EE 746-Neuromorphic Computing, Homework 3

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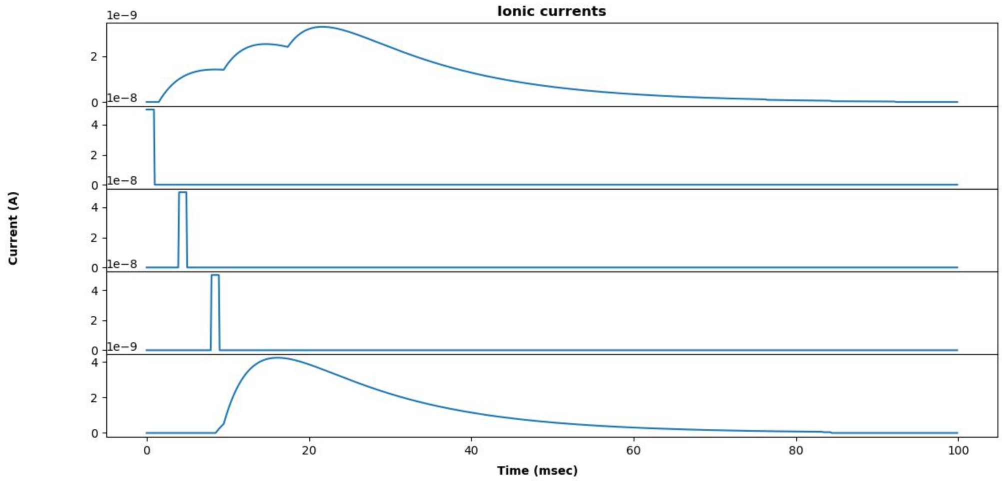
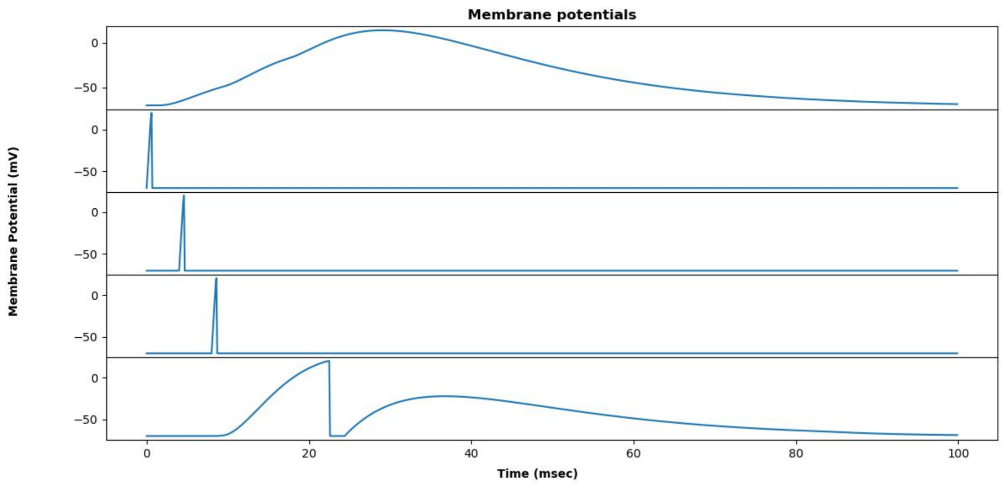
The codes for each of the parts has been named and numbered accordingly and stored in a single folder titled "Code". Within this folder the code for say question 4 is contained in the file "q4.py".
All the code has been written in Python 2.7. To see the results of any of the codes, simply open a terminal and type "python filename.py", replacing filename with the name of the file to be run.
Note that q1(b) has two cases and the codes for cases 1 and 2 has respectively stored in files "q1_1.py" and "q1_2.py".

Question 1

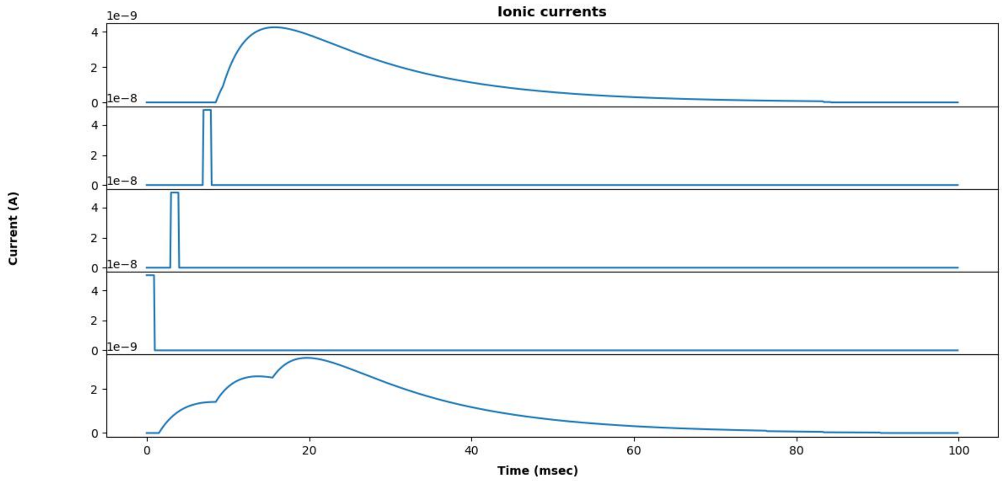
a) As the code was written in Python, a list of lists was used instead of cell arrays to store connectivity information. In particular, for each neuron a list of its downstream neurons along with the corresponding synaptic weight and delay was stored. In q4 and q5 where upstream connectivity is also needed for STDP, the corresponding pointers to the downstream connectivity matrix are stored in a separate matrix and this comprises the upstream connectivity matrix. Note that pointers are used so that the synaptic weights only need to be stored and changed in one place.

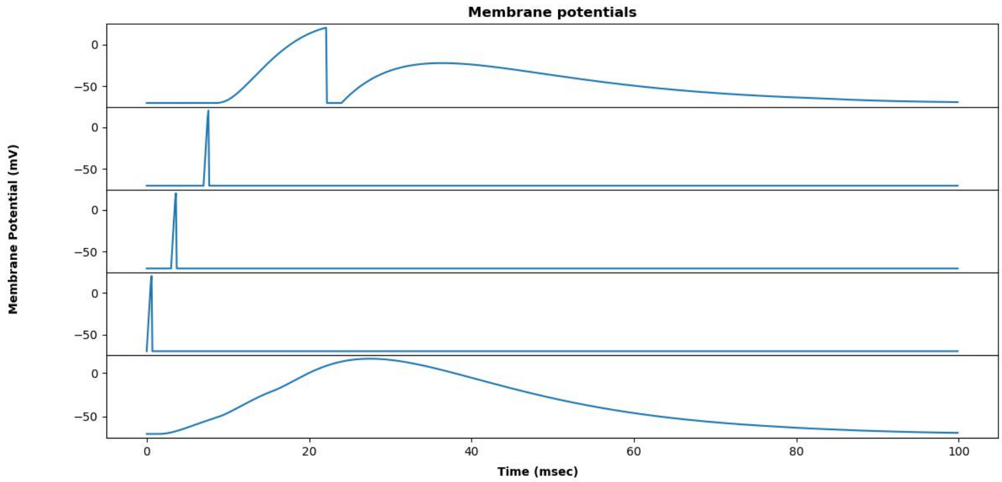
b) Case 1:





Case 2:

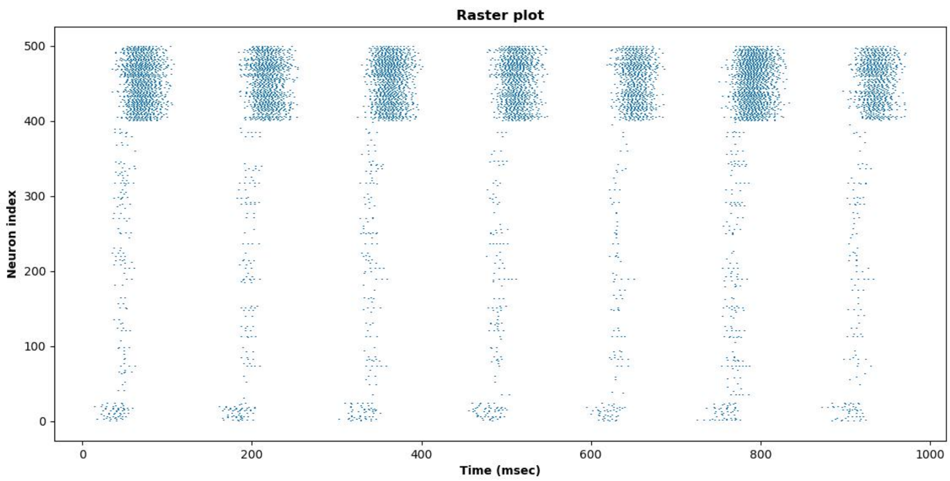




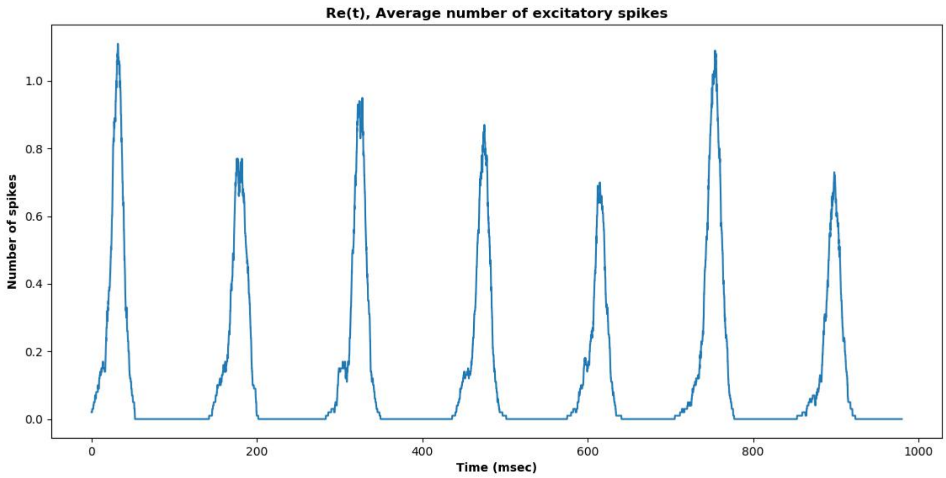
We note that in case 1, neuron e fires while neuron a does not. In case 2, neuron a fires while neuron e does not.

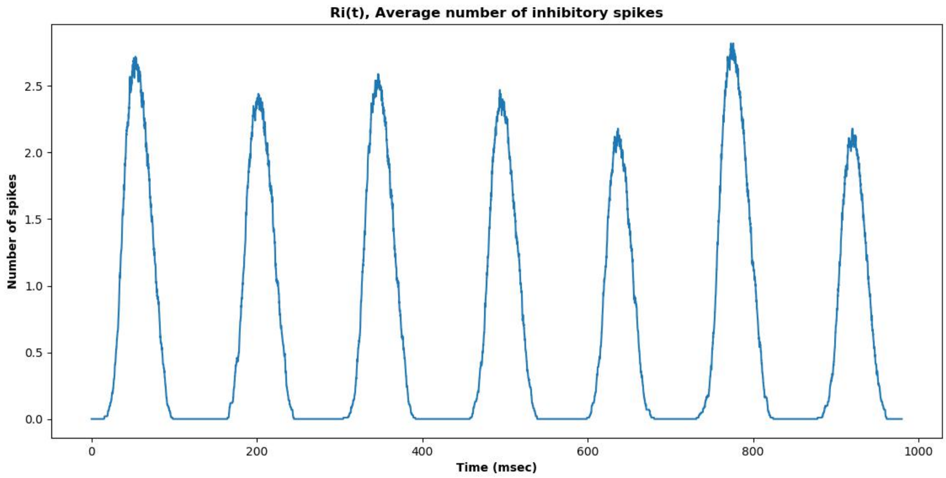
Question 2

a)



b)



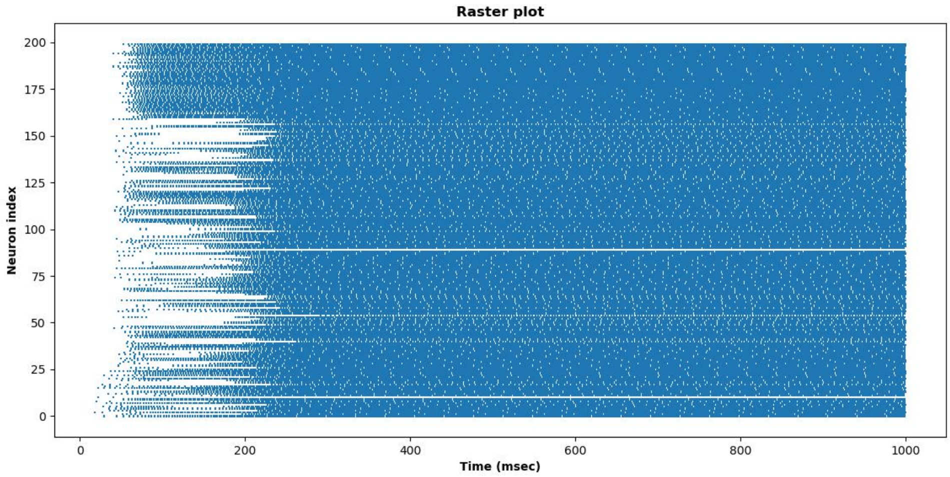


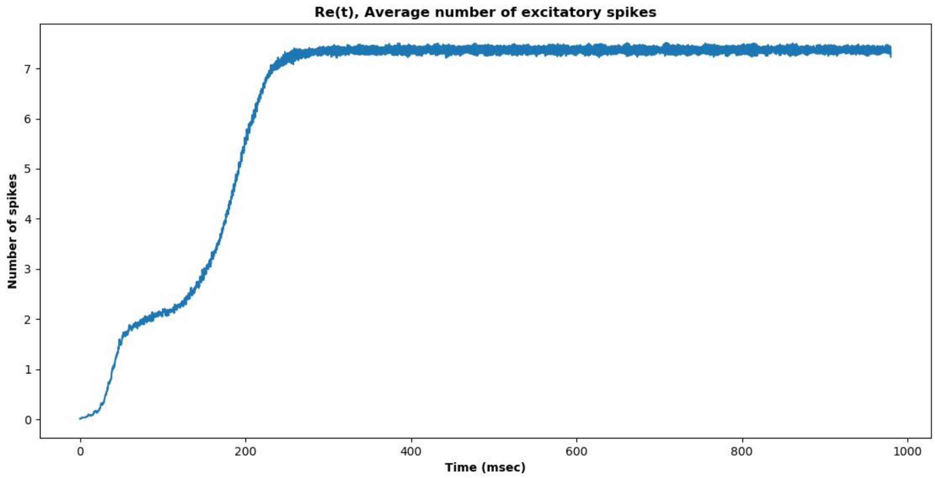
c) What we observe are a model for delta oscillations, the slowest type of oscillations observed in the brain.

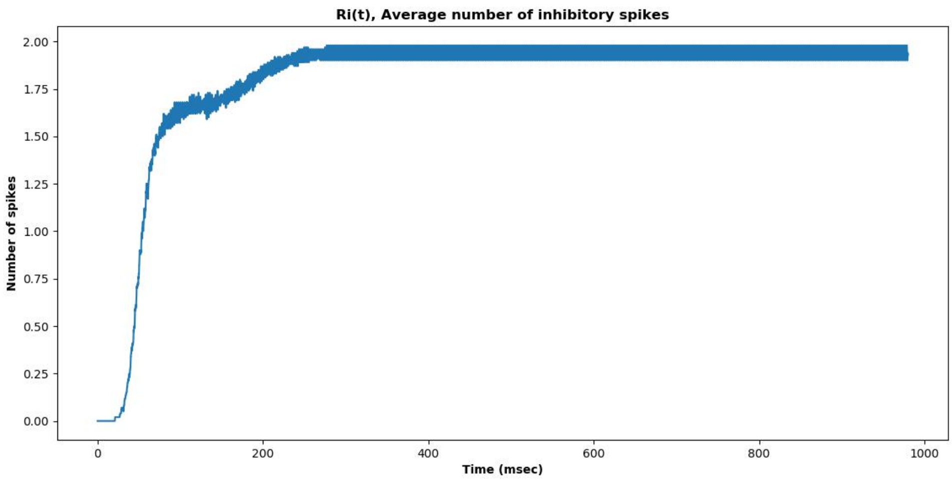
The external Poisson stimulus injects enough current to make a few excitatory neurons. These neurons then inject current into other neurons, including other excitatory neurons, hence amplifying the number of excitatory neurons. As the number of spiking excitatory neurons increases, more and more current gets injected into the inhibitory neurons which also start spiking and hence silence the excitatory neurons. After a while, the external Poisson stimulus is again able to make a few excitatory neurons spike and the cycle repeats, hence setting up oscillations.

Question 3

a)



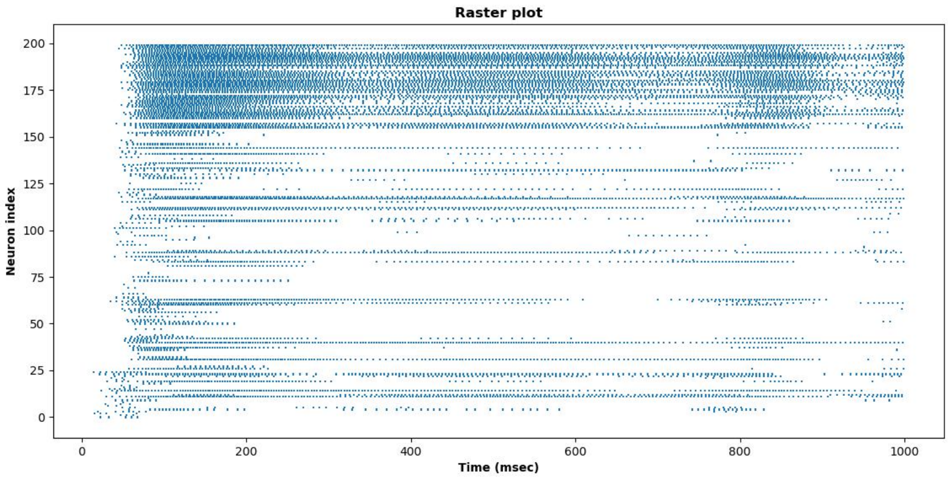


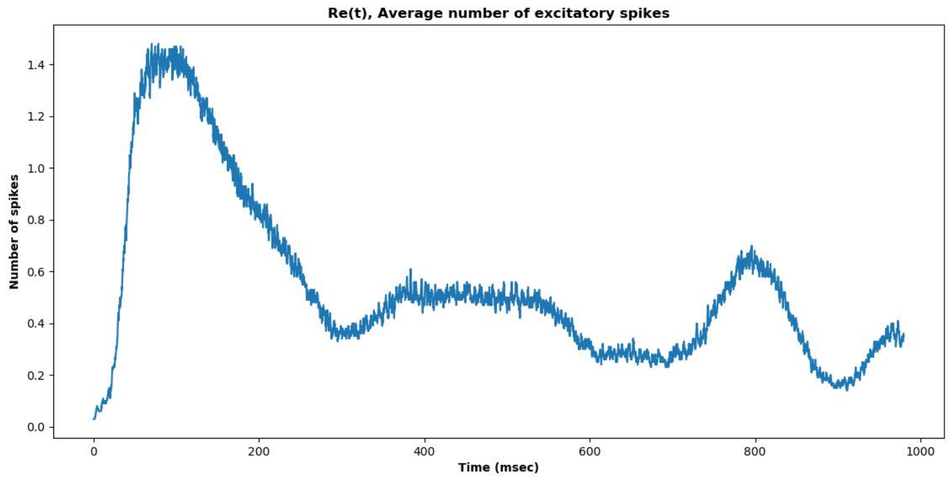


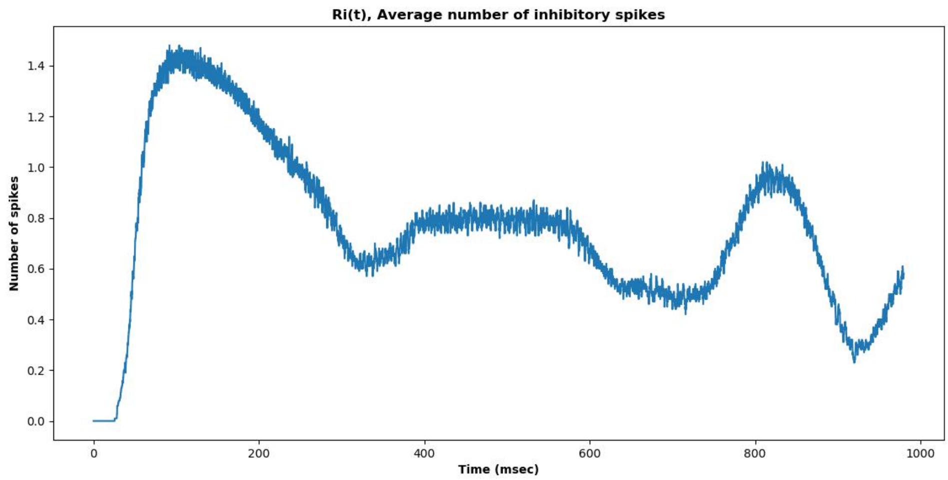
In this case, no oscillations are observed.

b)

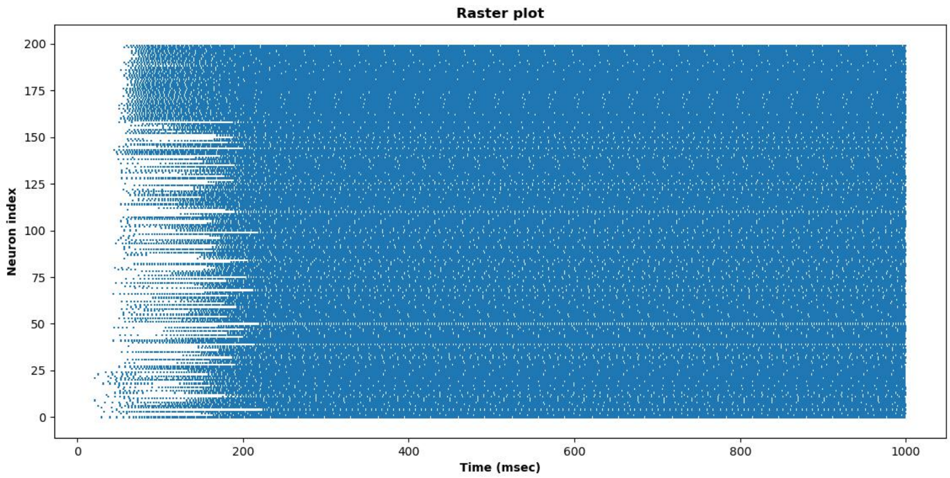
w_e = 2500:

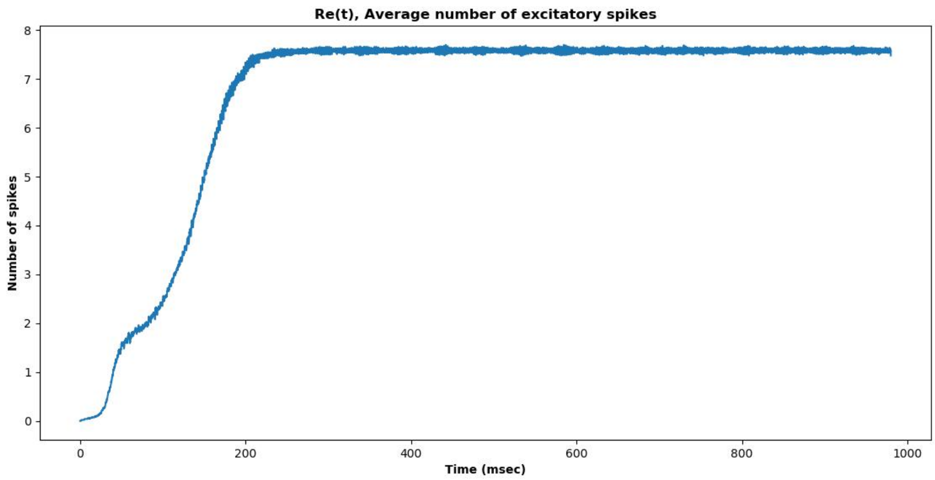

Raster plot
Neuron index
0
25
50
75
100
125
150
175
200
Time (msec)
0
200
400
600
800
1000

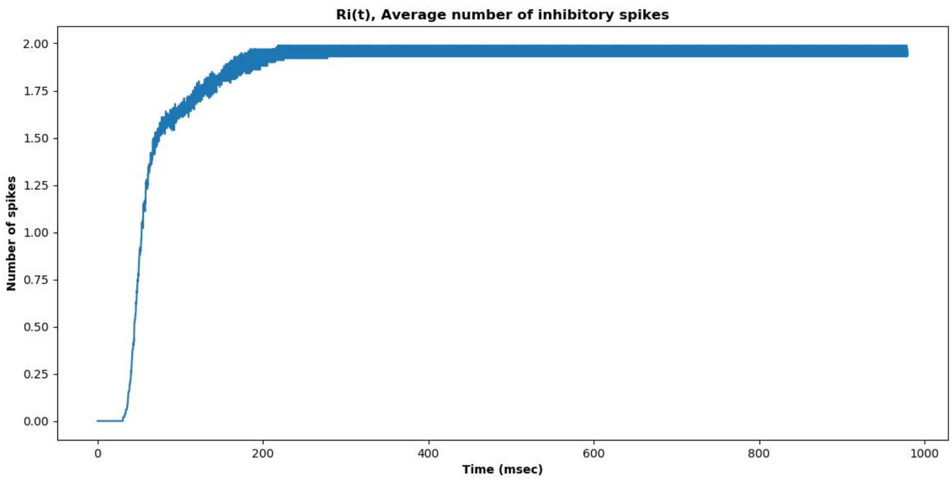

Re(t), Average number of excitatory spikes
Number of spikes
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
Time (msec)
0
200
400
600
800
1000


Ri(t), Average number of inhibitory spikes
Number of spikes
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
Time (msec)
0
200
400
600
800
1000

w_e = 3500:



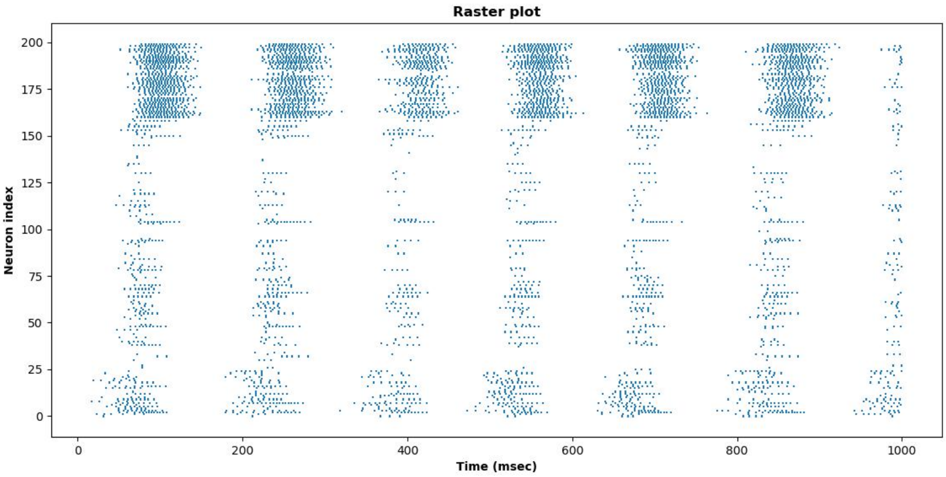


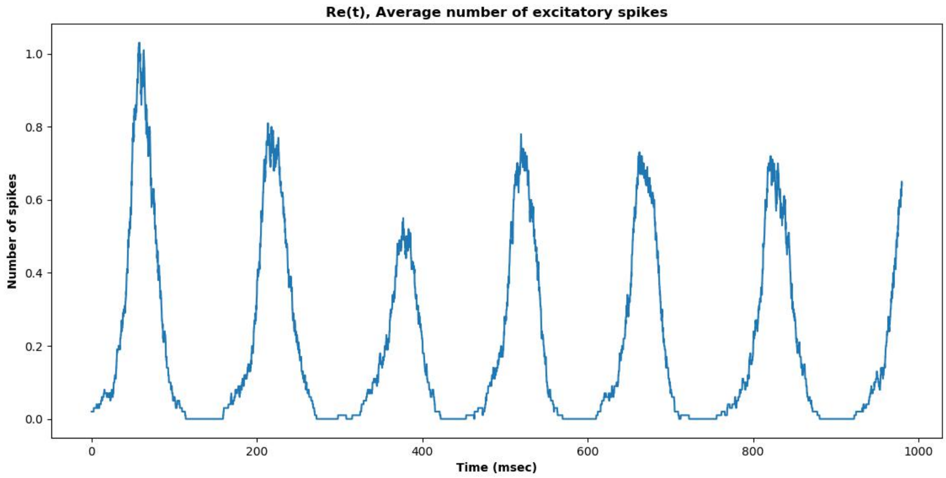


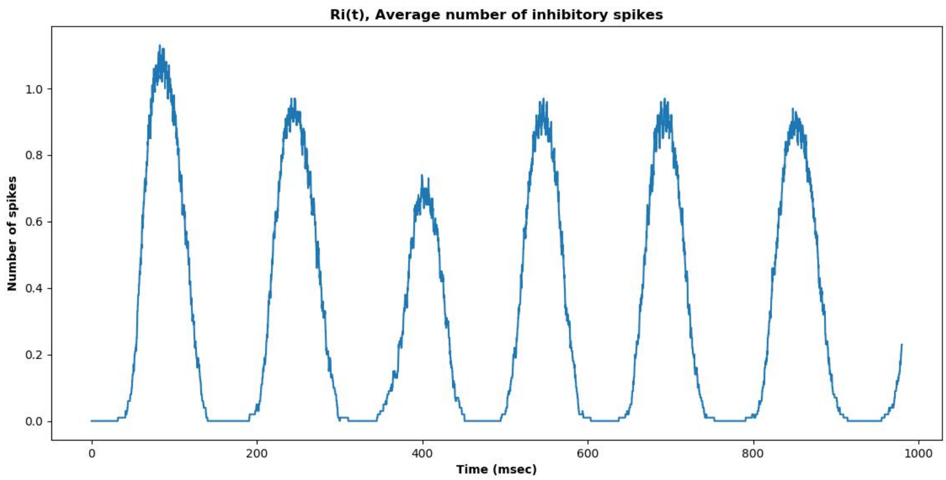
Hence we can't get oscillations for any value of w_e if $w_e = w_i$.

c) The neurons are spiking too much. Hence the inhibition needs to be increased.

d) Setting $w_e = -0.75 * w_i$ yields (hence $\gamma = 0.75$):

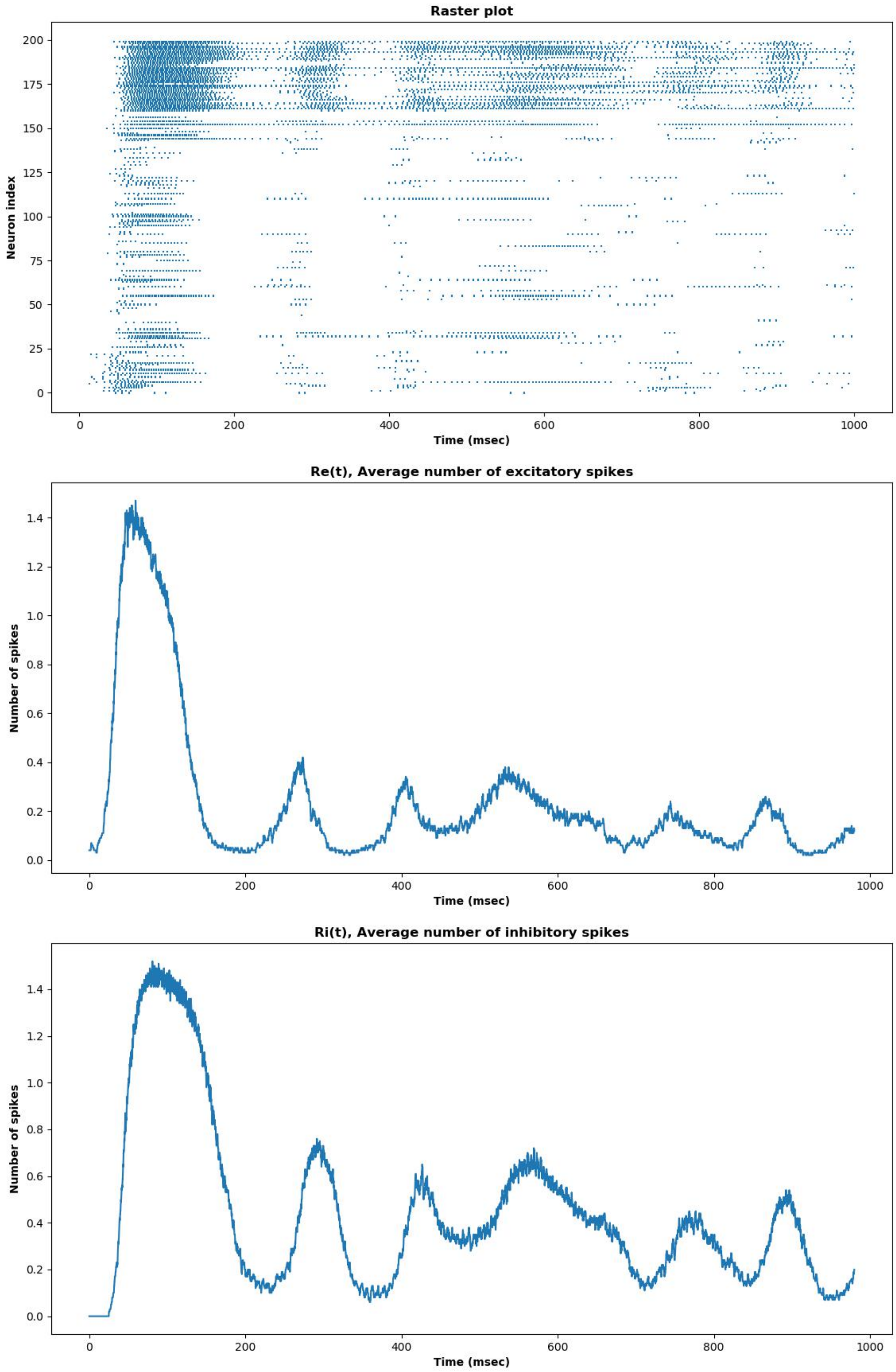




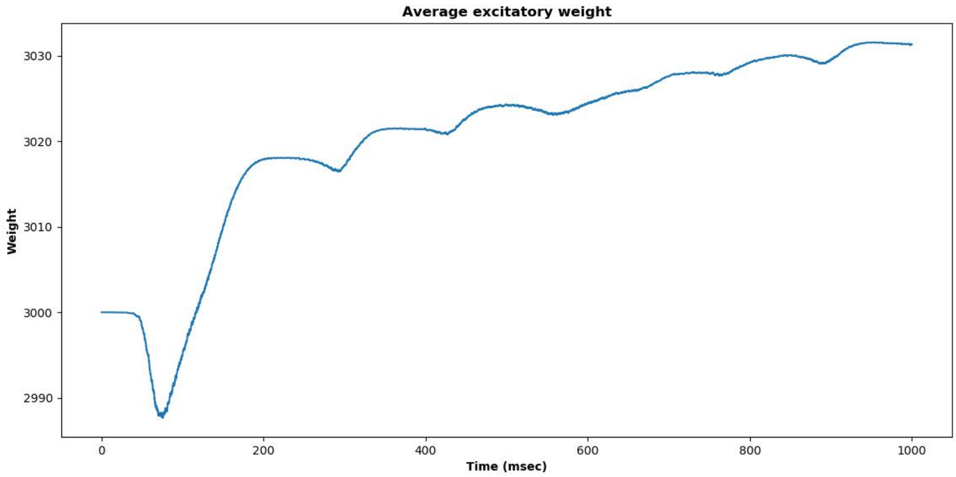


Question 4

a) Implementing STDP yields:


Raster plot
Neuron index
Time (msec)
Re(t), Average number of excitatory spikes
Number of spikes
Time (msec)
Ri(t), Average number of inhibitory spikes
Number of spikes
Time (msec)

b)

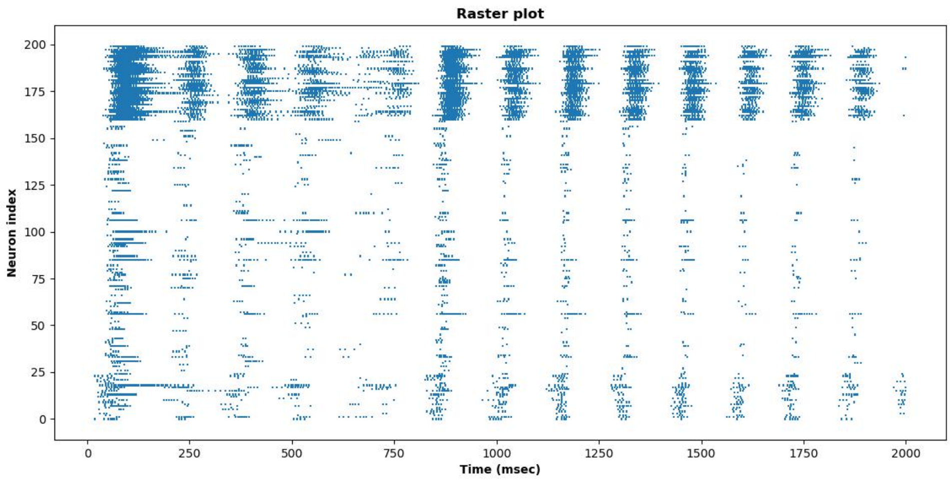


Clearly, the excitatory weights are increasing. But this does not lead to sustained oscillations in this case.

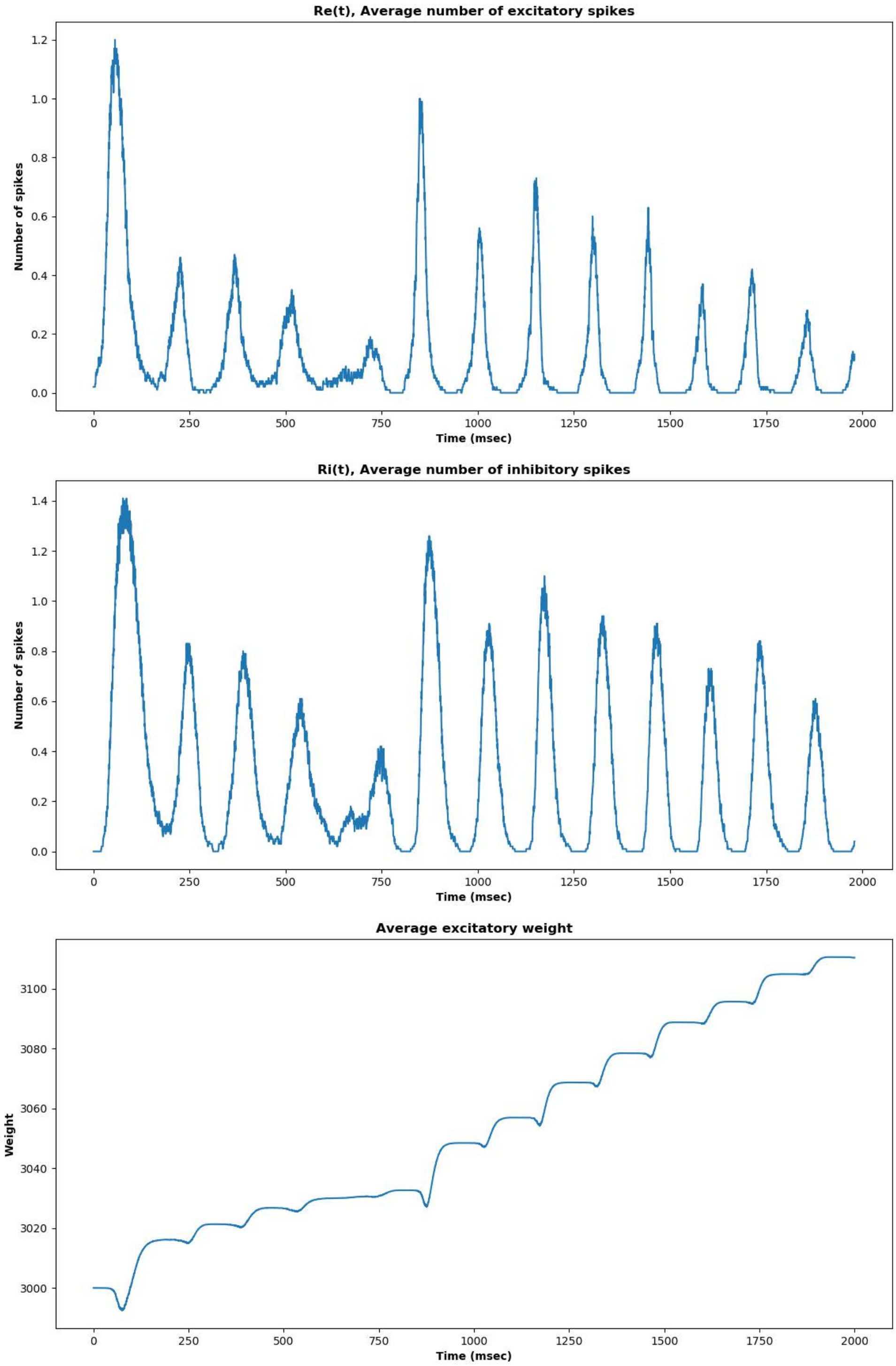
Question 5

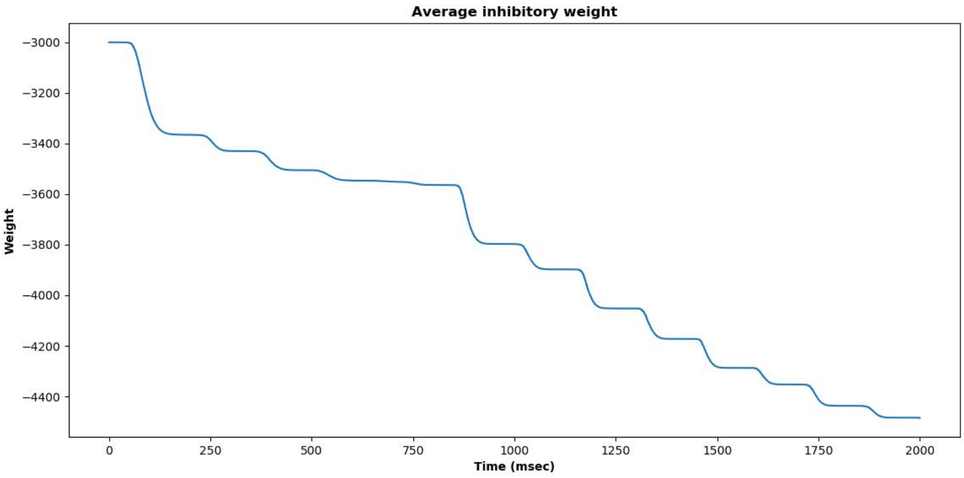
a) We essentially want to enforce the dynamic wherein excitatory neurons that receive external stimulus excite other excitatory neurons. This is a causal relationship and hence we will use normal STDP for excitatory neurons.
We also want to enforce the dynamic in which inhibitory neurons inhibit the firing of excitatory neurons. In this scenario, the downstream excitatory neurons fired first and then the inhibitory neuron fired, and thus inhibited the excitatory neuron from firing again. This is anti-causal and hence we will use anti-STDP for inhibitory neurons.

b)



c)


Re(t), Average number of excitatory spikes
Number of spikes
Time (msec)
Ri(t), Average number of inhibitory spikes
Number of spikes
Time (msec)
Average excitatory weight
Weight
Time (msec)


Average inhibitory weight
Weight
Time (msec)
−3000
−3200
−3400
−3600
−3800
−4000
−4200
−4400
0
250
500
750
1000
1250
1500
1750
2000