MERIT FAIR
BIEN 2008

A Hardware Implementation of the Wake-Sleep Algorithm

Presented By

Guy Lipworth — *University of Florida*
Kyle McMillan — *West Virginia University*

Graduate Advisors

Timir Datta
Anshu Sarje

Faculty Advisors

Dr. Timothy Horiuchi
Dr. Pamela Abshire

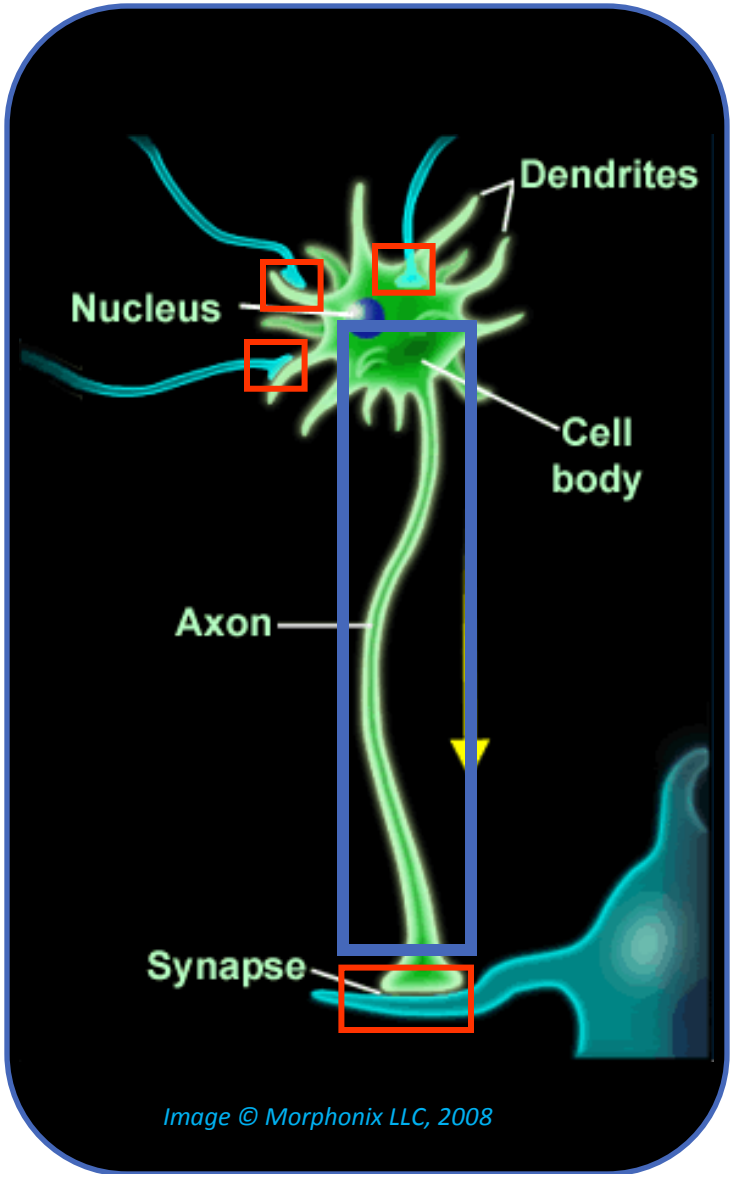
MERIT FAIR
BIEN 2008

Outline

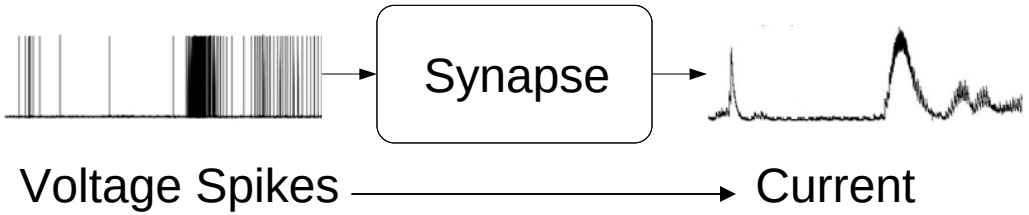
- Motivation
- The Biological Neuron/Synapse
- Synaptic Weights
- Wake Sleep Algorithm
- Analog VLSI circuits
- Simulation results
- Conclusion and Future Work

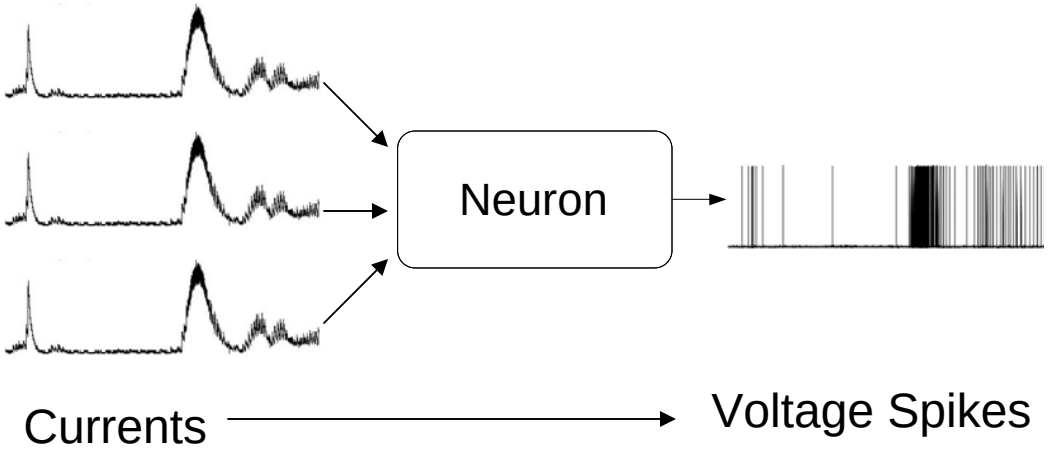
MERIT FAIR
BIEN 2008

The Biological Neuron/Synapse



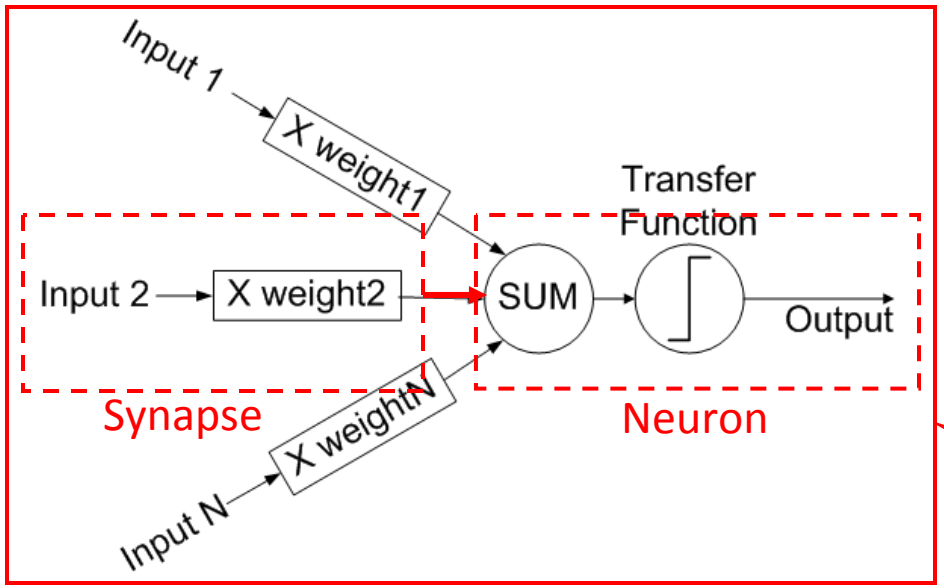
- Synapses connect neurons and allow them to signal each other
- Electrical Engineers treat the synapse and the neuron as two separate devices





MERIT FAIR
BIEN 2008

Perceptrons and Neural Networks

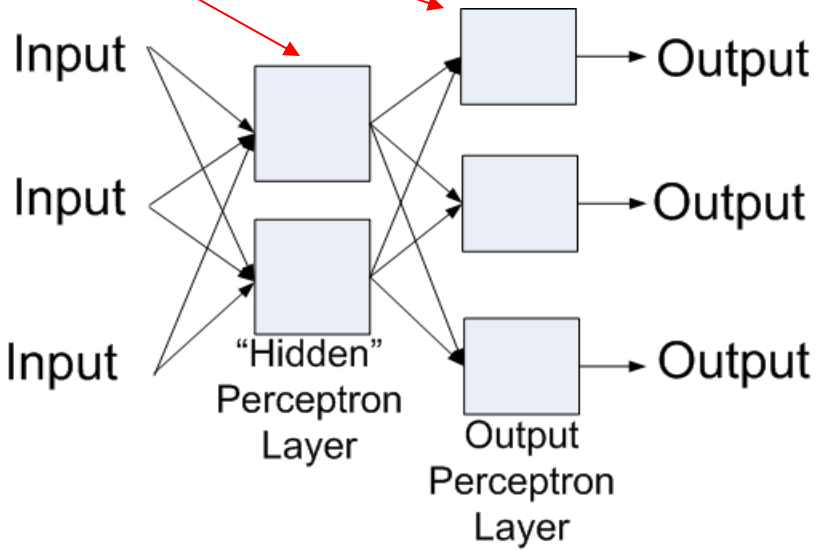


Weights:

- Each input has a weight
- Weight Tells us "how important" the input is
- Weights are of Analog Value
- Goal is to binarize the weights
  - long term storage in hardware

Neural Networks:

- Create networks by using output of one perceptron as inputs of others
- An Auto-Encoder network trains its weights until the network outputs are identical to its inputs

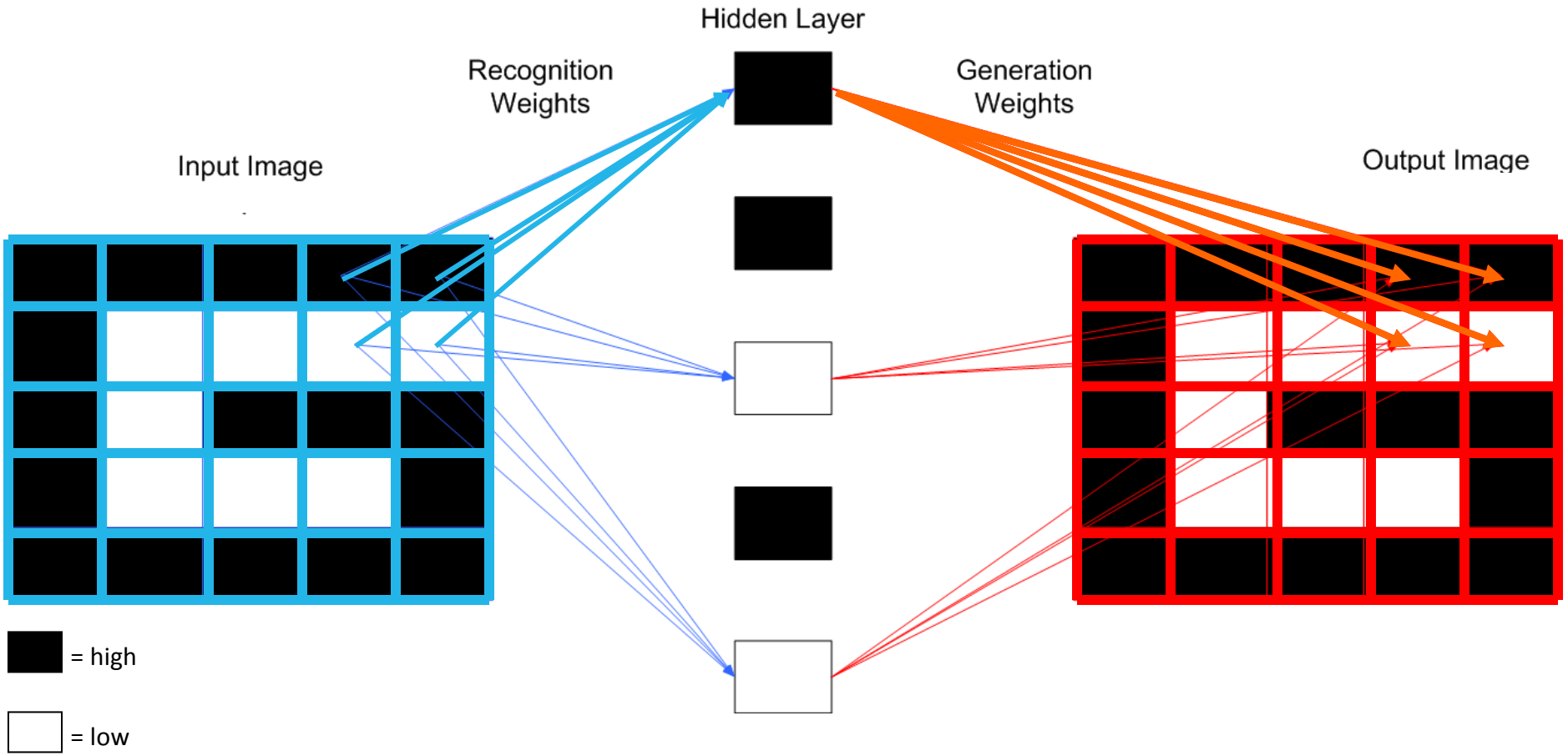


MERIT FAIR
BIEN 2008

Wake Sleep Algorithm

Wake Cycle:

1.Display Input Image
2.Pixels go through Recognition Weights to Hidden layer
3.Through Generation Weights to produce Output
4. Calculate error and train Generation Weights

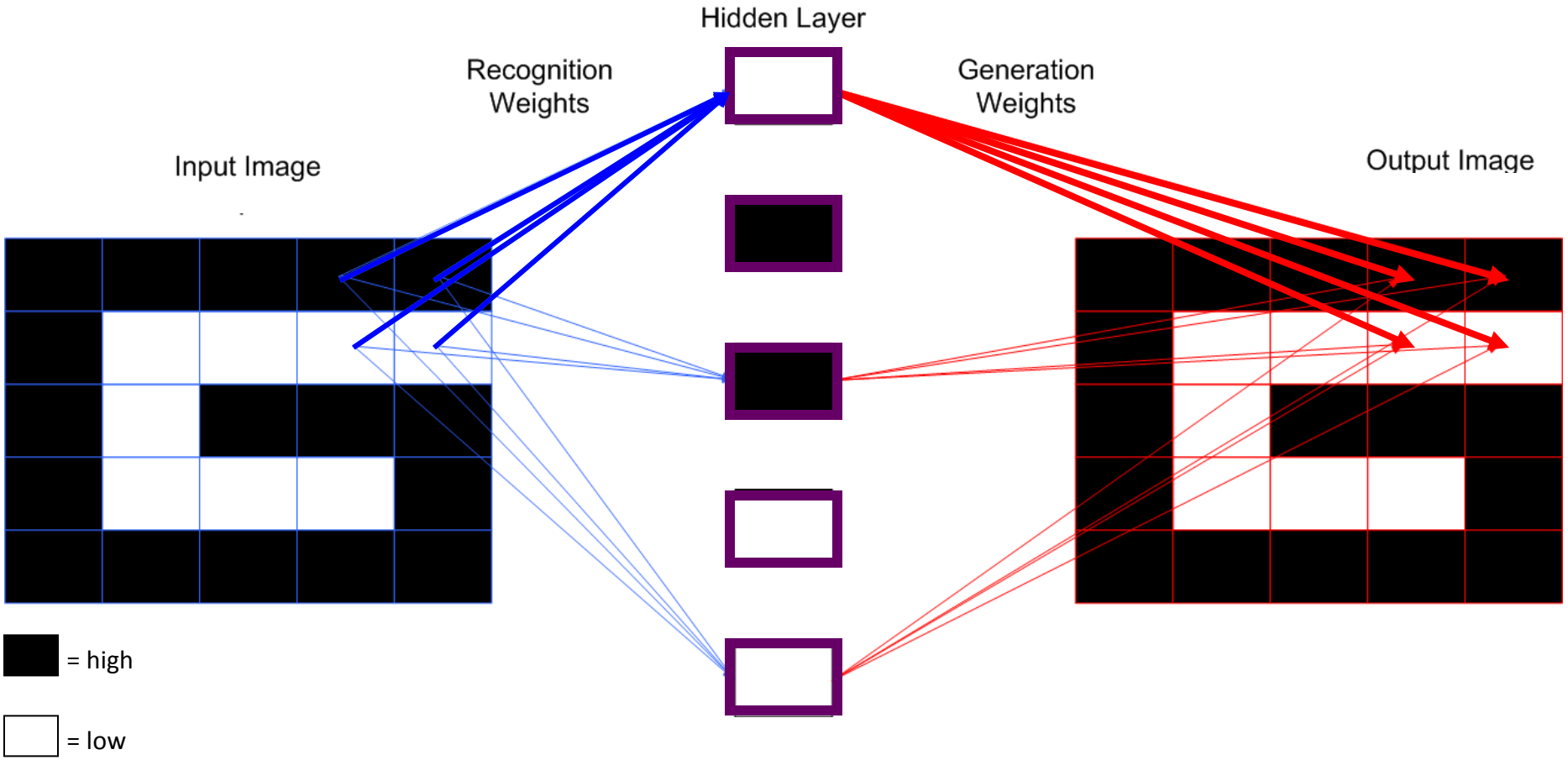


MERIT FAIR
BIEN 2008

Wake Sleep Algorithm

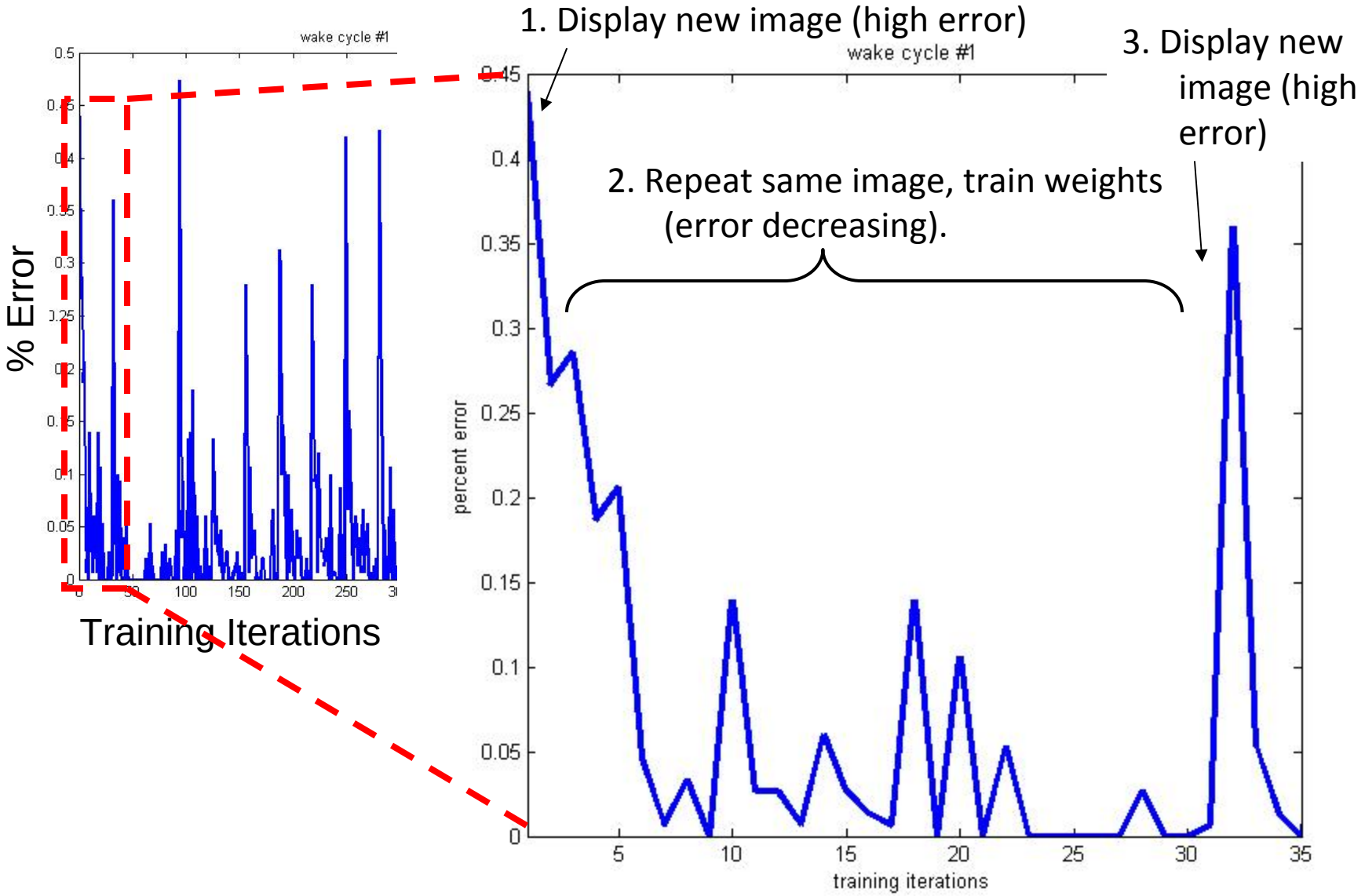
Sleep Cycle:

1. Randomly Excite Hidden Layer
2. Hidden states go through Generation Weights
3. Then through Generation Weights
4. Calculate error and train Recognition Weights



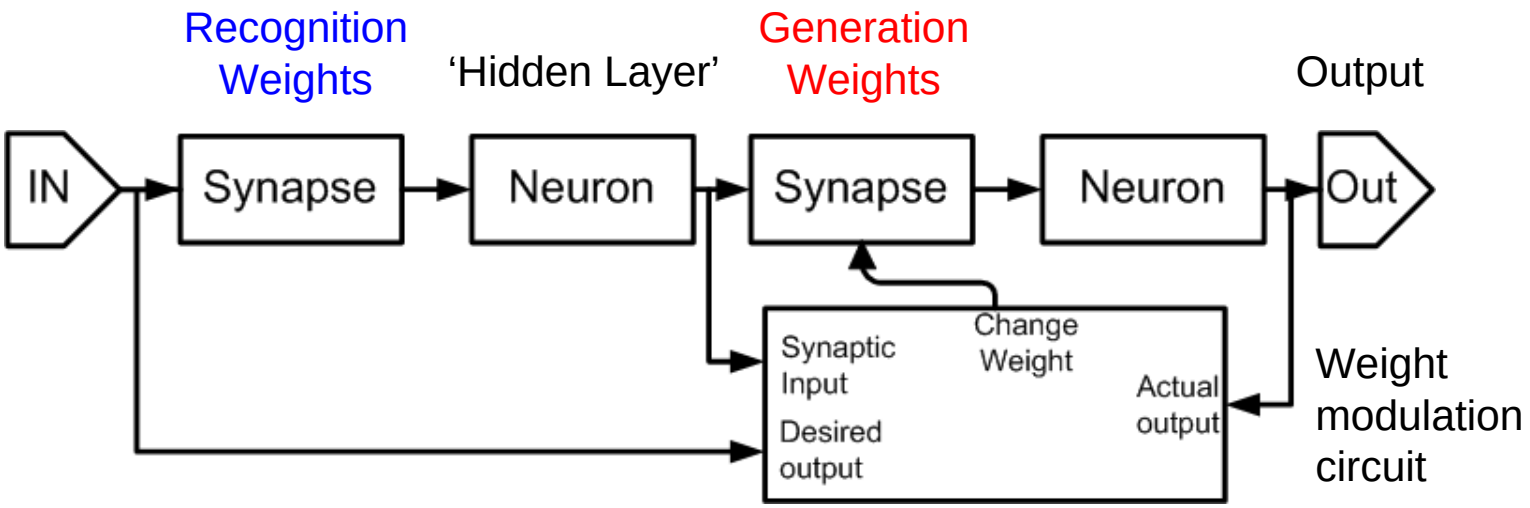
MERIT FAIR
BIEN 2008

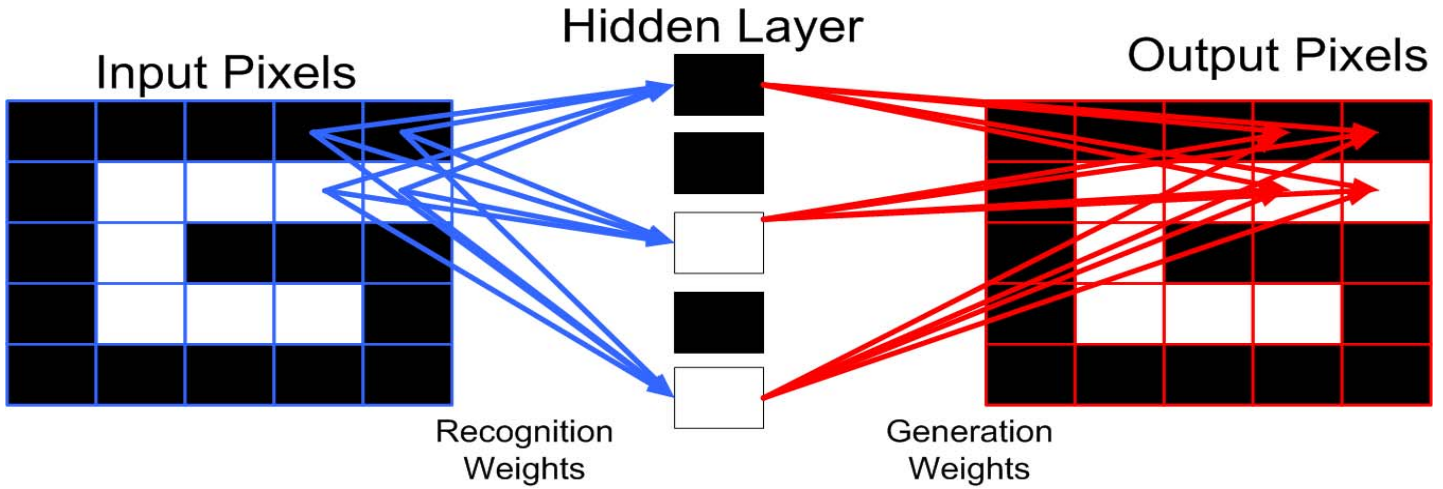
Training Iterations



MERIT FAIR
BIEN 2008

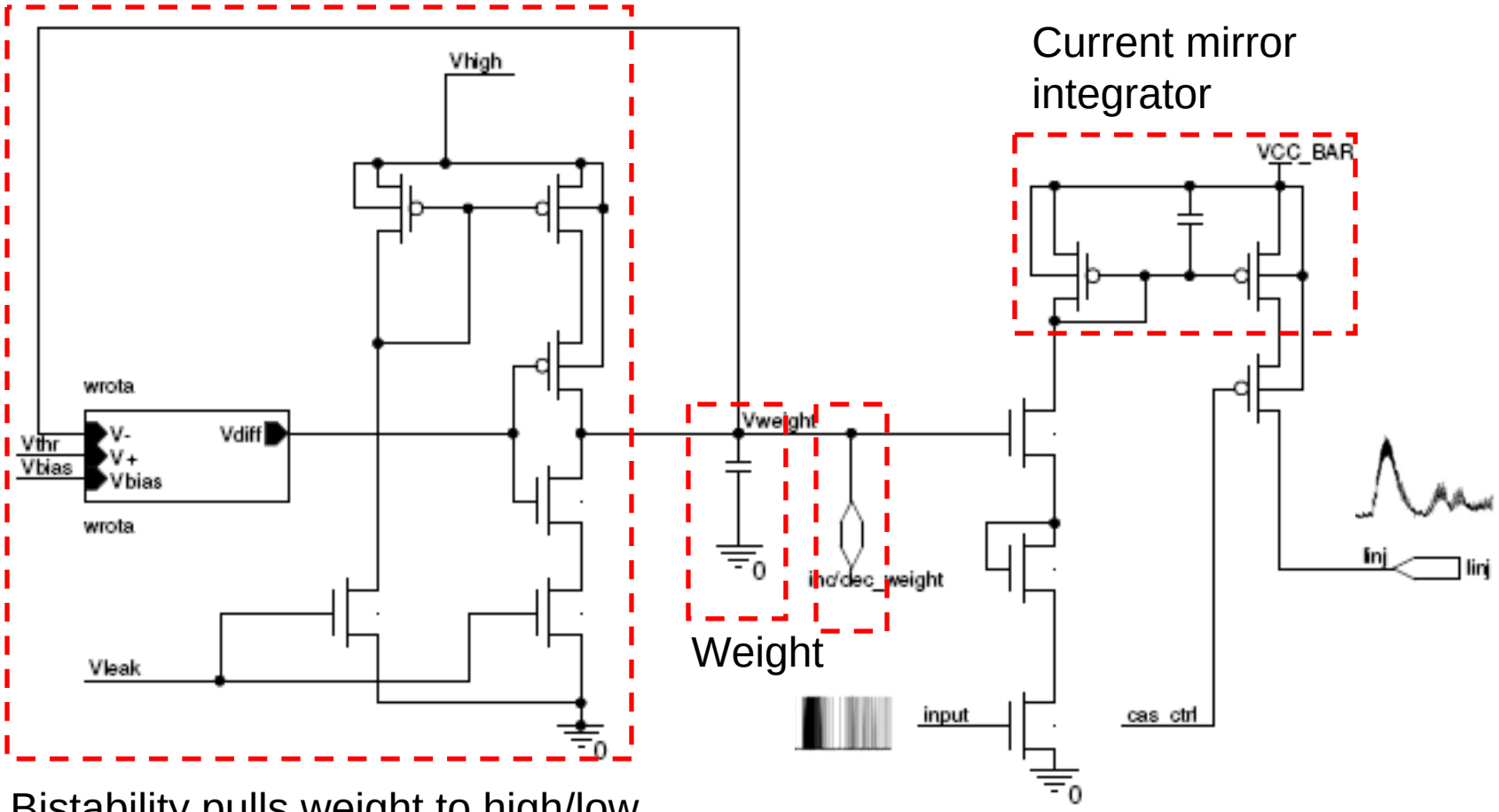
System Architecture





MERIT FAIR
BIEN 2008

Synapse Circuit



Current mirror integrator

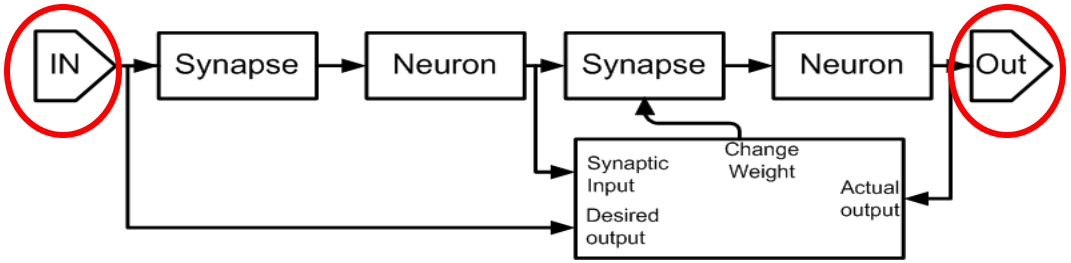
Weight

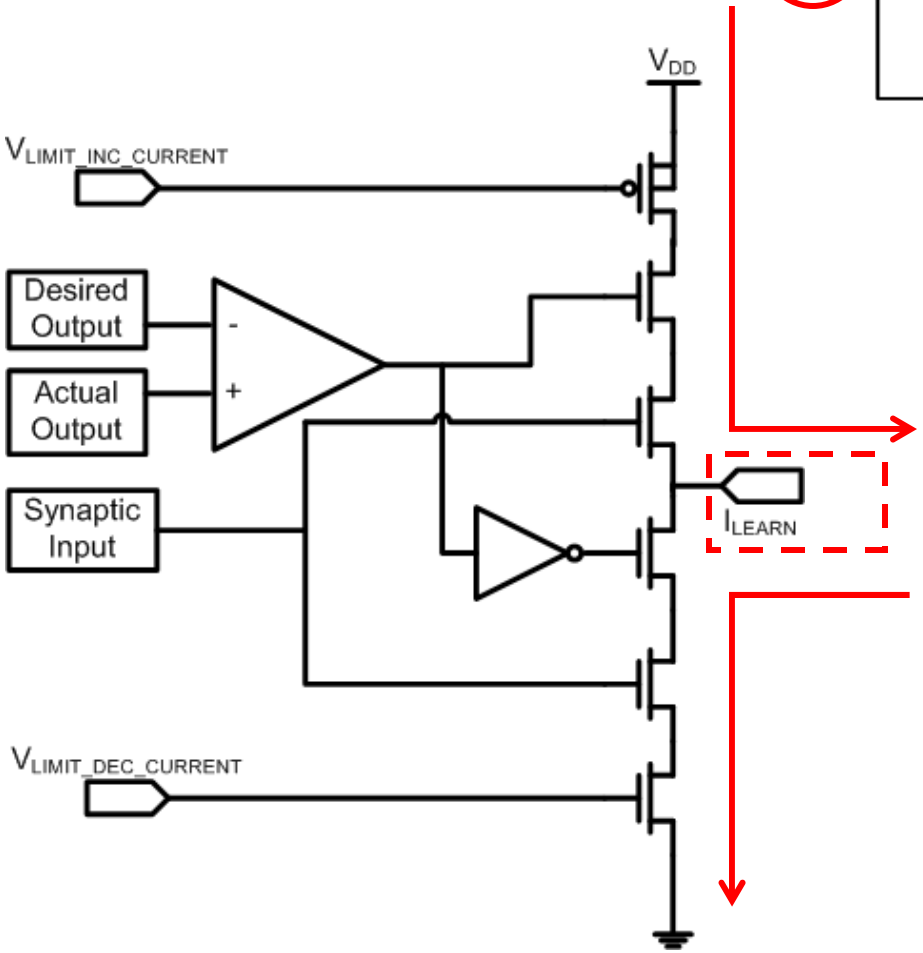
Bistability pulls weight to high/low value over long periods

Current to increase/decrease weight

MERIT FAIR
BIEN 2008

Weight Modification Circuit





Output Current I_{learn}:

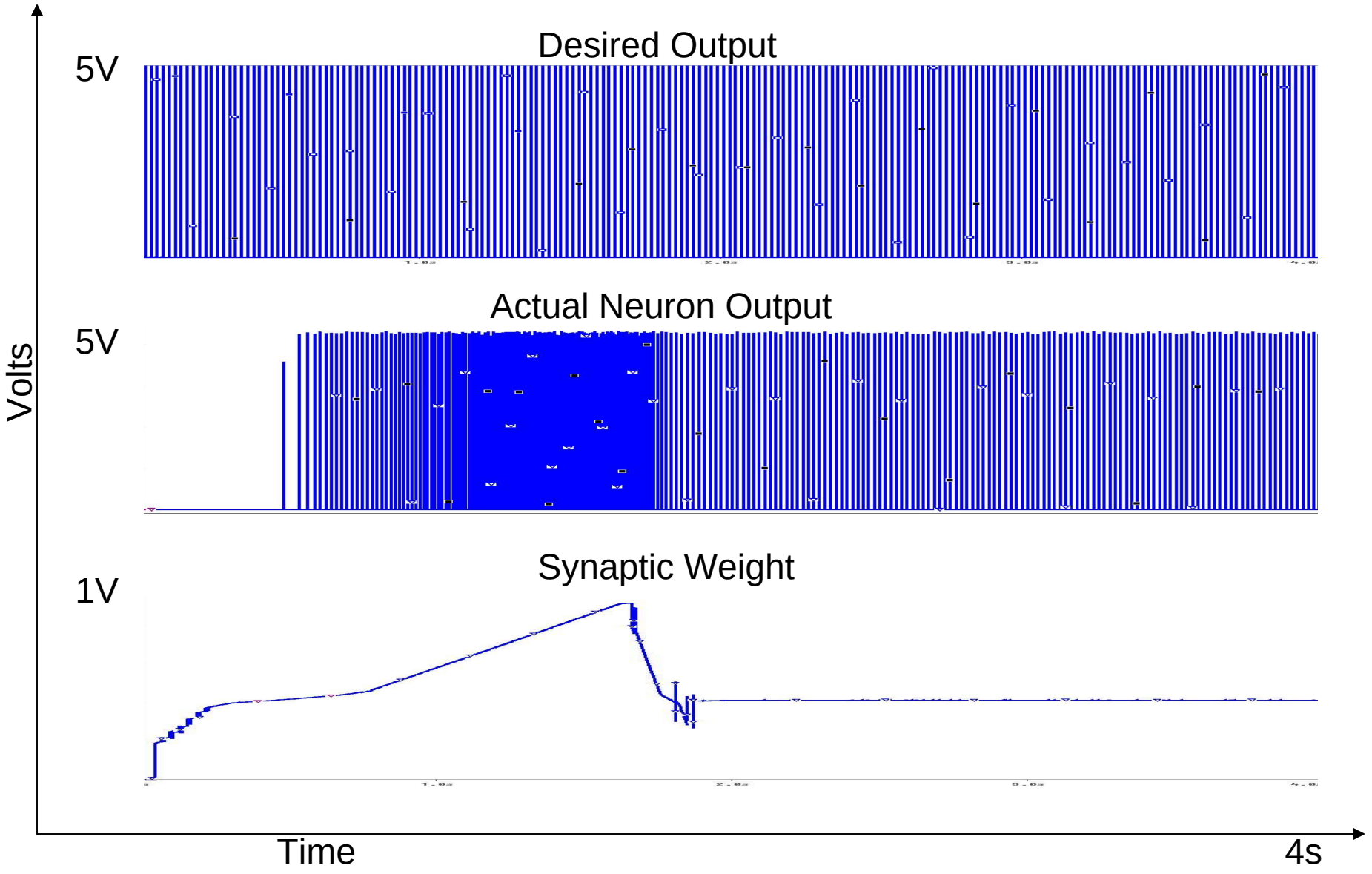
- Charges the synaptic capacitor to increase weight
- Discharges capacitor to decrease weight

<u>Increase Weight:</u>
Desired output > actual output
AND synaptic input is high

<u>Decrease Weight:</u>
Desired output < actual output
AND synaptic input is high

MERIT FAIR
BIEN 2008

Circuit Simulation



MERIT FAIR
BIEN 2008

Conclusions and Future Work

•Simulations in MATLAB® show that binary weights work on the auto-encoder neural network trained with the Wake-Sleep Algorithm.

•In simulations, the circuits successfully trained the synaptic weights in an analog manner.

Future Work:

•Implement networks with many more synapses to see if their weights will tend to become binary over the long term.

MERIT FAIR
BIEN 2008

Acknowledgements

- National Science Foundation CISE award #0755224

- Professors Timothy Horiuchi and Pamela Abshire

- Timir Datta and Anshu Sarje

Questions?