BT6270-COMPUTATIONAL NEUROSCIENCE
Assignment2

Sweta Kumari
BT17D019

The goal of this assignment is simulating and Understanding FitzHugh-Nagumo neuron model taught in the class.

Simulate the two variable FitzHugh-Nagumo neuron model using the following equations:

$$\frac{dv}{dt} = f(v) - w + I_m$$

where $$f(v) = v(a - v)(v - 1)$$

$$\frac{dw}{dt} = bv - rw$$

where a=0.5; choose b, r values as discussed in the class (small positive values, say 0.1)

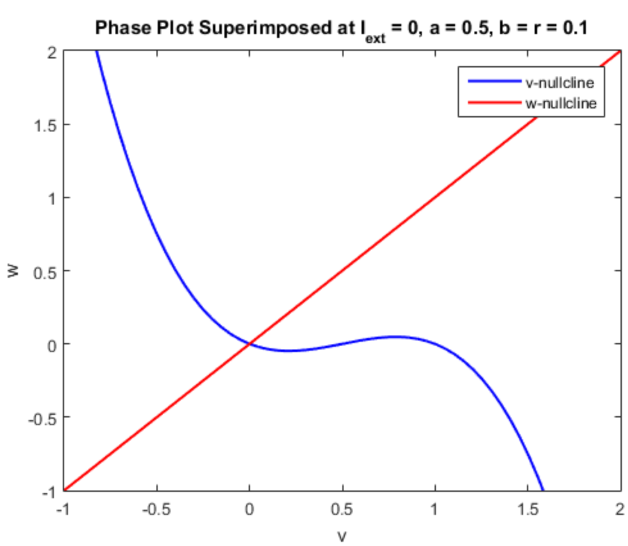
Use single forward Euler Integration

$dv/dt = \Delta v/ \Delta t$

$\Delta v(t) = v(t+1) - v(t) = [fv(t) - w(t) + I_{ext}(t)]* \Delta t$ given v(0) --> v(Δt) --> v(2* Δt) -->....

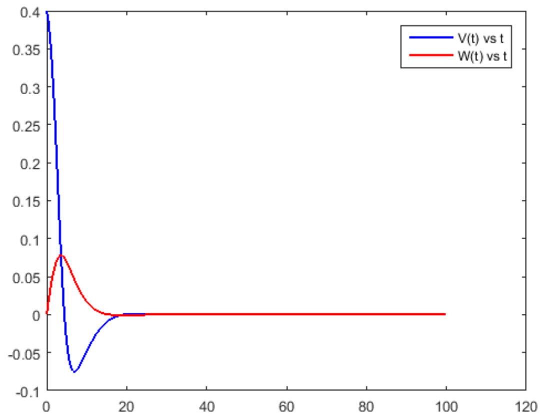
Case 1: $I_{ext} = 0$

(a) Draw a Phase Plot superimposed (use hold on command in MATLAB)



(b) Plot V(t) vs t and W(t) vs t and also show the trajectory on the phase plane for the both cases

(i) V(0) < a and ω (0)= 0



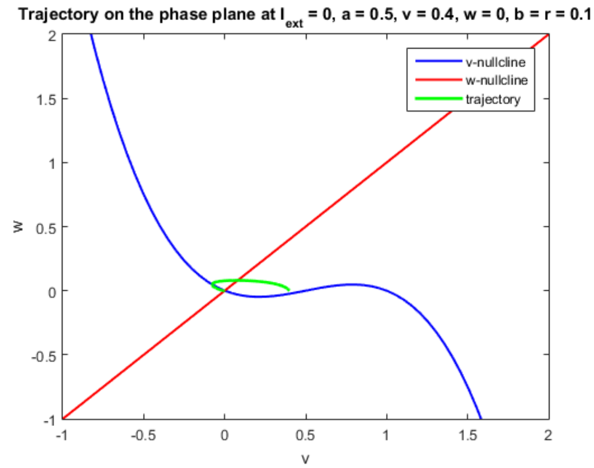
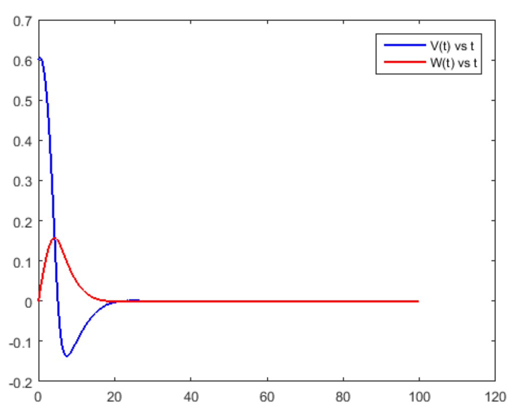


Fig: V(t) and W(t) vs t @ Iext = 0, v = 0.4, w = 0, b=r=0.1

(ii) V(0) > a and ω (0)= 0



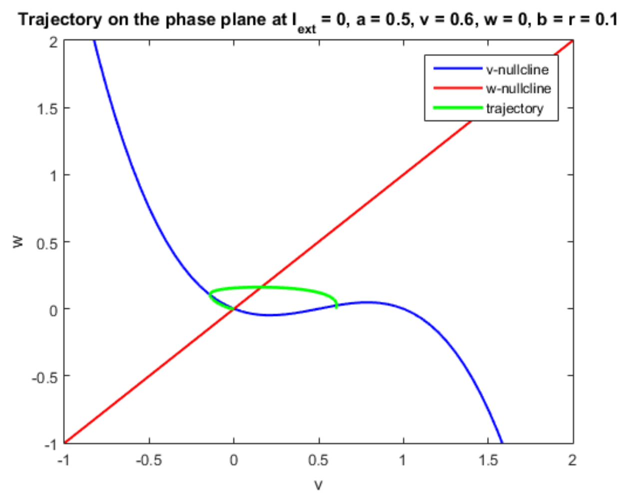
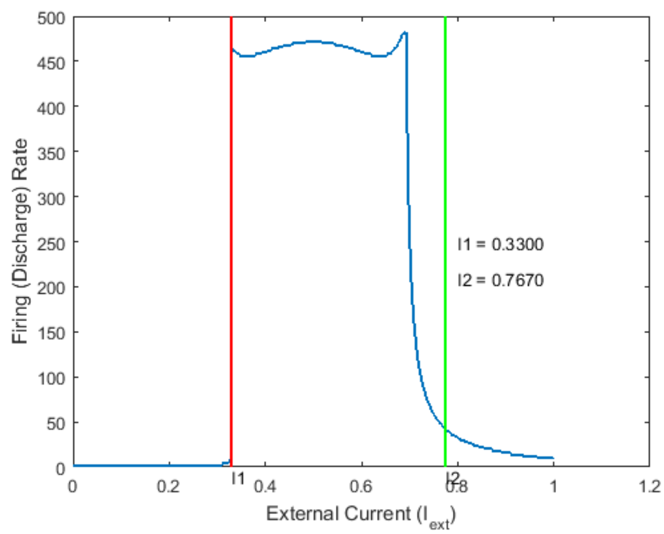


Fig: V(t) and W(t) vs t @ Iext = 0, v = 0.6, w = 0, b=r=0.1

Case 2: Choose some current value $I_1 < I_{ext} < I_2$ where it exhibit oscillations. Find the values of I_1 and I_2.

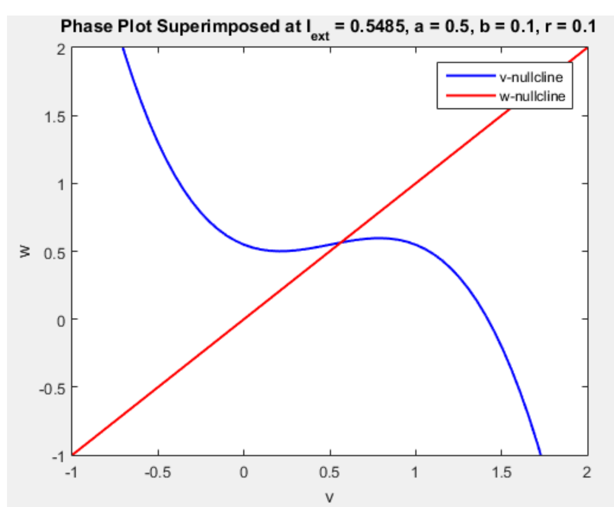
A.

- ✓ I1 = 0 and I2 = 1 mA current values are chosen to obtain the Iext value where it exhibits oscillations.
- ✓ Peak of greater than 0.5 is considered as an action potential.
- ✓ Minimum number of peaks is 20 where it exhibits the oscillations.
- ✓ Finally **I1 = 0.3300 to I2 = 0.7670** range is obtained where the oscillations was observed.



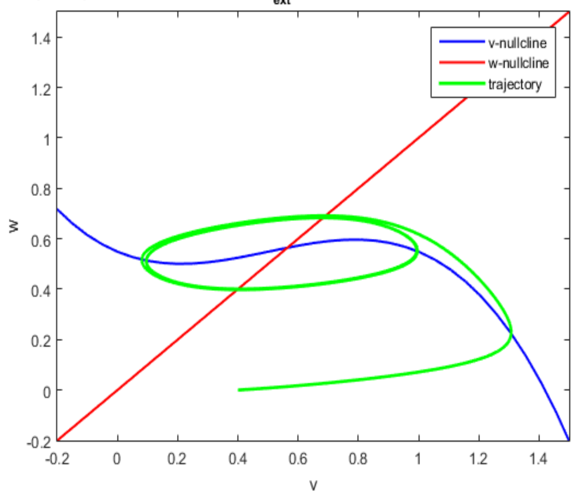
(a) Draw a Phase Plot for some sample value of I_{ext}

A. Chosen Iext = (I1 + I2)/2 where I1 < Iext = 0.5485 < I2



B. Show that the fixed point is unstable i.e., for a small perturbation there is a no return to the fixed point (show the trajectory on the phase plane) – also show limit cycle on the phase plane

Trajectory on the phase plane at I_{ext} = 0.5485, a = 0.5, v = 0.4, w = 0, b = r = 0.1



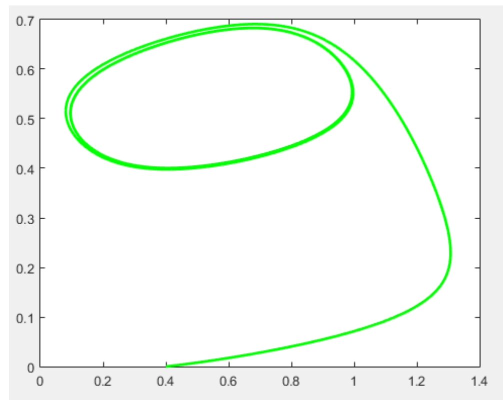
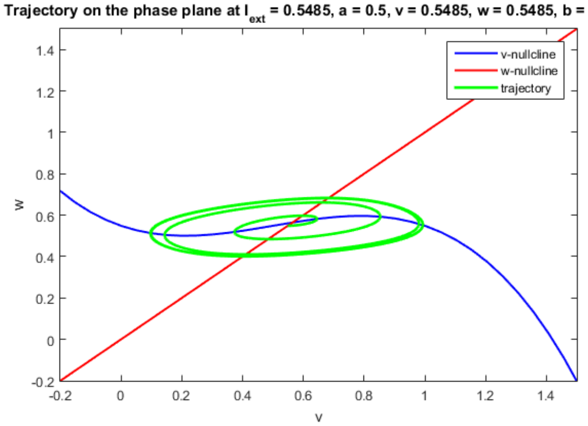
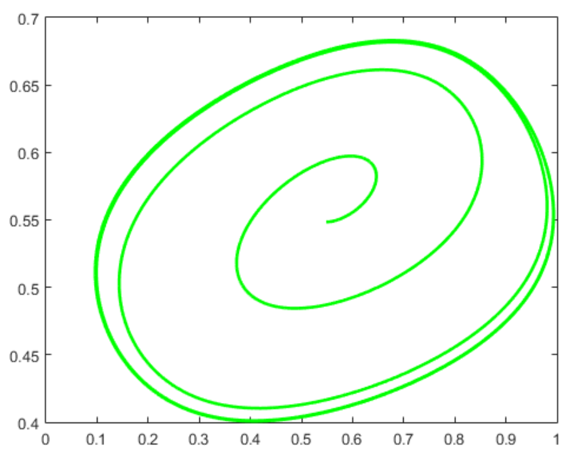


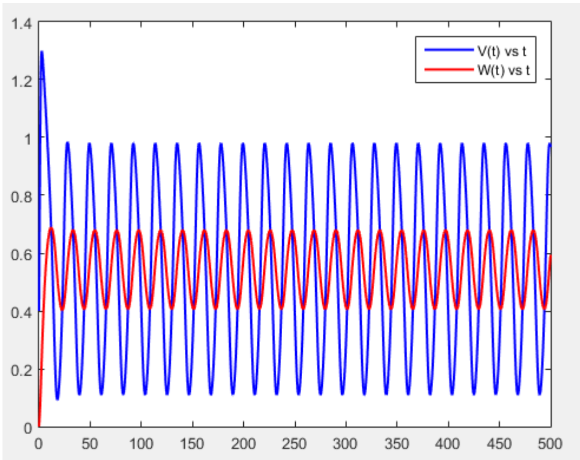
Fig: limit cycle @ Iext = 0. 5485, v = 0. 4, w = 0, b=r=0.1

Trajectory on the phase plane at I_{ext} = 0.5485, a = 0.5, v = 0.5485, w = 0.5485, b = r = 0.1





A. Plot V(t) vs t and W(t) vs t



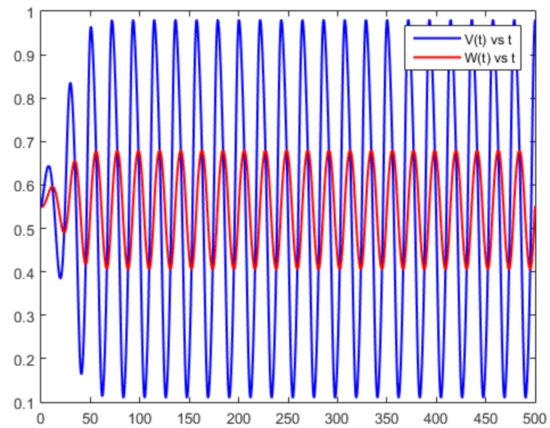


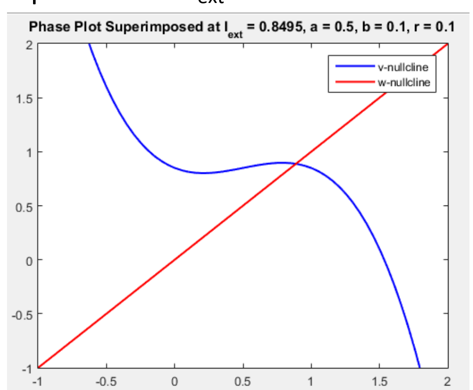
Fig: V(t) and W(t) vs t @ Iext = 0.5485, b=r=0.1, (a) v = 0. 4, w = 0 **(b) v = 0. 5485, w = 0. 5485**

Case 3: Choose some $I_{ext} > I_2$

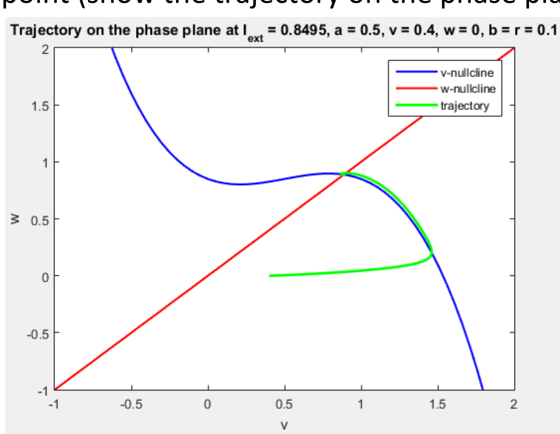
A. Iext = (I1 /4)+ I2 which is greater than I2, Iext > I2

Iext = 0.8495

(a) Draw a Phase Plot for some sample value of I_{ext}



(b) Show that the fixed point is stable i.e., for a small perturbation there is a return to the fixed point (show the trajectory on the phase plane)



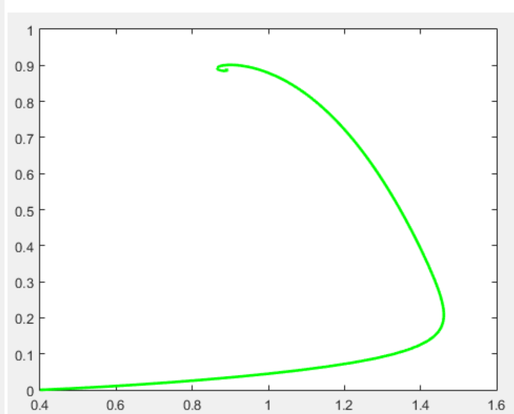
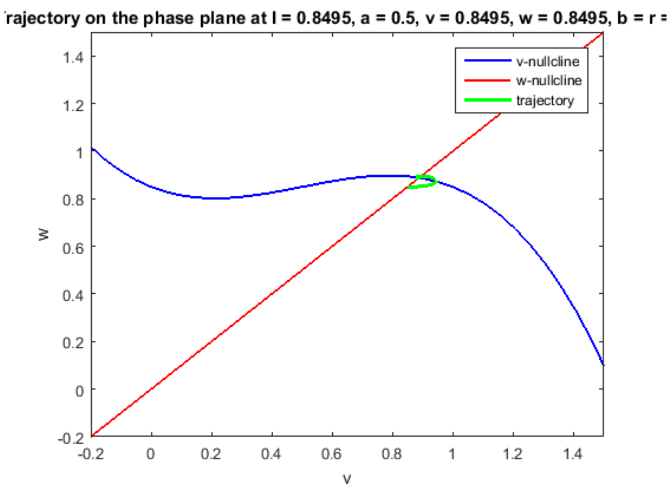


Fig: Limit cycle @ Iext = 0.8495, v = 0. 4, w = 0, b=r=0.1



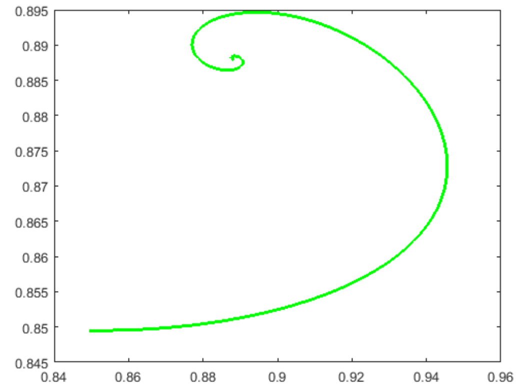
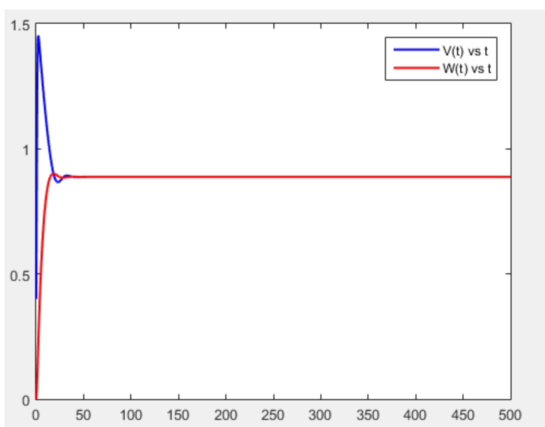


Fig: Limit cycle @ Iext = 0.8495, v = 0. 8495, w = 0. 8495, b=r=0.1

(c) Plot V(t) vs t and W(t) vs t



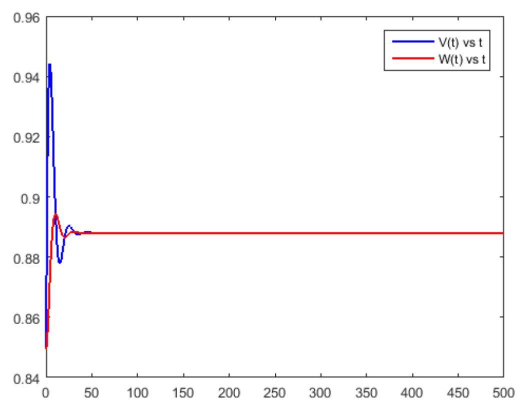
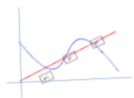


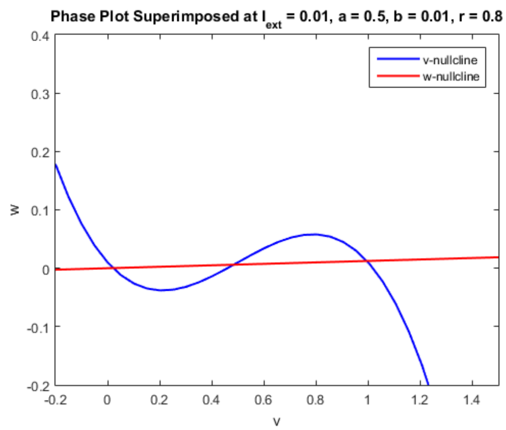
Fig: V(t) and W(t) vs t @ Iext = 0.8495, b=r=0.1 (a)v = 0. 4, w = 0 **(b) v = 0. 8495, w = 0. 8495**

Case 4: Fine suitable values of I_{ext} and (b/r) such that the graph looks as phase plot shown as below.

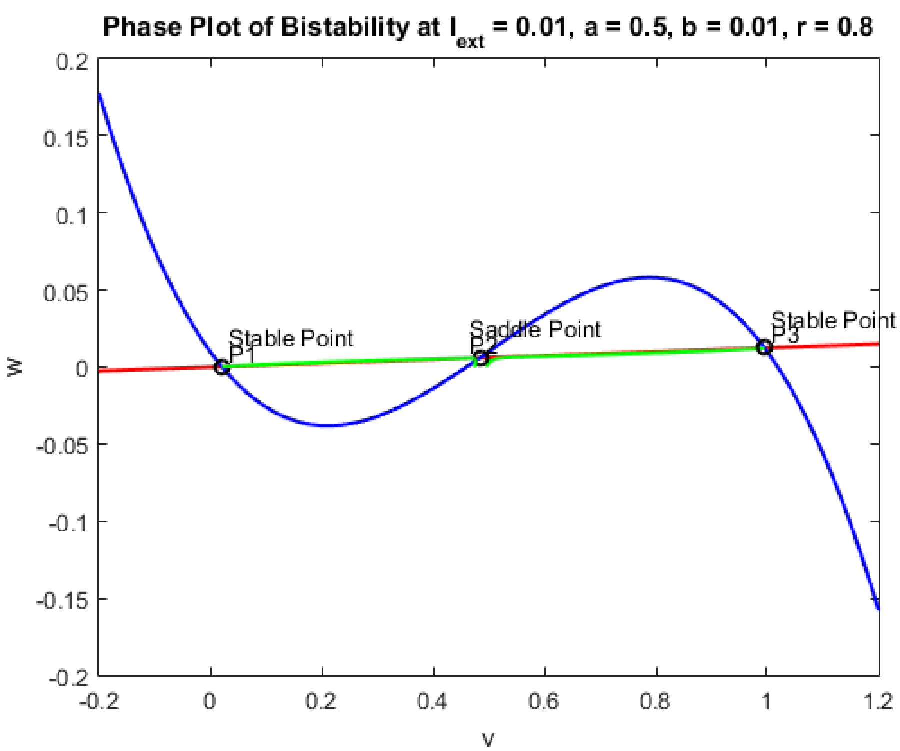


A. Obtained suitable values for such graph is **Iext = 0.01, b = 0.01, r = 0.8 and a = 0.5, where b/r = 0.0125**

(a) Redraw the Phase plot



(b) Show suitability of P1, P2, P3 (**Bistability**)



(c) Plot V(t) vs t and W(t) vs t

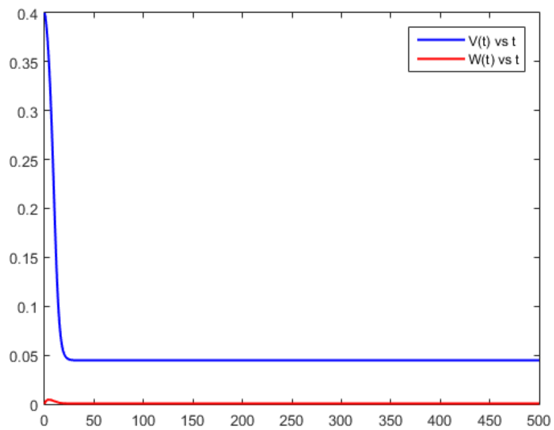


Fig: V(t) and W(t) vs t @ Iext = 0.01, v = 0. 4, w = 0, b=0.01,r=0.8

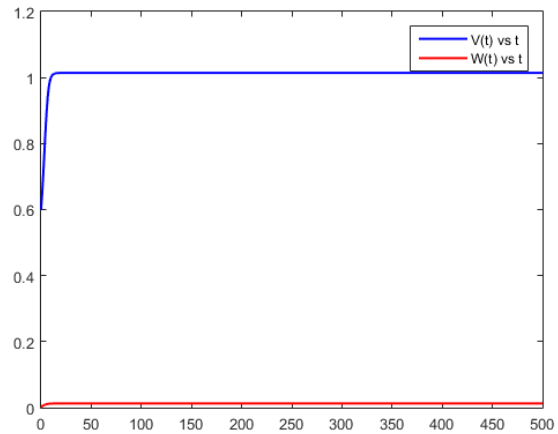


Fig: V(t) and W(t) vs t @ Iext = 0.01, v = 0. 6, w = 0, b=0.01,r=0.8

Results & Conclusion

FitzHugh-Nagumo Neuron Model is more simple and effective comparative to the Hodgkin- Huxley Model. Important behaviors of neuron firings are observed such as oscillation and limit cycle with only two numbers of variables (v and w).