ASIC IMPLEMENTATION OF A PRE-TRAINED NEURAL NETWORK FOR ECG FEATURE EXTRACTION

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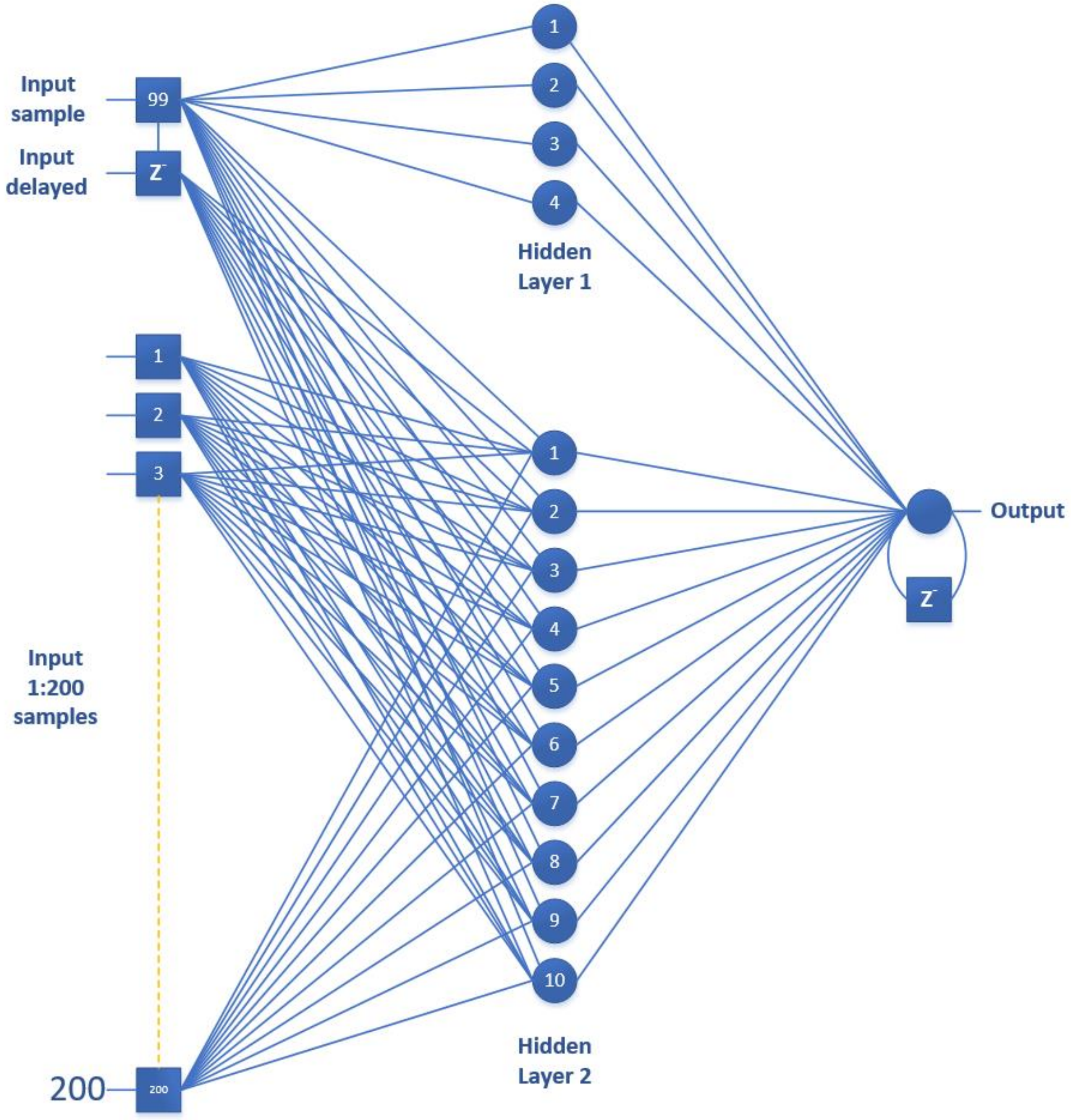
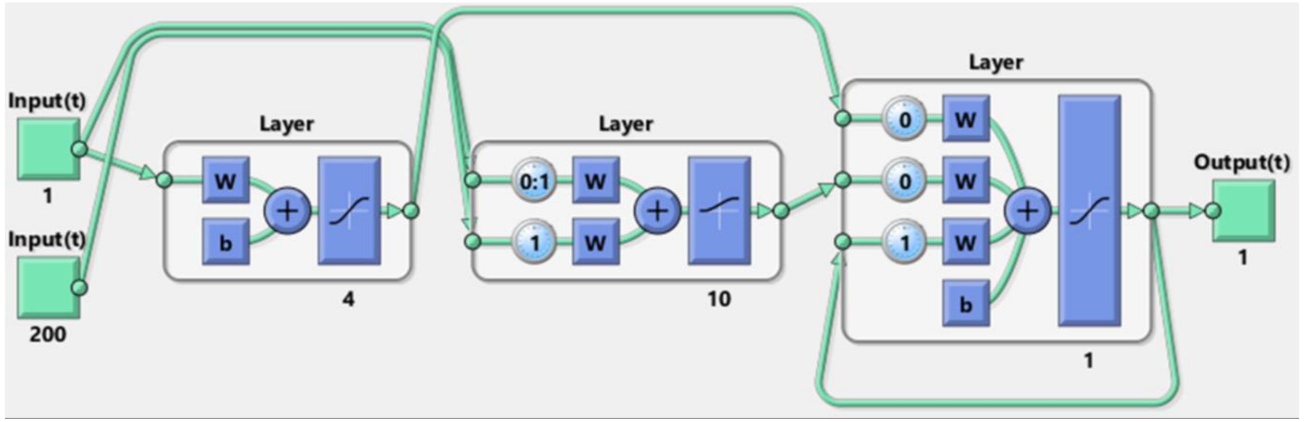
Background information and Motivation

- Success of ANN applications in ECG feature extraction
- It removes the need for hand-crafted features
- Deep Neural Network (1D CNN and LSTM) are common for 1 dimensional data
- It is growing in terms of accuracy and complexity
- The computation involved is heavy for deep networks
- Shallow networks are also capable of learning complex features similar to deep networks [1]
- Hardware implementation of QRS detection using shallow architecture neural network

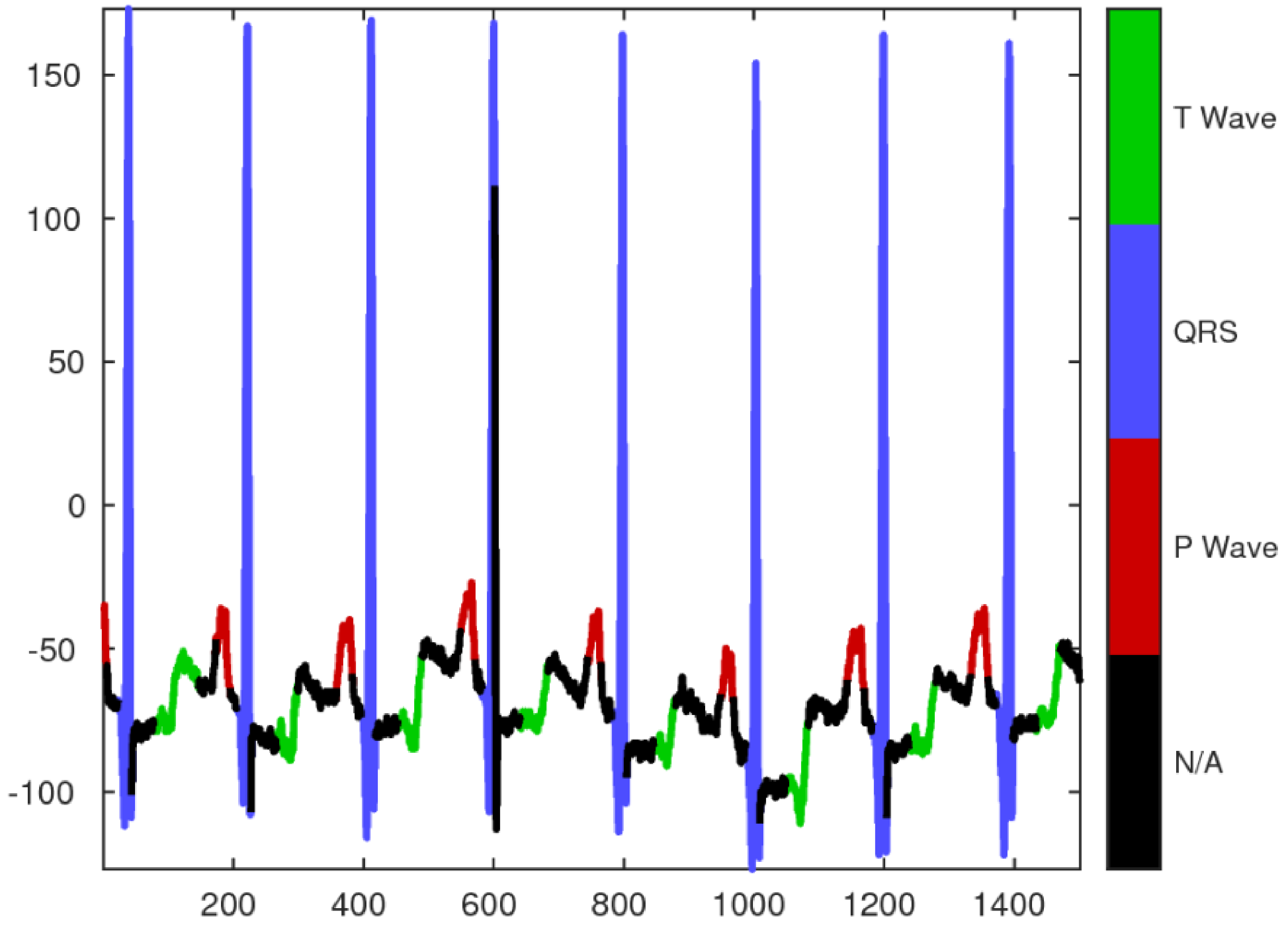
[1] Ba, Jimmy, and Rich Caruana. ”Do deep nets really need to be deep?.” Advances in neural information processing systems. 2014

Proposed neural network model





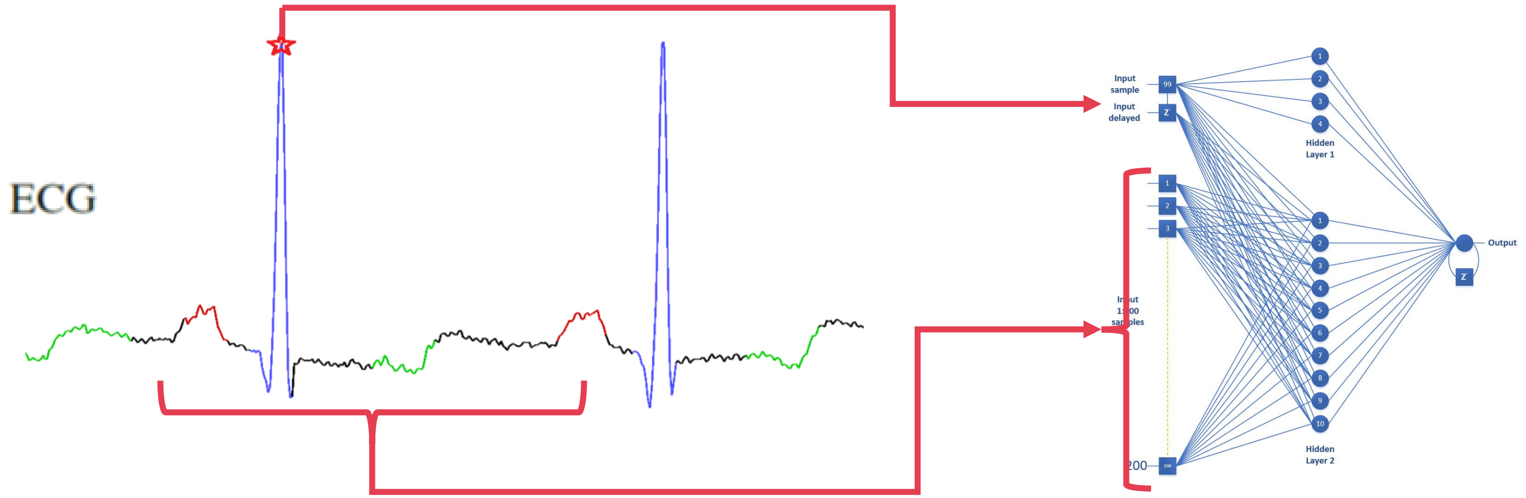
Dataset: PhysioNET labeled data

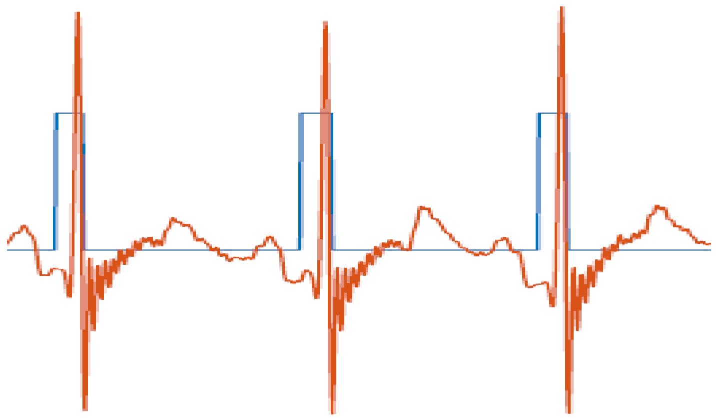


1	'n/a'	-79
2	'n/a'	-77
3	'n/a'	-79
4	'n/a'	-81
5	'n/a'	-80
6	'n/a'	-83
7	'QRS'	-84
8	'QRS'	-86
9	'QRS'	-82
10	'QRS'	-82

Dataset: Data Preparation

- **Input: A matrix of two vectors**



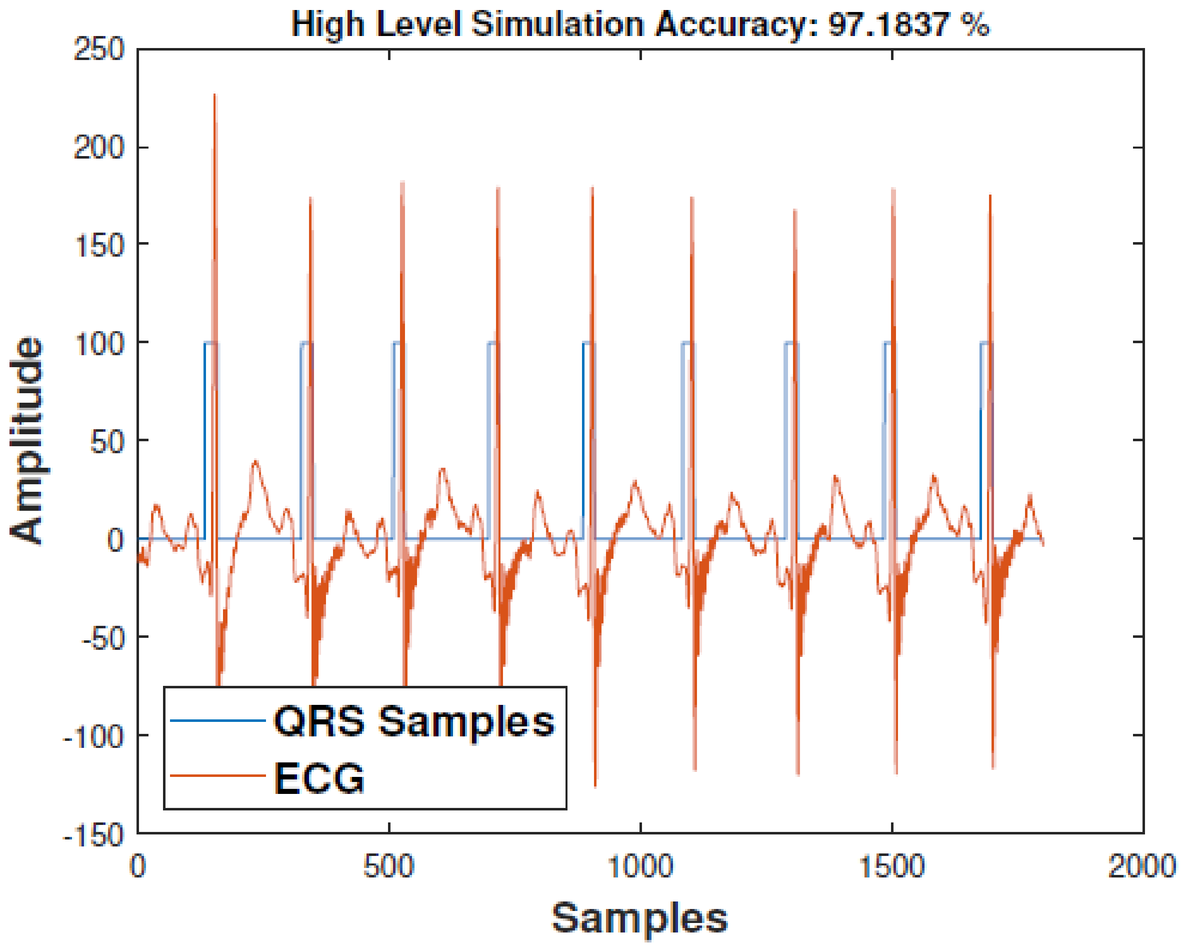


Label vector in blue

$$\begin{bmatrix} \mathrm{ECG(i)} \\ \begin{bmatrix} \mathrm{ECG(i\text{-}100)} & \ldots & \mathrm{ECG(i)} & \ldots & \mathrm{ECG(i+99)} \end{bmatrix} \end{bmatrix}$$

where *i* is mid sample index of the running window

High level accuracy



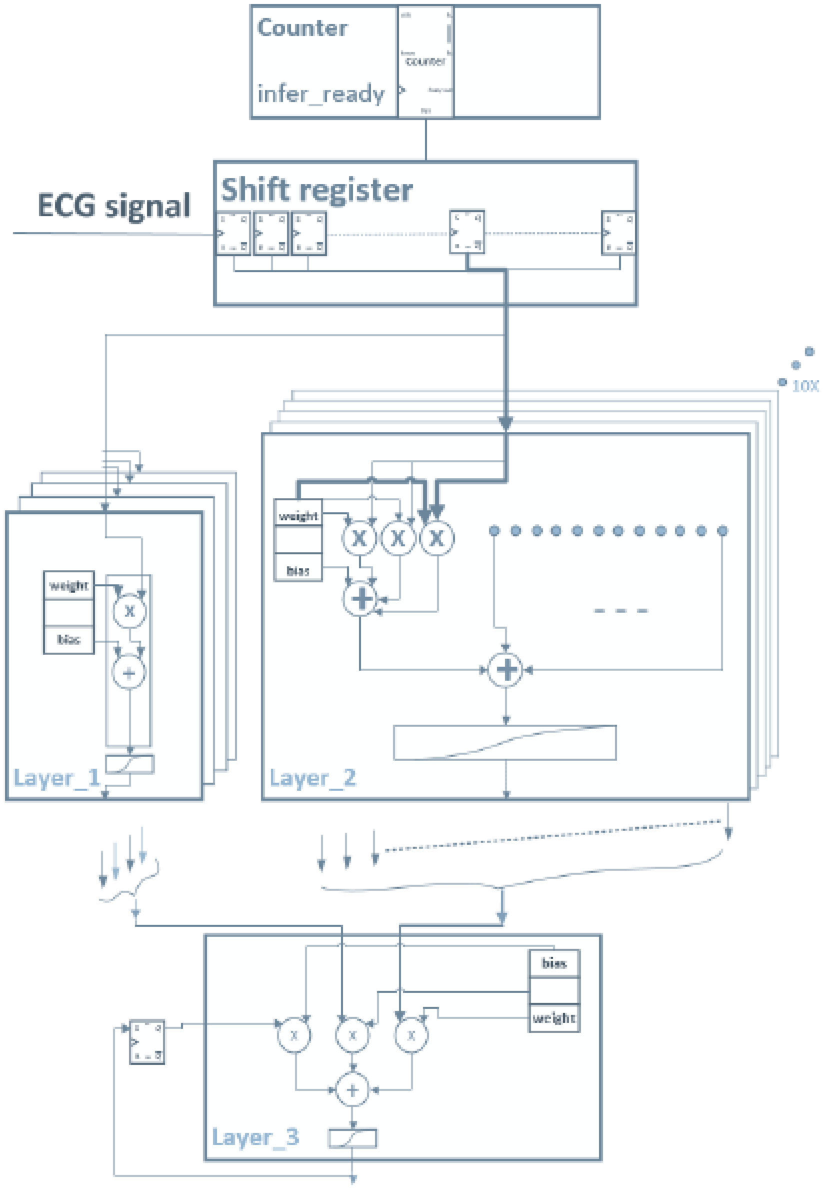
High level accuracy

- In addition to the QRS feature, the network was analyzed for P & T wave detection

Percentage	Train Data			Test Data		
	Acc	Sen	PPR	Acc	Sen	PPR
QRS	97.18	96.98	82.81	96.51	95.76	79.47
P wave	97.67	98.23	88.57	95.71	91.17	84.34
T wave	94.04	94.62	86.08	85.04	79.87	74.83

Hardware Implementation

- **RTL for the inference phase**
- **Use parameters obtained in training**
- **Convert parameters to a fixed point representation**
- **The design was simulated for functional verification**



No of parameters = 202x10 + (4+4) + 14 + 1+1 = **2044**

Category	*Value*
Internal Power (mW)	14.45
Net Switching Power (mW)	1.58
Leakage Power (W)	184.71
Total Power (mW)	**16.03**

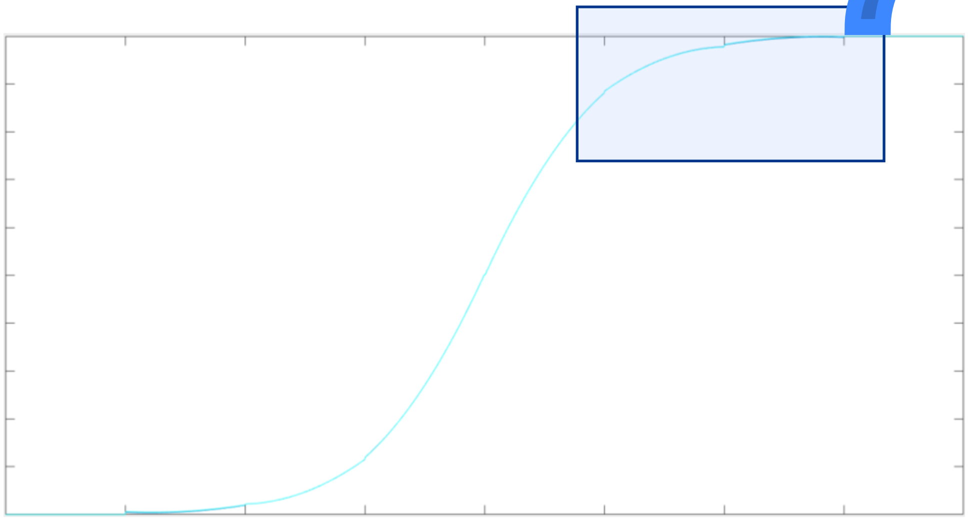
Hardware Implementation

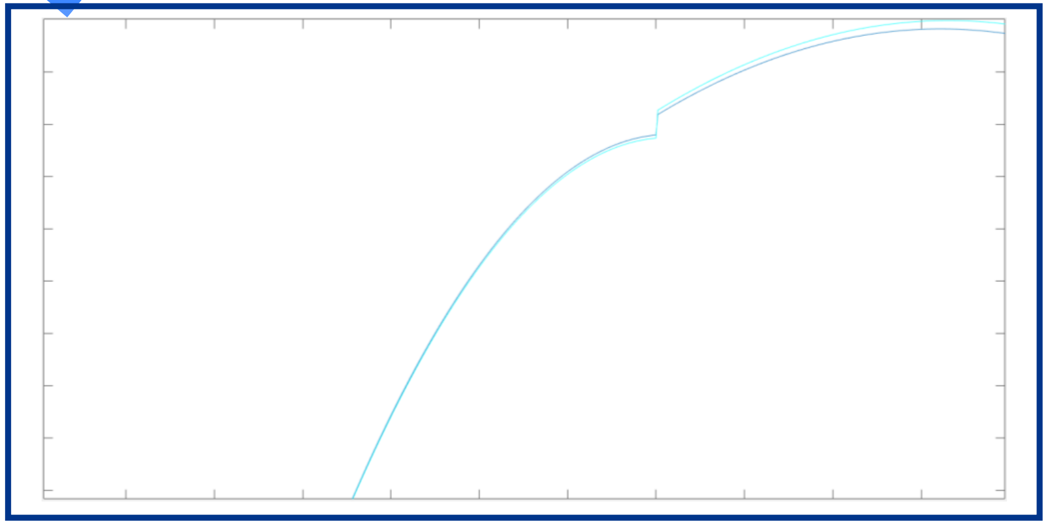
$$y = \frac{1}{1 + e^{-x}}$$

Sigmoid

$$y) = \begin{cases} 0, & \text{if } x \leq -6 \\ 0.1998 + 0.0703 * x + 0.0063 * x^2, & \text{if } -6 < x \leq -4 \\ 0.3803 + 0.1756 * x + 0.0215 * x^2, & \text{if } -4 < x \leq -2 \\ 0.5020 + 0.2727 * x + 0.0406 * x^2, & \text{if } -2 < x \leq 0 \\ 0.4982 + 0.2723 * x - 0.0404 * x^2, & \text{if } 0 < x \leq 2 \\ 0.6179 + 0.1768 * x - 0.0217 * x^2, & \text{if } 2 < x \leq 4 \\ 0.7968 + 0.0718 * x - 0.0064 * x^2, & \text{if } 4 < x \leq 6 \\ 0.9923 + 0.0021 * x - 0.0001 * x^2, & \text{if } 6 < x \leq 8 \\ 1, & \text{if } x > 8 \end{cases}$$

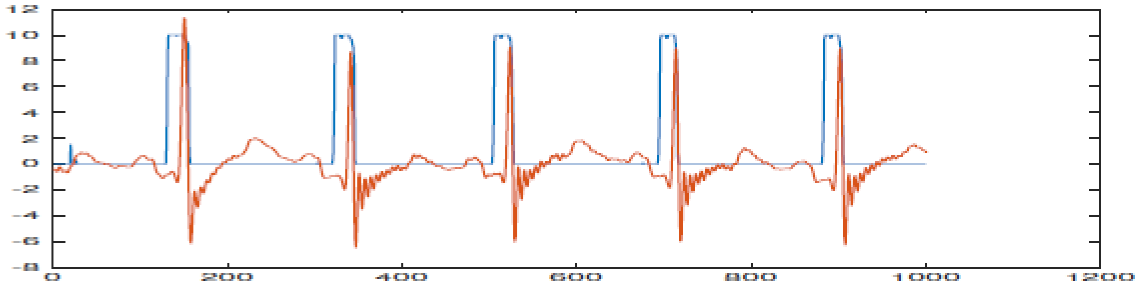
Polynomial approximation



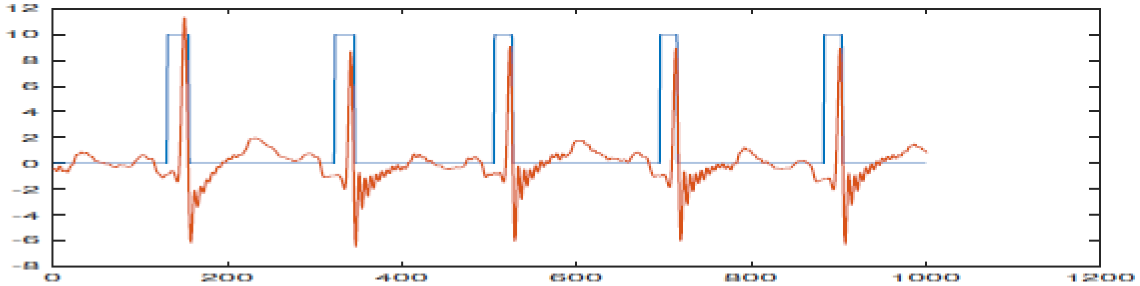


Simulation Result

- **Hardware Performance output before and after applying threshold**



(a) Before



(b) After

Conclusion

- **Shallow networks can**
  - Learn useful relationship between input and output
  - Achieve accuracy comparable to deeper networks

Thank You!