Exercise 1 – Phase 1

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Code Summary

the models are implemented in class structures, one for LIF models which is the mother class (super class), and another for AELIF which is the child class (inherited class).

Class methods:

__init__ method : which obviously initiates the inputs which are the hyper parameters and those we would need later on, like derak(deerak ?, dearuk ?, dearak ? (IDK)) function and such

Simulate method : which runs the neuron simulation for the specified Time period in the Init. Simply a while loop which calculates the potential of each time step using the formula presented in the Slides

$$\tau \cdot \frac{du}{dt} = -(u - u_{rest}) + R \cdot I(t); \quad \text{If firing: } (u = u_{reset})$$

For those instances who are going to be simple LIF there's a explicit method for calculating and plotting the FI_curve, this method could be merged with Simulate method, but for the cause of having more modularity and of course more optimized runtime it is implemented individually.

And the are a method for each Plot (U, I, FI, W) and they will be called individually when needed

AELIF class

This class is a child class of the previous one, meaning we only change the Simulate Function to match our needs, this time when using the formula above, we have 2 more terms, one for adding Adaptiveness and the other for adding Exponentiality to our code. (this 2 features could be turned off or on so that we would be able to try out an input with only 1 of these features if desired, though I didn't implement what I just implied but it's only one line of code and will be implemented if necessary)

$$
\begin{aligned}
\tau_m \frac{du}{dt} &= F(u) - R \sum_k w_k + RI(t), \\
\tau_k \frac{dw_k}{dt} &= a_k(u - u_{rest}) - w_k + b_k \tau_k \sum_{t^f} \delta(t - t^f),
\end{aligned}
$$

With F(u) representing the exponential term with the formula of :

$$
\tau \cdot \frac{du}{dt} = \boxed{-(u - u_{rest}) + \Delta_T \exp\left(\frac{u - \theta_{rh}}{\Delta_T}\right)} + R \cdot I(t);
$$

Now let's look at some simulations.

These 3 are simulations based on a simple LIF model. Note that the FI curve of the first 2 simulations look the same due the fact the all the hyperparameters of those 2 are the same except for the Current Input(I) which wouldn't play any role in the calculation of our FI_Curve

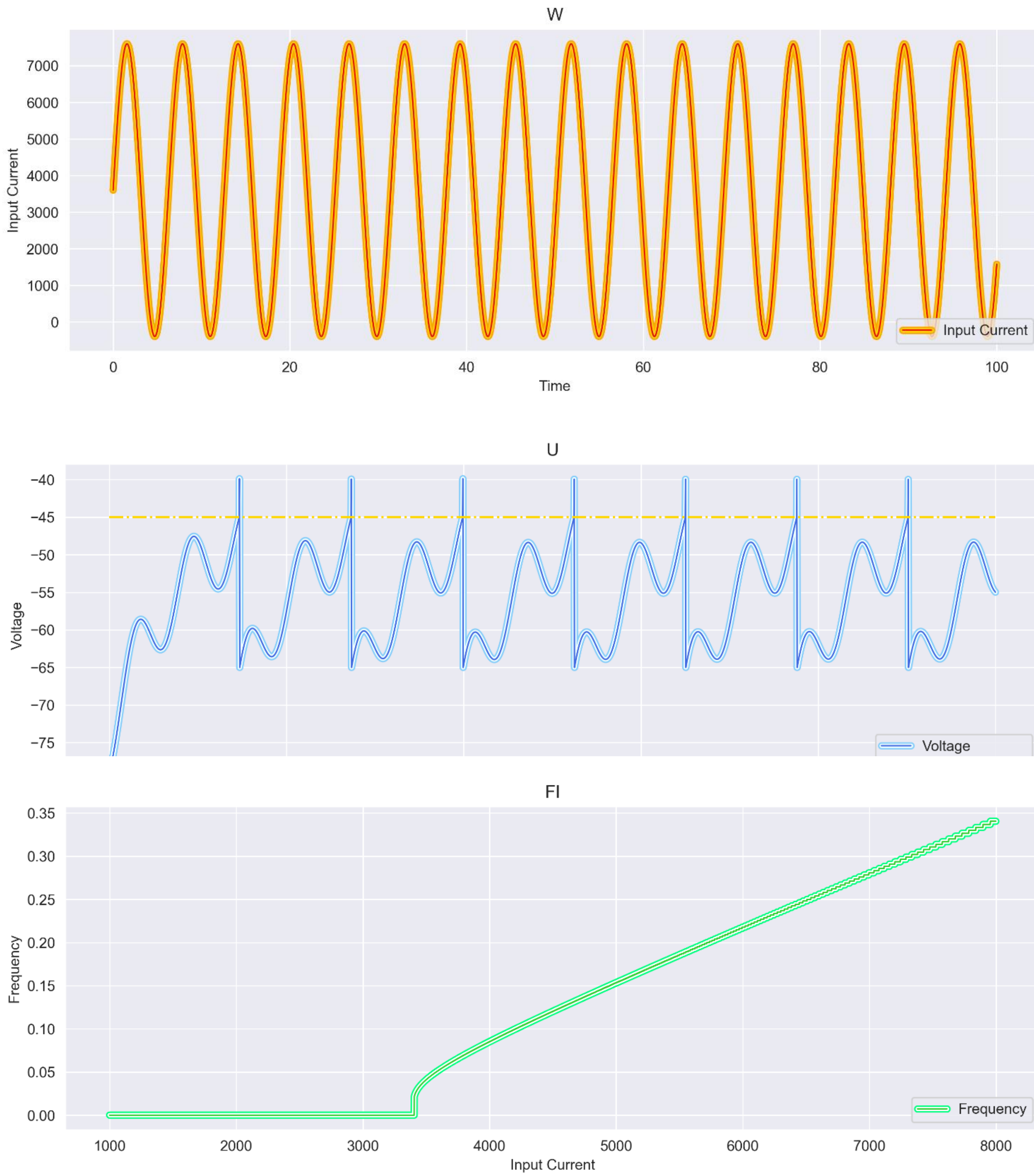
The first one uses the exact parameters stated in the DOC which is as it follows :

Parameters

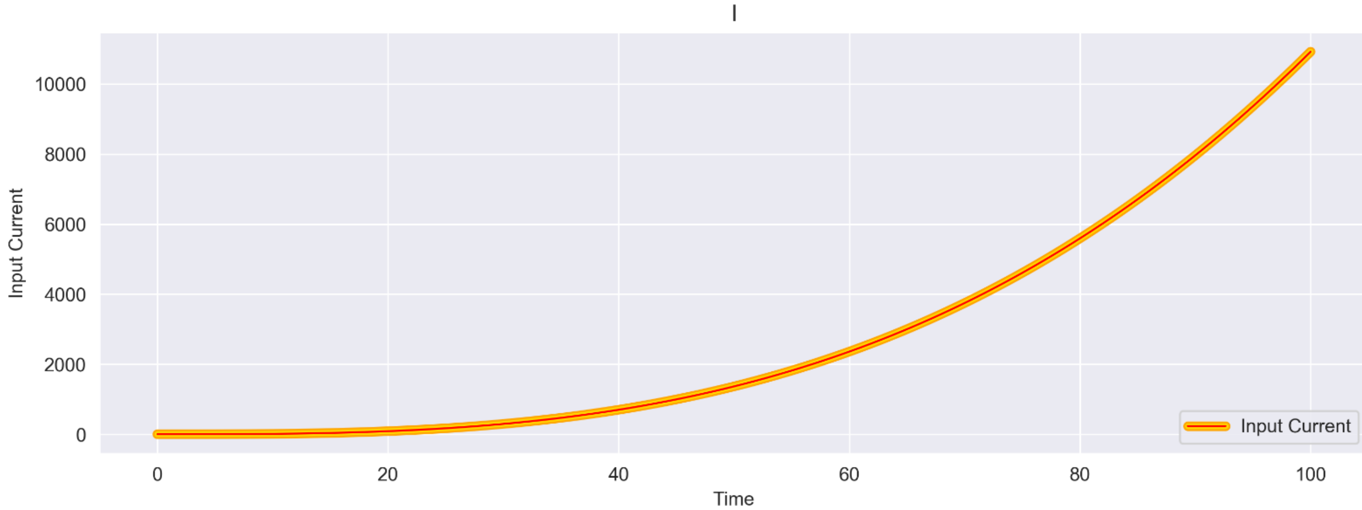
Total Time Frame: 100 ms
dt: 0.03125 ms

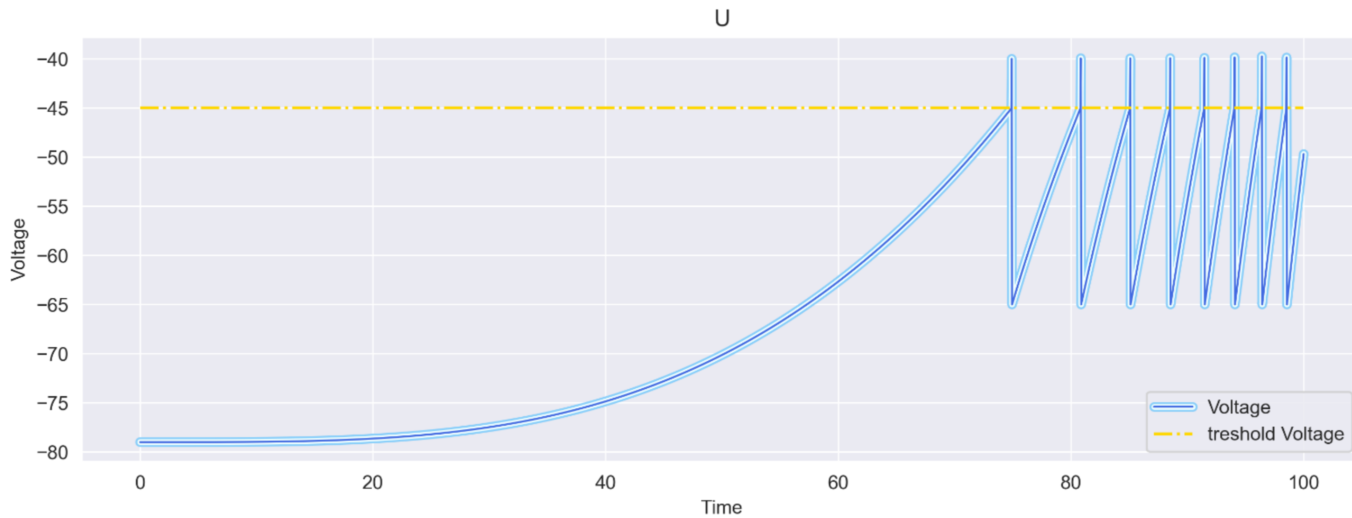
Initial Refractory Time: 0 ms
Refractory Period: 0 ms

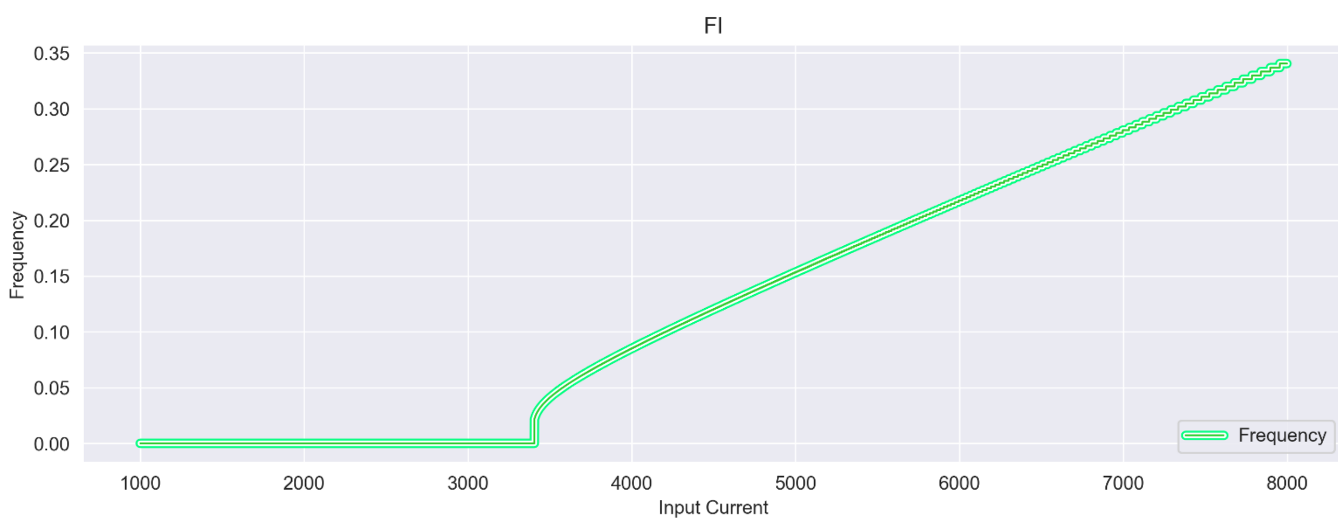
R_m: 10 MΩ
τ_m: 8 ms
$V_{threshold}$: -45 mV
V_{rest}: -79 mV
V_{reset}: -65 mV
V_{spike}: 5 mV



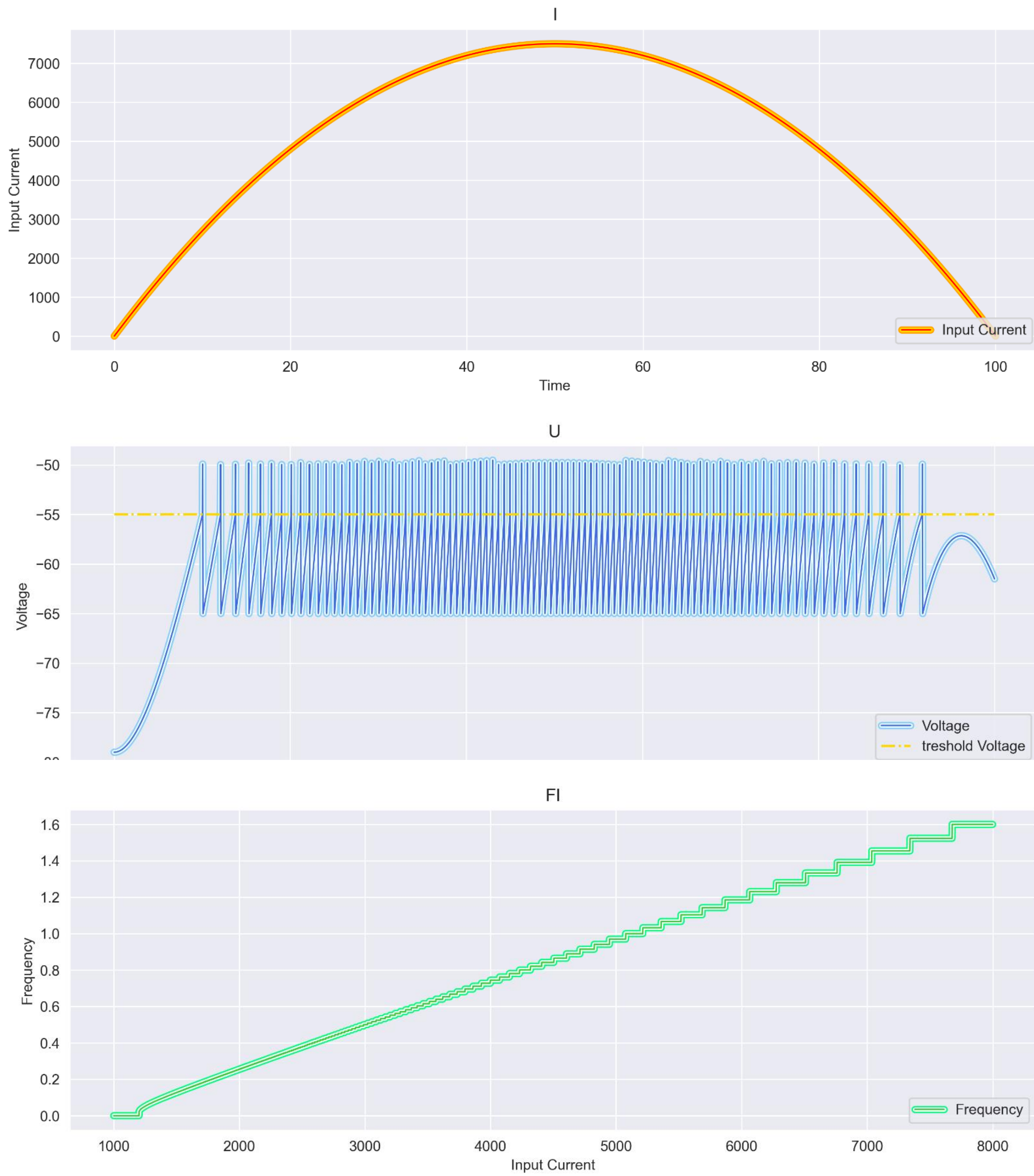
This one uses the same inputs only the different Current Input (I)



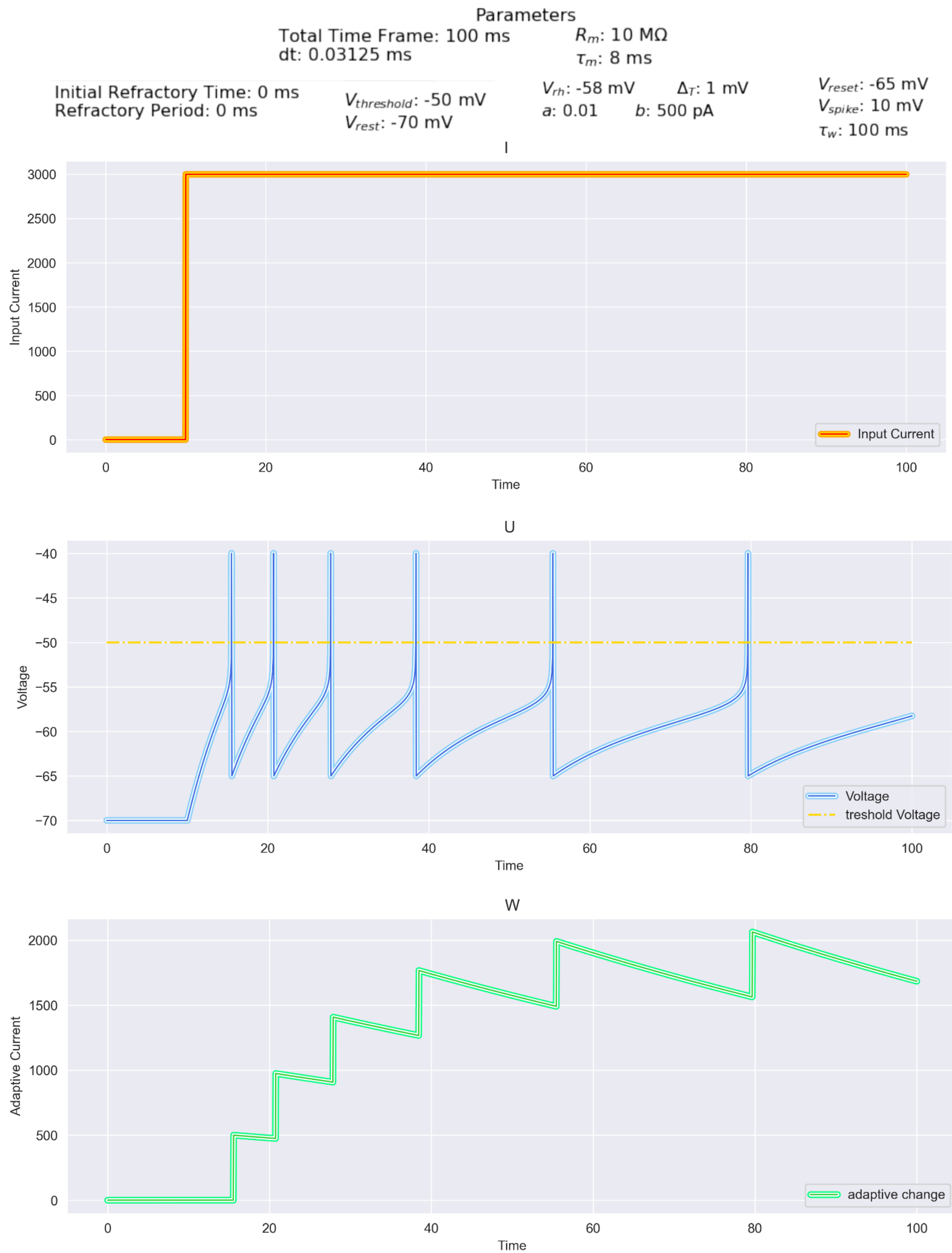


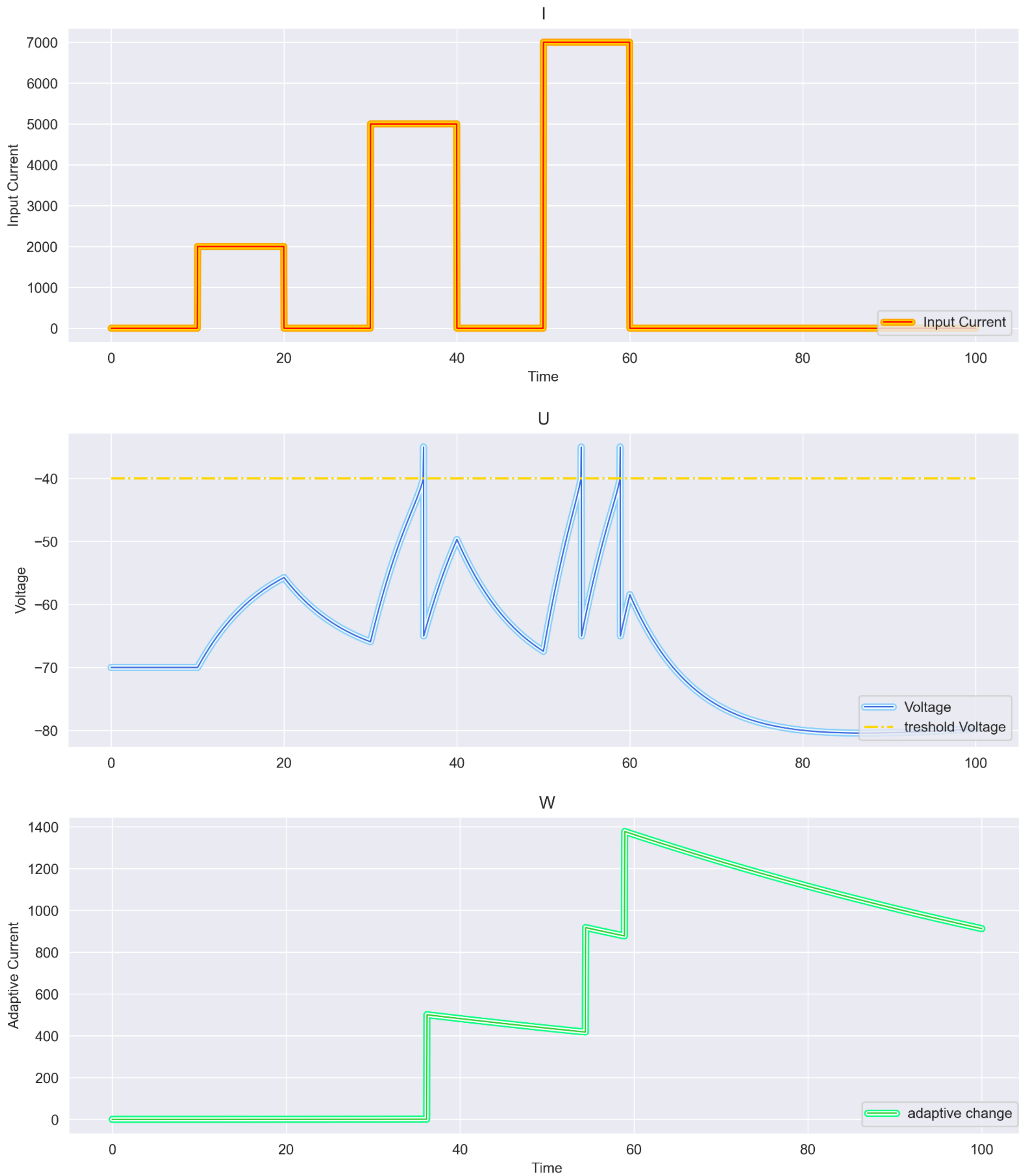


The third one has the same parameters except for R being changed to 20 and threshold being changed to -55, here a change has been applied to the FI_Curve which shows that with reducing the threshold and increasing in R we will have a higher rate of Spikes (1.6 frequency at top rate vs 0.35 frequency of Spiking at top rate) the rest of the information in the plots Speaks for themselves, and require no more need of explanation.



There are 5 more simulation made with the AELIF model which is shown below, also there is a slight analysis at the end of the images. (the first two use the exact param as the DOC did)





Parameters

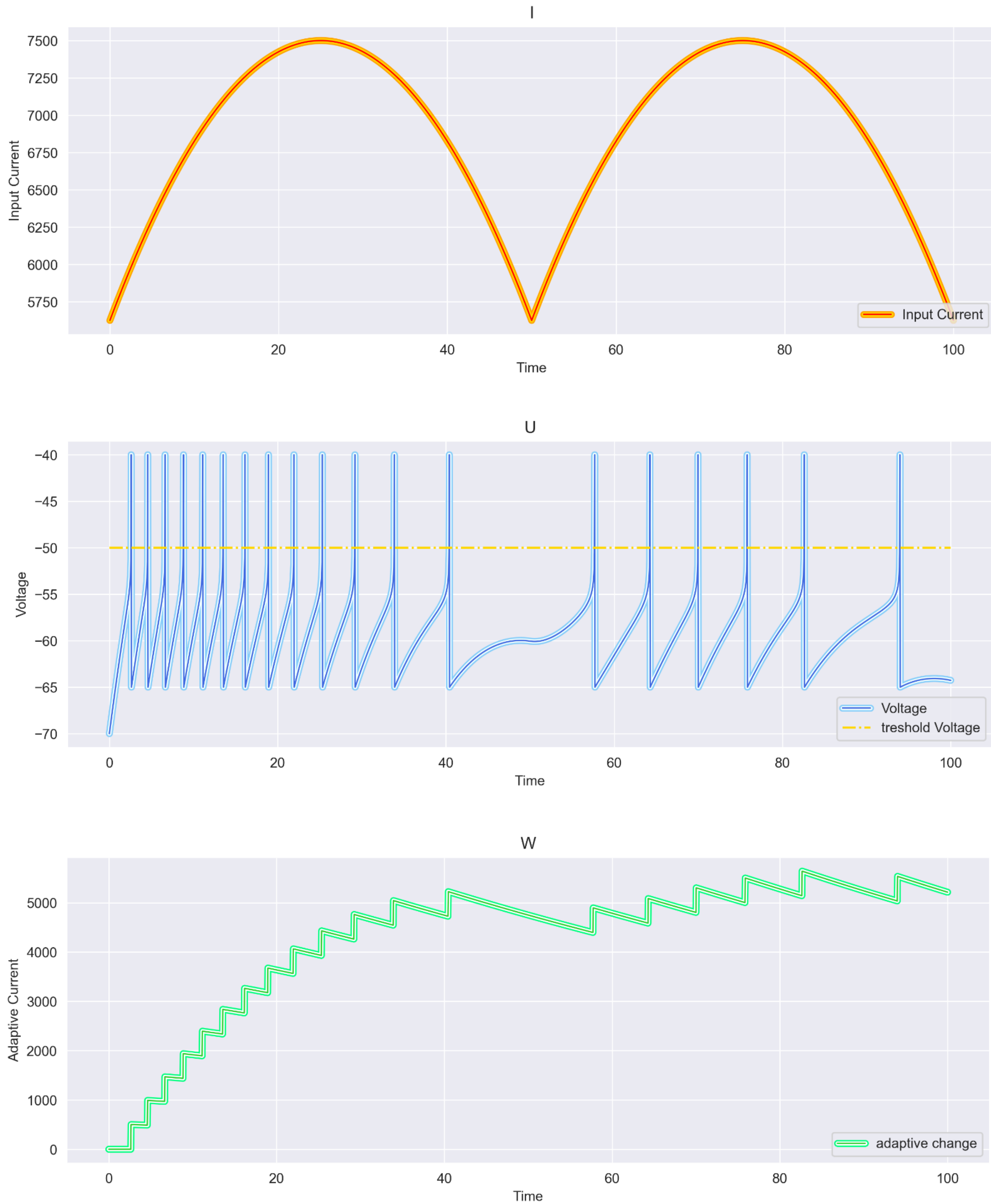
Total Time Frame: 100 ms
dt: 0.03125 ms
Initial Refractory Time: 0 ms
Refractory Period: 2 ms

R_m: 10 MΩ
τ_m: 8 ms
$V_{threshold}$: -40 mV
V_{rest}: -70 mV

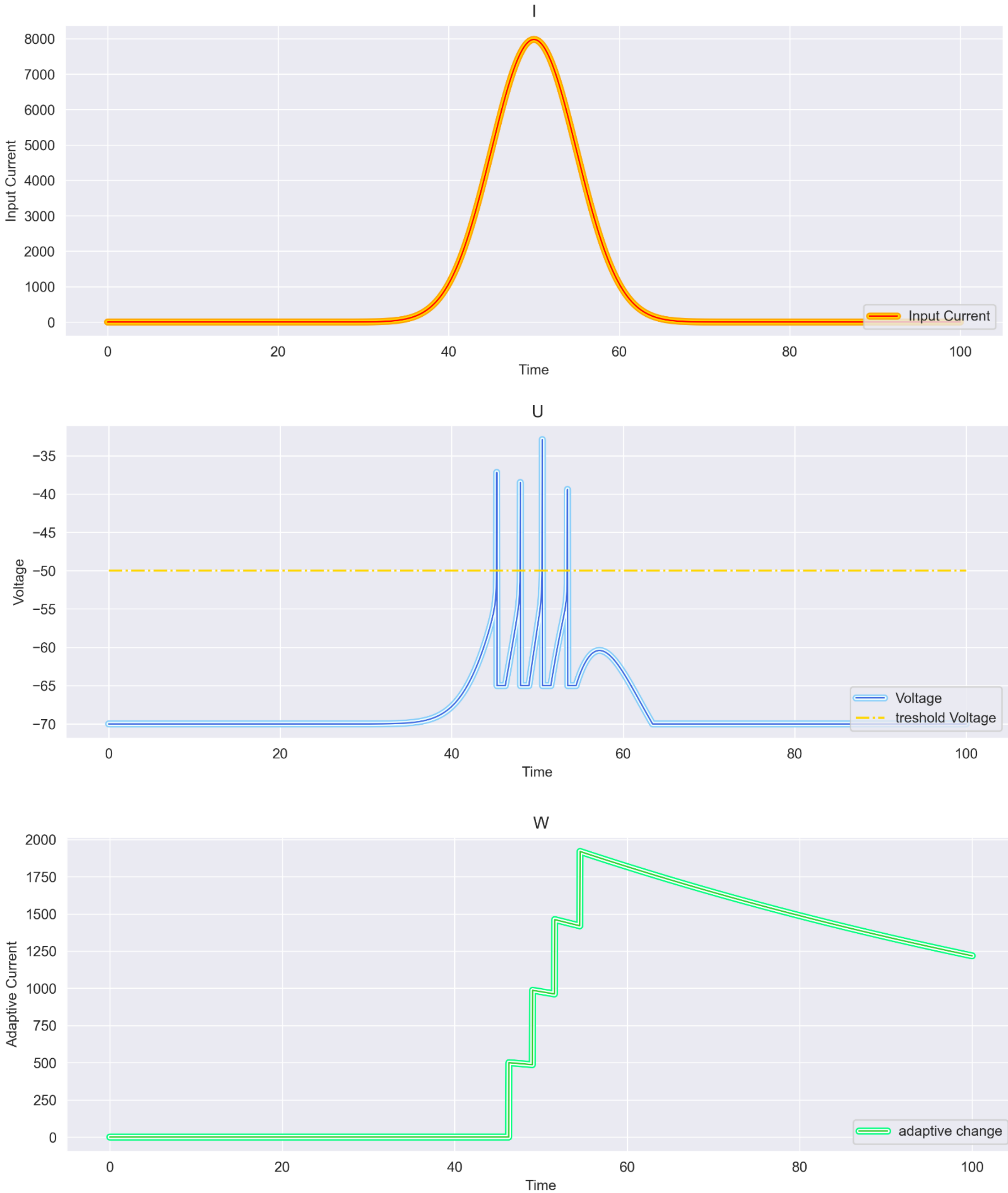
V_{rh}: -45 mV Δ_T: 2 mV
a: 0.01 b: 500 pA

V_{reset}: -65 mV
V_{spike}: 5 mV
τ_w: 100 ms

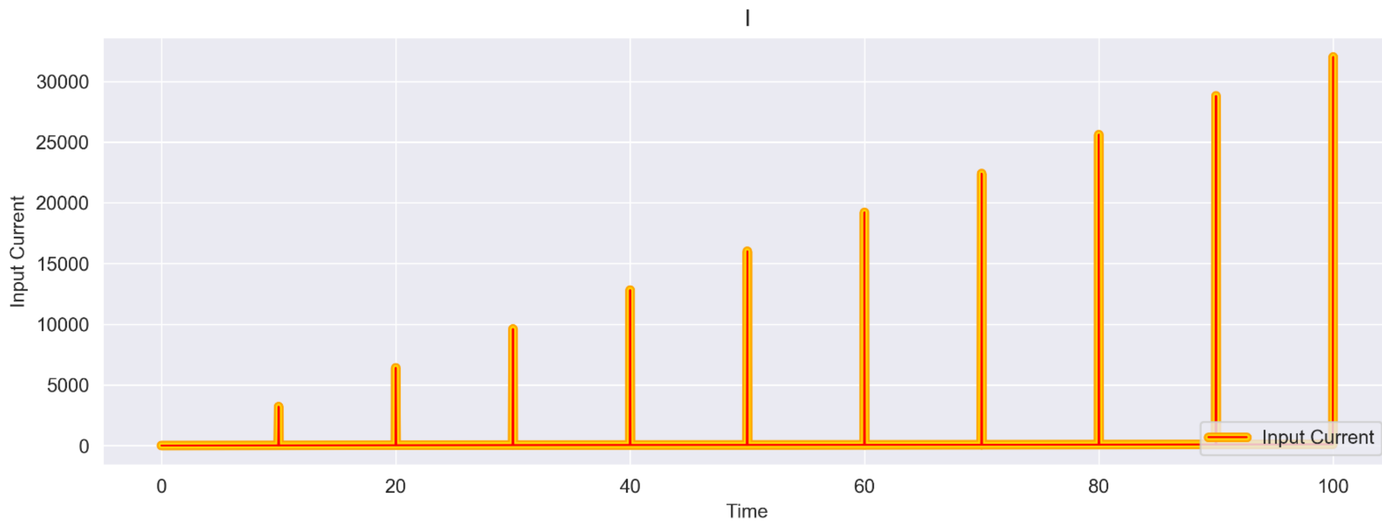
The rest of the simulations are using the settings same as the first AELIF.



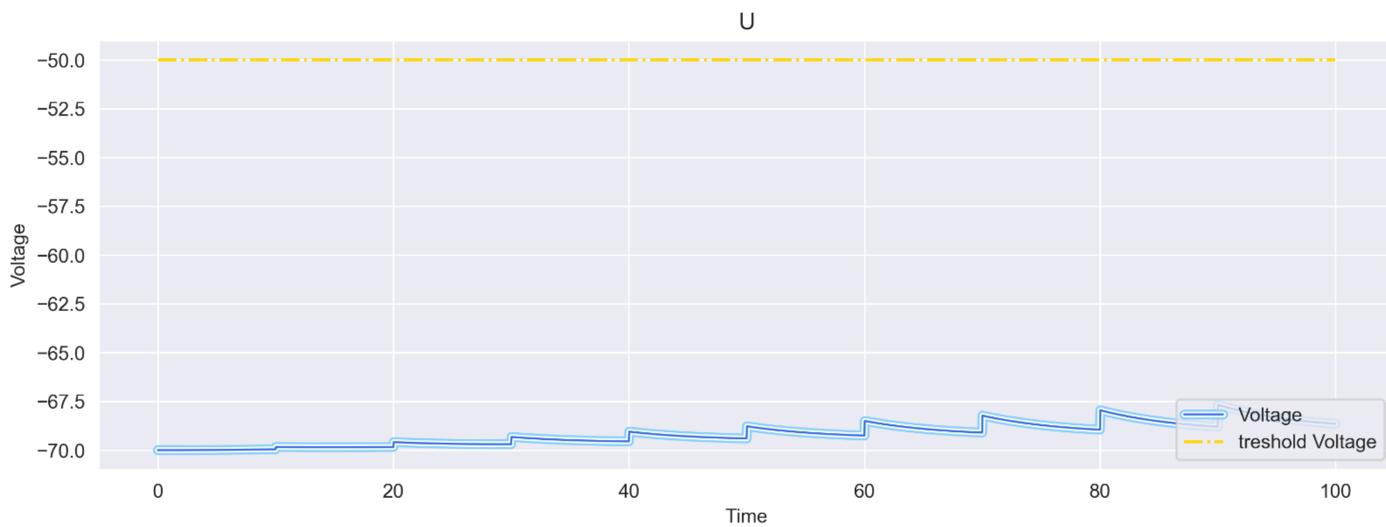
A gaussian distribution :



This last one is a simulation based on glancing inputs where we have 10 momentary bursts of Input Current, I tried 2 variations of it, the first which is shown below didn't cause any spikes as it was not enough to excite the neuron enough to reach threshold. The inputs are around 10 K in average, seemingly it is not enough for burst inputs current and we need higher currents

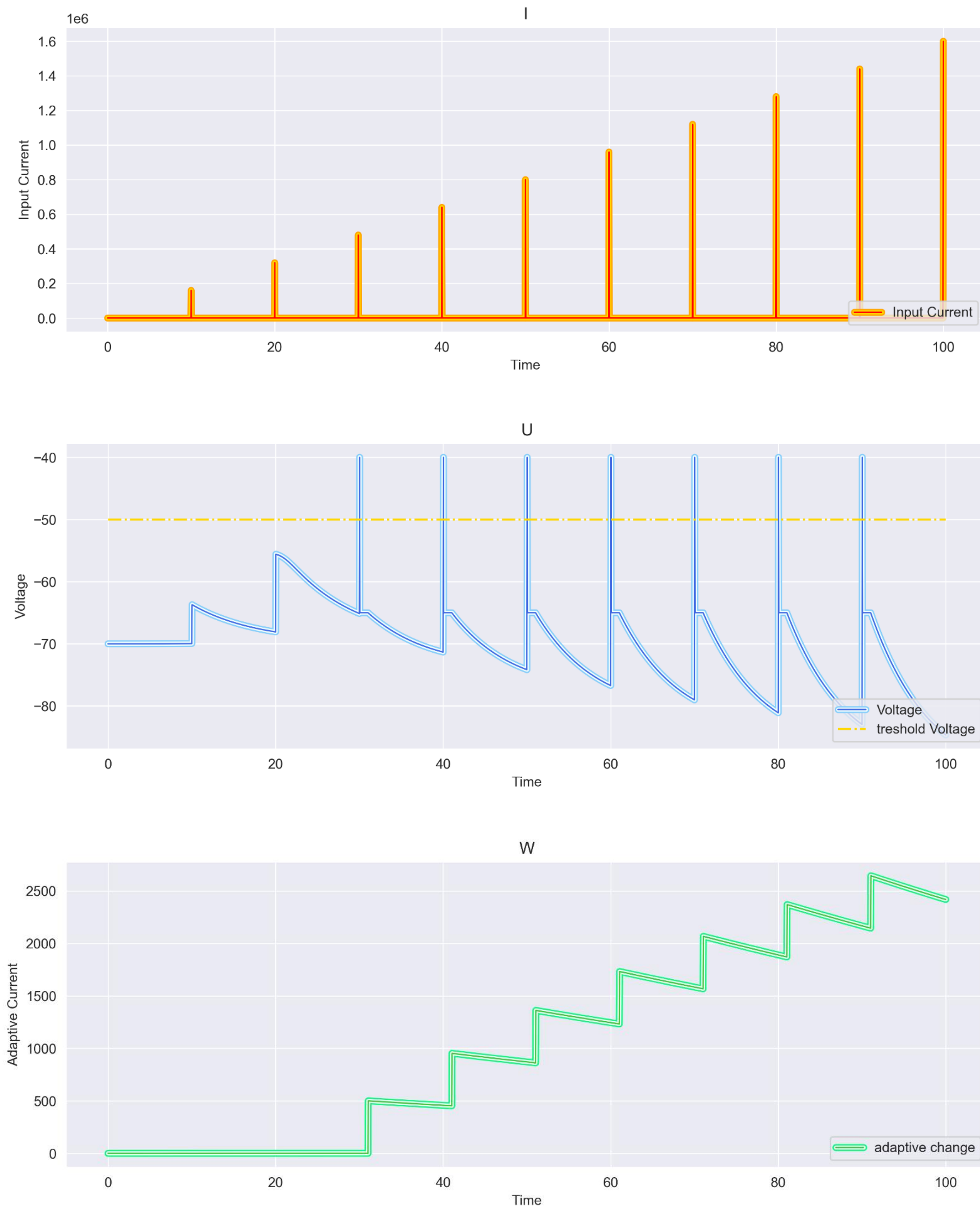


For the next variation I tried a much higher burst currents (equal to around 50000 times higher



than the previous ones) this time not only there were spikes on each burst of current but also the spikes were so "sky scraper like" that I had to limit them to the threshold for the plot to have a reasonable look. Here is the results

Also params are the same as the first AELIF model



I
1e6
Input Current
Time
Input Current
U
Voltage
Time
Voltage
treshold Voltage
W
Adaptive Current
Time
adaptive change

The plots do really speak for themselves but for a sake of a quick summary :

The adaptiveness works seemingly as it should be. For example by looking at the 3rd AELIF simulation. Even though we have the same inputs in the ranges of 0 to 50 secs and 50 to 100 secs but the amount of spikes we're receiving are differing from one another

(also I should note that I had to multiply both "a" and "b" parameters by a constant to have the same results as the DOC showed. A constant of around 30)

But we're seeing a slight difference (not exactly "slight" though) in the 2nd AELIF simulation from which we we're given in the DOC as in the DOC we had only one spike in the range of 50 to 60 seconds but here we're seeing 2, that's because of the exponential term that was added, even though this term is a simple term added as F(u) but I couldn't work out why this was acting a little bit off as increasing or decreasing the sharpness factor by a constant had major escalating effects and I just decided to leave the sharpness factor be as It is.