

## Introduction

Machine learning is meant to mimic humans' learning process, but it has changed to work to utilize a memory storage method that differs from our brains called Von Neumann Architecture (Fig 1). As the large amounts of data require heavy computation and high energy consumption, alternate methods are being spotlighted. One such inspiration is our brains, which are streamlined to be faster and more energy efficient. Therefore, Professor Kapadia's lab is trying to find a way to better model a brain using electrical components.

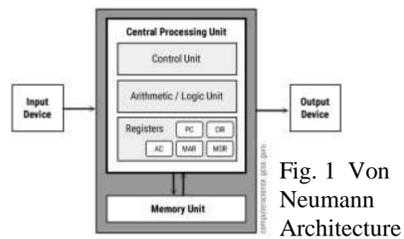


Fig. 1 Von Neumann Architecture

## Neuron

Brain neurons have many different components such as dendrites, the soma, and axon. The soma is the body of the neuron from which dendrites branch off. Dendrites receive chemical signals from other neurons allowing ion channels to open. These channels allow charged ions to flow into the neuron, making the voltage more negative. Once the voltage reaches a threshold, the action potential is activated to run through the axon of the neuron to release chemical signals which sends signals to the next neuron.

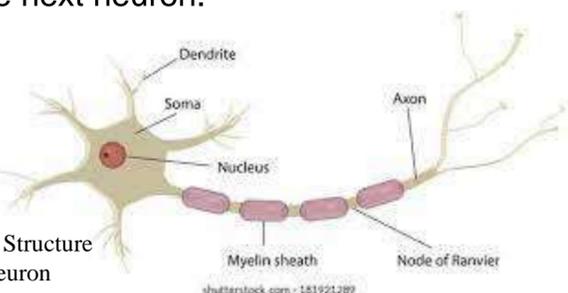


Fig. 2 Structure of a Neuron

## Hodgkin Huxley Model

The Hodgkin Huxley model (Fig 3) is a circuit which models various parts of a neuron. The circuit has a constant current being pushed through that divides into the different paths. On the farthest left path there is a capacitor which stores the electrical charge, which increases over time. The resistors in the middle are voltage sensitive, increasing or decreasing the resistance based on the voltage they receive, mimicking the ion channels in the neuron. As the resistivity increases, the capacitor must release some of its stored charge to even out the current flow to each path. This ebb and flow of the charge of the capacitor is made to follow the same pattern as a neuron's action potential.

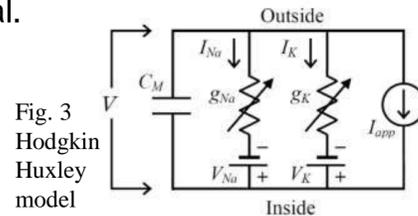


Fig. 3 Hodgkin Huxley model

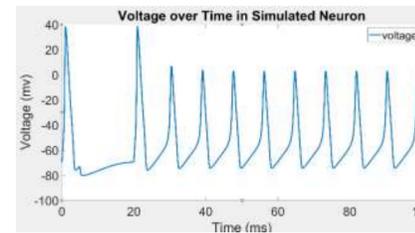


Fig. 4 Voltage vs Time graph of Hodgkin Huxley model

## Analyzing Data

We used MATLAB to analyze the data from our circuit which models a neuron. We found it to follow the same pattern as the action potential in neurons do. As seen in Fig 5 and Fig 6, there is a gradual increase in voltage as time increases until a threshold is reached. Then a drastic increase in voltage occurs over a short period of time before the voltage suddenly drops down further than it initially started, known as hyperpolarization. The voltage then slowly increases until it reaches the resting state. This pattern repeats multiple times in the data collected (Fig 6) showing that it consistently follows the same pattern that the action potential (Fig 5) does. The data shows a frequency of about 833 Hz which can be adjusted to match the different frequencies of neurons by changing the inductance of the device.

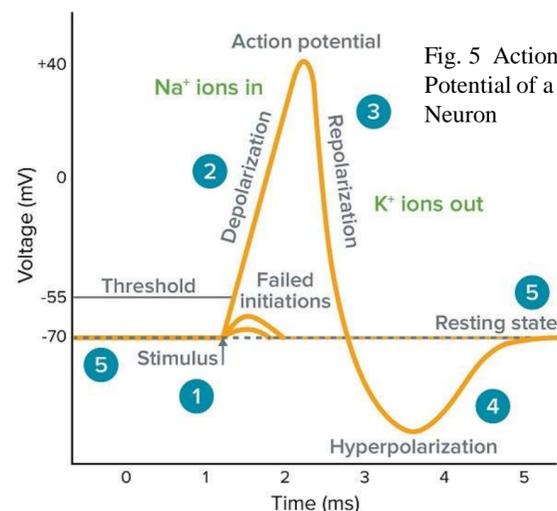


Fig. 5 Action Potential of a Neuron

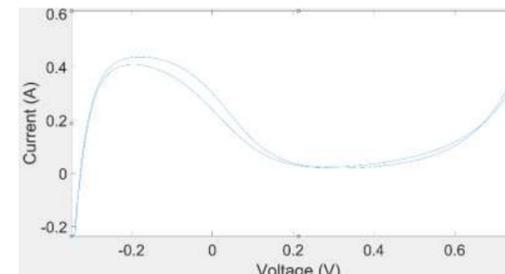


Fig. 7 Current vs Voltage graph of data

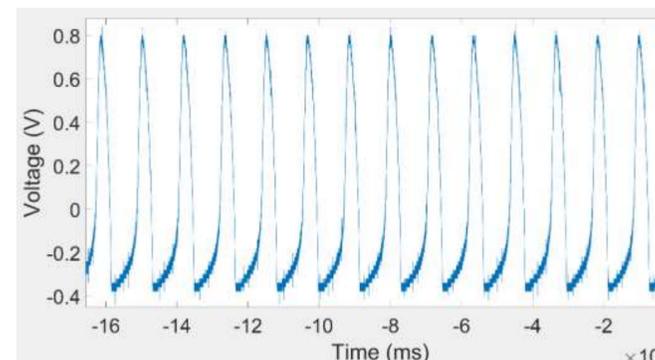


Fig. 6 Voltage vs Time graph of data

## Conclusion

As this data has proven to closely follow the same pattern as a neuron and can be adjusted for different neurons, further work can be done to see test how data is sent through this device and if it causes any limitations that must be changed. This can also lead to the creation of a fully functional neural network to be created with more of these semiconductor devices.

## Skills Learned

- How different types transistors work
  - Basic p-n junctions
  - BJT (Bipolar Junction Transistor)
  - FET (Field-Effect Transistor)
- MATLAB coding
- Python coding
- Neuron structure
- How a neuron works
- Different parts of circuits and how they can be used
- How a semiconductor works
- The way different types of sciences can be used together and how they can connect, such as biology and electrical engineering

## Acknowledgements

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