Report on Exercise Series 1

Exercise Topic: Implementation of three models AELIF, ALIF, LIF
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Introduction:

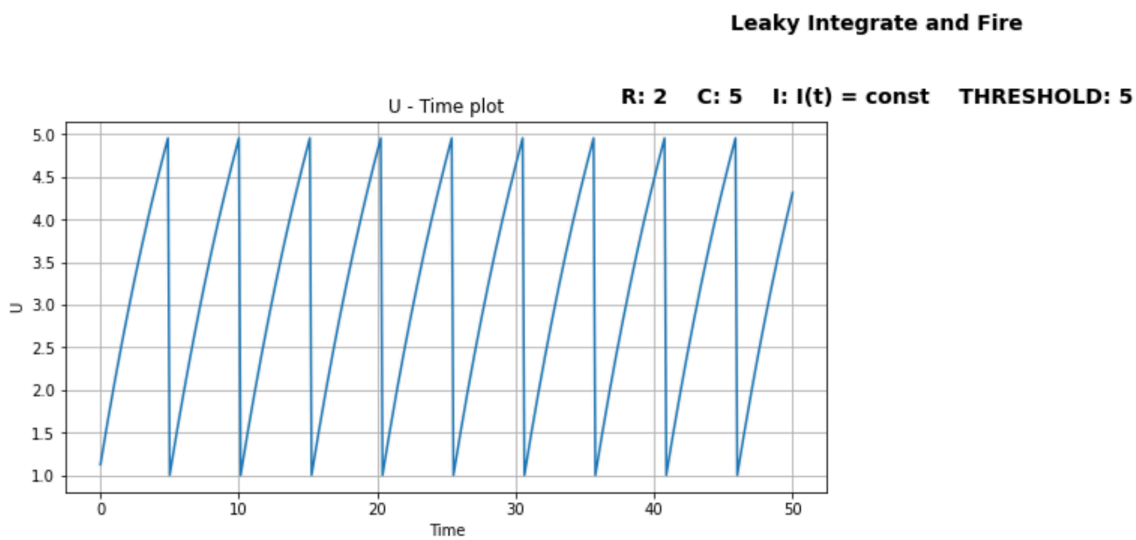
This report focuses on the implementation and analysis of three neuron models: LIF (Leaky Integrate and Fire), ALIF (Adaptive Leaky Integrate and Fire), and AELIF (Adaptive Exponential Leaky Integrate and Fire). These models simulate the behavior of neurons under different types of input currents, including constant, linear, and sinusoidal inputs. In this exercise, we examine the three models LIF, ALIF, and AELIF by plotting three graphs for each: t_U, t_I, and I_F. The purpose of this assignment is to explore how these models respond to various stimuli by plotting their voltage over time (t_U), input current (t_I), and firing rate (I_F). Implementing these models in Python, using libraries like `numpy` and `matplotlib`, allows us to test and analyze their behavior under different conditions, adjusting parameters such as resistance, capacitance, and threshold to observe the resulting neuronal spikes and frequency patterns.

<<LIF Model>>
Depending on the type of current, which can be linear, sinusoidal/cosinusoidal, or constant, the corresponding graphs will differ:

- **Constant Current**: For example, we define the following model with its initial properties:

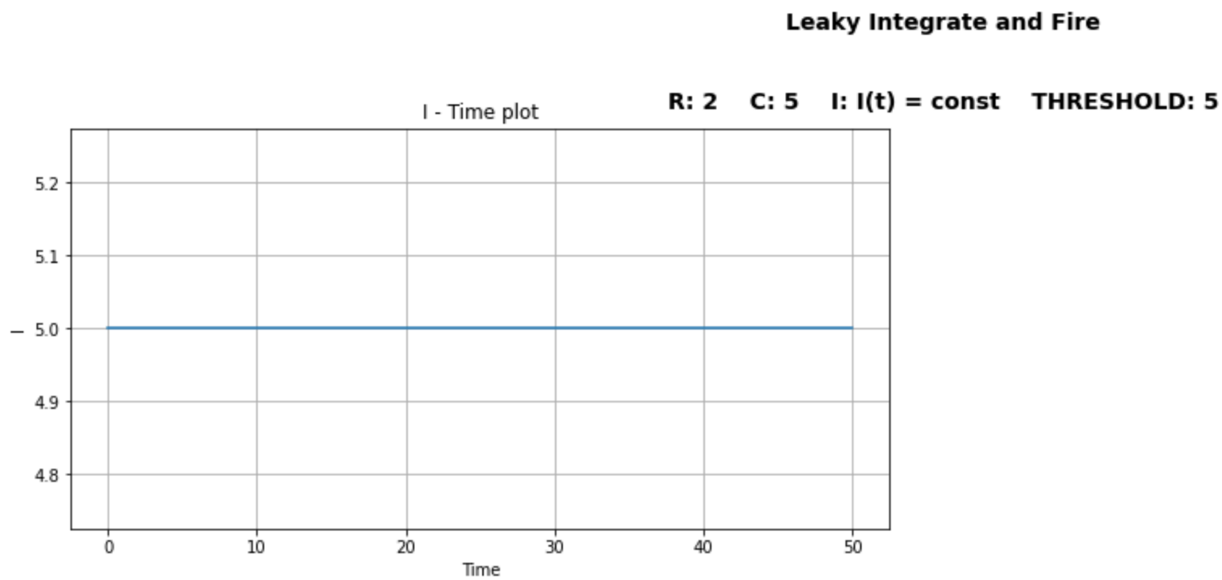
```
lif1 = LIF(i = 2, time_interval=50, C=5, threshold=5, save_name="LIF1")
```

❖ Thus, the t_U graph will be:



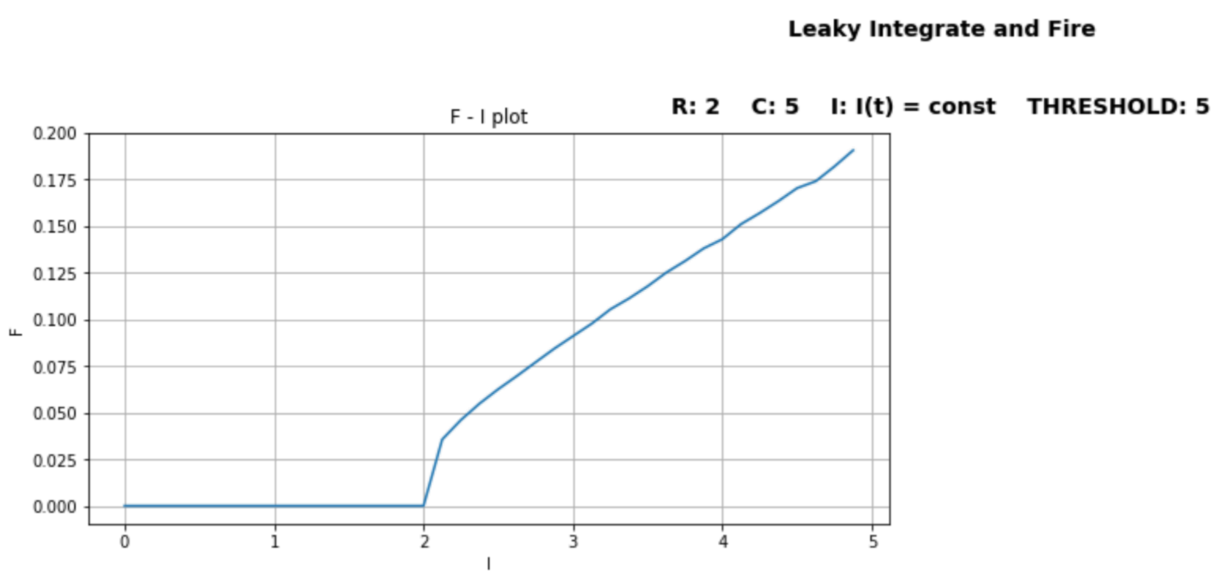
We observe that at first, with the input current, the neuron exits the resting state and reaches the threshold at 5 seconds. After reaching the threshold, the potential decreases until it returns to the resting state. This process repeats periodically.

❖ The t_I graph will be:



Because the current in this case is constant and is, for example, set to 5.

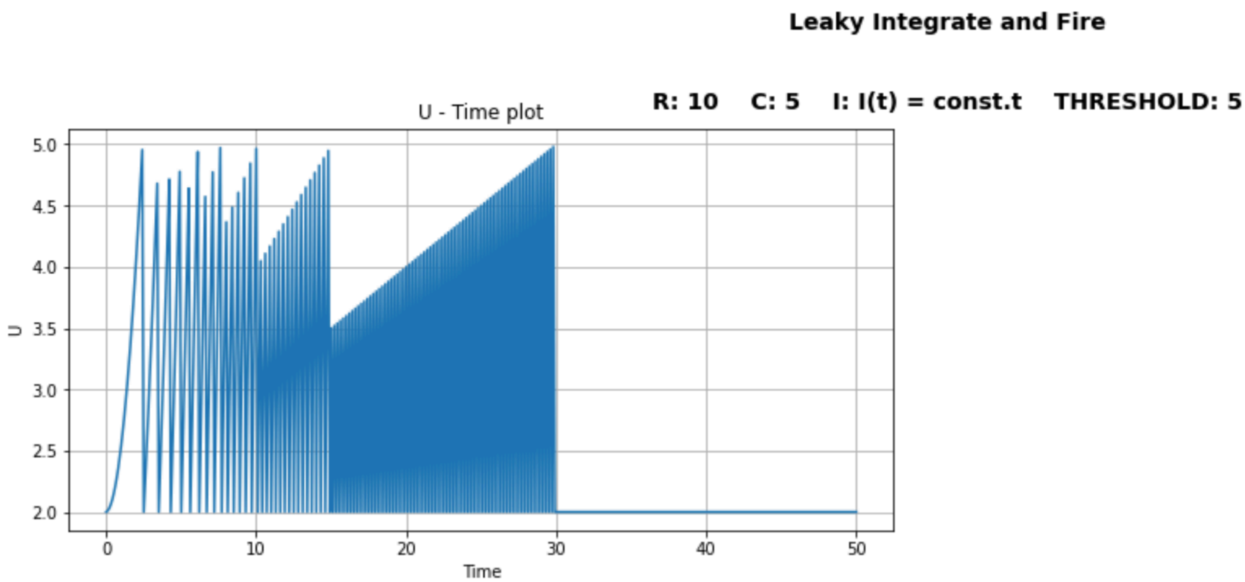
- The I_F graph will be:



- **Linear Current**: In this case, the current changes continuously at each moment.
  For example, we define the following model:

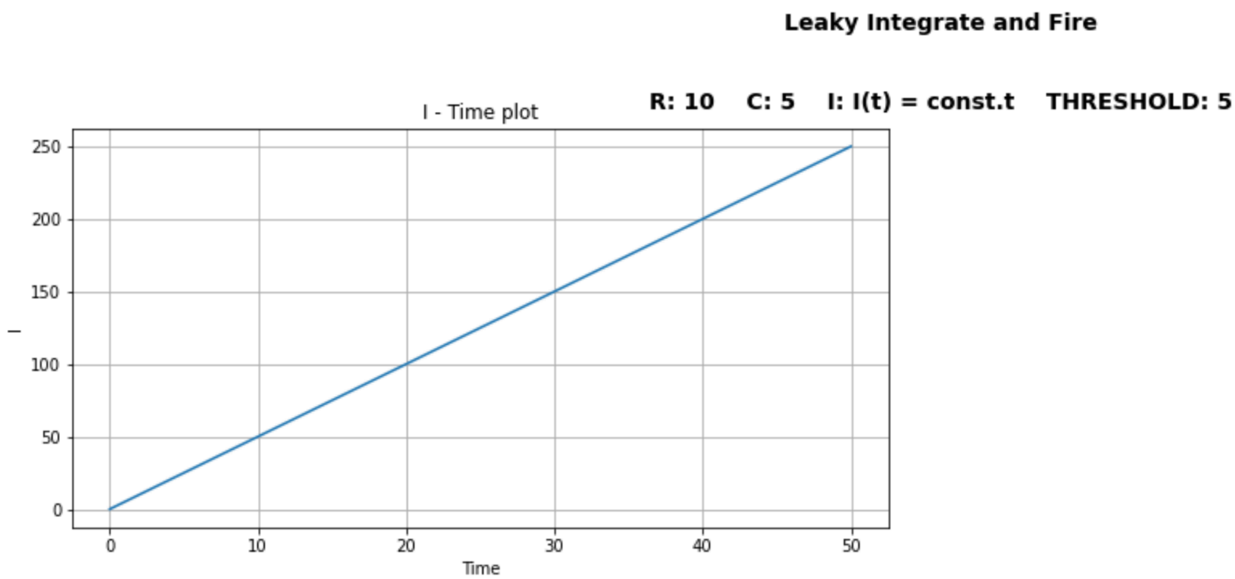
```
lif2 = LIF(i = 5, time_interval=50, u_rest=2, R=10,
C=5, threshold=5, save_name="LIF2")
```

❖ Thus, the t_U graph will be:



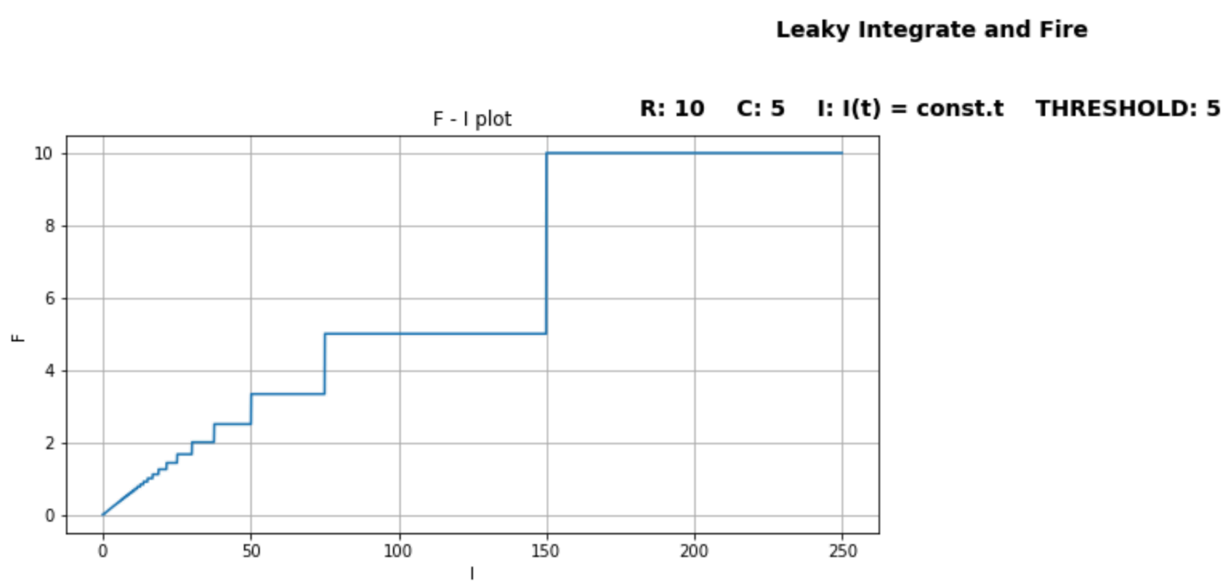
We observe that at first, with the input current, the neuron exits the resting state and reaches the threshold at 5 seconds. After reaching the threshold, the potential decreases until it returns to the resting state. This process repeats periodically.

❖ The t_I graph will be:



Because the current in this case is constant and is, for example, set to 5.

❖ The I_F graph will be:

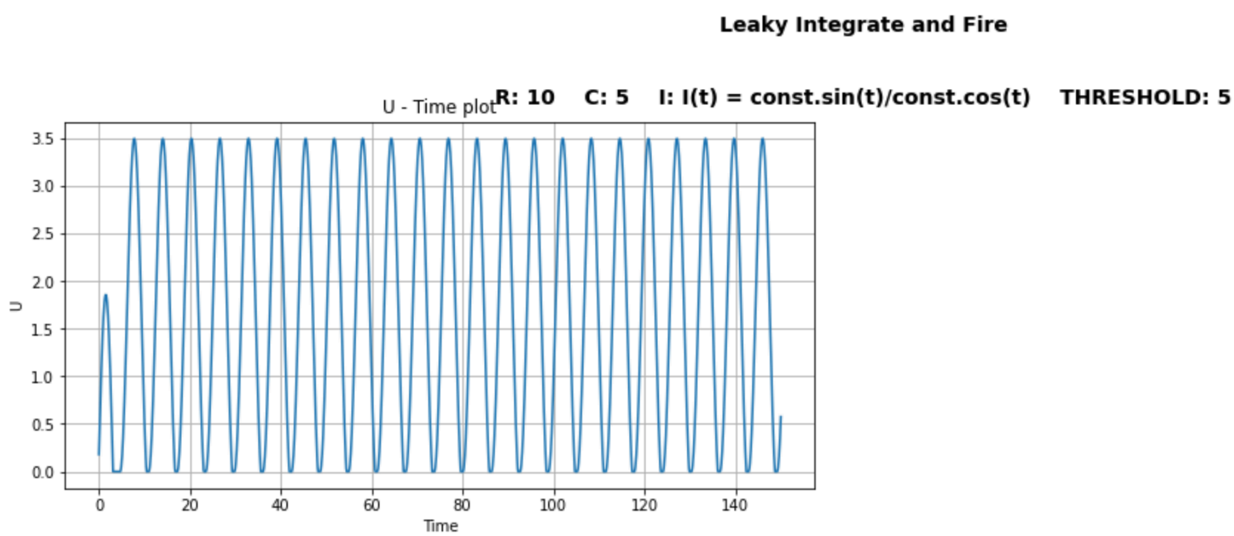


- **Sinusoidal/Cosinusoidal Current**: In this case, the current fluctuates periodically. Therefore, we do not have uniform spikes. When the current is rising and positive, the intervals between spikes increase. When the current is decreasing and negative, the intervals between spikes shorten. When the current is increasing, the neuron reaches the spike threshold faster.

  We define the following model to plot the graph:

```
lif3 = LIF(i = 1, time_interval=150, u_rest=0,
R=10, C=5, threshold=5, save_name="LIF3")
```

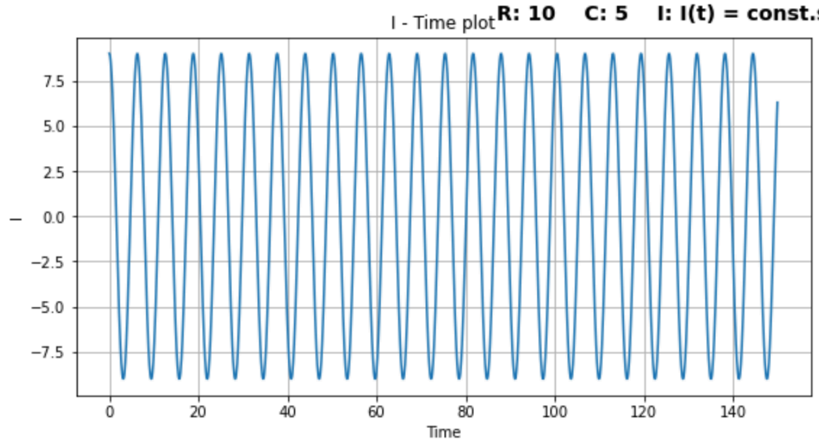
❖ The t_U graph will be:



❖ The t_I and I_F graphs will be:

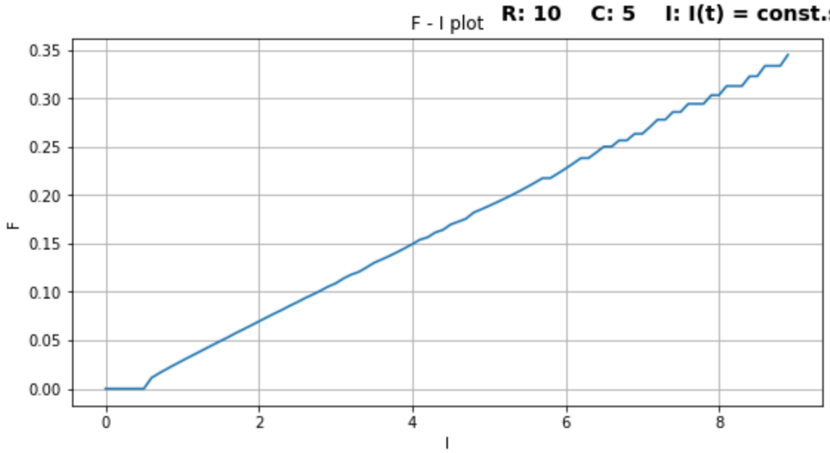
Leaky Integrate and Fire

R: 10   C: 5   I: I(t) = const.sin(t)/const.cos(t)   THRESHOLD: 5



Leaky Integrate and Fire

R: 10   C: 5   I: I(t) = const.sin(t)/const.cos(t)   THRESHOLD: 5

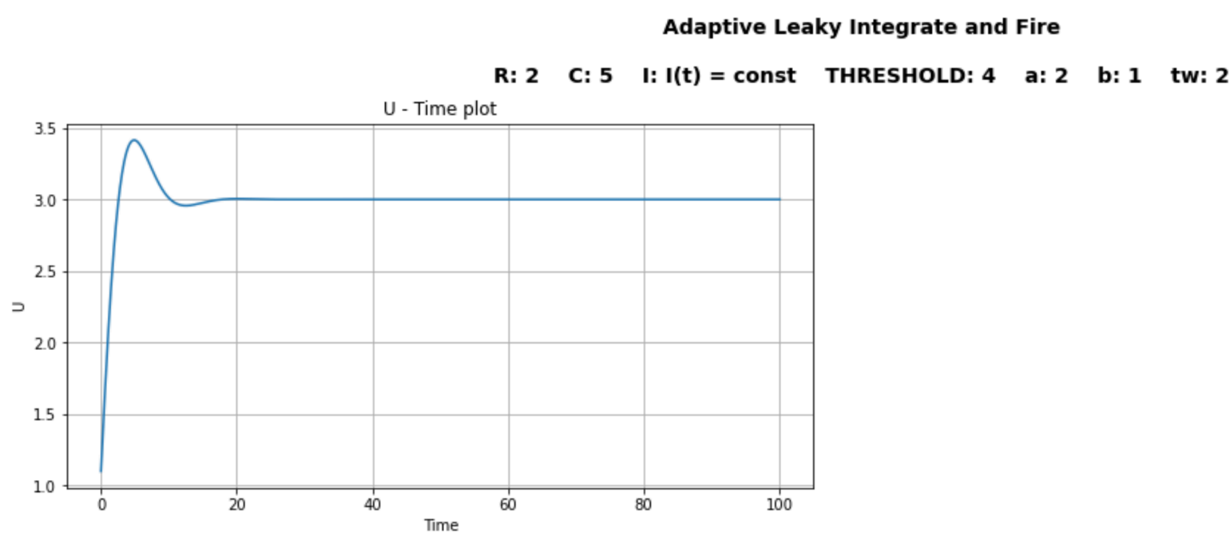


<<ALIF Model>>

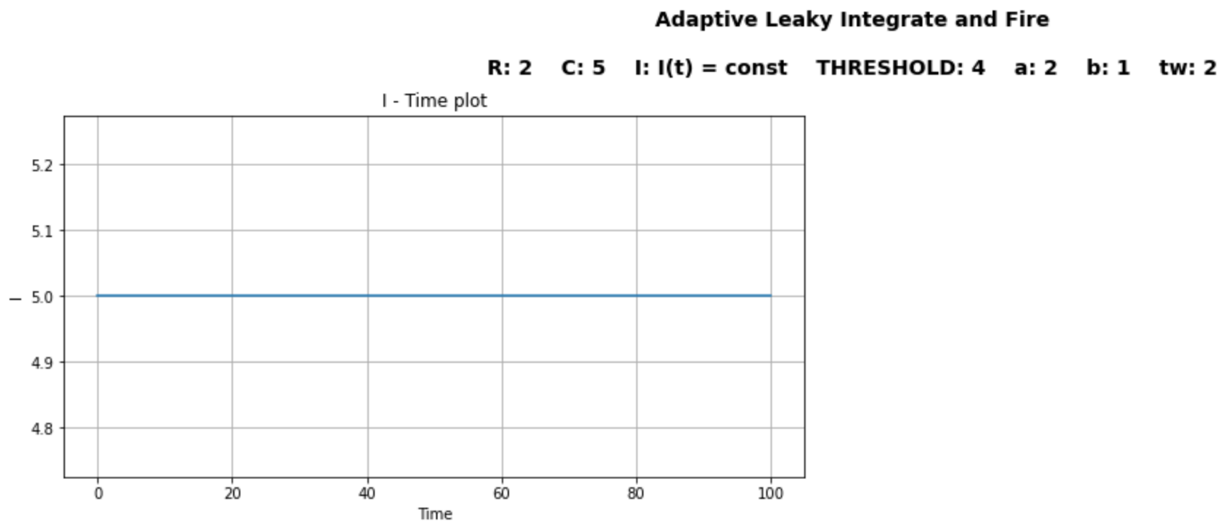
Similar to the previous model, we can apply three types of currents to this model.
We define the following model and apply the three types of currents to it:

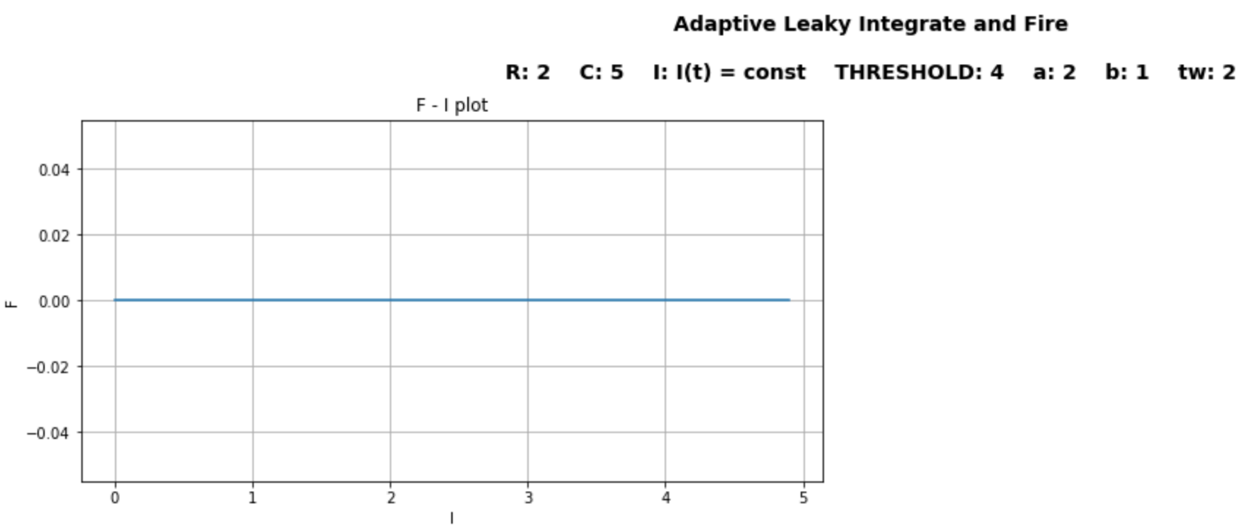
```
alif1 = ALIF(I = 1, time_interval=150, u_rest=0, R=10,
C=5, theta=4, threshold=5, a=1, b=1, save_name="LIF3")
```

- **Constant Current**:
  The constant current is applied to the neuron, and the adaptation factor eventually causes it to stop affecting the neuron.
    - ❖ The t_U graph will be:



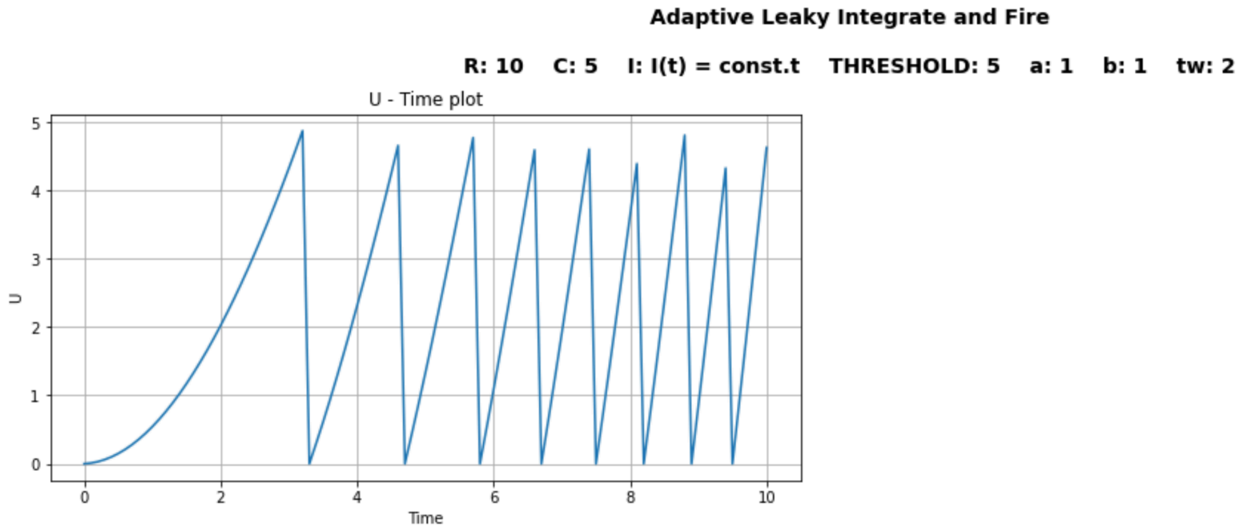
    - ❖ The t_I and I_F graphs will be:



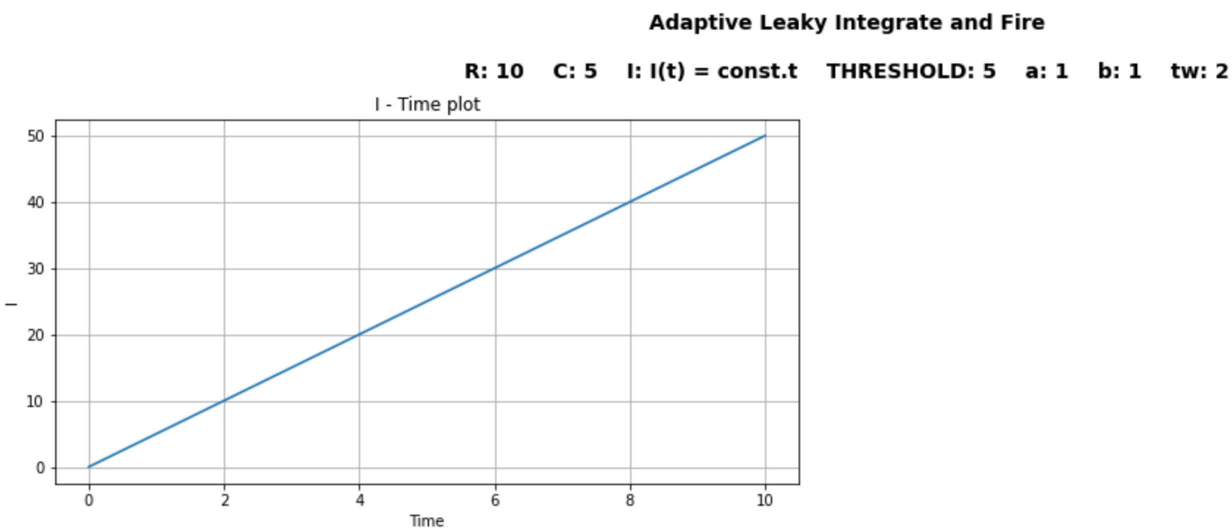


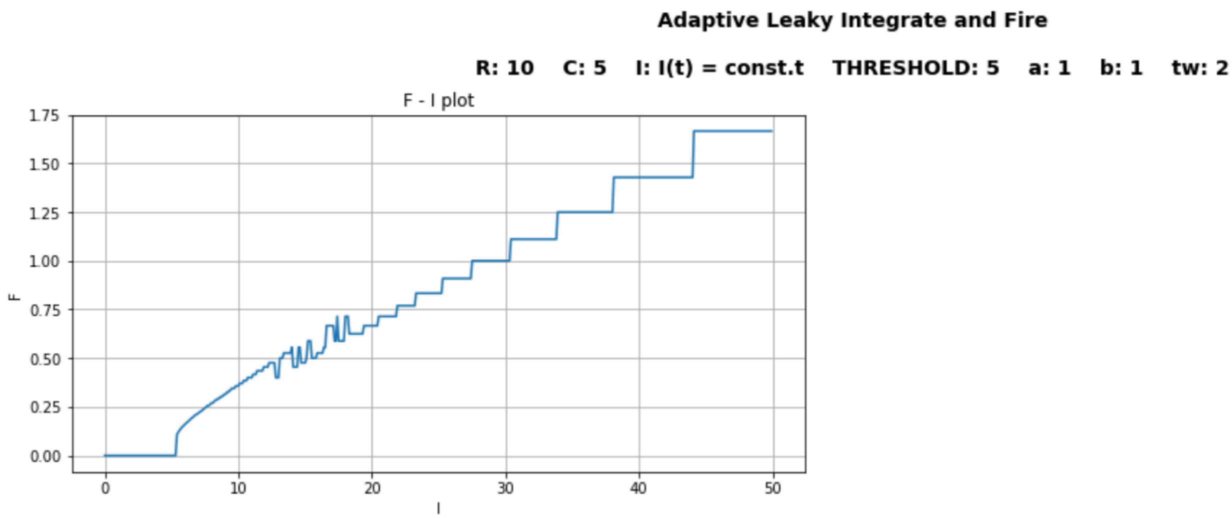
- **Linear Current**:
  In this case, the current increases over time, causing more frequent spikes, leading to short intervals between spikes. As a result, the period decreases, and the frequency increases.

  - ❖ The t_U graph:



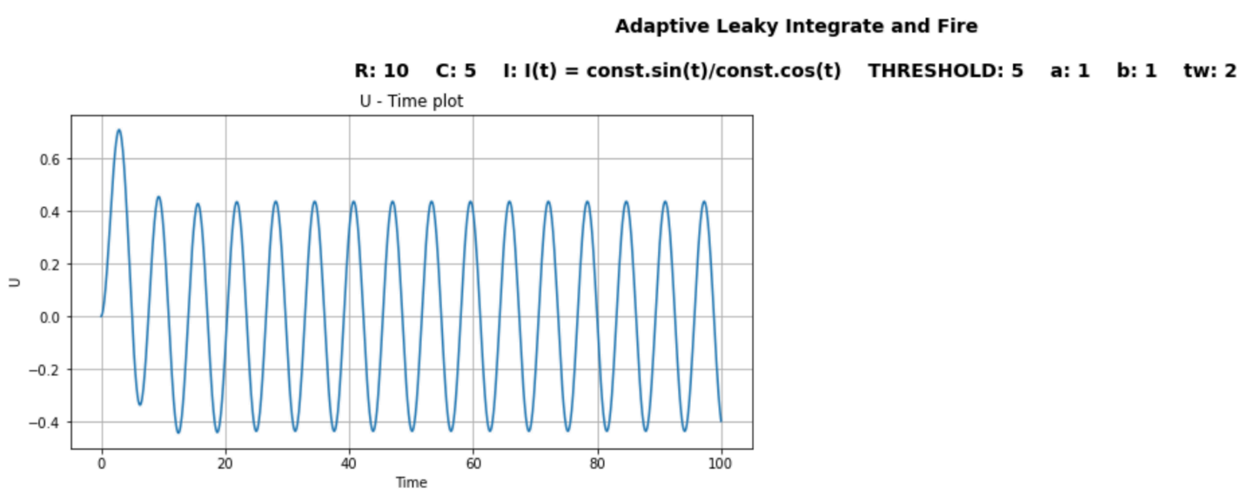
❖ The I_t and I_F graphs will be:





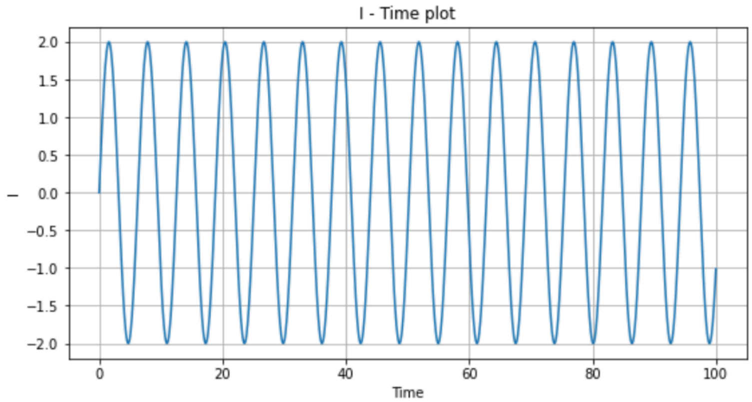
- **Sinusoidal/Cosinusoidal Current**:
  The behavior is similar to the LIF model. Occasionally, despite a positive current, the potential may decrease during the downward phase of the current.

  - ❖ The corresponding graphs will be:



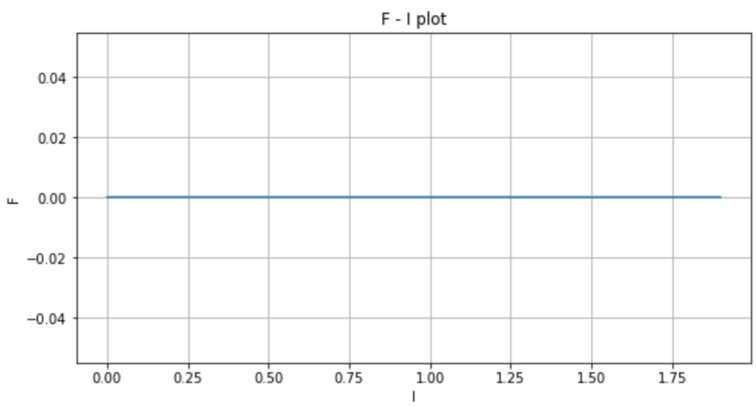
Adaptive Leaky Integrate and Fire

R: 10 C: 5 I: I(t) = const.sin(t)/const.cos(t) THRESHOLD: 5 a: 1 b: 1 tw: 2



Adaptive Leaky Integrate and Fire

R: 10 C: 5 I: I(t) = const.sin(t)/const.cos(t) THRESHOLD: 5 a: 1 b: 1 tw: 2



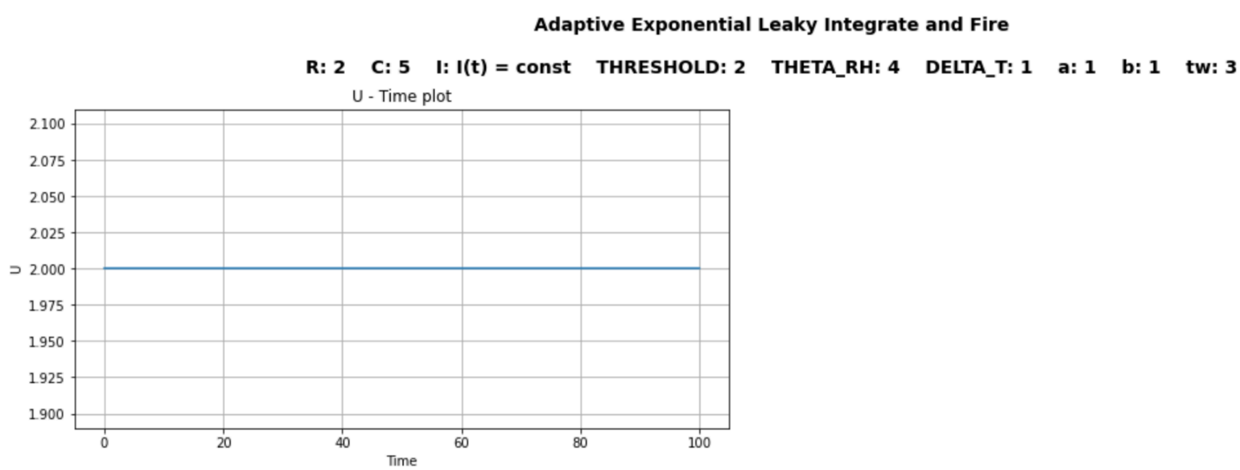
<<AELIF Model>>

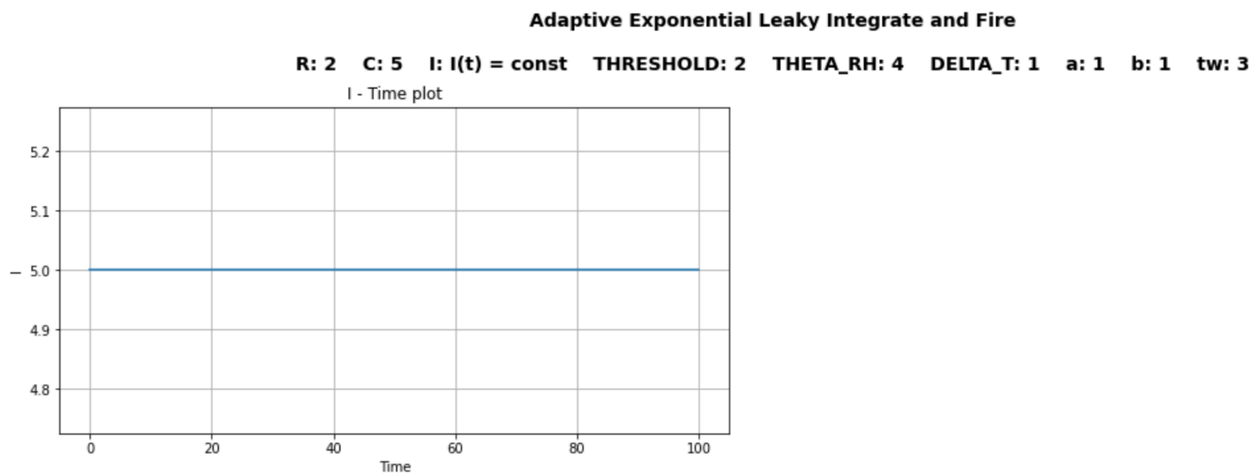
Like the previous models, we apply three types of currents to this model:
First, we define the following model to show different currents:

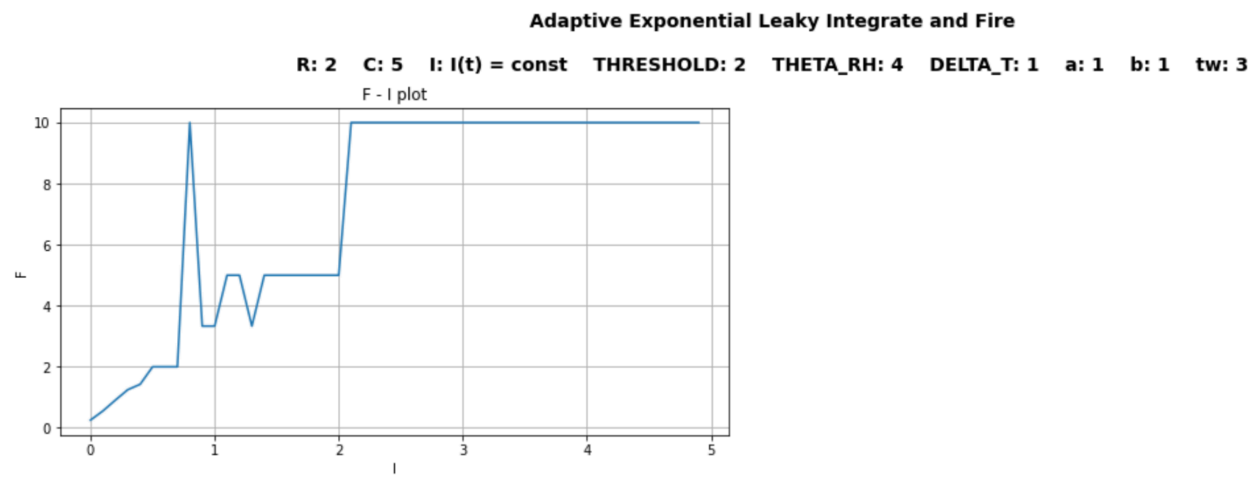
```
aelif1 = AELIF(i_func = current.i_interval, u_rest=2,
R=2, C=5, threshold=2, delta=1, theta=4, const_w=3,
a=1, b=1, save_name="AELIF1")
```

- **Constant Current**:
  Initially, the neuron is in the resting state, and the constant current is applied over time. Then the potential increases, and the neuron spikes. After the initial spike, the potential starts increasing again after a delay. Gradually, the interval between spikes increases. When the current is stopped, the potential suddenly drops, and the neuron returns to its resting state.

  - ❖ The corresponding graphs:





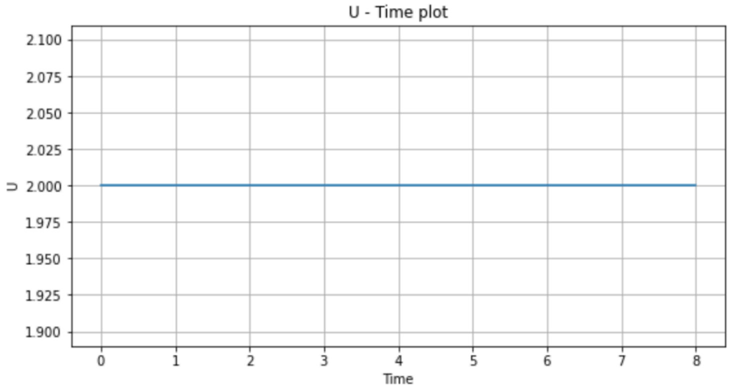


- **Linear Current**:
  With this type of current, over time, the interval between neuronal spikes decreases.

  - ❖ The corresponding graphs:

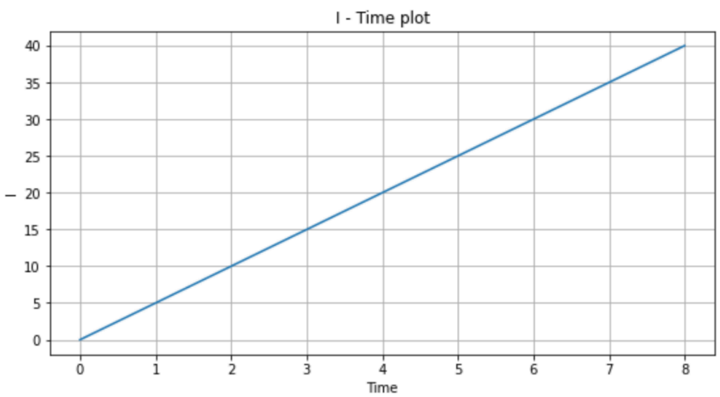
Adaptive Exponential Leaky Integrate and Fire

R: 2   C: 5   I: I(t) = const.t   THRESHOLD: 2   THETA_RH: 2   DELTA_T: 1   a: 1   b: 1   tw: 3



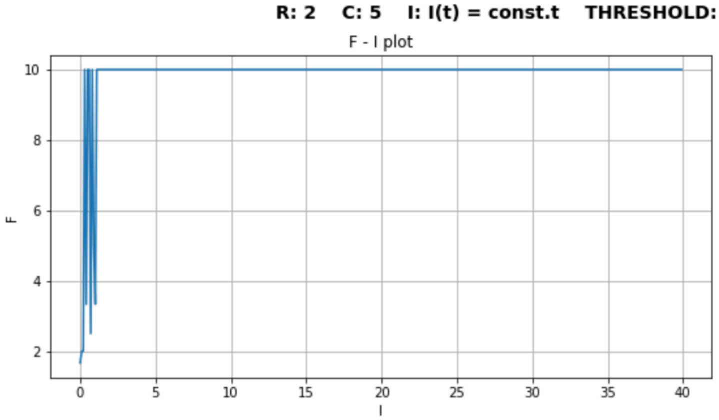
Adaptive Exponential Leaky Integrate and Fire

R: 2   C: 5   I: I(t) = const.t   THRESHOLD: 2   THETA_RH: 2   DELTA_T: 1   a: 1   b: 1   tw: 3



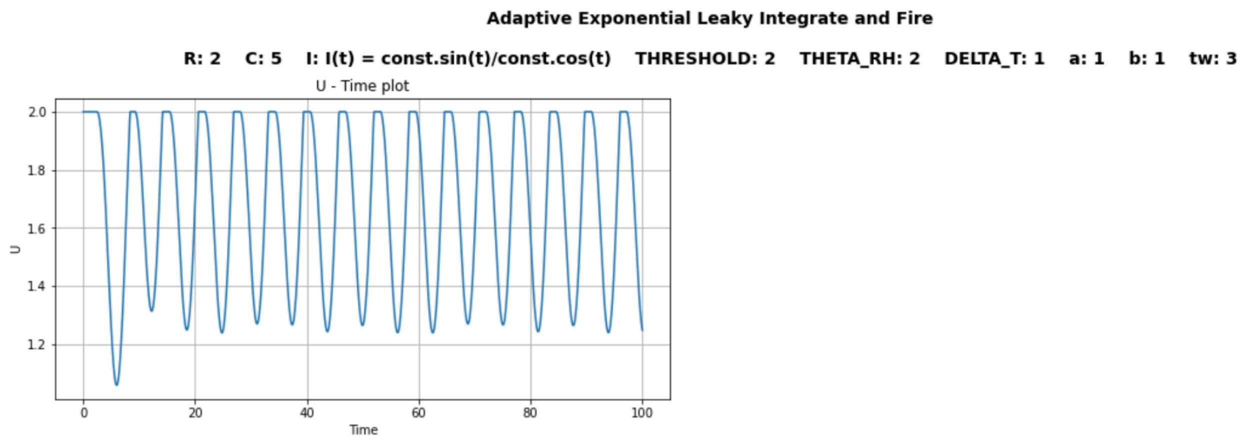
Adaptive Exponential Leaky Integrate and Fire

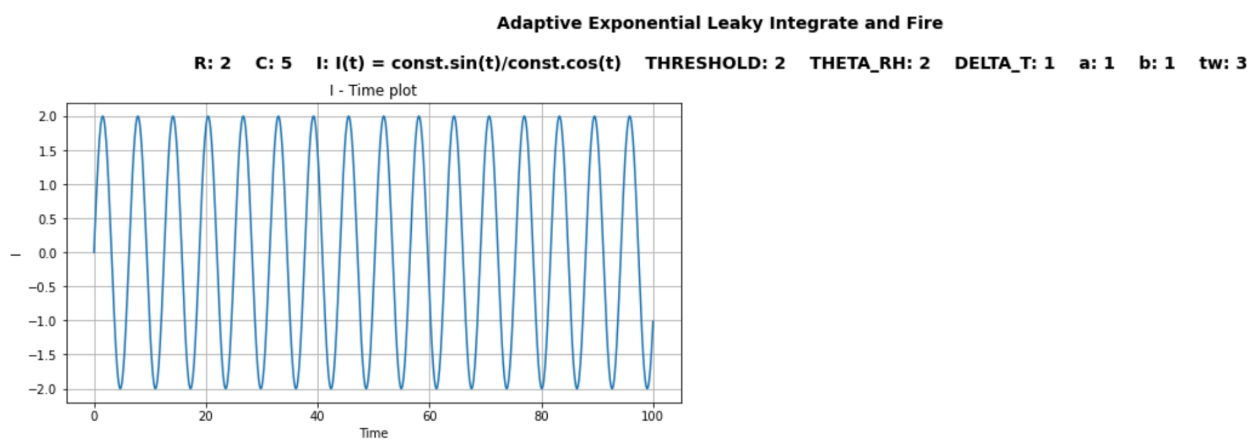
R: 2   C: 5   I: I(t) = const.t   THRESHOLD: 2   THETA_RH: 2   DELTA_T: 1   a: 1   b: 1   tw: 3



- **Sinusoidal/Cosinusoidal Current**:
  Its behavior is similar to the LIF model, and due to the adaptation factor, the potential may decrease during the downward phase of the current, even if the current remains positive.

  - ❖ The corresponding graphs:





Adaptive Exponential Leaky Integrate and Fire

R: 2   C: 5   I: I(t) = const.sin(t)/const.cos(t)   THRESHOLD: 2   THETA_RH: 2   DELTA_T: 1   a: 1   b: 1   tw: 3