Problem 2

Out[1]: Toggle Code

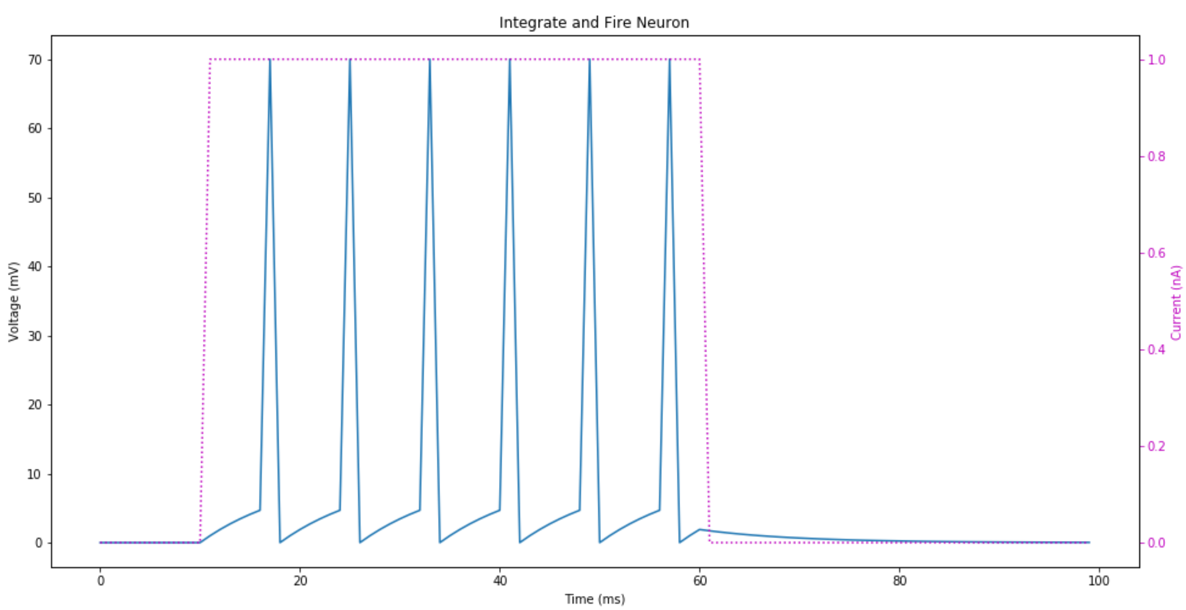
Methods

a.) We create an Integrate and Fire neuron using the equations and parameters defined in part a of the problem. The model was run with a step current injecion of 1 nA for 50 ms and its membrane potential, $V(t)$, plotted. Additionally, several sinusoidal inputs with frequencies 1 Hz, 2 Hz, 5 Hz, 10 Hz, 20 Hz, 50 Hz, and 100 Hz were tested on the model, while membrane potential was plotted. Spike count over each frequecies was also examined.

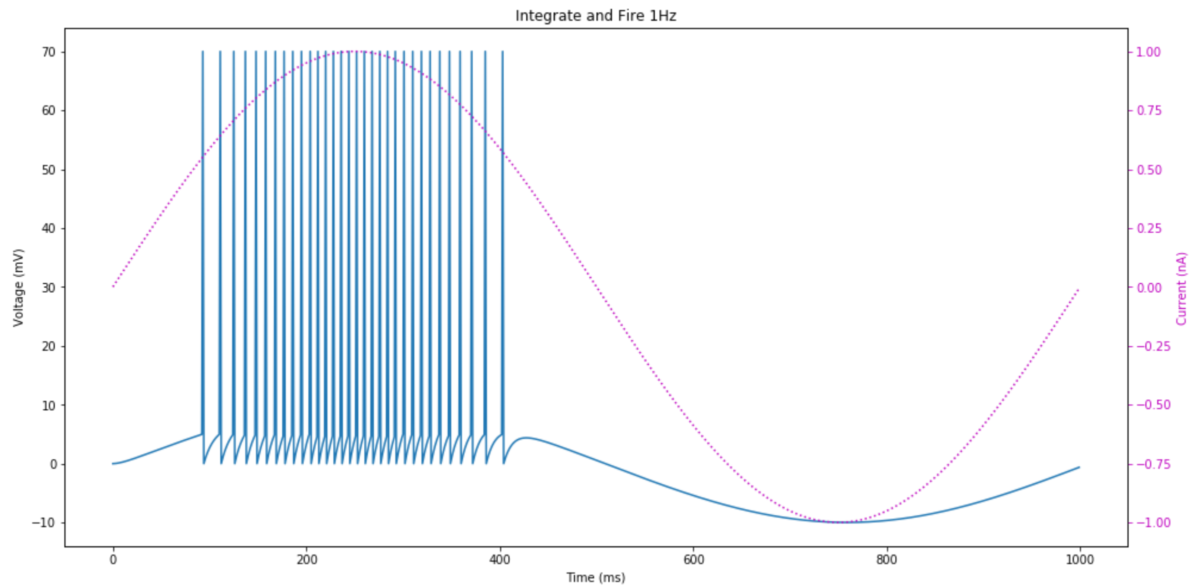
b.) The same procedure was carried on the model described in part b. We also plot the response of threshold function, $U(t)$, alongside the membrance potential, $V(t)$.

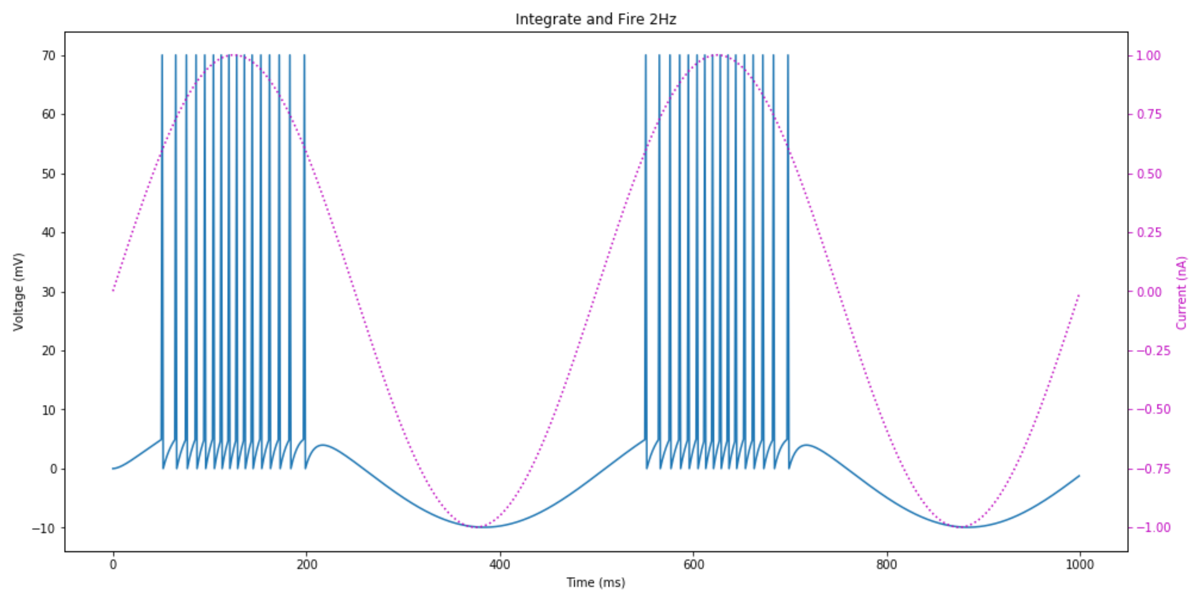
c.) A Two-Neuron oscillator was modelled using the parameters and equations given by part c. A constant asymmetric current input was given to the two neuron system, 1.1 nA to neuron 1, and 0.9 nA to neuron 2. Membrane potential, $V(t)$, was plotted for both neurons over 1500 ms.

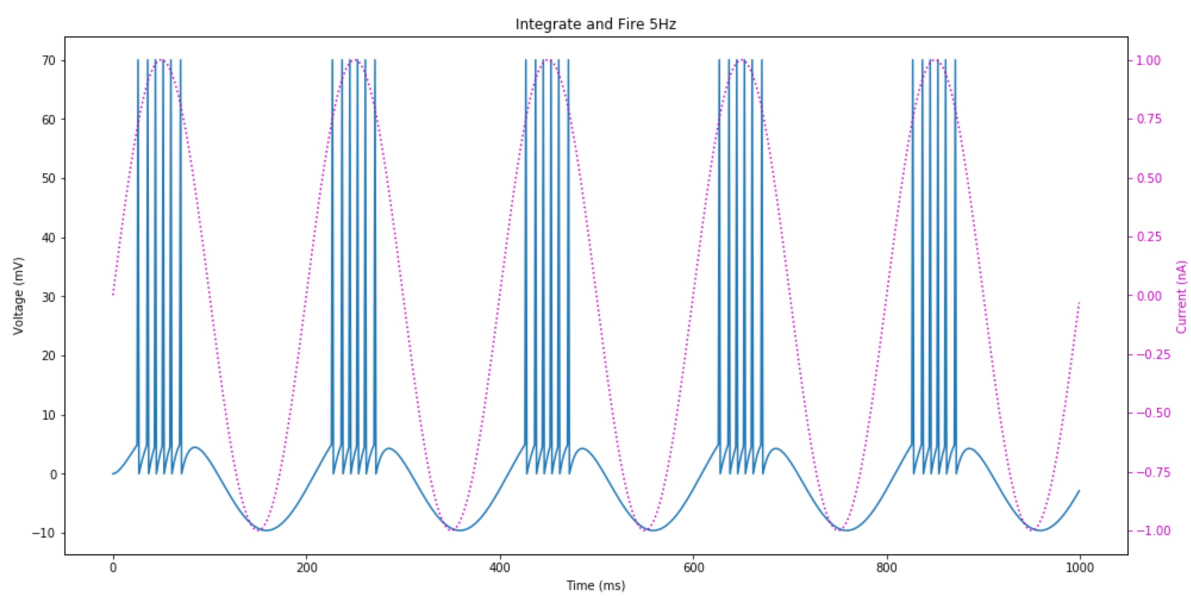
(i) Integrate and Fire

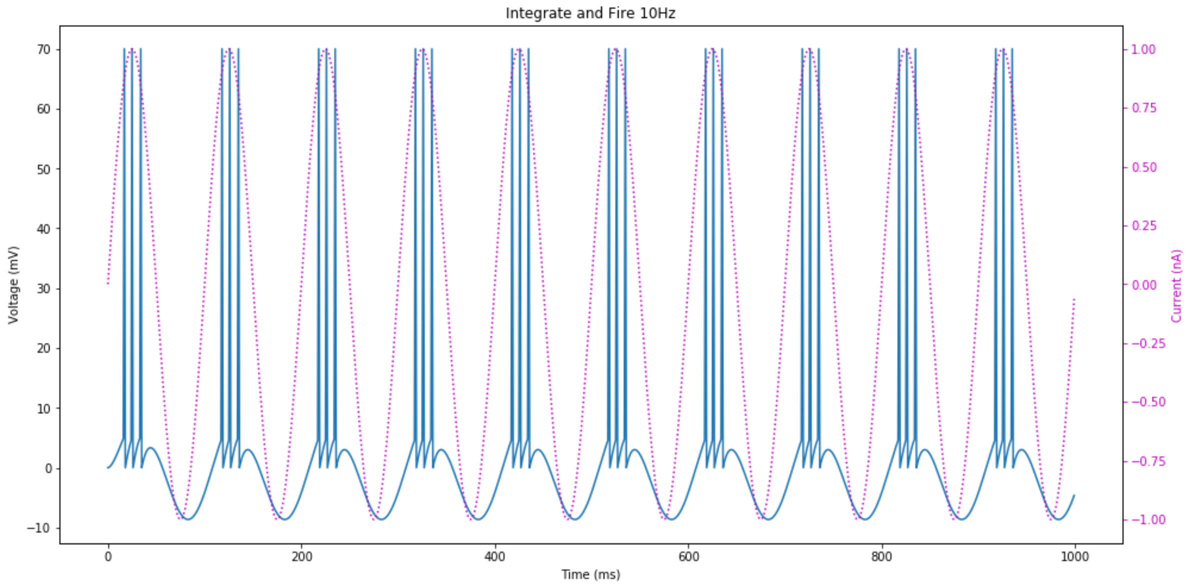


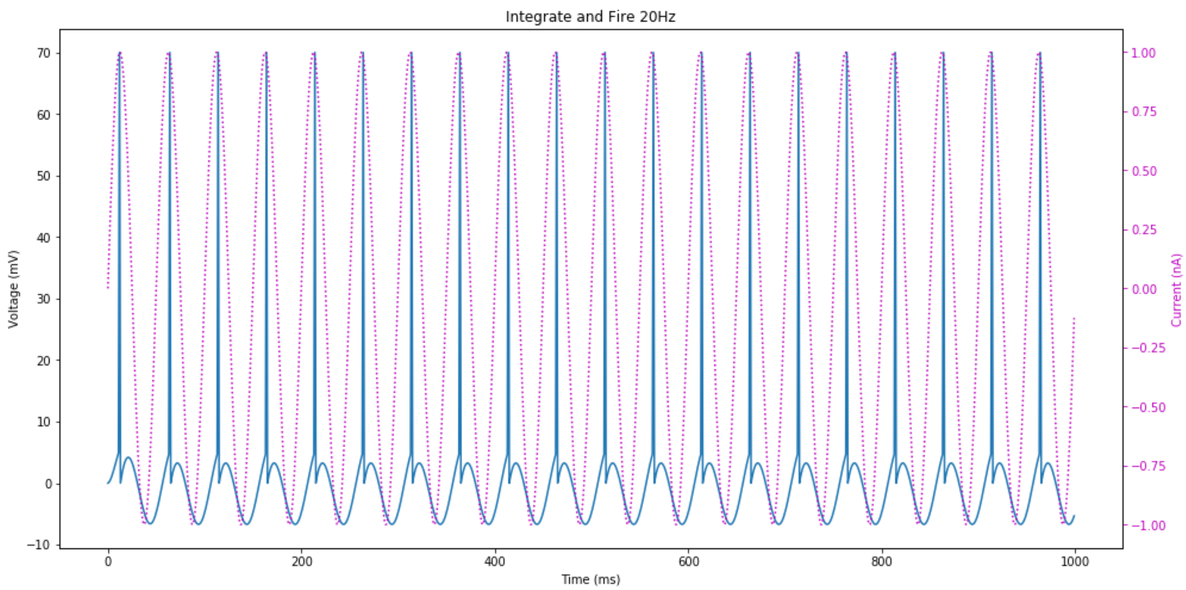
(ii) Integrate and Fire at Various Sinusoidal Frequencies

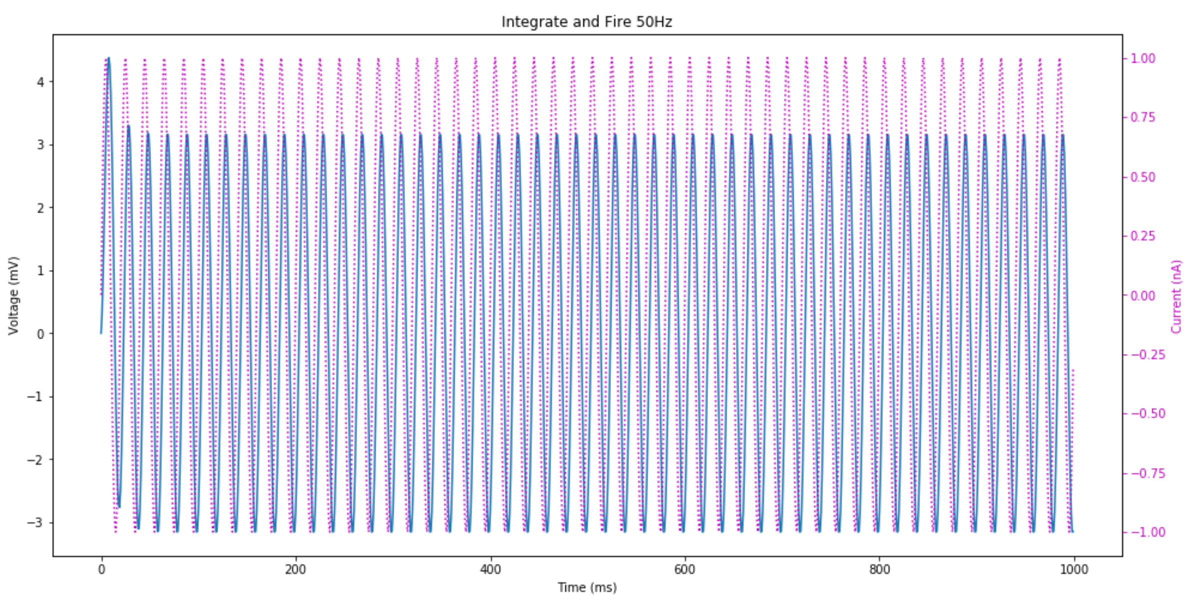

Integrate and Fire 1Hz
Voltage (mV)
Current (nA)
Time (ms)

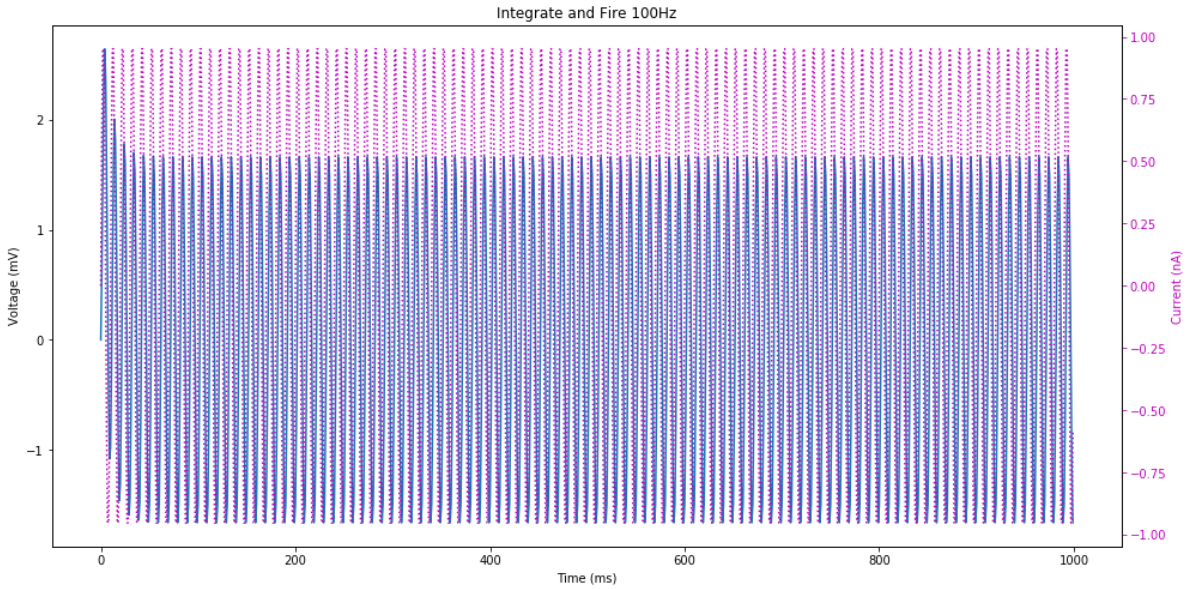

Integrate and Fire 2Hz
Voltage (mV)
Current (nA)
Time (ms)

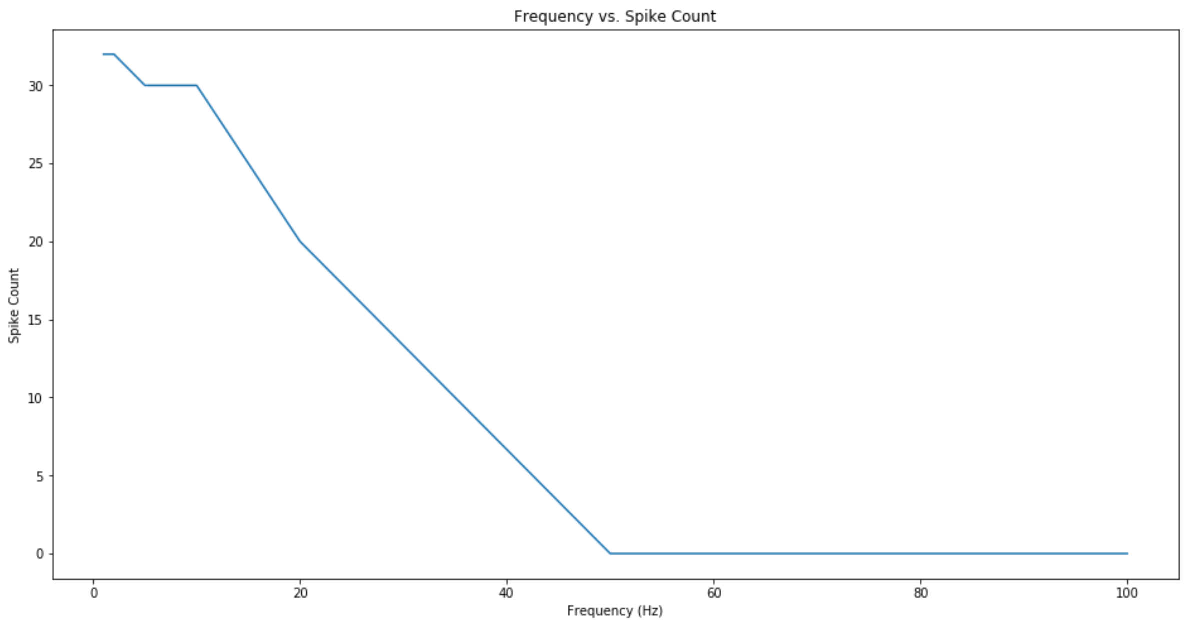

Integrate and Fire 5Hz
Voltage (mV)
Current (nA)
Time (ms)


Integrate and Fire 10Hz
Voltage (mV)
Current (nA)
Time (ms)

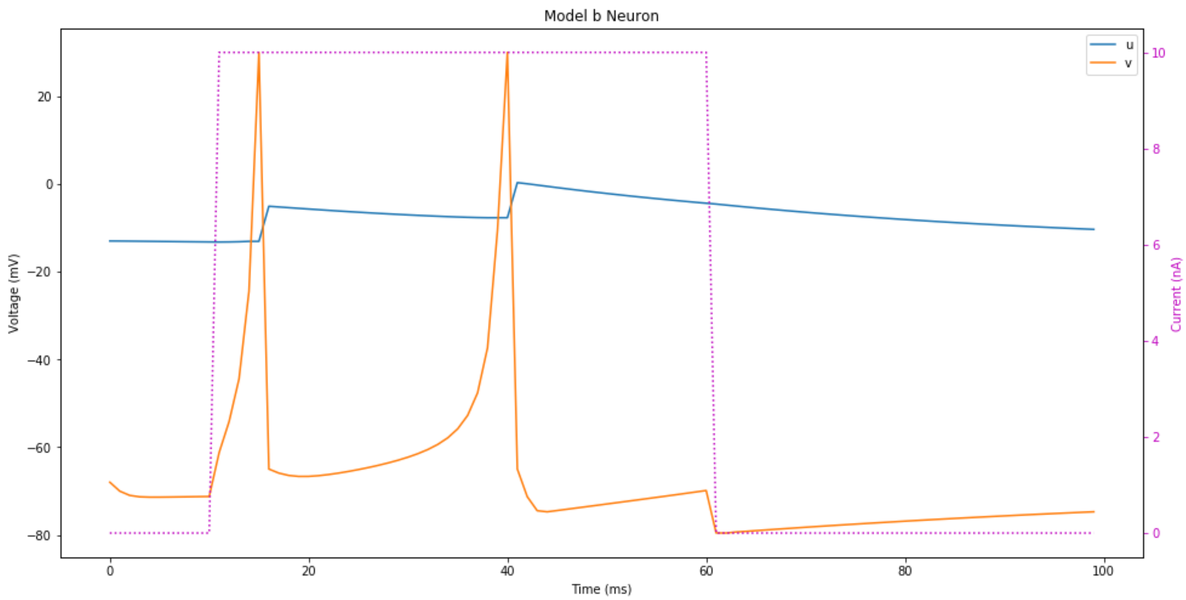

Integrate and Fire 20Hz
Voltage (mV)
Current (nA)
Time (ms)


Integrate and Fire 50Hz
Voltage (mV)
Current (nA)
Time (ms)

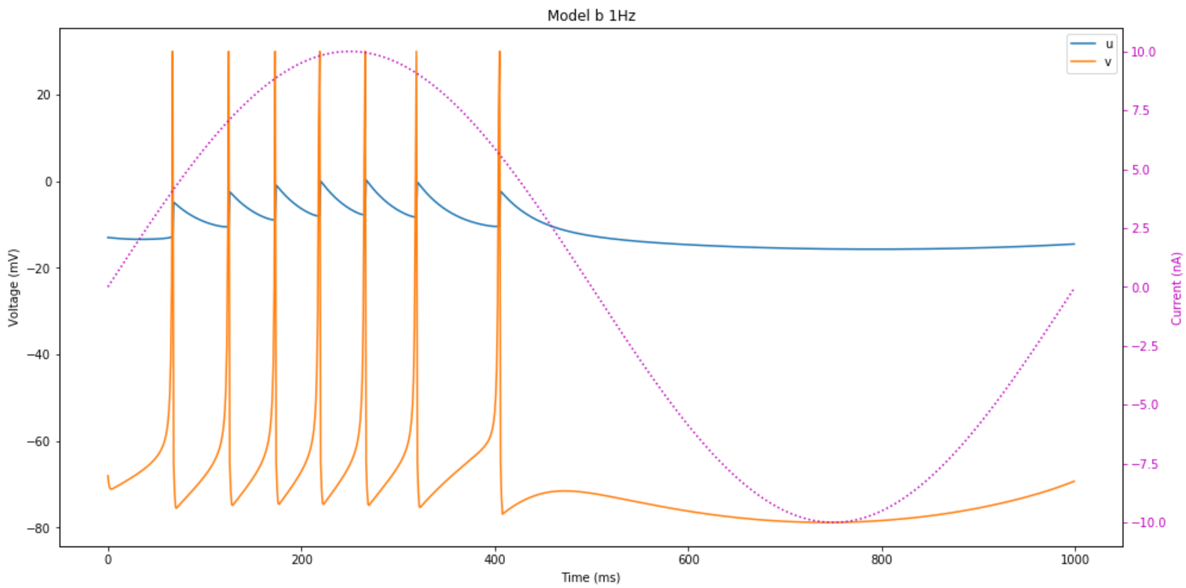


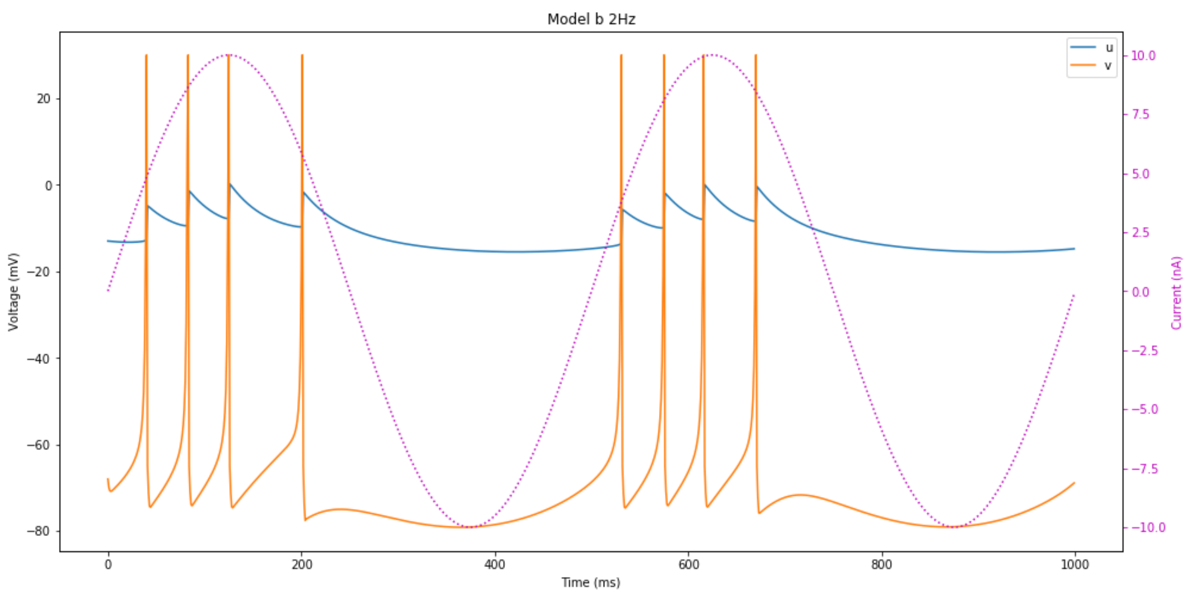


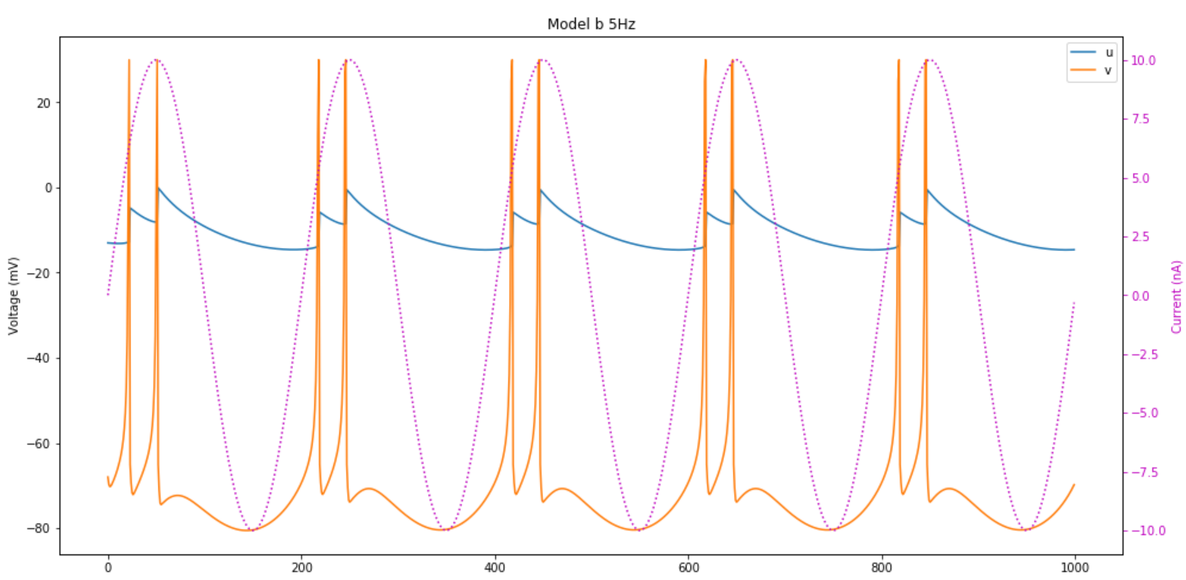
(iii) Part b Neuron

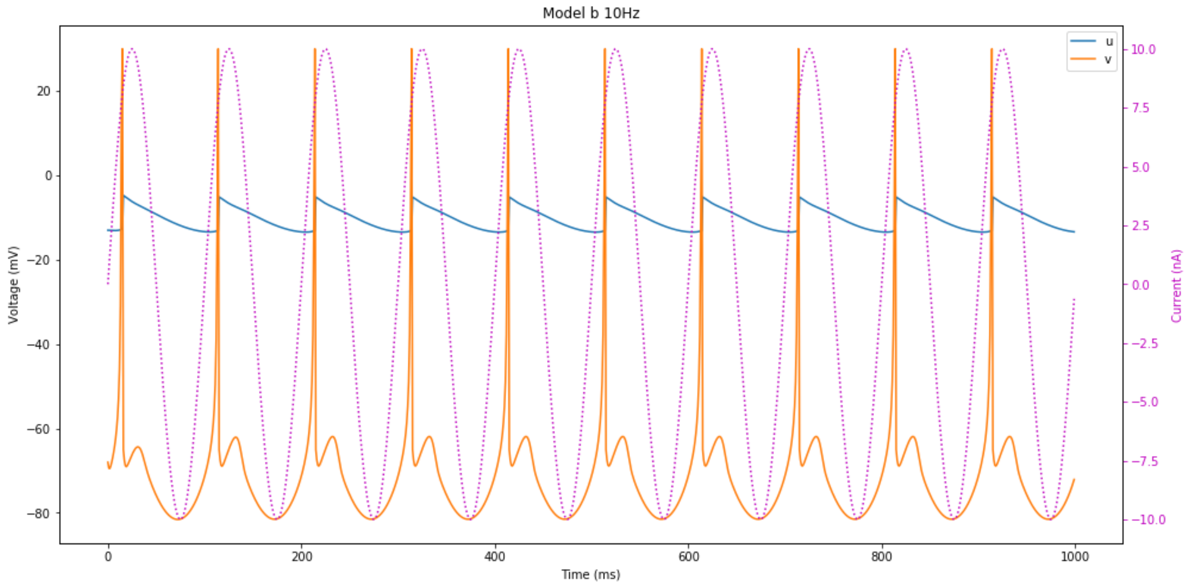


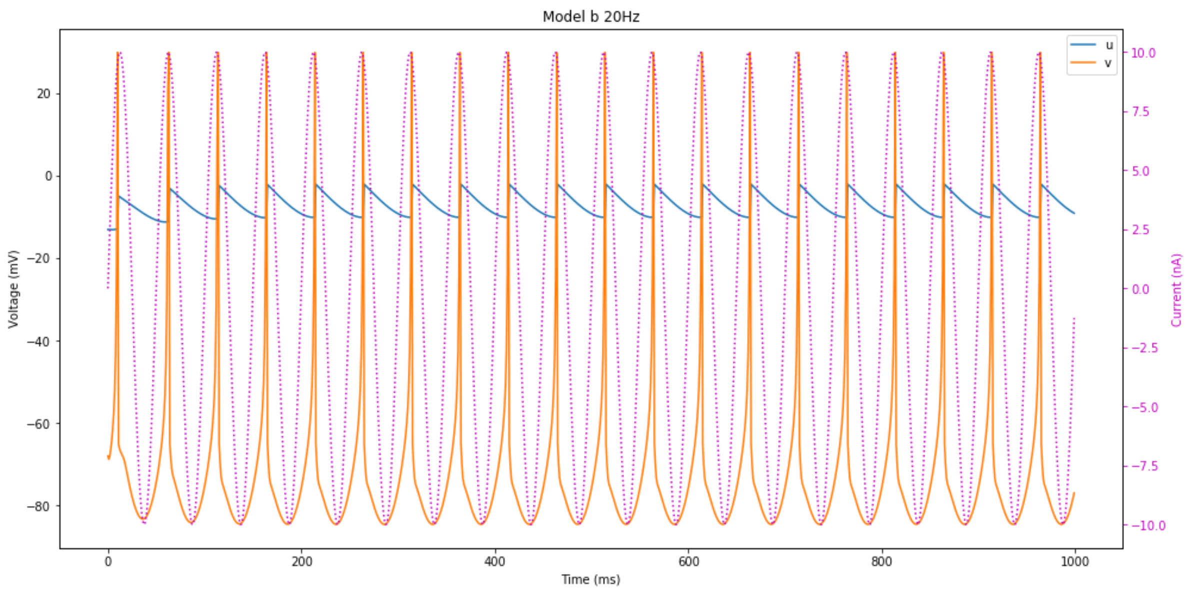
(iv) Part b Neuron at Various Sinusoidal Frequencies

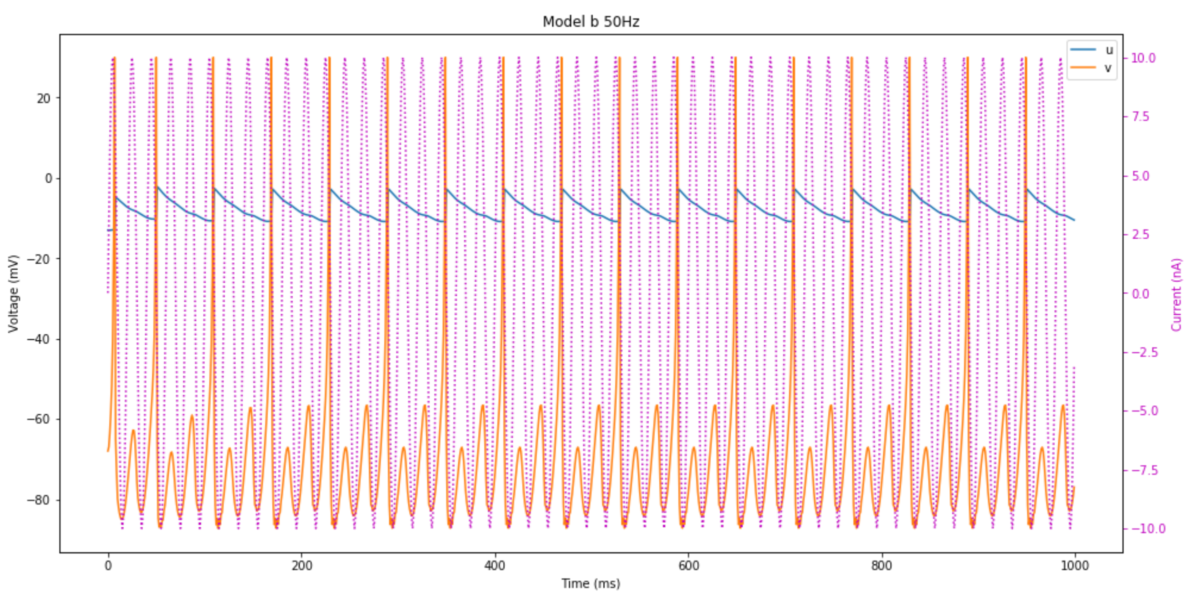

Model b 1Hz
u
v
Voltage (mV)
Current (nA)
Time (ms)

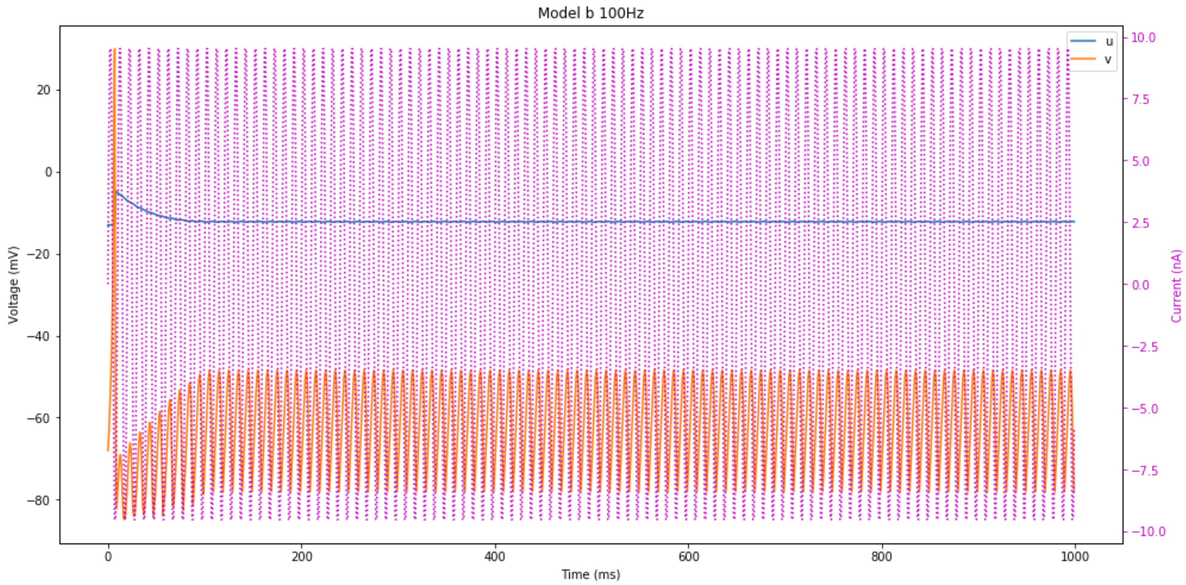

Model b 2Hz
u
v
Voltage (mV)
Current (nA)
Time (ms)

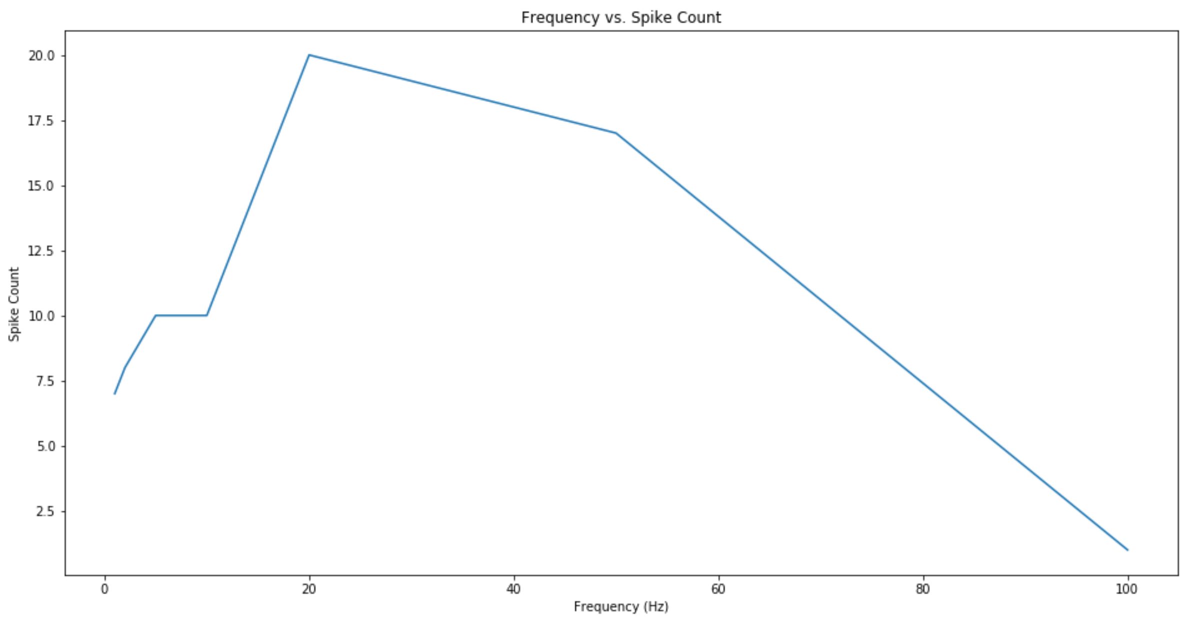

Model b 5Hz
u
v
Voltage (mV)
Current (nA)
Time (ms)


Model b 10Hz
Voltage (mV)
Current (nA)
Time (ms)
u
v

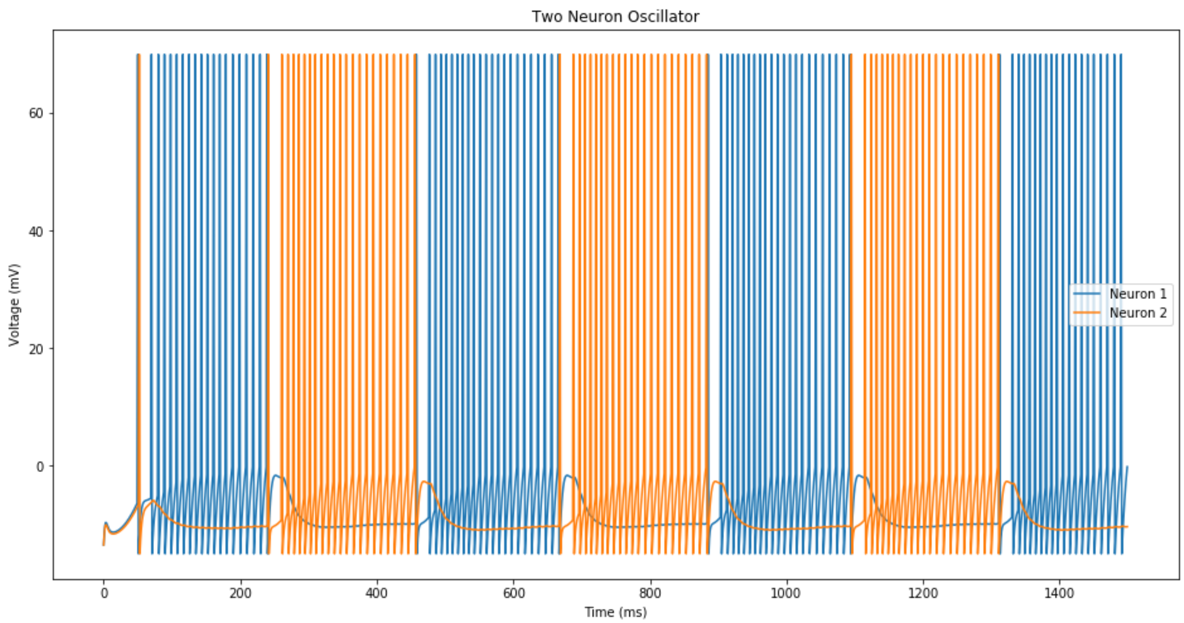

Model b 20Hz
Voltage (mV)
Current (nA)
Time (ms)
u
v


Model b 50Hz
Voltage (mV)
Current (nA)
Time (ms)
u
v





(v) Two Neuron Oscillator



Discussion

a.) The Integrate and Fire neuron is a simpler model compared to the Hodgkin-Huxley model. It provides an approximate model of the spiking behavior of neurons, and can be useful when one wants to model the number of spikes a neuron responds to given a current injection input. As can be seen by the various sinusoidal current inputs. The neuron model only fires when both current intensity and it's duration are sufficient. This can easily be seen at the higher frequecy current inputs, where the current amplitude is kept the same, but the neuron still does not fire since the duration of the stimulus current is so short. Modeling spike count vs. current input, we easily see that the Integrate and Fire neuron is a low-pass filter.

b.) The part b neuron has similar behavior to the Integrate and Fire neuron. However, the introduction of the threshold function, $U(t)$, seems to slow the firing rate of the neuron, as it requires time for the threshold function to decrease before firing again. This attempts to mimic the repolarization phase of the neuron. The spike count vs. current input plot shows that this neuron model seems to be similar to a band-pass filter.

c.) The Two-neuron oscillator model shows two neurons connected in mutual inhibitory relationship. This means that the firing of one neuron inhibits the firing of the other neuron and vice-versa. This inhibitory relationship is counteracted by the threshold function, $\theta(t)$, which causes an inhibitory effect on the firing of the neuron the more frequently it fires. Thus, the oscillatory behavior of the two-neuron model can be seen as a balancing of these two forces. Since, neuron 1 is stimulated with a higher initial current, it takes the opportunity to fire first, inhibiting neuron 2. This firing ceases after approximately 200 ms, at which it's threshold function prevents it from firing any further. This decreases the inhibitory effect on neuron 2 and allows it to fire which inhibits neuron 1. Neuron 2 continues to fire until it's threshold function prevents it from firing any further, and the cycle from neuron 1 repeats yet again.