](#)



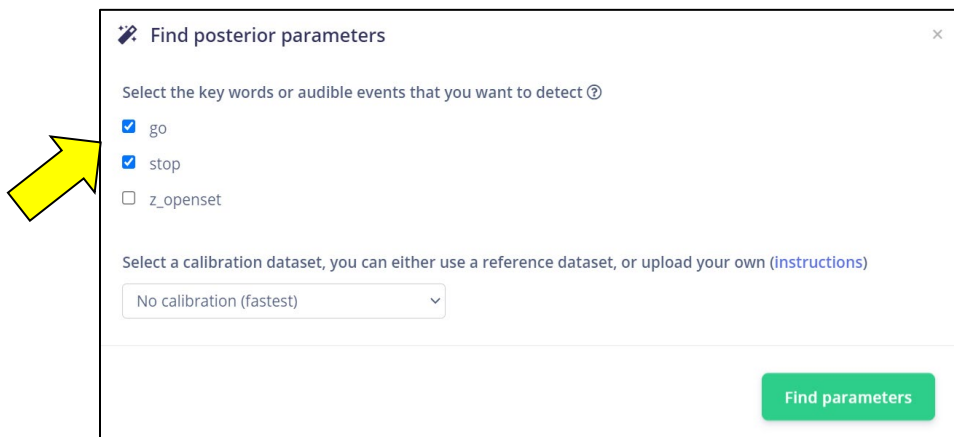
9 Section 2 – Deployment

In this section you will learn how to deploy the neural network model into the Syntiant TinyML board.

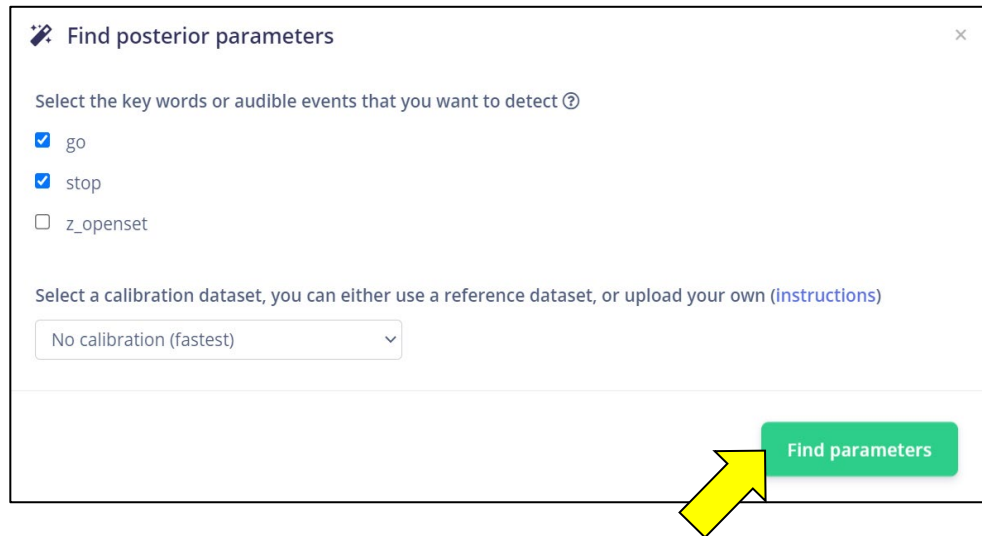
- Click on [Deployment](#). The right panel will change. Click on [Syntiant TinyML](#). Click on [Find posterior parameters](#).



In the *Find posterior parameters* window, check only the *go* and *stop* classifiers.



- Click on [Find parameters](#). Allow 5-10 minutes to complete



Find posterior parameters

Select the key words or audible events that you want to detect ?

☒ go

☒ stop

☐ z_openset

Select a calibration dataset, you can either use a reference dataset, or upload your own ([instructions](#))

No calibration (fastest)

Find parameters

- Confirm that it shows [Job completed](#).



Find posterior parameters

Best quantization arguments: (None, ('uniform', 4, 'min'), None, ('uniform', 4, 'min'), None, ('uniform', 4, 'min'), None, ('uniform', 4, 'min'), None)

Found posterior parameters:

go:

Best FRR: 0

Best FAR: 0

Best Posterior Handler Parameters:

Smoothing: 1

Threshold: 0.7

Window: 5

stop:

Best FRR: 0

Best FAR: 0

Best Posterior Handler Parameters:

Smoothing: 1

Threshold: 0.7

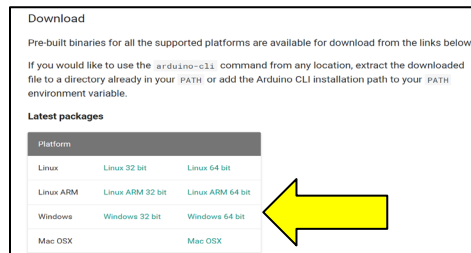
Window: 5

Wrote output to /home/output.json

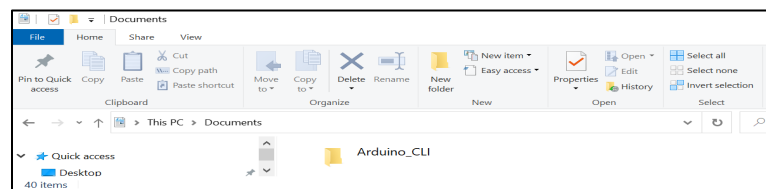
Job completed

In your Windows 10 Laptop/PC, first start by installing Arduino CLI so that you can upload the SAMD21 firmware.

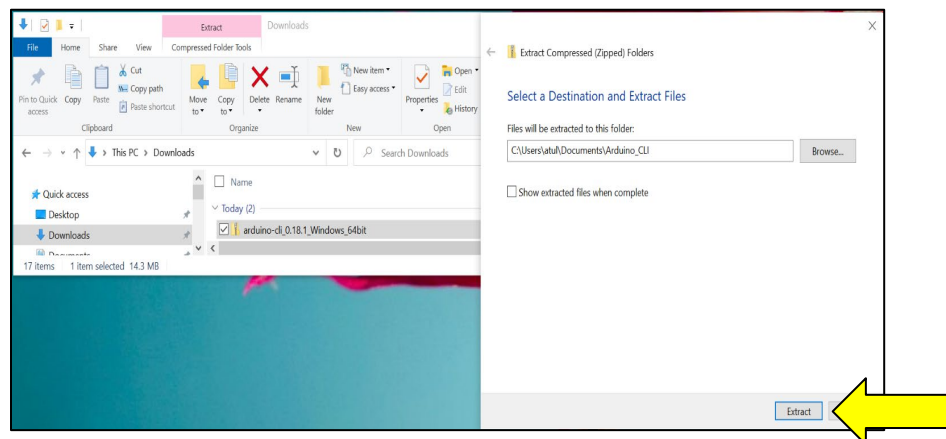
- Click on the link [Installation – Arduino CLI](#) to download Arduino CLI
- Choose the appropriate download file (e.g. *Windows 64 bit*)



- Create a new directory called *Arduino_CLI* in your computer under *Documents*. If you wish to create this directory elsewhere, then remember the directory location for the next step.
- Extract the downloaded file *arduino-cli_0.18.1_Windows_64bit*.

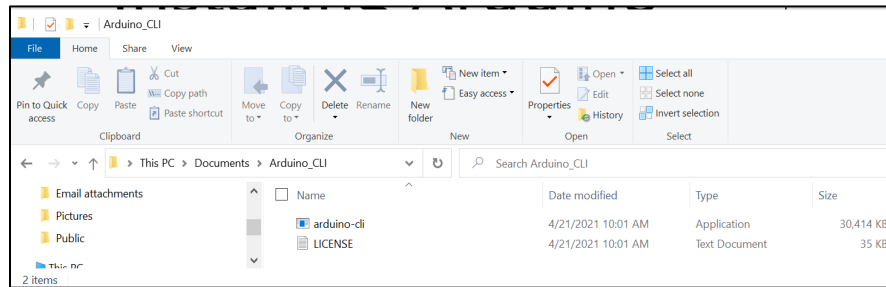


- Right-click on the download file, then select *Extract all* in the drop-down menu
- Browse to find the *Arduino_CLI* you just created.



- Click Extract.

- Confirm that the file is extracted in the directory. Ensure that the **arduino-cli** application and **LICENSE** files are saved directly under the **Arduino_CLI** directory and not under any other subdirectory.

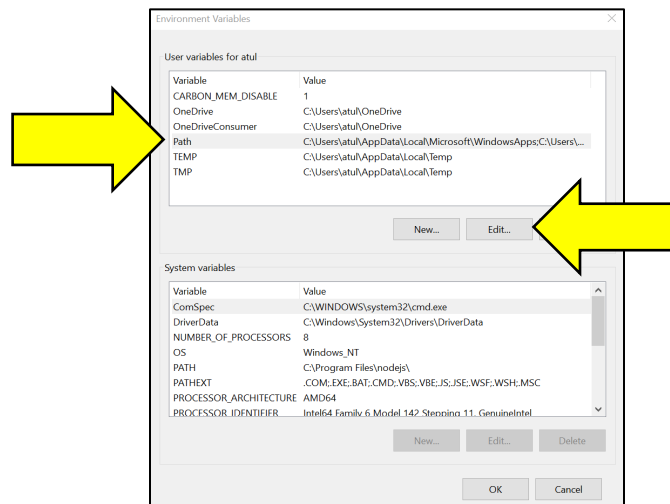


Next, add Arduino CLI to the environment path:

- Type **edit environment variables for your account** in the search window in the bottom left corner. The suggestion to open the window **Environmental variables** will appear.

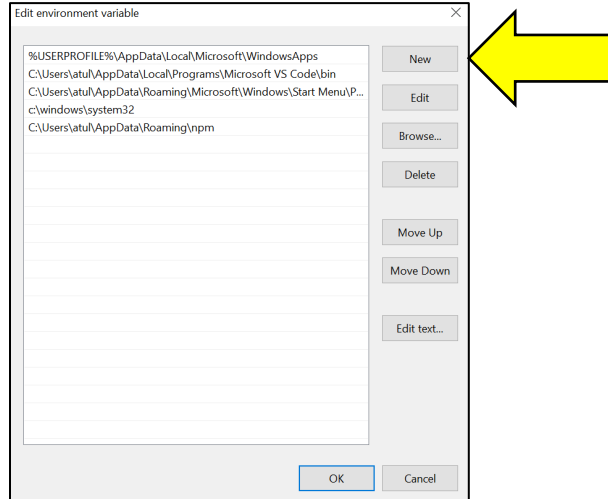


- Right click on the **Path** row.

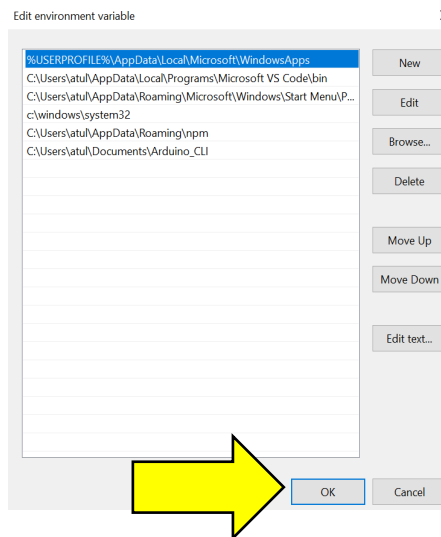


- Click on **Edit**. A new **Edit environment variables** window will open.

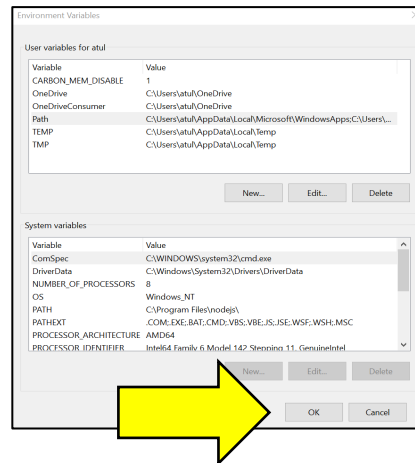
- Click on **New**. A new row will be added.



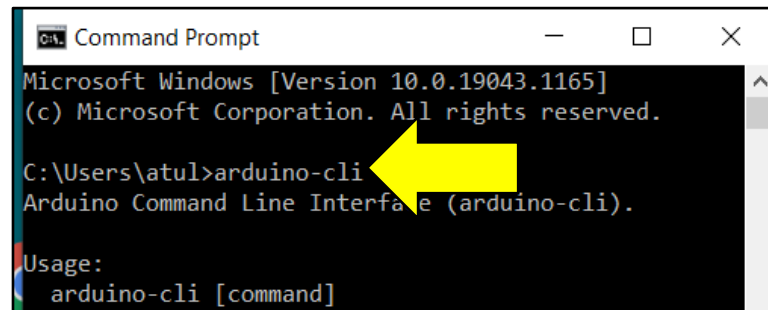
- Type **C:\Users\atulu\Documents\Arduino_CLI** in the new row. Replace appropriate username.
Hint: **Windows will not show the full path starting from C:.** Left click in the explorer window to show the full path. **Ensure that you have the same address as where the *arduino-cli* app file is located.**
- Click on **OK** to save.



- Click on **OK** to save. Reboot the computer.



After your computer reboots, open a CMD window and enter **arduino-cli**. It should print several lines starting with text “**Arduino Command Line Interface (arduino-cli)**” confirming that the path of **arduino-cli** is set properly.



The next steps outline how to connect the Syntiant TinyML board to your computer:

- Connect the Syntiant TinyML board to your computer via the USB port.
- The green LED on the TinyML board should be solidly lit. The orange LED is solid or flashing.
- The RGB LED will blink in the following sequence:
 - Dark for about 5-7 seconds after being plugged in to the USB port. It will blink blue for less than a second. Then it will be dark for about 3 seconds. It will once again blink blue for less than a second
 - Red for about 2 seconds
 - Green for another 2 seconds
 - Once the green light turns off, it is ready to detect factory programmed keywords.

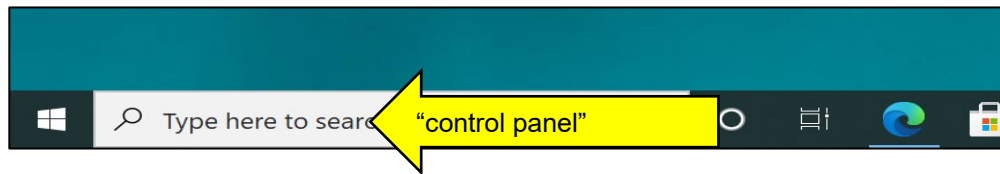
In order to test the hardware after unboxing, following these steps:

- Say “**Alexa, play music**”. You should see a purple light turn on.

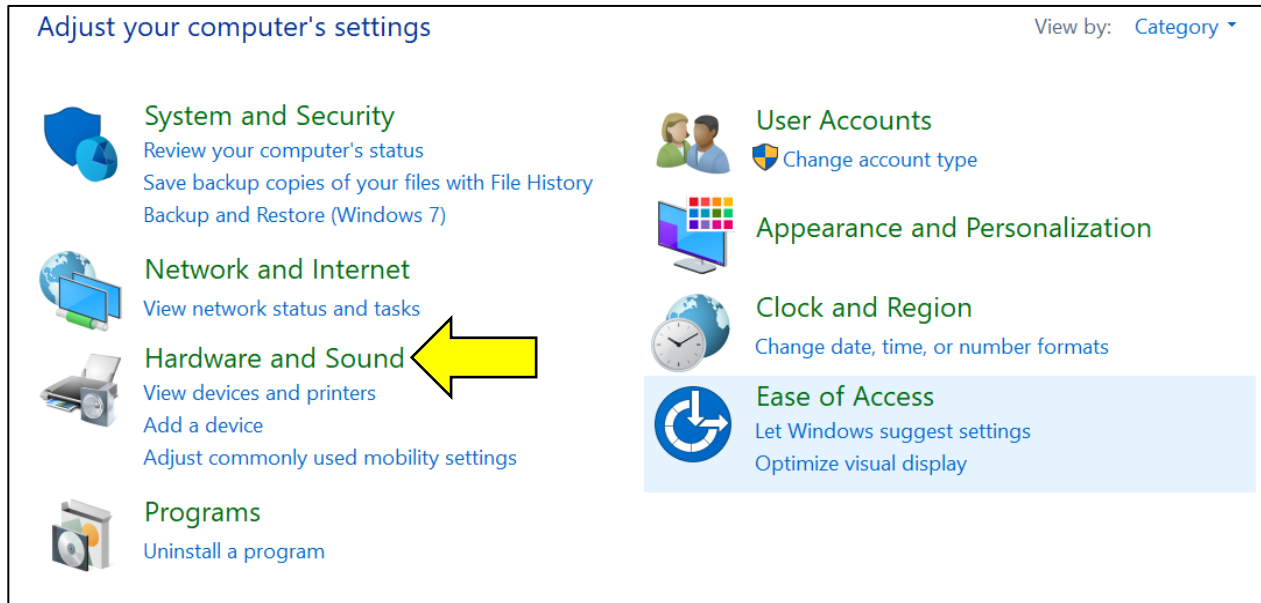
In rare cases, your accent may not be recognized by the system, despite several attempts. In such a situation, play the “Alexa, play music” wav file at this [link](#). **Warning: Once you reflash any program, the factory installed “Alexa, play music” model will no longer work.**

Next check which COM port number is assigned to the hardware.

- Search for *control panel* in your computer, and open the control panel

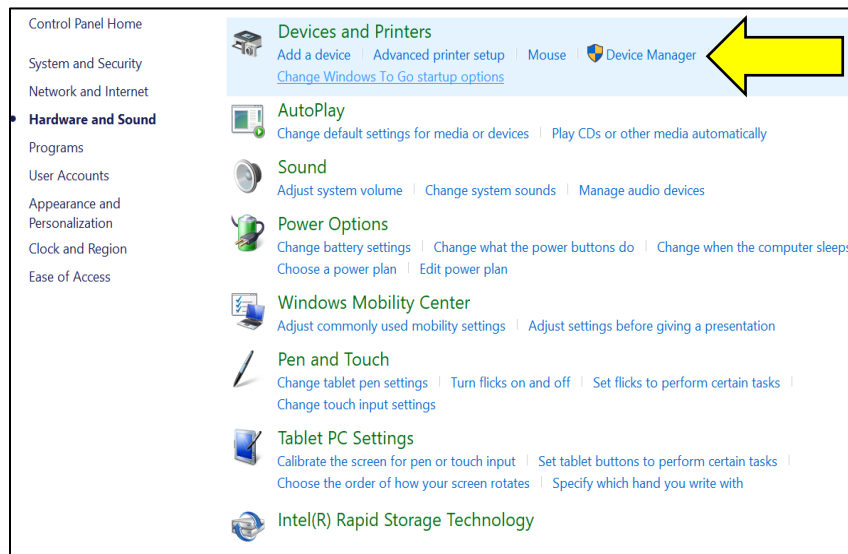


- Select *Hardware and Sound*

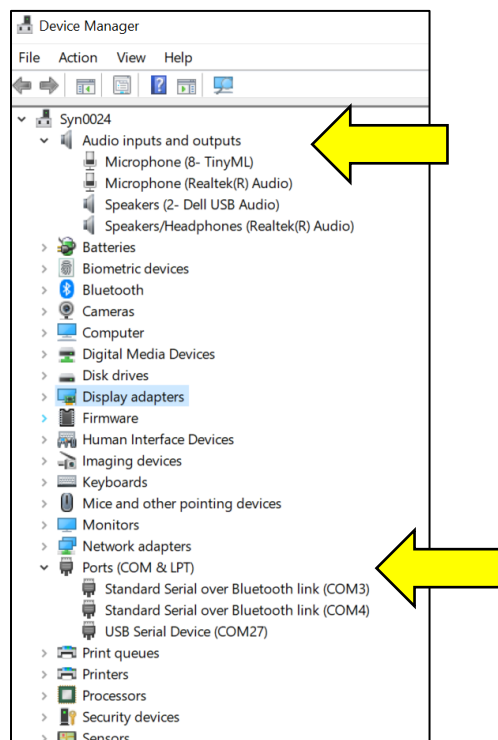


Make sure that the [Syntiant TinyML](#) board is plugged in to your computer.

- Click on Device Manager



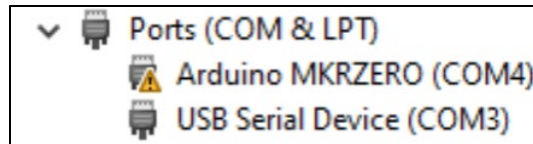
- Click the arrow symbol to unfold the sub menus for [Audio inputs and outputs](#)



- Click the arrow symbol to unfold the sub menus under Ports (COM & LPT). Note how many Audio inputs and outputs you have, and also which COM port number is assigned to the board under Ports (COM & LPT).

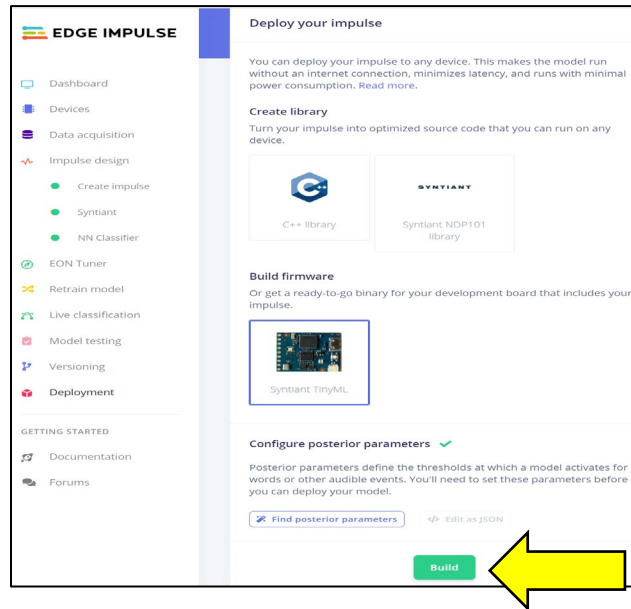
You can unplug the board and then plug it back in if needed to see which COM port it shows up in.

If you see an orange triangle with an exclamation point in the center (as shown below), please follow [USB Port Issue of the Troubleshooting section](#).

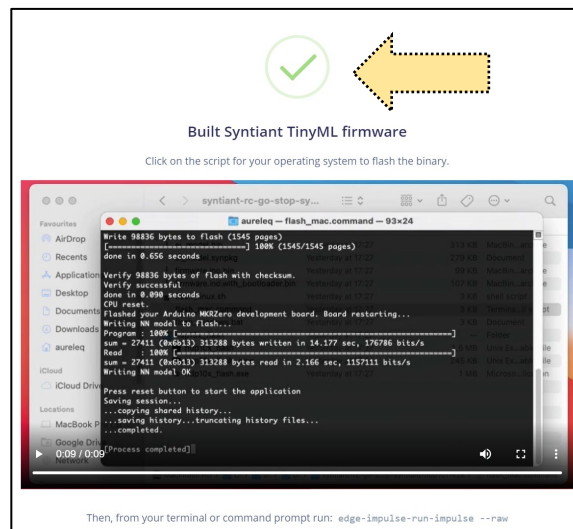


Now that we are done with our Windows 10 setting, we are ready to click on [build](#). For this, you will need to be back where we left off on the [first page of the deployment section](#) (you should be logged in to Edge Impulse, in the Deployment section and with posterior parameters set).

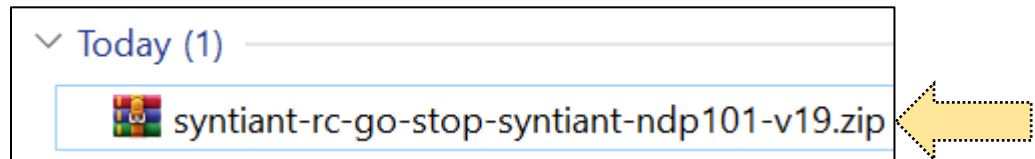
- Continuing from the initial deployment page, click on [Build](#). This may take 5-10 minutes to complete



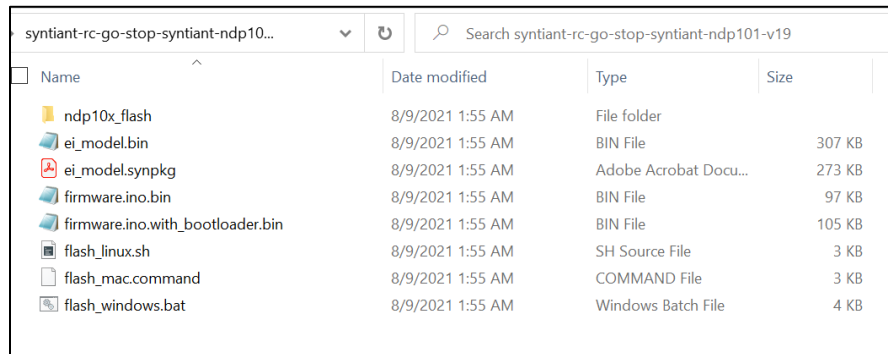
- Confirm that there is a pop-up window showing [Built Syntiant TinyML Firmware](#) with a green check mark



- Check your download directory. You should see a file that looks like what is shown below

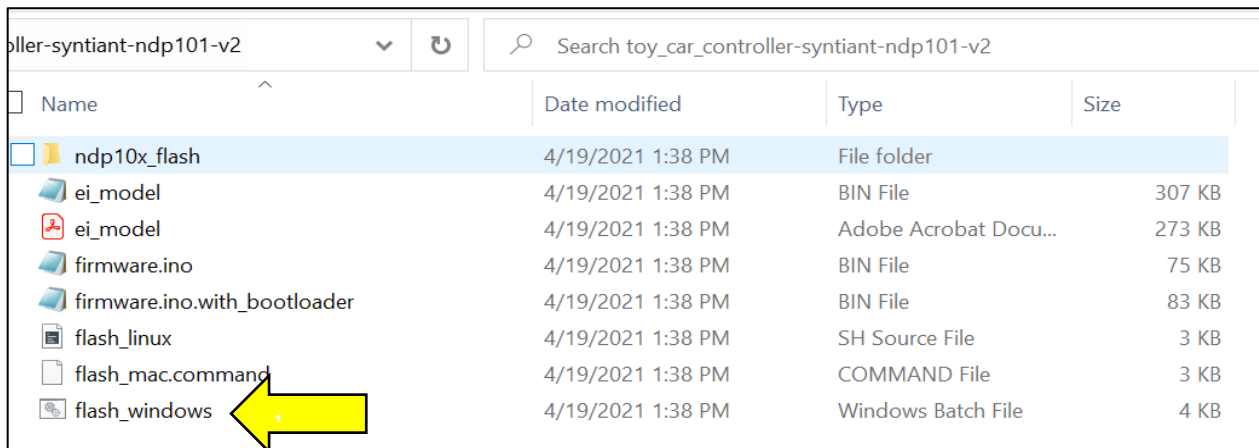


- Unzip the file. It should generate the directory for flashing the Syntiant TinyML board

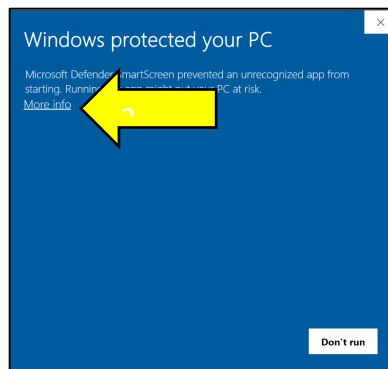


Next, build the flashing download file.

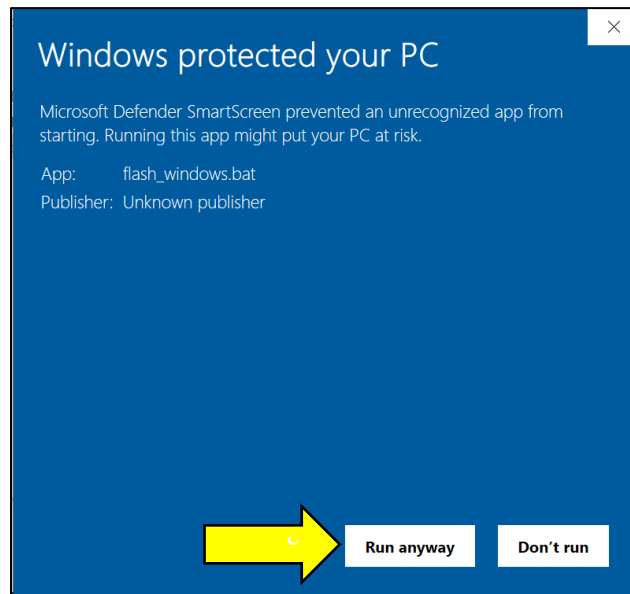
- In Windows explorer, go to the place where you saved the download file



- You will see a *Windows protected your PC* warning. Click on *More info*



- The window will change, displaying a new option that says *Run anyway*



- Click on *Run anyway*

The flashing sequence takes about 30-40 seconds. The red LED will turn on several times. Check for the successful execution messages.

```

C:\WINDOWS\system32\cmd.exe
You're using an untested version of Arduino CLI, this might cause issues (found: 0.18.1, expected: 0.13.x)
Finding Arduino SAMD core v1.8.9...
arduino:samd 1.8.9      1.8.9  Arduino SAMD Boards (32-bits ARM Cortex-M0+)
Finding Arduino SAMD core OK
Finding Arduino MKRZero...
Finding Arduino MKRZero OK at COM38
Flashing Arduino firmware...
Atmel SMART device 0x10010005 found
Device      : ATSAM21G18A
Chip ID     : 10010005
Version     : v2.0 [Arduino:XYZ] Apr 11 2019 13:09:53
Address     : 8192
Pages       : 3968
Page Size   : 64 bytes
Total Size  : 248KB
Planes      : 1
Lock Regions : 16
Locked      : none
Security     : false
Boot Flash  : true
BOD         : true
BOR         : true
Arduino     : FAST_CHIP_ERASE
Arduino     : FAST_MULTI_PAGE_WRITE
Arduino     : CAN_CHECKSUM_MEMORY_BUFFER
Erase flash
done in 0.832 seconds

Write 98836 bytes to flash (1545 pages)
[=====] 100% (1545/1545 pages)
done in 0.935 seconds

Verify 98836 bytes of flash with checksum.
Verify successful
done in 0.111 seconds
CPU reset.
Flashed your Arduino MKRZero development board. Board restarting...

Waiting for 0 seconds, press CTRL+C to quit ...
Writing NN model to flash...
Program : 100% [=====]
sum = 16731 (0x415b) 313608 bytes written in 17.121 sec, 146537 bits/s
Read    : 100% [=====]
sum = 16731 (0x415b) 313608 bytes read in 4.400 sec, 570196 bits/s
Writing NN model OK
Press reset button to start the application
Press any key to continue . . .

```

If you get series of error messages like *0x000000: read 0x04 != expected 0x01* then go to Flashing errors sub-section of the Troubleshooting section.

10 Section 3 – Real Time Testing

Now your Syntiant TinyML board is ready for a test drive. Remove the board from the USB cable and then plug it back in. You should see the following sequence:

- The green light is lit solidly
- The orange light is either off, solidly lit or flashing
- The RGB light is dark for about 5-7 seconds after plugging in to the USB port
- The red LED turns on for about 2 seconds
- The green LED turns on for about 2 seconds

Once the green LED turns off, it is ready to test the “Go” and “Stop” keywords. If you say “Go” or “Stop”, the RGB LED will turn *green* or *red*, respectively.

11 Summary

Congratulations! With this tutorial, you have completed the entire flow to successfully program the Syntiant TinyML board and test the results in real time. Thank you for taking the time to complete this tutorial.

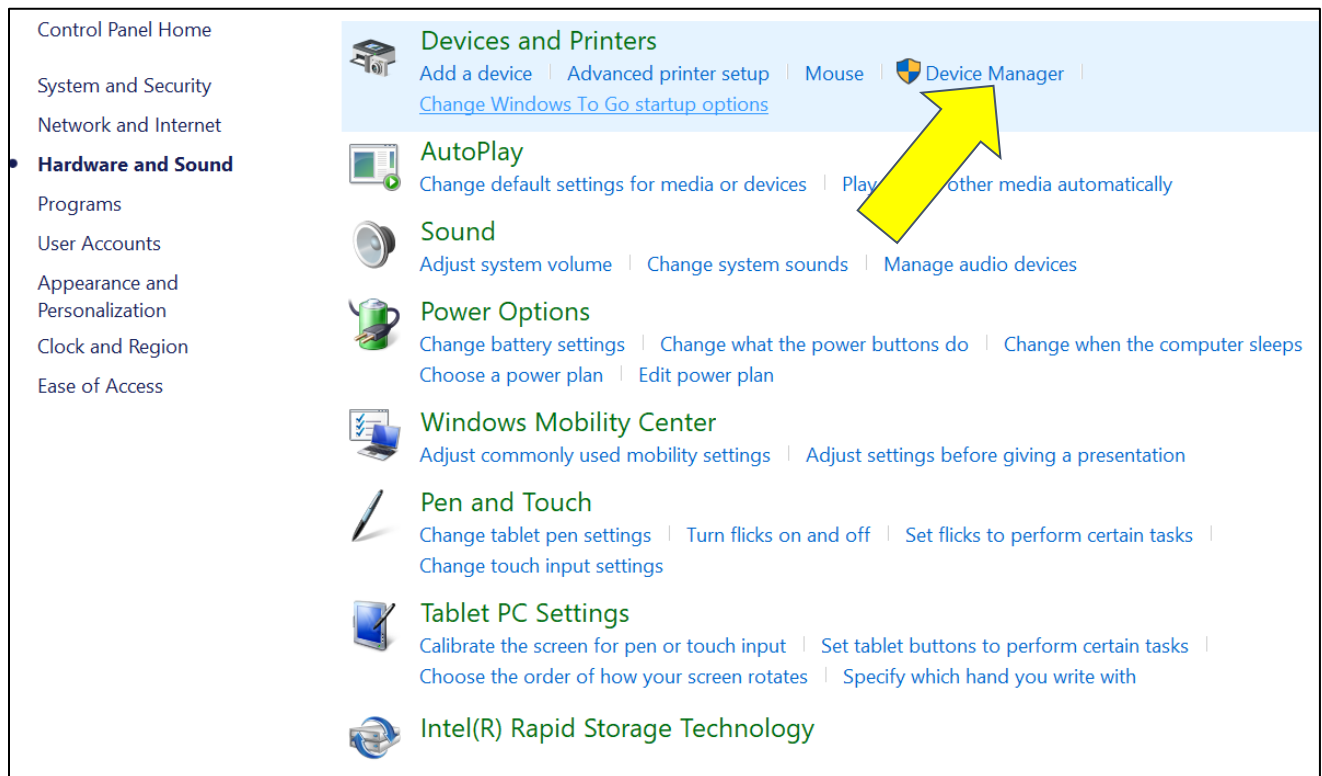
12 Troubleshooting

In this section, we will go over the steps to troubleshoot and solve some potential issues with your USB port, as well as some possible flashing errors.

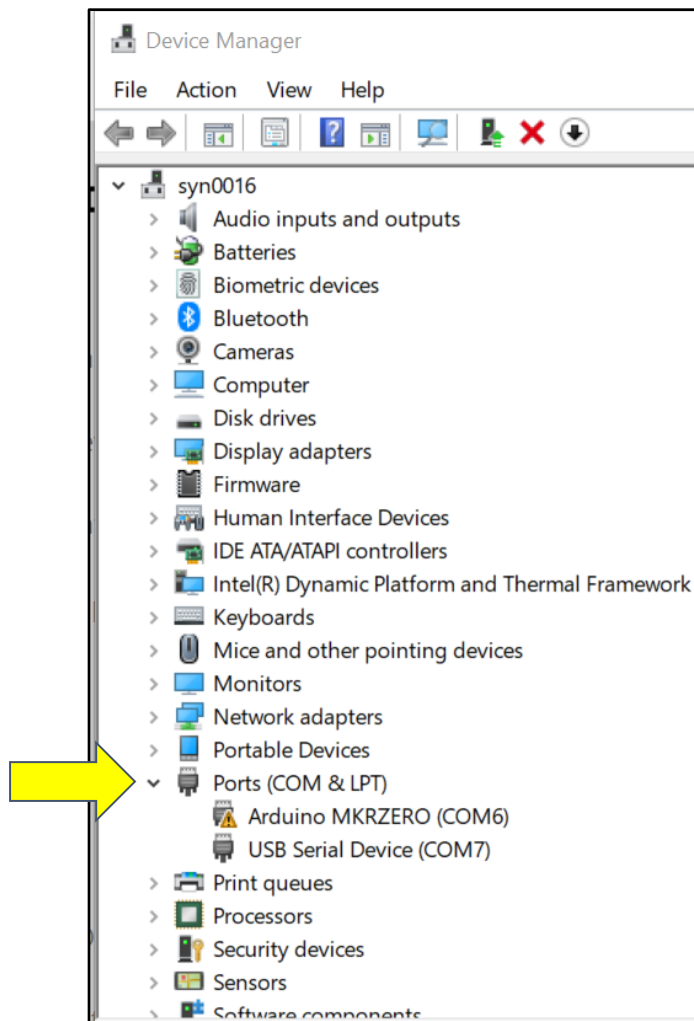
12.1 USB port issue

In case you encounter issues related to your USB port, make sure that the USB Dongle is plugged into the computer.

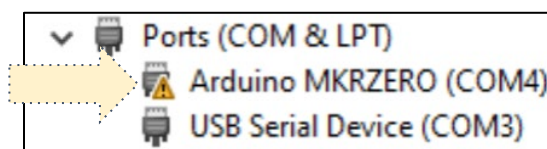
- Click on [Device Manager](#).



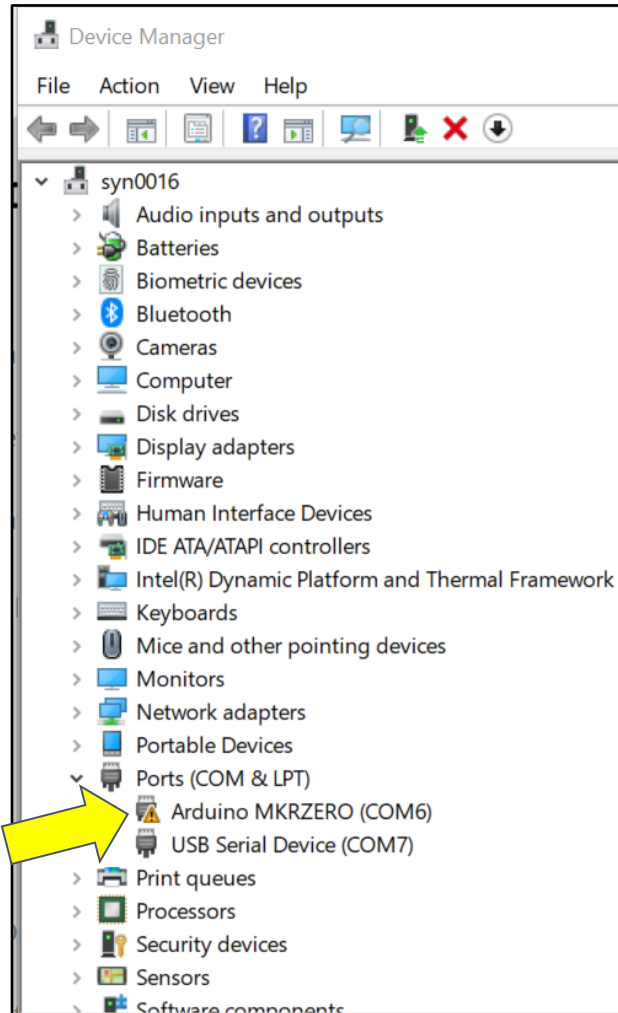
- Click on the arrow to open the drop-down menu under [Ports \(COM & LPT\)](#).



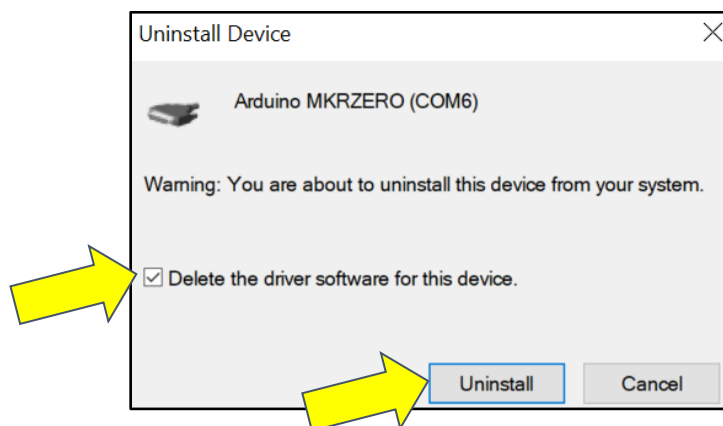
- Check to see if there is a symbol showing an exclamation point inside a yellow triangle in front of the USB port that corresponds with the board.



- Right click on the port corresponding to the TinyML board and click on uninstall.



- A new window will pop up; check the box for *Delete the driver software for the device*, then click *Uninstall*.

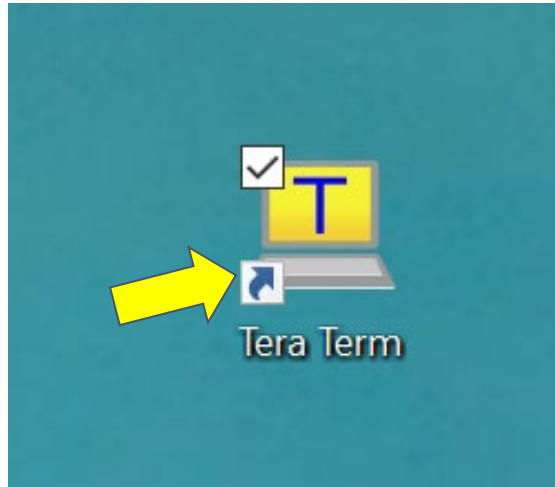


- Once the drive is removed, unplug the board, then plug it back in. It should work now.

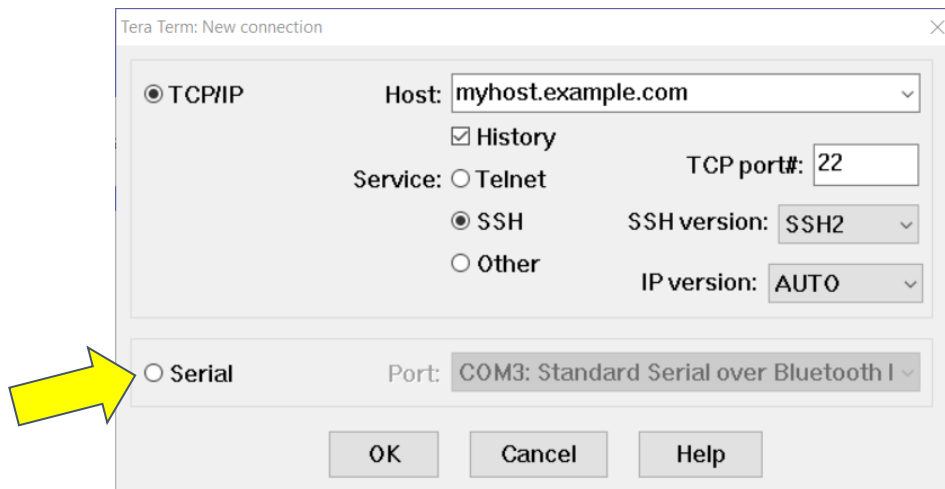
12.2 Flashing errors

In case you run into flashing error using Term, the following might help resolve the issue:

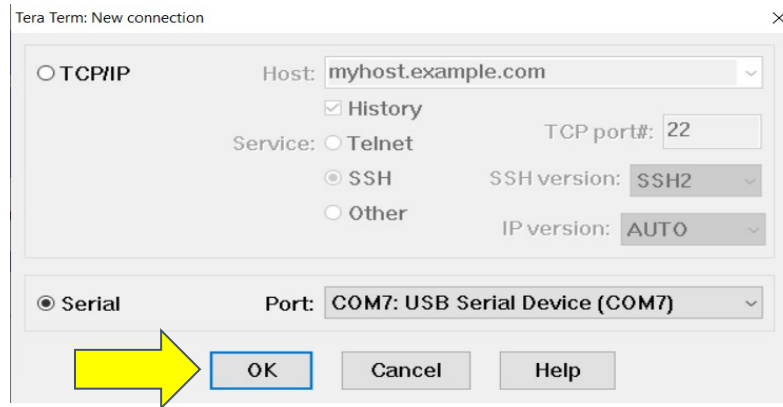
- First, download the Tera Term software [here](#).
- Click on the [Tera Term](#) app in your computer. This software is a prerequisite, as mentioned in the Prerequisites and Materials section of this tutorial.



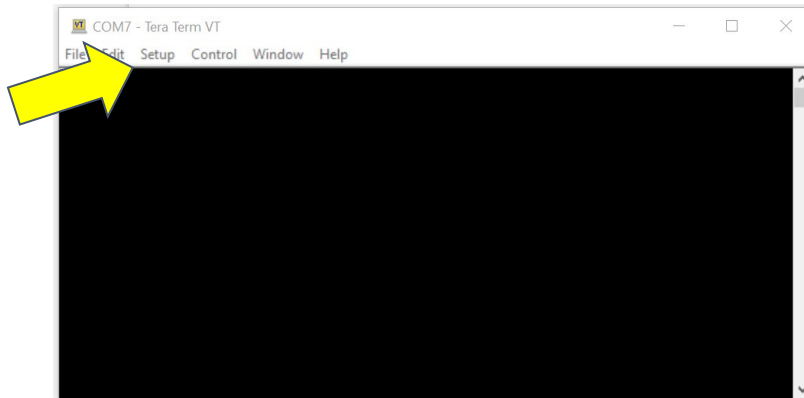
- Check the [Serial](#) option.



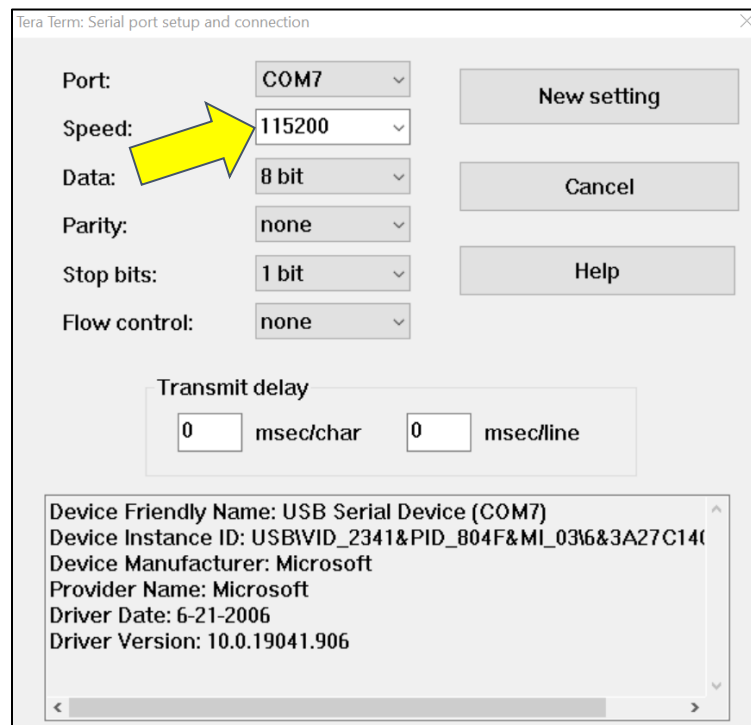
- Scroll down to the COM port assigned to the [Syntiant TinyML](#) hardware.
- Click [OK](#).



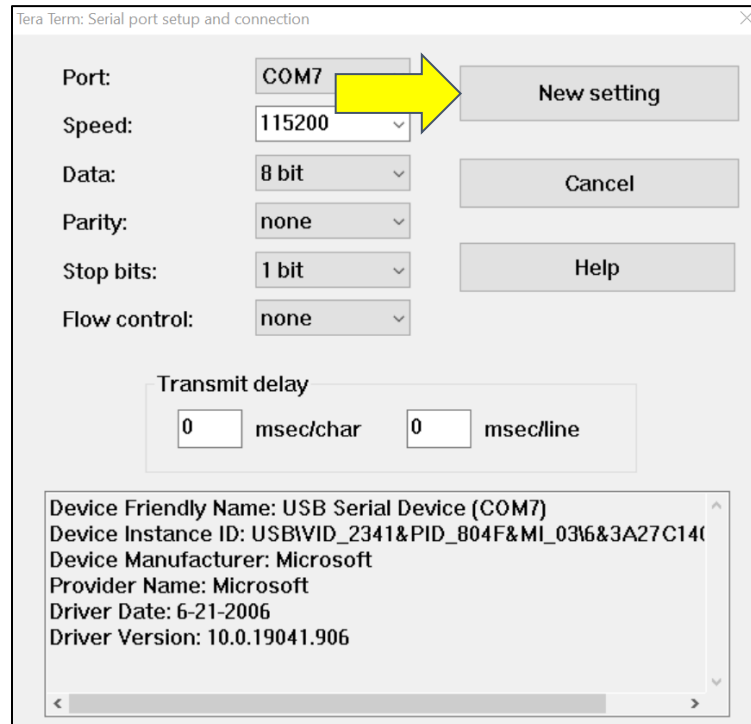
- Click on [setup](#) in Term Term, then select [serial port](#). It will open a new window.



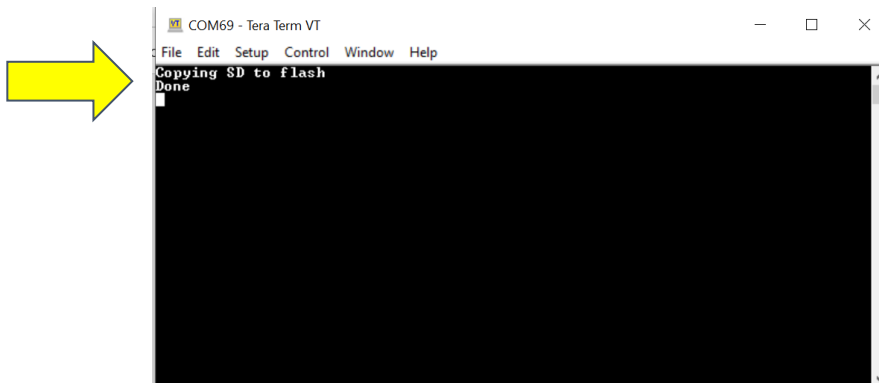
- Scroll down on speed and select [115200](#) baud rate.



- Click on [New Setting](#) to save these settings.



- Type `:F` in the window; you will see a message indicating that copying SD to flash has been completed. Note that `:F` will not be shown in the Tera Term window
- Now try flashing the Syntiant TinyML board again.



Revision History

Version	Date	Description
1.0	August 27, 2021	Initial release.

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