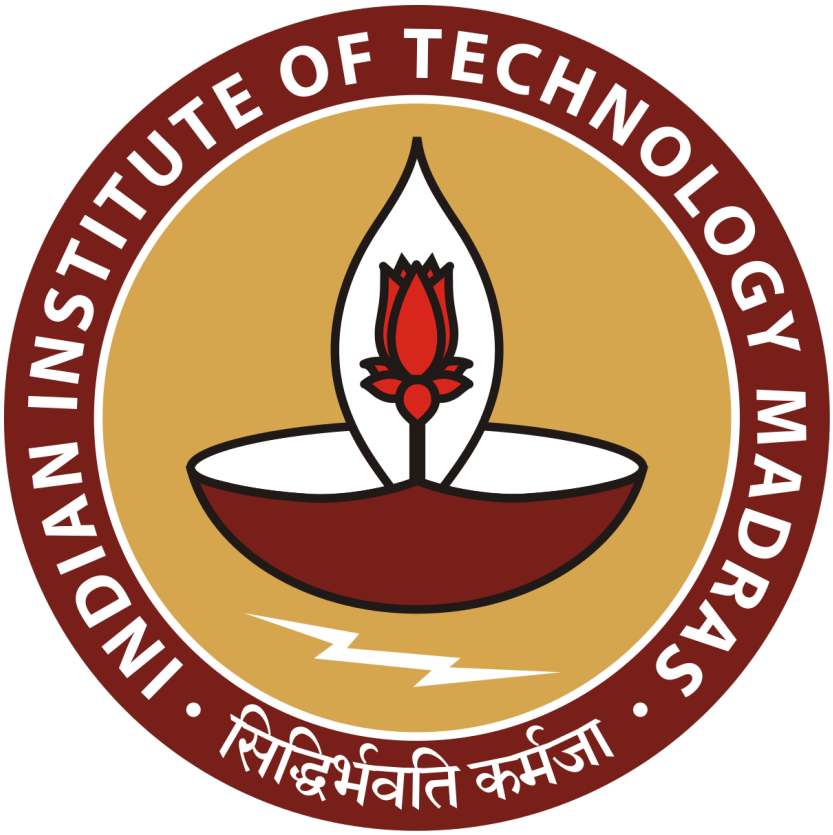

BT6270: Computational Neuroscience
Assignment 1

EE20B149
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September 10, 2023

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.

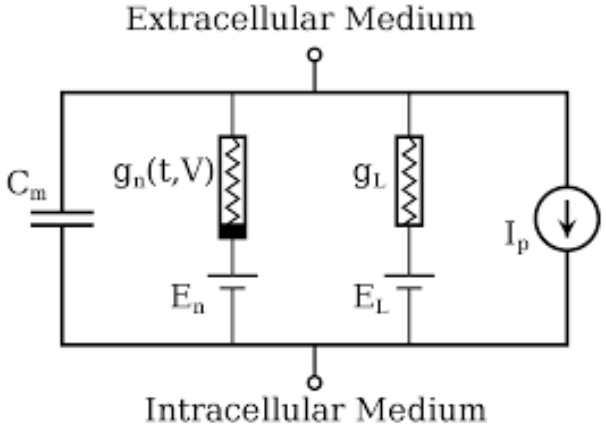


Figure 1: Hodgkin-Huxley model circuit

2 Neural Firing Frequencies and Thresholding

2.1 Threshold Values of External Current

The Threshold Currents are as follows:

- I1 = 0.023 $\mu A/mm^2$
- I2 = 0.0615 $\mu A/mm^2$
- I3 = 0.458 $\mu A/mm^2$

These values were obtained by setting the sampling interval to 0.001 between [0,0.6]. The value of 0.6 is chosen after hit and trial on the MATLAB code and analyzing the Voltage vs Time graph. All the I1, I2 and I3 values don't exceed more than 0.6.

2.2 Assumptions

Assumptions for the plot are as follows:

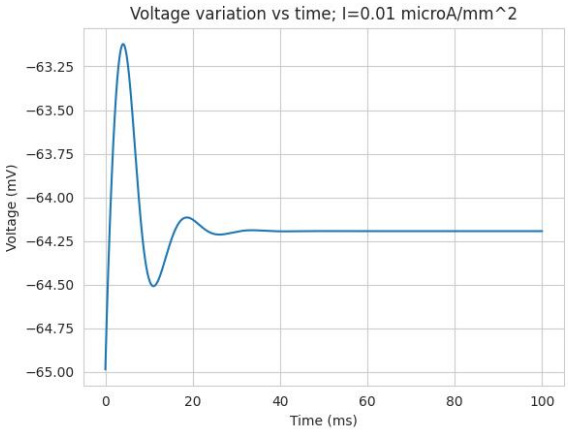
- A peak must exceed a threshold voltage of **5 mV** in order to be classified as an action potential.
- I1 is calculated at the initial non-zero value of the number of Voltage Peaks.
- I2 is calculated at the input current value where the following current instant has **3** or more voltage peaks exceeding **5 mV**.
- I3 is calculated as the input current value at which there are **7** or more voltage peaks above 5 mV in the next current instant.

2.3 Plots

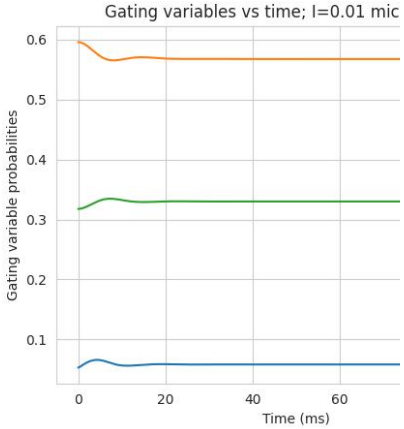
2.3.1 Frequency vs Input current

- As we can see in the obtained plots, we start getting periodic action potentials from 0.0224μA to 0.5432μA.
- Thus we can obtain a frequency vs input current plot for the same. The frequency will be zero initially till 0.0224μA.
- After that we get a frequency value at 0.0224μA and it increases till the input current in increased till 0.5432μA.
- After 0.5432μA again we get zero frequency as we do not have action potentials.

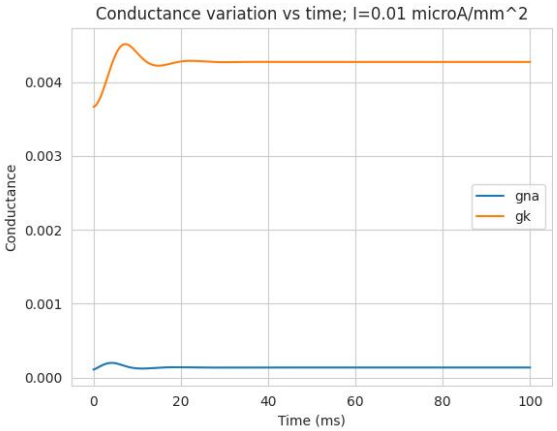
2.3.2 Region 1



(a) Plot of Voltage vs Time for I=0.01μA

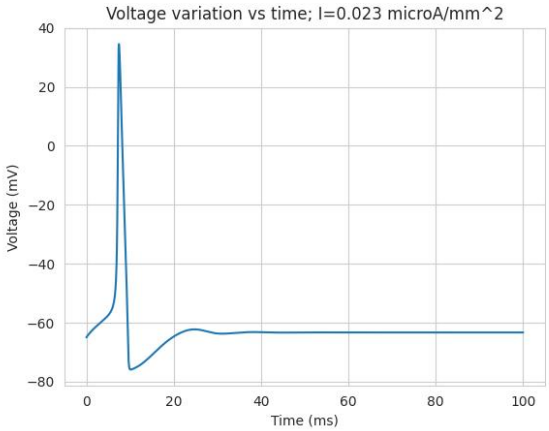


(b) Plot of gating variables for I=0.01μA

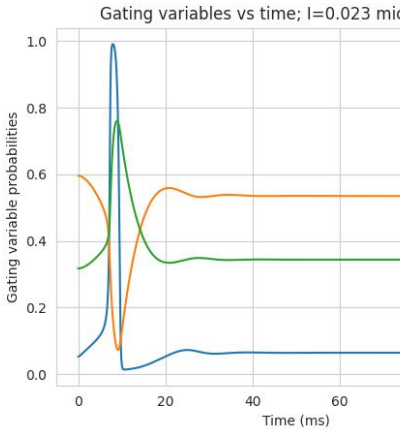


(c) Plot of conductances for I=0.01μA

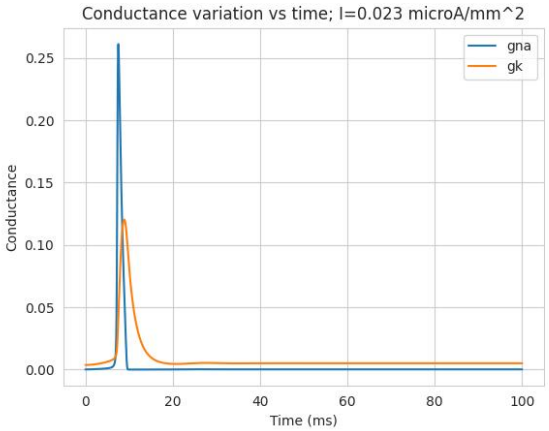
2.3.3 Region 2



(a) Plot of Voltage vs Time for I=0.023μA

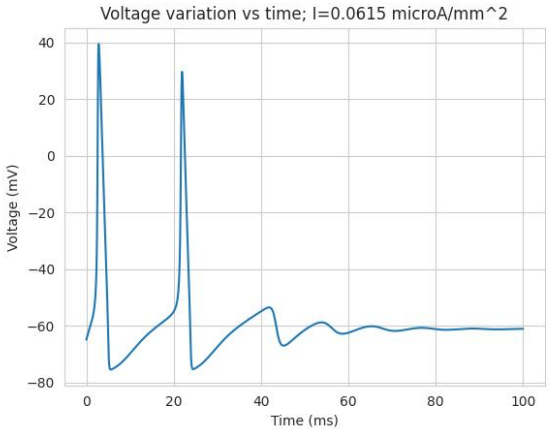


(b) Plot of gating variables for I=0.023μA

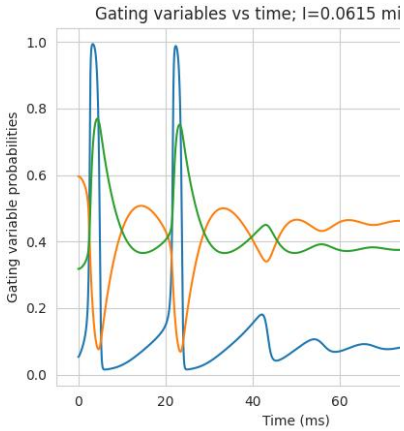


(c) Plot of conductances for I=0.023μA

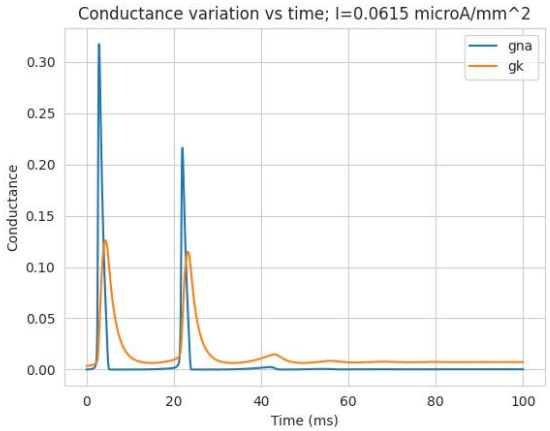
2.3.4 Region 3



(a) Plot of Voltage vs Time for I=0.0615μA

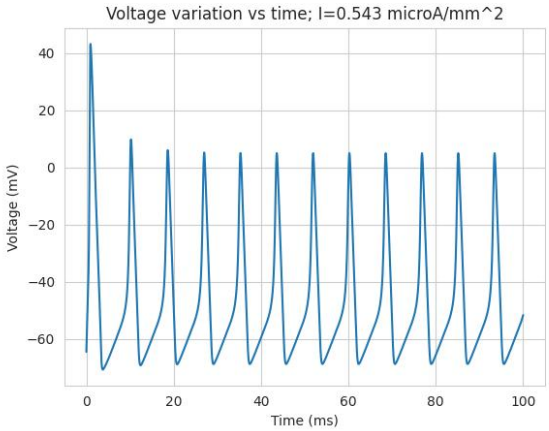


(b) Plot of gating variables for I=0.0.0615μA

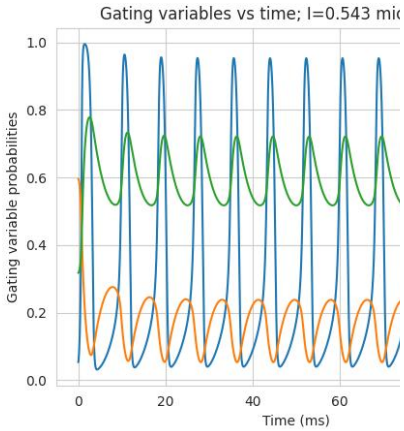


(c) Plot of conductances for I=0.0615μA

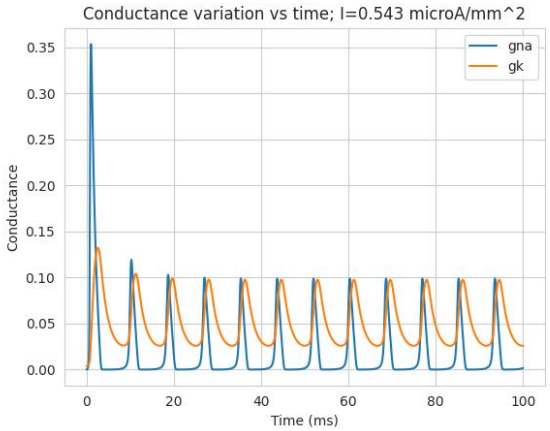
2.3.5 Region 4



(a) Plot of Voltage vs Time for I=0.543μA

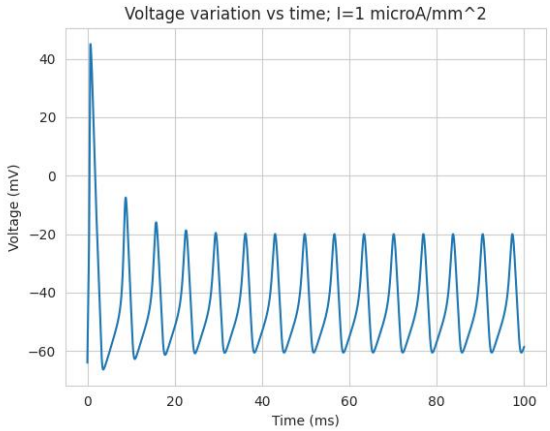


(b) Plot of gating variables for I=0.543μA

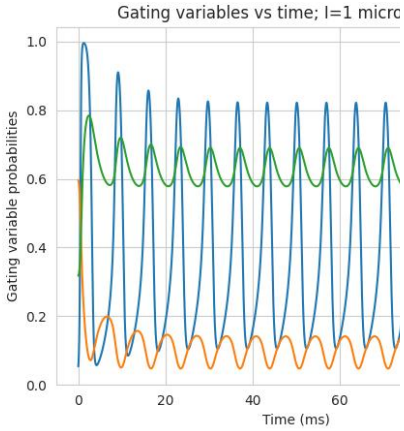


(c) Plot of conductances for I=0.543μA

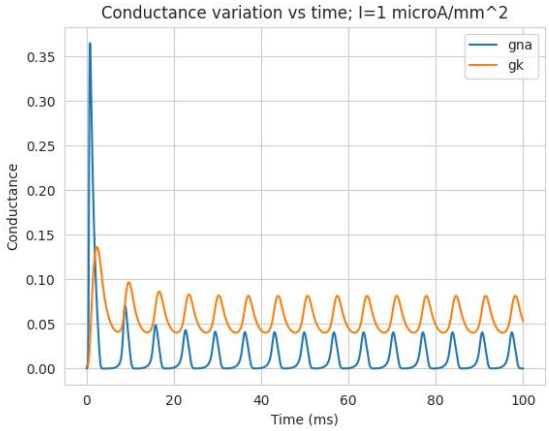
2.3.6 Region 5



(a) Plot of Voltage vs Time for I=1μA



(b) Plot of gating variables for I=1μA



(c) Plot of conductances for I=1μA

3 Frequency vs Input current plot

We have zero frequency before and after Region 3.

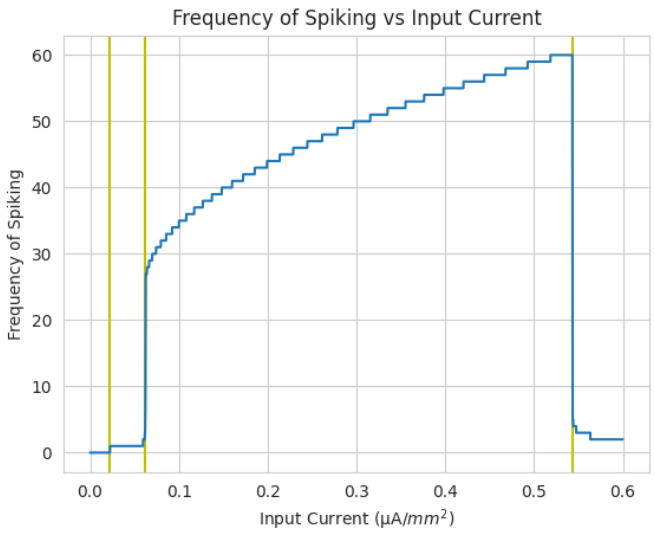


Figure 7: Frequency vs Input current plot