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In this project we will study the dynamics of five neuron models in response to different kinds of input currents.

Leaky integrate-and-fire (LIF) neuron model

The LIF model is one on the simplest models of a neuron where the subthreshold membrane potential dynamics is described by:

$$\tau \frac{dV}{dt} = -V + R \cdot I(t)$$

where τ is the time constant equal to $R.C$. And when the membrane potential reaches the threshold level, we will reset the neuron.

Adaptive LIF neuron model

In order to make the LIF model a little more life-like just like a real neuron we'll make it adapt to the given current to do so we will introduce a new variable ω where the dynamics of it is described by:

$$\tau_w \frac{dw}{dt} = a(u - u_r) - w + b\tau_\omega \cdot \sum_{tf} \delta\left(t - t^f\right)$$

Where $\sum_{tf} \delta\left(t - t^f\right)$ is one when we just had a spike, other wise its equal to zero.

In this model while calculating the subthreshold membrane potential dynamics we will simply subtract the amount Rw from the $\frac{dV}{dt}$. So, we'll have:

$$\tau \frac{dV}{dt} = -V + R \cdot I(t) - R.w$$

Exponential LIF neuron model

In this model we will make the potential relation to current non-linear to match that of real life.

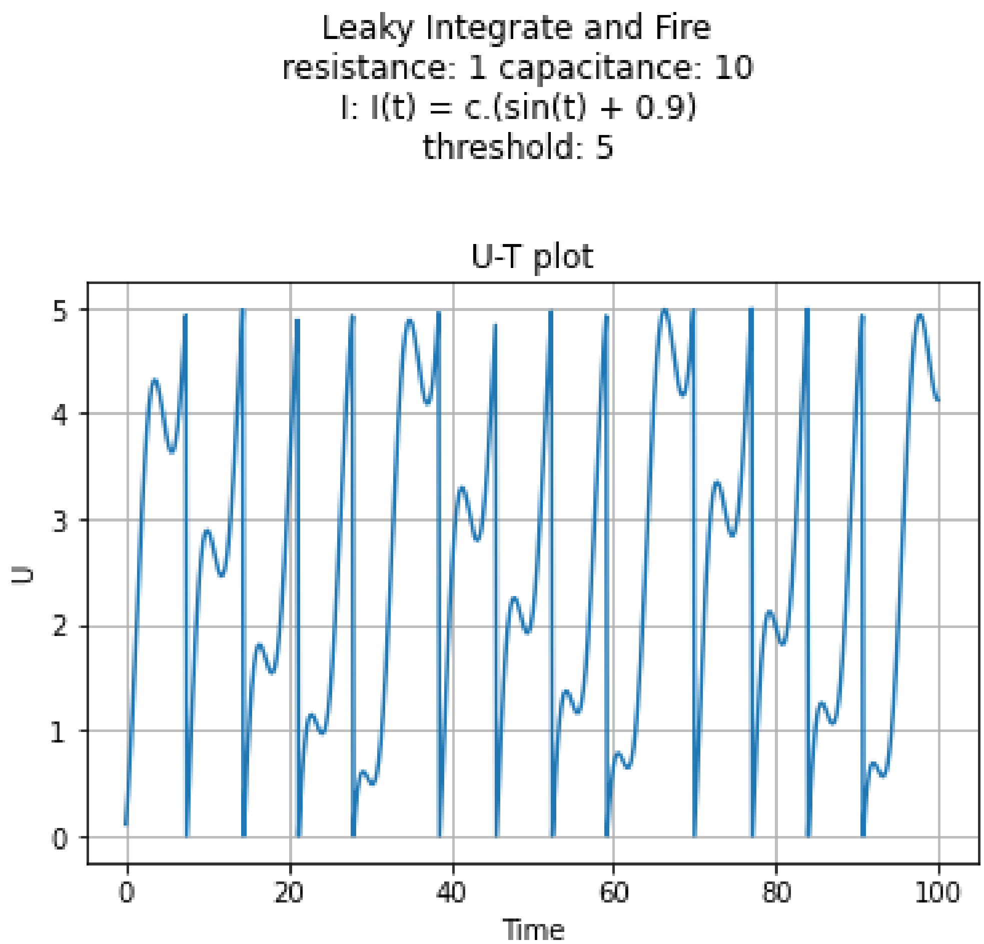
$$\tau \frac{dV}{dt} = -V + R \cdot I(t) + \Delta_T . e^{\frac{u - \Theta rh}{\Delta_T}}$$

Exponential Adaptive LIF neuron model

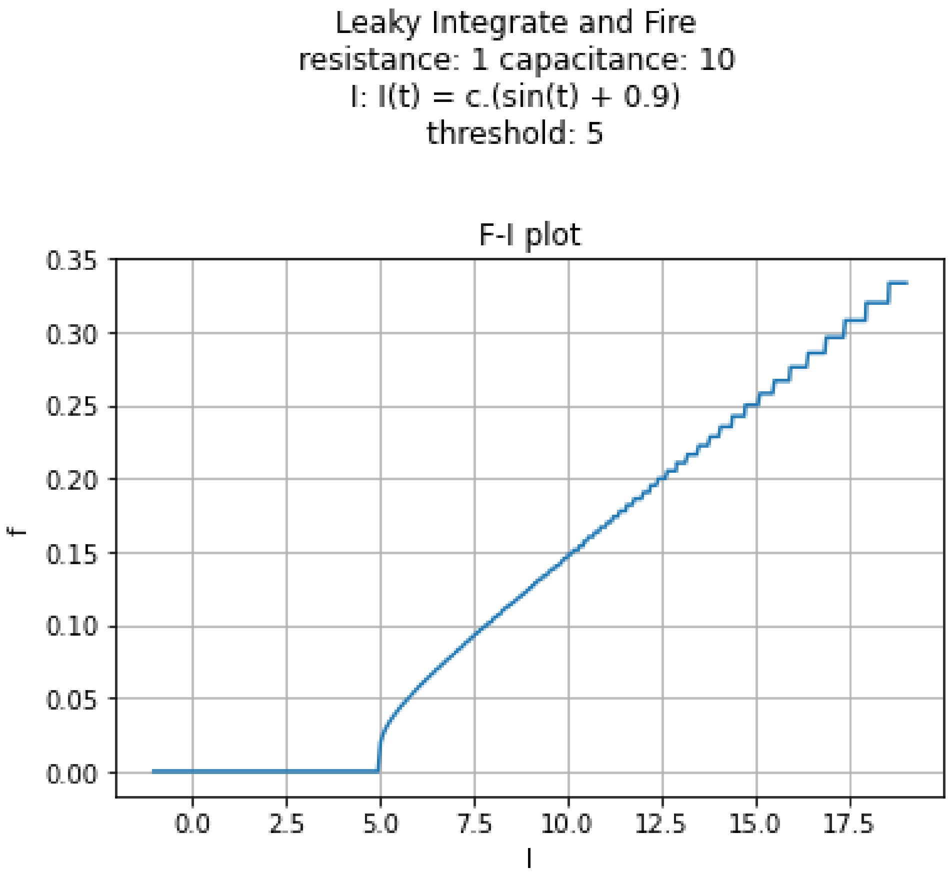
This model is a combination of the two past models which makes it adaptive and exponential at the same time.

Now let’s check how each model reacts to different variables and inputs.

Sinus input current:

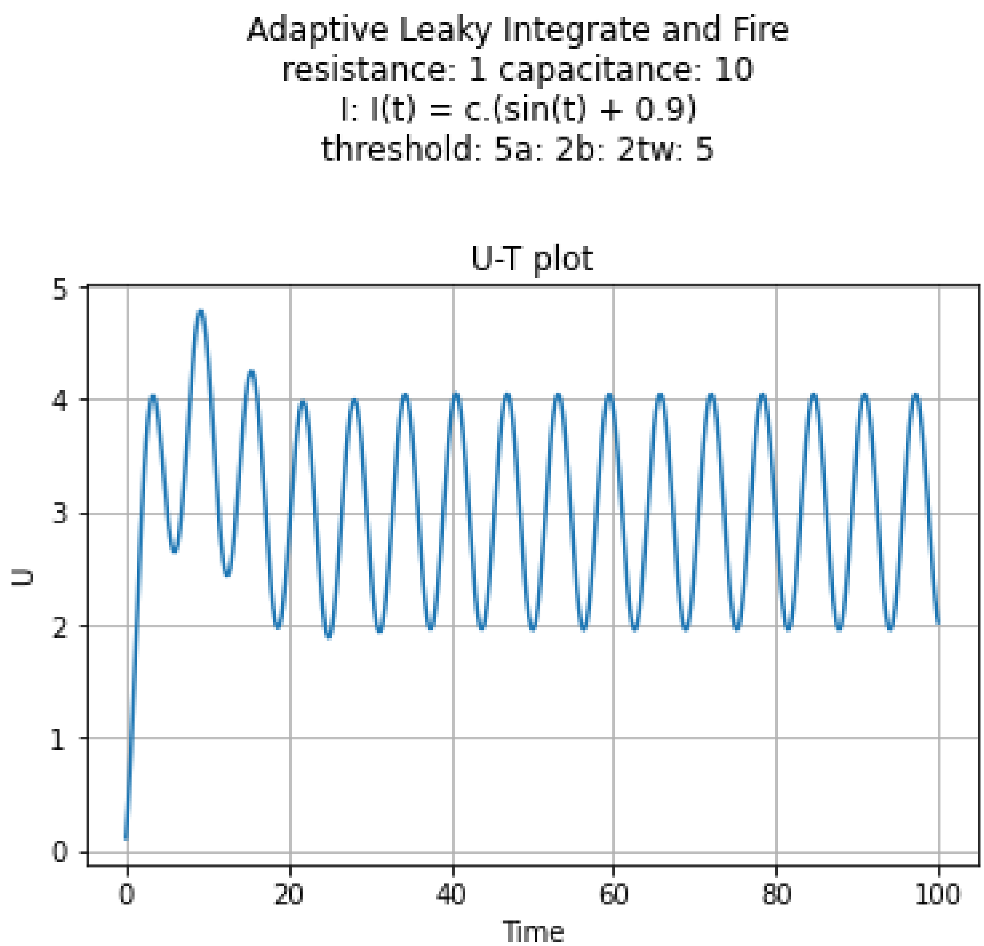


Looking at the above figure you can easily spot where the sinus becomes negative. Where the current is positive it causes the membrane potential to increase and where it’s negative it causes it to come down and get closer to the resting potential.

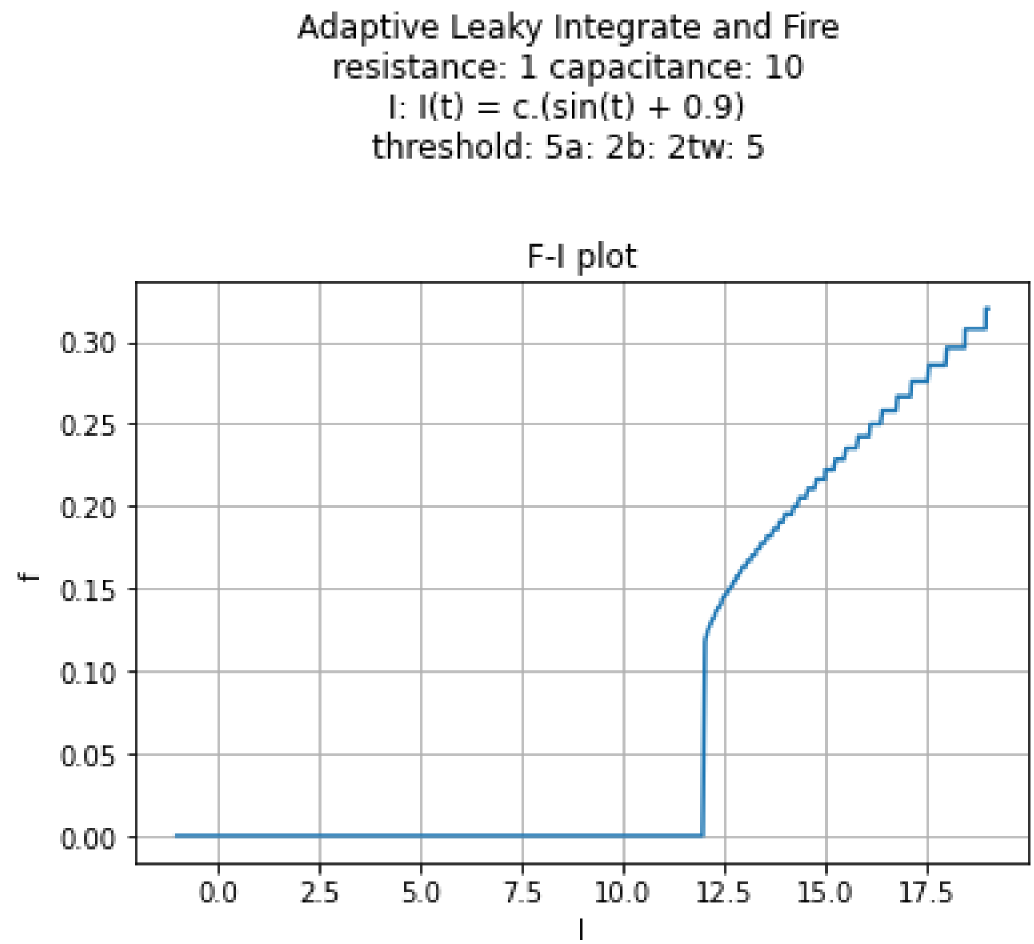


looking at the relation between the input current and the frequency of the spikes it can be said that the more power full the current is the faster the neuron will reach the threshold.

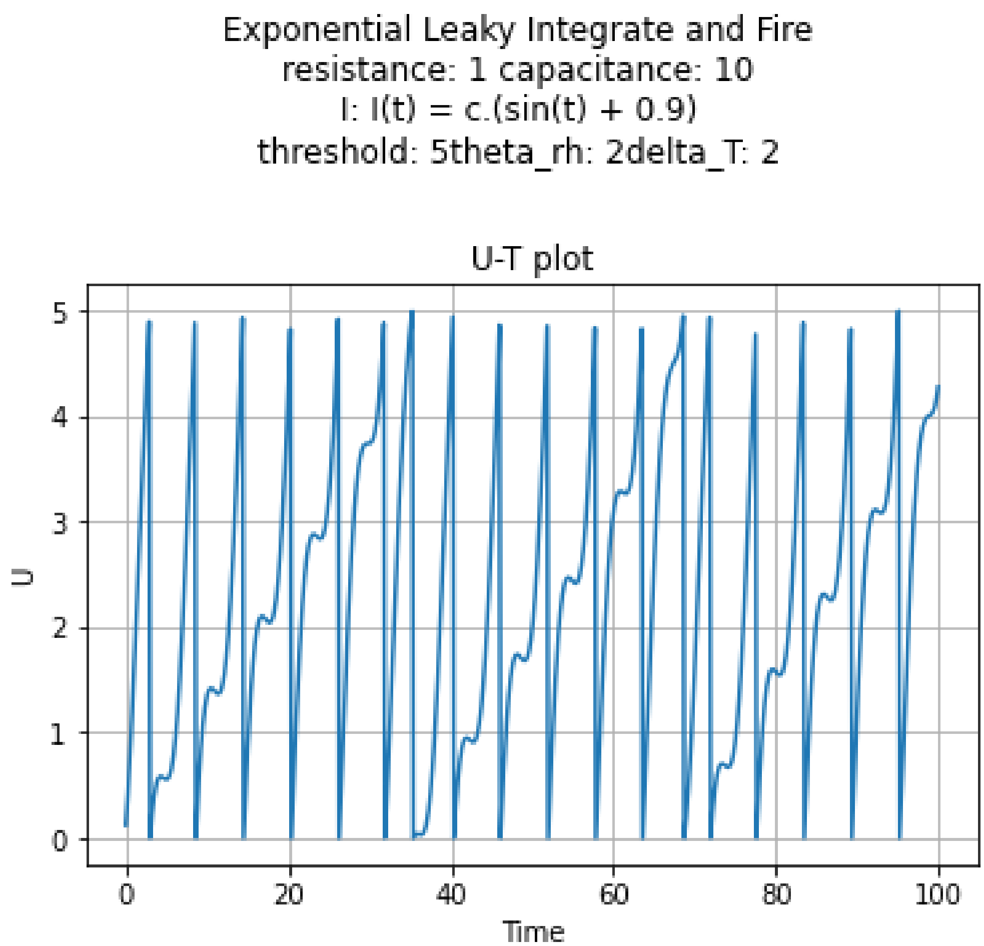
Now let’s see what will happen if our model becomes adaptive.



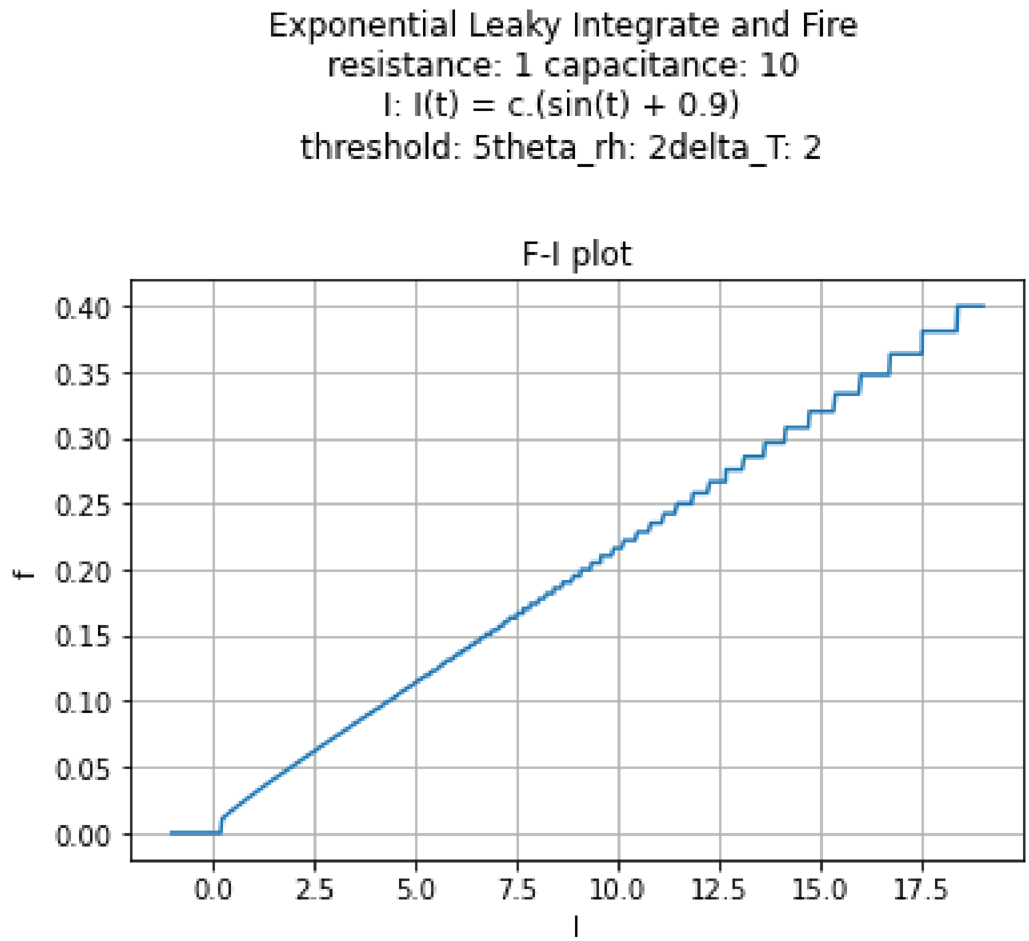
By making our model adaptive the membrane potential with the given current will never reach the threshold.



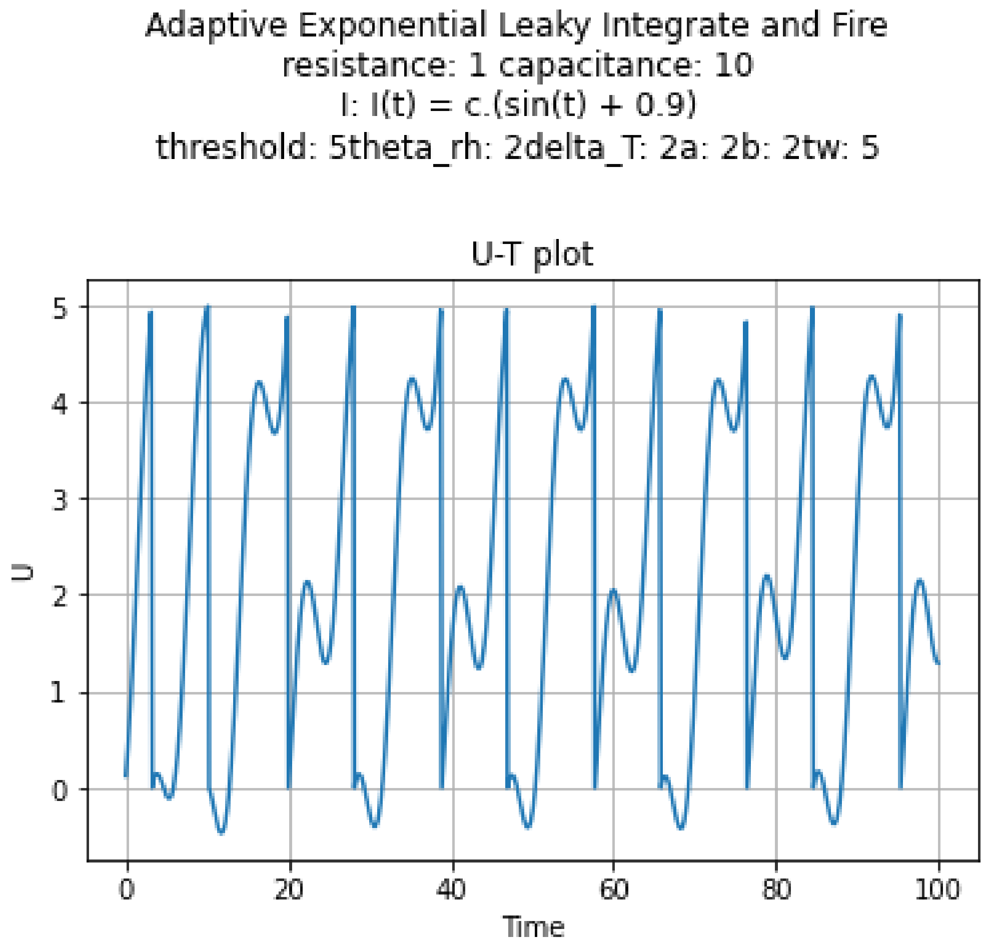
Now by comparing the f-I relation between the adaptive and the simple model we'll see that as expected with the same input currents we would have less spikes. Now let's check the ELIF model:

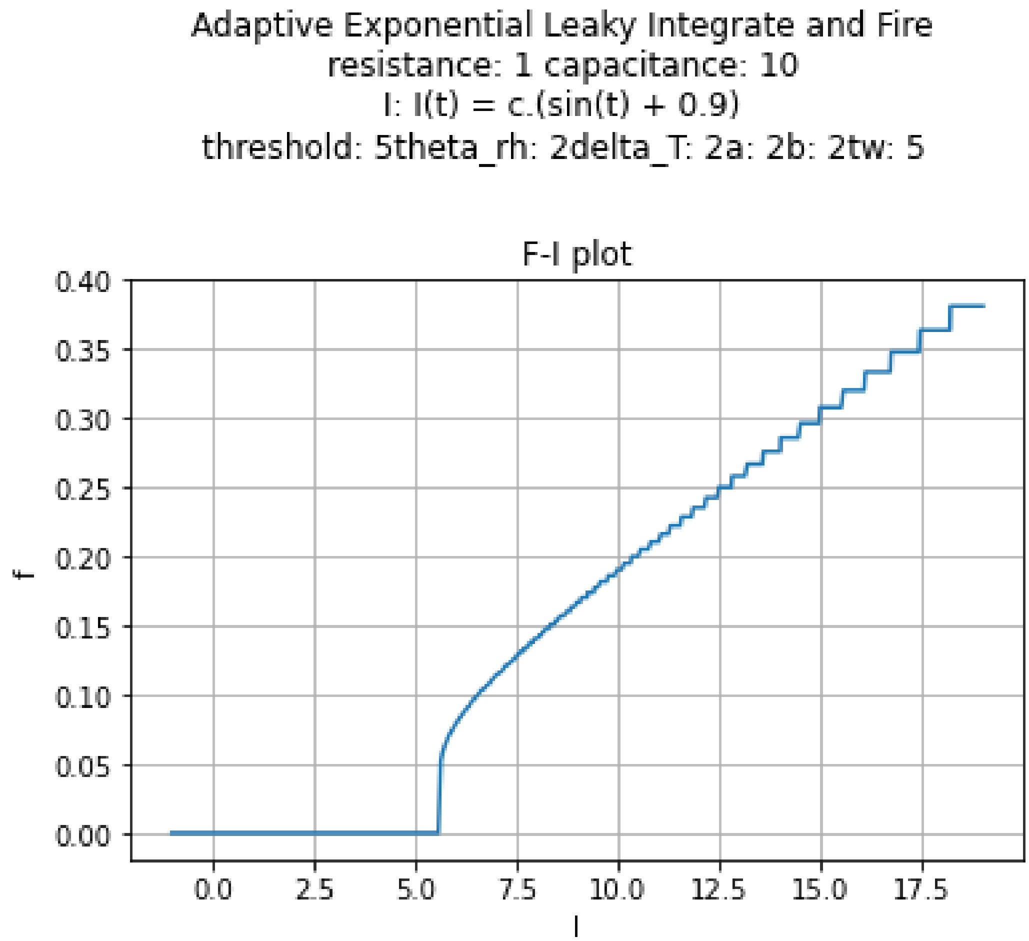


By making the relation exponential we expect the membrane potential to rise faster and by doing so we expect a higher frequency.



Now if check the graphs of the AELIF mode we expect it to have more spikes than the ALIF model and less than that of the ELIF.


Adaptive Exponential Leaky Integrate and Fire
resistance: 1 capacitance: 10
I: I(t) = c.(sin(t) + 0.9)
threshold: 5theta_rh: 2delta_T: 2a: 2b: 2tw: 5
U-T plot
U
Time
0
1
2
3
4
5
0
20
40
60
80
100



There are more inputs given to our models and you could check them out in the notebook file in the project but we expect to see the same results in the other conditions too.