Report for tutorial 4.3

Question 1 (Overview). Both `PR_dend_gating.m` and `PR_soma_gating.m` are saved in the folder. The main function file is `intrinsic_burster.m`

Function `gating_variable.m` is a helping method, which is used to calculate change of gating variable in each time step. `PR_dend_gating.m` and `PR_soma_gating.m` are downloaded from online material, calculates the rate constants. Edit variable `question_number` in `intrinsic_burster.m` to view plots from different questions in the tutorial. Accepted values for `question_number` are 2, 3, 5, and 6. The figures returned for each question number are illustrated as follow:

`question_number`=2 will return plots of rate constants' relationship to either membrane potential or Ca concentration in fig. 1.

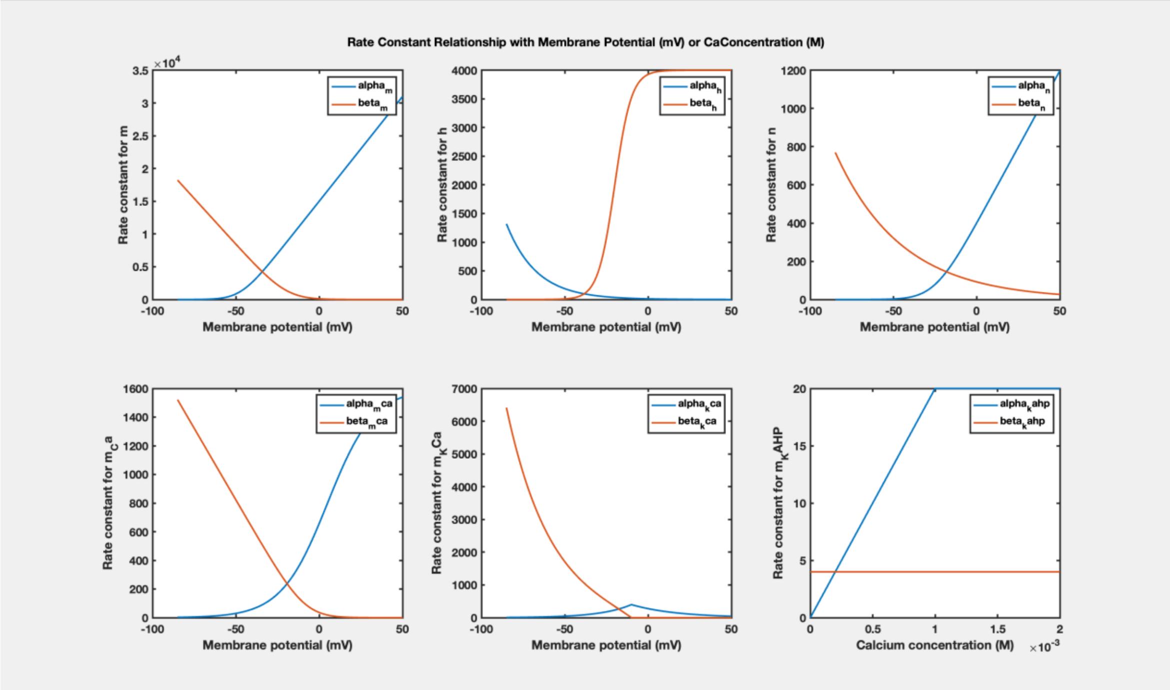
`question_number`=3 (or 4) will return both somatic and dendritic membrane potential in fig. 2, simulating the Rinsky-Rinzel model for 2 seconds. There will be counts of spikes and bursts returned in the command window.

`question_number`=5 will return the plot as question 3 (fig. 3-6, change `G_link` value at line 132 to view them). It will additionally return plot (fig.7, 8) showing the correlation between G_link value (0-100nS) and spike number in 2 second, as well as the number of spikes per burst, in the model from question 3.

`question_number`=6 will return plots as in question 3 (fig. 9-11, 14-16, change `Iapp_D and Iapp_S` at line 142 and 143 to view them). It will additionally return plots (fig.12, 13, 17, 18) showing the correlation between applied (0-200pA) current and spike number in 2 second, as well as the number of spikes per burst, in the model from question 3. Switch `mode` at line 6 to either 's' or 'd' to apply the current to either soma or dendrite.

Question 2.

Fig.1



Question 3.

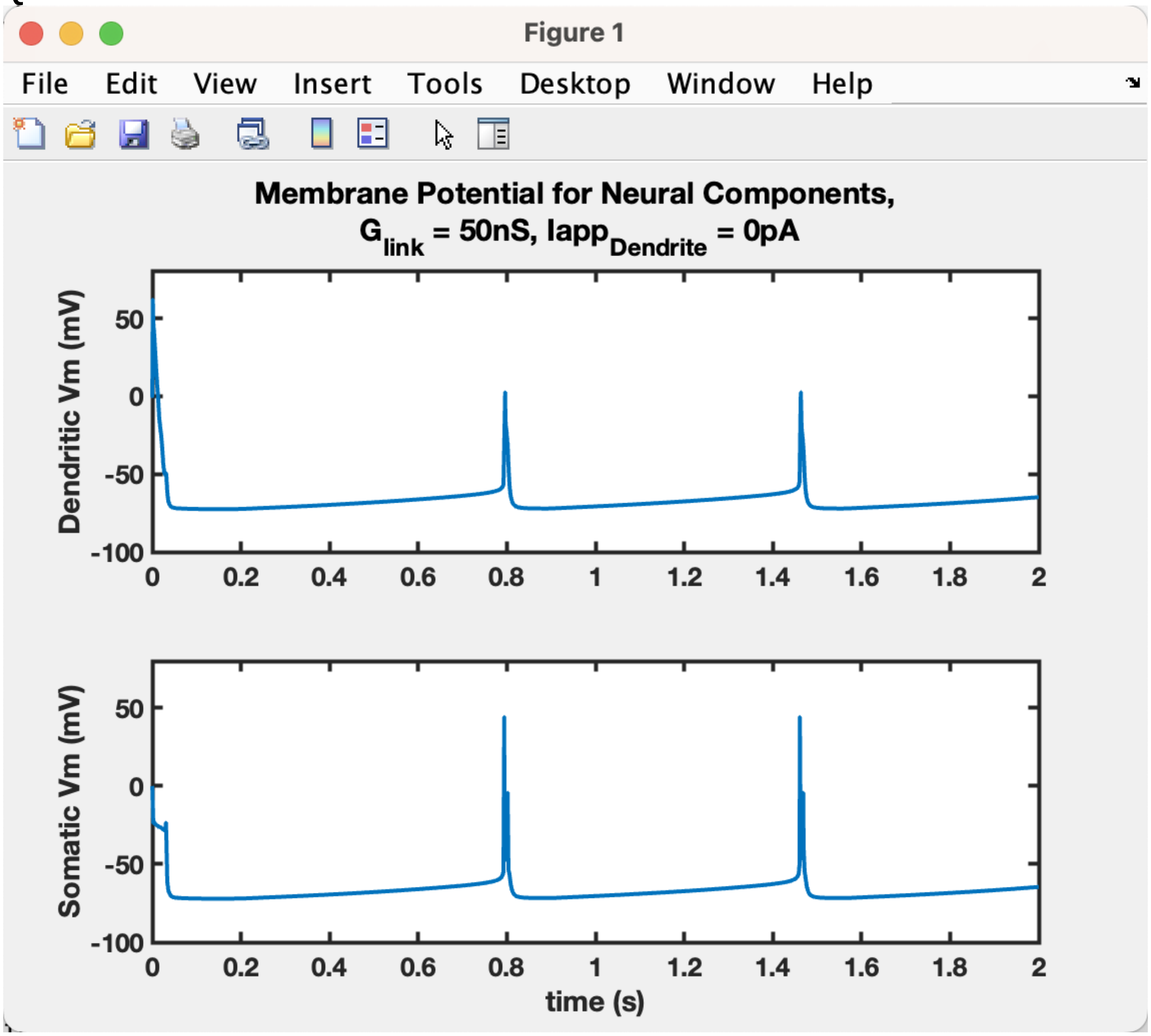


Fig.2

Question 4.

Number of peaks detected in question 3 plot is 8 when G_link is 50nS.

Question 5

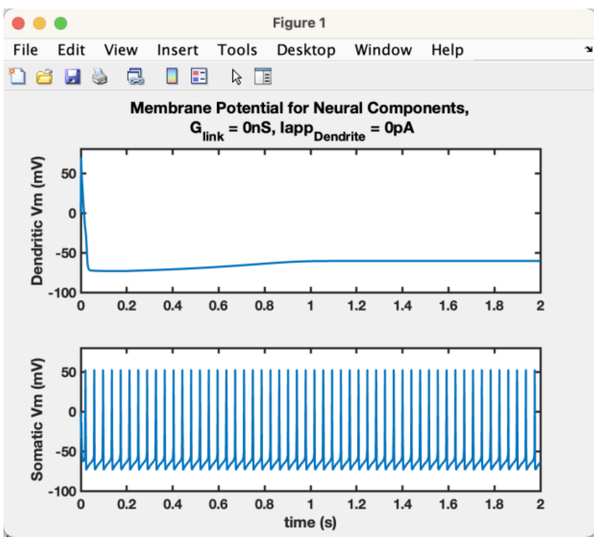


Fig. 3

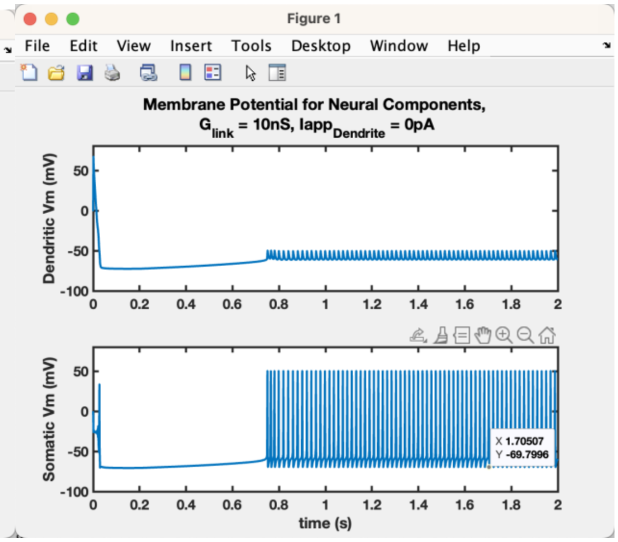


fig. 4

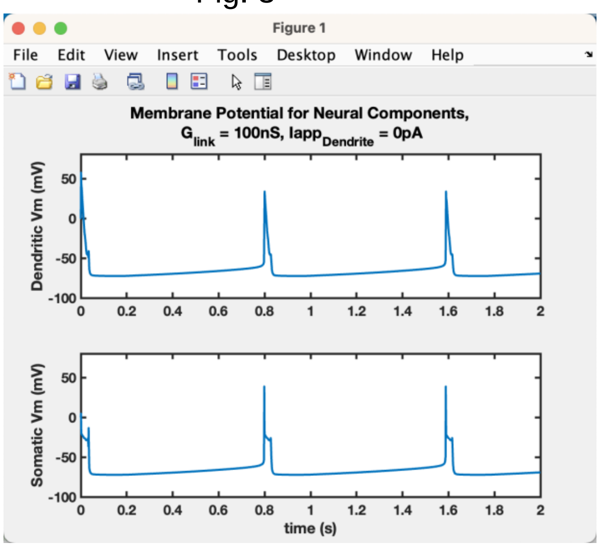


Fig. 5

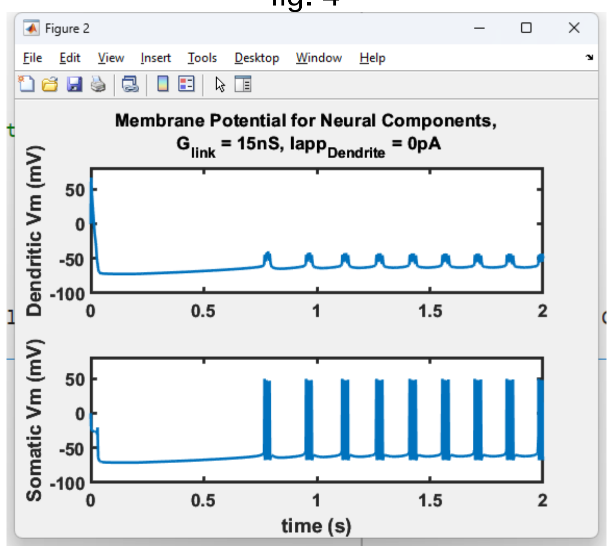


fig. 6

Without any external applied current, the number of somatic peaks in 2 seconds is 52 when G_link is 0 nS. (fig. 3)
When G_link is 10 nS, the number of somatic peaks in 2 seconds is 67. (fig. 4)
When G_link is 100nS, there are only 2 somatic spikes in two seconds. (fig. 5)
There isn't a linear relationship between G_link value and number of spikes. The number of spikes would maximize when G_link is around 10-13nS at 67. The spike number would suddenly drop when G_link increases from 15 to 18nS. It will then fluctuates at low number (<=10 spikes) when G_link is 20-60nS. When G_link is greater than 60nS (less than 100nS), the spike number would stabilize at 2. (fig. 7A)

The spike numbers are plotted in the following graphs. Left (7A) has G_link range from 0 to 100 nS, right (7B) has range from 0 to 20 nS to show the general trend.

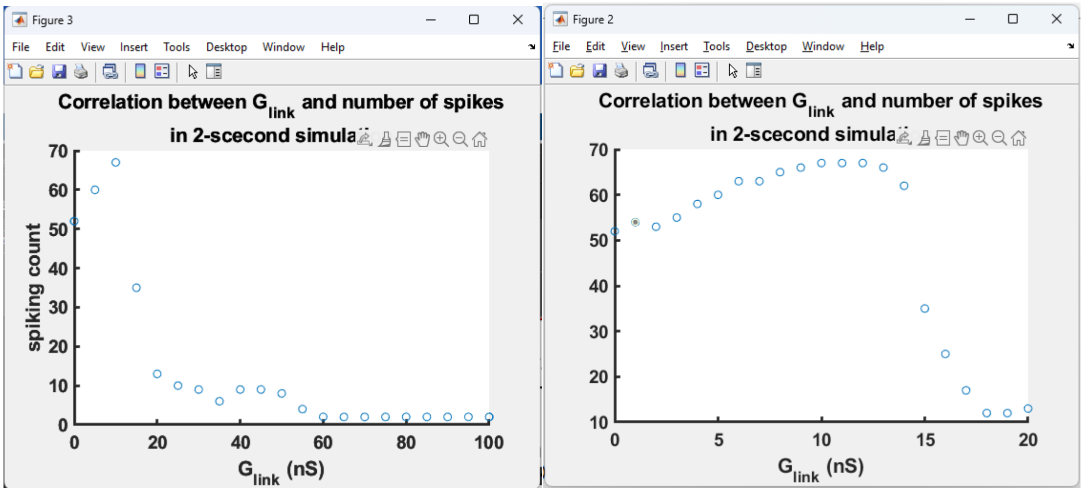


Fig. 7 (A) (B)

When G_link = 0-14nS, there's continuous firing throughout the simulation with increasing inter-spike intervals (reaching a constant firing rate).

There's huge drop when G_link >= 15nS, because the somatic compartment starts to reveal the behavior of an intrinsically bursting neuron (fig. 6). There's a firing burst, with more than 100ms interval between each burst. The firing is no longer continuous. Within each burst, there are multiple condensed spikes within each burst, fires at a high firing rate.

When G_link is greater than 60nS, the number of spikes stabilizes because there is only spike within each burst. Within a burst, the somatic membrane potential oscillates after the spike, but it is unable to reach the upper threshold for spiking.

This observation would be clear if we plot the average number of spikes per plot under different G_link values (fig. 8). I count the number of bursts when inter-spike interval is greater than 12ms. If the number of spikes per burst is above 1.5, it shows the behavior of intrinsic burster. And the range of G_link is between 15 and 60 nS.

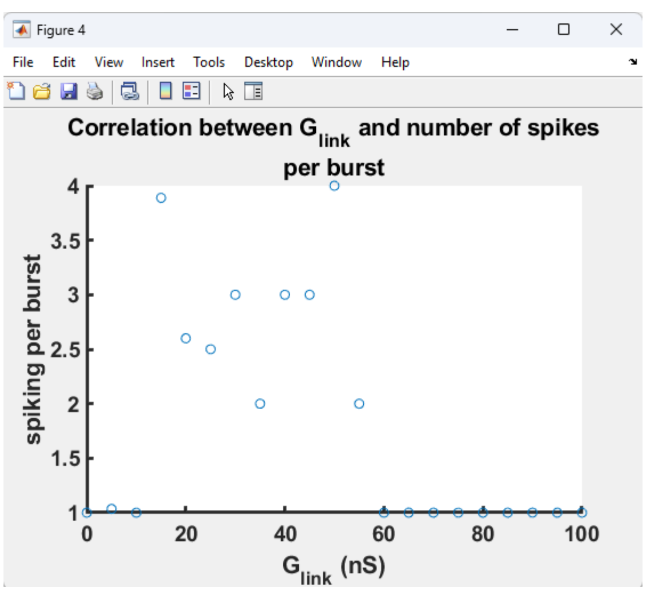


fig.8 (left)

G_link is the reverse of resistance, deciding the flow of link current from compartments. When G_link is too small, R is large, link current would be small, soma and dendrites are relatively more independent from each other. Somatic spiking could be analogous to single-compartement neuron models.

In contrast, when G_link is too large, link current would be large, flowing from higher membrane potential (dendrite) to lower membrane potential (soma). Therefore, the current would not be strong enough to support firing for multiple times during bursting. Either case would terminate models' bursting behavior.

Question 6.

Assessment to Dendritic Applied current:

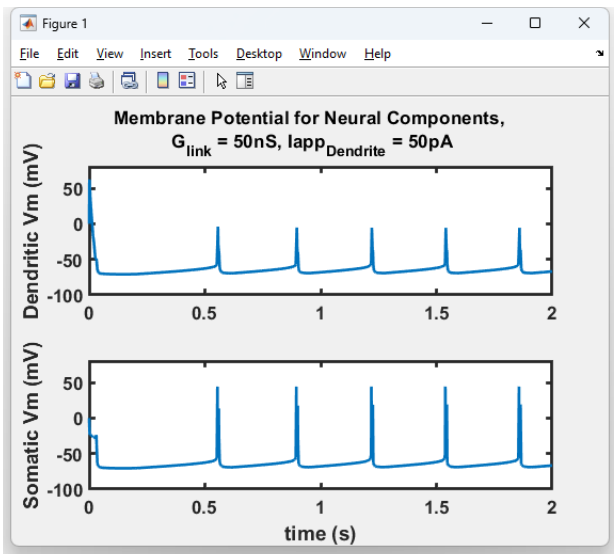


Fig. 9

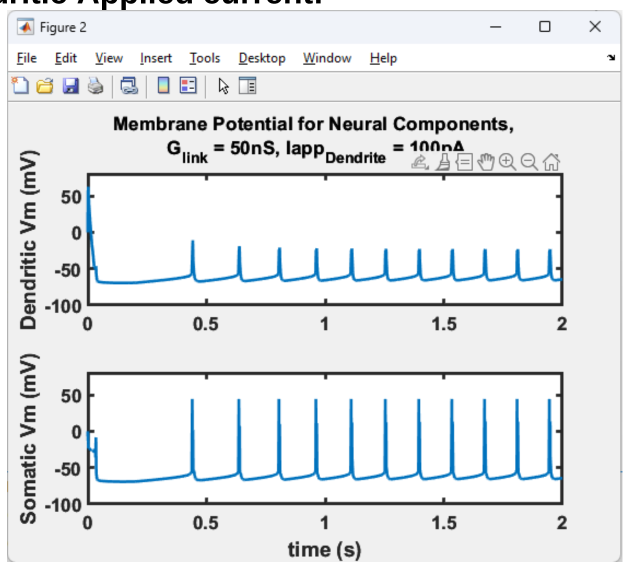


fig. 10

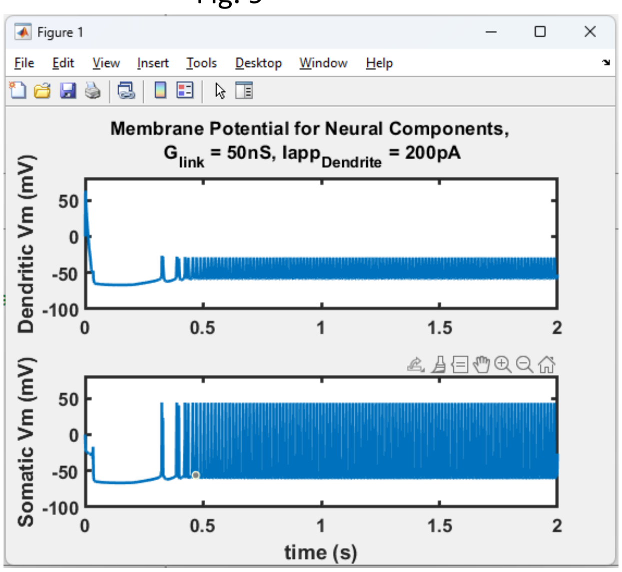


Fig. 11

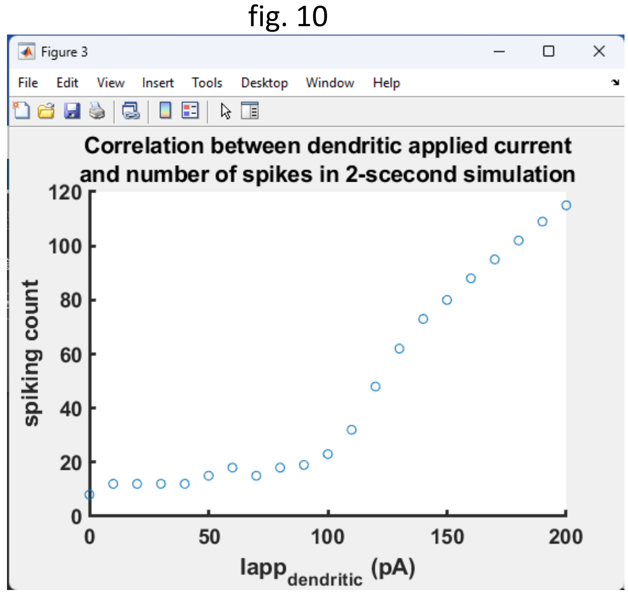


fig. 12

There are 15 somatic spikes when the dendritic applied current is 50 pA (fig.9), 23 somatic spikes when dendritic applied current is 100 pA (fig.10), and 115 somatic spikes when Iapp is 200 pA (fig. 11). There's a positive correlation between dendritic applied current and number of spikes.

Figure 12 shows a positive correlation between number of spikes and dendritic applied current. This makes sense because applied current would increase the firing rate. Furthermore, to show when the model behaves as the intrinsic burster, I did the same plot as question 5 – count spike number and bursting number, then plot the average number of spikes per burst (fig.13) by Iapp_D value. The graph shows a degradation in the average number of spikes per burst. It's obvious that the model stops showing intrinsic bursting properties when the Iapp to dendrite is greater than 150pA. When Iapp increases, the inter-burst interval would decrease, and ISI within a burst would increase. Gradually, when Iapp is greater than 150pA, the intrinsic bursting behavior would disappear, and the dendrites tends to fire at a constant firing rate.

At a reasonable G_link condition, soma would burst even without applied current to dendrite. When Iapp increases, the firing rate would increase (spikes number increases); meanwhile, the interval between each burst decrease (i.e. the number of burst increases). To compromise this trend, the number of spikes per burst would decrease when Iapp increases. When the number of spikes drops to 1, the neuron no longer shows the behavior of intrinsic burst (when Iapp_D is 150 pA).

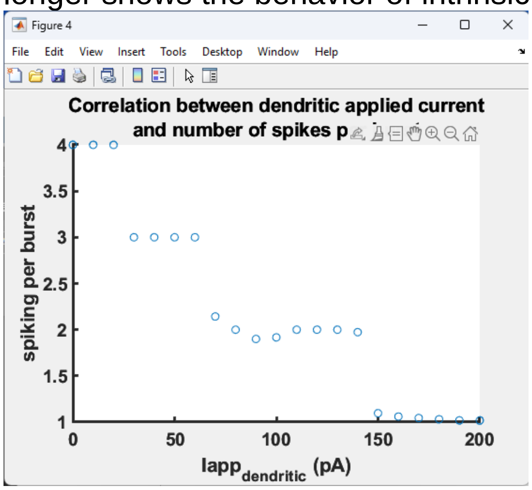


fig. 13

Assessment to somatic applied current:

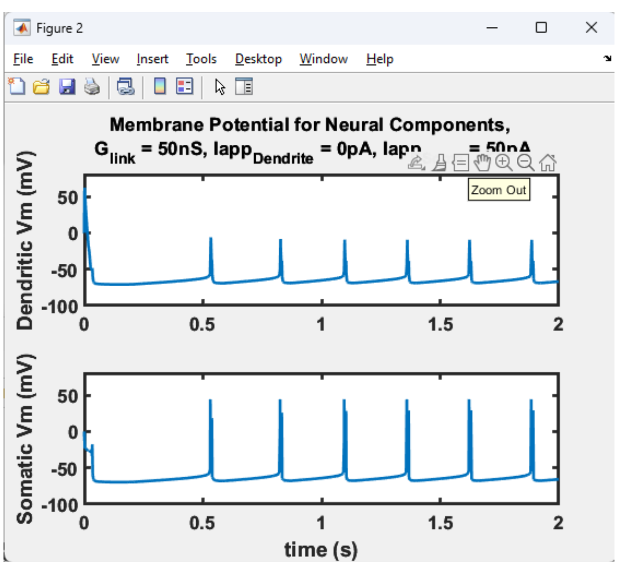


Fig. 14

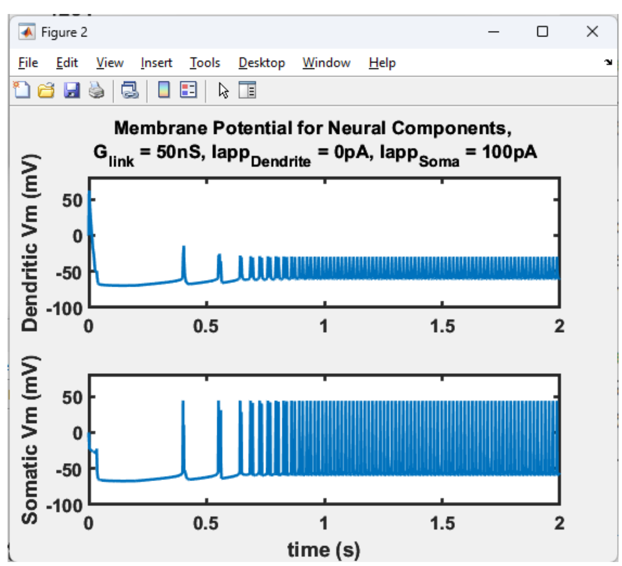


fig. 15

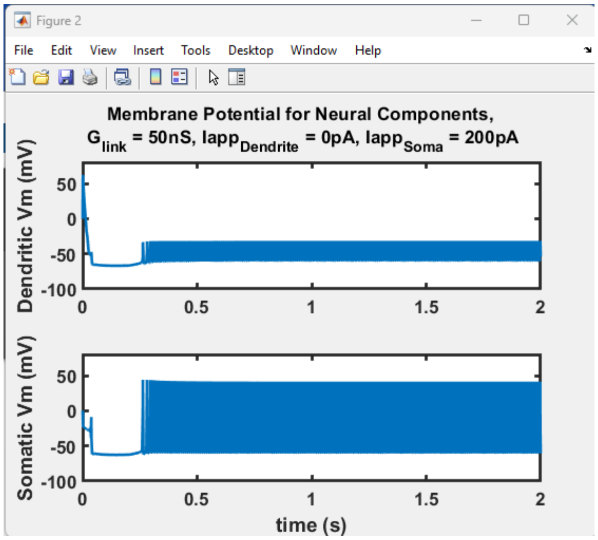


Fig. 16

Applied current on soma shows similar behavior as on dendrite. Only difference is that the Iapp threshold for the model to stop showing intrinsic bursting behavior becomes lower. The threshold Iapp to soma to let the model stop making intrinsic bursting is 100 pA, compared to 150pA when applied to dendrite (fig. 17, 18). This is because when Iapp is on dendrite, there would be less amount of current transported from the linkage; when current is applied on soma, there would be higher proportion of applied current that contributes to firing and bursting (considering reasonable amounts of current "leaked" from soma to dendrite), since Iapp_soma could have more direct effects on soma compared to Iapp_dendrite. Otherwise, Iapp_S and Iapp_D have the same influence on model's bursting properties.

Noted the firing rate is too high when Iapp_soma is above 100pA, and the original method cannot distinguish bursts (ISI is too small). Therefore, if it counts more than 5 spikes per burst, I assume that there's no bursting behavior at all (please ignore the bursts count in console when mode='s' and Iapp_S is greater than 100 pA).

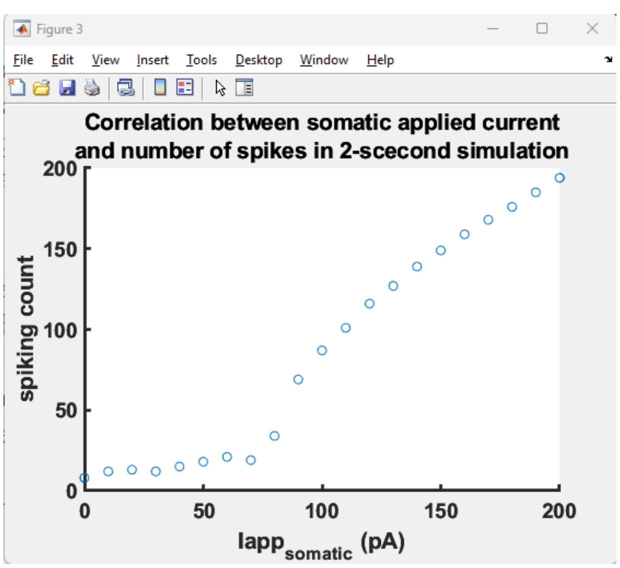


Fig. 17

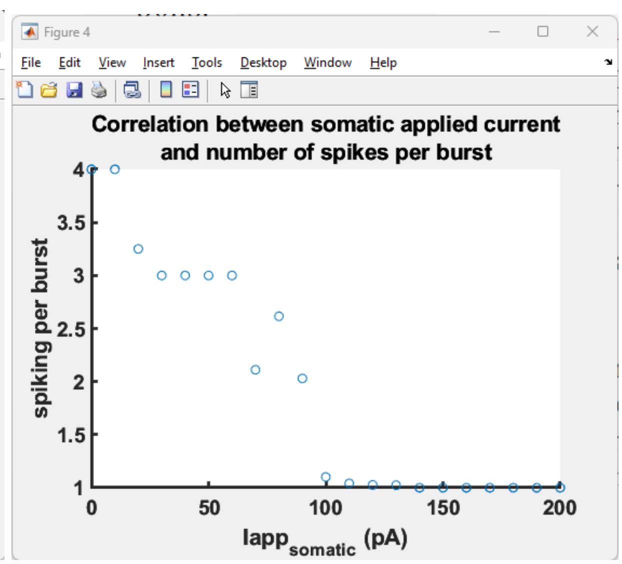


fig. 18