

# Assignment 1 : Action Potential

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## 1 Aim

Modify the MATLAB code for Hodgkin Huxley model and compute the following :

- Threshold values for the external applied currents  $I_1$  ,  $I_2$  , and  $I_3$  in which shift of dynamical behavior from one to another is seen, such as no AP, finite number of AP's, Continuous firing and then followed by distortion resulting in no more APs is portrayed.
- A graph which depicts the firing rate (frequency) as you change the applied external current ( i.e.  $I_{ext}$  vs. Firing rate (f))

## 2 Firing rate

The firing rate is obtained using the below specified algorithm.

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**Algorithm 1** Firing rate

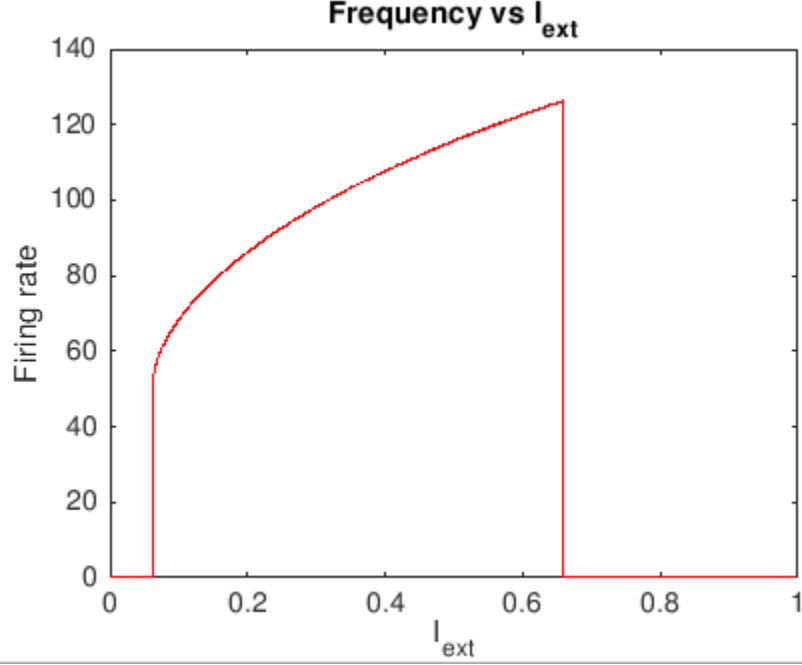
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```
1:  $[peaks, locs] = findpeaks(vhist)$ 
2: if  $length(peaks) > 2 \ \&\& \ peaks(2) < 0$  then
3:    $freq(k) \leftarrow 0$ .
4: else
5:   if  $length(peaks) > 2 \ \&\& \ peaks(3) > 0$  then
6:      $freq(k) \leftarrow 1000.0 / (t(locs(3)) - t(locs(2)))$ 
7:   else
8:      $freq(k) \leftarrow 0$ 
```

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In the above algorithm, frequency is defined as  $\frac{1}{TimePeriod}$ . and since time is assumed to be in milliseconds, it becomes  $\frac{1000}{TimePeriod}$

The corresponding frequency plot is given by :



### 3 Methods

#### 3.1 Method 1: Based on no. of spikes

Here, a count based approach has been utilized in order to find the values of  $I_1$ ,  $I_2$ ,  $I_3$  and plot the graph. The corresponding code is named "method1.m". The no. of local maxima of the oscillating graph is stored in an array "count" for each value of the external current starting from 0 to 1 with an increment of 0.0005.

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##### Algorithm 2 No. of spikes

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```

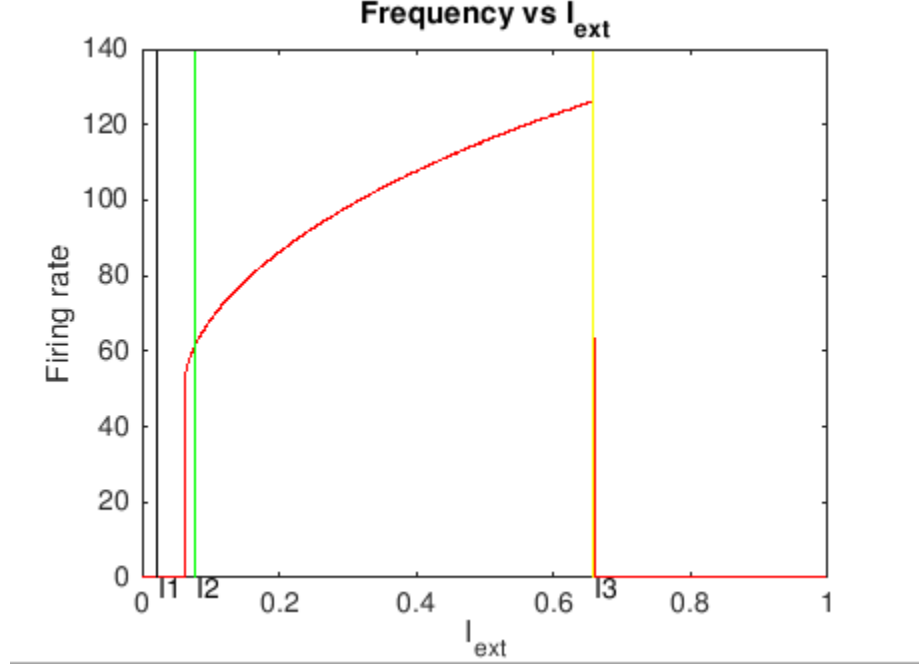
1: if  $ImpCur < 0.0224$  % Threshold mentioned in the code given then
2:    $I_1 \leftarrow ImpCur$ .
3: else
4:   if  $freq(k) \neq 0$  then
5:     if  $count(k) < 7$  %Finite no. of peaks - verified manually then
6:        $I_2 \leftarrow ImpCur$ 
7:     else
8:        $I_3 \leftarrow ImpCur$ 

```

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In the above algorithm, the no. of finite peaks were measured using "[pks,locs] = findpeaks(data)" function in MATLAB.

The corresponding frequency plot is given by :



The values of the currents are :

Current	Value
I1	0.0220
I2	0.0775
I3	0.6585

### 3.2 Based on continuity of oscillations

Here, the continuity of oscillations according limit cycle behaviour has been utilized inorder to find the values of I1, I2, I3 and plot the graph. The corresponding code is named "method2.m". The no. of local maxima of the oscillating graph is stored in an array "count" for each value of the external current starting from 0 to 1 with an increment of 0.0005.

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#### Algorithm 3 Continuity of oscillations

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```

1: if ImpCur < 0.0224 % Threshold mentioned in the code given then
2:   I1 ← ImpCur.
3: else
4:   if freq(k) ≠ 0 then
5:     if ending_time > ending_time_of_significant_last_peak − 20 × time_of_1_oscillation then
6:       I2 ← ImpCur
7:     else
8:       I3 ← ImpCur

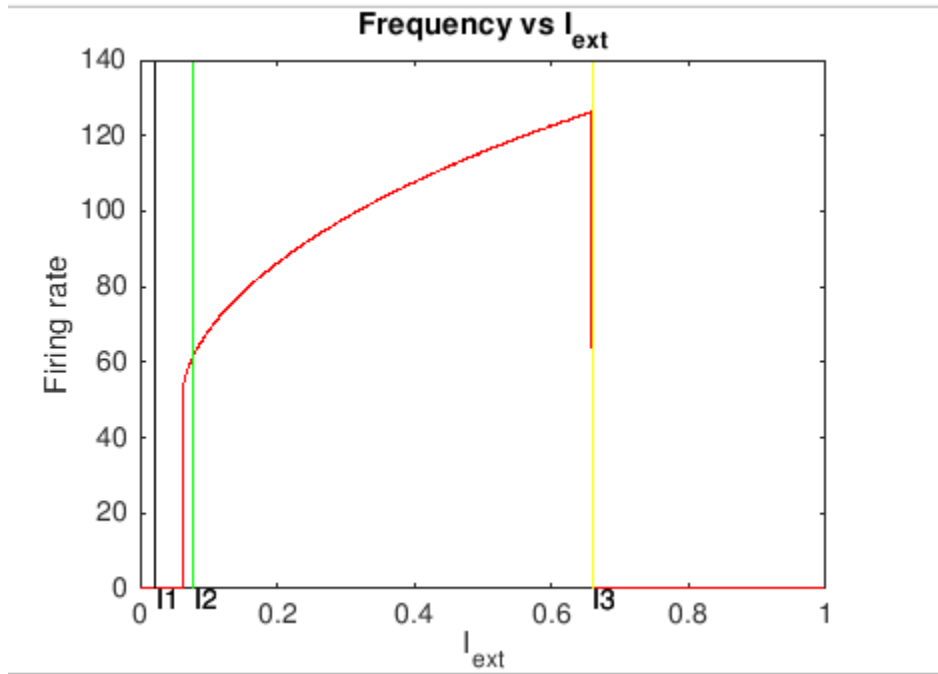
```

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The logic here is that finite no. of peaks is defined by : last significant peak occurs before last time =j, Finite no. of peaks

**Note :** The last significant peak has been defined to be 75% of the highest peak. Anything oscillations than that, beyond that location is omitted.

The corresponding frequency plot is given by :



The values of the currents are :

Current	Value
$I_1$	0.0220
$I_2$	0.0780
$I_3$	0.6590

## 4 Plots

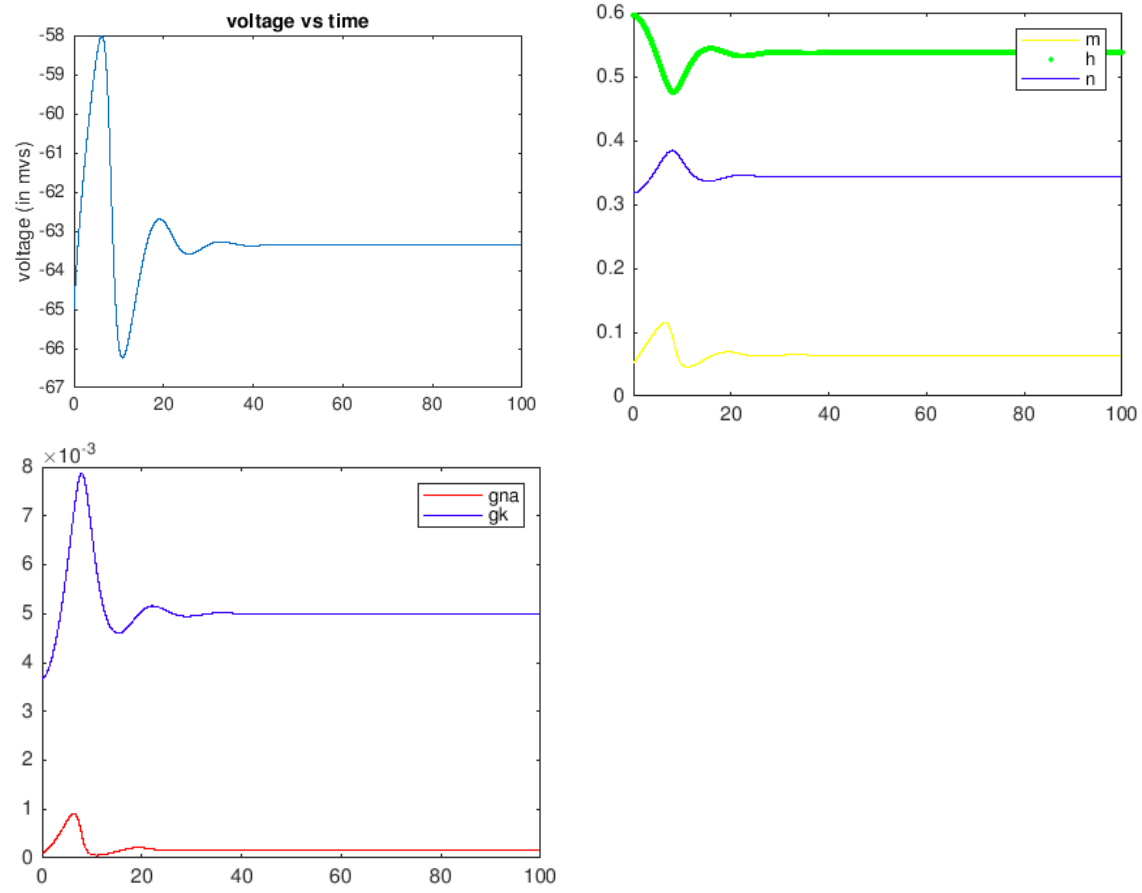


Figure 1: Threshold : Finite no. of APs

#### 4.1 At $I_{ext} = 0.0775$

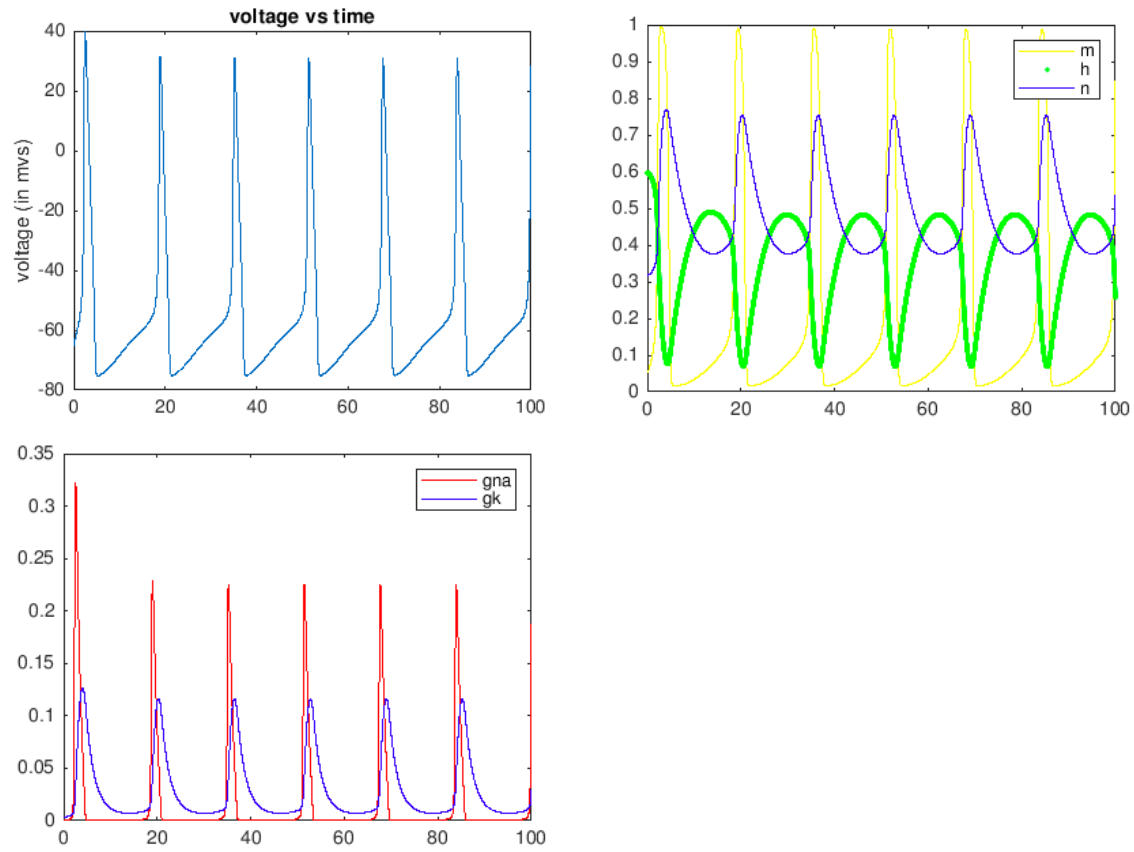


Figure 2: Threshold : Continuous firing

## 4.2 At $I_{ext} = 0.6585$

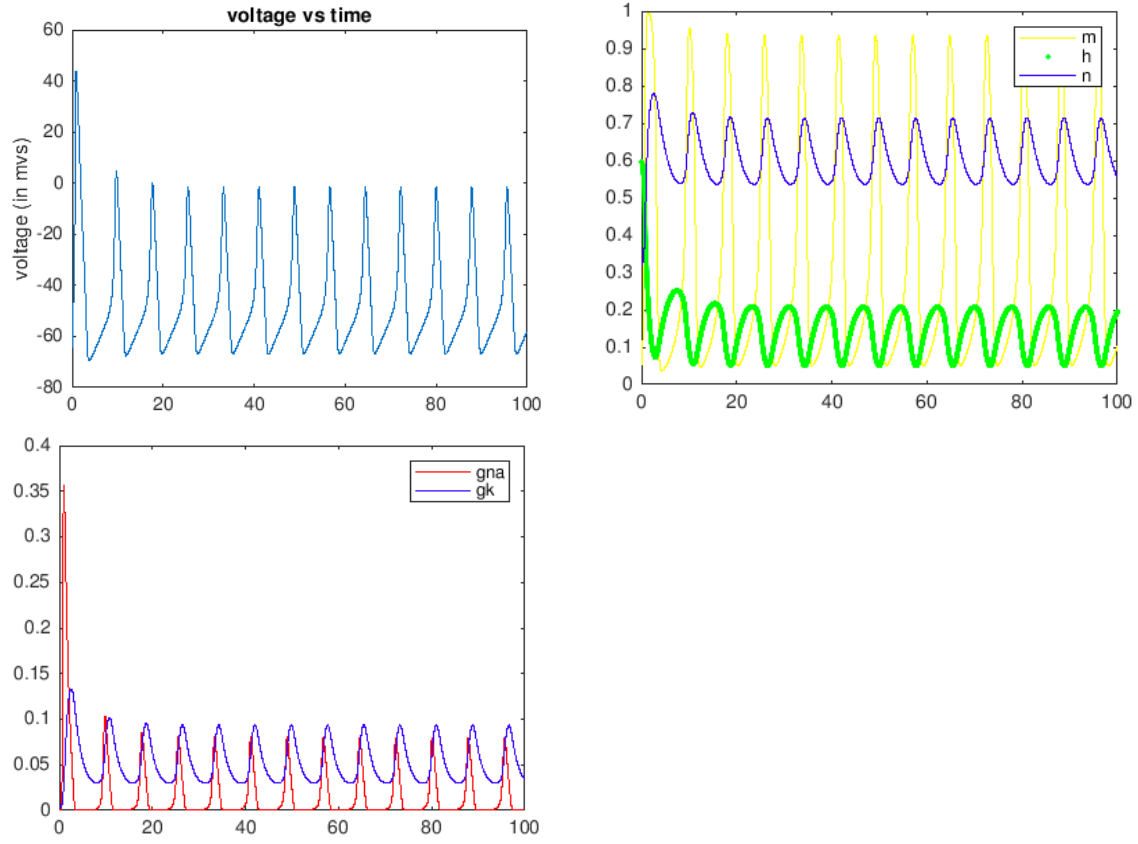


Figure 3: Threshold : Distortion resulting in no more APs

## 4.3 To be noted

All the plots and values have been calculated through both manual observation as well as through programs. All the necessary codes have been attached. In case further clarification required, please let me know.