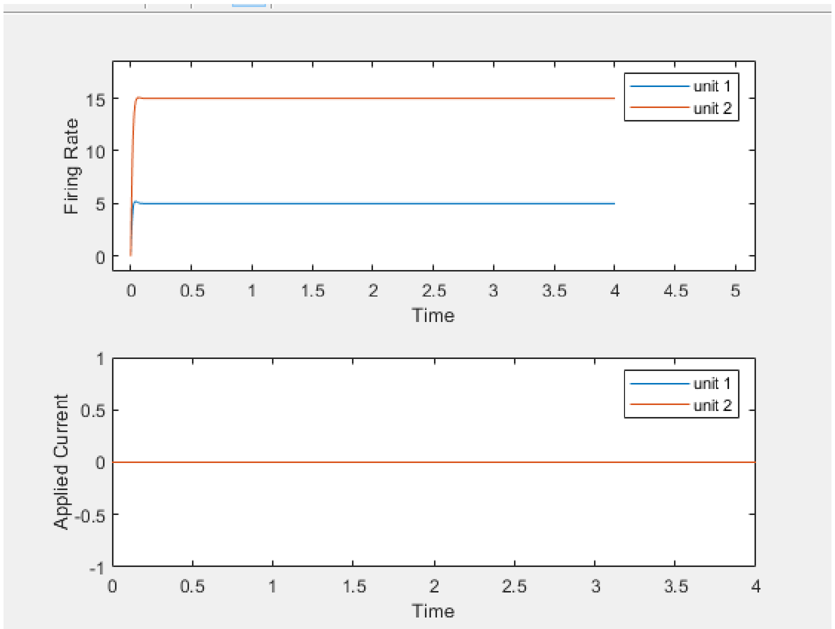
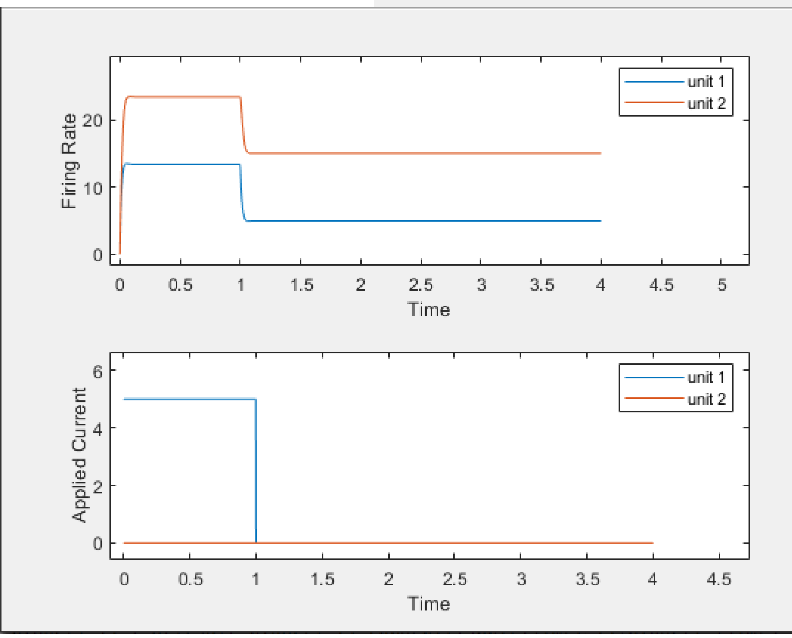
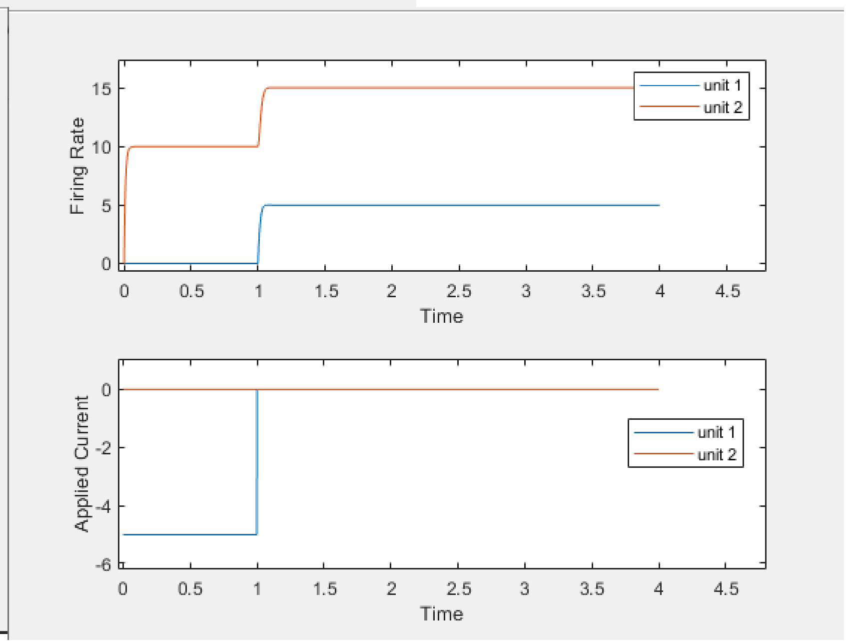
Connor Zawacki

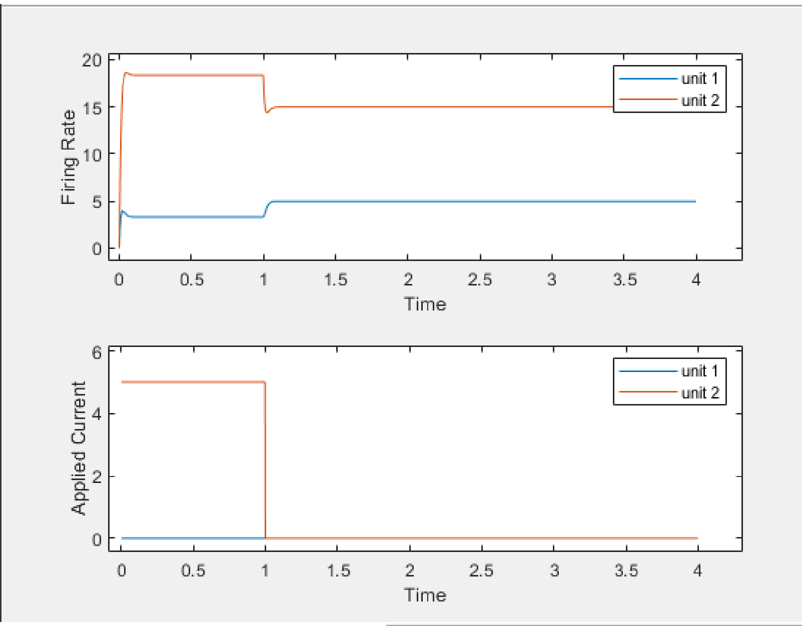
Tutorial 7.2

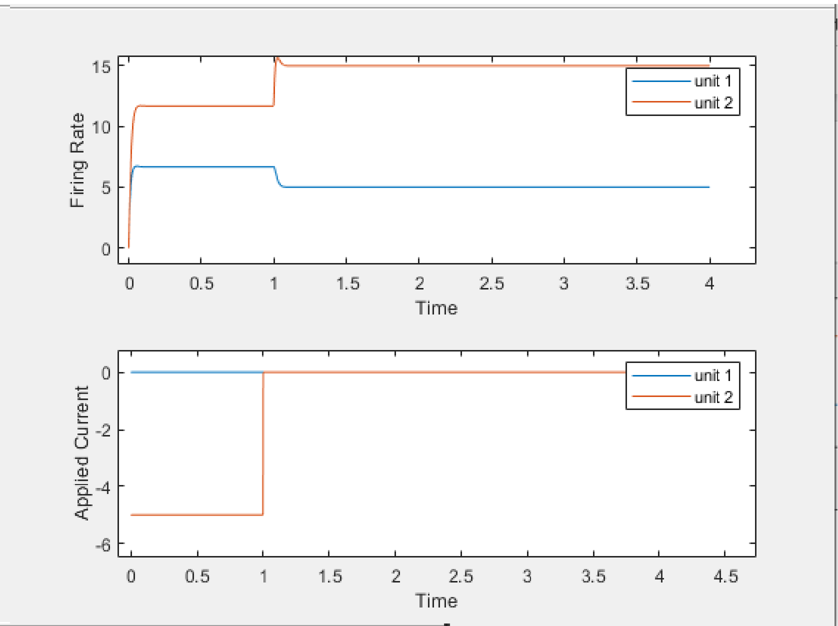
1.)

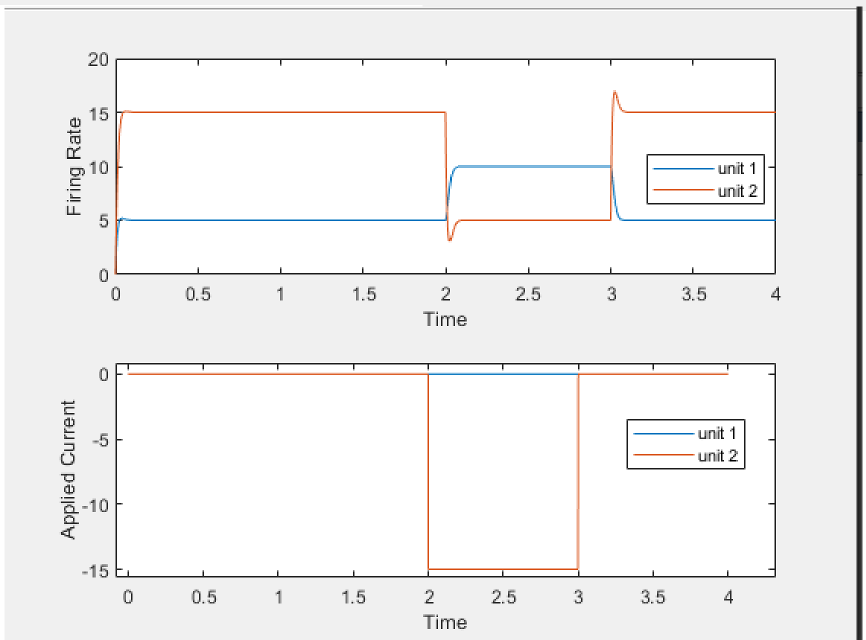







Firing Rate
Time
Applied Current
Time
unit 1
unit 2


Firing Rate
Time
Applied Current
Time
unit 1
unit 2


Firing Rate
Time
Applied Current
Time
unit 1
unit 2

Unit 1: Self excites (0.6), excites unit 2 (1), spontaneously active

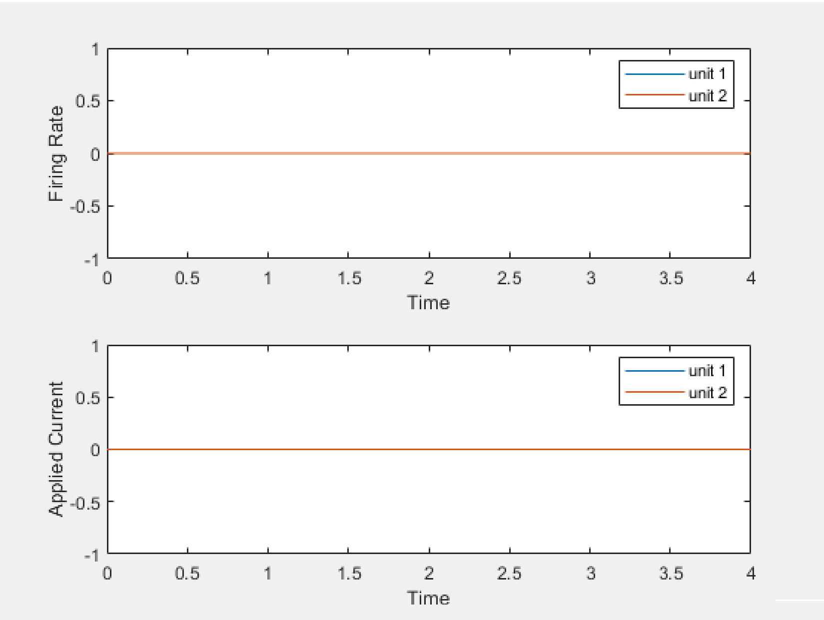
Unit 2: Inhibits unit 1, no self connection, twice as active as unit 1 spontaneously

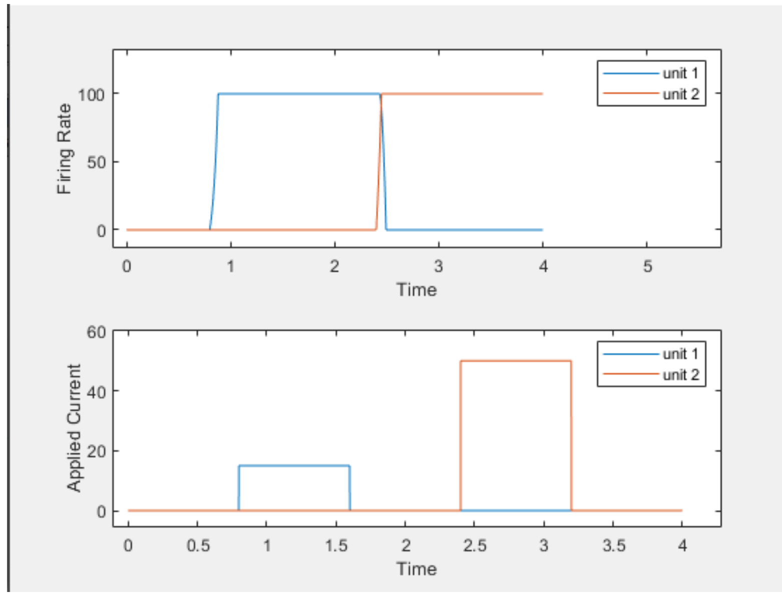
Unit 3: N/A

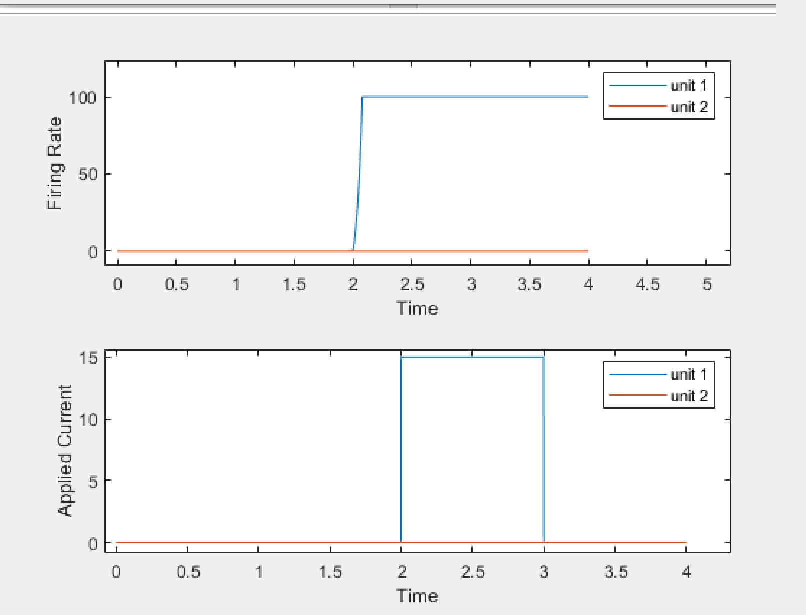
Steady States: Unit 1 firing at 5 hz, unit 2 firing at 15 hz. System will always return to this state in the absence of input.

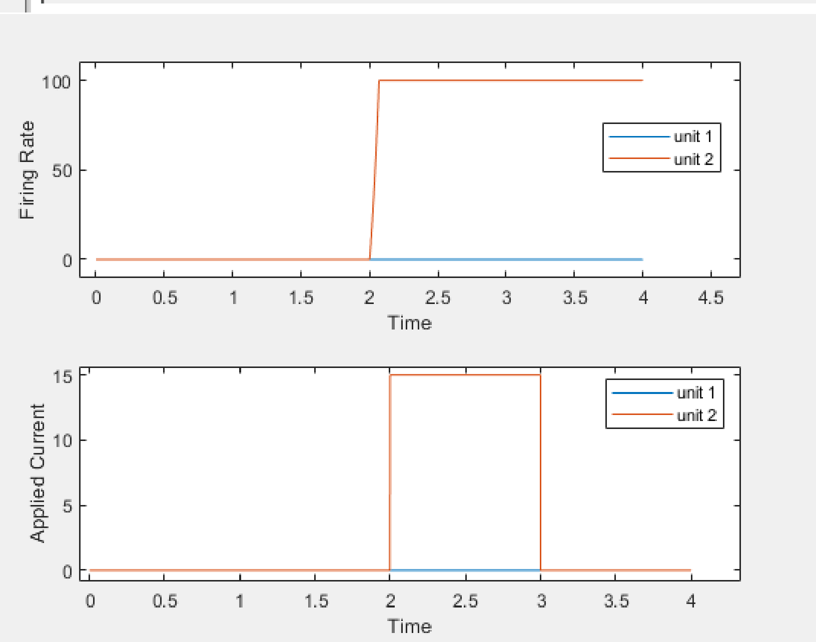
System: Deterministic

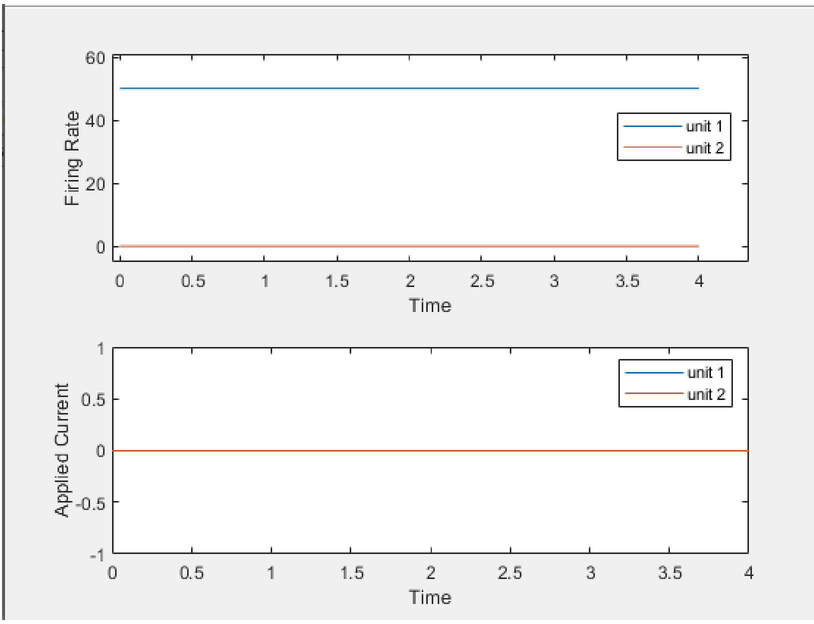
2.)


Firing Rate
Time
unit 1
unit 2
Applied Current
Time
unit 1
unit 2

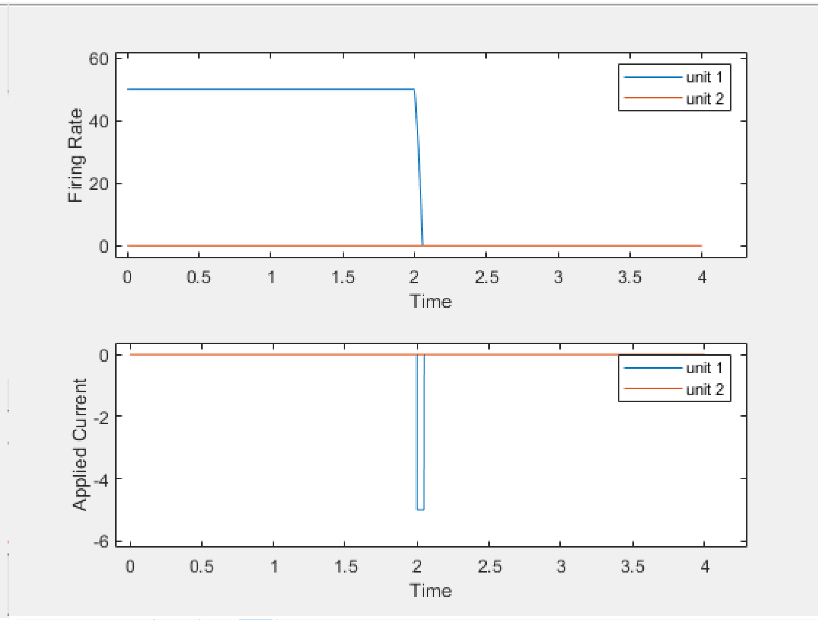

Firing Rate
Time
unit 1
unit 2
Applied Current
Time
unit 1
unit 2


Firing Rate
Time
unit 1
unit 2
Applied Current
Time
unit 1
unit 2

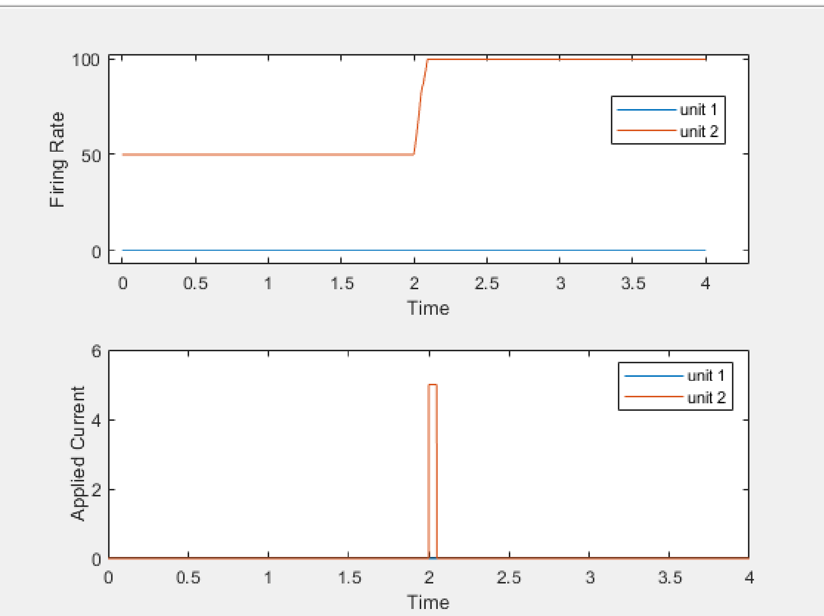

Firing Rate
Time
unit 1
unit 2
Applied Current
Time
unit 1
unit 2



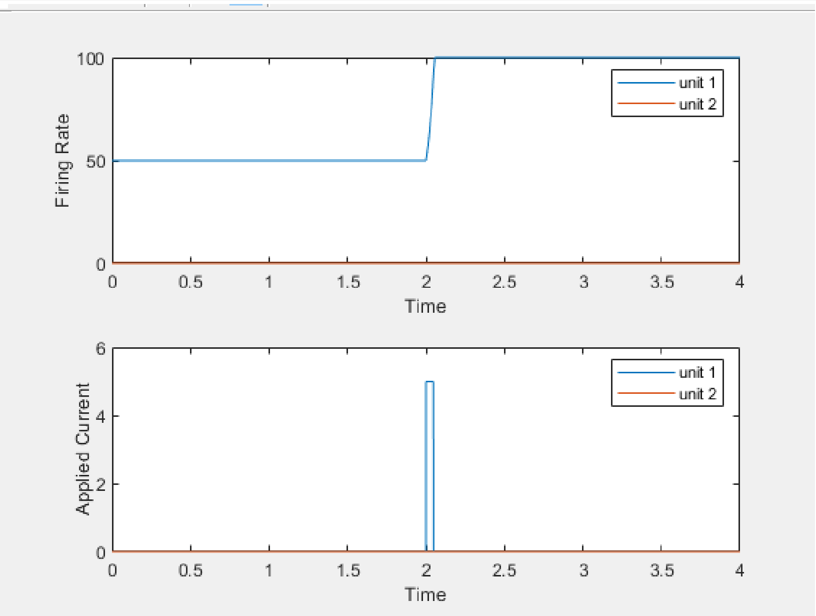
Firing Rate
Time
unit 1
unit 2
Applied Current
Time
unit 1
unit 2



Firing Rate
Time
unit 1
unit 2
Applied Current
Time
unit 1
unit 2



Firing Rate
Time
unit 1
unit 2
Applied Current
Time
unit 1
unit 2



Firing Rate
Time
unit 1
unit 2
Applied Current
Time
unit 1
unit 2

Unit 1: Self excites (1.2), inhibits unit 2 (-0.3). Threshold for activity = 10

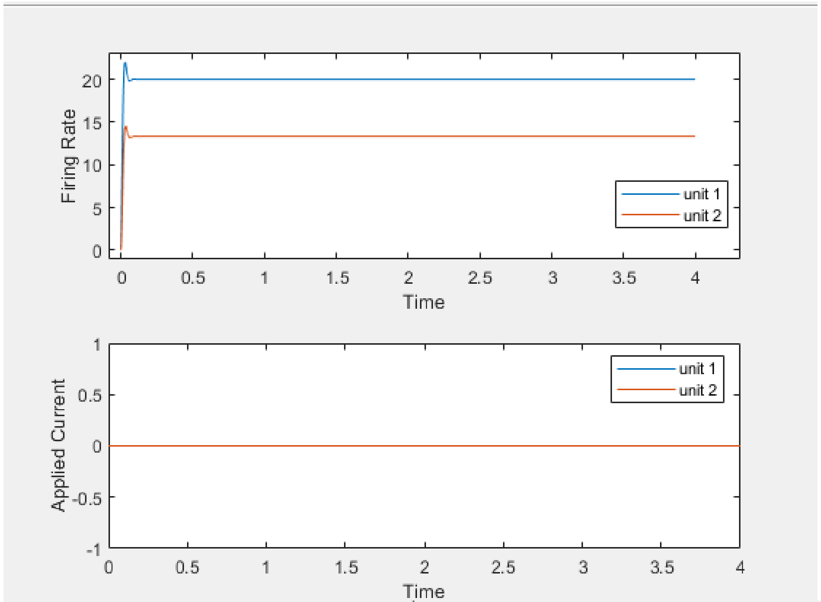
Unit 2: lower inhibition to unit 1 (-0.2), smaller self excitation (1.1). Smaller threshold for activity (=5)

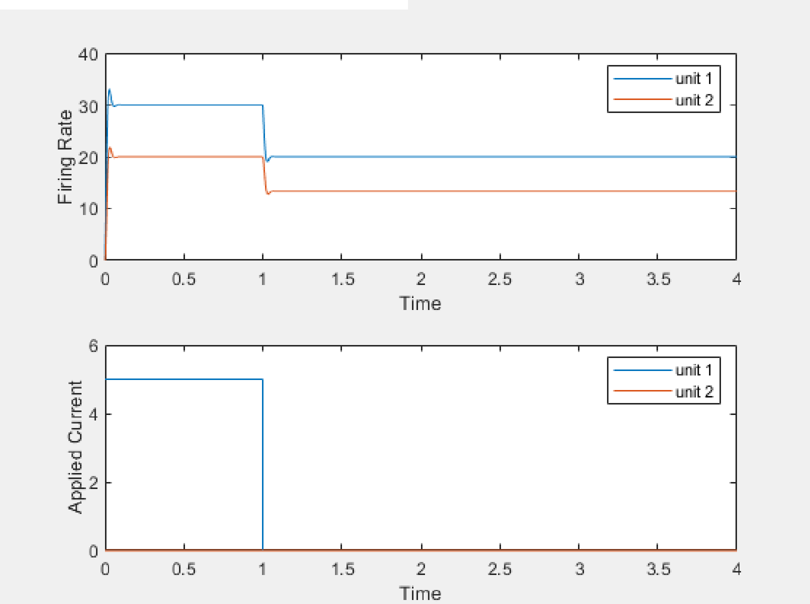
Unit 3:N/A

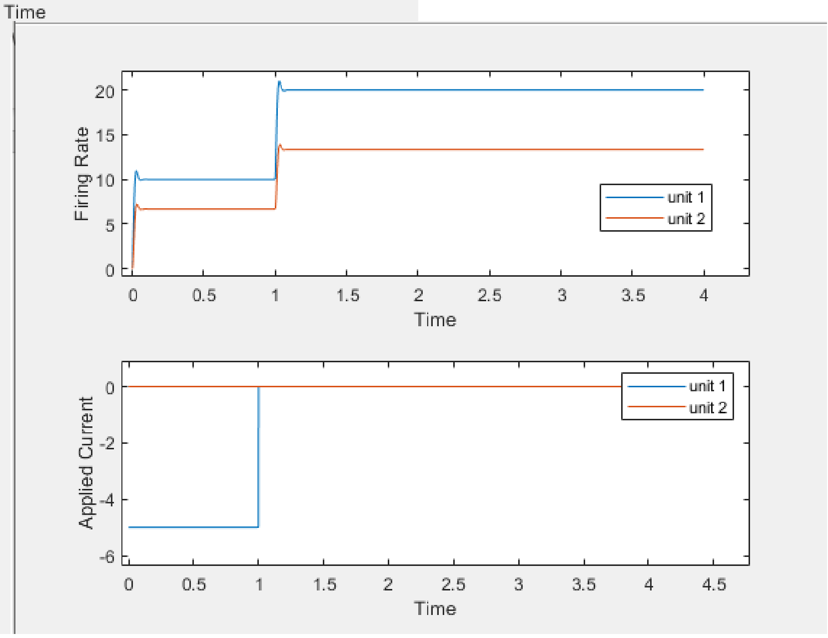
Steady States: Zero activity is stable because neither unit is spontaneously active. There is a stable steady state at unit 1 firing at rmax and unit 2 not firing, and another one vice versa. There are unstable steady states where unit 1 is firing at 50hz and unit 2 being inactive, and vice versa.

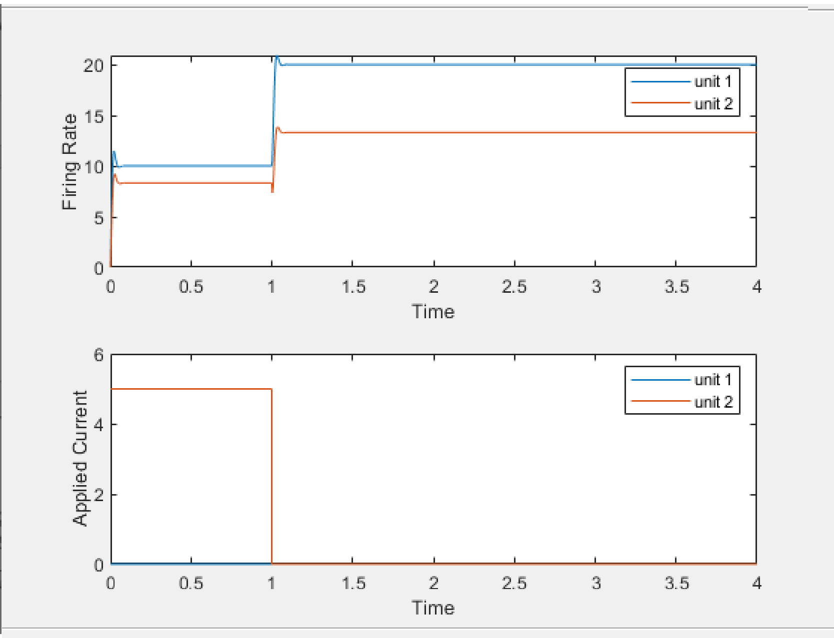
System: Bistable, (tristable if you consider absence of activity). Similar dynamics to a winner takes all decision making circuit in that high firing rate is only stable for one unit at a time, but not similar in that it is a poor integrator of evidence.

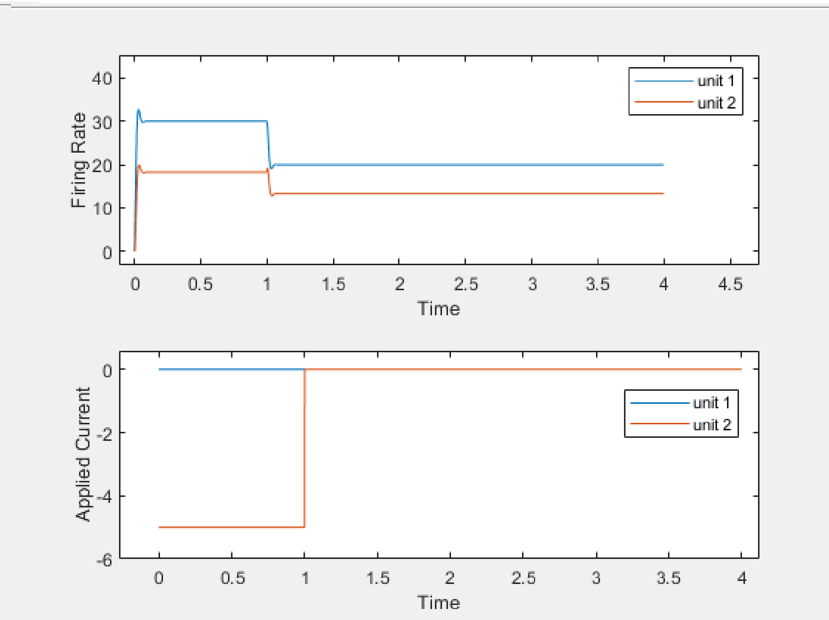
3.)

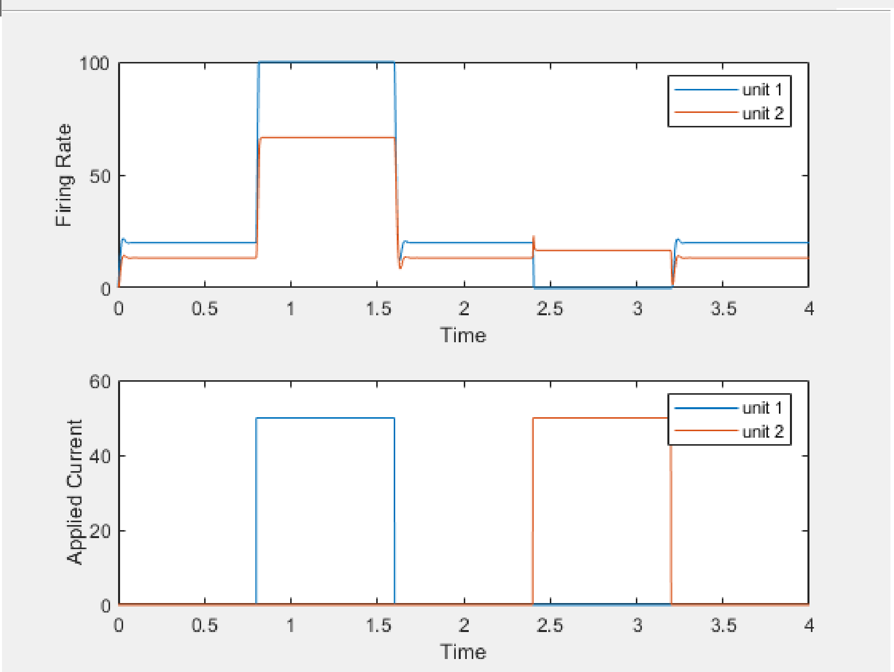

Firing Rate
Time
unit 1
unit 2
Applied Current
Time
unit 1
unit 2


Firing Rate
Time
unit 1
unit 2
Applied Current
Time
unit 1
unit 2


Firing Rate
Time
unit 1
unit 2
Applied Current
Time
unit 1
unit 2


Firing Rate
Time
unit 1
unit 2
Applied Current
Time
unit 1
unit 2


Firing Rate
Time
unit 1
unit 2
Applied Current
Time
unit 1
unit 2


Firing Rate
Time
unit 1
unit 2
Applied Current
Time
unit 1
unit 2

Unit 1: Spontaneously active, self-excitatory (2.5), excites unit 2 (2).

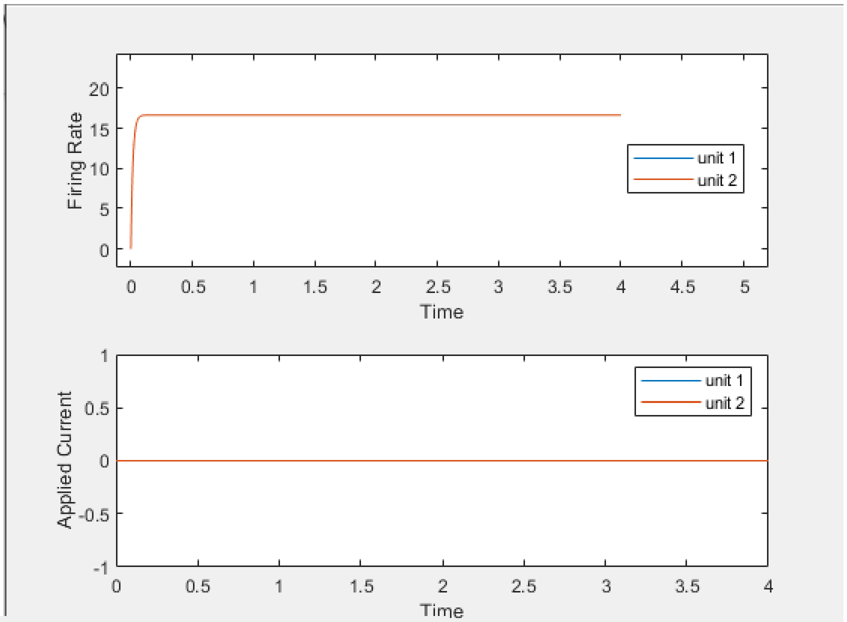
Unit 2: no threshold for activity. Inhibits unit 1 heavily (-3), self inhibits (-2).

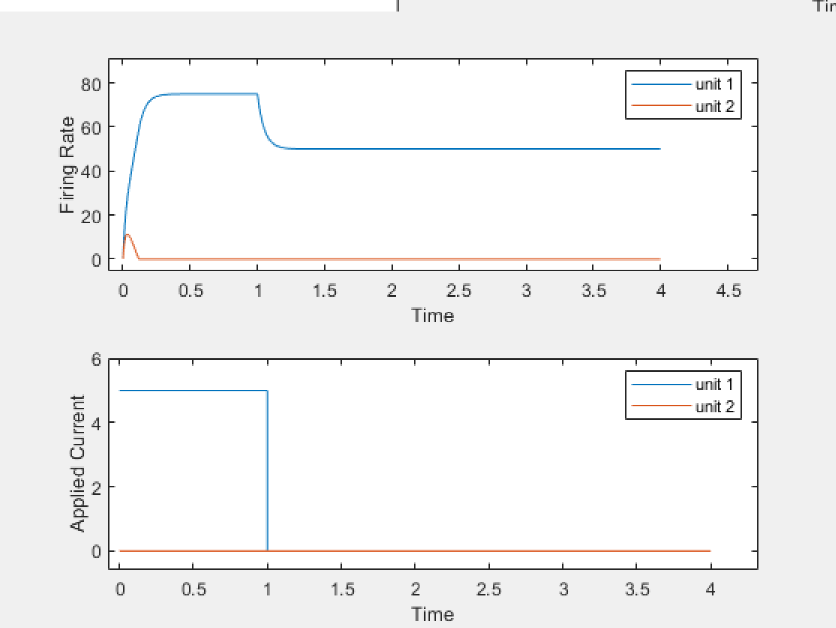
Unit 3: N/A

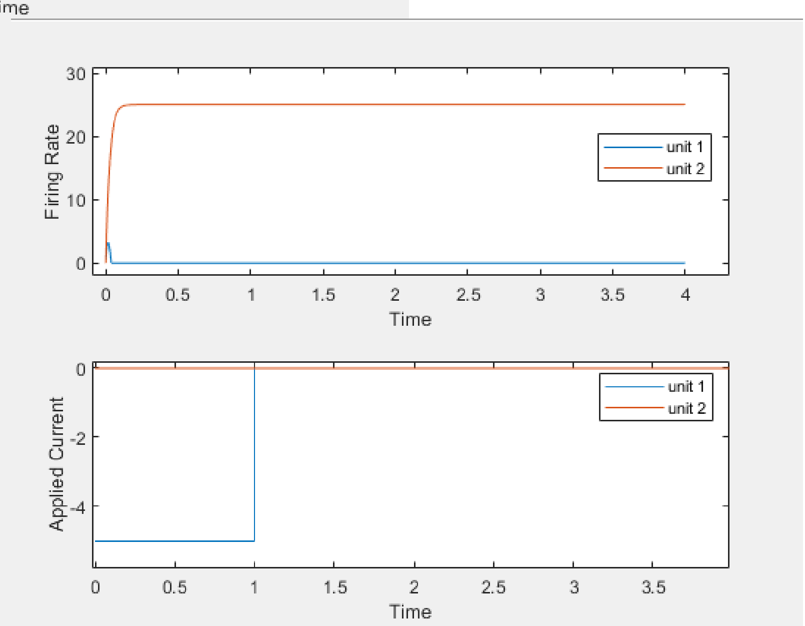
Steady States: stable steady state where unit 1 fires at 3/2 the rate of unit 2. In the absence of input this always returns to unit 1 firing at 20 hz and unit 2 firing at 13.33 hz.

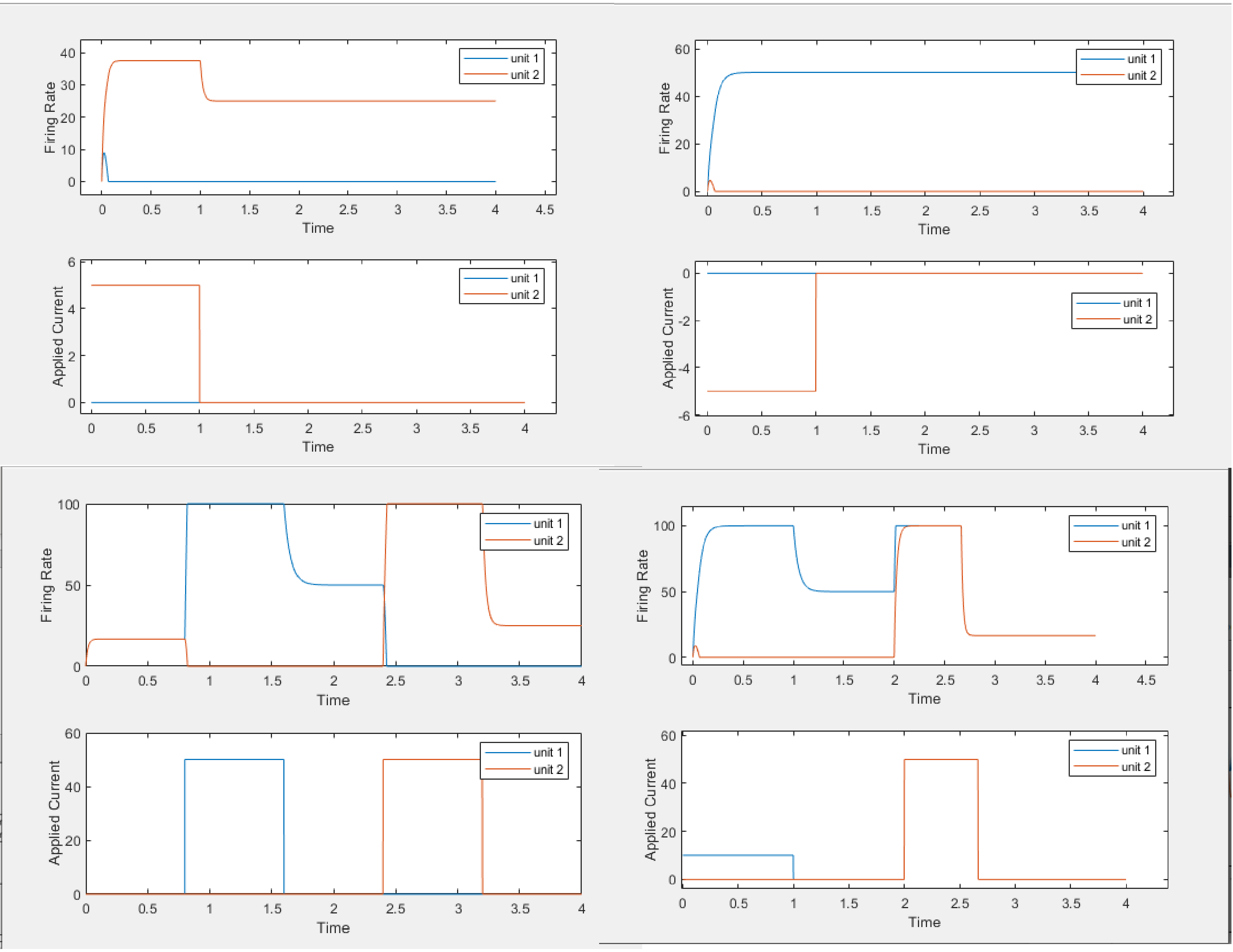
System: Deterministic. Unit 1 will always return to 20hz making unit 2 return to 13.33 hz. If provided constant input, unit 2’s new firing rate will be 2/3 of unit 1.

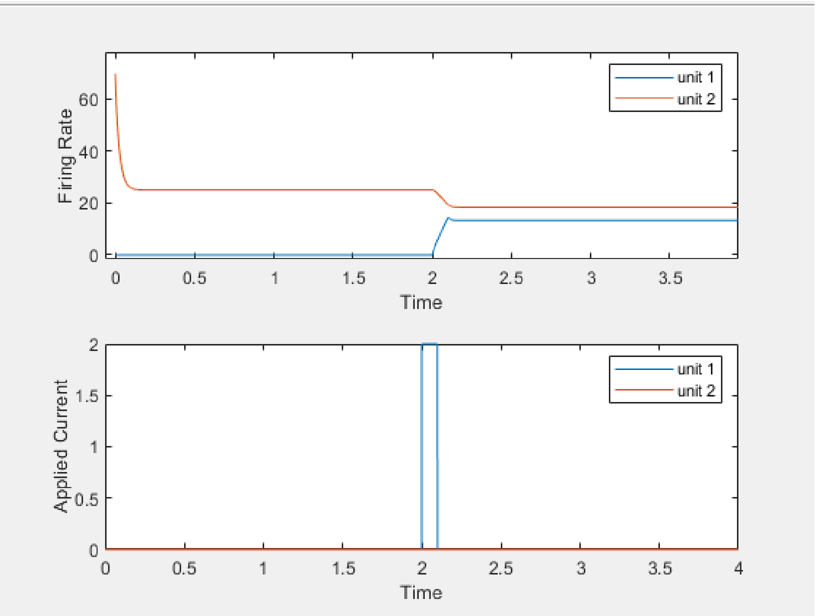
4.)

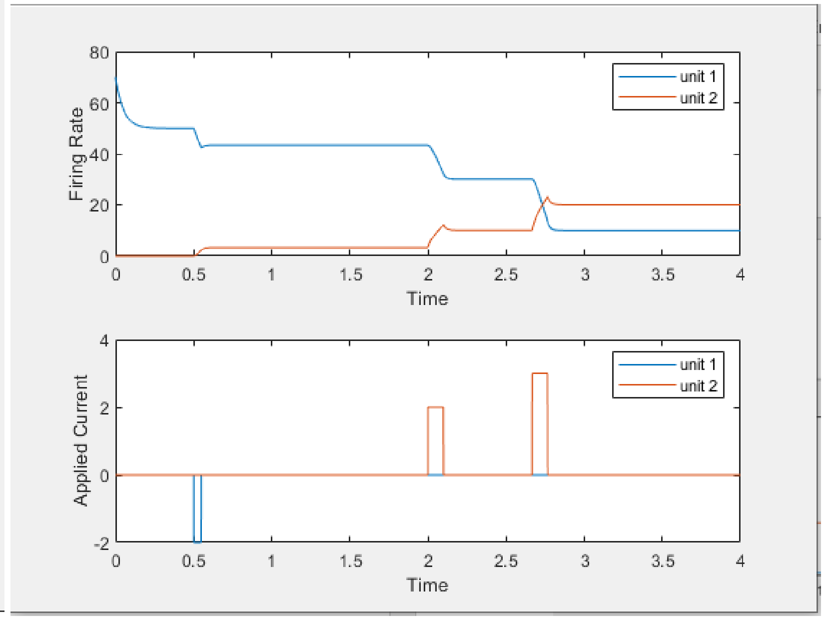

Firing Rate
Time
unit 1
unit 2
Applied Current
Time
unit 1
unit 2


Firing Rate
Time
unit 1
unit 2
Applied Current
Time
unit 1
unit 2


Firing Rate
Time
unit 1
unit 2
Applied Current
Time
unit 1
unit 2


Firing Rate
Time
Applied Current
unit 1
unit 2





Unit 1: self excites (0.8) and inhibits unit 2 (-0.2). Spontaneously active = -10

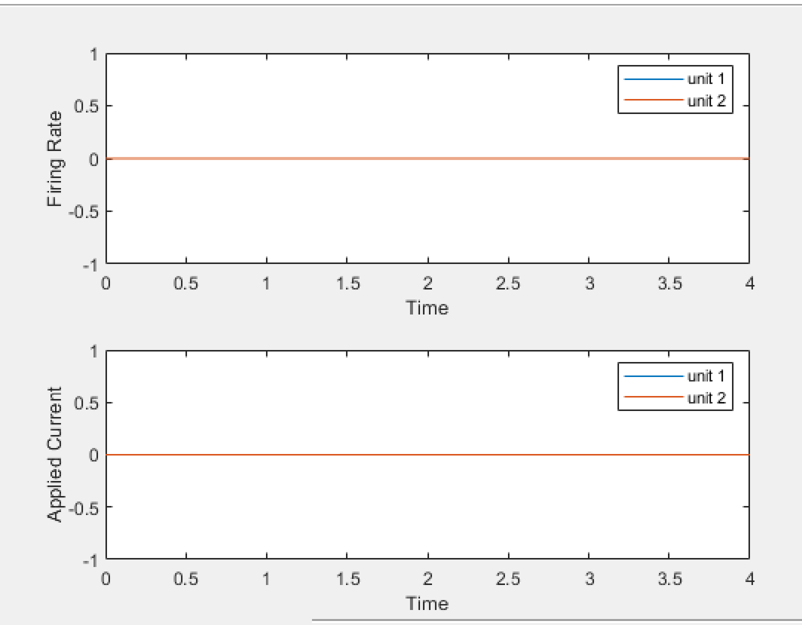
Unit 2: a sort of mirror of unit 1. Self excites a slightly less (0.6) and inhibits unit 1 slightly more (proportional to the difference in self excitation between the two units) (-0.4). Spontaneously active to the exact same degree (-10)

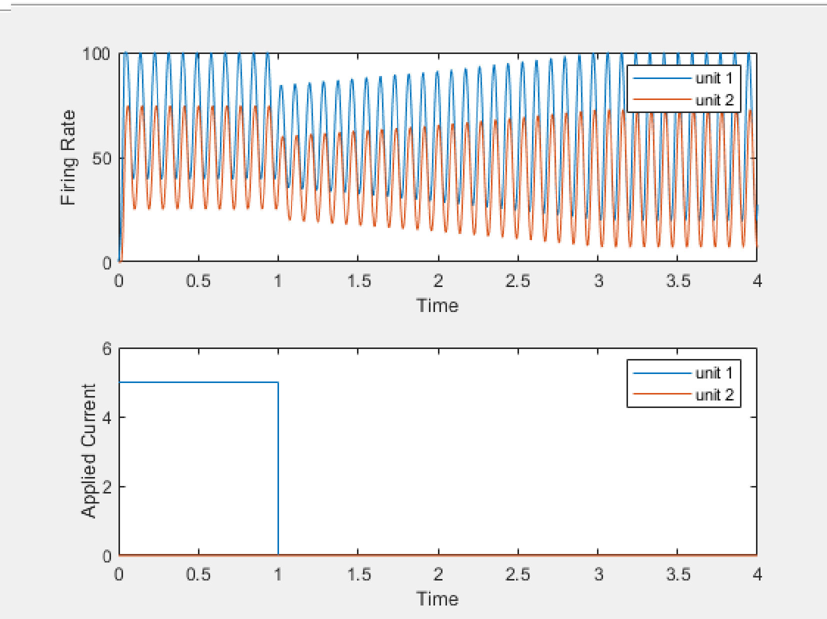
Unit 3:N/A

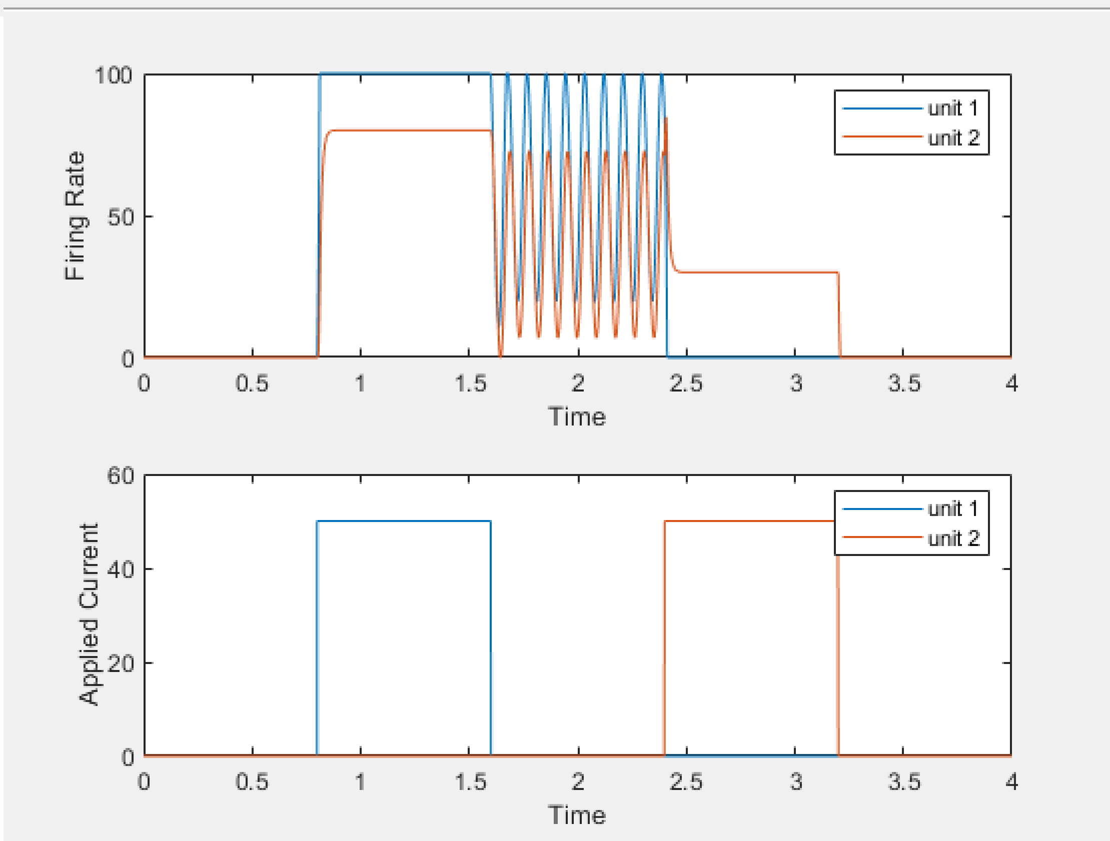
Steady States: Line attractor. Many states are stable in the above network, allowing it to act as an integrator. I didn't realize this until some of my later figures, as my earlier ones had step pulses too large or too long to allow the system to properly integrate them. After sufficient input is given to get one of the units to a point much higher than the other (so that the inhibition drives the less active unit to 0, there is a steady state for the system where the active unit fires an amount dependent on which unit is actually the active one (50hz for unit 1, 25 for unit 2). Any further input to try and crease the active unit will decay back to this steady state, but the line attractor is still present and any input away from this state can be recorded by the system. Also worth noting is that if sufficient excitatory or inhibitory input is equally given to both cells (such that they are both firing at 0 or rmax,) the state at which both units continue to fire at the exact same rates can be restored,

System: Integrator. Behavior is deterministic.

5.)


Firing Rate
Time
unit 1
unit 2
Applied Current
Time
unit 1
unit 2


Firing Rate
Time
unit 1
unit 2
Applied Current
Time
unit 1
unit 2


Firing Rate
Time
unit 1
unit 2
Applied Current
Time
unit 1
unit 2

Unit 1: no threshold for activity, self-excitatory (2), excites unit 2 (1).

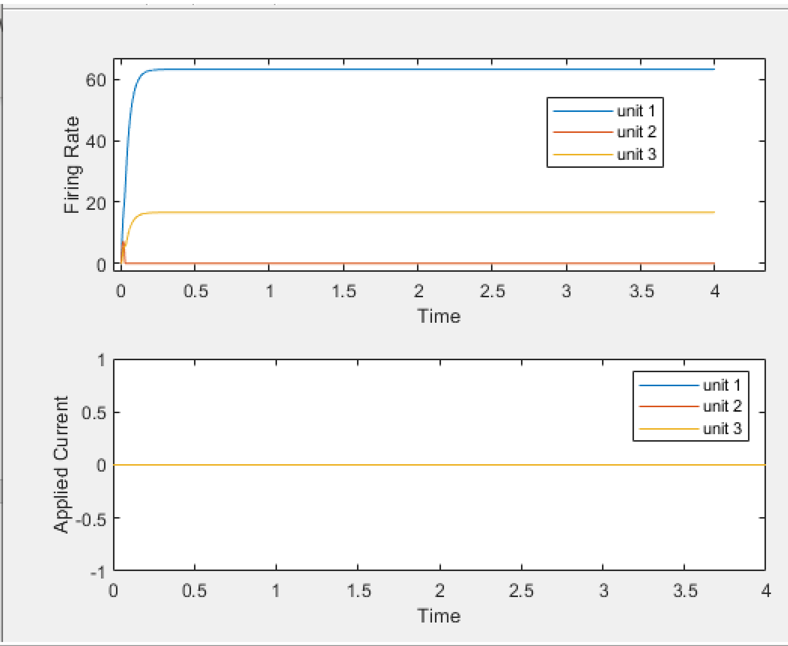
Unit 2: high threshold for activity. Inhibits unit 1 (-1.5), no self connection

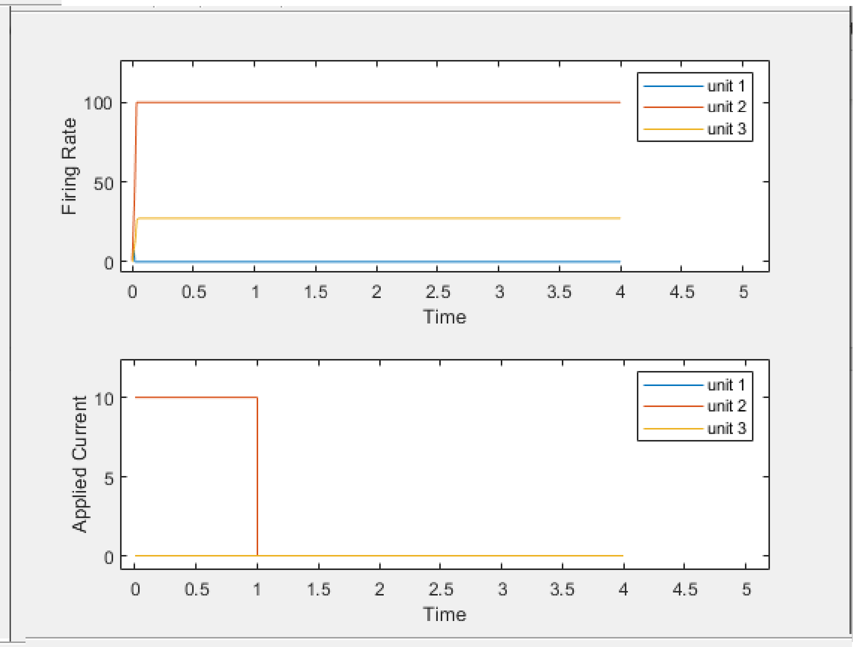
Unit 3: N/A

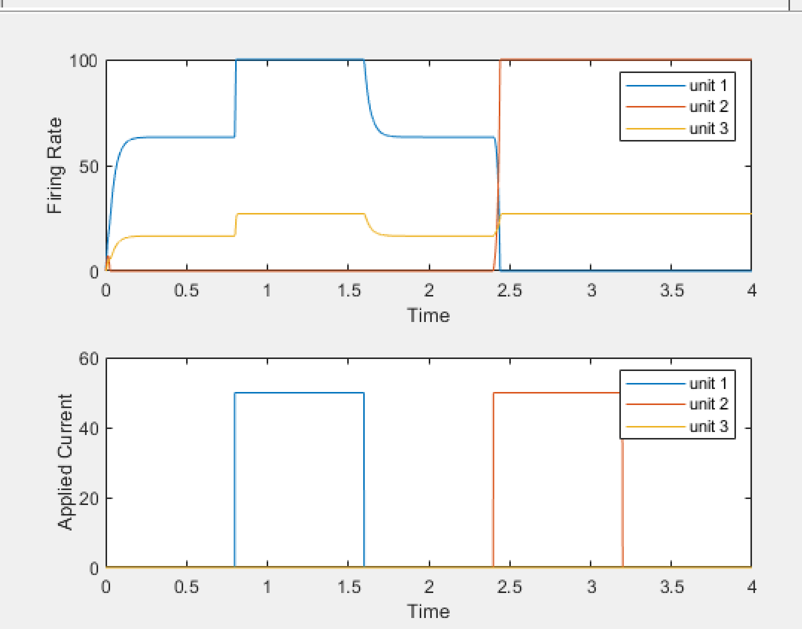
Steady States: unstable steady state at 0 firing rate, which the system can be forced back to provided sufficient applied excitation to unit 2 or inhibition to unit 1. Other than that, the system is an oscillator, whose amplitude approaches a value over different timescales depending on conditions that initiated the oscillations.

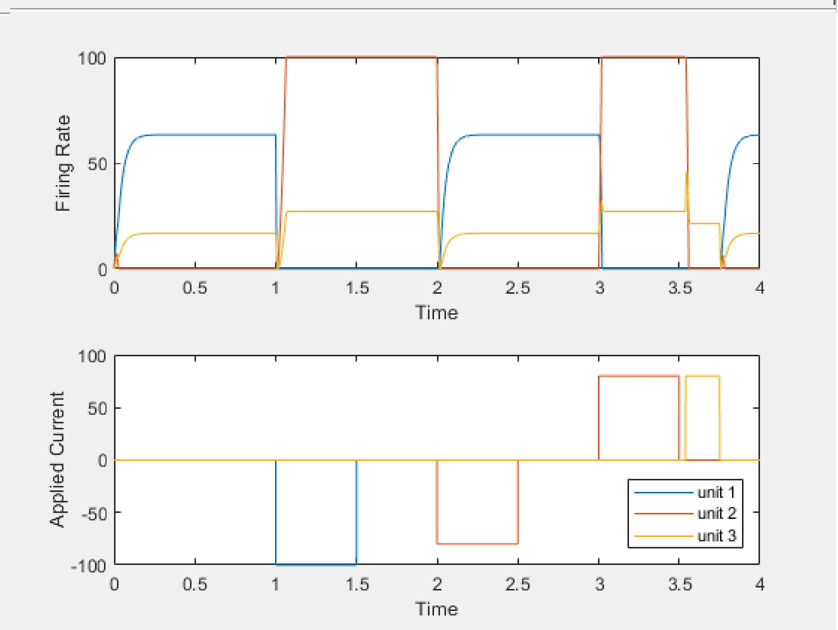
System: Chaotic. Activity of unit 1 and 2 at any given time point in the simulation varies on the order of the system depending on original parameters.

6.)


Firing Rate
Time
unit 1
unit 2
unit 3
Applied Current
Time
unit 1
unit 2
unit 3


Firing Rate
Time
unit 1
unit 2
unit 3
Applied Current
Time
unit 1
unit 2
unit 3


Firing Rate
Time
unit 1
unit 2
unit 3
Applied Current
Time
unit 1
unit 2
unit 3


Firing Rate
Time
Applied Current
Time
unit 1
unit 2
unit 3

Unit 1: spontaneously active, self-excitatory (1.5), excites unit 3 (1).

Unit 2: spontaneously active, self-excitatory (2), excites unit 3 (1).

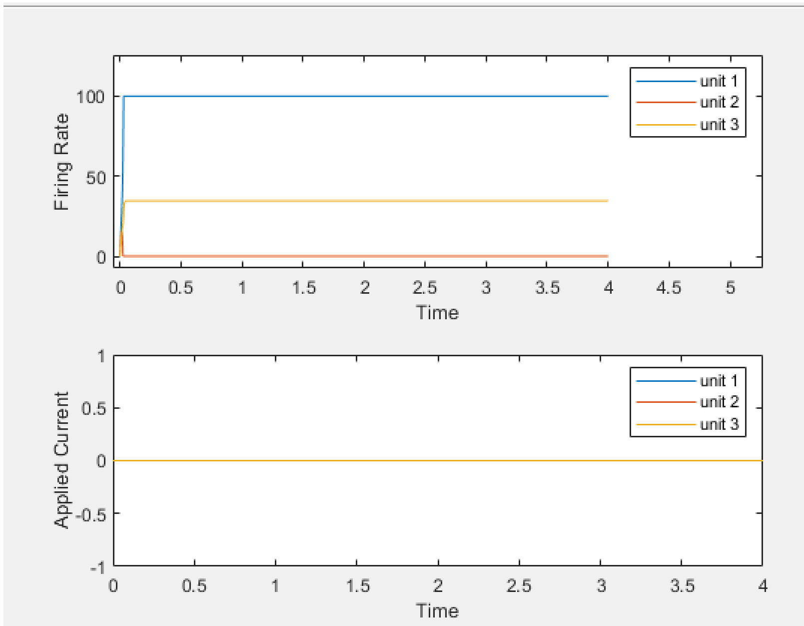
Unit 3: Strictly inhibitory low threshold for activity

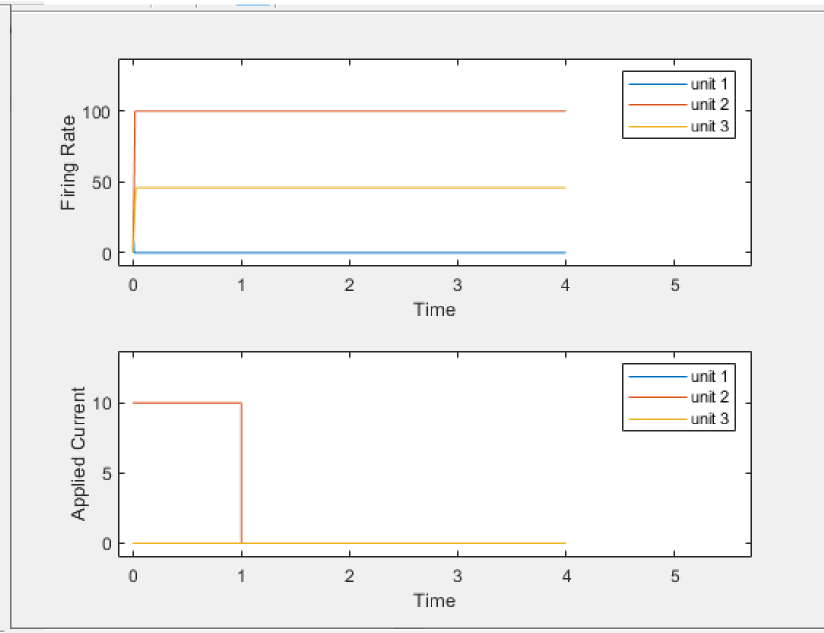
Steady States: stable steady state where unit 2 fires at rmax and unit 1 doesn't fire. Stable steady state where unit 1 fires at 60hz and unit 2 doesn't fire.

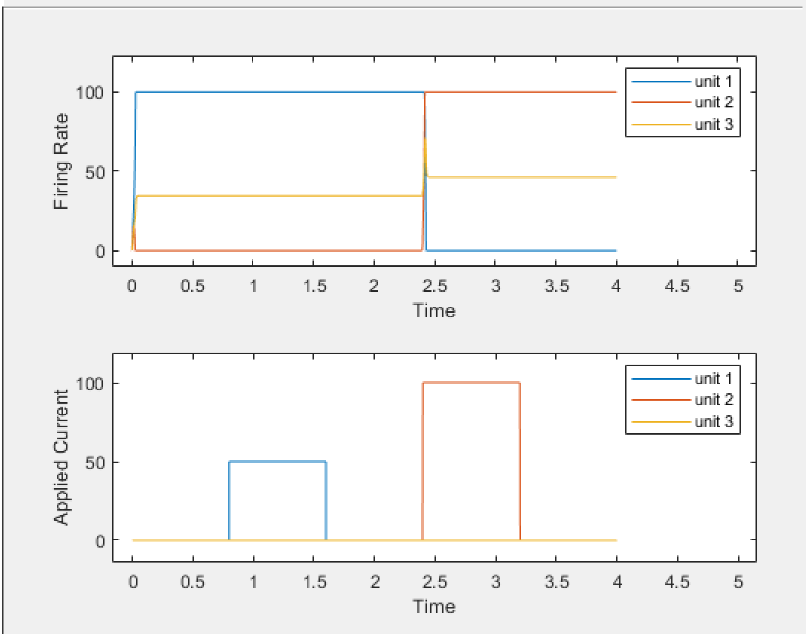
System: unit 1 and 2 are competitive because of the presence of unit 3. In fact, despite the fact that unit 1 self excites less than unit 2, it will still dominate first in the case where each unit starts at 0 firing rate. This is because unit 3's connections are actually most important when considering the end behavior, because as both unit 1 and 2 begin to grow, they both excite unit 3. Unit 3 inhibits unit 2 at a higher rate, favoring unit 1 when starting from a "neutral start". However, when unit 1 and 2 both start at rmax, unit 2 will dominate because at higher firing rates, the self excitation has a greater impact, making unit 1 begin to fall quicker, and once the process begins, unit 2 becomes more and more favored to stay at a high firing rate. Transition between the two states can be given through sufficient input to the inactive unit, or very high levels of inhibitory input to the active unit (sufficient enough to counteract its already very high self excitation.) "Turning off" unit 3 (forcing its firing rate to 0 or providing it absurdly high levels of inhibitory input) forces the system into a sort of "reset", as both other units saturate at rmax, and after unit 3 is released from its hold, unit 2 will dominate as described above.

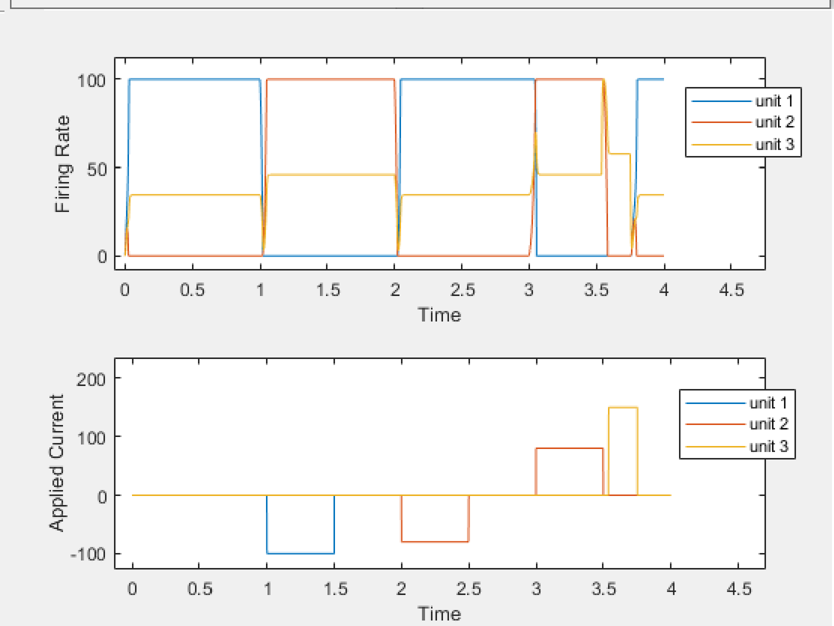
Transition between states can occur in a variety of ways (as pictured in the final figure), but only if input provided is significant (states are stable, and transition will not occur for small levels of input)

7.)


Firing Rate
Time
unit 1
unit 2
unit 3
Applied Current
Time
unit 1
unit 2
unit 3


Firing Rate
Time
unit 1
unit 2
unit 3
Applied Current
Time
unit 1
unit 2
unit 3


Firing Rate
Time
unit 1
unit 2
unit 3
Applied Current
Time
unit 1
unit 2
unit 3


Firing Rate
Time
unit 1
unit 2
unit 3
Applied Current
Time
unit 1
unit 2
unit 3

Unit 1: spontaneously active, self-excitatory (2.2), excites unit 3 (0.9), inhibits unit 2 (-0.5).

Unit 2: spontaneously active, self-excitatory (2), excites unit 3 (1.2) inhibits unit 1 (-0.7).

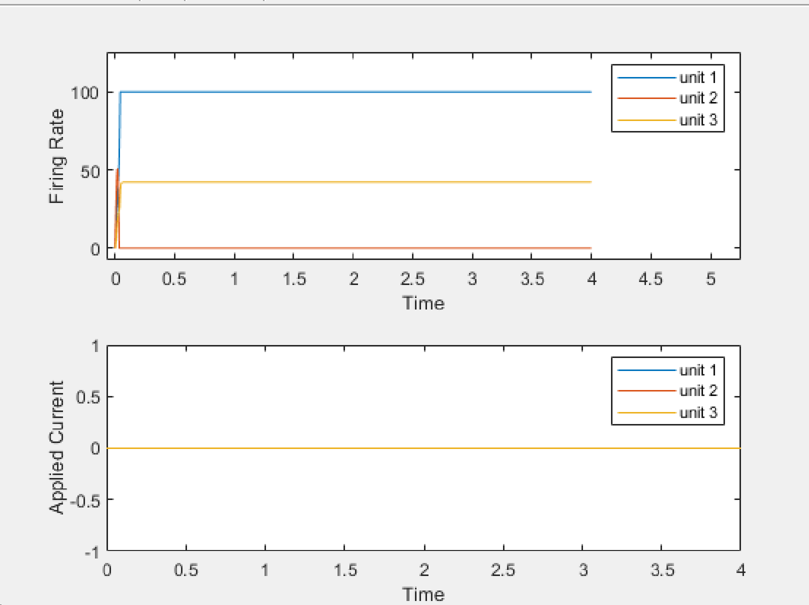
Unit 3: Strictly inhibitory, no self connection, no threshold for activity

Steady States: stable steady state where unit 2 fires at rmax and unit 1 doesn't fire. Stable steady state where unit 1 fires at rmax and unit 2 doesn't fire (in this state unit 3 will fire less than the previous because of unit 1's slightly less strong excitatory connection to unit 3).

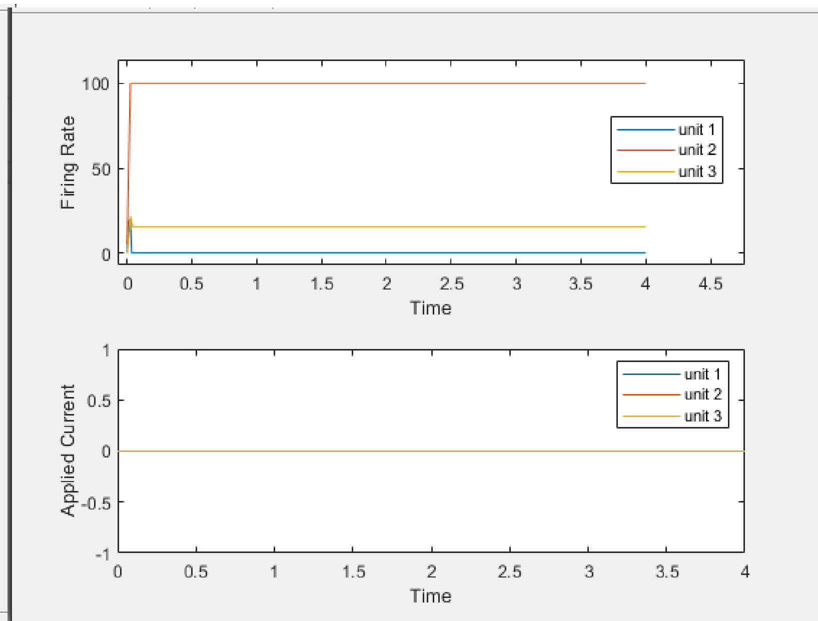
System: unit 1 and 2 are competitive even in the absence of unit 3. Without unit 3, the system would be functionally similar to the 4th system we simulated. However, there is a fair amount of nuance in which unit dominates when we include the third unit. Most of the time, the unit starting with the higher firing rate will dominate, as self excitation and cross inhibition would suggest. However, unit 3 inhibits each unit unequally, and is excited unequally by each unit. In the case where both units start at a high firing rate, the system favors unit 2 because of unit 3's stronger inhibition on unit 1, even if unit 1 starts at a marginally higher rate. As with the previous system, state transitions are possible with a variety of causes, but input must be significant .

The system is deterministic?

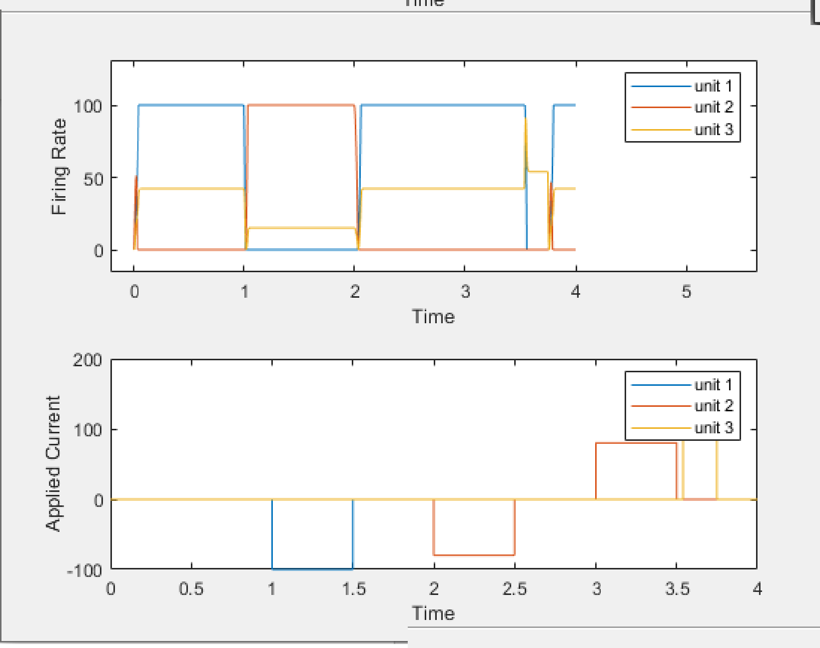
8.)



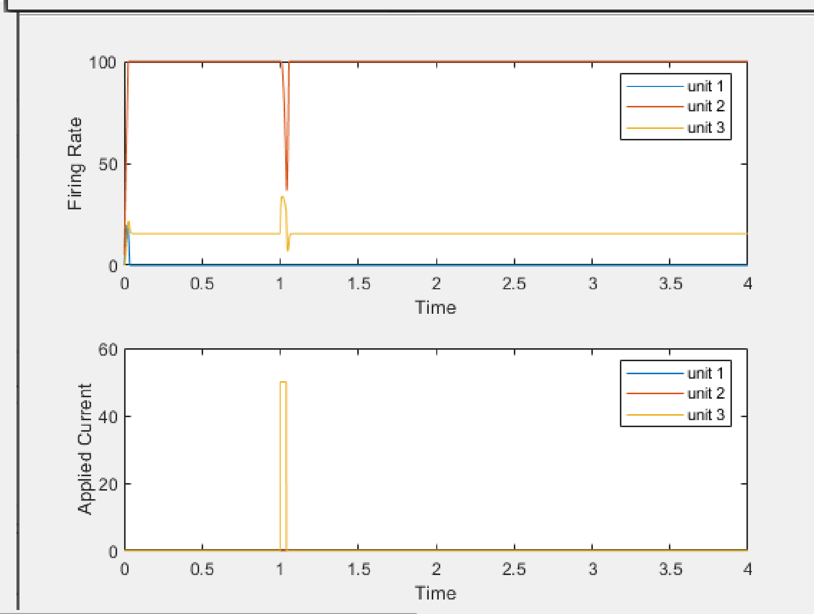
Firing Rate
Time
unit 1
unit 2
unit 3
Applied Current
Time
unit 1
unit 2
unit 3



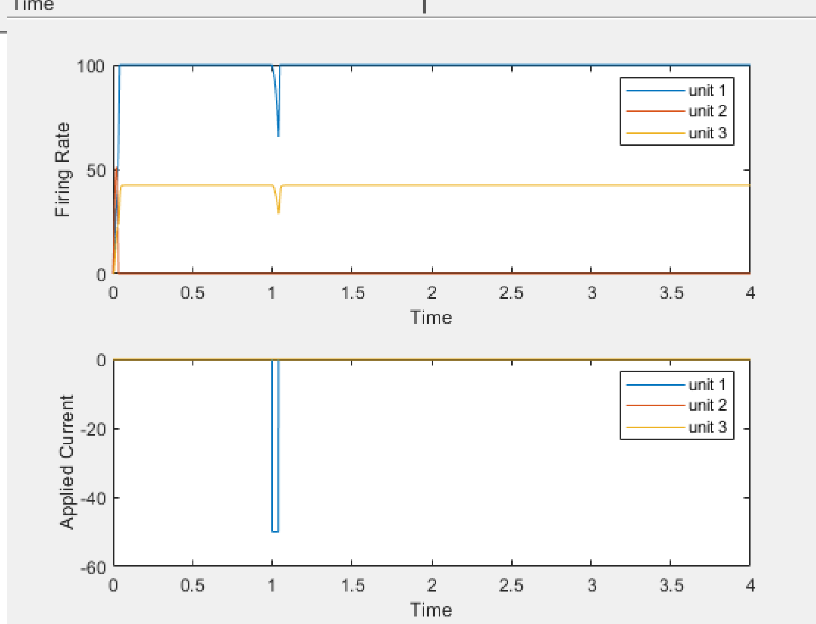
Firing Rate
Time
unit 1
unit 2
unit 3
Applied Current
Time
unit 1
unit 2
unit 3



Firing Rate
Time
unit 1
unit 2
unit 3
Applied Current
Time
unit 1
unit 2
unit 3



Firing Rate
Time
unit 1
unit 2
unit 3
Applied Current
Time
unit 1
unit 2
unit 3



Firing Rate
Time
unit 1
unit 2
unit 3
Applied Current
Time
unit 1
unit 2
unit 3

Unit 1: spontaneously active, self-excitatory (2.05), excites unit 3 (1.2) inhibits unit 2 (-0.2).

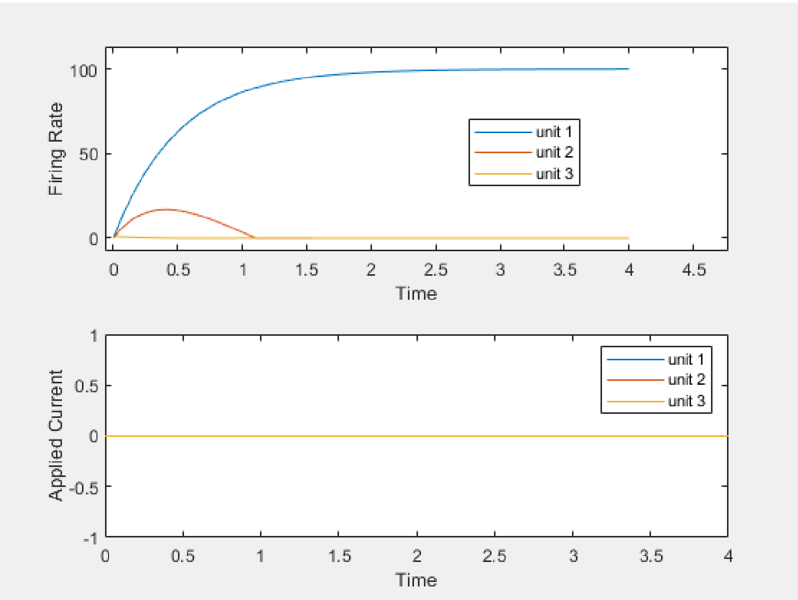
Unit 2: spontaneously active, self-excitatory (2.1), excites unit 3 (0.5) inhibits unit 1 (-0.05).

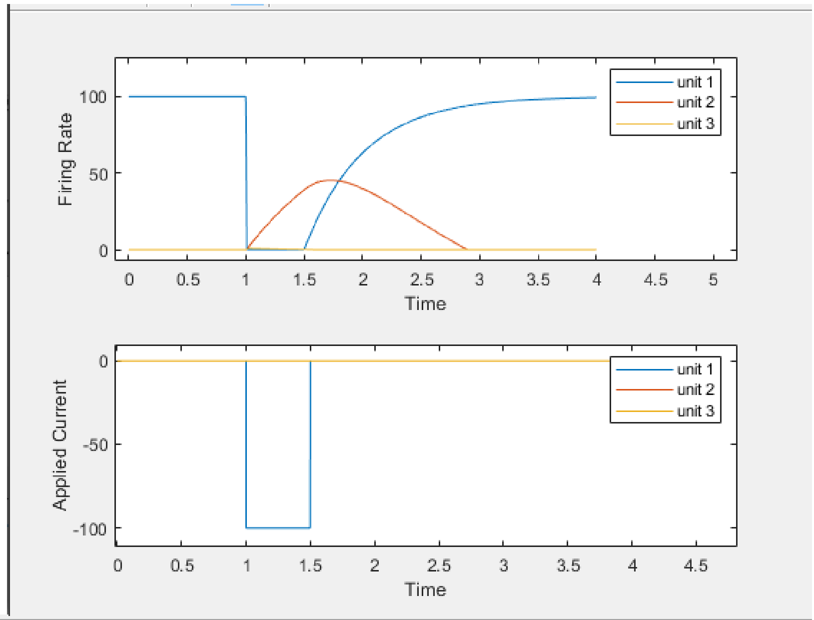
Unit 3: Strictly inhibitory, no self connection, threshold for activity (10)

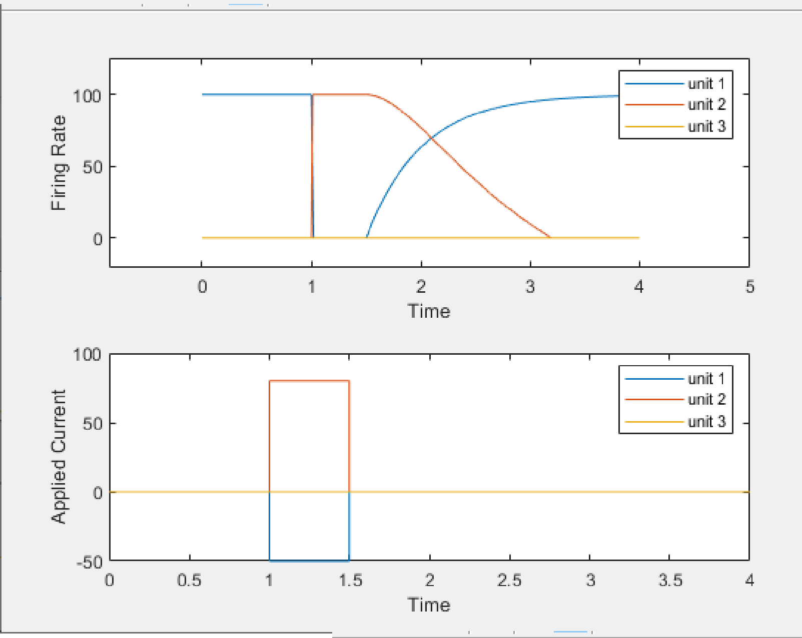
Steady States: stable steady state where unit 2 fires at rmax and unit 1 doesn't fire. Stable steady state where unit 1 fires at rmax and unit 2 doesn't fire (in this state unit 3 will fire more than the previous because of unit 1's stronger excitatory connection to unit 3).

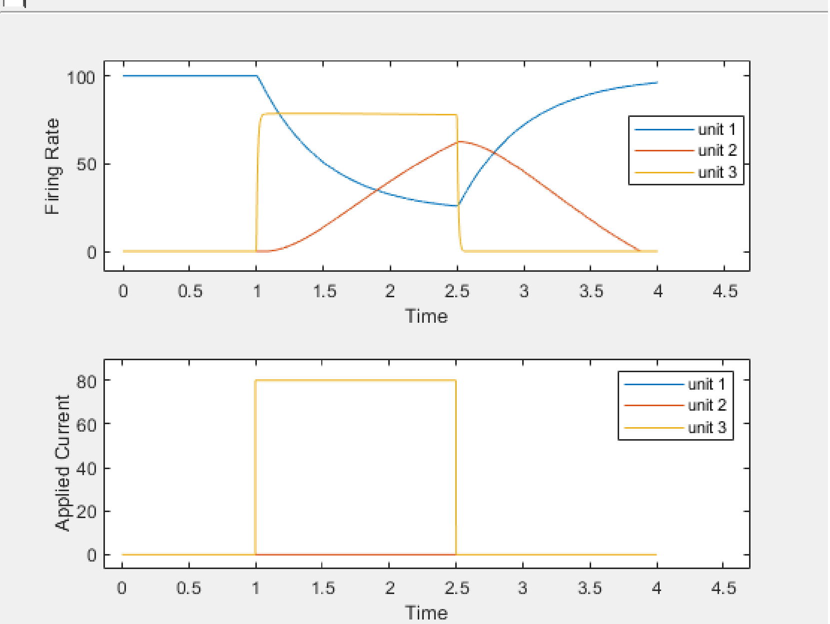
System: Deterministic? Couldn't seem to get the system to exist in anything but a predictable movement to one of two steady states despite several kinds of perturbation.

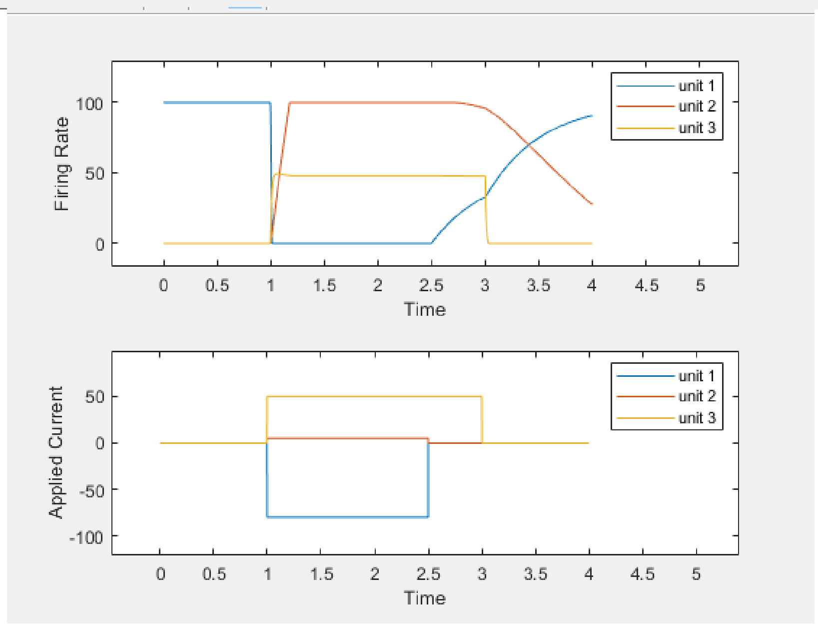
9.)


Firing Rate
Time
unit 1
unit 2
unit 3
Applied Current
Time
unit 1
unit 2
unit 3


Firing Rate
Time
unit 1
unit 2
unit 3
Applied Current
Time
unit 1
unit 2
unit 3


Firing Rate
Time
unit 1
unit 2
unit 3
Applied Current
Time
unit 1
unit 2
unit 3


Firing Rate
Time
unit 1
unit 2
unit 3
Applied Current
Time
unit 1
unit 2
unit 3


Firing Rate
Time
unit 1
unit 2
unit 3
Applied Current
Time
unit 1
unit 2
unit 3

Unit 1: spontaneously active, self-excitatory (0.98), inhibits unit 3 (-0.01) inhibits unit 2 (-0.015).

Unit 2: spontaneously active, self-excitatory (0.99), inhibits unit 3 ((-0.02).

Unit 3: inhibits unit 1 (-0.02), excites unit 2 (0.005), self excitatory (1.01)

Steady States: stable steady state where unit 1 fires at rmax and other 2 units are inactive. It seems like in the absence of input, the system will always go towards this state. Unit 2 being highly active is unstable with or without activity from unit 3, as the self excitation is insufficient to keep the unit from decaying once the spontaneous activity of unit 1 begins to inhibit it. Unit 3 is inhibited by both other units, and excites unit 2, making unit 3's activity bound for inactive, because while increasing unit 3 activity will increase unit 2 activity enough to destabilize any level of activity in unit 3. Worth noting that due to smaller levels of spontaneous activity and less powerful connection strengths, this network is definitely the slowest moving of any considered.

System: Not really sure what to call this network. It is deterministic in that after any input is ceased, the system will move towards a predetermined point at a predetermined rate, regardless of type of input. That being said, it will take the system a different amount of time to reach that state depending on the type of perturbation. Seeing as how these new input create new fixed points that are stable until input is ceases, at which point there is gradual movement to the original fixed point, this can almost be considered a heteroclinic sequence? Honestly I'm not sure. This is definitely one of my weaker assignments and I think I plan to drop it, but I'd love to go over this all in office hours or something because I feel like I may have missed something to this assignment.