

Assignment 1

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1 Introduction

The Hodgkin-Huxley model explains how the dynamics of ion channels (Na⁺, K⁺ etc) contribute to the generation of an Action Potential in a neuron.

An Action Potential is a sharp voltage spike elicited by stimulating a neuron with a current that exceeds a certain threshold value. The current amplitude is increased gradually, at a threshold amplitude, the voltage response does not increase proportionally.

It shows a sharp, disproportionate increase.

Once the membrane voltage reaches a threshold value, it increase further rapidly to maximum value and drops again rapidly to a value that is less than resting value, before returning to the baseline value after a delay.

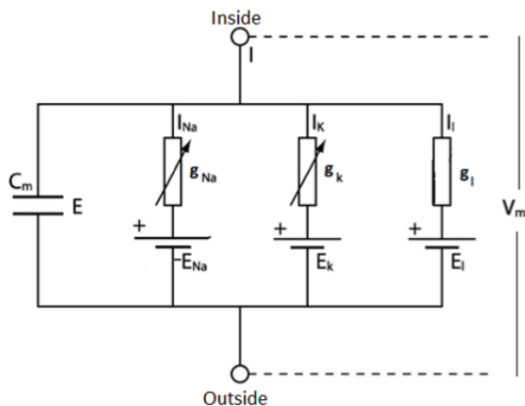


Figure 1: Hodgkin-Huxley model circuit

2 Results

The plot of voltage vs time behaves differently for different applied external current. At some particular values of input current even a small change causes the system dynamics to change a lot.

For input current ranging from $0\mu\text{A}$ to $0.02235\mu\text{A}$ we do not get any action potentials. For a change in input current from $0.02235\mu\text{A}$ to $0.02236\mu\text{A}$ we suddenly start getting action potentials but they are not periodic.

For a change in input current from $0.0622\mu\text{A}$ to $0.06223\mu\text{A}$ we suddenly start getting periodic action potentials.

For a change in input current from $0.450\mu\text{A}$ to $0.451\mu\text{A}$ we stop getting action potentials(i.e. assuming if peak voltage is below 10mV then we do not consider it as an action potential).

3 Frequency vs Input current

As we can see in the obtained plots, we start getting periodic action potentials from $0.06223\mu\text{A}$ to $0.450\mu\text{A}$.

Thus we can obtain a frequency vs input current plot for the same. The frequency will be zero initially till $0.0622\mu\text{A}$.

After that we get a frequency value at $0.06223\mu\text{A}$ and it increases till the input current is increased till $0.450\mu\text{A}$.

After $0.450\mu\text{A}$ again we get zero frequency as we do not have action potentials.

4 Region 1

Figure 2: Plot of Voltage vs Time for $I=0.01\mu A$

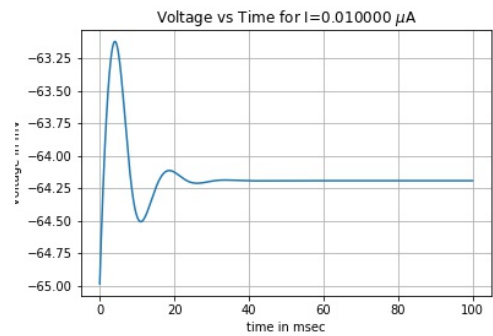


Figure 3: Plot of gating variables for $I=0.01\mu A$

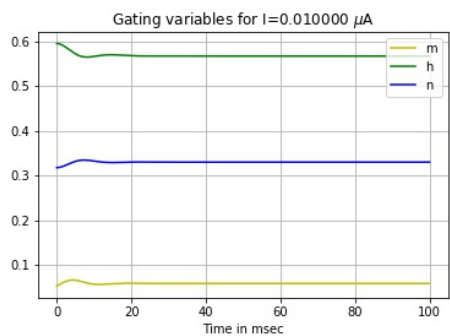
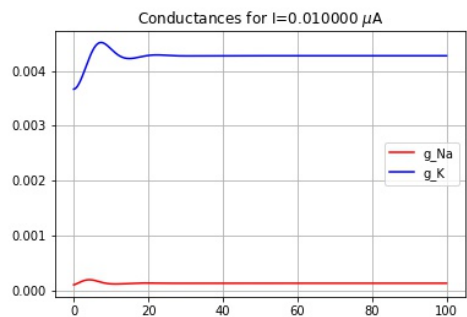


Figure 4: Plot of conductances for $I=0.01\mu A$



5 Region 2

Figure 5: Plot of Voltage vs Time for $I=0.03\mu A$

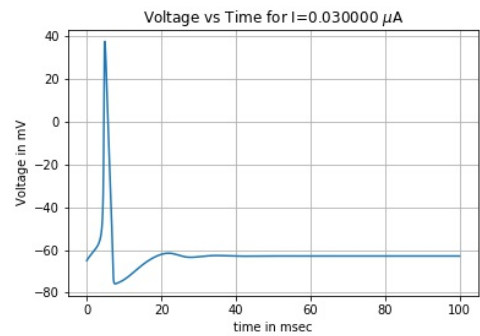


Figure 6: Plot of gating variables for $I=0.03\mu A$

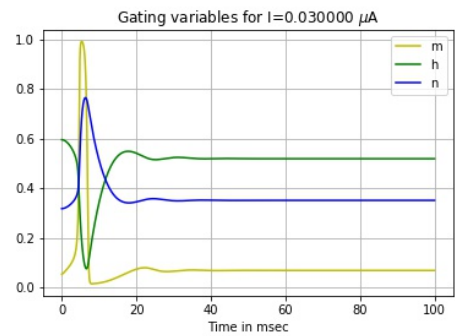
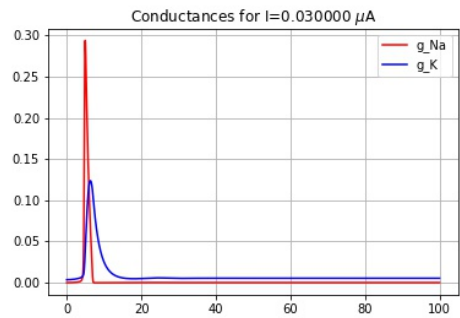


Figure 7: Plot of conductances for $I=0.03\mu A$



6 Region 3

Figure 8: Plot of Voltage vs Time for $I=0.3\mu A$

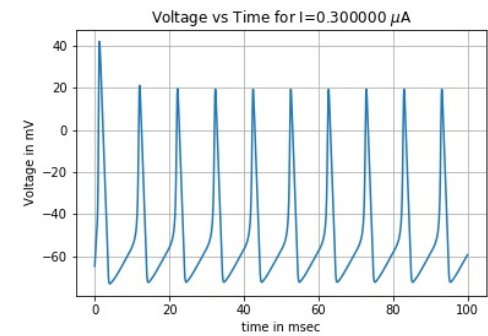


Figure 9: Plot of gating variables for $I=0.3\mu A$

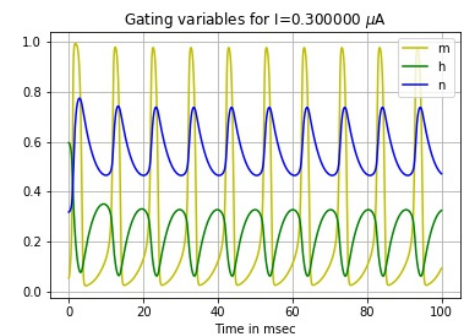
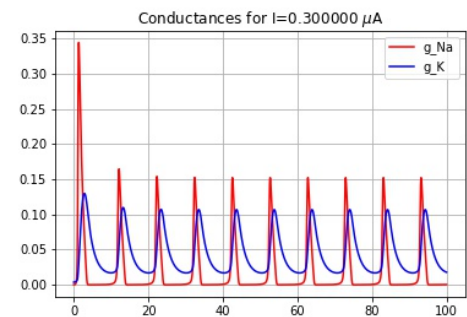


Figure 10: Plot of conductances for $I=0.3\mu A$



7 Region 4

Figure 11: Plot of Voltage vs Time for $I=0.6\mu A$

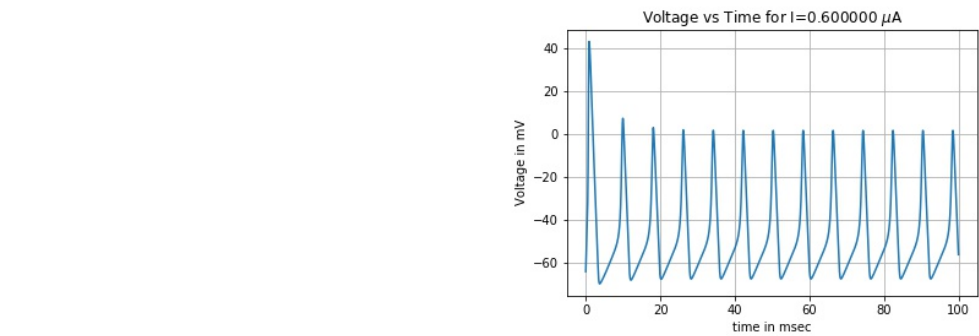


Figure 12: Plot of gating variables for $I=0.6\mu A$

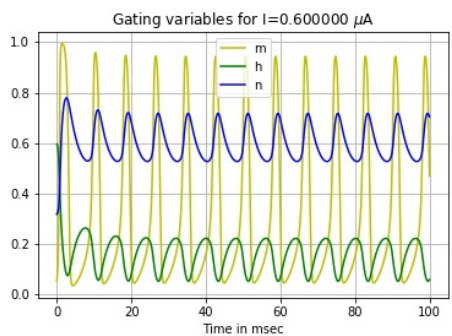
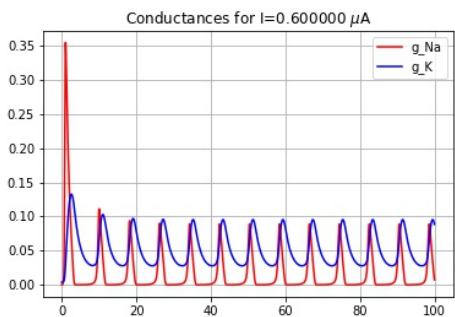


Figure 13: Plot of conductances for $I=0.6\mu A$



8 Frequency vs Input current plot

We have zero frequency before and after Region 3.

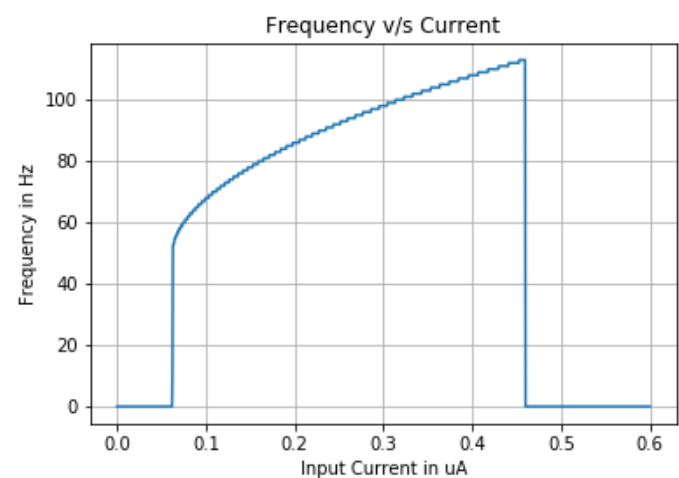


Figure 14: Frequency vs Input current plot