Embedded Vision Workshop Series:

From Zero to Hero with PYNQ

Session 1

Getting Started with PYNQ

Lab Workbook

Presented by

element14
AN AVNET COMMUNITY

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PYNQ Workshop Series

About This Workbook

This workbook is intended to be used with **Session 1**: **Getting Started with PYNQ** of the **Embedded Workshop Series: From Zero to Hero with PYNQ**, presented by element14.

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Your Instructor

Adam Taylor
Founder and
Principal Consultant
ADIUVO

Please email any questions you may have to your instructor at adam@adiuvoengineering.com.

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Required Hardware and Software

To complete this lab series, you will need the following hardware:

1. PYNQ-Z2 board
2. Micro SD card greater than equal to 16 GB
3. Micro SD card adapter
4. Micro USB cable
5. Ethernet cable
6. Ethernet access to your WIFI network or Ethernet connector on a PC
7. Sports camera e.g. https://www.amazon.co.uk/Crosstour-Waterproof-Underwater-Wide-angle-Rechargeable/dp/B073WWSYJK?ref_=fsclp_pl_dp_1
8. HDMI to micro HDMI cable https://www.amazon.co.uk/AmazonBasics-High-speed-latest-standard-meters/dp/B014I8TZXW

To be able to complete these three labs you will need the following software on your development machine:

1. Vivado Design Suite 2019.1 – used for the development of custom overlays
2. 7-Zip - https://www.7-zip.org/
3. Etcher - https://www.balena.io/etcher/
4. Tera Term - https://ttssh2.osdn.jp/index.html.en
5. Pynq-Z2 board definition files - https://d2m32eurp10079.cloudfront.net/Download/pynq-z2.zip
6. WinSCP - https://winscp.net/eng/index.php

All project files and support files can be found at
https://github.com/ATaylorCEngFIET/Element14_PYNQ

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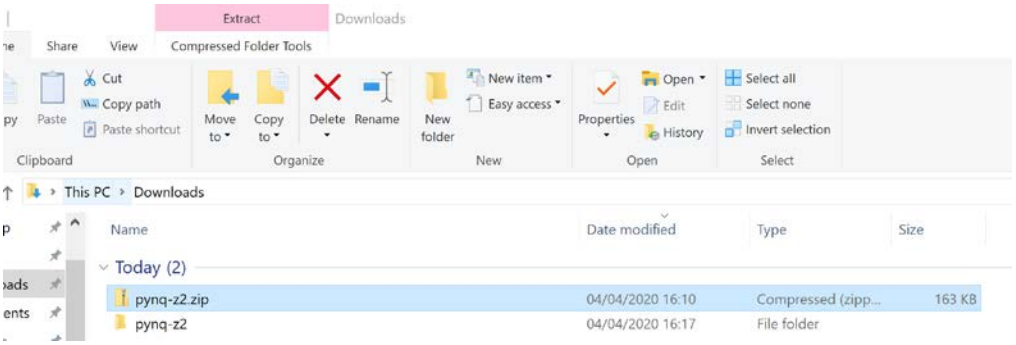
Pre-Lab One

This lab should be completed prior to the starting the labs

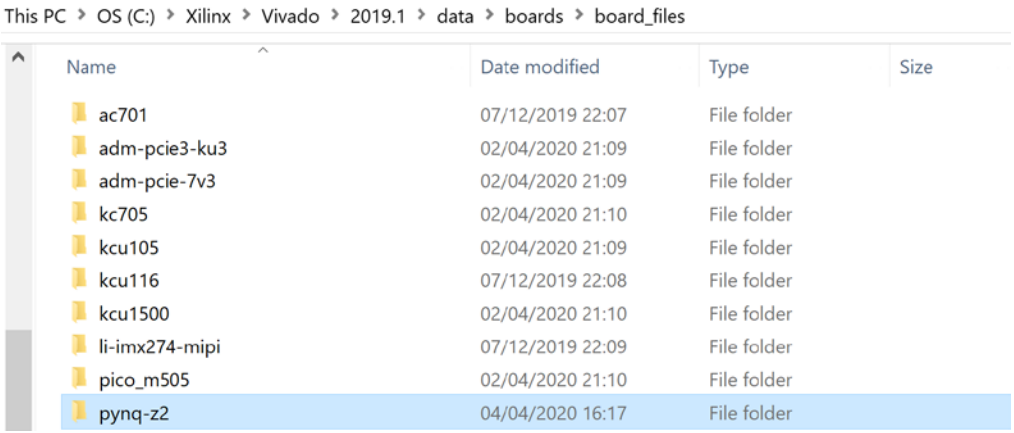
Getting Set Up Vivado

1. Install the webpack version of Vivado Design Suite 2019.1.

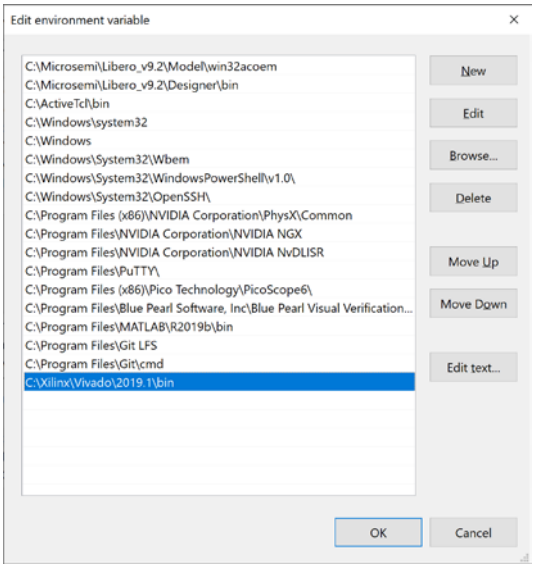
2. Once installed, unzip the Pynq-Z2 board definitions.



3. Copy the resulting directory into the Vivado boards directory. The path for this will be <install location>\Xilinx\Vivado\2019.1\data\boards\board_files.



4. Ensure Vivado is declared in the path within your environment variables.



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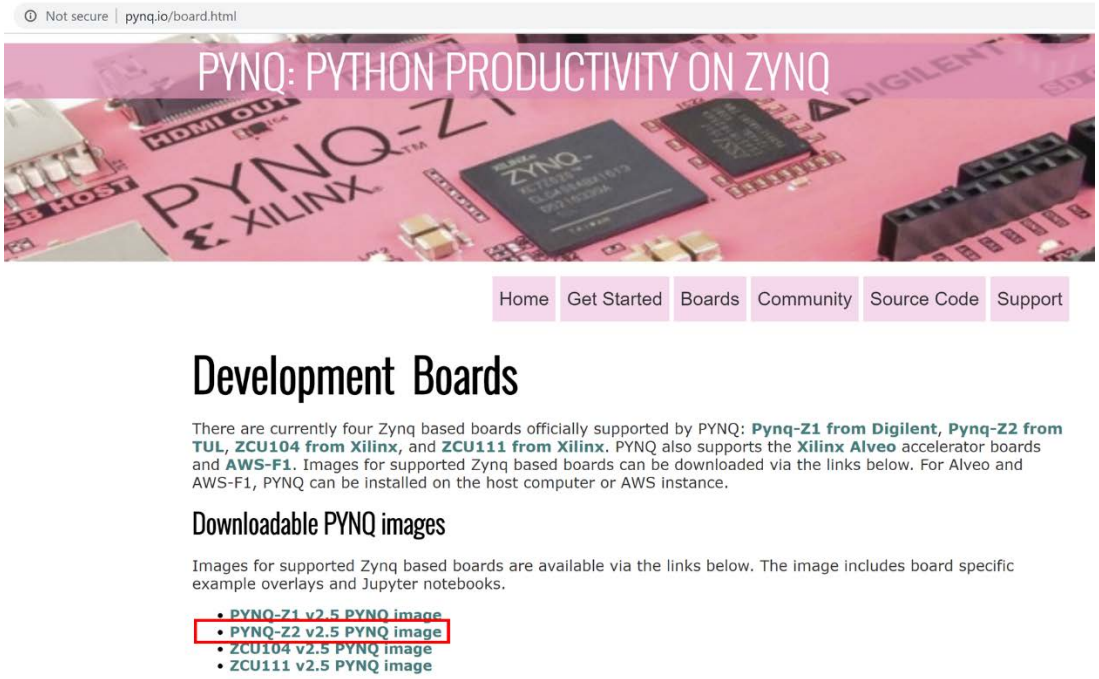
Getting Up and Running with PYNQ

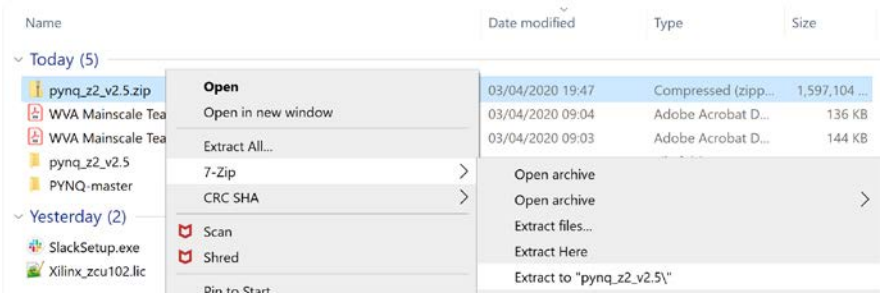
To be able to get working with the PYNQ-Z2 board, the first thing we need to do is create an SD card containing the PYNQ image.

1. Go to www.pynq.io/boards and download the PYNQ-Z2 V2.5 PYNQ image. To download the image, you will need a Xilinx account. If you do not have one already, the download process will allow you to create one.



2. The file which is downloaded will be compressed.

3. Un-compress the image using 7-Zip.



4. Insert the micro SD card into the adaptor and insert into your computer.

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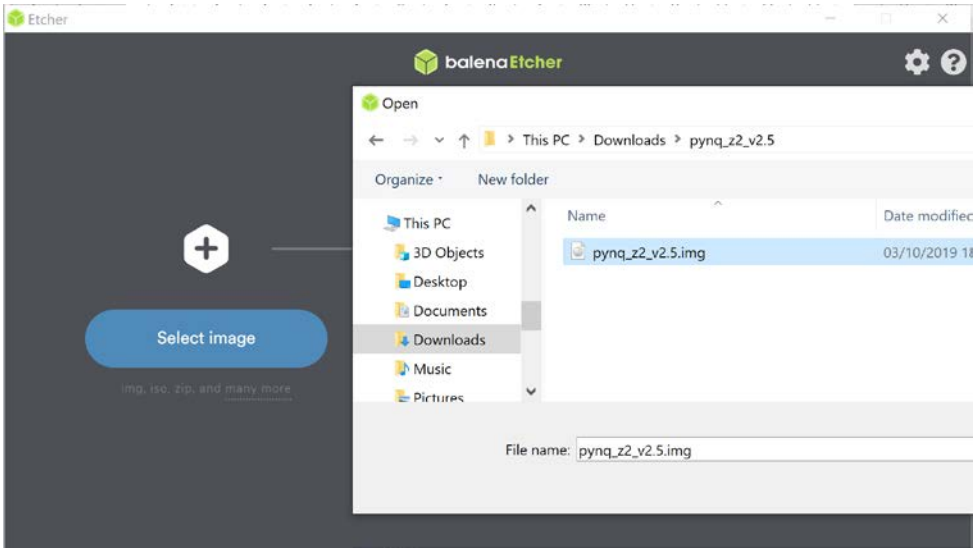
5. Open Etcher and select the PYNQ image.



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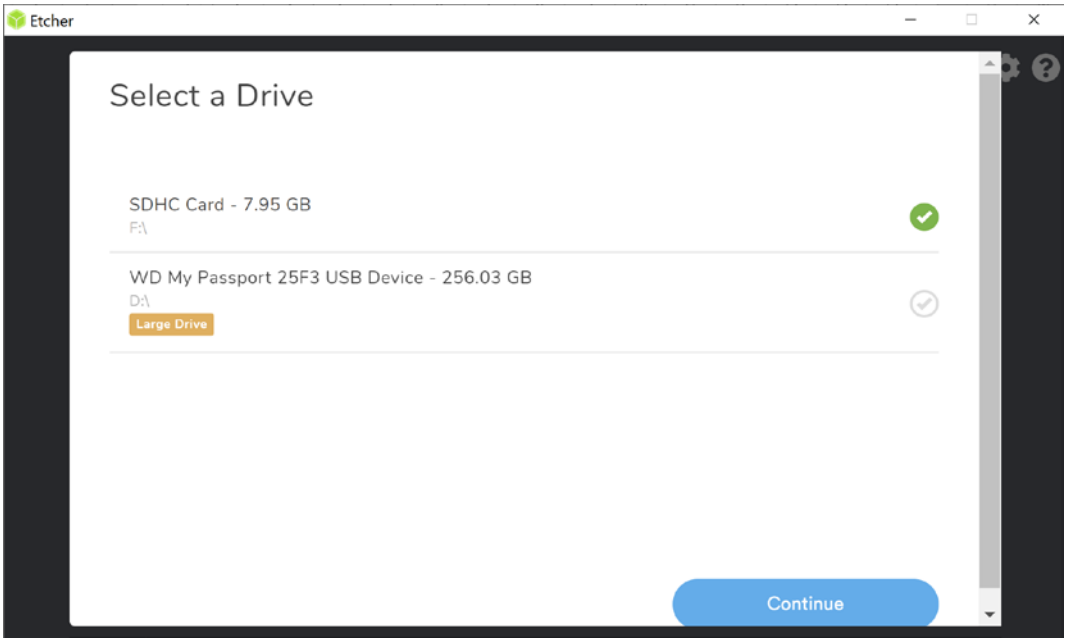
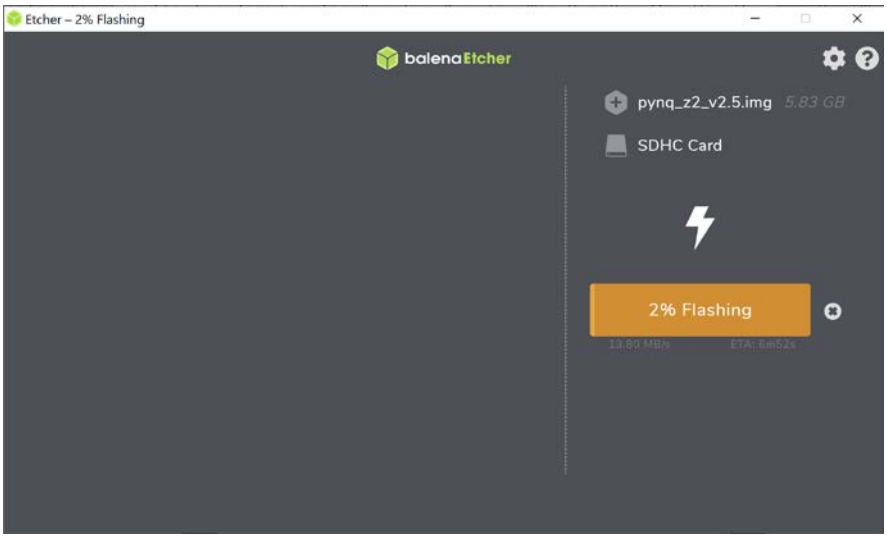
6. Select the SDHC card in Etcher.



7. Start the write to the SDHC card.



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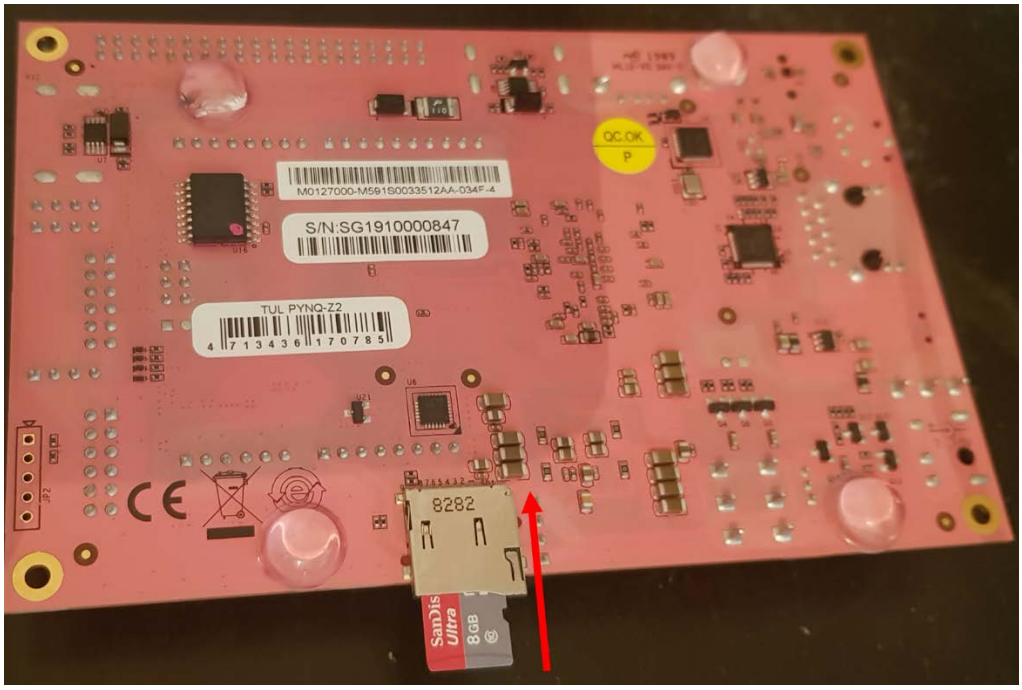
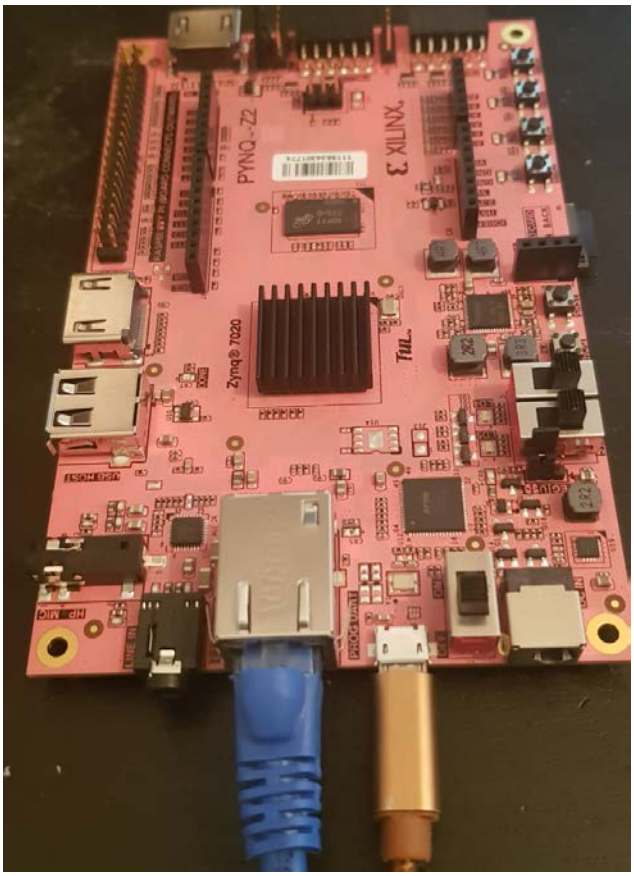
8. Once the write is completed, remove the SD card from your computer and insert it into the PYNQ-Z2 board. Ensure the PYNQ-Z2 is powered off during this operation.



9. Connect the micro USB cable between the PYNQ-Z2 and your laptop. Also connect the Ethernet cable (see Annex A if connecting Ethernet directly to PC).



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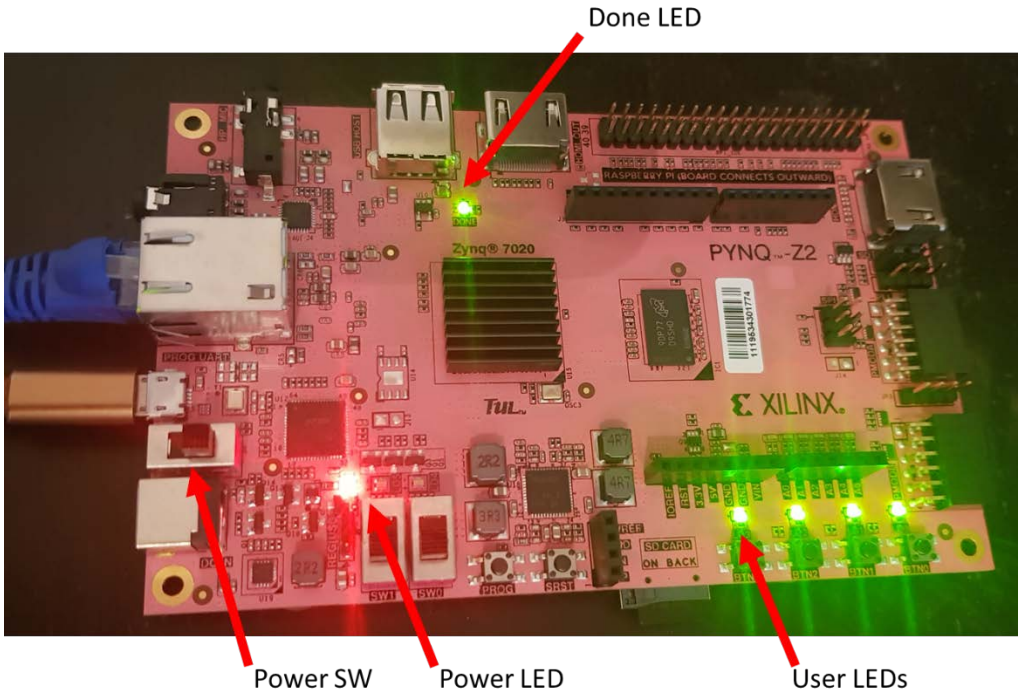
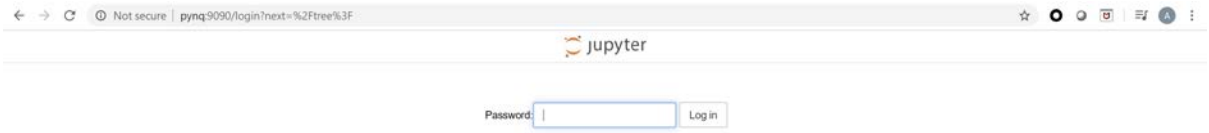
10. Power on the PYNQ-Z2. After a few seconds you will see the LED illuminate and the user LEDs flash and remain lit. This indicates the PYNQ-Z2 board has completed booting PYNQ.



11. The next step is to check that we can access the Jupyter Notebooks. On your computer, open a web browser and navigate to PYNQ:9090. You should see a Jupyter labs log in. The password for which is Xilinx.



12. Logging in, you will see we are ready to begin our development with PYNQ.

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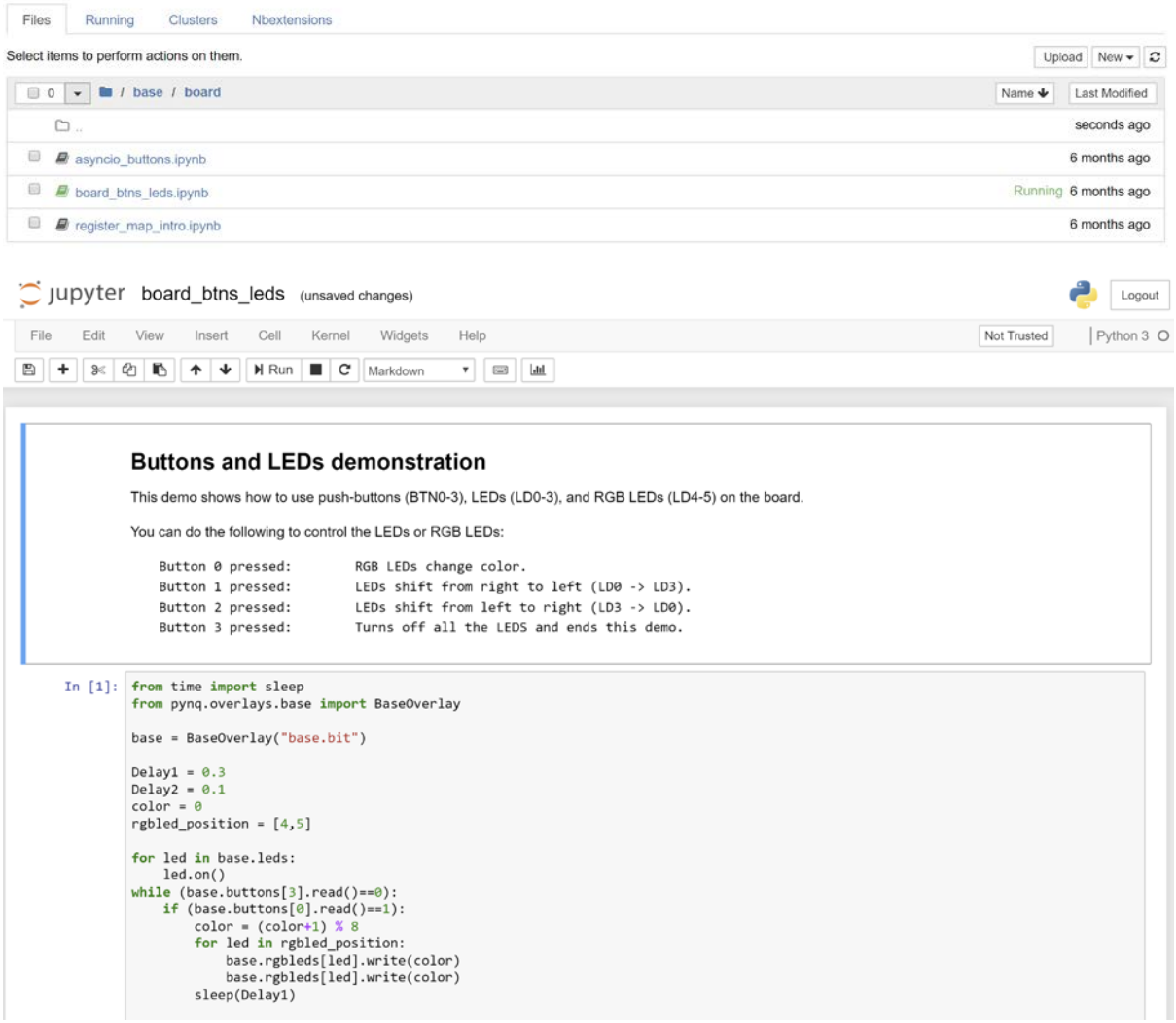
Lab One

In this lab, we are going to explore the base and logic tools overlay and look at how we can add in overlays from the PYNQ user community.

1. Power up your PYNQ-Z2 and log in to the Jupyter Notebook environment. If this is your first time, see Pre-Lab One above.

2. PYNQ works on a series of Jupyter Notebooks to enable us to work with the PS and the PL of the Zynq device. Notebooks can download programmable logic designs to the PL element of the design and interact with the PL using Python.

3. Let's take a look at one of the base overlay notebooks. In Jupyter labs, click on Base -> Board -> board_btns_leds.ipynb. This will open a new browser tab which contains the notebook.



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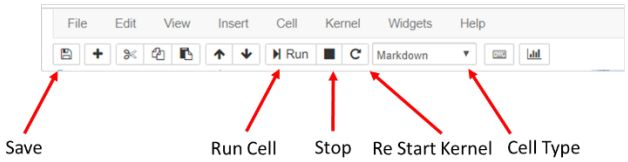
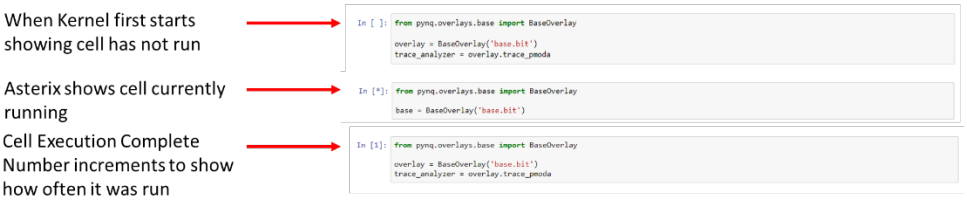
4. Run the cell of Python code by clicking on it and pressing Run Cell.

Working With Jupyter Notebooks





5. This will run an application which uses the LEDs and buttons on the Zynq device using the base overlay.
    a. Press and hold button 0. You will see the tri color LED cycle around colors while being held.
    b. Press and hold button 1. You will see the LED 0 – 3 flash in a pattern right to left.
    c. Press and hold button 2. You will see the LED 0 – 3 flash in a pattern left to right.
    d. Press button 3 and the demonstration will end.

6. Close the notebook board_btns_leds.ipynb. This will not stop the kernel running. On the home page, click on Running and you will see that it is still shown as running. Click on Shutdown. This will stop the kernel from running.

7. The base overlay provides the ability to quickly and easily interface and work with all of the interfaces on the PYNQ board, including the HDMI, Audio, Pmod, RPI and Shield Connector.

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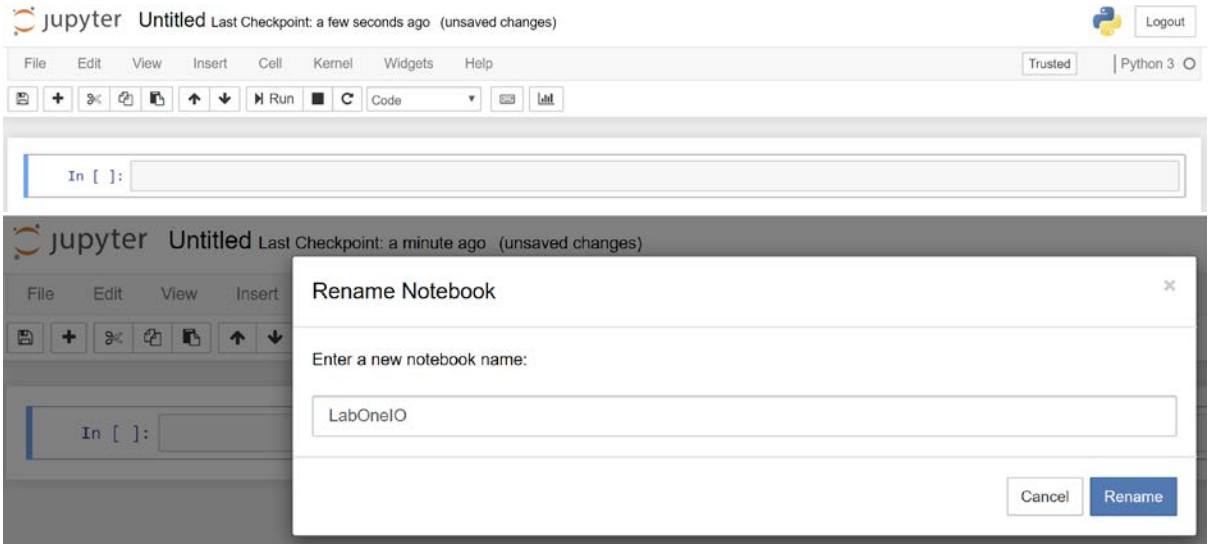
8. Open the logictools directory from the homepage.

9. Create a new notebook by clicking on New->Python3.

10. Change the name of the notebook by clicking on Untitled and enter the name LabOneIO.



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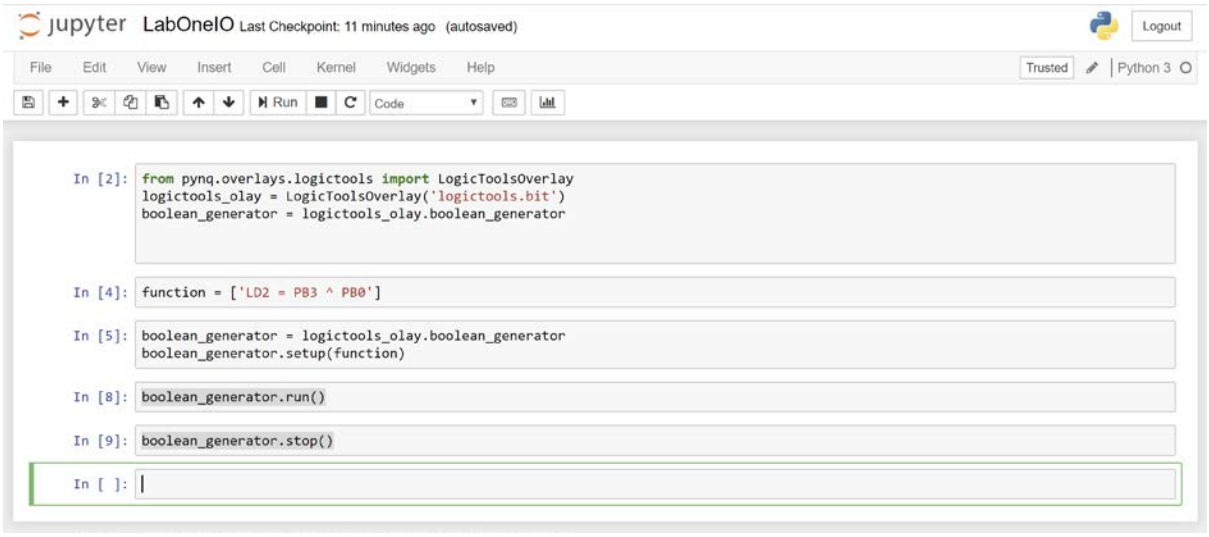
11. Enter the following code into the cell:

```
from pynq.overlays.logictools import LogicToolsOverlay
logictools_olay = LogicToolsOverlay('logictools.bit')
boolean_generator = logictools_olay.boolean_generator
function = {'XOR_gate': 'LD2 = PB3 ^ PB0'}
boolean_generator = logictools_olay.boolean_generator
boolean_generator.setup(function)
boolean_generator.run()
boolean_generator.stop()
```



12. Press the BTN3 and BTN2 and see the implementation of an OR gate that lights up the LED 3.

13. Try different logic implementations. AND = &, XOR = ^, OR = | and NOT = ~.

14. Congrats, you have created your first PYNQ application (do not worry we are going to get much more complicated).

15. Close the notebook and shutdown the kernel as we did in step 6.

16. Create an new notebook and call it LabOneWave (steps 9 & 10 show how to do this).

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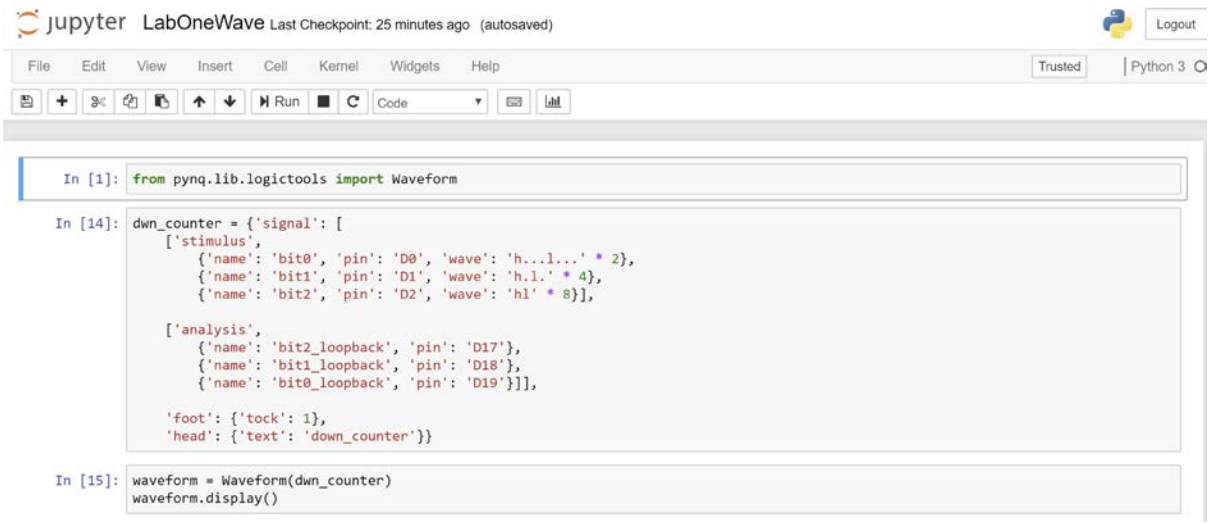
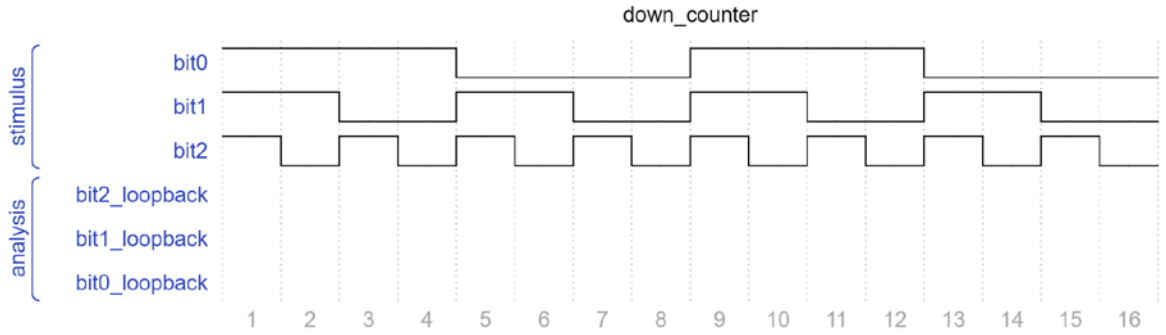
17. Enter the following code:

```
from pynq.lib.logictools import Waveform

dwn_counter = {'signal': [
   ['stimulus',
      {'name': 'bit0', 'pin': 'D0', 'wave': 'h...l...' * 2},
      {'name': 'bit1', 'pin': 'D1', 'wave': 'h.l.' * 4},
      {'name': 'bit2', 'pin': 'D2', 'wave': 'hl' * 8}],

   ['analysis',
      {'name': 'bit2_loopback', 'pin': 'D17'},
      {'name': 'bit1_loopback', 'pin': 'D18'},
      {'name': 'bit0_loopback', 'pin': 'D19'}]],

   'foot': {'tock': 1},
   'head': {'text': 'down_counter'}}

waveform = Waveform(dwn_counter)
waveform.display()
```



18. Run each of these cells. You should see a binary down counter however, the analysis elements will be empty.



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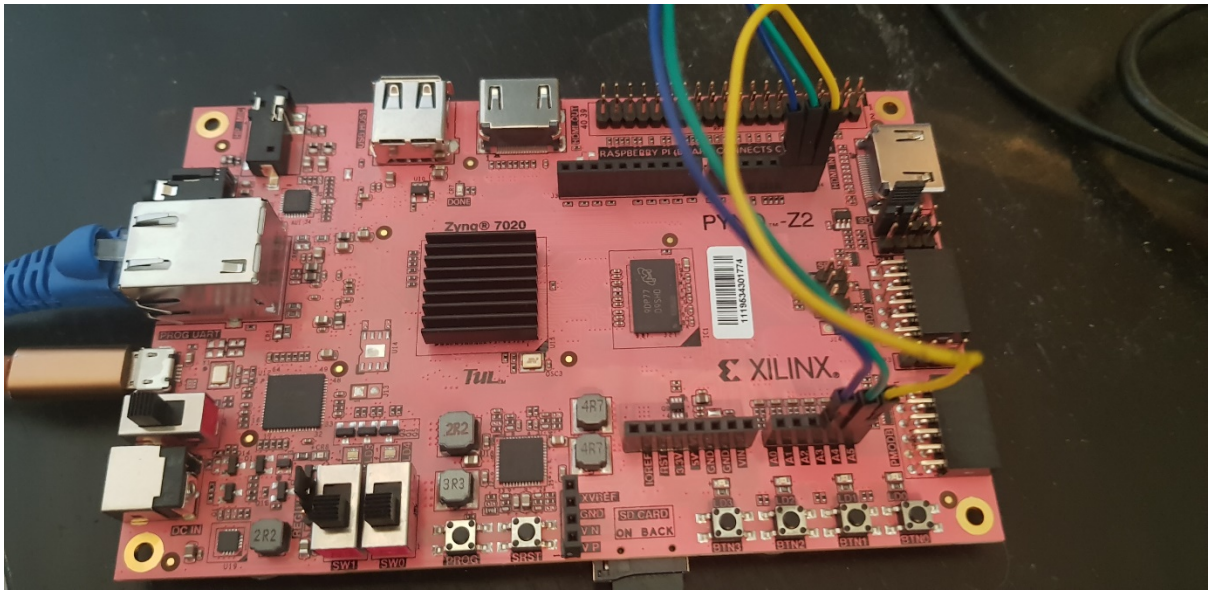
19. To be able to loop these back, we need to connect the flying lead connectors between the Arduino header as shown below. Make sure the PYNQ-Z2 is powered down.



20. Power up the board and re-open the LabOneWave notebook. Enter the following code in the notebook:

```
pattern_generator = logictools_olay.pattern_generator
pattern_generator.trace(num_analyzer_samples=16)
pattern_generator.setup(dwn_counter, stimulus_group_name='stimulus',
analysis_group_name='analysis')

pattern_generator.run()
pattern_generator.show_waveform()
```

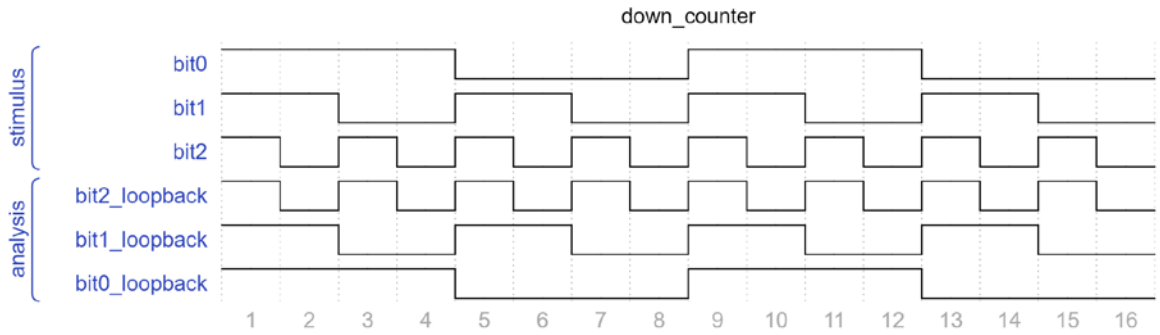
```
In [11]: pattern_generator = logictools_olay.pattern_generator

         pattern_generator.trace(num_analyzer_samples=16)

         pattern_generator.setup(dwn_counter, stimulus_group_name='stimulus', analysis_group_name='analysis')

In [12]: pattern_generator.run()
         pattern_generator.show_waveform()
```

21. Run the notebook cells and you should see the received patterns as output.



This ability to generate and capture waveforms really helps when we want to quickly and easily interface and test with sensors.

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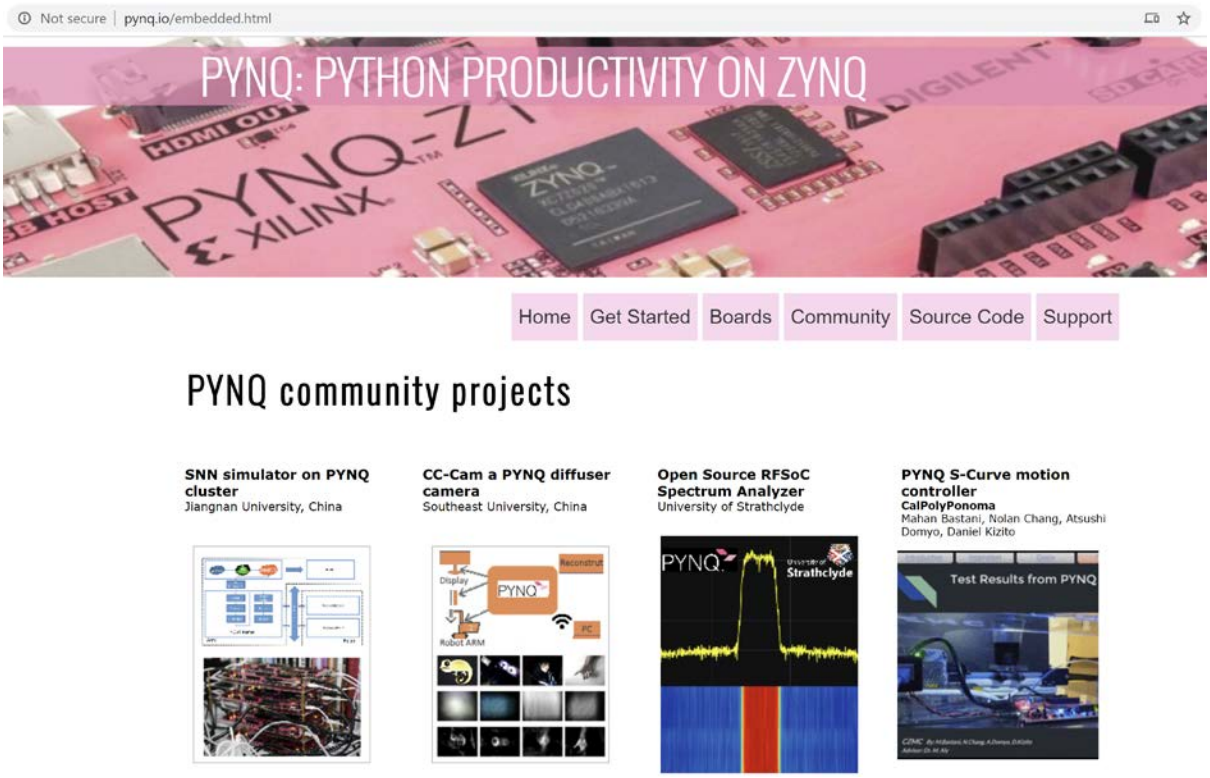
22. Close the notebook and shut it down as we have previously.

23. Open a new terminal window from the home screen.

24. We are going to use this terminal to install a new overlay.

25. In a browser on your computer open [http://www.pynq.io/embedded.html.](http://www.pynq.io/embedded.html)



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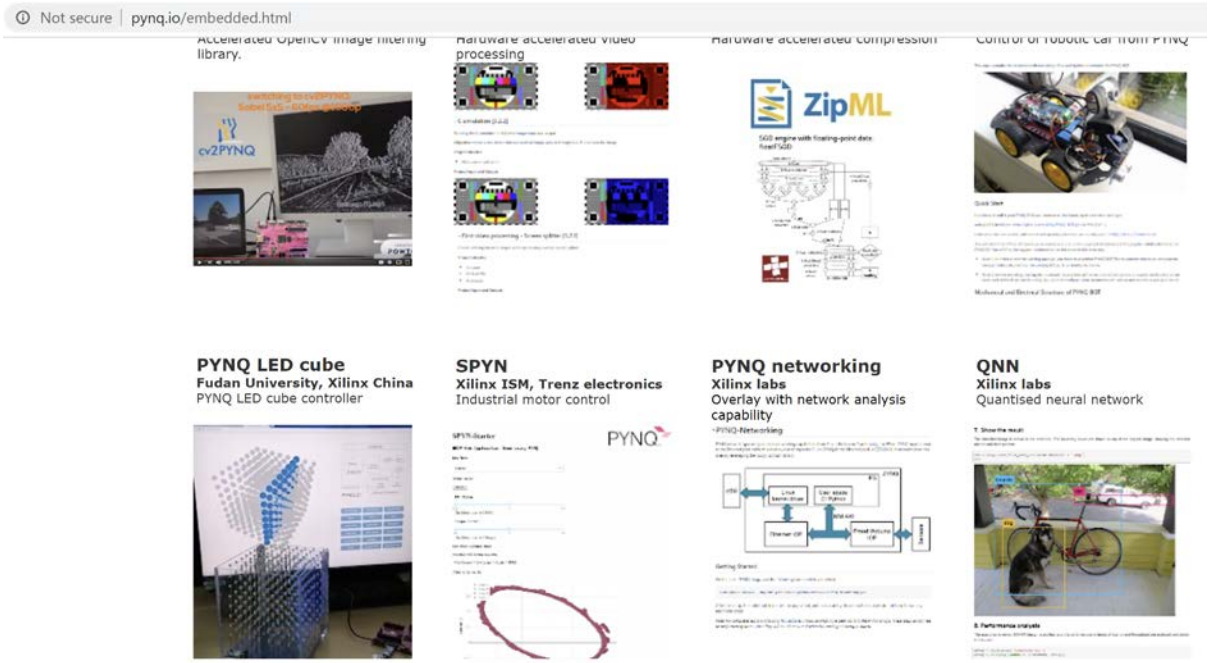
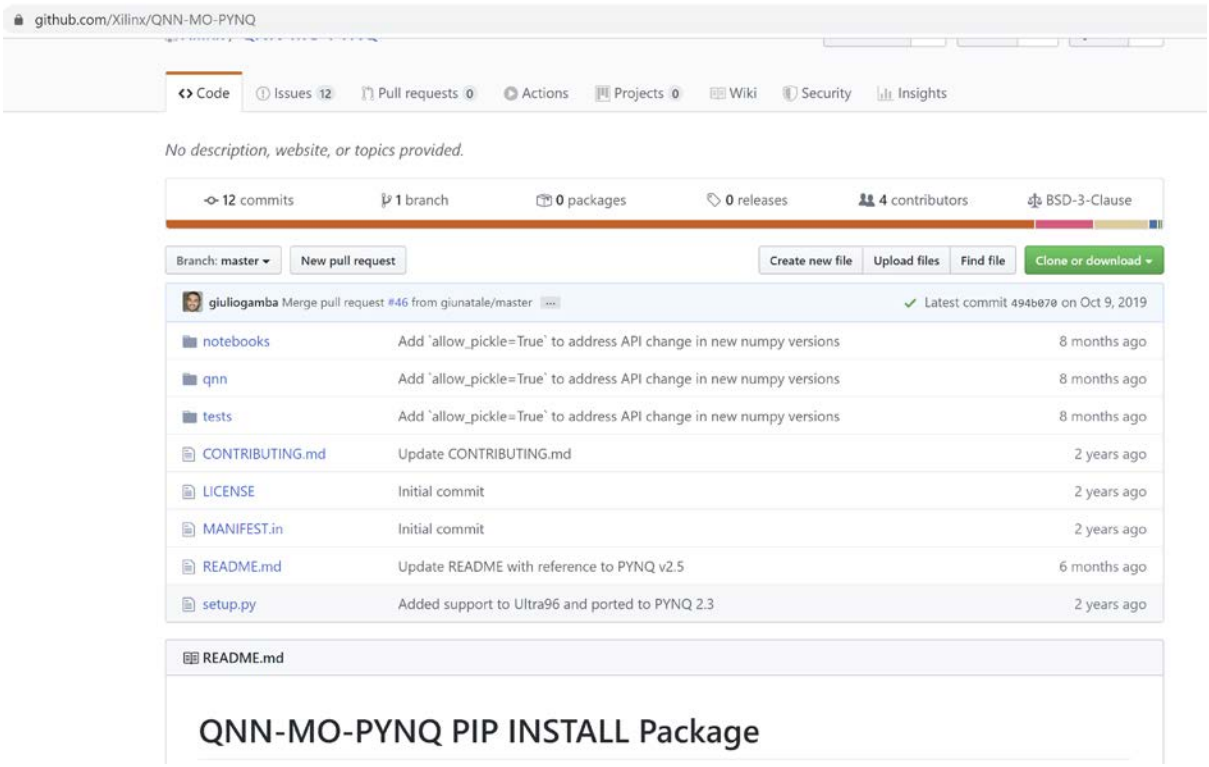
26. Scroll down until you find the QNN Xilinx Labs.



27. Click on the QNN overlay. This will take you to the GitHub for the overlay.



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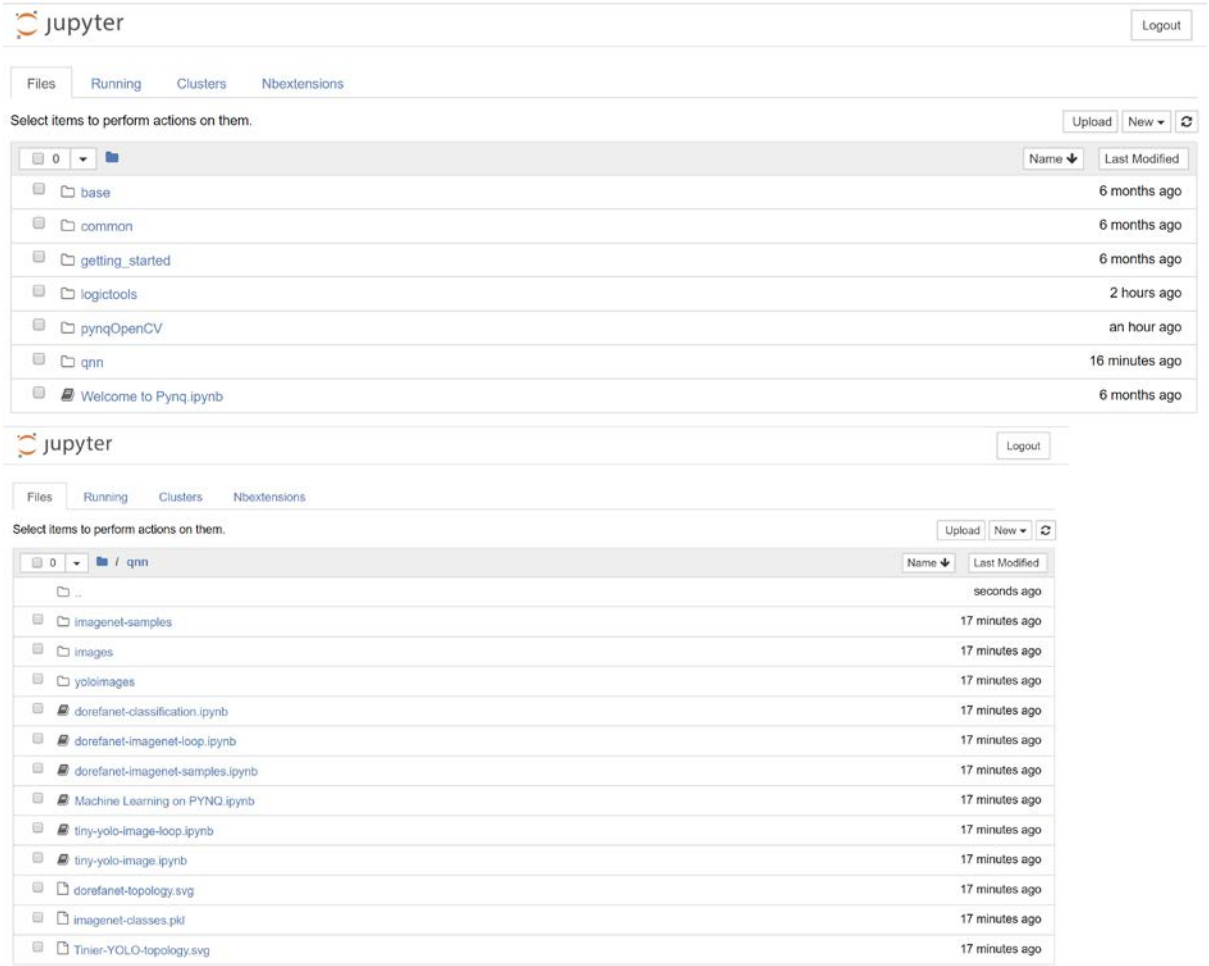
28. Copy the installation code from the GitHub, paste it in the terminal and press Enter.

29. On the homepage you should see a new directory called QNN. Open it.



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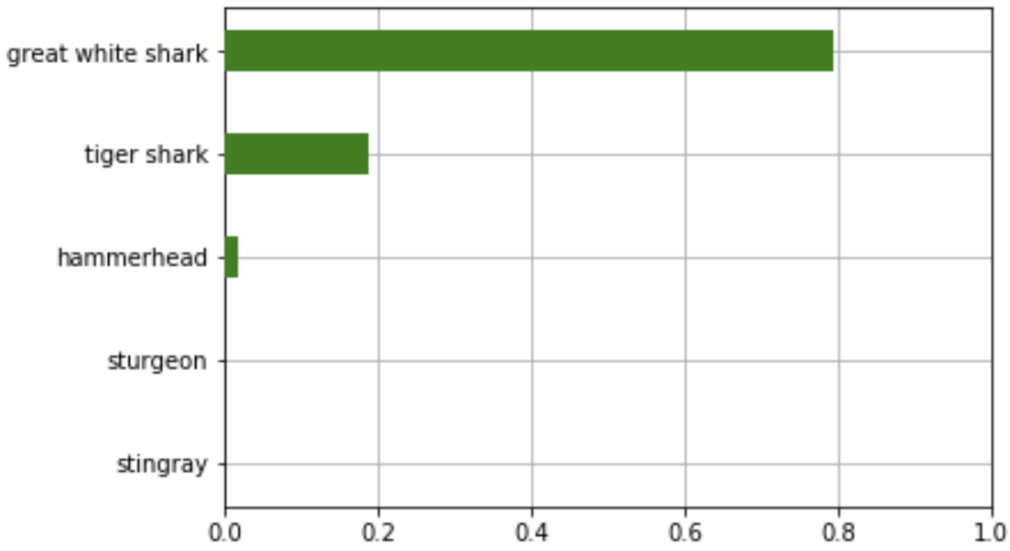
30. Open the dorefanet-classification.ipynb and run each of the cells.

```
class:   great white shark      probability:  79.40%
class:         tiger shark      probability:  18.92%
class:          hammerhead      probability:   1.63%
class:             sturgeon     probability:   0.01%
class:             stingray     probability:   0.01%
```



This demonstrates not only the ease with which overlays can be added to the system but also how complicated functions which use the programmable logic can be implemented and controlled from Python to give a significant acceleration.

In the next lab we will look at how we can develop our own overlay!

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