بسمه تعالی

دانشگاه شهید بهشتی

دانشکده علوم ریاضی

گزارش پروژه

درس علوم اعصاب

استاد : دکتر خردپیشه

گردآورنده :

فاطمه انصافی 96222015

مقدمه : هدف از این گزارش ساخت 3 مدل و رسم نمودارهای متفاوت برای جریان ورودی ها ی مختلف به ازای تابع های متفاوت است .

مدل اول :LIF : این مدل از 2 بخش تشکیل شده . هدف این است که در نرون ما با دادن اسپایک بتوانیم پتانسیل آنرا بالا ببریم تا واکنش نشان دهد اما این پتانسیل میتواند منفی هم بشود اما باید بتوانیم بازه هایی برای این تغییرات هم تعریف کنیم .

در قسمت اول متغییر تعریف میکنیم

```
def __init__(self,
                 dt=0.03125,
                 tau=8,
                 theta=-45,
                 R=10,
                 U_rest=-79,
                 U_reset=-65,
                 U_spike=5,
                 ref_time=0,
                 ref_period=0):
        self.dt = dt
        self.tau = tau
        self.theta = theta
        self.R = R / 1000
        self.U_rest = U_rest
        self.U_reset = U_reset
        self.U_spike = U_spike
        self.ref_time = ref_time
        self.ref_period = ref_period
        self.U = self.U_rest
        self.last_fired = False
```

درقسمت 2 شروع به ساخت اجزای مختلف میکنیم :

```
def du(self, It):
        self.U += (-
(self.U - self.U_rest) + self.R * It) * self.dt / self.tau

    def fire(self):
        self.last_fired = True
        self.ref_time = self.ref_period
        self.U = self.U_spike

    def simulate_one_step(self, It):
        self.du(It)
        self.ref_time = max(self.ref_time - self.dt, 0)

        if self.last_fired or self.ref_time != 0:
```

```python
            self.last_fired = False
            self.U = self.U_reset
            return self.U, It

        if self.U >= self.theta:
            self.fire()

        return self.U, It
```

ساخت مدل ELIF :

باز هم ابتدا متغیر هارا توصیف میکنیم

```python
class ELIF:
    def __init__(self,
                 dt=0.03125,
                 tau=8,
                 theta=-45,
                 R=10,
                 U_rest=-79,
                 U_reset=-65,
                 U_spike=5,
                 ref_time=0,
                 ref_period=0,
                 theta_rh=-58,
                 delta_t=1):
        self.dt = dt
        self.tau = tau
        self.theta = theta
        self.R = R / 1000
        self.U_rest = U_rest
        self.U_reset = U_reset
        self.U_spike = U_spike
        self.ref_time = ref_time
        self.ref_period = ref_period
        self.U = self.U_rest
        self.last_fired = False

        self.theta_rh = theta_rh
        self.delta_t = delta_t
```

سپس تابع را میسازیم

```python
    def du(self, It):
        self.U += (-
(self.U - self.U_rest) + self.delta_t * (exp((self.U - self.thet
a_rh) / self.delta_t)) + self.R * It) * self.dt / self.tau

    def fire(self):
        self.last_fired = True
        self.ref_time = self.ref_period
        self.U = self.U_spike

    def simulate_one_step(self, It):
        self.du(It)
        self.ref_time = max(self.ref_time - self.dt, 0)

        if self.last_fired or self.ref_time != 0:
            self.last_fired = False
            self.U = self.U_reset
            return self.U, It

        if self.U >= self.theta:
            self.fire()

        return self.U, It
```

آخرین مدل AELIF است

باز هم متغیر تعریف میکنیم

```python
   def __init__(self,
                 dt=0.03125,
                 tau=8,
                 theta=-45,
                 R=10,
                 U_rest=-79,
                 U_reset=-65,
                 U_spike=5,
                 ref_time=0,
                 ref_period=0,
                 a=0.01,
                 b=500,
                 tau_k=100,
                 theta_rh=-58,
                 delta_t=1):
        self.dt = dt
        self.tau = tau
```

```
        self.theta = theta
        self.R = R / 1000
        self.U_rest = U_rest
        self.U_reset = U_reset
        self.U_spike = U_spike
        self.ref_time = ref_time
        self.ref_period = ref_period
        self.U = self.U_rest
        self.last_fired = False

        self.theta_rh = theta_rh
        self.delta_t = delta_t

        self.a = a * 32.25
        self.b = b * 32.25
        self.tau_k = tau_k
        self.w_k = 0
```

مرحله مدل سازی را اینجا انجام میدهیم :

```
    def du(self, It):
        def dirac(): return int(self.last_fired)
        old_u = self.U

        self.U += (-
(self.U - self.U_rest) + self.delta_t * (exp((self.U - self.thet
a_rh) / self.delta_t)) + self.R * It - (self.R * self.w_k)) * se
lf.dt / self.tau

        if self.last_fired:
            self.w_k += (self.a * (old_u - self.U_rest) - self.w
_k + self.tau_k * self.b) * self.dt / self.tau_k
        else:
            self.w_k += (self.a * (old_u - self.U_rest) - self.w
_k) * self.dt / self.tau_k

    def fire(self):
        self.last_fired = True
        self.ref_time = self.ref_period
        self.U = self.U_spike

    def simulate_one_step(self, It):
        self.du(It)
```

```
        self.ref_time = max(self.ref_time - self.dt, 0)

        if self.last_fired or self.ref_time != 0:
            self.last_fired = False
            self.U = self.U_reset
            return self.U, It

        if self.U >= self.theta:
            self.fire()

        return self.U, self.w_k
```

توابع را برای رسم تعریف میکنیم :

```
from matplotlib import pyplot as plt


def plot_mv_ms(mv, time_list, name=1, top=None, bottom=None):
    plt.plot(time_list, mv)
    plt.ylim(top=top, bottom=bottom)
    plt.ylabel('Membrane Potential (mV)')
    plt.xlabel('Time (ms)')
    if name!=1: name=" for "+name
    name="Voltage-Current"+name
    plt.title(name)
    plt.savefig(name)
    plt.show()


def plot_current(current, time_list, name=1):
    plt.plot(time_list, current)
    plt.ylabel('Input current (pA)')
    plt.xlabel('Time (ms)')
    if name!=1: name=" for "+name
    name="Time-Current"+name
    plt.title(name)
    plt.savefig(name)
    plt.show()


def plot_internal_current(current, time_list, name=1):
    plt.plot(time_list, current)
    plt.ylabel('Adaption current (pA)')
    plt.xlabel('Time (ms)')
    if name!=1: name=" for "+name
    name="Time-Adaption Current"+name
```

```
    plt.title(name)
    plt.savefig(name)
    plt.show()


def get_freq_vs_current(type, *args, **kwargs):
    current_list = [i for i in range(1000, 8000, 50)]
    freq_list = []
    for const_I in current_list:
        print("checking with current="+str(const_I))
        U_over_t, _, current = simulate_with_func(
            type, 10000, lambda x: const_I, *args, **kwargs)
        freq_list.append(len([0 for a in U_over_t if a > 0]) / 1
0000.0)

    plt.plot(current_list, freq_list)
    plt.ylabel('Frequency (KHz)')
    plt.xlabel('Input Current')
    plt.show()


def random_smooth_array(l):
    from numpy import random, array, convolve, ones, linspace
    x=linspace(0, 1000, num=l*10)
    y = 0
    result = []
    for _ in x:
        result.append(y)
        y += random.normal(scale=1)
    r_x=10
    random_array=convolve(array(result), ones((r_x,)) / r_x)[(r_
x - 1):]
    return lambda x: abs(random_array[int(x*10)])*200
```

حالا به سراغ دستور دادن برای رسم کردن میرویم :

هدف کلی رسم 5 تابع برای 3 مدل است

```
from numpy import sin


total_time_frame = 100
dt = 0.03125
time_steps = int(total_time_frame // dt)

time_list = [i * dt for i in range(time_steps)]  # Total Time Fr
ame / dt
```

```
constant_current = lambda x: int(10 <= x) * 3000
step_function_current = lambda x: (int(10 <= x <= 20) * 2000 + i
nt(30 <= x <= 40) * 5000 + int(50 <= x <= 60) * 7000)
sine_wave_current = lambda x: 4000 * (sin(x) + 0.9)
random_current = random_smooth_array(time_steps)  # Total Time F
rame / dt


# --------------------------- LIF --------------------------- #
# get_freq_vs_current(type=" + config[0] +","+ config[1]+")

## Constant Current
neuron = LIF()
U_over_t = []
inter_curr = []
current = [constant_current(t * neuron.dt) for t in range(time_s
teps)]
for i in current:
    u, w_k = neuron.simulate_one_step(i)
    U_over_t.append(u)
    inter_curr.append(w_k)

title = "LIF - Constant Current"
plot_mv_ms(U_over_t, time_list, name=title, top=-35, bottom=-80)
plot_internal_current(inter_curr, time_list, name=title)
plot_current(current, time_list, name=title)


## Step-Function Current
neuron = LIF()
U_over_t = []
inter_curr = []
current = [step_function_current(t * neuron.dt) for t in range(t
ime_steps)]
for i in current:
    u, w_k = neuron.simulate_one_step(i)
    U_over_t.append(u)
    inter_curr.append(w_k)

title = "LIF - Step-Function Current"
plot_mv_ms(U_over_t, time_list, name=title, top=-35, bottom=-80)
plot_internal_current(inter_curr, time_list, name=title)
plot_current(current, time_list, name=title)
```

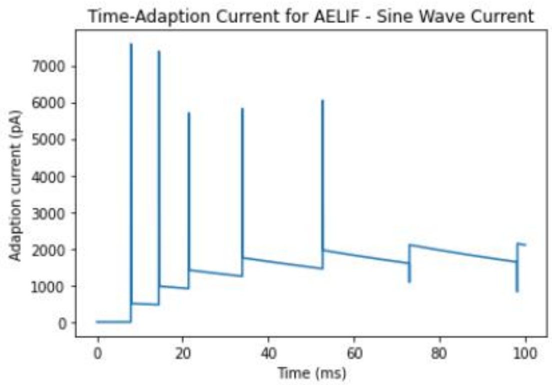
```
## Sine Wave Current
neuron = LIF()
U_over_t = []
inter_curr = []
current = [sine_wave_current(t * neuron.dt) for t in range(time_
steps)]
for i in current:
    u, w_k = neuron.simulate_one_step(i)
    U_over_t.append(u)
    inter_curr.append(w_k)

title = "LIF - Sine Wave Current"
plot_mv_ms(U_over_t, time_list, name=title, top=-35, bottom=-80)
plot_internal_current(inter_curr, time_list, name=title)
plot_current(current, time_list, name=title)


## Random Input Current
neuron = LIF()
U_over_t = []
inter_curr = []
current = [random_current(t * neuron.dt) for t in range(time_ste
ps)]
for i in current:
    u, w_k = neuron.simulate_one_step(i)
    U_over_t.append(u)
    inter_curr.append(w_k)

title = "LIF - Random Input Current"
plot_mv_ms(U_over_t, time_list, name=title, top=-35, bottom=-80)
plot_internal_current(inter_curr, time_list, name=title)
plot_current(current, time_list, name=title)


# --------------------------- ELIF --------------------------- #

## Constant Current
neuron = ELIF()
U_over_t = []
inter_curr = []
current = [constant_current(t * neuron.dt) for t in range(time_s
teps)]
for i in current:
    u, w_k = neuron.simulate_one_step(i)
    U_over_t.append(u)
    inter_curr.append(w_k)
```

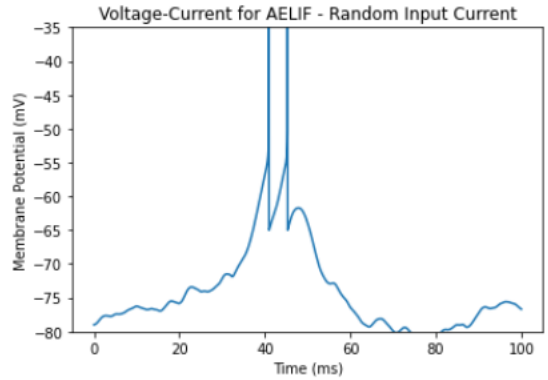
```python
title = "ELIF - Constant Current"
plot_mv_ms(U_over_t, time_list, name=title, top=-35, bottom=-80)
plot_internal_current(inter_curr, time_list, name=title)
plot_current(current, time_list, name=title)

## Step-Function Current
neuron = ELIF()
U_over_t = []
inter_curr = []
current = [step_function_current(t * neuron.dt) for t in range(t
ime_steps)]
for i in current:
    u, w_k = neuron.simulate_one_step(i)
    U_over_t.append(u)
    inter_curr.append(w_k)

title = "ELIF - Step-Function Current"
plot_mv_ms(U_over_t, time_list, name=title, top=-35, bottom=-80)
plot_internal_current(inter_curr, time_list, name=title)
plot_current(current, time_list, name=title)


## Sine Wave Current
neuron = ELIF()
U_over_t = []
inter_curr = []
current = [sine_wave_current(t * neuron.dt) for t in range(time_
steps)]
for i in current:
    u, w_k = neuron.simulate_one_step(i)
    U_over_t.append(u)
    inter_curr.append(w_k)

title = "ELIF - Sine Wave Current"
plot_mv_ms(U_over_t, time_list, name=title, top=-35, bottom=-80)
plot_internal_current(inter_curr, time_list, name=title)
plot_current(current, time_list, name=title)

## Random Input Current
neuron = ELIF()
U_over_t = []
inter_curr = []
current = [random_current(t * neuron.dt) for t in range(time_ste
ps)]
for i in current:
```

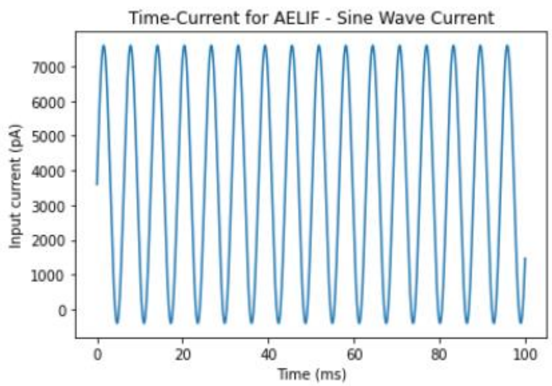
```
    u, w_k = neuron.simulate_one_step(i)
    U_over_t.append(u)
    inter_curr.append(w_k)

title = "ELIF - Random Input Current"
plot_mv_ms(U_over_t, time_list, name=title, top=-35, bottom=-80)
plot_internal_current(inter_curr, time_list, name=title)
plot_current(current, time_list, name=title)
# --------------------------- AELIF ---------------------------
- #

## Constant Current
neuron = AELIF()
U_over_t = []
inter_curr = []
current = [constant_current(t * neuron.dt) for t in range(time_s
teps)]
for i in current:
    u, w_k = neuron.simulate_one_step(i)
    U_over_t.append(u)
    inter_curr.append(w_k)

title = "AELIF - Constant Current"
plot_mv_ms(U_over_t, time_list, name=title, top=-35, bottom=-80)
plot_internal_current(inter_curr, time_list, name=title)
plot_current(current, time_list, name=title)


## Step-Function Current
neuron = AELIF()
U_over_t = []
inter_curr = []
current = [step_function_current(t * neuron.dt) for t in range(t
ime_steps)]
for i in current:
    u, w_k = neuron.simulate_one_step(i)
    U_over_t.append(u)
    inter_curr.append(w_k)

title = "AELIF - Step-Function Current"
plot_mv_ms(U_over_t, time_list, name=title, top=-35, bottom=-80)
plot_internal_current(inter_curr, time_list, name=title)
plot_current(current, time_list, name=title)


## Sine Wave Current
```

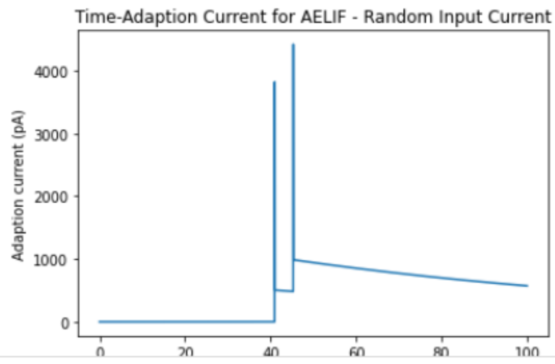
```
neuron = AELIF()
U_over_t = []
inter_curr = []
current = [sine_wave_current(t * neuron.dt) for t in range(time_
steps)]
for i in current:
    u, w_k = neuron.simulate_one_step(i)
    U_over_t.append(u)
    inter_curr.append(w_k)

title = "AELIF - Sine Wave Current"
plot_mv_ms(U_over_t, time_list, name=title, top=-35, bottom=-80)
plot_internal_current(inter_curr, time_list, name=title)
plot_current(current, time_list, name=title)


## Random Input Current
neuron = AELIF()
U_over_t = []
inter_curr = []
current = [random_current(t * neuron.dt) for t in range(time_ste
ps)]
for i in current:
    u, w_k = neuron.simulate_one_step(i)
    U_over_t.append(u)
    inter_curr.append(w_k)

title = "AELIF - Random Input Current"
plot_mv_ms(U_over_t, time_list, name=title, top=-35, bottom=-80)
plot_internal_current(inter_curr, time_list, name=title)
```

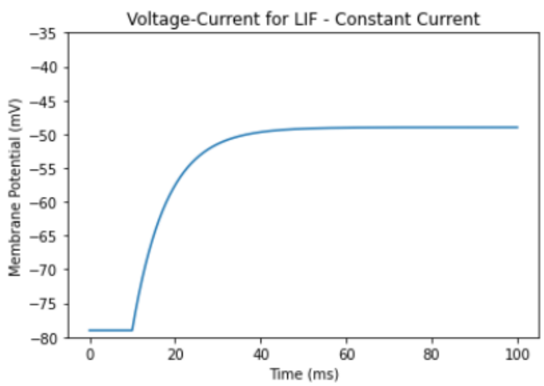
```
plot_current(current, time_list, name=title)
```

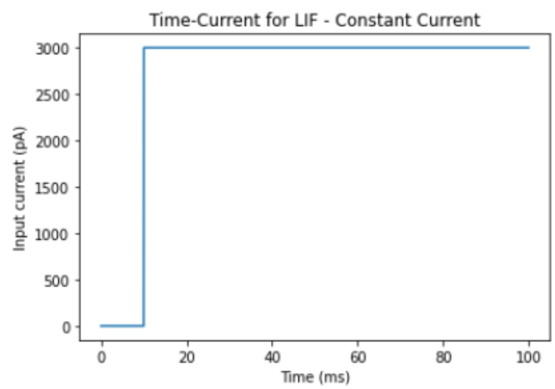


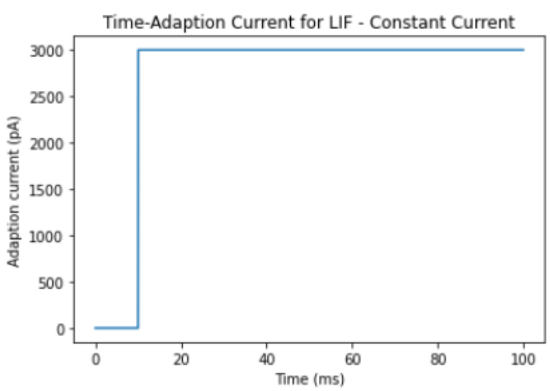


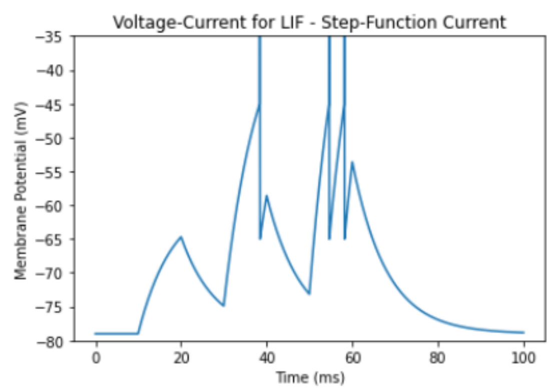


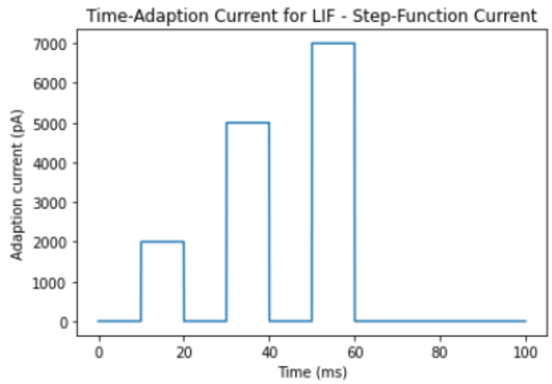


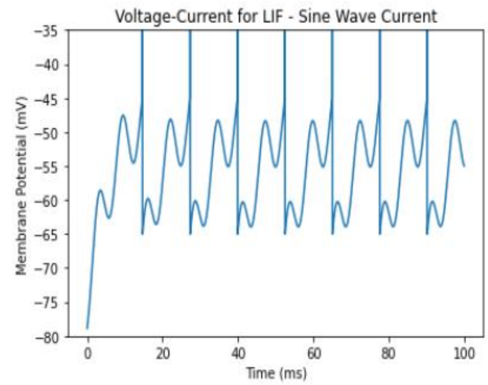


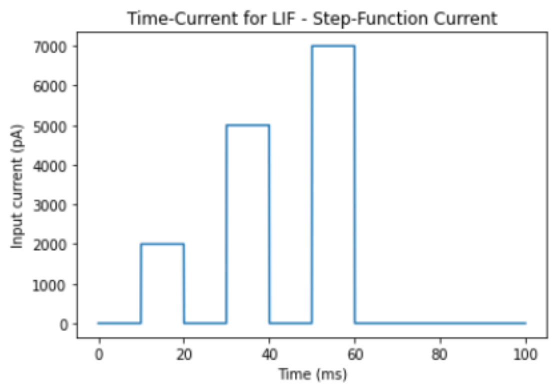


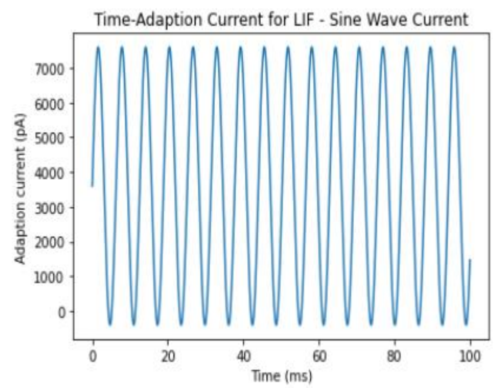


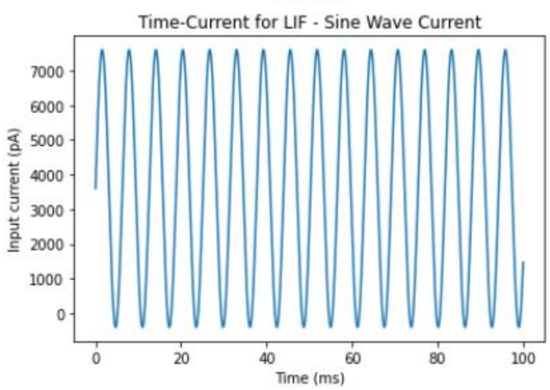


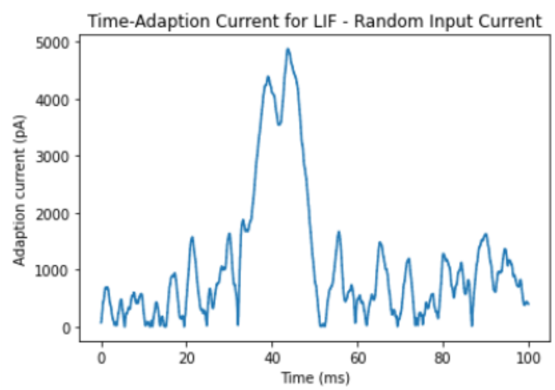

Time-Adaption Current for LIF - Step-Function Current
Adaption current (pA)
Time (ms)

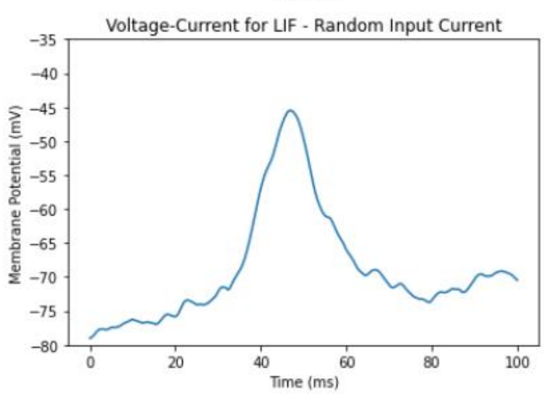

Voltage-Current for LIF - Sine Wave Current
Membrane Potential (mV)
Time (ms)

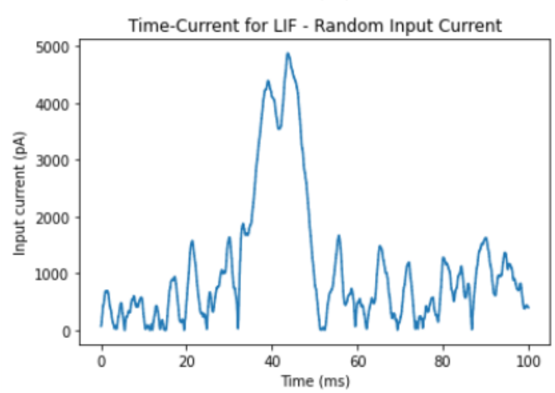

Time-Current for LIF - Step-Function Current
Input current (pA)
Time (ms)

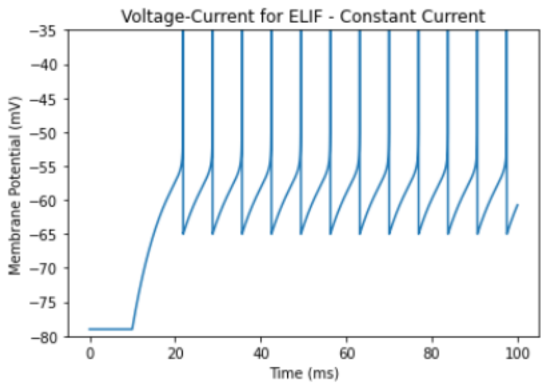

Time-Adaption Current for LIF - Sine Wave Current
Adaption current (pA)
Time (ms)

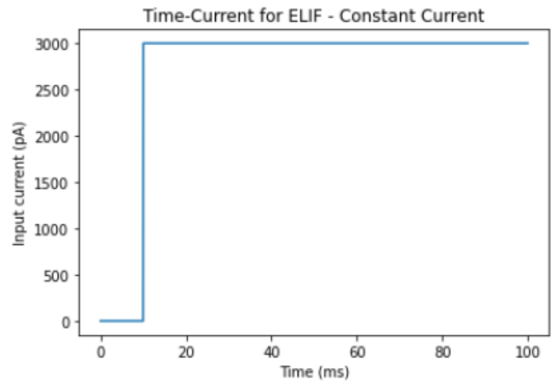

Time-Current for LIF - Sine Wave Current
Input current (pA)
Time (ms)

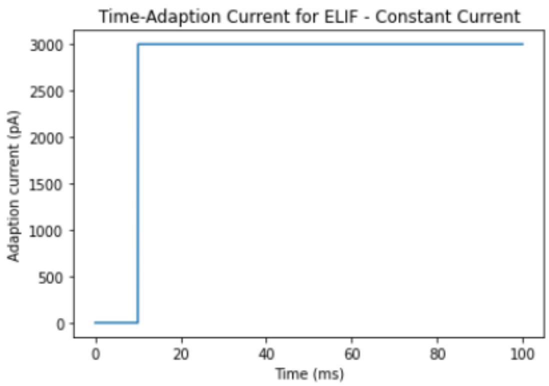

Time-Adaption Current for LIF - Random Input Current
Adaption current (pA)
Time (ms)

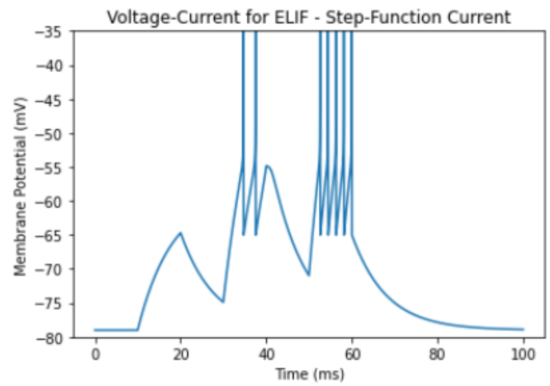

Voltage-Current for LIF - Random Input Current
Membrane Potential (mV)
Time (ms)

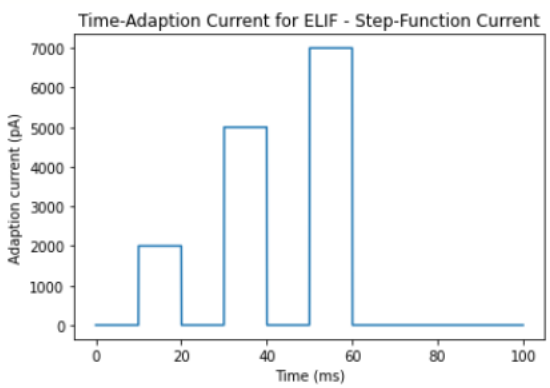

Time-Current for LIF - Random Input Current
Input current (pA)
Time (ms)

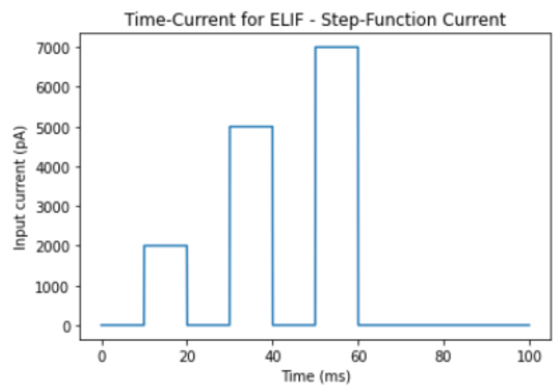

Voltage-Current for ELIF - Constant Current
Membrane Potential (mV)
Time (ms)

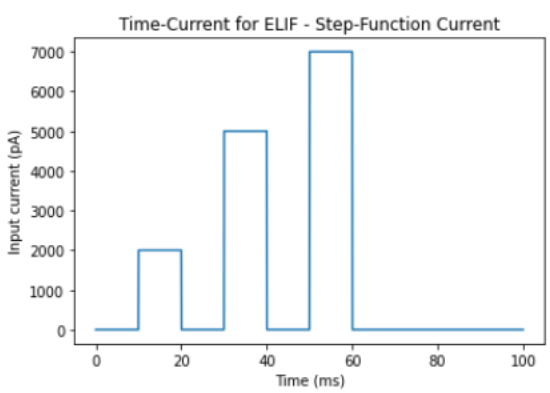

Time-Current for ELIF - Constant Current
Input current (pA)
Time (ms)

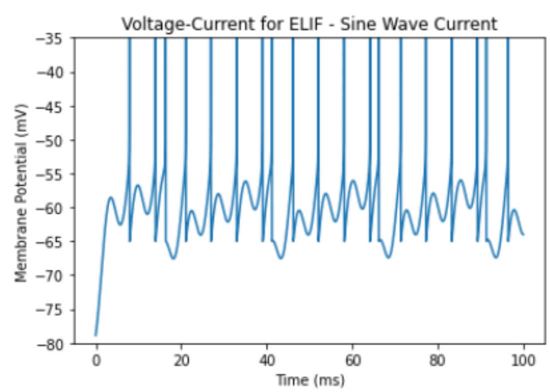

Time-Adaption Current for ELIF - Constant Current
Adaption current (pA)
Time (ms)

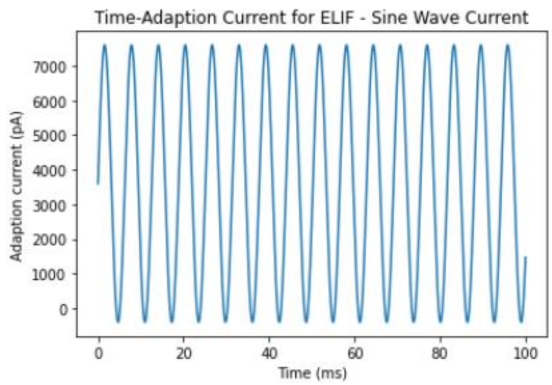

Voltage-Current for ELIF - Step-Function Current
Membrane Potential (mV)
Time (ms)

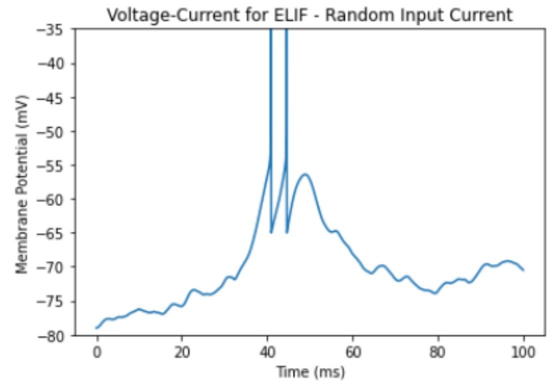

Time-Adaption Current for ELIF - Step-Function Current
Adaption current (pA)
Time (ms)

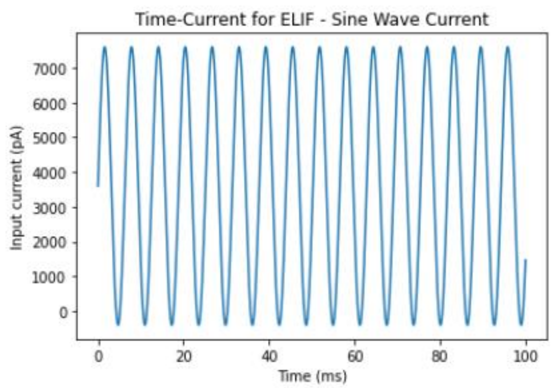

Time-Current for ELIF - Step-Function Current
Input current (pA)
Time (ms)

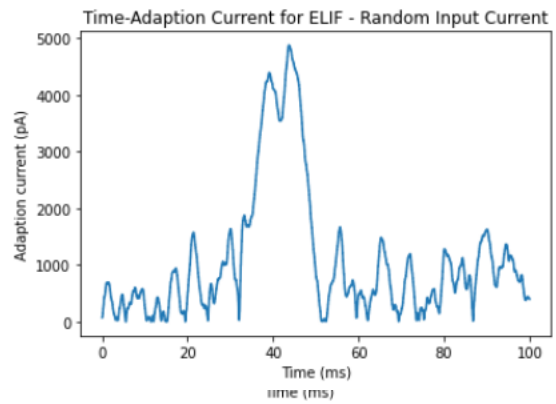

Time-Current for ELIF - Step-Function Current
Input current (pA)
Time (ms)

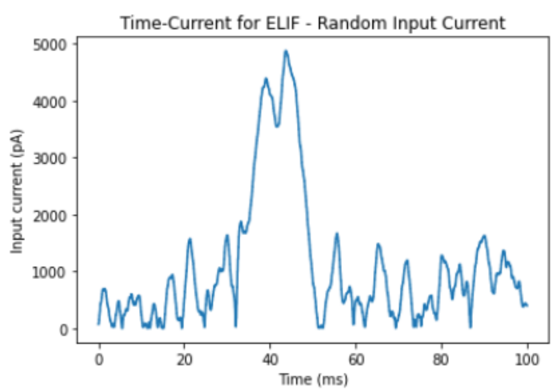

Voltage-Current for ELIF - Sine Wave Current
Membrane Potential (mV)
Time (ms)

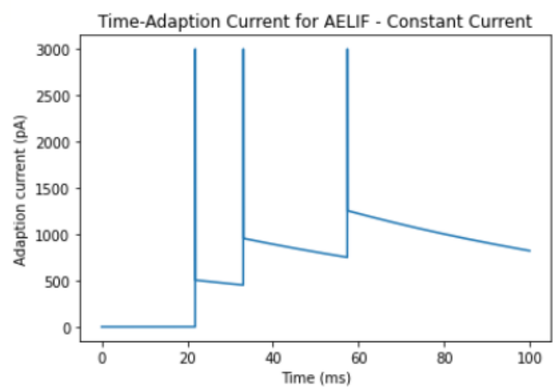

Time-Adaption Current for ELIF - Sine Wave Current
Adaption current (pA)
Time (ms)

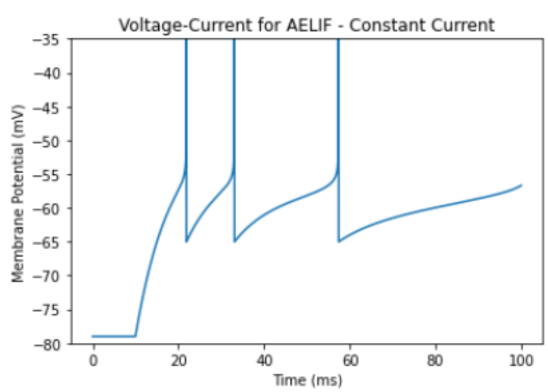

Voltage-Current for ELIF - Random Input Current
Membrane Potential (mV)
Time (ms)

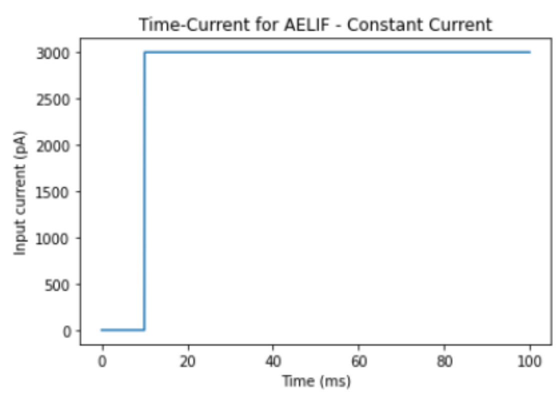

Time-Current for ELIF - Sine Wave Current
Input current (pA)
Time (ms)

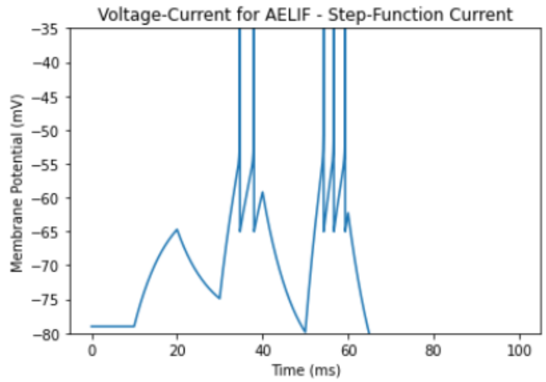

Time-Adaption Current for ELIF - Random Input Current
Adaption current (pA)
Time (ms)

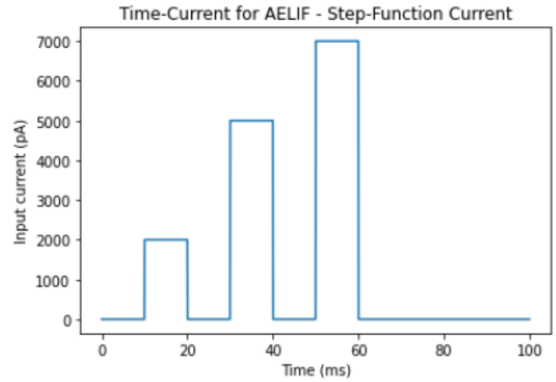

Time-Current for ELIF - Random Input Current
Input current (pA)
Time (ms)

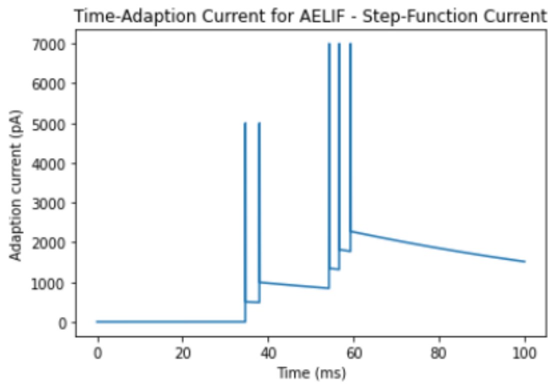

Time-Adaption Current for AELIF - Constant Current
Adaption current (pA)
Time (ms)

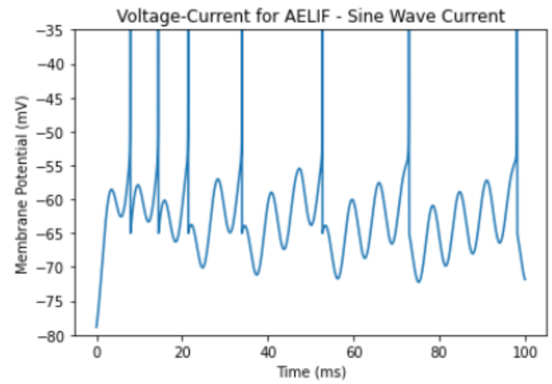

Voltage-Current for AELIF - Constant Current
Membrane Potential (mV)
Time (ms)


Time-Current for AELIF - Constant Current
Input current (pA)
Time (ms)


Voltage-Current for AELIF - Step-Function Current
Membrane Potential (mV)
Time (ms)


Time-Current for AELIF - Step-Function Current
Input current (pA)
Time (ms)


Time-Adaption Current for AELIF - Step-Function Current
Adaption current (pA)
Time (ms)


Voltage-Current for AELIF - Sine Wave Current
Membrane Potential (mV)
Time (ms)