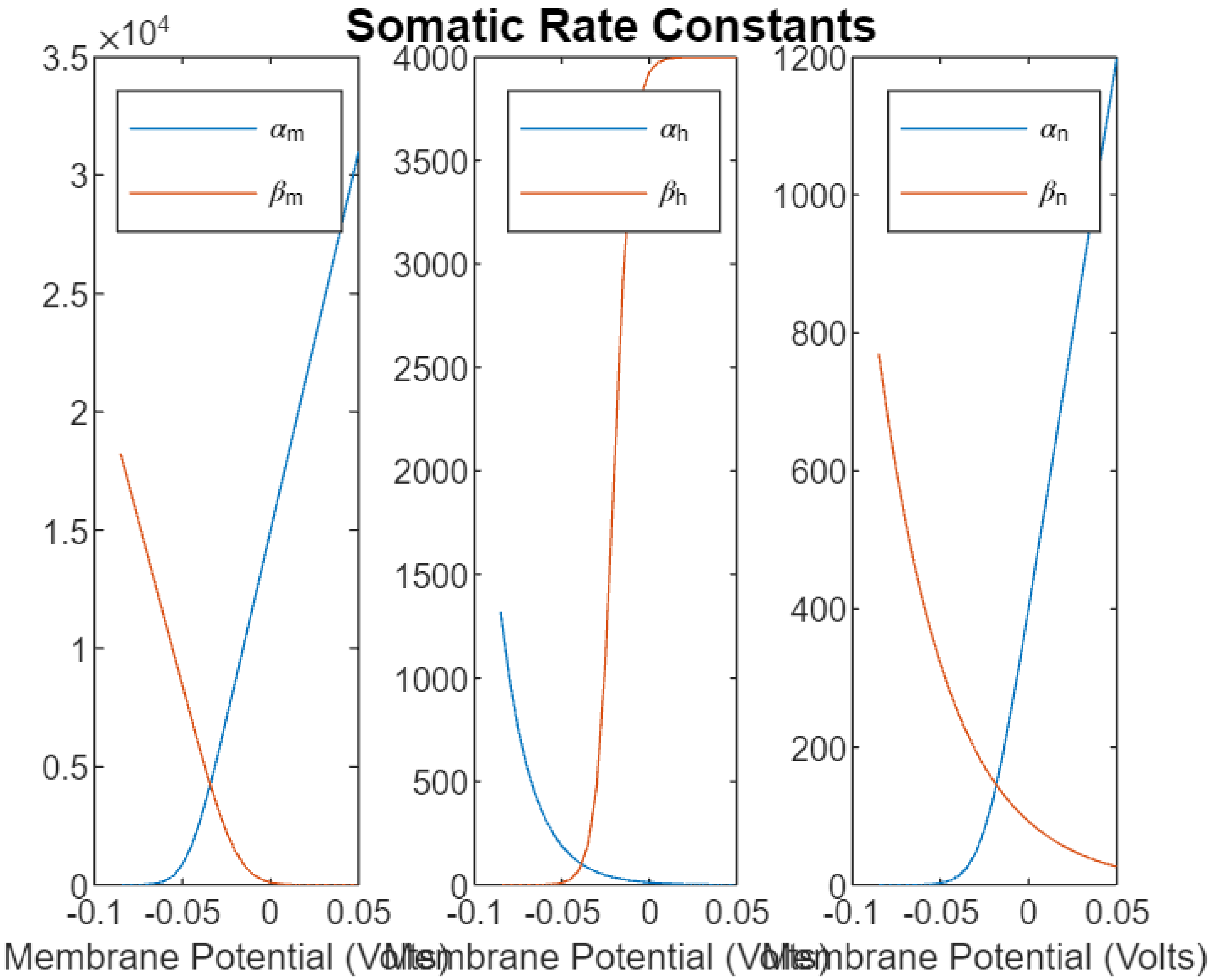
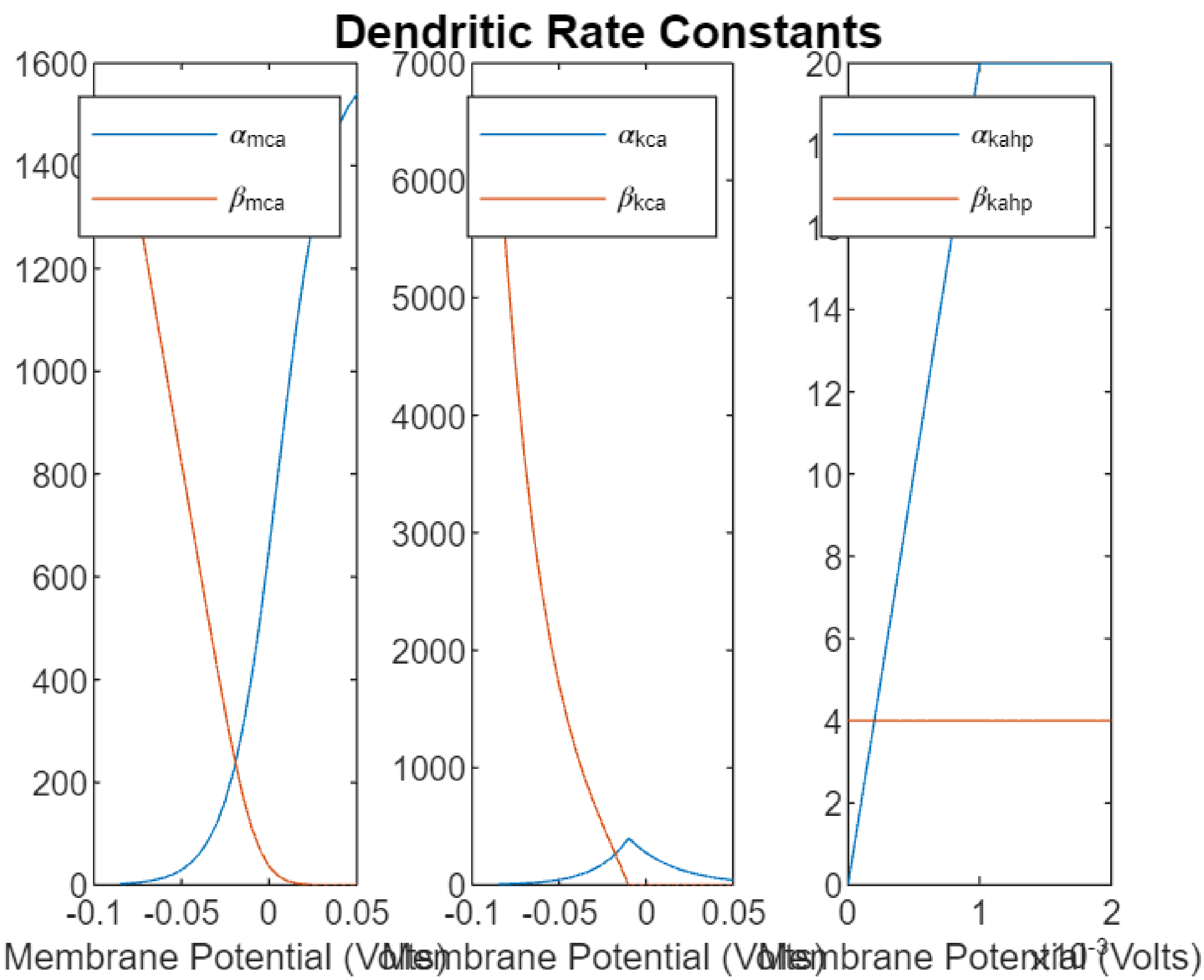
```
%All is done of Friday from 10PM to 2:30AM.
%% Question 2 - Set up Parameters (Anthony)
% Create vectors for membrane potential and calcium concentration.
v = [-0.085:0.005:0.05];
ca = [0:0.1e-3:2e-3];
[alpha_m, beta_m, alpha_h, beta_h , alpha_n, beta_n] = PR_soma_gating(v);
[alpha_mca, beta_mca, alpha_kca, beta_kca, alpha_kahp, beta_kahp ] = PR_dend_gating(v, ca);

% Plot for somatic gating variables. (Anthony)
figure(1)
%Plot for gating variable m
subplot(1,3,1);
plot(v, alpha_m);
hold on
plot(v, beta_m);
legend("\alpha_m", "\beta_m");
xlabel("Membrane Potential (Volts)");
hold off

%Plot for gating variable h
subplot(1,3,2);
plot(v, alpha_h);
hold on
plot(v, beta_h);
legend("\alpha_h", "\beta_h")
xlabel("Membrane Potential (Volts)")
hold off

%Plot for gating variable n
subplot(1,3,3);
plot(v, alpha_n);
hold on
plot(v, beta_n);
legend("\alpha_n", "\beta_n")
xlabel("Membrane Potential (Volts)")
hold off

a = axes;
t1 = title('Somatic Rate Constants');
a.Visible = 'off';
```




```
t1.Visible = 'on';
```

```
% Plot for dendritic gating variables. (Anthony)
%Plot for gating variable mca

figure(2)
subplot(1,3,1);
plot(v, alpha_mca);
hold on
plot(v, beta_mca);
legend("\alpha_{mca}", "\beta_{mca}");
xlabel("Membrane Potential (Volts)");

%Plot for gating variable kca
subplot(1,3,2);
plot(v, alpha_kca);
hold on
plot(v, beta_kca);
```

```
legend("\alpha_{kca}", "\beta_{kca}");
xlabel("Membrane Potential (Volts)");

%Plot for gating variable kahp
subplot(1,3,3);
plot(ca, alpha_kahp);
hold on
plot(ca, beta_kahp);
legend("\alpha_{kahp}", "\beta_{kahp}");
xlabel("Membrane Potential (Volts)");
hold off

a = axes;
t1 = title('Dendritic Rate Constants');
a.Visible = 'off';
```




```
t1.Visible = 'on';
```

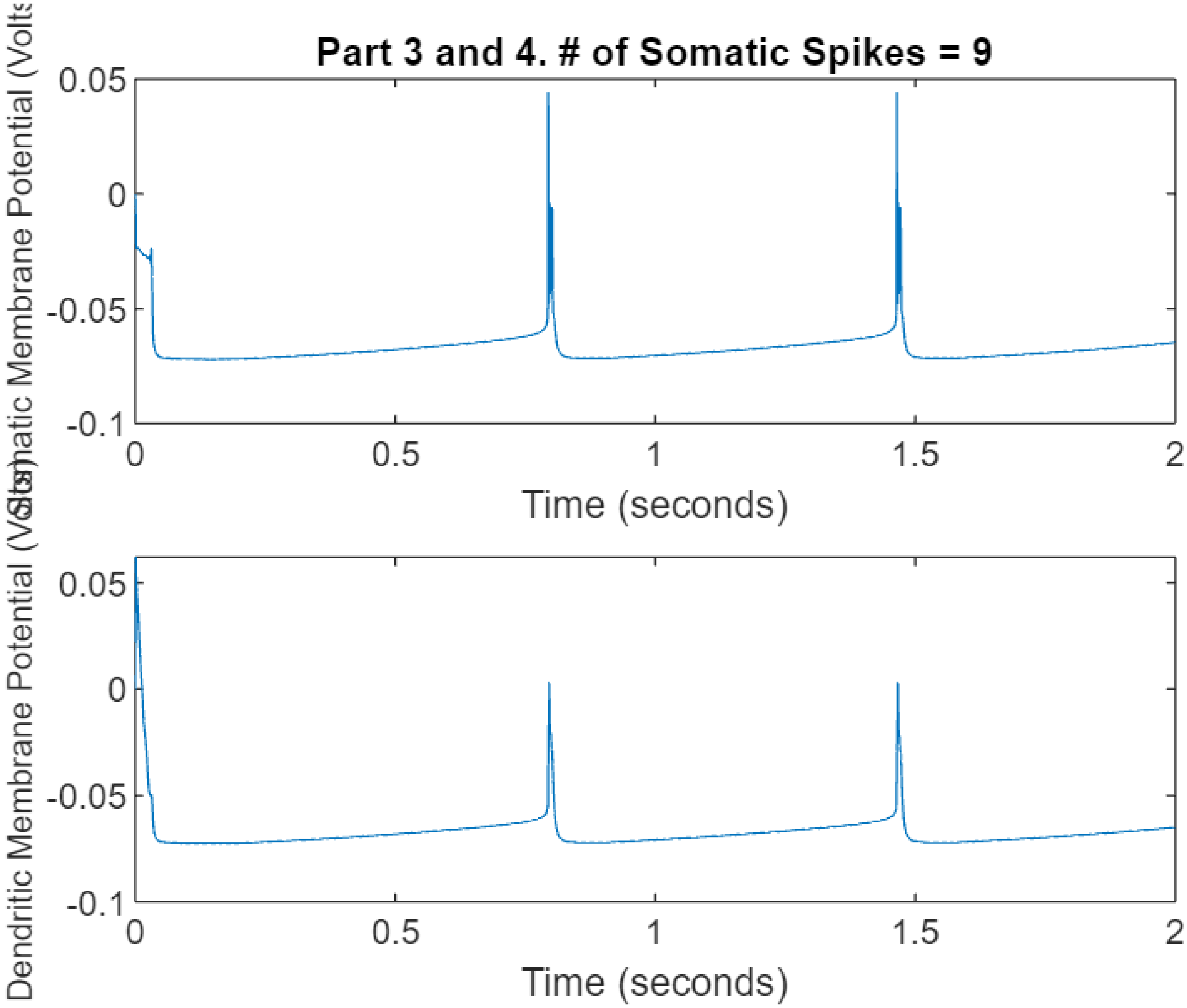
```
%%Problem 3: Model Implementation & Problem 4 - Detecting Somatic Spikes
```

```
%Define time in SI units (Eric)
clear
tspan = [0:2*10^-6:2]; % time span in sec

%Initial Values (Anthony)
Vm_soma0 = 0;
m0 = 0;
h0 = 0;
n0 = 0;
Vm_dend0 = 0;
mca0 = 0;
mkca0 = 0;
mkahp0 = 0;
ca_conc0 = 0;
y0 = [Vm_soma0;m0;h0;n0;Vm_dend0;mca0;mkca0;mkahp0;ca_conc0];

%ODE45 Implementation (All)
[t,y] = ode45(@(t,y) output(t,y),tspan,y0)
```

```
t = 1000001×1
         0
    0.0000
    0.0000
    0.0000
    0.0000
    0.0000
    0.0000
    0.0000
    0.0000
    0.0000
      ⋮

y = 1000001×9
         0         0         0         0         0         0         0         0 ⋯
   -0.0000    0.0296    0.0000    0.0008   -0.0000    0.0013    0.0006    0.0000
   -0.0000    0.0582    0.0000    0.0016   -0.0000    0.0026    0.0011    0.0000
   -0.0000    0.0861    0.0001    0.0024   -0.0000    0.0039    0.0017    0.0000
   -0.0000    0.1131    0.0001    0.0032   -0.0000    0.0052    0.0022    0.0000
   -0.0000    0.1392    0.0001    0.0040   -0.0000    0.0065    0.0028    0.0000
   -0.0000    0.1647    0.0001    0.0048   -0.0000    0.0079    0.0033    0.0000
   -0.0000    0.1893    0.0002    0.0056   -0.0000    0.0092    0.0039    0.0000
   -0.0000    0.2132    0.0002    0.0064   -0.0000    0.0105    0.0044    0.0000
   -0.0001    0.2364    0.0002    0.0072   -0.0001    0.0117    0.0050    0.0000
      ⋮
```

```
%Extract Vm of Dendrite and Soma (Anthony)
Vm_soma = y(:,1);
Vm_dend = y(:,5);

%Count Spikes (Anthony)
blocker = 0; %use to block recording spikes before v is less than -30e-3
trigger_v = -10e-3; %above which we count a spike
unblock_v = -30e-3; %below which we allow new spikes to be counted
for n = 1:(length(t)-1)
```

```
    if Vm_soma(n) > trigger_v
        if blocker == 0 %if blocker was set to 0 due to v less than -30e-3
            spikes(n) = 1; %add a 1 to spikes vector
            blocker = 1; %turn on blocker
        end
    end

    if Vm_soma(n) < unblock_v
        blocker = 0;
    end
end

%Plot Results (Anthony)
hold off
subplot(2,1,1)
plot(t,Vm_soma);
ylabel("Somatic Membrane Potential (Volts)", "FontSize", 8);
xlabel("Time (seconds)");
title(sprintf("Part 3 and 4. # of Somatic Spikes = %d", sum(spikes)));
subplot(2,1,2)
plot(t,Vm_dend);
ylabel("Dendritic Membrane Potential (Volts)", "FontSize", 8);
xlabel("Time (seconds)");
```


Part 3 and 4. # of Somatic Spikes = 9
Somatic Membrane Potential (Volts)
0.05
0
-0.05
-0.1
0
0.5
1
1.5
2
Time (seconds)
Dendritic Membrane Potential (Volts)
0.05
0
-0.05
-0.1
0
0.5
1
1.5
2
Time (seconds)

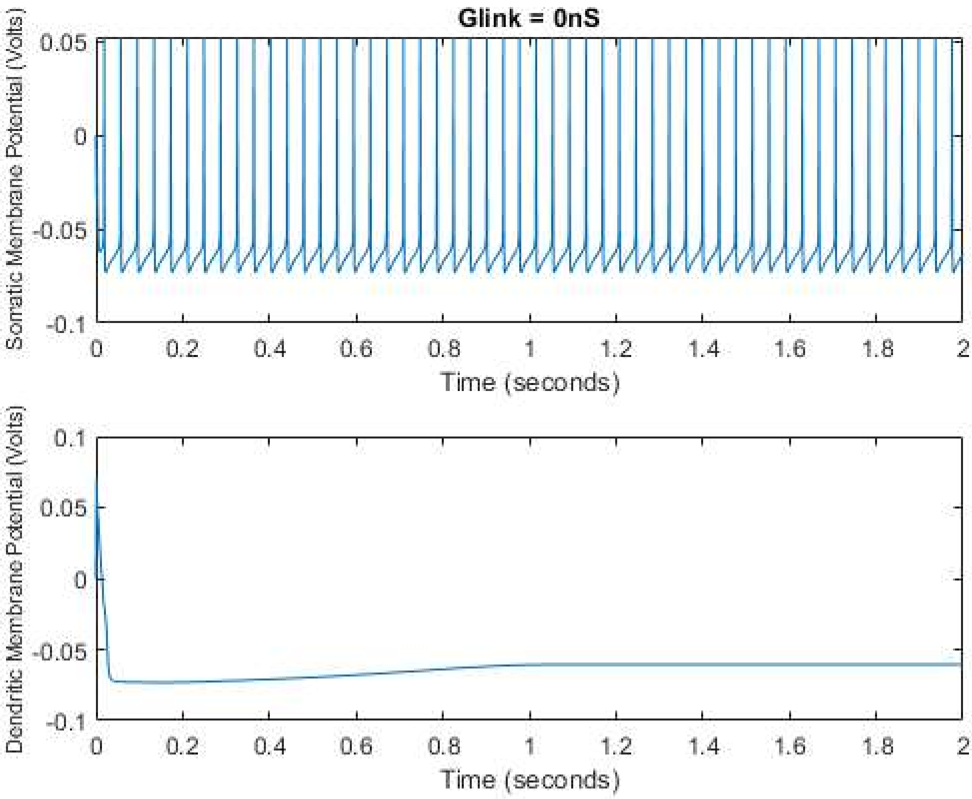
Contents

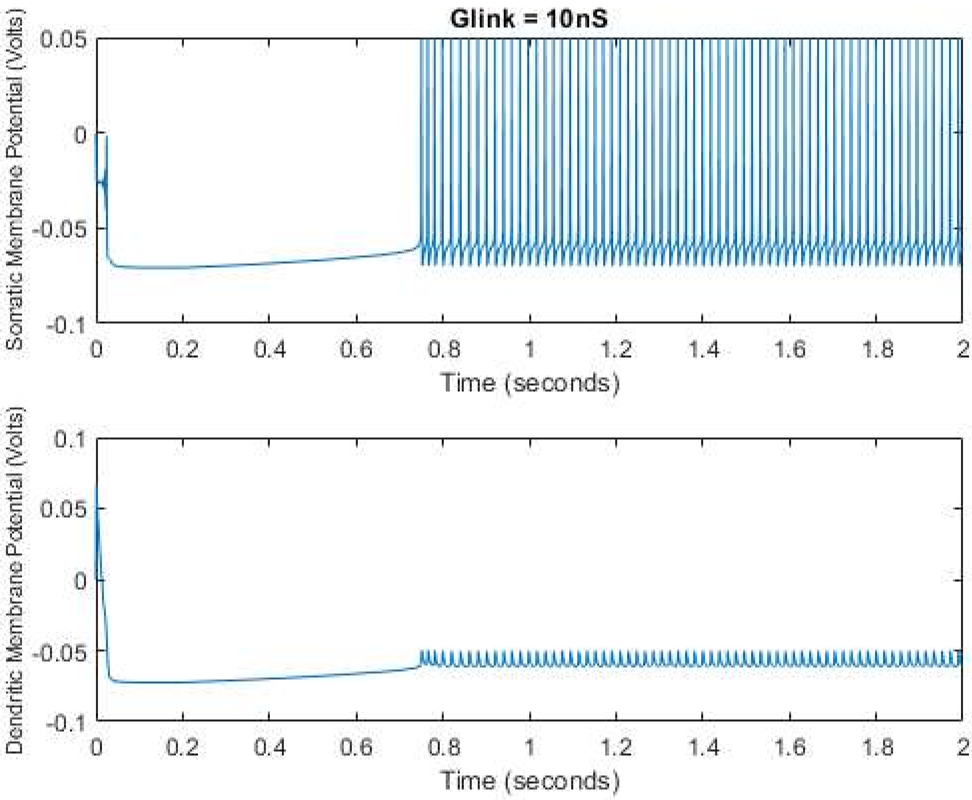
- Problem 5: Alternating Glink values
- Problem 6-Changing current

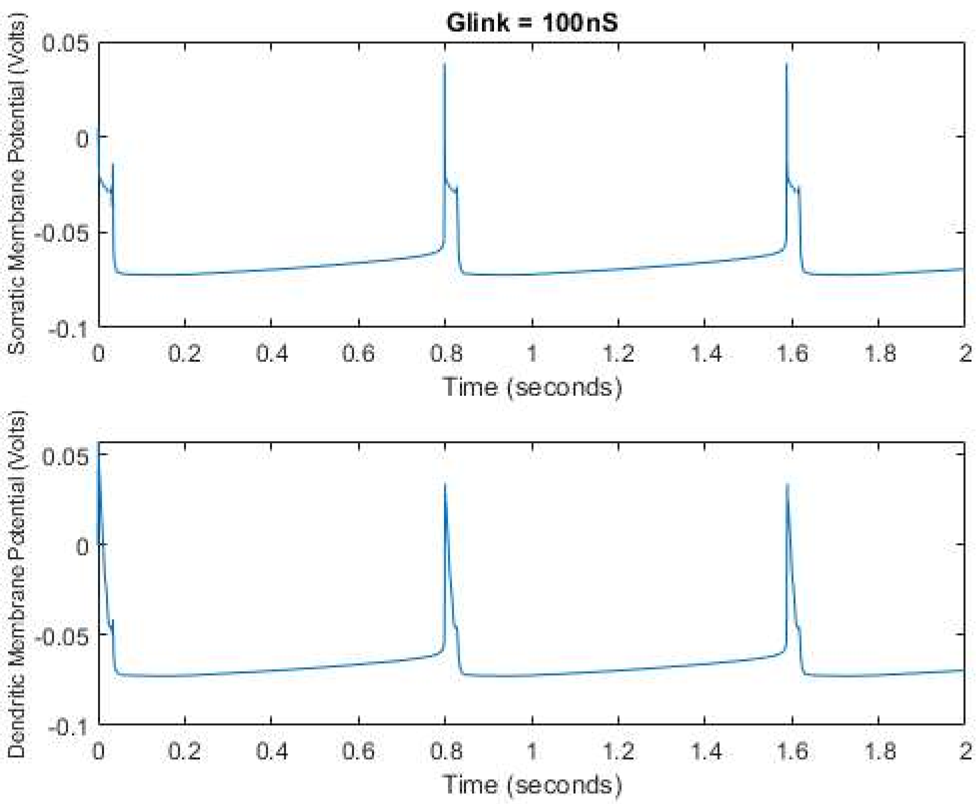
Problem 5: Alternating Glink values

```
tspan = [0:2*10^-6:2]; % time span in sec
%Initial Values
Vm_soma0 = 0;
m0 = 0;
h0 = 0;
n0 = 0;
Vm_dend0 = 0;
mca0 = 0;
mkca0 = 0;
mkahp0 = 0;
ca_conc0 = 0;
y0 = [Vm_soma0;m0;h0;n0;Vm_dend0;mca0;mkca0;mkahp0;ca_conc0];

%ODE45 Implementation
[t,y] = ode45(@(t,y) eric0nS(t,y),tspan,y0);
[~,y1] = ode45(@(t,y) eric10nS(t,y),tspan,y0);
[~,y2] = ode45(@(t,y) eric100nS(t,y),tspan,y0);

%Extract Vm of Dendrite and Soma
Vm_soma1 = y(:,1);
Vm_dend1 = y(:,5);
Vm_soma2 = y1(:,1);
Vm_dend2 = y1(:,5);
Vm_soma3 = y2(:,1);
Vm_dend3 = y2(:,5);

%Plot Results
%Glink = 0nS;
figure(1)
subplot(2,1,1)
plot(t,Vm_soma1);
ylabel("Somatic Membrane Potential (Volts)", "FontSize", 8);
xlabel("Time (seconds)");
title("Glink = 0nS");
subplot(2,1,2)
plot(t,Vm_dend1);
ylabel("Dendritic Membrane Potential (Volts)", "FontSize", 8);
xlabel("Time (seconds)");
%Glink = 10nS;
figure(2)
subplot(2,1,1)
plot(t,Vm_soma2);
ylabel("Somatic Membrane Potential (Volts)", "FontSize", 8);
xlabel("Time (seconds)");
title("Glink = 10nS");
subplot(2,1,2)
plot(t,Vm_dend2);
ylabel("Dendritic Membrane Potential (Volts)", "FontSize", 8);
xlabel("Time (seconds)");
%Glink = 100nS;
figure(3)
subplot(2,1,1)
plot(t,Vm_soma3);
```

```
ylabel("Somatic Membrane Potential (Volts)", "FontSize", 8);
xlabel("Time (seconds)");
title("Glink = 100nS");
subplot(2,1,2)
plot(t,Vm_dend3);
ylabel("Dendritic Membrane Potential (Volts)", "FontSize", 8);
xlabel("Time (seconds)");

%Explanation
%If the link between the soma and the dendrite is zero, you can see that
%only the soma has action potentials while the dendrite has barely
%anything. If there is a little bit link, the soma didn't burst off action
%potentials until 0.8seconds while dendrite shows the same, this is
%probably because the leak to the dendrite doesn't allow the soma to have
%action potentials.When the link between the soma and dendrite is 100nS,
%the membrane potentials of soma and dendrite peaked at the same time.
```


Glink = 0nS
Somatic Membrane Potential (Volts)
0.05
0
-0.05
-0.1
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (seconds)
Dendritic Membrane Potential (Volts)
0.1
0.05
0
-0.05
-0.1
Time (seconds)


Glink = 10nS
Somatic Membrane Potential (Volts)
0.05
0
-0.05
-0.1
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (seconds)
Dendritic Membrane Potential (Volts)
0.1
0.05
0
-0.05
-0.1
Time (seconds)

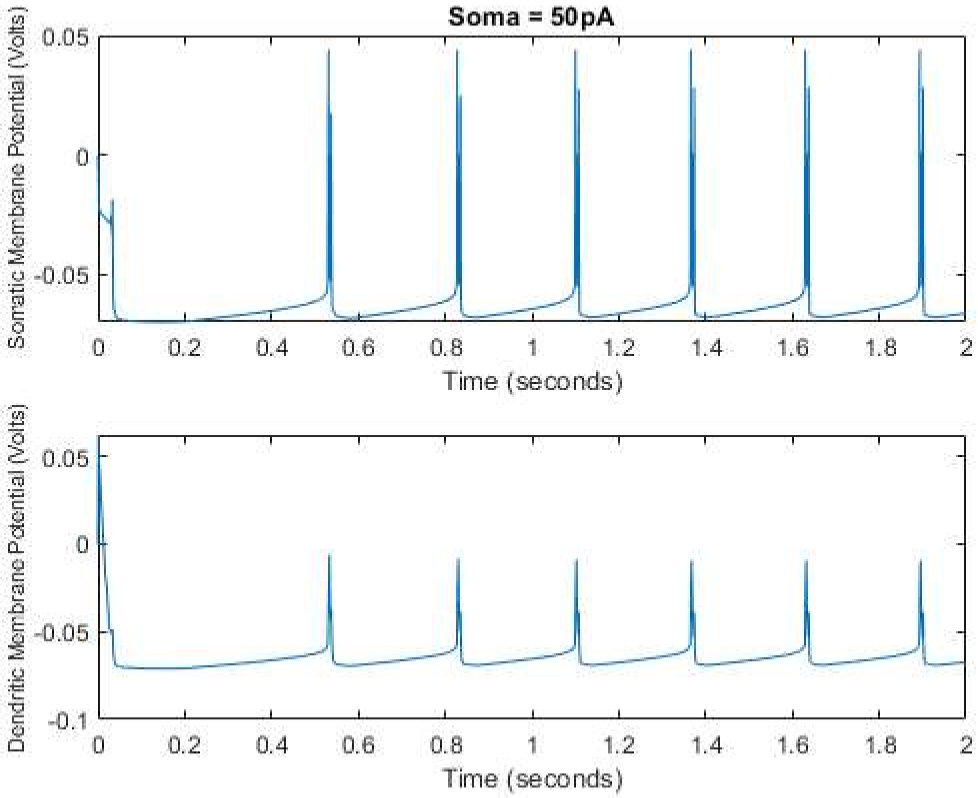


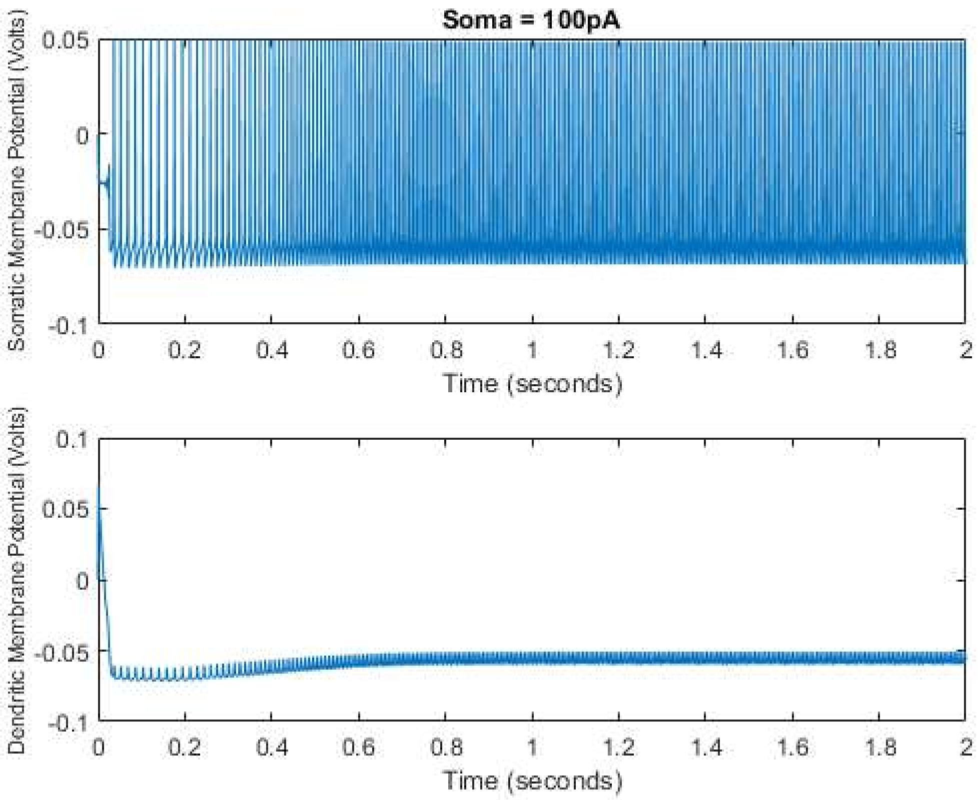
Problem 6-Changing current

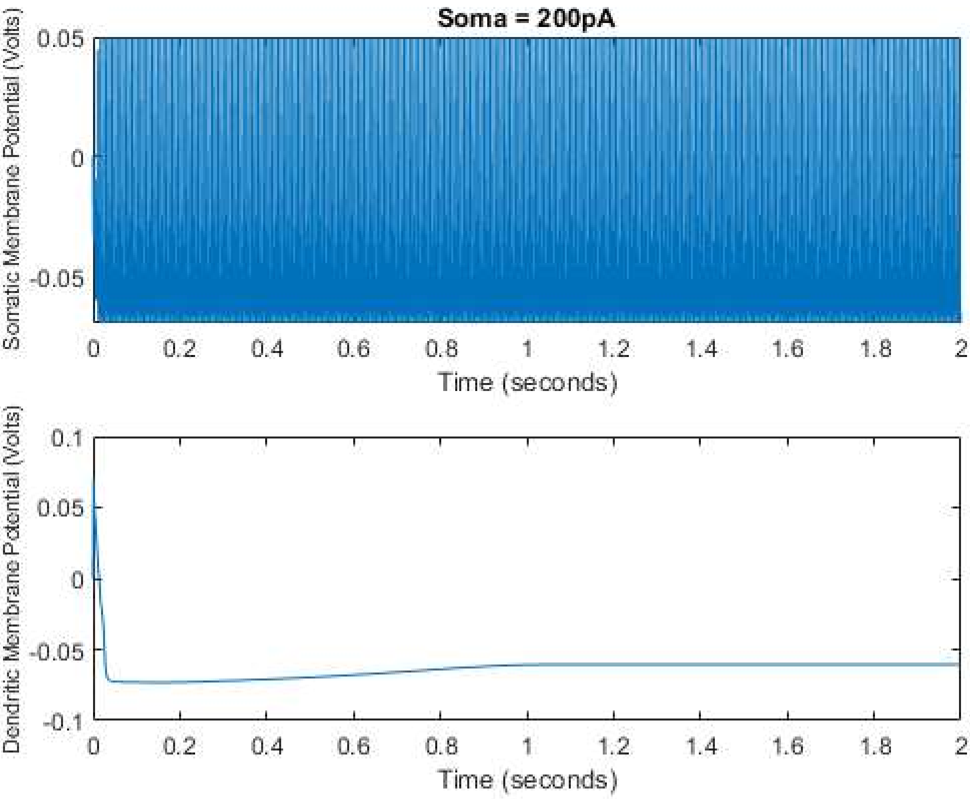
```
%ODE45 Soma change current
[t,y] = ode45(@(t,y) zeroS(t,y),tspan,y0);
[~,y1] = ode45(@(t,y) oneS(t,y),tspan,y0);
[~,y2] = ode45(@(t,y) twoS(t,y),tspan,y0);
%ODE 45 Dendrites change current
[~,y3] = ode45(@(t,y) zeroD(t,y),tspan,y0);
[~,y4] = ode45(@(t,y) oneD(t,y),tspan,y0);
[~,y5] = ode45(@(t,y) twoD(t,y),tspan,y0);
%Plot Results
%Extract Vm of Dendrite and Soma
Vm_soma1 = y(:,1);
Vm_dend1 = y(:,5);
Vm_soma2 = y1(:,1);
Vm_dend2 = y1(:,5);
Vm_soma3 = y2(:,1);
Vm_dend3 = y2(:,5);
Vm_soma4 = y3(:,1);
Vm_dend4 = y3(:,5);
Vm_soma5 = y4(:,1);
Vm_dend5 = y4(:,5);
Vm_soma6 = y5(:,1);
Vm_dend6 = y5(:,5);
%Soma = 50pA;
figure(4)
subplot(2,1,1)
plot(t,Vm_soma1);
ylabel("Somatic Membrane Potential (Volts)", "FontSize", 8);
xlabel("Time (seconds)");
title("Soma = 50pA");
subplot(2,1,2)
plot(t,Vm_dend1);
ylabel("Dendritic Membrane Potential (Volts)", "FontSize", 8);
xlabel("Time (seconds)");
```

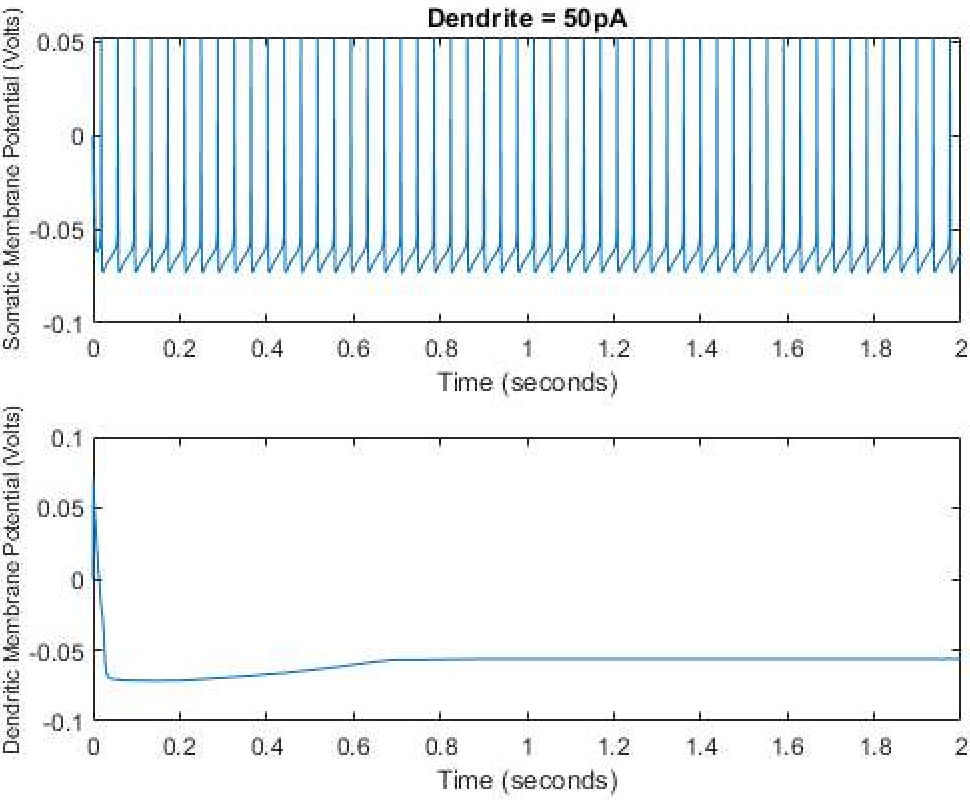
```
%Soma = 100pA;
figure(5)
subplot(2,1,1)
plot(t,Vm_soma2);
ylabel("Somatic Membrane Potential (Volts)", "FontSize", 8);
xlabel("Time (seconds)");
title("Soma = 100pA");
subplot(2,1,2)
plot(t,Vm_dend2);
ylabel("Dendritic Membrane Potential (Volts)", "FontSize", 8);
xlabel("Time (seconds)");
%Soma = 200pA;
figure(6)
subplot(2,1,1)
plot(t,Vm_soma3);
ylabel("Somatic Membrane Potential (Volts)", "FontSize", 8);
xlabel("Time (seconds)");
title("Soma = 200pA");
subplot(2,1,2)
plot(t,Vm_dend3);
ylabel("Dendritic Membrane Potential (Volts)", "FontSize", 8);
xlabel("Time (seconds)");
%Dendrite = 50pA;
figure(7)
subplot(2,1,1)
plot(t,Vm_soma4);
ylabel("Somatic Membrane Potential (Volts)", "FontSize", 8);
xlabel("Time (seconds)");
title("Dendrite = 50pA");
subplot(2,1,2)
plot(t,Vm_dend4);
ylabel("Dendritic Membrane Potential (Volts)", "FontSize", 8);
xlabel("Time (seconds)");
%Dendrite = 100pA;
figure(8)
subplot(2,1,1)
plot(t,Vm_soma5);
ylabel("Somatic Membrane Potential (Volts)", "FontSize", 8);
xlabel("Time (seconds)");
title("Dendrite = 100pA");
subplot(2,1,2)
plot(t,Vm_dend5);
ylabel("Dendritic Membrane Potential (Volts)", "FontSize", 8);
xlabel("Time (seconds)");
%Dendrite = 200pA;
figure(9)
subplot(2,1,1)
plot(t,Vm_soma6);
ylabel("Somatic Membrane Potential (Volts)", "FontSize", 8);
xlabel("Time (seconds)");
title("Dendrite = 200pA");
subplot(2,1,2)
plot(t,Vm_dend6);
ylabel("Dendritic Membrane Potential (Volts)", "FontSize", 8);
xlabel("Time (seconds)");

%Explanation
%When the current is applied on the Soma, it's pretty clear that the more
%current you add onto the Soma the more spikes it's going to emit. While
%the current is applied to the dendrite, the spike counts did not change
%much, rather, the peaks of the dendrites are much higher when there is
%more current applied to the dendrites. The only thing that changed in the
```

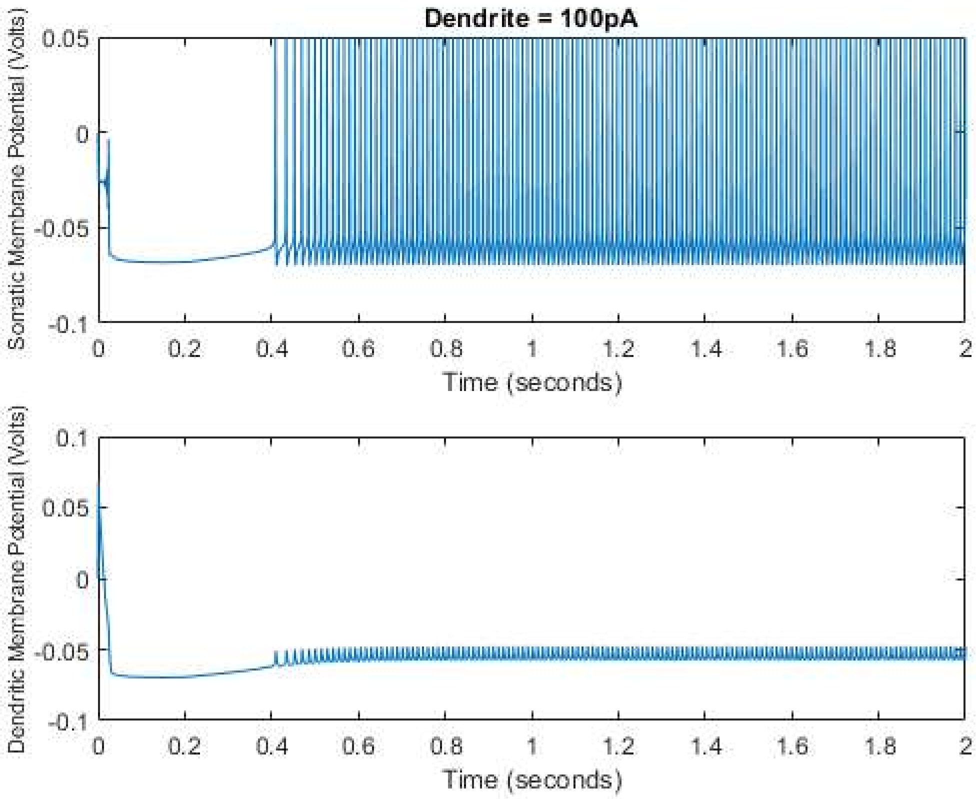
```
%soma is that the during 50pA the soma had that did not fire as crowded where
%as the case of the other two the Soma firing rates are much higher after
%some time.
```

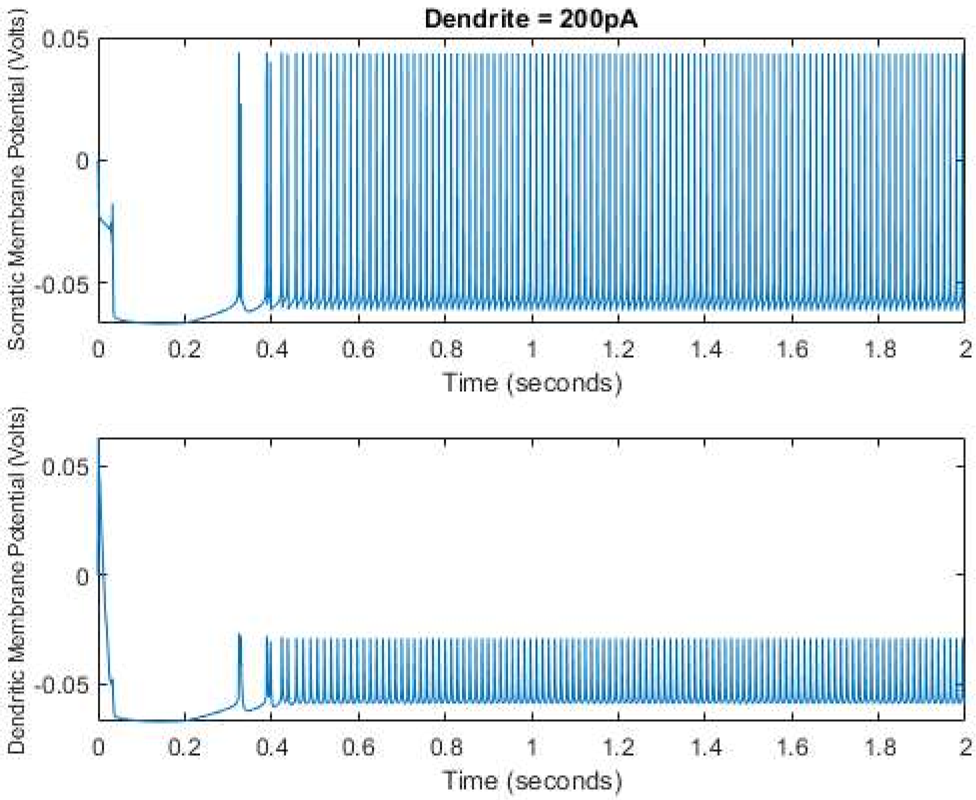





Soma = 200pA
Somatic Membrane Potential (Volts)
0.05
0
-0.05
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (seconds)
Dendritic Membrane Potential (Volts)
0.1
0.05
0
-0.05
-0.1
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (seconds)


Dendrite = 50pA
Somatic Membrane Potential (Volts)
0.05
0
-0.05
-0.1
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (seconds)
Dendritic Membrane Potential (Volts)
0.1
0.05
0
-0.05
-0.1
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Time (seconds)





Published with MATLAB® R2022b

For reference to the code

```
function dy = output(t,y)
%Output Variables  (Eric)
%Soma's matrix column
Vm_soma = y(1); %set matrix column to Vm_soma
m = y(2); % set matrix column to n
h = y(3); % set matrix column to m
n = y(4); % set matrix column to h
%Dendrite's matrix columns
Vm_dend = y(5); % set matrix column to Vm_dendrite
mca = y(6); % set matrix column to m_ca
mkca = y(7); % set matrix column to m_kca
mkahp = y(8); % set matrix column to m_kahp
% Calcium concentration
ca_conc = y(9);

%Defining rate constants (Eric)
[alpha_m, beta_m, alpha_h, beta_h, alpha_n, beta_n ] = PR_soma_gating(Vm_soma);
[alpha_mca, beta_mca, alpha_kca, beta_kca, alpha_kahp, beta_kahp ] = PR_dend_gating(Vm_dend,ca_

% Define constants for the equation (Eric)
AS = 1/3; % fractional area of soma
AD = 2/3; % fractional area of dendrite
GS_leak = AS*5*(10^-9); % somatic leak conductance (S)
GD_leak = AD*5*(10^-9); % dendrite leak conductance (S)
GNa_max = AS * 3 * (10^-6); % maximum sodium conductance (S)
GK_max = AS * 2 * (10^-6); % maximum potassium conductance (S)
GCa_max = AD * 2 * (10^-6); % maximum calcium conductance (S)
GKCa_max = AD * 2.5 * (10^-6); % max calcium-dependent potassium conductance (S)
GKAHP_max = AD * 40 * (10^-9); % max after-hyperpolarization conductance (S)
GLink = 50*10^-9; % link conductance (S)
ENa = 60 * (10^-3); % sodium reversal potential (V)
ECa = 80 * (10^-3); % calcium reversal potential (V)
EK = -75 * (10^-3); % potassium reversal potential (V)
EL = -60 * (10^-3); % leak reversal potential (V)
CS = AS * 100 * (10^-12); % capacitance of soma (F)
CD = AD * 100 * (10^-12); % capacitance of dendrite (F)
tau_Ca = 50 * (10^-3); % calcium delay time constant (s)
k = (5 * 10^6) / AD; % conversion charge->concentration (MC^-1)

%Applied Currents (Eric)
IS_app = 0; % soma applied current (A)
ID_app = 0; % dendrite applied current (A)

%Steady state for all gating variables (Eric and Anthony)
mca_infi = alpha_mca/(alpha_mca + beta_mca);
mkca_infi = alpha_kca/(alpha_kca+beta_kca);
mkahp_infi = alpha_kahp/(alpha_kahp+beta_kahp);
h_infi = alpha_h/(alpha_h+beta_h);
```

```
m_infi = alpha_m/(alpha_m+beta_m);
n_infi = alpha_n/(alpha_n+beta_n);

%Time constant for all gating variables (Eric and Anthony)
mca_tau = 1/(alpha_mca + beta_mca);
mkca_tau = 1/(alpha_kca+beta_kca);
mkahp_tau = 1/(alpha_kahp+beta_kahp);
m_tau = 1/(alpha_m + beta_m);
h_tau= 1/(alpha_h + beta_h);
n_tau = 1/(alpha_n + beta_n);

%ODE for soma gating (Eric and Anthony)
dm_over_dt = (m_infi-m)/m_tau;
dh_over_dt = (h_infi-h)/h_tau;
dn_over_dt = (n_infi-n)/n_tau;
%ODE for dendrite gating (Eric and Anthony)
dmca_over_dt = (mca_infi-mca)/mca_tau;
dmkca_over_dt = (mkca_infi-mkca)/mkca_tau;
dmkahp_over_dt = (mkahp_infi-mkahp)/mkahp_tau;
%ODE for Ca concentration (Eric and Anthony)
Ica = GCa_max*mca^2*(ECa-Vm_dend);
dca_over_dt = (-ca_conc/tau_Ca) + k * Ica;
%X as function of Ca_conc (Eric)
if (4000*ca_conc < 1)
    X_val = 4000*ca_conc;
else
    X_val = 1;
end
%ODE for Soma (Mauricio)
I_leak_soma = GS_leak*(EL-Vm_soma);
Na_leak = GNa_max*m^2*h*(ENa-Vm_soma);
K_leak = GK_max*n^2*(EK-Vm_soma);
link_soma = GLink*(Vm_dend-Vm_soma);
Vms_over_dt = (I_leak_soma + Na_leak + K_leak + link_soma + IS_app) / CS;

%ODE for Dendrite (Mauricio)
I_leak_den = GD_leak*(EL-Vm_dend);
Ca_leak = GCa_max*mca^2*(ECa-Vm_dend);
Ca_dep_K_I = GKCa_max*mkca*X_val*(EK-Vm_dend);
Kahp_I = GKAHP_max * mkahp * (EK-Vm_dend);
link_den = -1*(GLink * (Vm_dend-Vm_soma));
Vmd_over_dt = (I_leak_den + Ca_leak + Ca_dep_K_I + Kahp_I + link_den + ID_app) / CD;

%Wrapper function
dy = [Vms_over_dt;dm_over_dt;dh_over_dt;dn_over_dt;Vmd_over_dt;dmca_over_dt;dmkca_over_dt;dmkah

end %function end
```