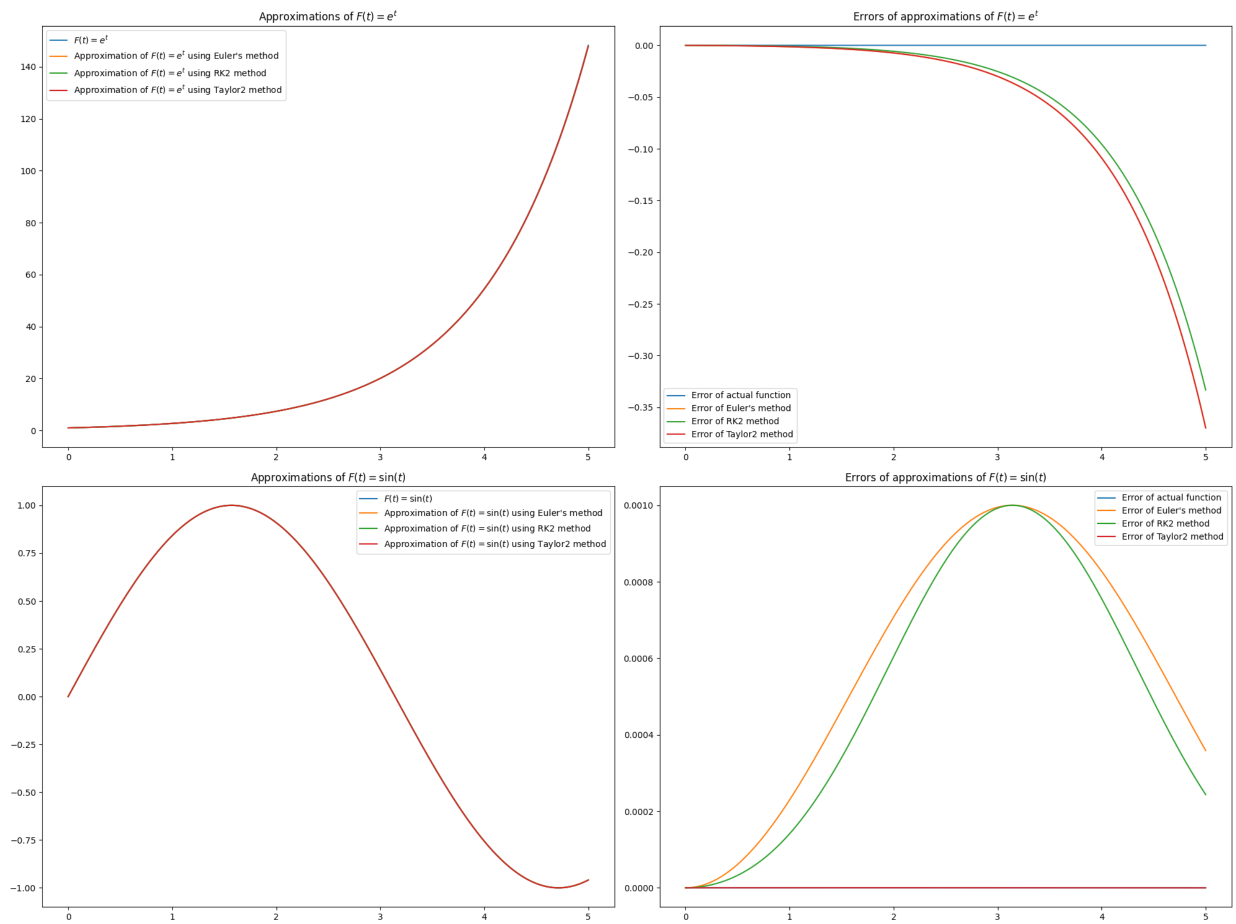
Instructions

This package assumes you have numpy installed.

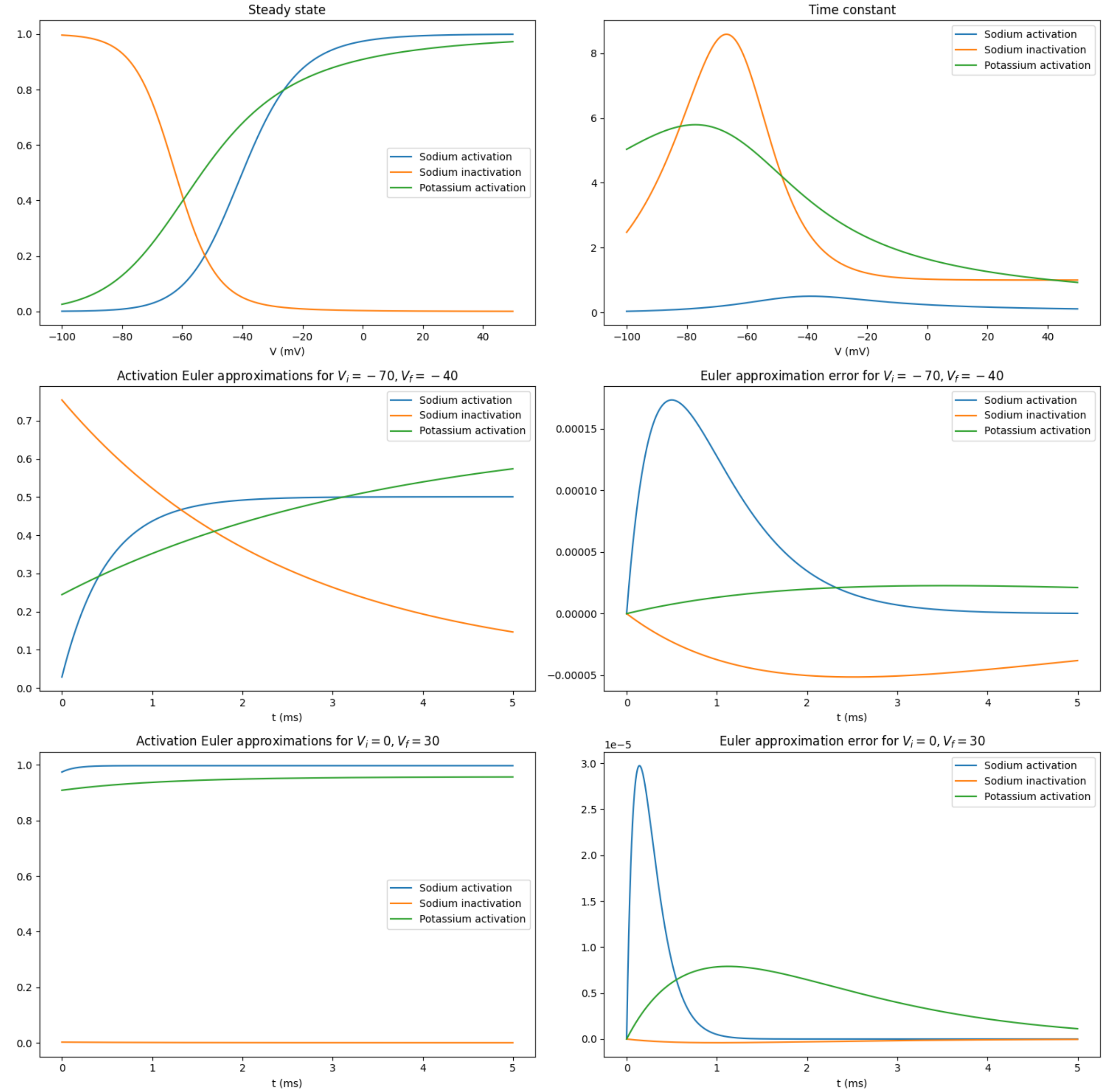
```
git clone https://github.com/bri25yu/Rhythms-of-the-brain.git
cd Rhythms-of-the-brain
python3 main.py  # or your version of python
```

Description

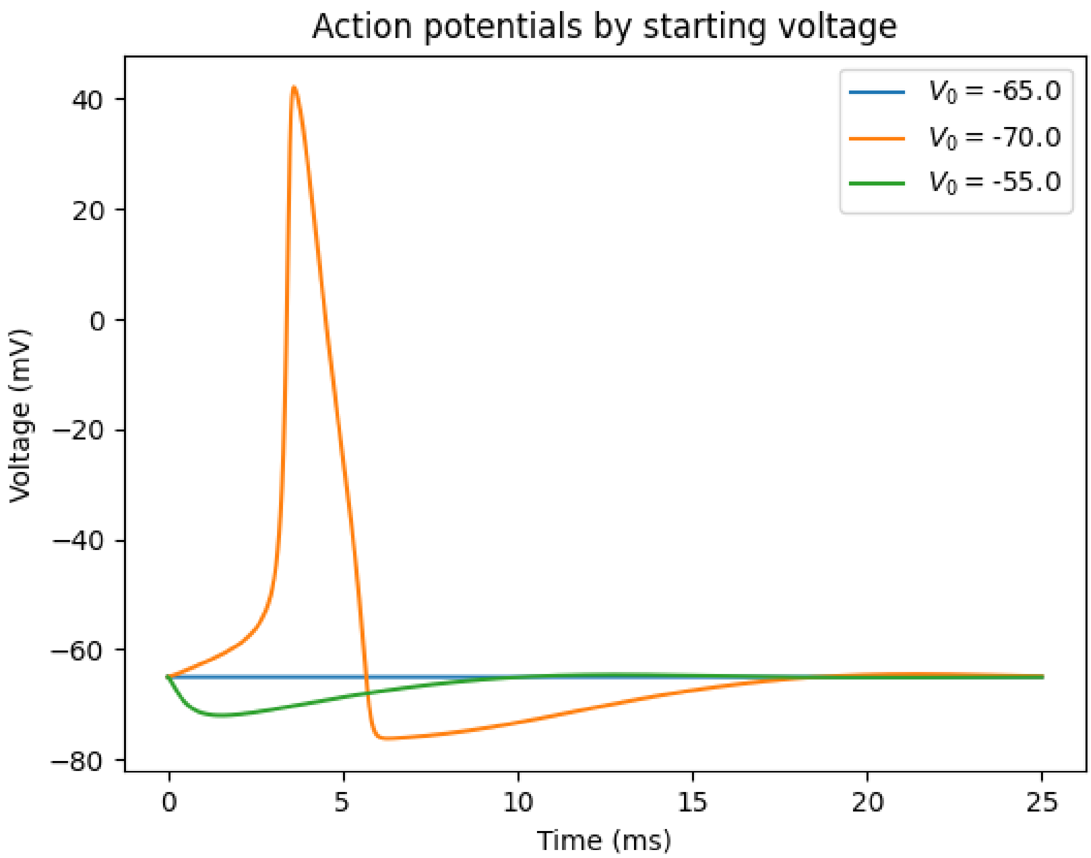
We need to numerically approximate a solution to the Hodgkin-Huxley partial differential equation, so we write some approximation methods first, including the Euler, Runge-Kutta order 2 (RK2), and Taylor order 2 approximation methods.



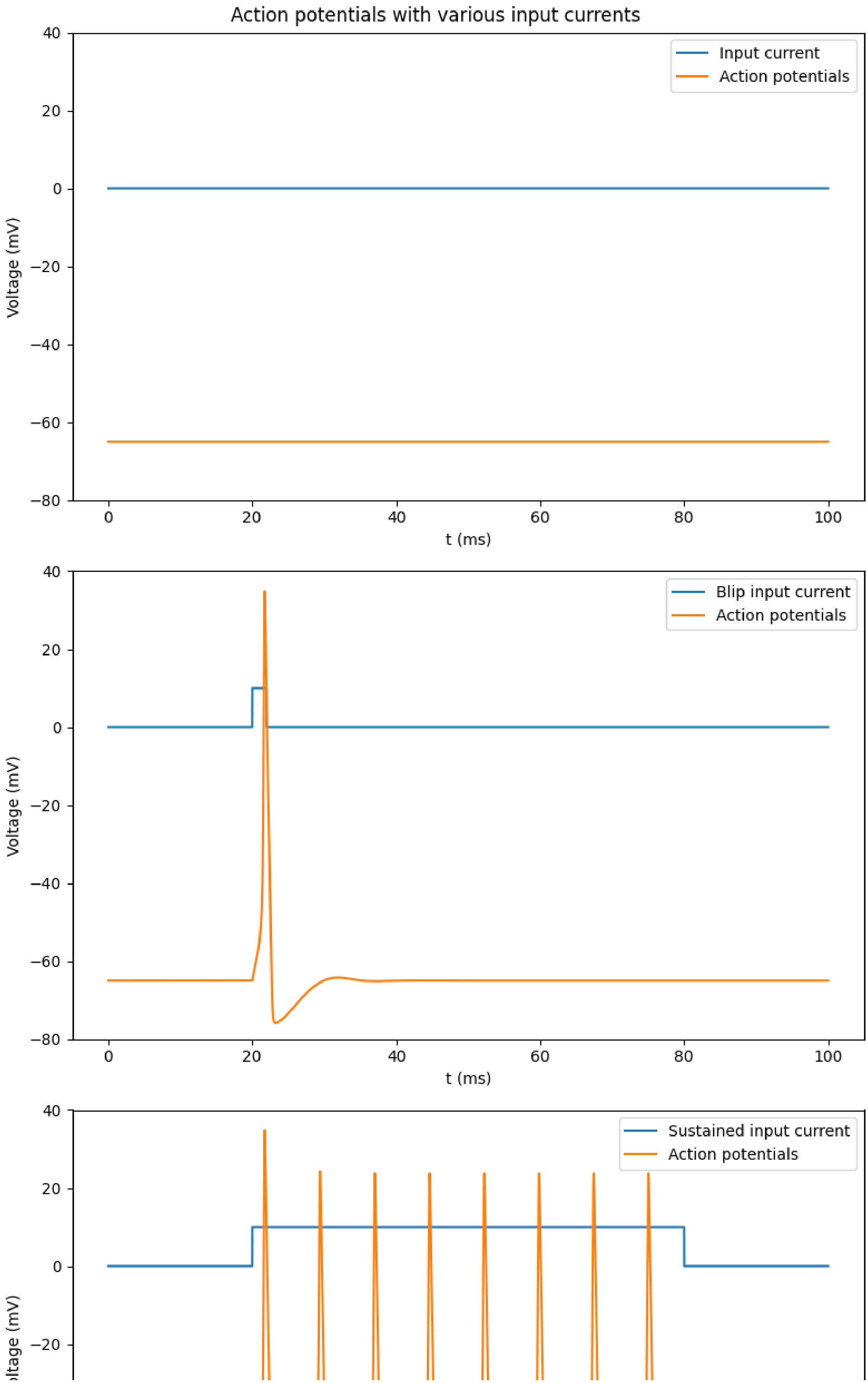
We use the previous Euler approximation method to approximate solutions to voltage-clamped experiments and measure the response of the Sodium activation, Sodium inactivation, and Potassium activation.

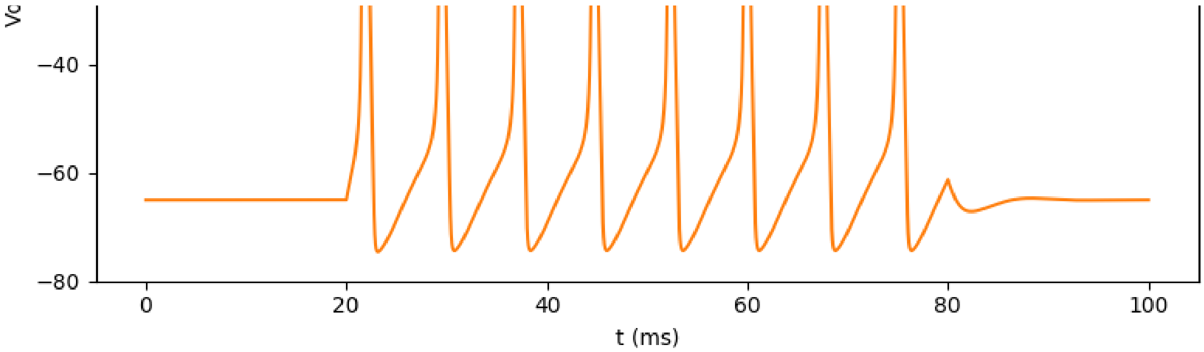


Putting these activation gates together, we can finally model and approximate a solution to an action potential at different starting potentials.

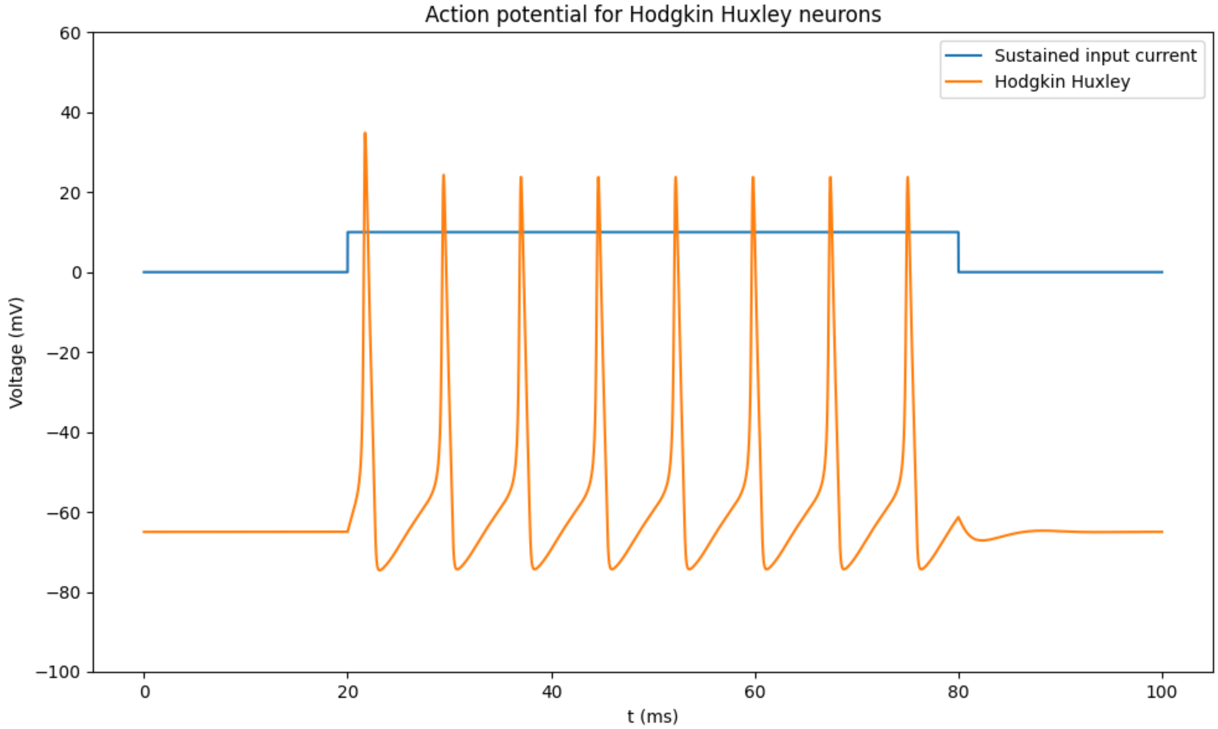


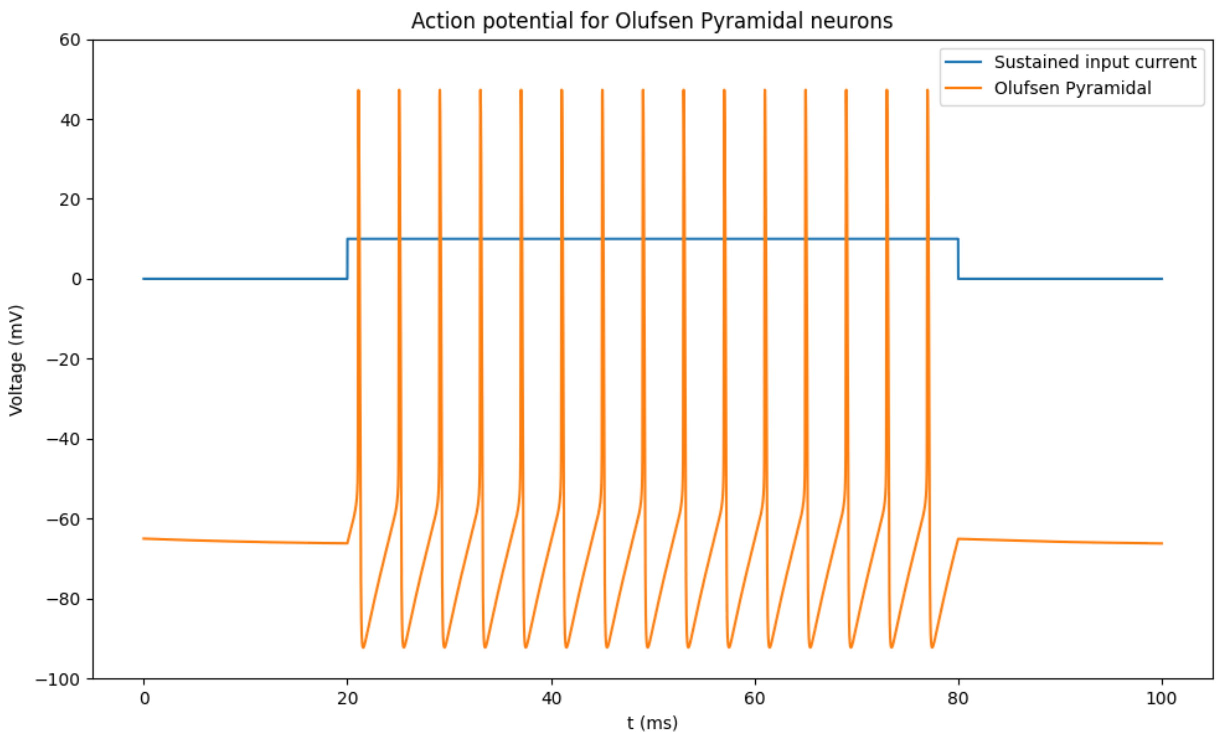
We can further model an input current's effect on our action potential model, simulating an artificial example of the output of the presynaptic neuron potential into the current neuron.

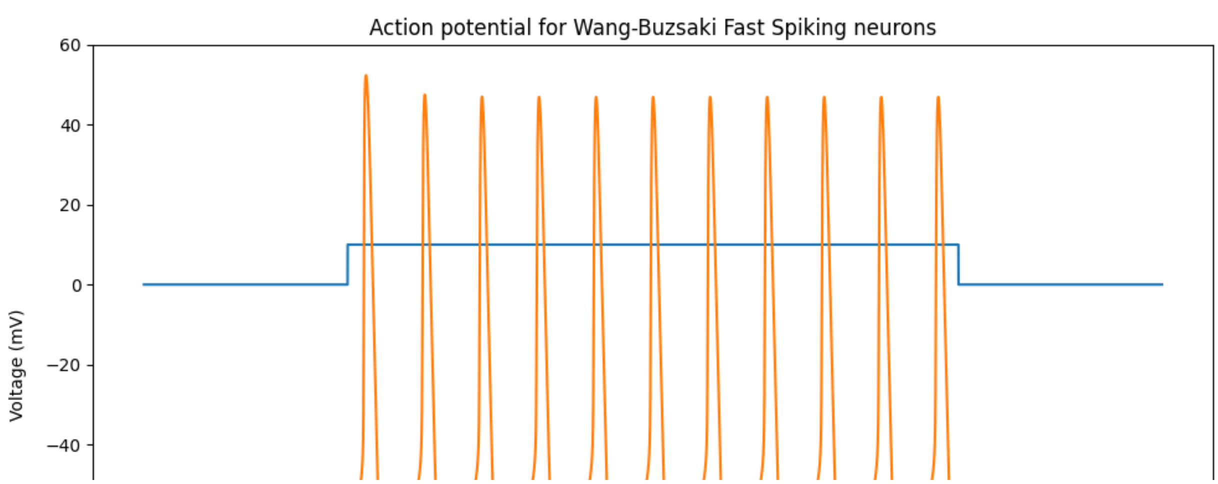

Action potentials with various input currents
Input current
Action potentials
Voltage (mV)
t (ms)
Blip input current
Action potentials
Voltage (mV)
t (ms)
Sustained input current
Action potentials
oltage (mV)
40
20
0
−20
−40
−60
−80
0
20
40
60
80
100

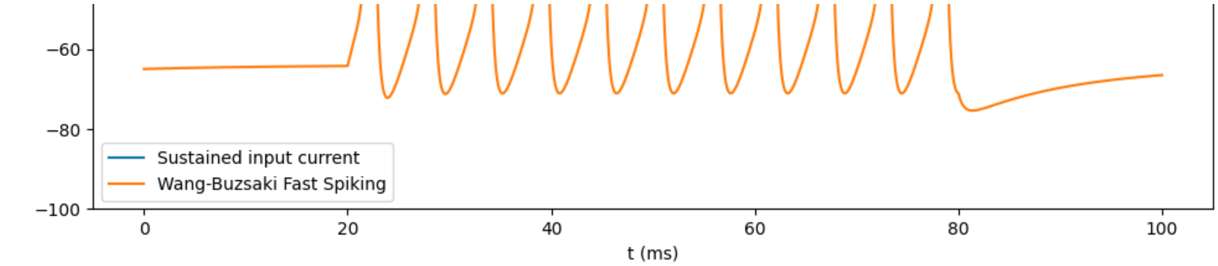

Vo
−40
−60
−80
0
20
40
60
80
100
t (ms)

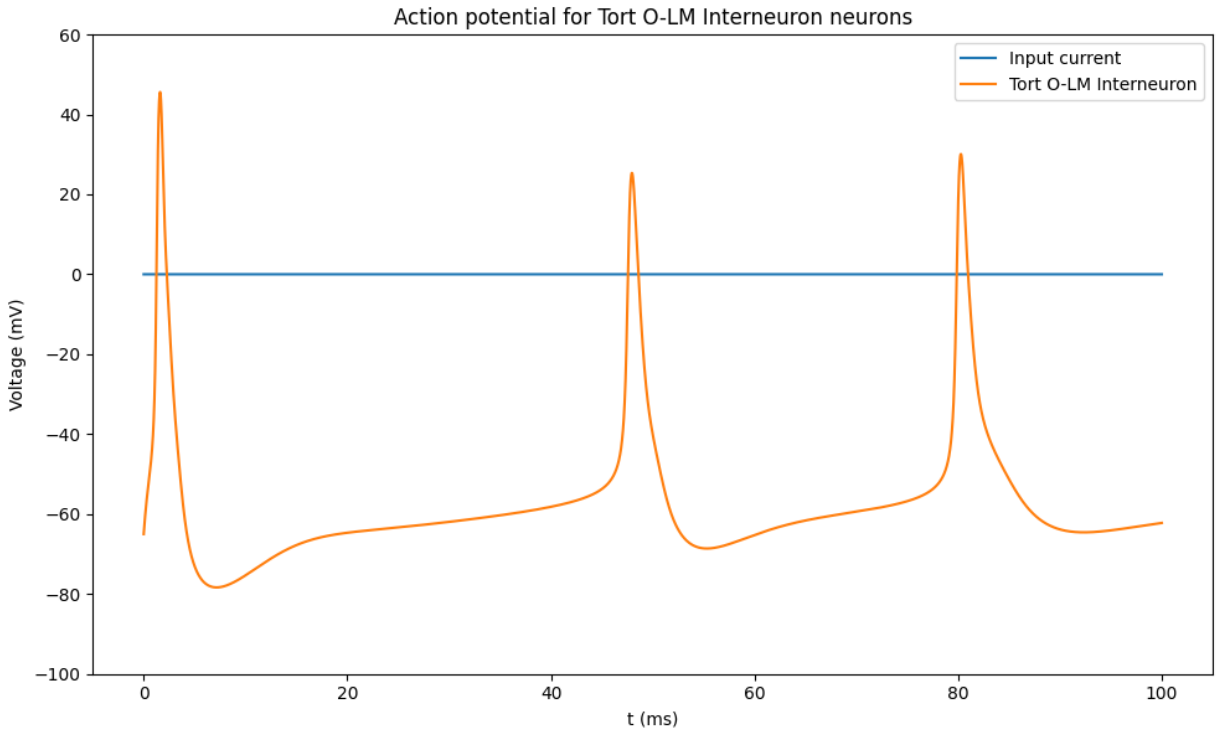
In order to produce theta and gamma rhythms, we investigate the behavior of several different types of neurons; specifically, we compare the original Hodgkin-Huxley neuron model with the Olufsen Pyramidal neuron, Wang-Buzsaki fast-spiking neuron, and the Tort O-LM interneuron models.


Action potential for Hodgkin Huxley neurons
Sustained input current
Hodgkin Huxley
Voltage (mV)
60
40
20
0
−20
−40
−60
−80
−100
0
20
40
60
80
100
t (ms)

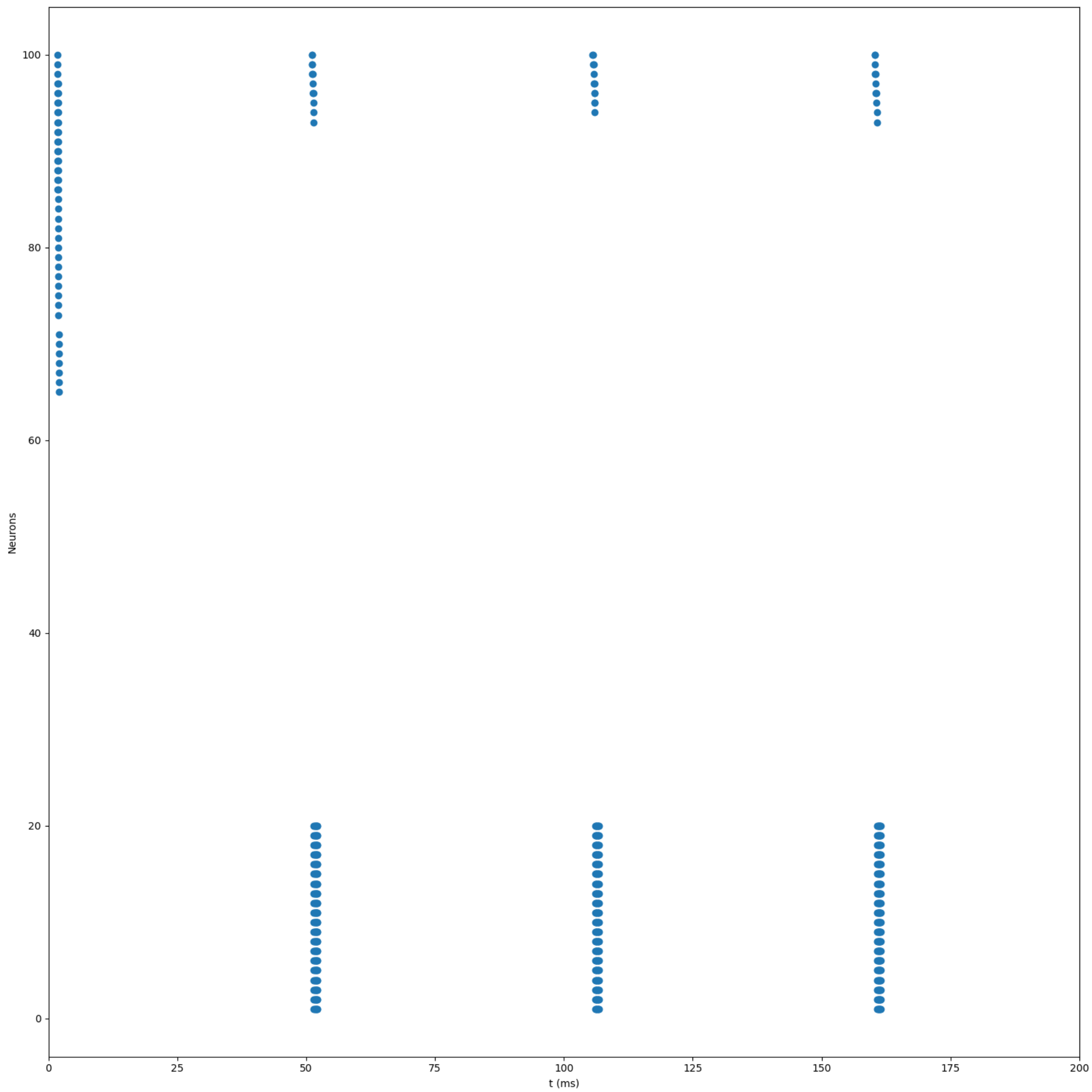

Action potential for Olufsen Pyramidal neurons
Sustained input current
Olufsen Pyramidal
Voltage (mV)
60
40
20
0
−20
−40
−60
−80
−100
0
20
40
60
80
100
t (ms)

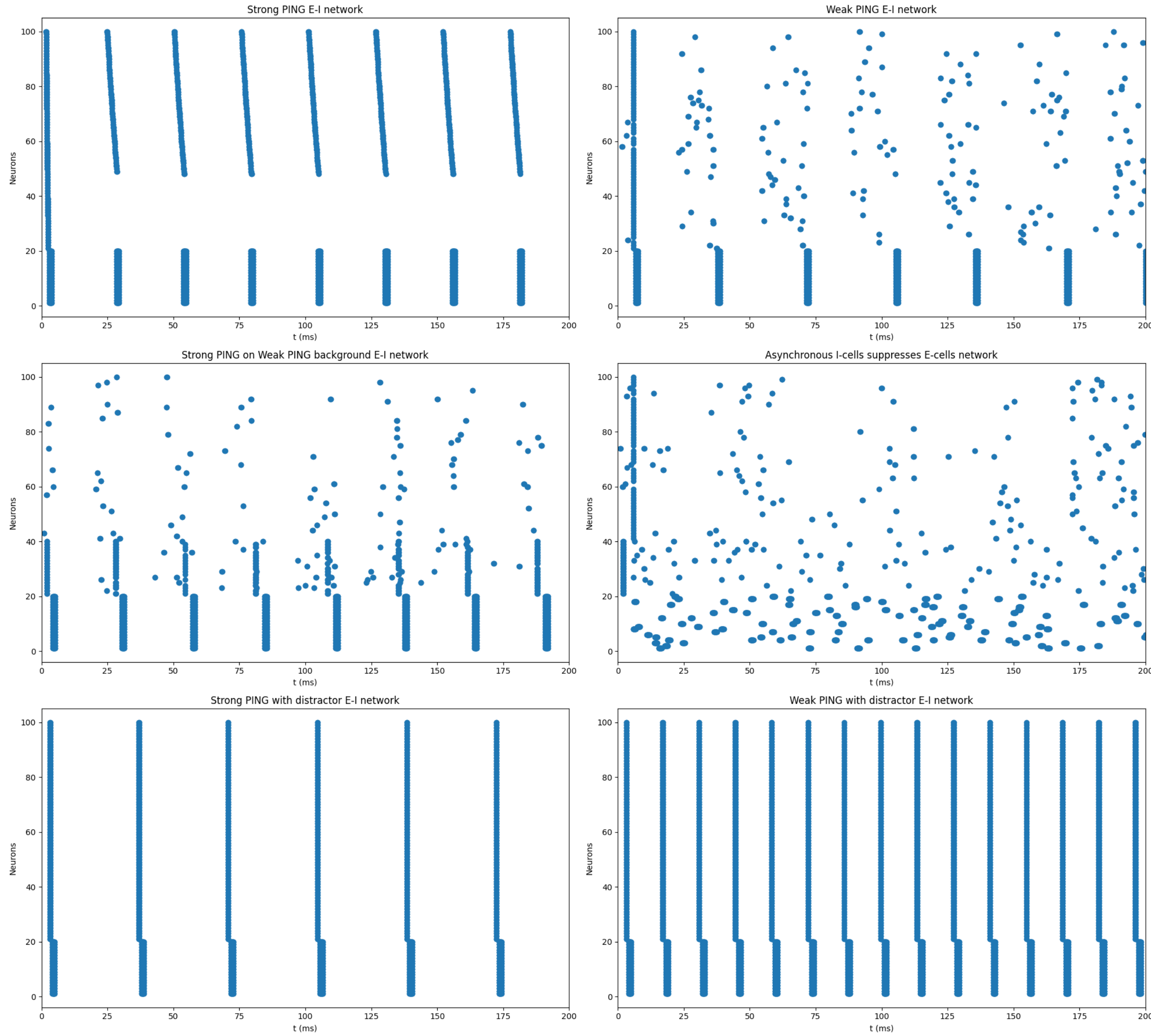

Action potential for Wang-Buzsaki Fast Spiking neurons
Voltage (mV)
60
40
20
0
−20
−40


−60
−80
−100
Sustained input current
Wang-Buzsaki Fast Spiking
0
20
40
60
80
100
t (ms)


Action potential for Tort O-LM Interneuron neurons
Input current
Tort O-LM Interneuron
Voltage (mV)
60
40
20
0
−20
−40
−60
−80
−100
0
20
40
60
80
100
t (ms)

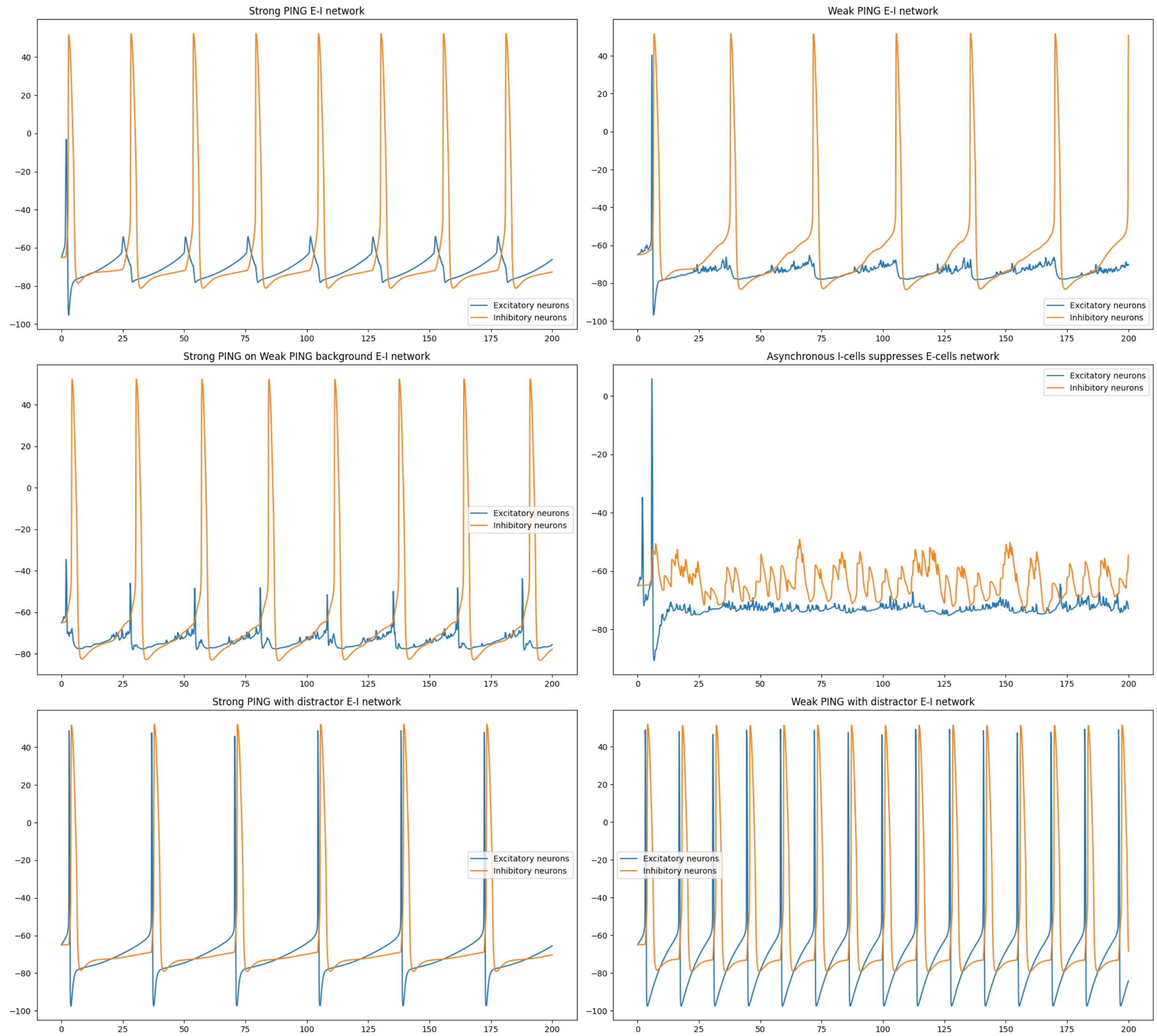
Using 80 Excitatory (pyramidal) and 20 Inhibitory (fast spiking basket) neurons, we can mimic PING rhythms. Neurons 1-20 are I and neurons 21-100 are E.

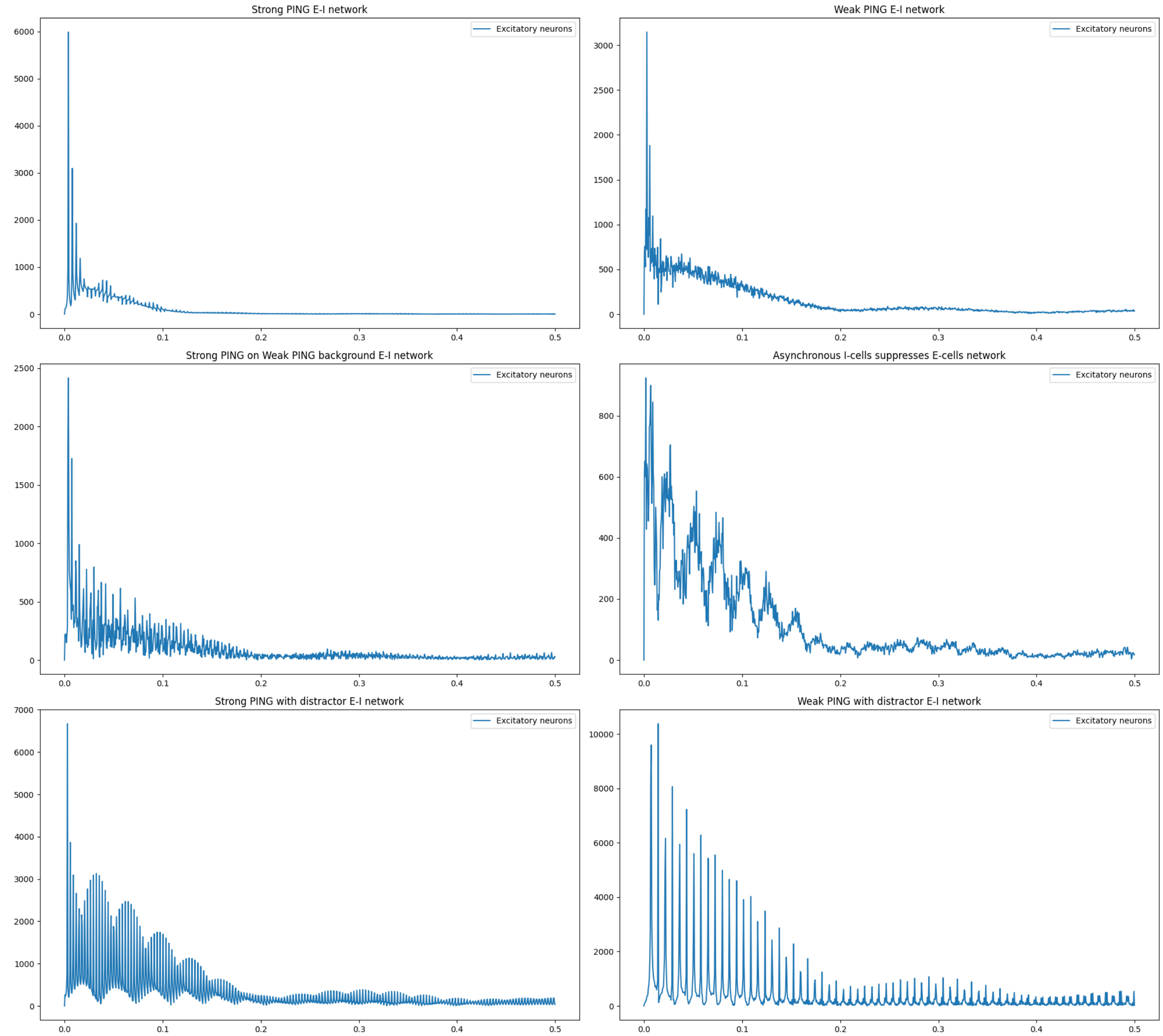




Strong PING E-I network
Weak PING E-I network
Strong PING on Weak PING background E-I network
Asynchronous I-cells suppresses E-cells network
Strong PING with distractor E-I network
Weak PING with distractor E-I network
Neurons
t (ms)
0
20
40
60
80
100
0
25
50
75
100
125
150
175
200

We can use signal processing to describe our rhythms using frequency.





Strong PING E-I network
Excitatory neurons
Weak PING E-I network
Excitatory neurons
Strong PING on Weak PING background E-I network
Excitatory neurons
Asynchronous I-cells suppresses E-cells network
Excitatory neurons
Strong PING with distractor E-I network
Excitatory neurons
Weak PING with distractor E-I network
Excitatory neurons
0.0
0.1
0.2
0.3
0.4
0.5