Quadratic LIF

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1 Quadratic LIF

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1.1 Comparing Linear LIF and Quadratic LIF

Mathematically, the difference between a linear LIF and a quadratic LIF is the equation that governs its behaviour.

The equation that governs linear LIF is:
if not in refractory state:

$$\tau.\frac{du}{dt} = -(u - u_{rest}) + RI_{ext}$$

if threshold is reached:

$$u = u_{reset}$$

$$refractory\ state = True$$

The equation that governs quadratic LIF is:
if not in refractory state:

$$\tau.\frac{du}{dt} = a_o(u - u_{rest})(u - u_c) + RI_{ext}$$

if threshold is reached:

$$u = u_{reset}$$

$$refractory\ state = True$$

Here, u_c is a constant voltage and a_o is a constant. Rest of the terms carry the same meaning as the linear model that was taught in the class and the implications are: - $a_o > 0$ - $u_c > u_{rest}$

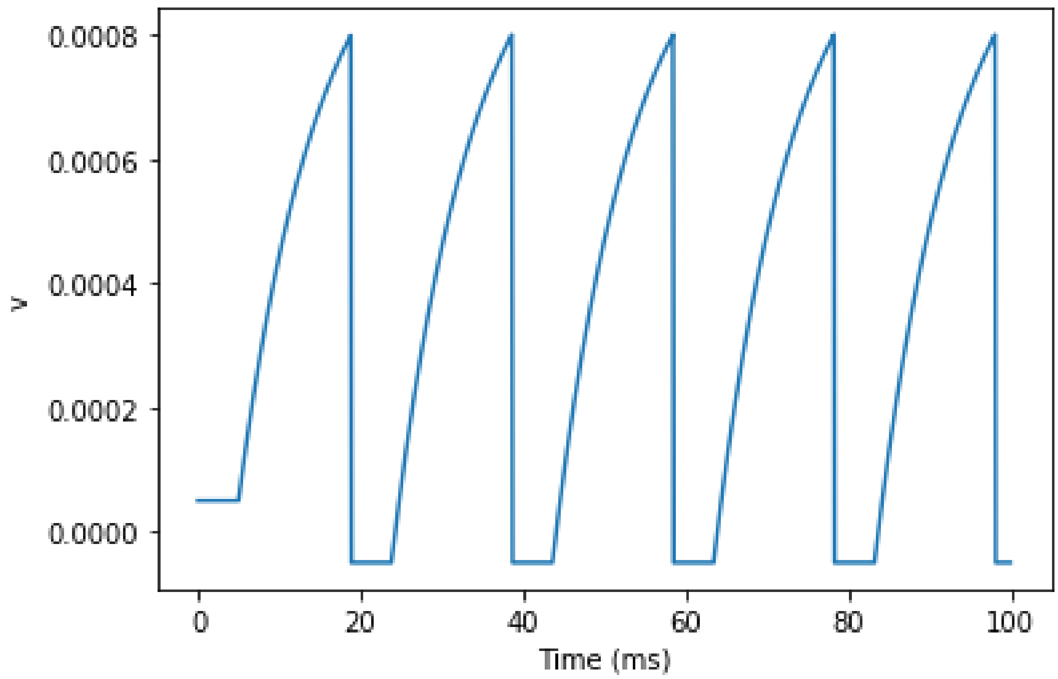
1.2 Step Current as the Input

In the current simulations we set τ as 10ms, refratory period as 5 milli seconds, amplitude as 0.1 nano amps, resistance as 10 Mega ohms, voltage threshold (for the model to spike) as 0.8 milli volts, resting voltage as 0.05 milli volts and reset voltage of value -0.05 milli volts.

We run this simulation for 0.1 * seconds

1.2.1 Linear LIF

```
Spike times: [18.8 38.6 58.4 78.2 98. ] ms
```

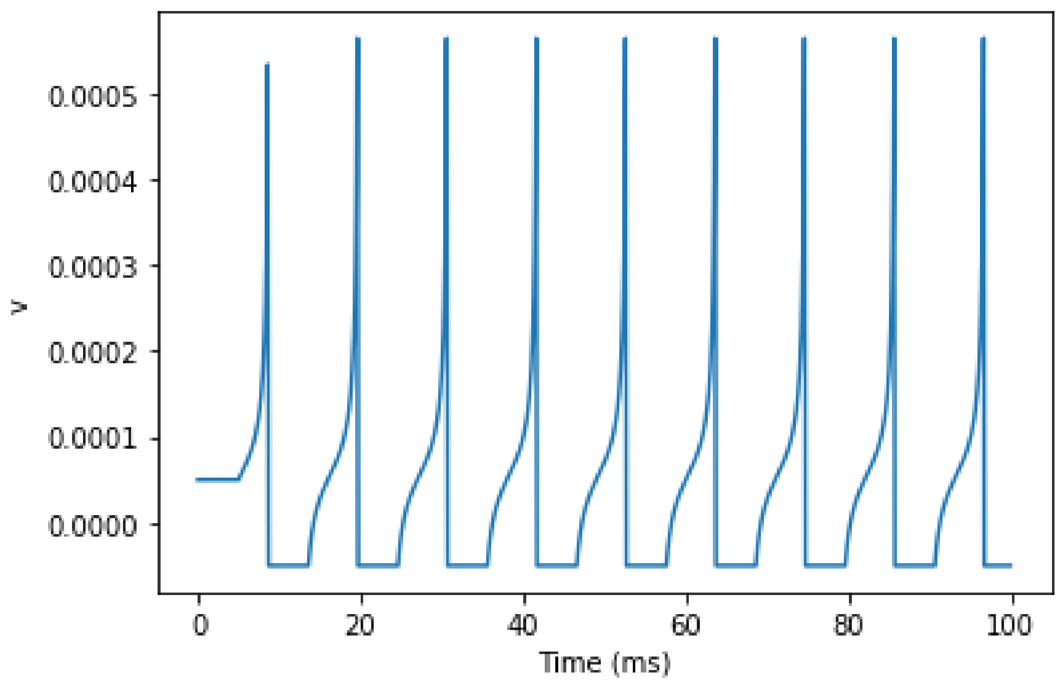


1.2.2 Quadratic LIF

In addition to the above settings we have to choose the value of u_c and a_o.

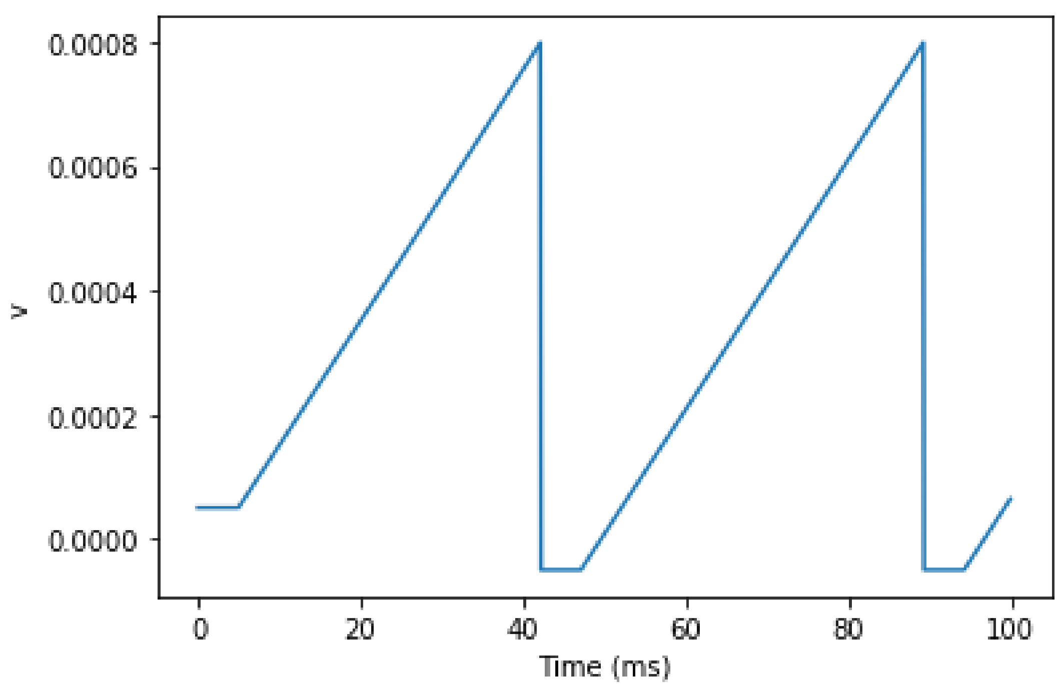
Effect of the constant 'a_o' Here, we set the value u_c as 0.06 milli volts and analyse the role the value of a plays in the quadratic LIF. We initially set the value of a_o as 100/(mV).

```
Spike times: [ 8.6 19.6 30.6 41.6 52.6 63.6 74.6 85.6 96.6] ms
```



We change the value of a_o to 0.01/(mV) below

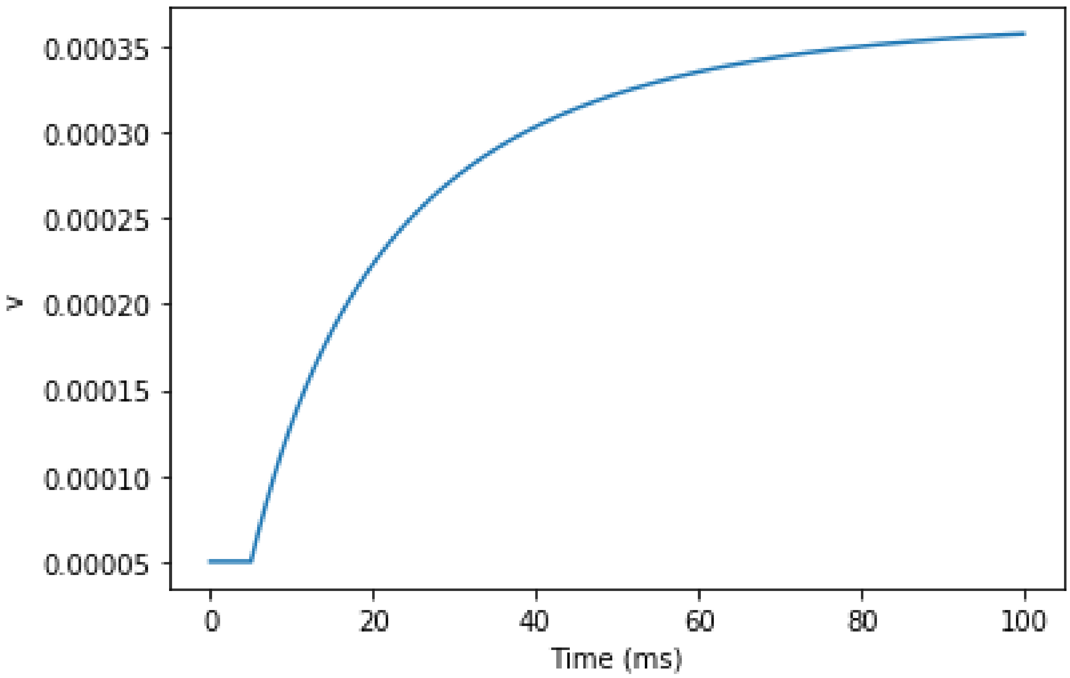
```
Spike times: [42.1 89.2] ms
```



Effect of u_c: Here, we set a_o as 1/(mV) and keep it constant while we explore the role u_c plays. NOTE: amplitude is changed to 0.003 nano amps so that the effect of u_c becomes clear.

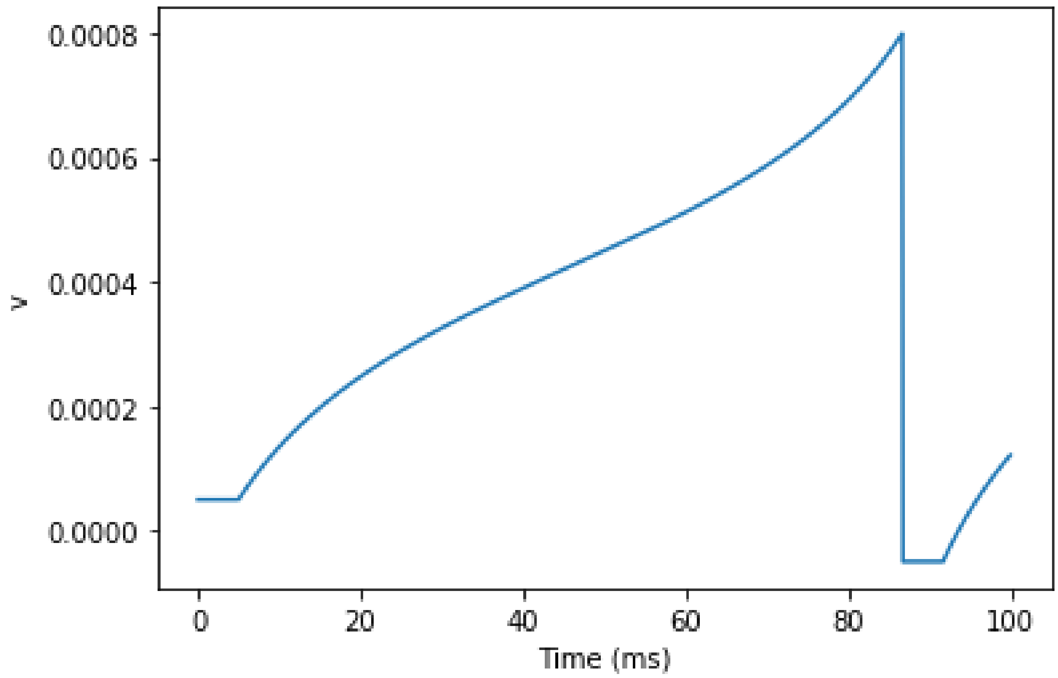
We initially set the value of u_c as 1* mV (a value that that's very big when compared to u_c and is higher than the threshold voltage)

```
Spike times: [] s
```



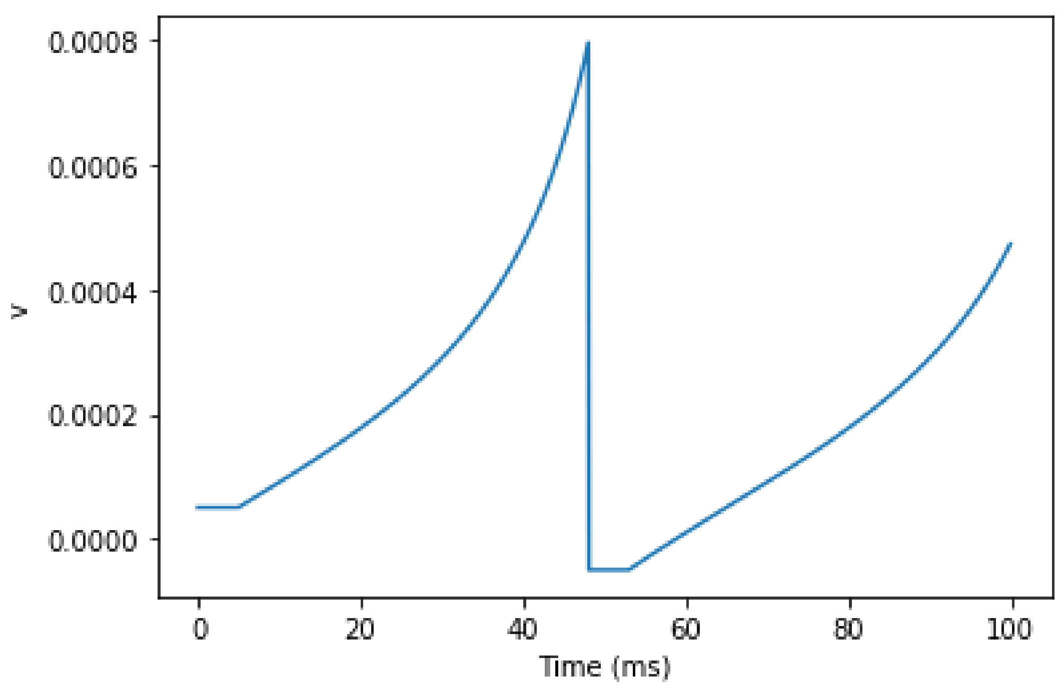
We changed the value of u_c to be 0.8 * mV which is equal to the threshold voltage.

```
Spike times: [86.6] ms
```



We change u_c to be very close to u_{rest} in the below simulation

```
Spike times: [48.] ms
```



1.2.3 Observations:

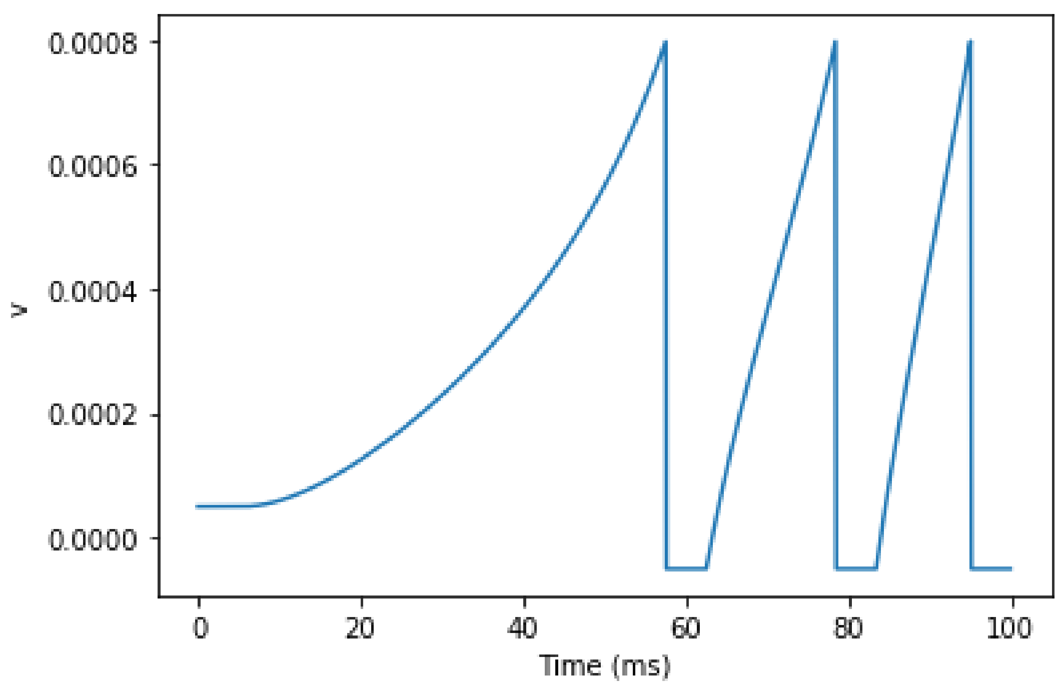
- Increase in the constant a_o increases the chances of the model spiking. This happens because it multiplies with the other part of the equation and only increases the final voltage. This increases the chances of the voltage crossing the threshold voltage.
- When u_c is closer to u_{rest} it increases the chances of the model spiking cause this reduces the 'effective threshold'. This can be seen by the minumum current needed for the for the model to spike. When u_c is 0.055 mV I_{min} is 0.008 nano amps, when u_c is 0.08 mV I_{min} is 0.02 nano amps and when u_c is 1mV I_{min} is 0.008 nano amps.

- The shape of curves of the both of spiking models (Linear LIF and Quadratic LIF) are strikingly different eventhough the input is the same.

1.3 Ramp Current as Input

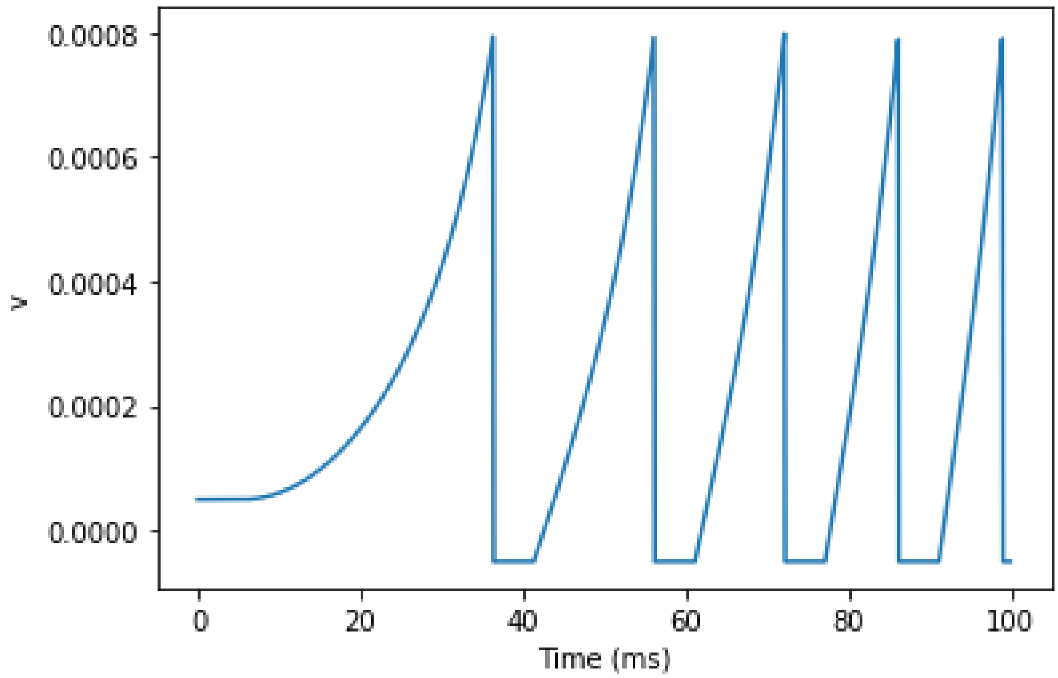
We set the value of the amplitude to be 0.1 nano amps to get reasonable results and the slow_ramp_t to be 100 ms. ### Quadratic LIF #### Effect of u_c:

```
Spike times: [57.5 78.4 95. ] ms
```



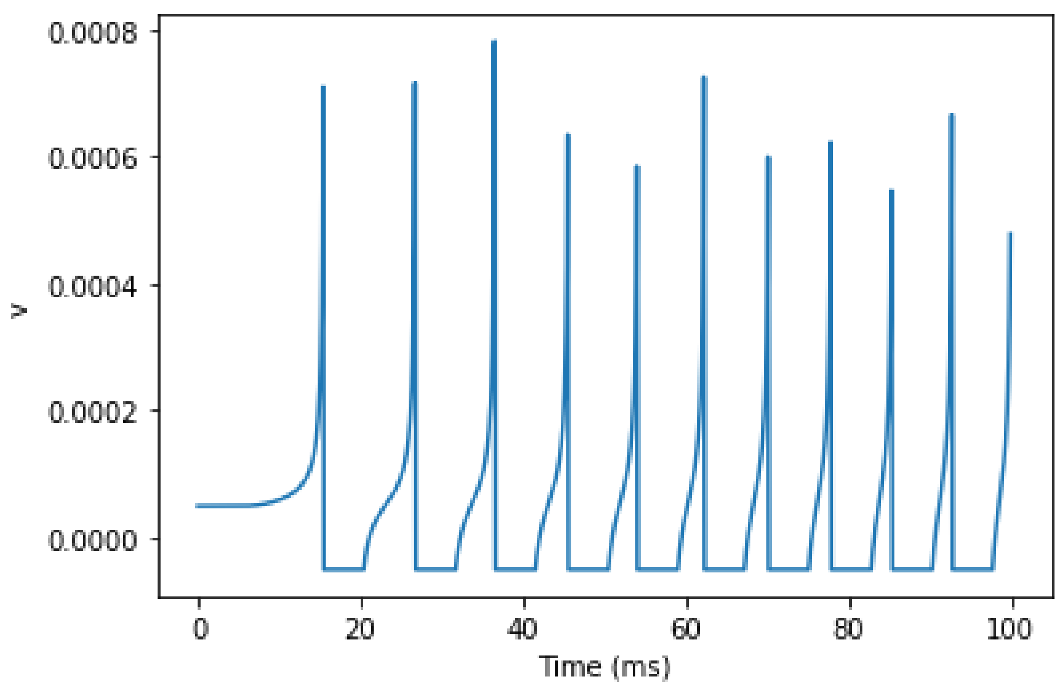
We decrease the value of u_c to 0.055 milli volts (close to u_{rest}) and run the simlution.

```
Spike times: [36.3 56.1 72.1 86.1 98.9] ms
```



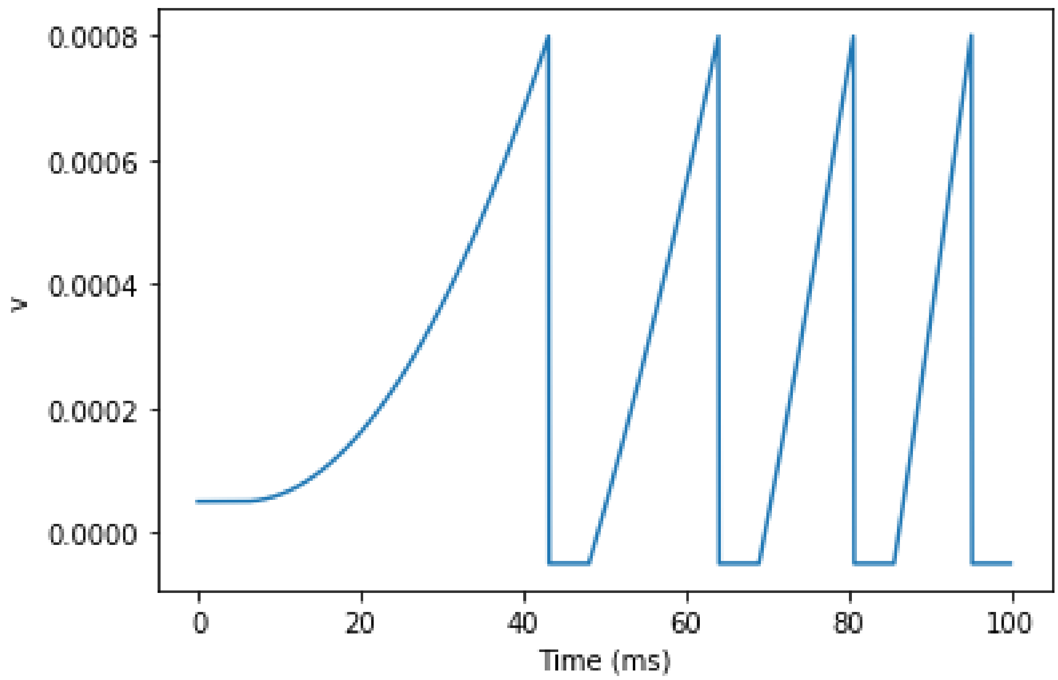
Effect of 'a': We set the value of a_o to 100/mV and run the simulation below

```
Spike times: [15.4 26.7 36.5 45.5 54.  62.2 70.1 77.8 85.3 92.7] ms
```



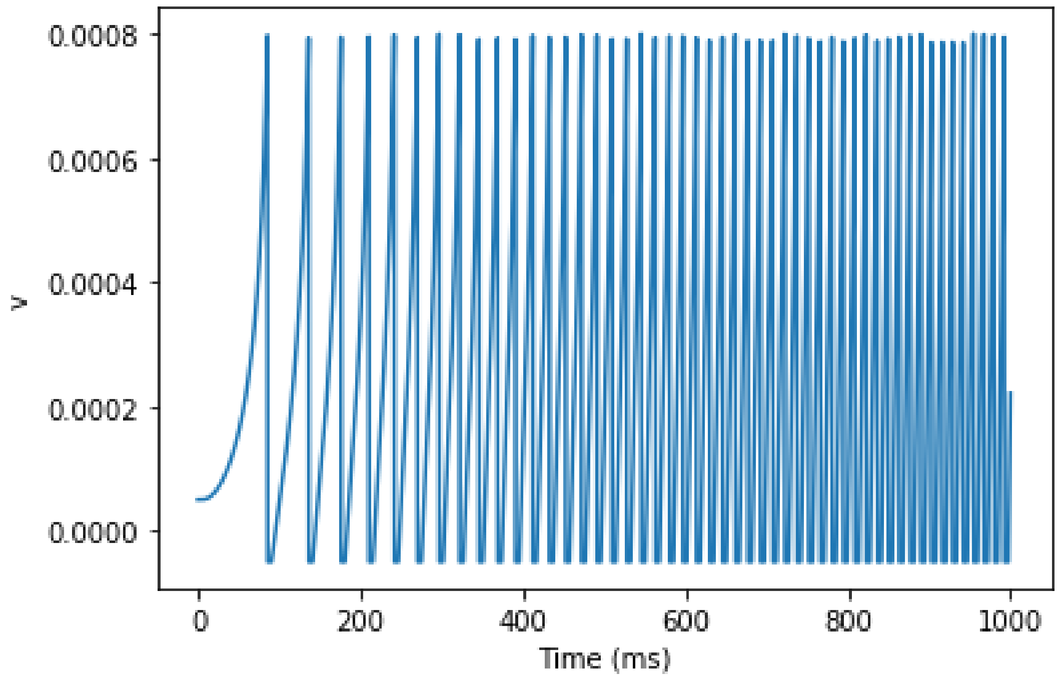
We decrease the value of a_o and run the simulation

```
Spike times: [43.1 64.  80.6 95.1] ms
```



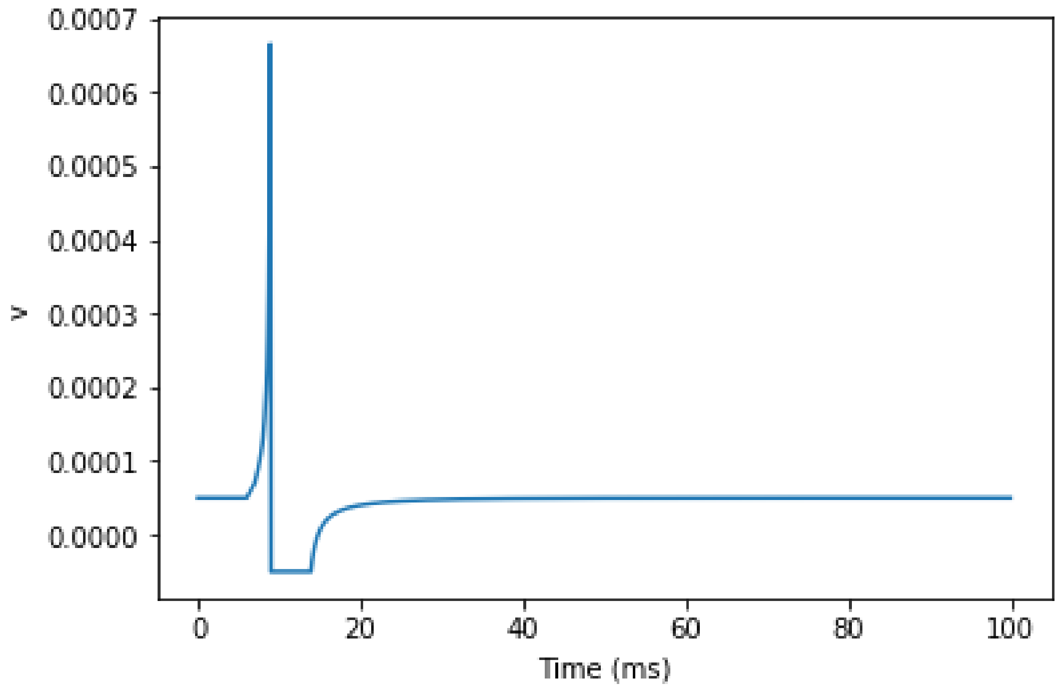
Effect of rampness of the current input We set ramp end time to be 1000 ms. So its a fast ramp.

```
Spike times: [0.0856 0.1363 0.1761 0.2105 0.2415 0.27   0.2967 0.3219 0.3458
0.3687
 0.3907 0.412  0.4326 0.4526 0.4721 0.4911 0.5096 0.5277 0.5455 0.5629
 0.58   0.5968 0.6133 0.6295 0.6455 0.6613 0.6768 0.6921 0.7072 0.7222
 0.737  0.7516 0.766  0.7803 0.7944 0.8084 0.8223 0.836  0.8496 0.8631
 0.8765 0.8898 0.9029 0.9159 0.9288 0.9416 0.9544 0.9671 0.9797 0.9922] s
```



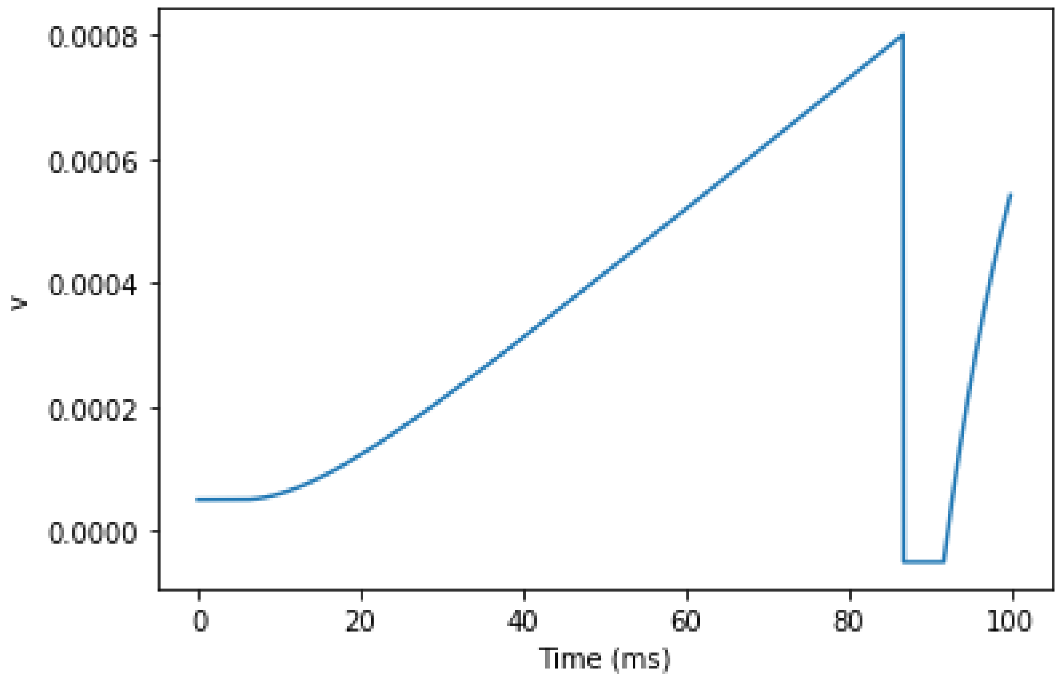
We set the ramp end time to be 10ms. So its a slow ramp

```
Spike times: [8.9] ms
```



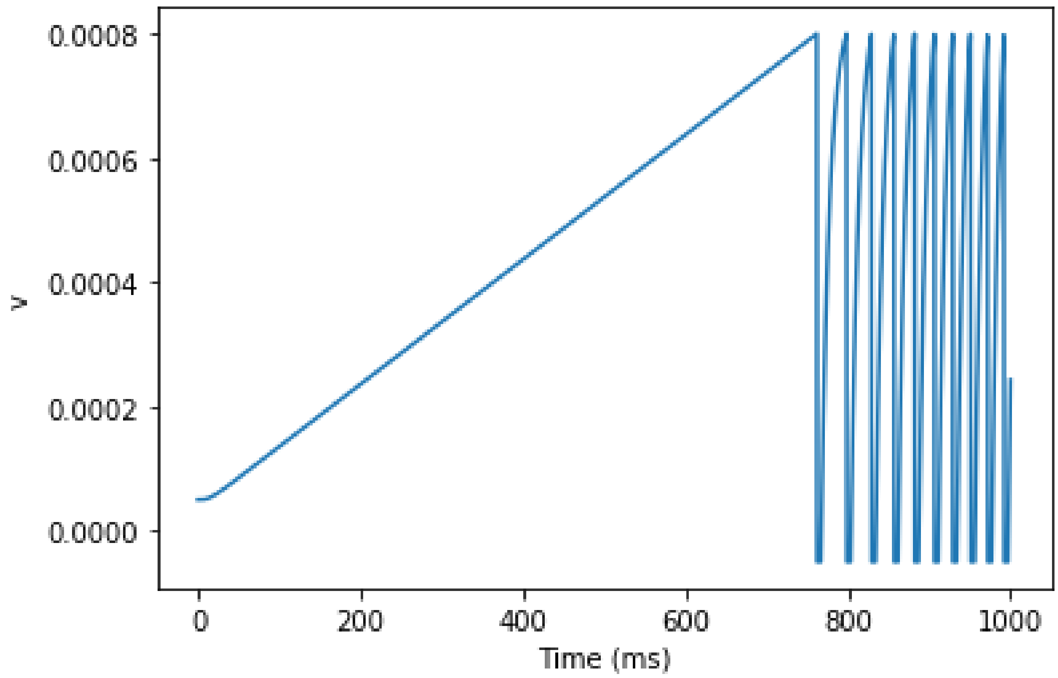
1.3.1 Linear LIF

```
Spike times: [86.7] ms
```



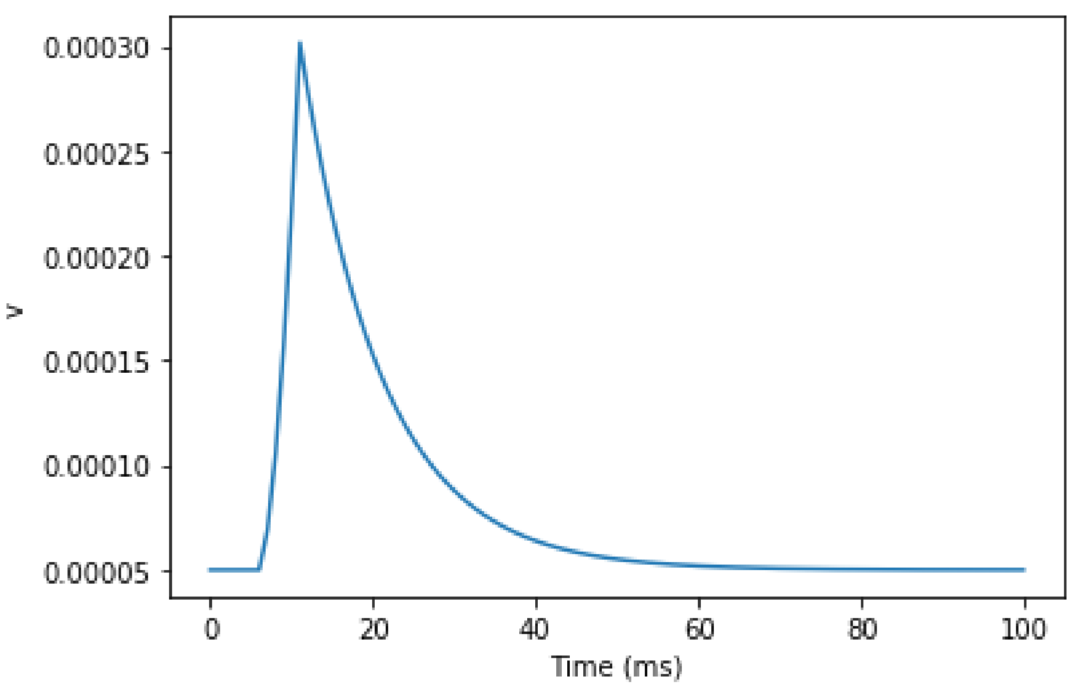
Effect of rampness of the input We set ramp end time to 1000 ms. So its a fast ramp input

```
Spike times: [0.7617 0.7982 0.8289 0.8565 0.8821 0.9061 0.9289 0.9507 0.9716
0.9918] s
```



We set the ramp end time to 10ms. So its a slow ramp.

```
Spike times: [] s
```



1.3.2 Observations:

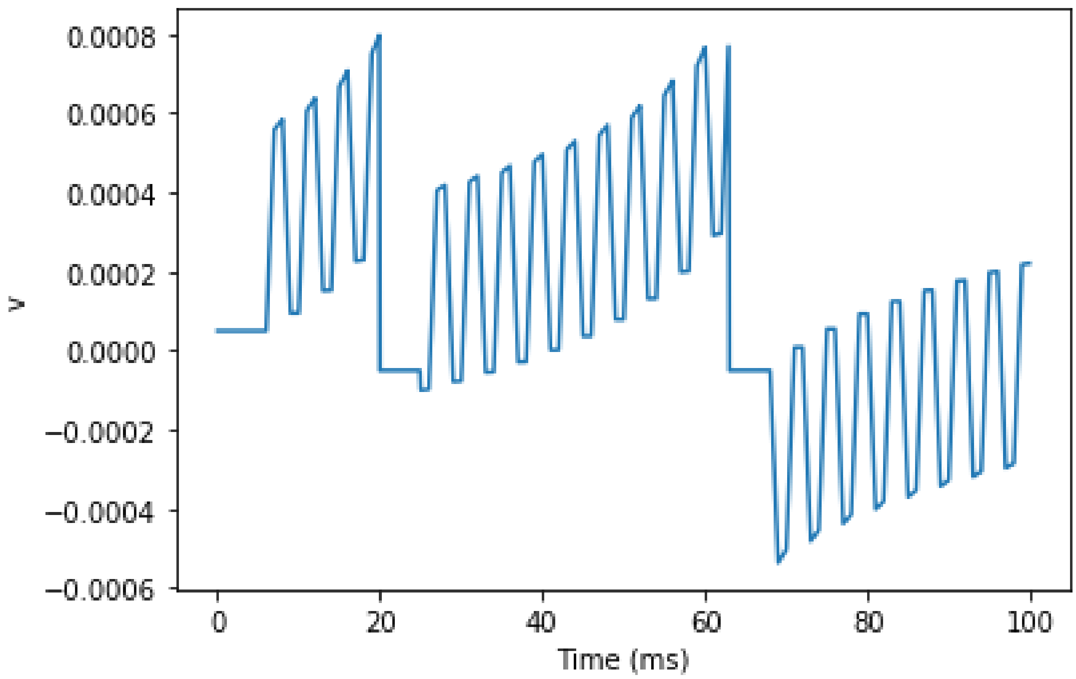
- Increasing the rampness of the input current increases the chances for the model to spike. This is valid for both QLIF and and LLIF
- Like before, increasing the value of a_o increases the chances of the model to spike and decreasing the difference between u_c and u_{rest} increases the chances for the model to spike

1.4 Sinusoidal Current as Input

1.4.1 Quadratic LIF

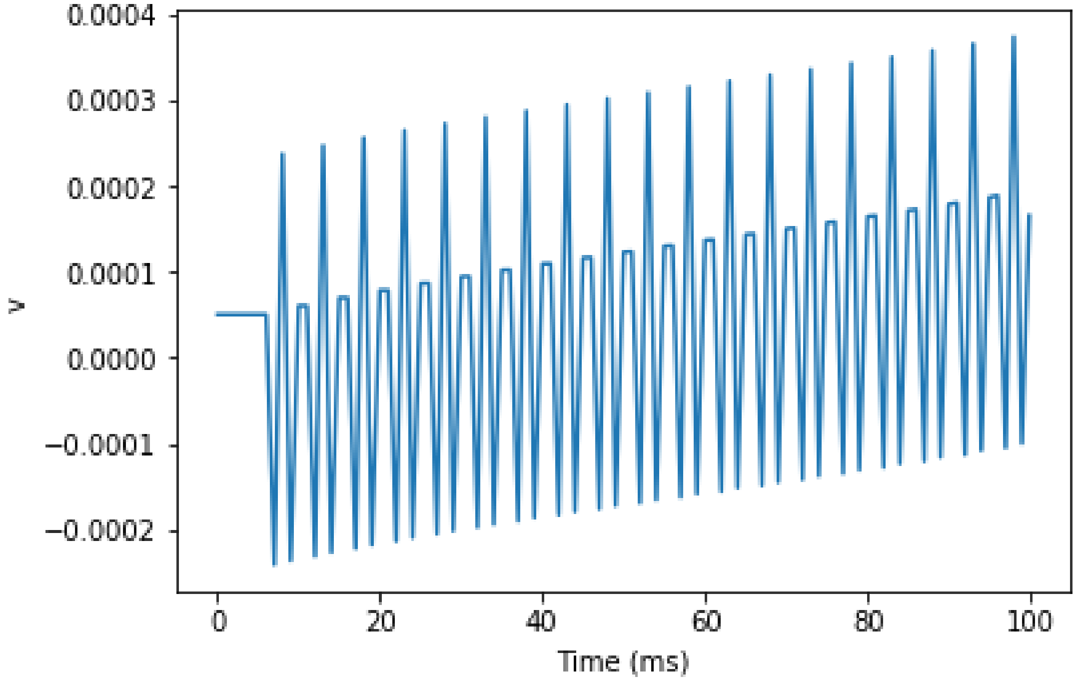
We set frequency of the sinusoidal input to 250 Hz and amplitude to 0.5 nano amps

```
Spike times: [19.9 62.9] ms
```



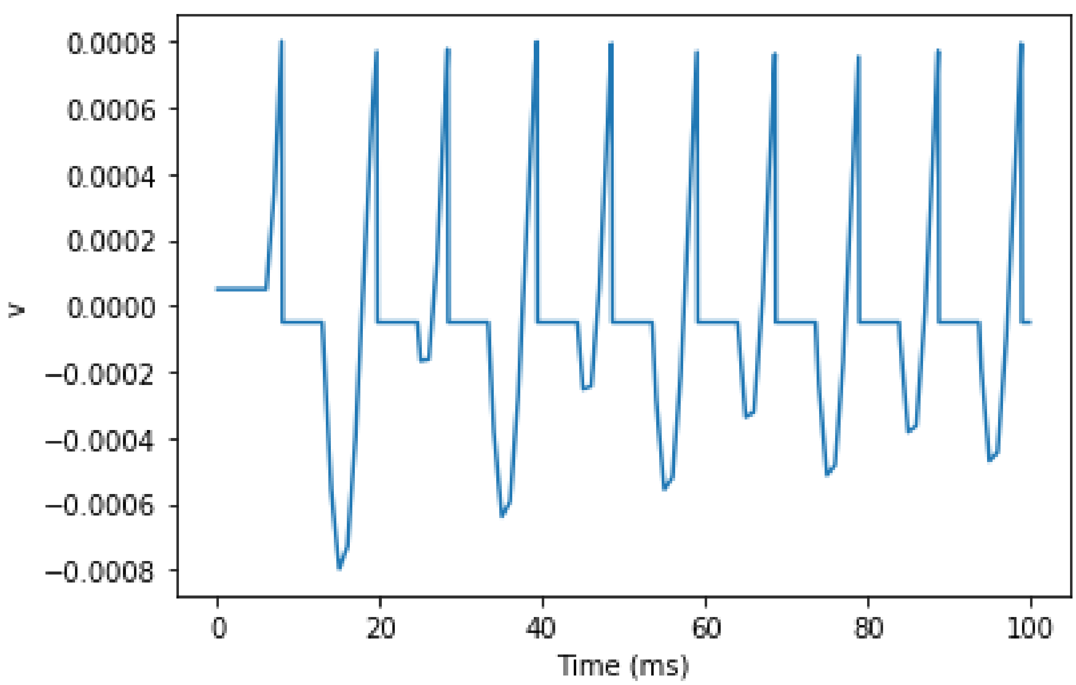
Effect of frequency of the sinusoidal input We set the frequency to 600 Hz

```
Spike times: [] s
```



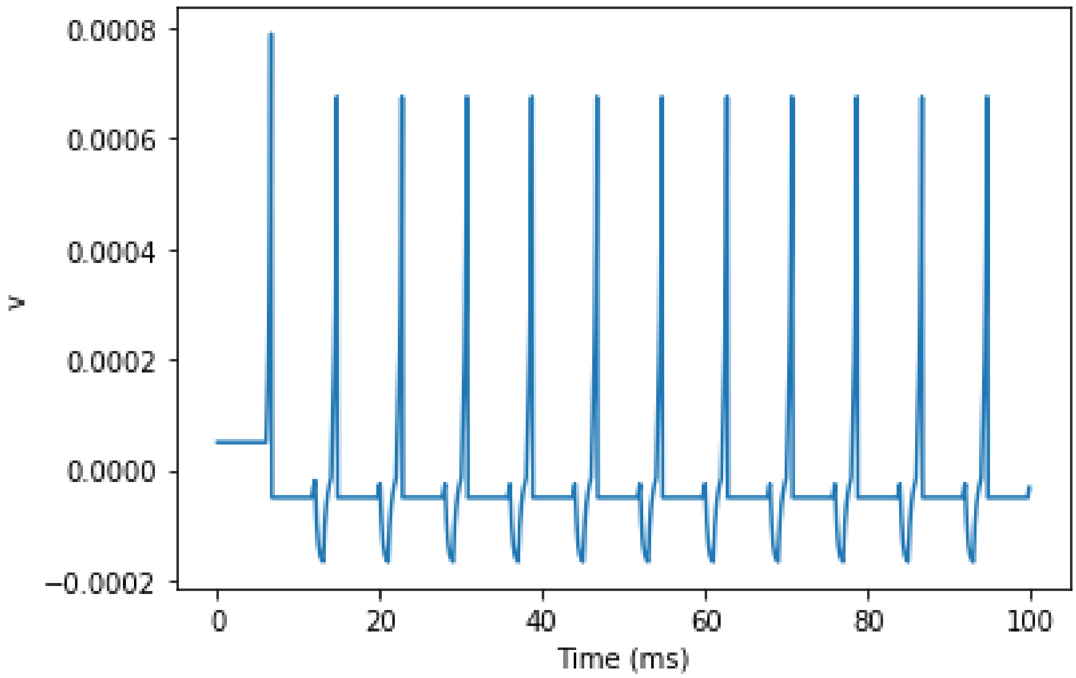
We set the frequency to 100 Hz

```
Spike times: [ 7.9 19.6 28.3 39.3 48.5 59.  68.6 78.9 88.7 98.9] ms
```

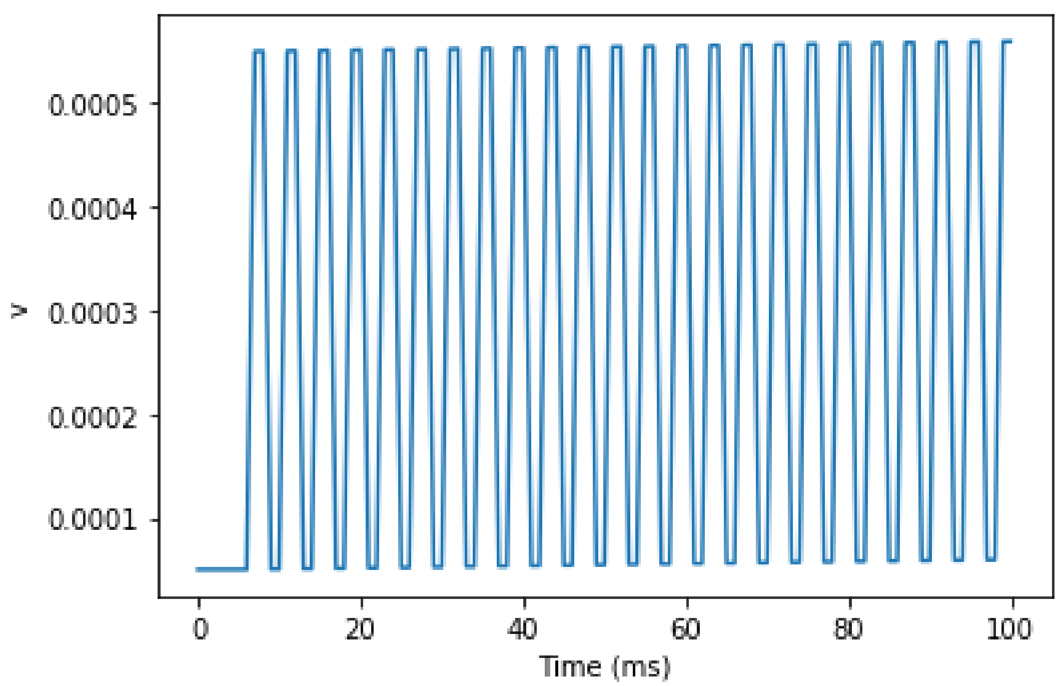


Effect of a: We increase the value of a_o to 100/(mV)

```
Spike times: [ 6.6 14.7 22.7 30.7 38.7 46.7 54.7 62.7 70.7 78.7 86.7 94.7] ms
```

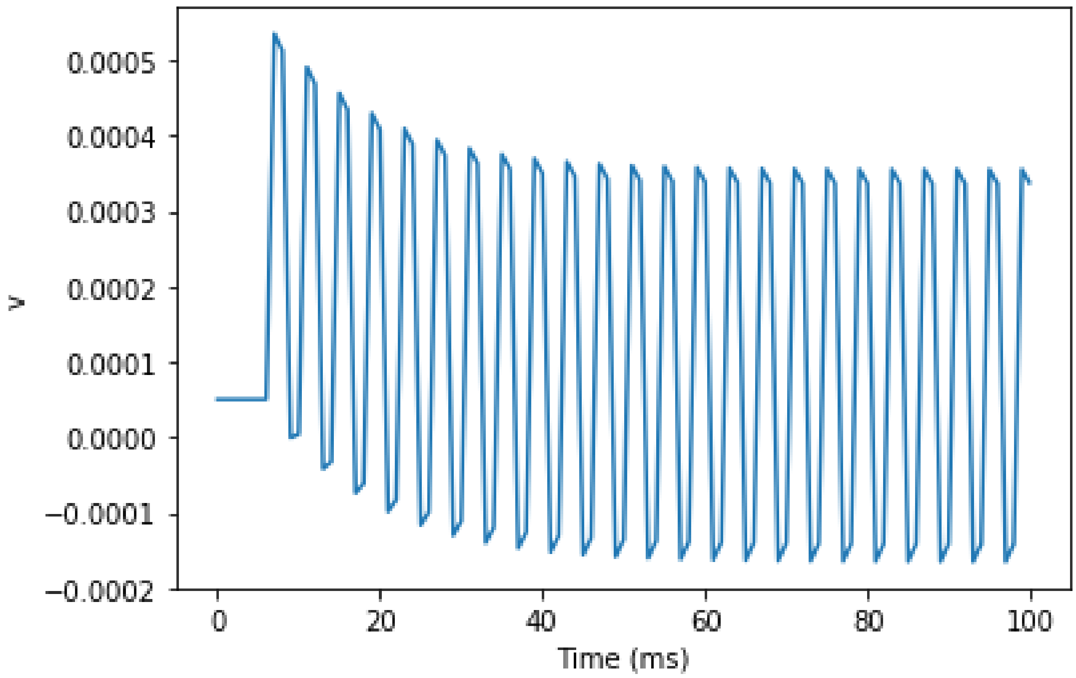



```
Spike times: [] s
```



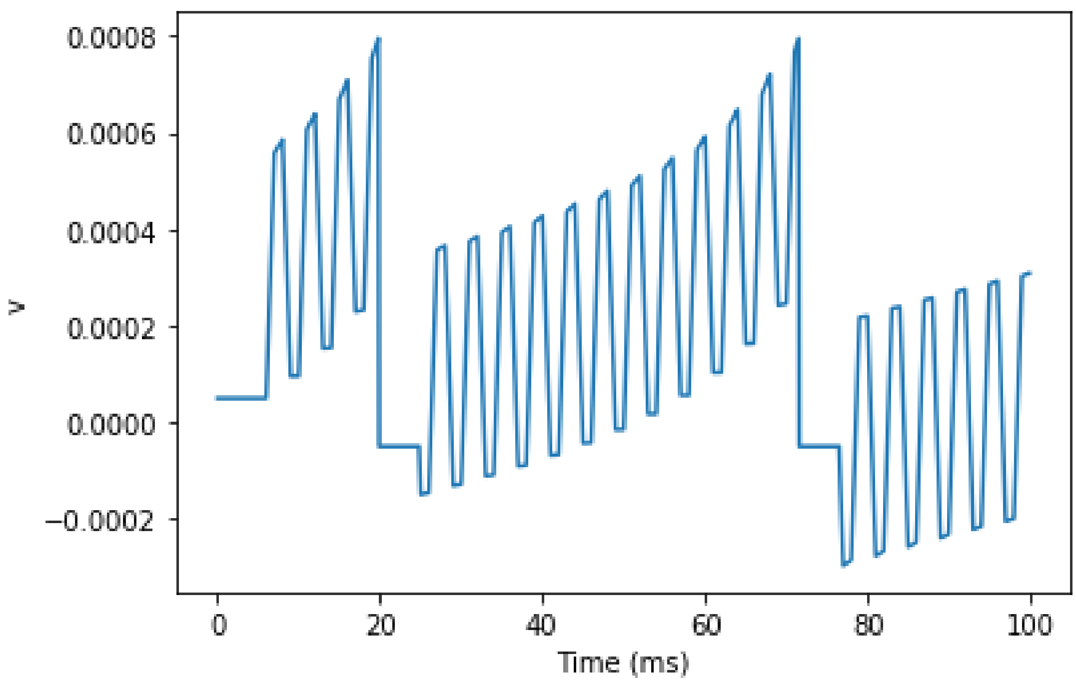
Effect of u_c: We increase the value of u_c to 1mV and run the simluation

```
Spike times: [] s
```



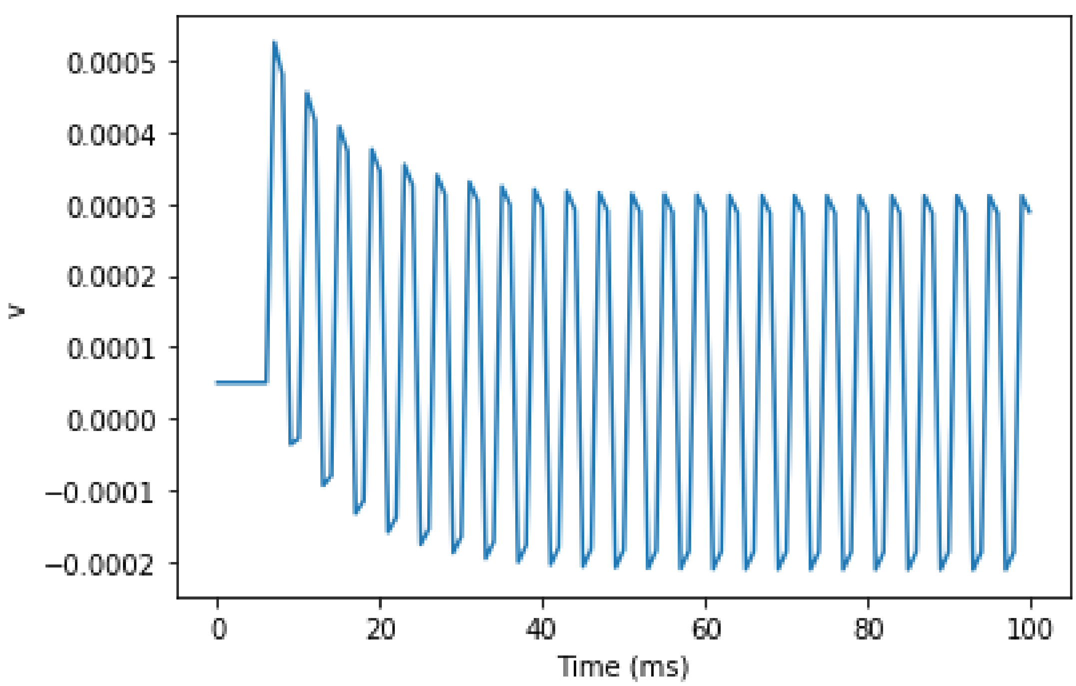
We decrease u_c value to 0.055 milli volts.

```
Spike times: [19.8 71.5] ms
```



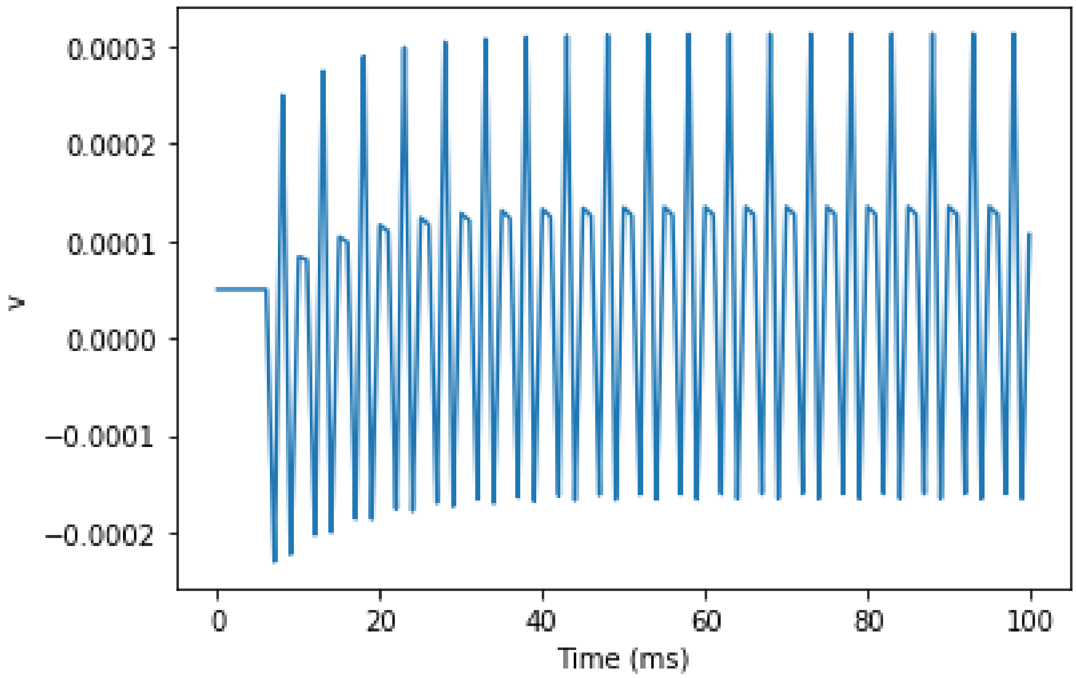
1.4.2 Linear LIF

```
Spike times: [] s
```



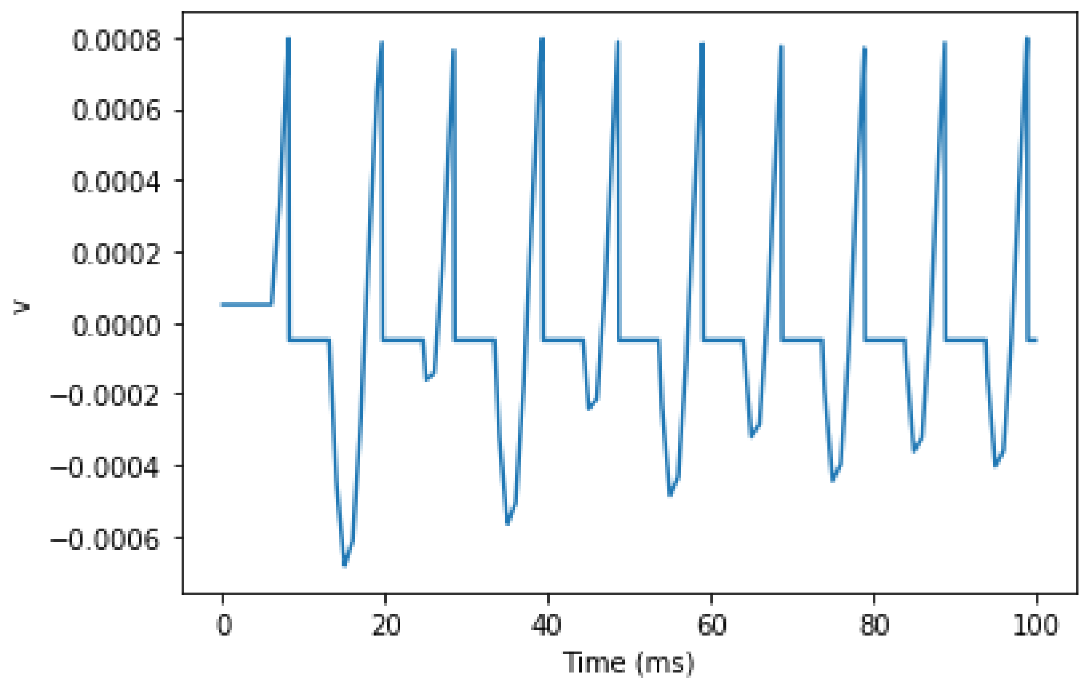
Effect of frequency of the sinusoidal input We increase the value of frequency of the sinusoidal input to 600 Hz

```
Spike times: [] s
```



We decrease the value of frequency of the sinusoidal input to 100 Hz

```
Spike times: [ 8.1 19.6 28.4 39.3 48.6 59.  68.7 78.9 88.8 98.9] ms
```



1.4.3 Observations

- Decreasing the frequency of the sinusoidal input of current increases the chances of the model spiking. This is applicable to both QLIF and LLIF
  - Although this is not always consistent. For example, 300 Hz input gives more spikes than 250 Hz input.
- Like the previous modes of input, it is clear that the when a_o increases then the model spikes more and when the difference between u_c and u_{rest} is less the model spikes more easily cause the 'effective' threshold decreases.