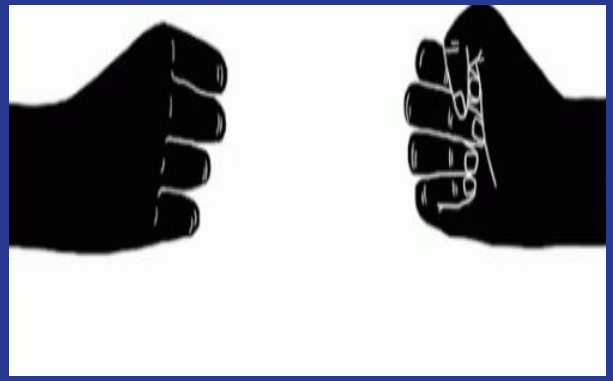
ECE532 - Digital Systems Design - *FINAL DEMO*



Rock, Paper, Scissors

Group 14

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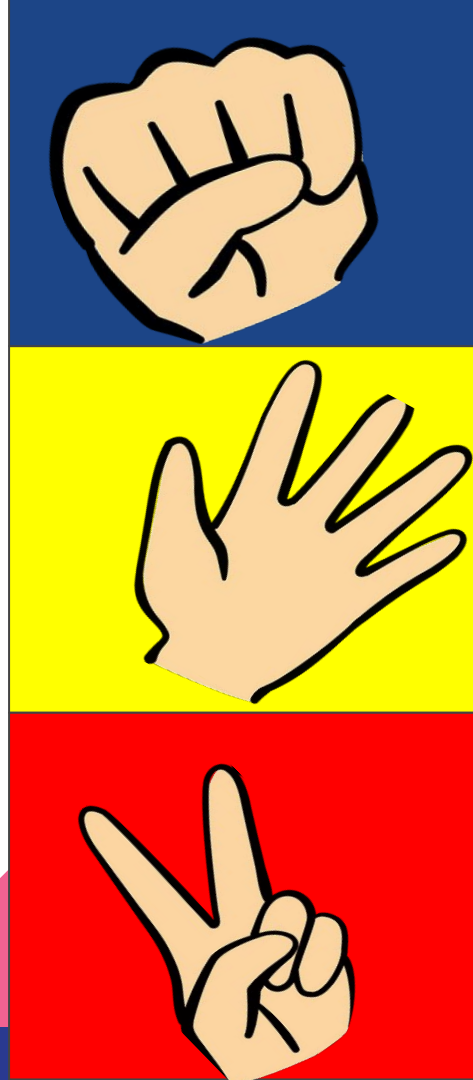
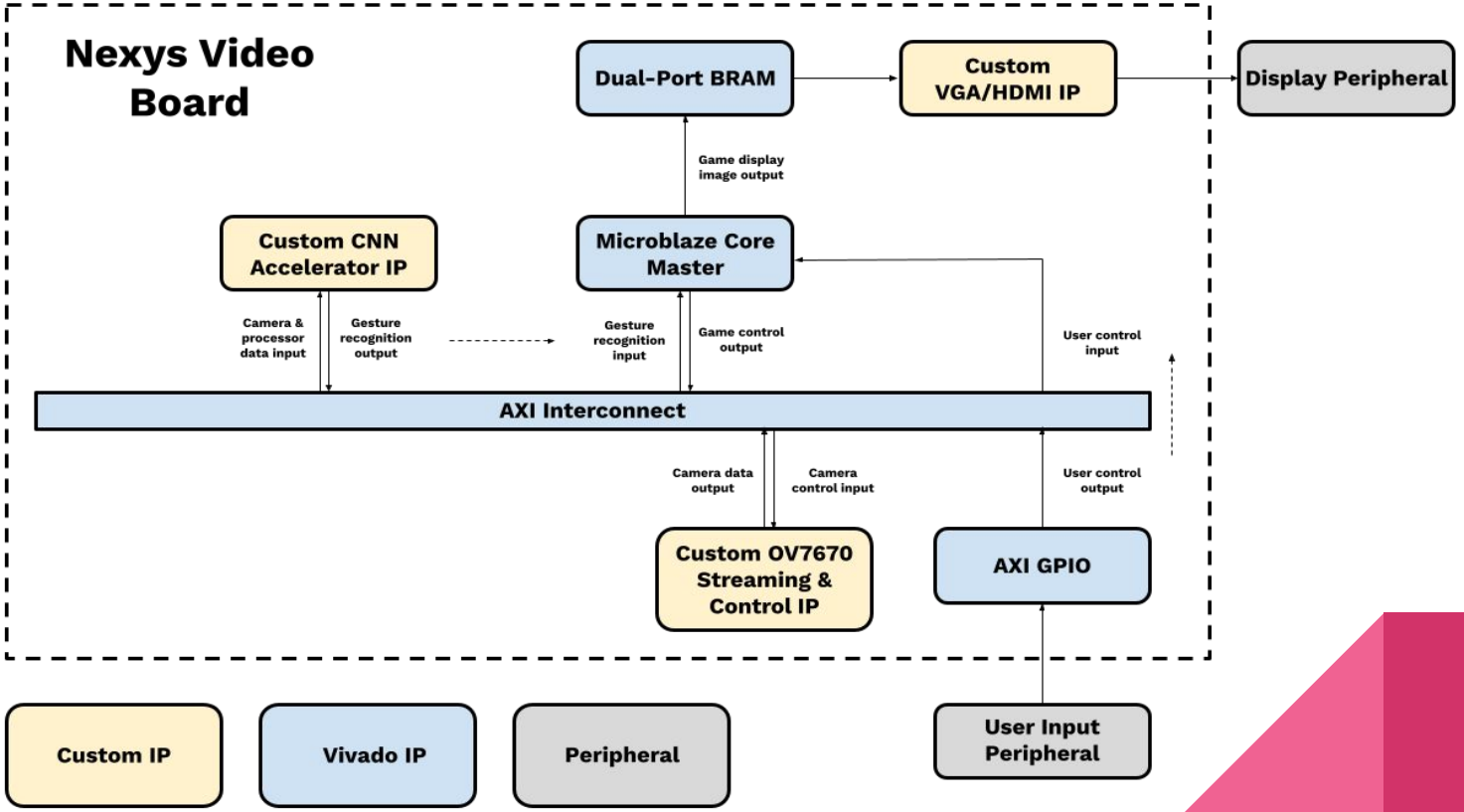
High-Level Project Description

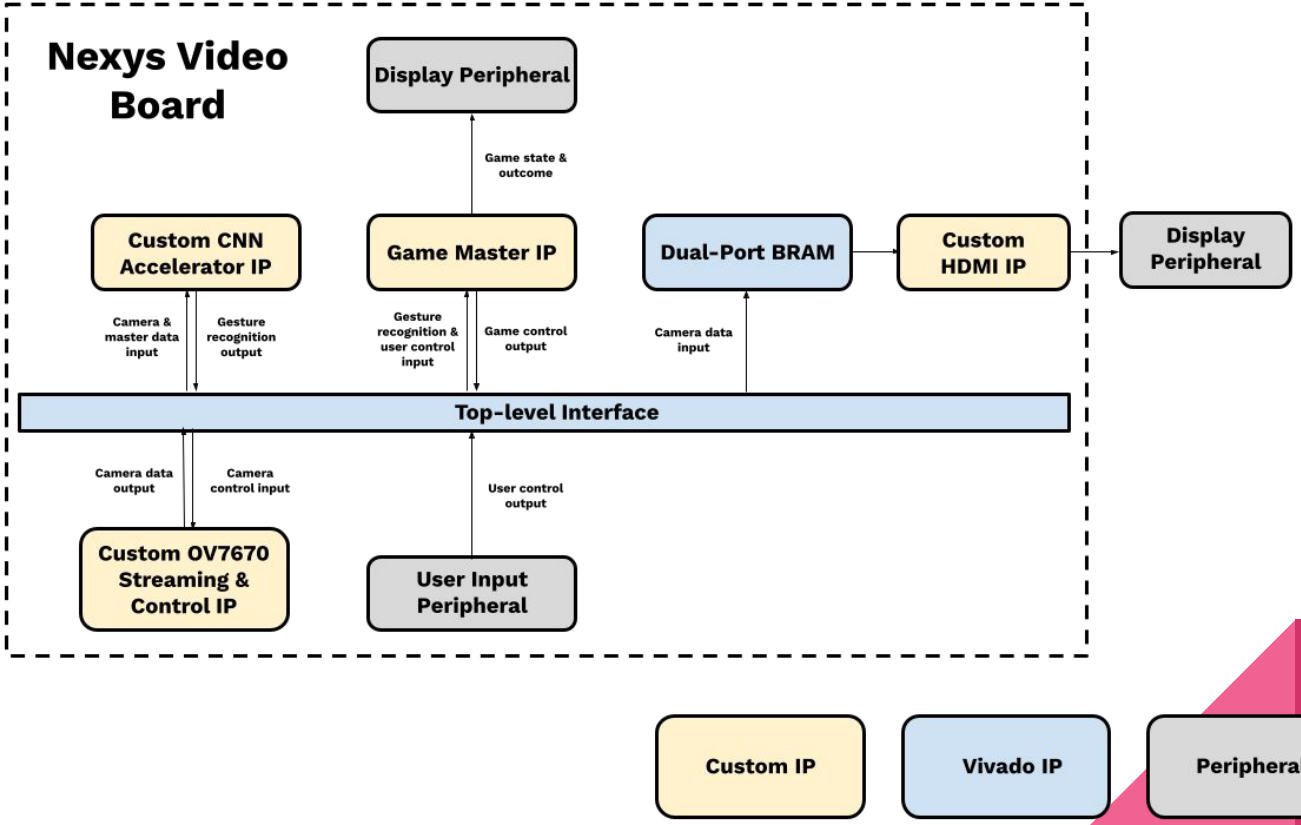
- Rock Paper Scissors universally recognised game
- Aims to create a human versus computer version of Rock Paper Scissors.
- Key components:
  - VGA camera to HDMI output
  - CNN accelerator
  - Image grayscale and compressor



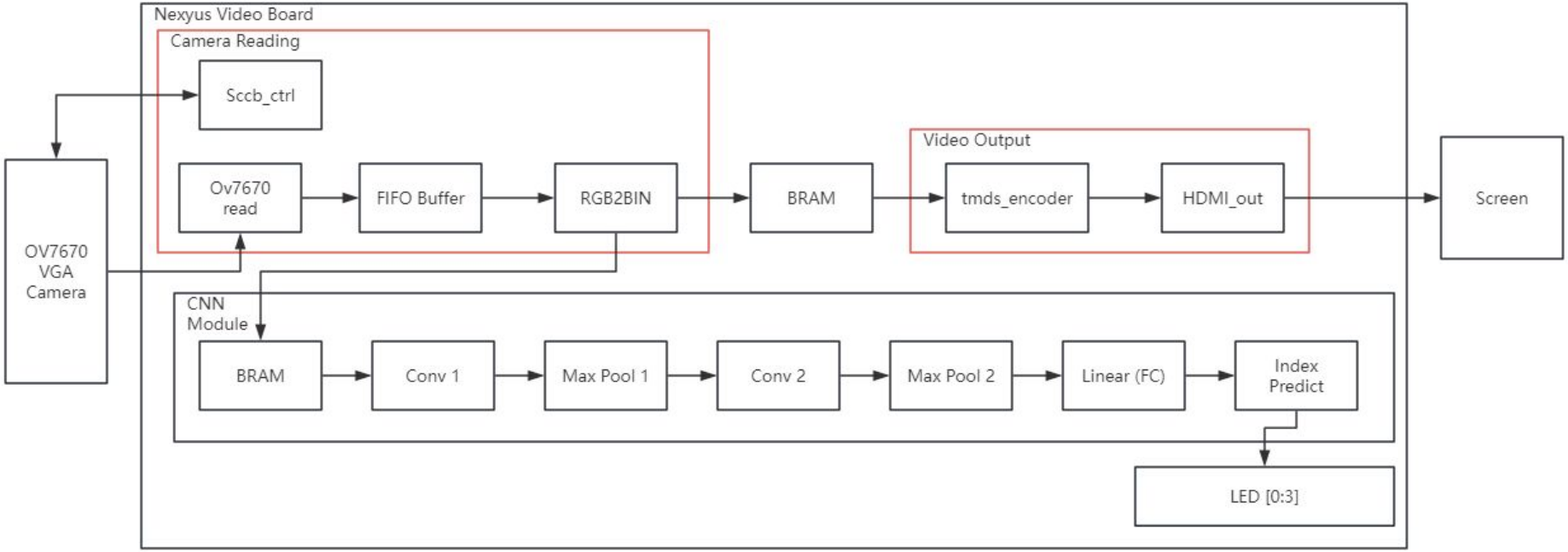
Project Description - Block Diagram (Initial Ver.)



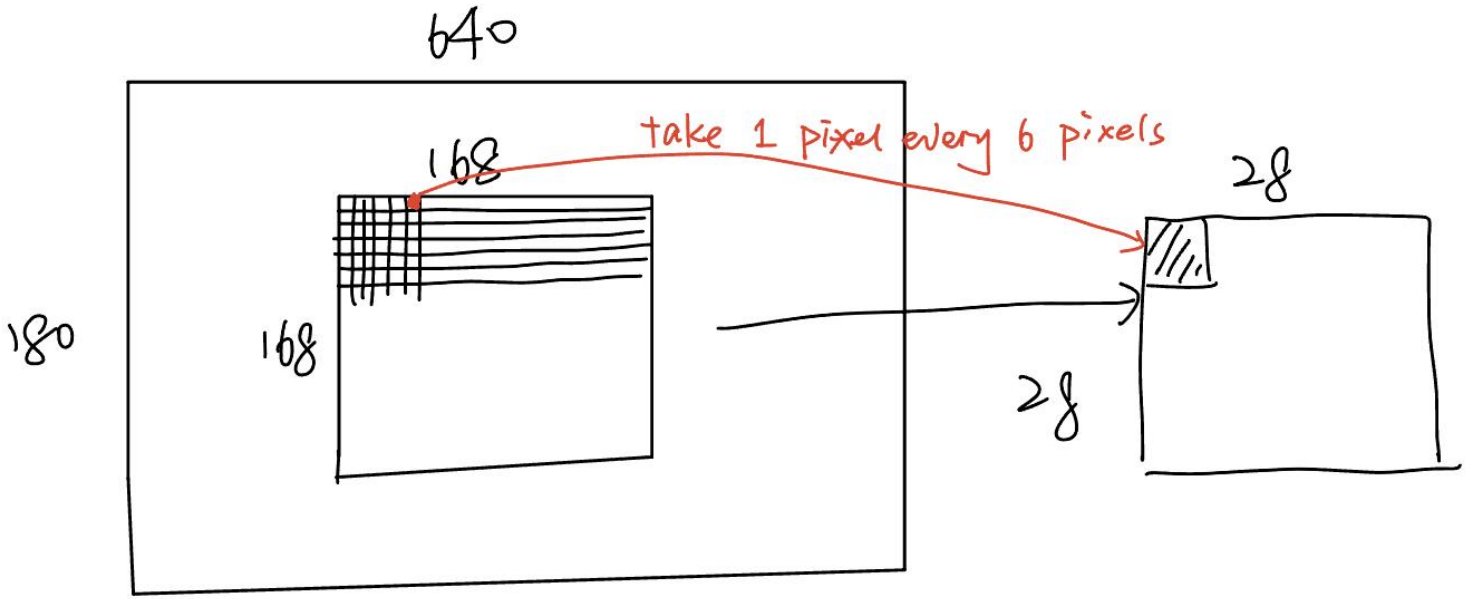
Project Description - Block Diagram (Final Ver.)



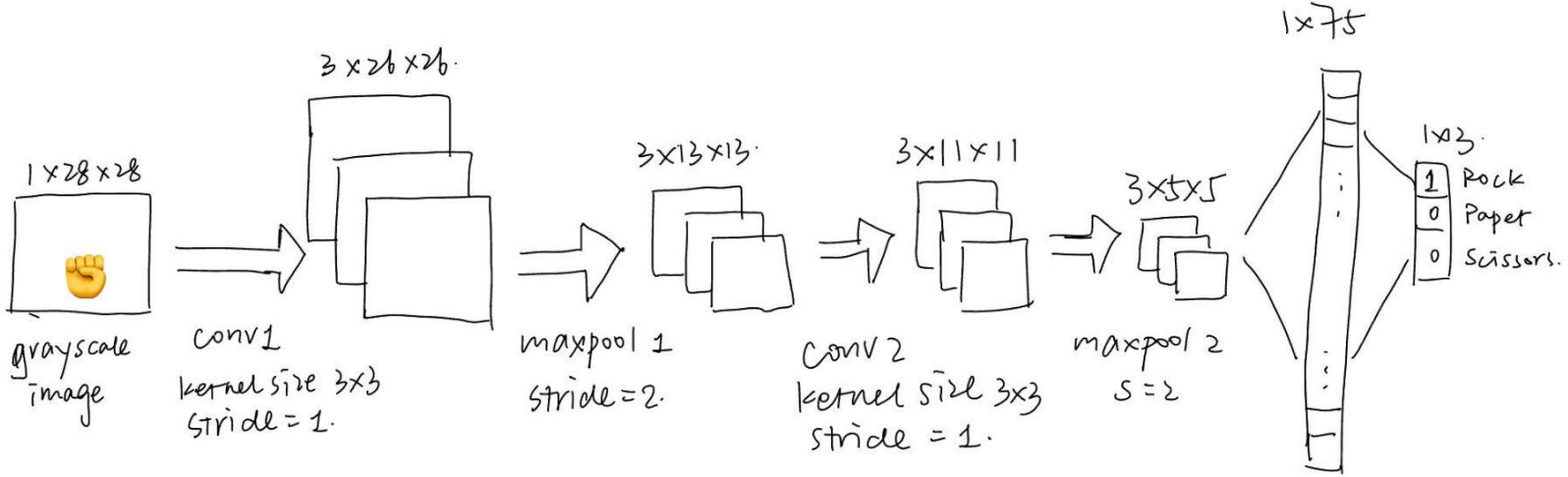
Explanation of Major Components - VGA Camera to HDMI



Explanation of Major Components - Image Compressor



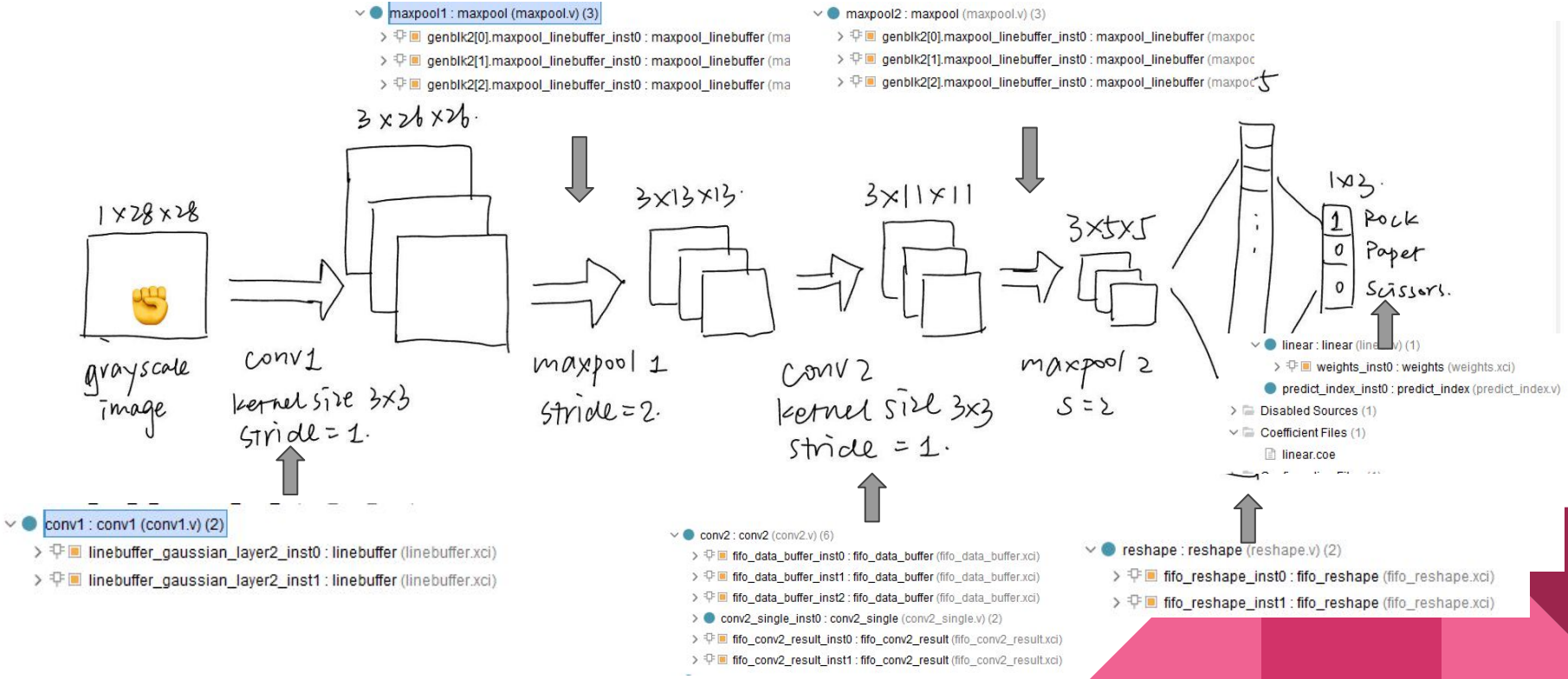
Explanation of Major Components - CNN (Software)



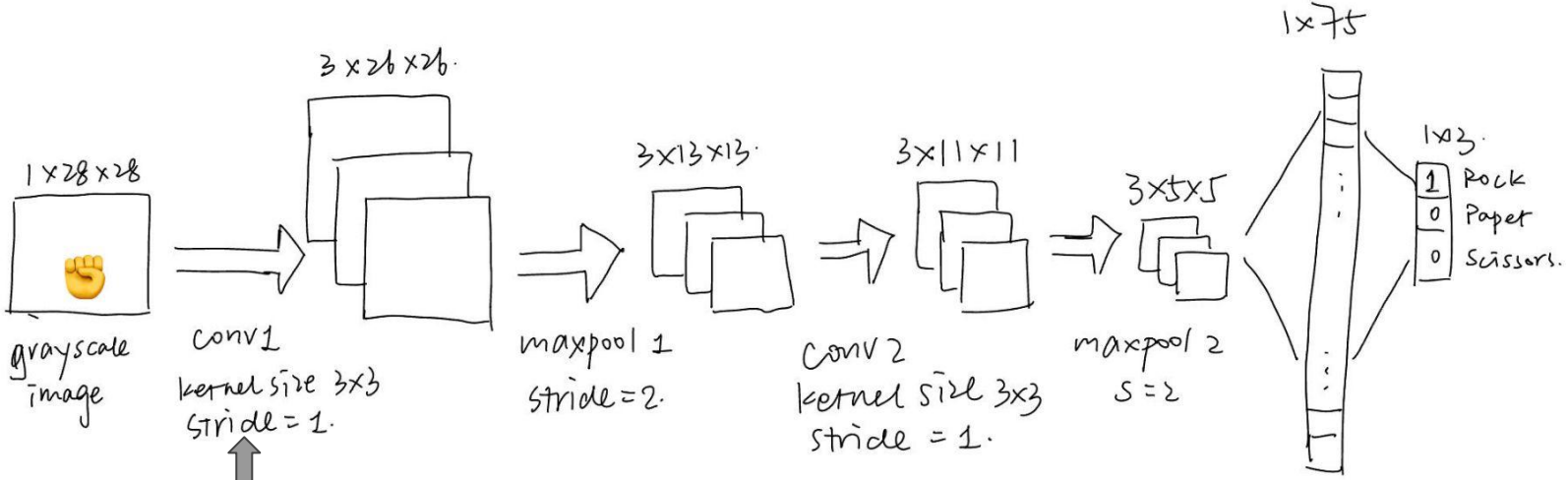
Explanation of Major Components - CNN (Software)

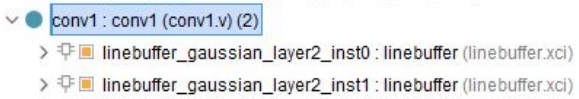
- Simplified LeNet
- 874 parameters
- float32 -> 10bit fixed point
- Accuracy: 82%

Explanation of Major Components - CNN Hardware



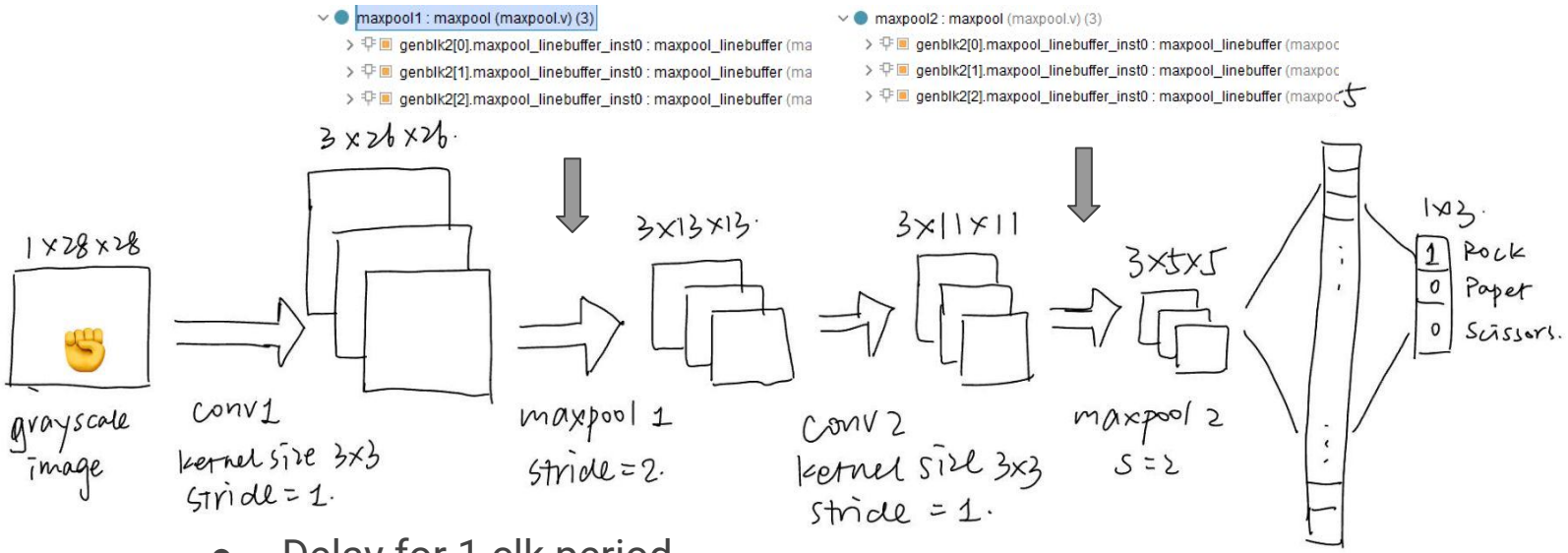
Explanation of Major Components - Conv 1





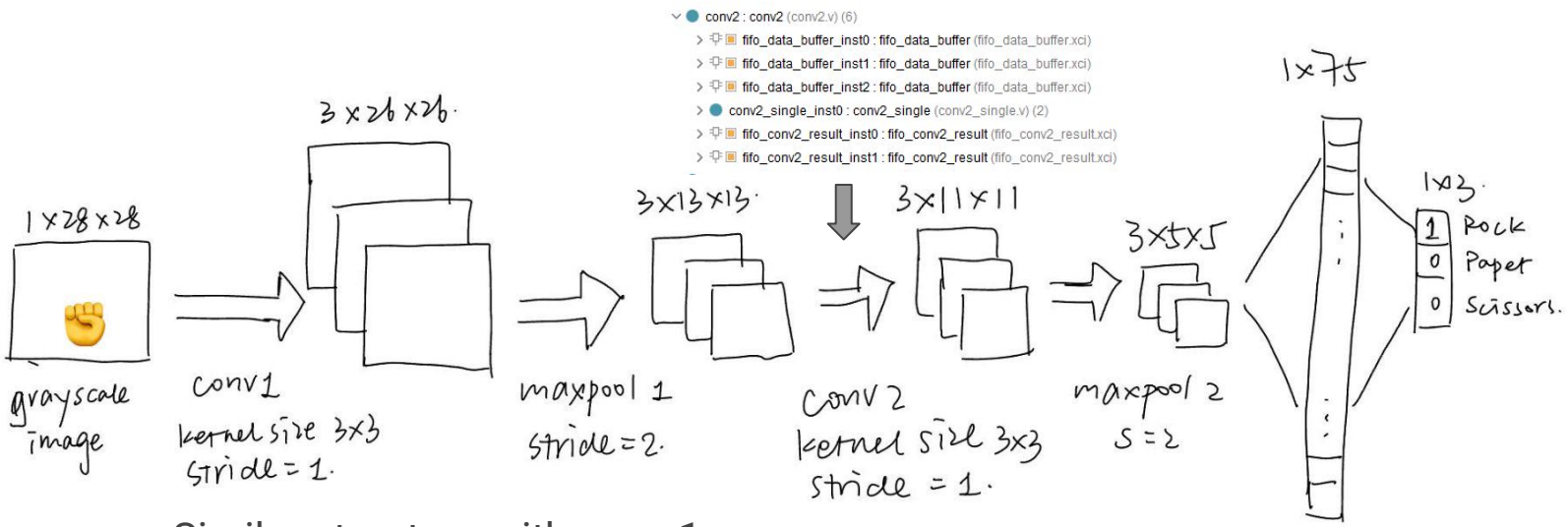
- Stream in data
- Linebuffer to store
- Convolution of 3 output channels computted in parallel

Explanation of Major Components - Maxpool



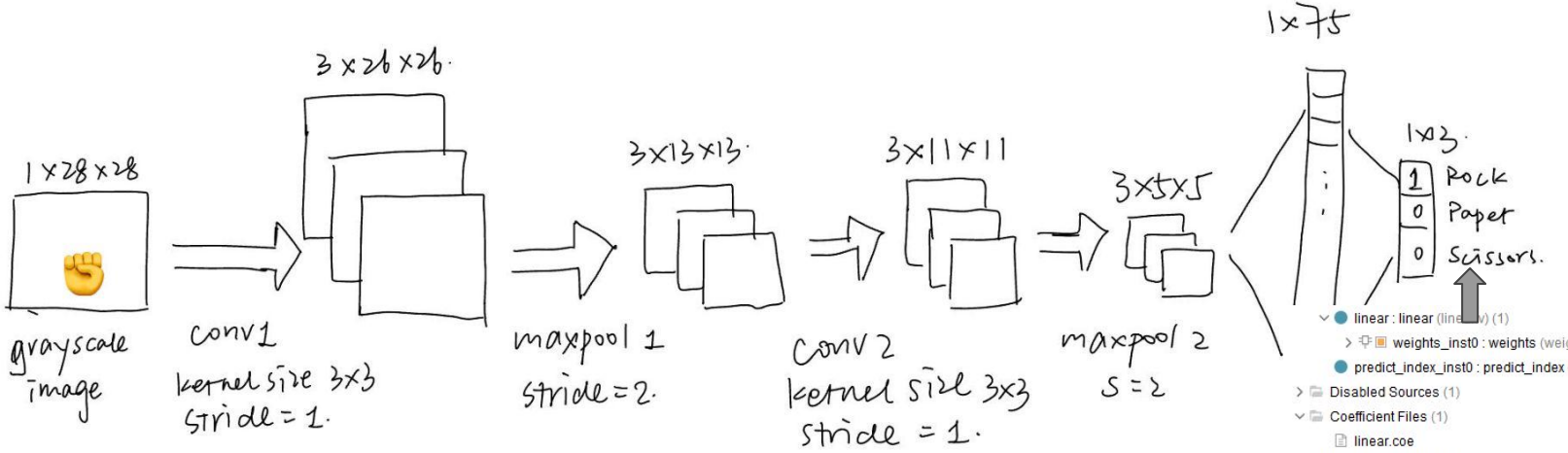
- Delay for 1 clk period
- Compare current pixel with previous pixel in one row
- Linebuffer to store
- Compare result with previous row
- Ouput feature map with reduced size

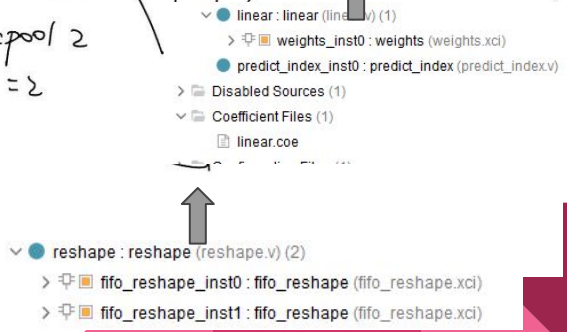
Explanation of Major Components - Conv2



- Similar structure with conv 1
- Save feature map 2 & 3, compute feature map 1
- Comput the convolution for each input feature map in parallel
- Store the result & store in FIFO
- Accumulate & RELU after 3 feature map are finished

Explanation of Major Components - Linear & output

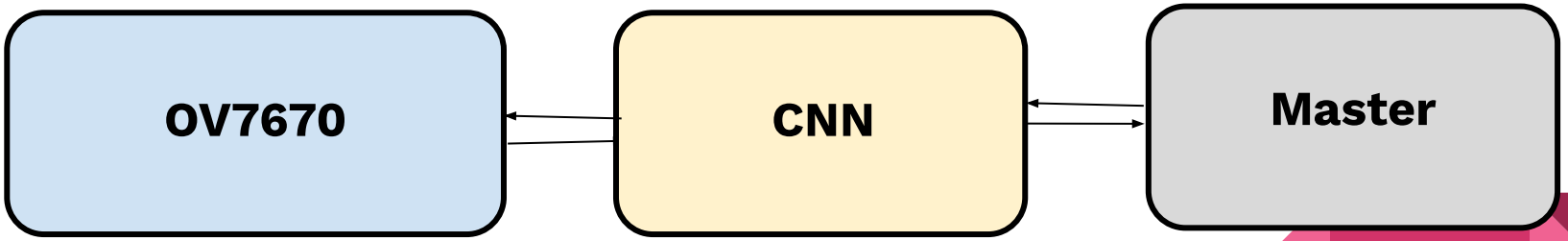




- Flatten the layer
- Weights stored by ROM (Block Memory Generator)
- 3 weights in a row => every input value
  => read 1 row from ROM and multiplication

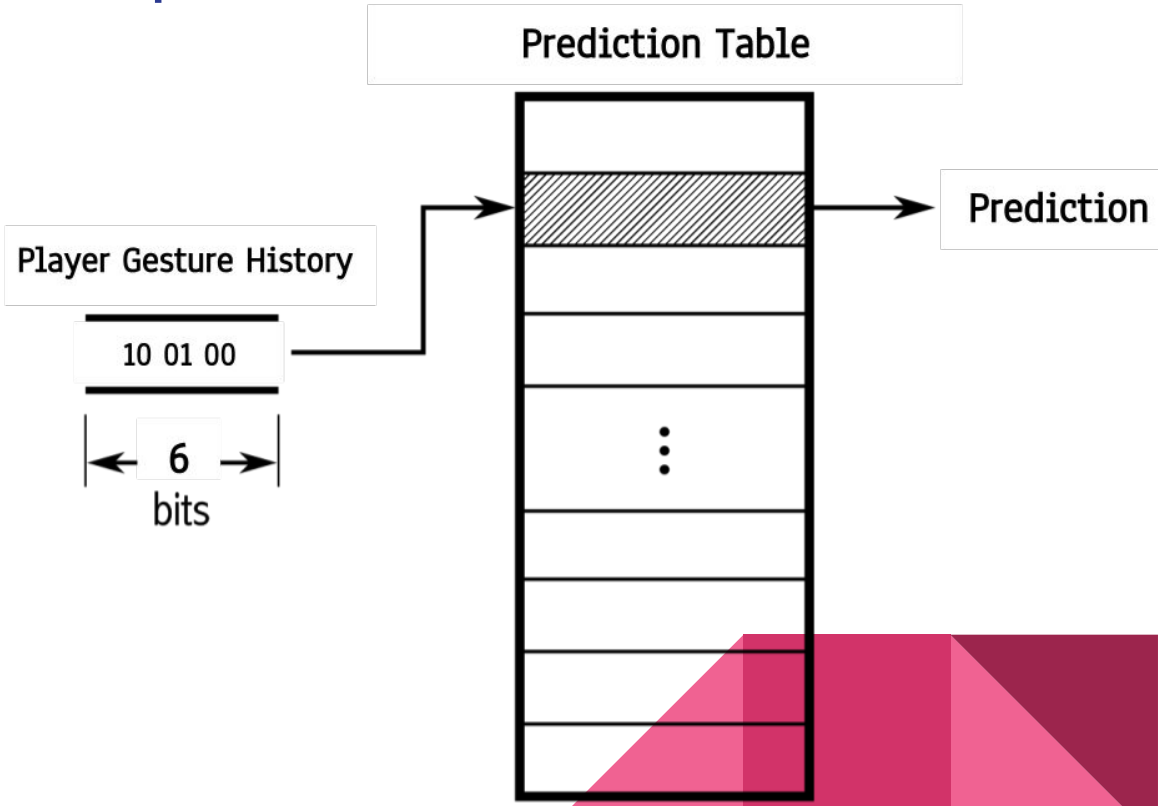
Explanation of Major Components - Integration

1. Camera-CNN interface
   a. image data
2. CNN-game master interface
   a. CNN gesture output to game master



Explanation of Major Components - Game Prediction

- Period 4 pattern detection
  - 6-bit Global History Buffer
  - 2^6 BRAM prediction table
- State machine prediction generator
  - Predicts if pattern detected
  - Generates random gesture otherwise



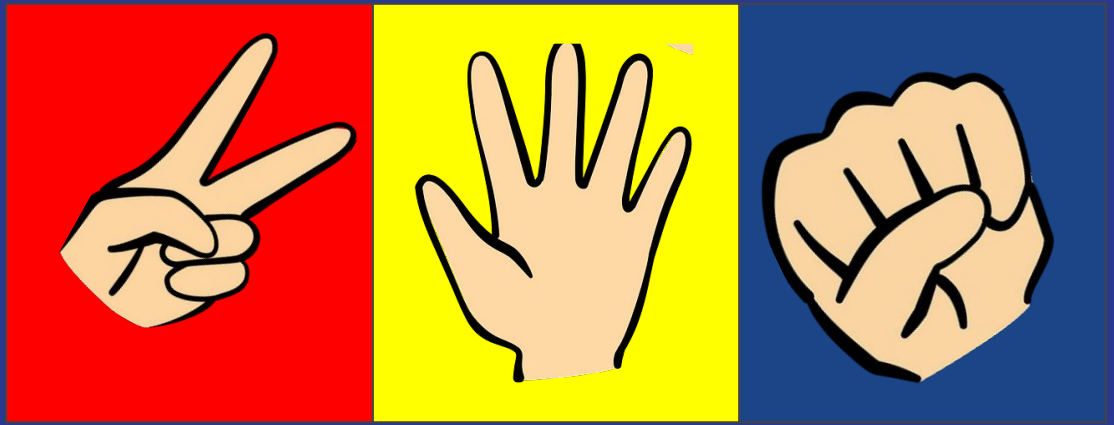
Final computed difficulty score

Components	**Score**
LEDS/Switches/Buttons	0
OV7670 VGA Camera	1
HDMI output on Nexsys-Video	1
CNN accelerator (IP Core implemented in FPGA Hardware)	2
Total	**4**

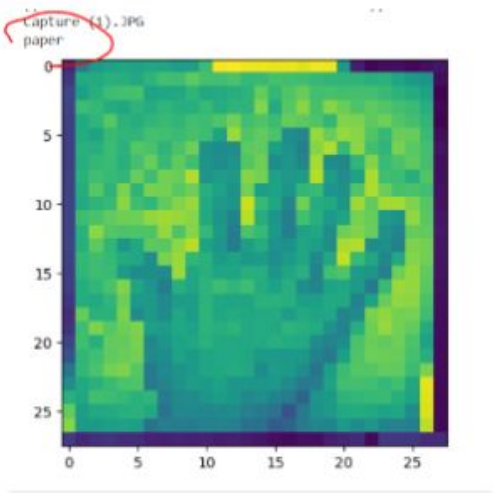
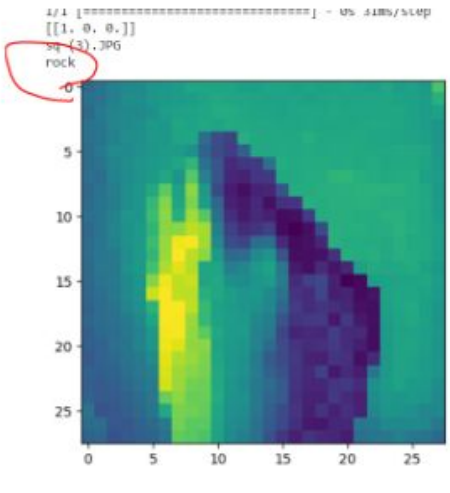
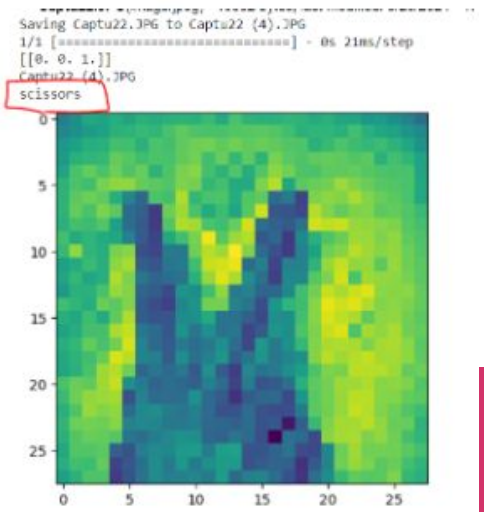
How to improve the project

1. Improve the model to achieve higher accuracy
   a. more dataset
   b. use data from camera
   c. use picture with higher resolution instead of 28x28
   d. model with larger kernel size => more trainable parameters
2. Display the game result on monitor

Demo Time



Some extra stuff for CNN
(in case CNN doesn’t work well)

rock	paper	scissor
		

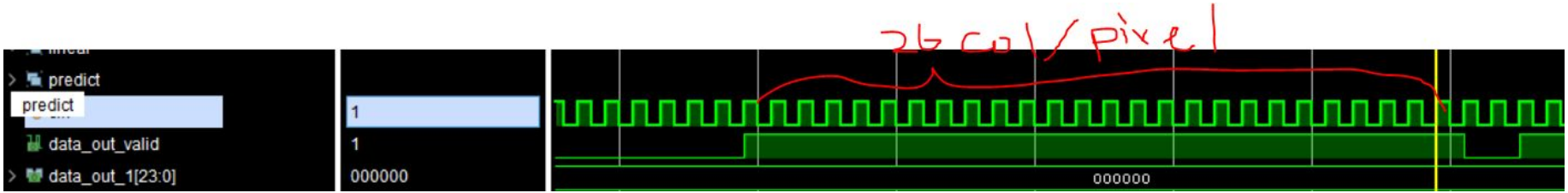
Some extra stuff for CNN (Sample Input)

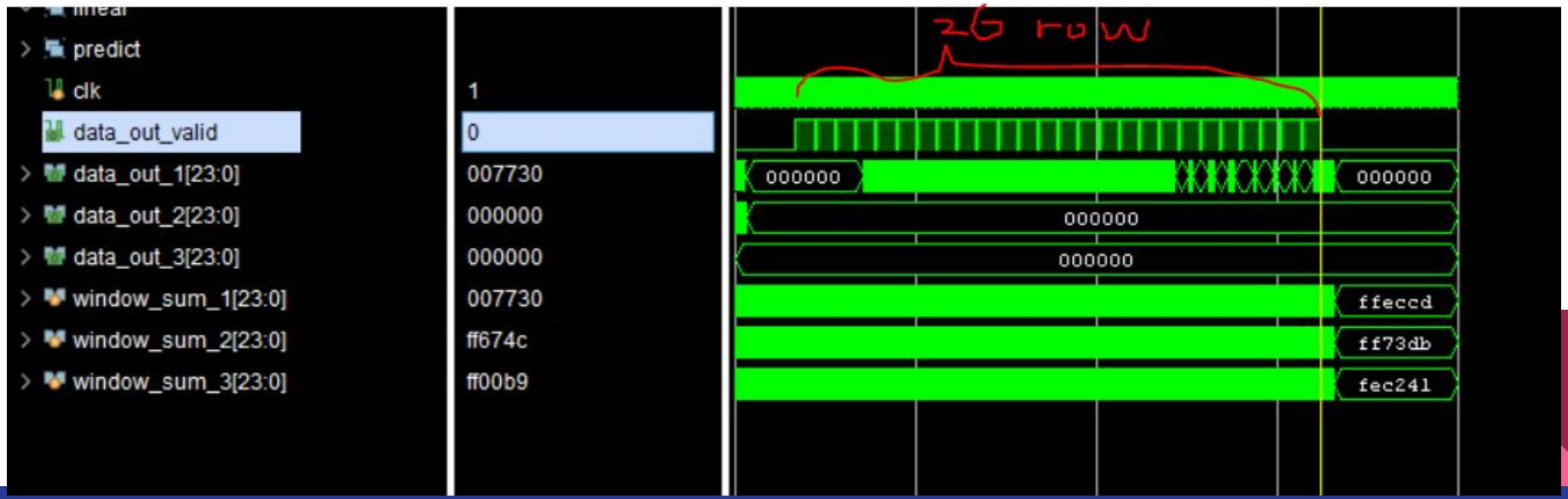
```
tensor(0)
```

Rock

```
11111101
11111101
11111101
11111101
11111101
11111101
11111101
11111101
11111101
11111101
11111101
11111101
11111101
11111101
```

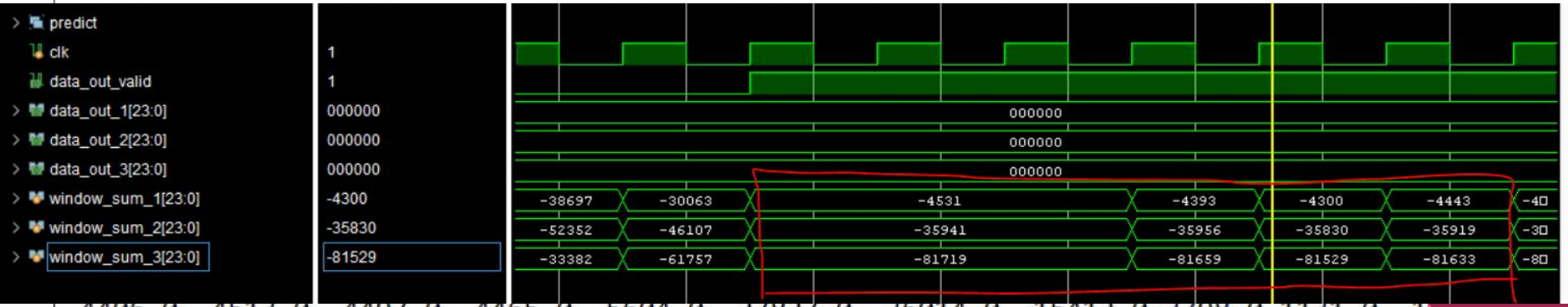
Some extra stuff for CNN (Conv1 Result - dimension)





Some extra stuff for CNN (Conv1 before RELU)

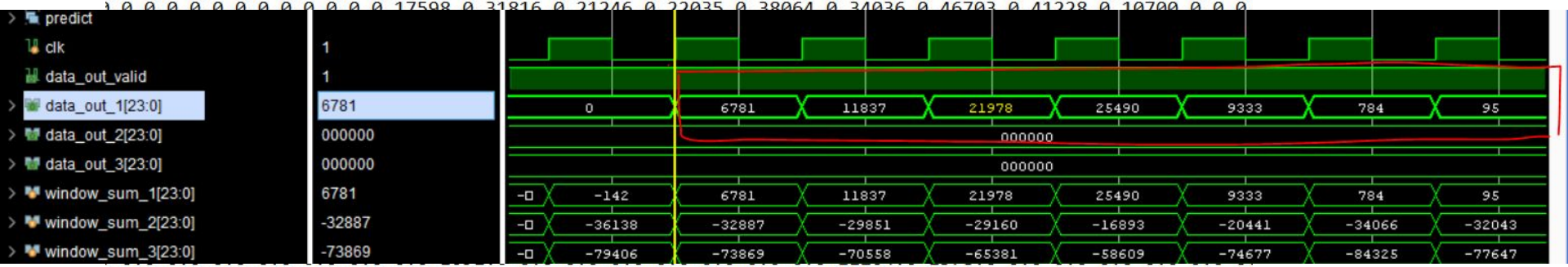
```
Channel: 0
-4531.0 -4531.0 -4531.0 -4393.0 -4300.0 -4443.0 -4230.0 -4180.0 -4459.0 -4552.0 -45
-4531.0 -4531.0 -4531.0 -4515.0 -4331.0 -4363.0 -4254.0 -4318.0 -4089.0 -4318.0 -45
-4531.0 -4531.0 -4393.0 -4574.0 -4547.0 -4513.0 -4513.0 -4513.0 -4361.0 -4196.0 -37
-4531.0 -4531.0 -4515.0 -4483.0 -4406.0 -4513.0 -4513.0 -4375.0 -142.0 6781.0 11837
-4531.0 -4393.0 -4574.0 -4547.0 -4513.0 -4513.0 -4513.0 -2427.0 13846.0 30180.0 346
```




```
-4406.0 -4513.0 -4497.0 -4465.0 -5604.0 -27827.0 -36014.0 -15412.0 3798.0 1131.0 -1
-4513.0 -4513.0 -4649.0 -4508.0 -4495.0 -14577.0 -43952.0 -29458.0 -4163.0 1669.0 3
-4513.0 -4513.0 -4649.0 -4508.0 -4495.0 -6607.0 -32943.0 -45408.0 -22652.0 -536.0 1
```

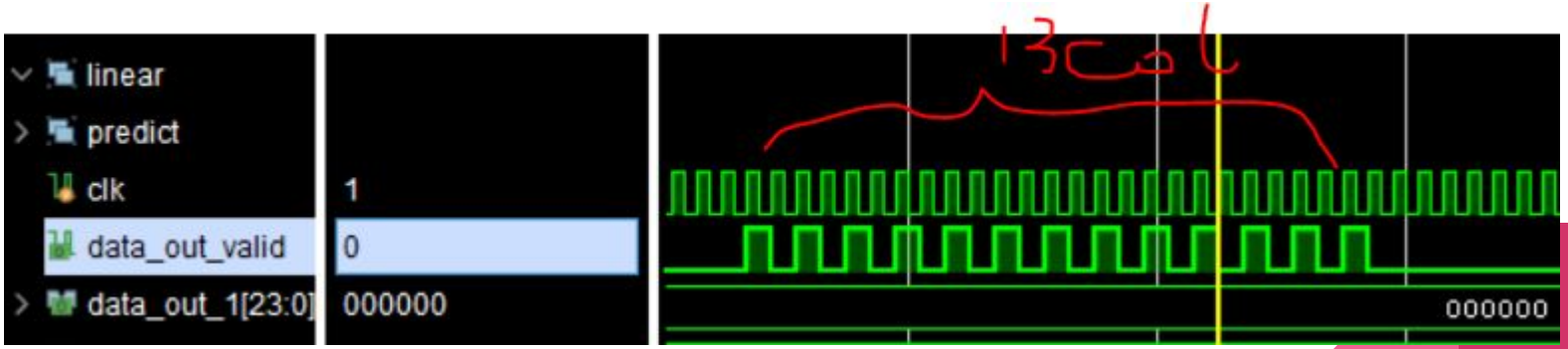
Some extra stuff for CNN (Conv1 Result)

```
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 6781.0 11837.0 21978.0 25490.0 9333.0 784.0 95.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 13846.0 30180.0 34634.0 27585.0 41078.0 53651.0 41743.0 29546.0 9478.0 0.0 0.0
```



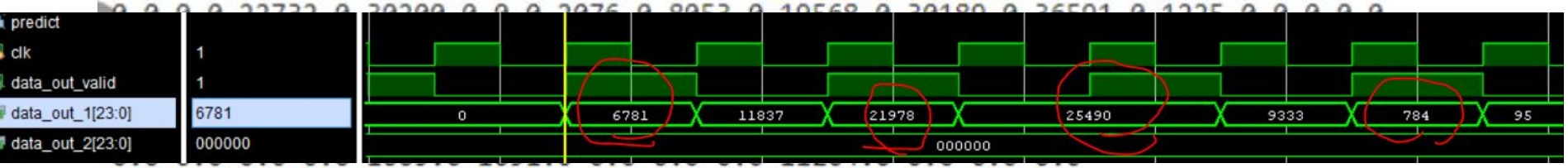

```
0.0 0.0 0.0 0.0 0.0 0.0 0.0 282.0 468.0 0.0 0.0 0.0 0.0 0.0 0.0 10493.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 1233.0 544.0 0.0 0.0 0.0 0.0 0.0 7356.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 2359.0 2124.0 1287.0 0.0 0.0 0.0 0.0 2778.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 1142.0 2264.0 500.0 0.0 0.0 9077.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 462.0 438.0 0.0 0.0 2901.0 20989.0 2740.0 0.0 0.0 0.0 0.0 0.0 0.
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 223.0 0.0 0.0 0.0 1108.0 25235.0 10445.0 0.0 0.0 0.0 0.0 0.0 0.
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 20972.0 15513.0 787.0 0.0 0.0 0.0 0.0 0.0 0.
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 15137.0 19213.0 2186.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 9440.0 21713.0 2726.0 0.0 0.0 0.0 0.0 0.0 0.
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 5449.0 22610.0 4154.0 0.0 0.0 0.0 0.0 0.0 0.
```

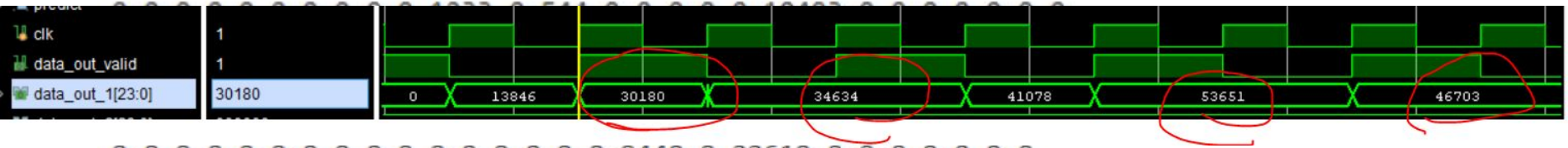
Some extra stuff for CNN (Maxpool 1 - dimension)



Some extra stuff for CNN (Maxpool 1)

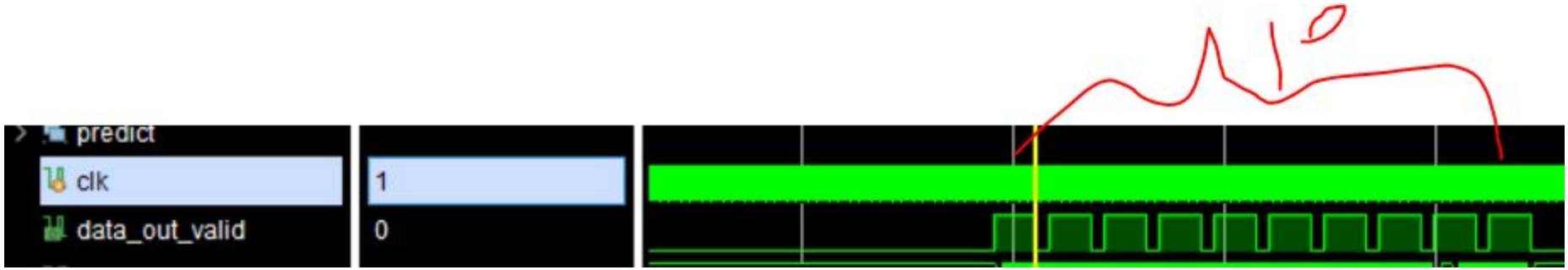
```
Channel: 0
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 6781.0 21978.0 25490.0 784.0 0.0 0.0 0.0 0.0 0.0
0.0 0.0 0.0 0.0 30180.0 34634.0 53651.0 46703.0 41228.0 0.0 0.0 0.0 0.0
```

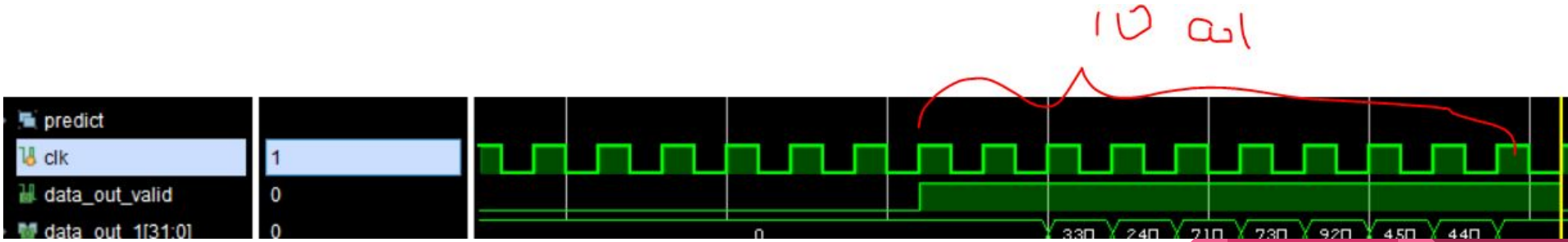





```
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 9440.0 22610.0 0.0 0.0 0.0
```

Some extra stuff for CNN (Conv2 - dimension)



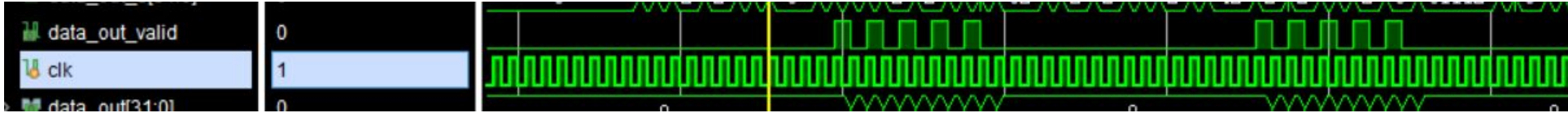


Some extra stuff for CNN (Conv2 after RELU)

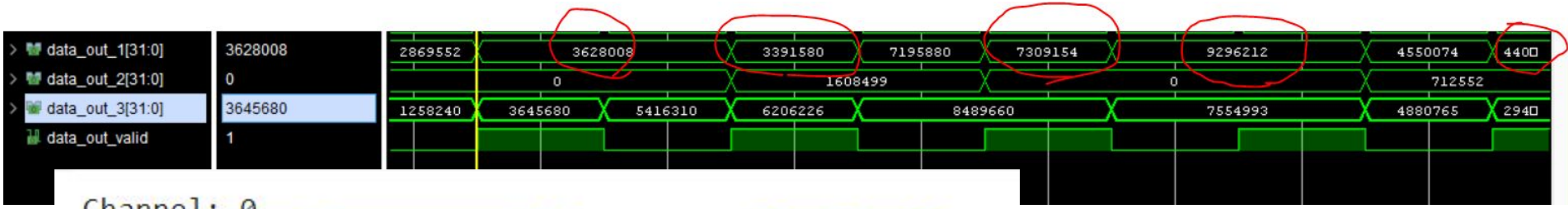
```
[0.0, 0.0, 3522652.0, 2585516.0, 7326952.0, 7440226.0, 9427284.0, 4681146.0, 4535080.0, 0.0, 0.0]
```


```
[0.0, 0.0, 98471.0, 525573.0, 418235.0, 258937.0, 1411740.0, 278438.0, 2245446.0, 132520.0, 0.0]
[0.0, 0.0, 0.0, -87665.0, 45696.0, -112335.0, 2643948.0, 1274417.0, 3554324.0, 1381623.0, 0.0]
[0.0, 0.0, 0.0, 139181.0, 432420.0, 420807.0, 1715763.0, 2362738.0, 1133939.0, 1631296.0, 0.0]
[0.0, 0.0, 0.0, 0.0, 27258.0, 64680.0, 1325943.0, 5145575.0, 1495899.0, 1797637.0, 0.0]
```

Some extra stuff for CNN (Maxpool 2 - dimension)



Some extra stuff for CNN (Maxpool 2)




```
Channel: 0
3628008.0 3391580.0 7309154.0 9296212.0 4404008.0
5676720.0 8980558.0 10223469.0 10177361.0 4237408.0
1466117.0 5127059.0 476403.0 4268827.0 3827193.0
0.0 604464.0 287163.0 1280668.0 2114374.0
0.0 8109.0 301348.0 2512876.0 3423252.0
```

Some extra stuff for CNN (Final Result)

Note: waveform output is reversed:

```
1 print(fc_out)
```

```
tensor([[ 34862., -11499., -62109.]])
```

-62274,-12890,34586

Questions