Report 1

Computational Neuroscience

Computer Assignment 1

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In [1]:
```
%matplotlib notebook
import torch
import numpy as np
```

In [2]:
```
from cnsproject.network.neural_populations import LIFPopulation
from cnsproject.plotting.plotting import plotting
from cnsproject.utils import step_function, two_way_step_function, random_step_function
from cnsproject.network.monitors import Monitor
```

Global Variables

$time$ parameter shows how often (seconds*scale/dt) we want to run our neuron. dt means with what resolution ($scale$) we want our seconds move forward.

In [3]:
```
time = 1500
dt = 1
scale = 100
step_size = 1
shape = (1,)
spike_trace = True
additive_spike_trace = True
tau_s = 10.
trace_scale = 1.
is_inhibitory = False
learning = False
R = 10
C = 10
```

Description

After defining our parameters, we need to modify a electric current(I). There are 3 functions that modified in utils file which are `step_function` , `two_way_step_function` , and `random_step_function` . Inputs of them are $time : int$, and $step\_size : int$. step_size is the scale value for the step functions. But it is the maximum value that random steps in the random function will produce.

In [4]:
```
I = step_function(time, step_size, scale)
```

In this step we will create LIF neuron model. The definition of inputs are written in its source code.

In [5]:
```
neuron = LIFPopulation(
            shape, spike_trace, additive_spike_trace, tau_s, trace_scale,
            is_inhibitory, learning, R, C
        )
neuron.dt = dt
```

For the next step, we should define a Monitor to be able to monitor the neuron in the $time$ duration. The parameters that we are going to monitor are s and u. s is a list with the length of time which is filled with whether the neuron spikes in that time or not. u also has the same length as s and shows the potential for each time.

In [6]:
```
monitor = Monitor(neuron, state_variables=["s", "u"])
monitor.set_time_steps(time, neuron.dt)
monitor.reset_state_variables()
```

In this part, we give the neuron the current in each resolution and track its action with monitor.

In `forward` function two steps handled:

1. Compute Potential:
   For computing the potential at each moment, I used the below formula:
   $U(t+\Delta) = U(t) - (\Delta/\tau).\left[(U(t) - U_{rest}) - R.I(t)\right]$
2. Check spiking:
   For checking whether the neuron spikes or not, I used the threshold to see whether the potential crosses it or not.

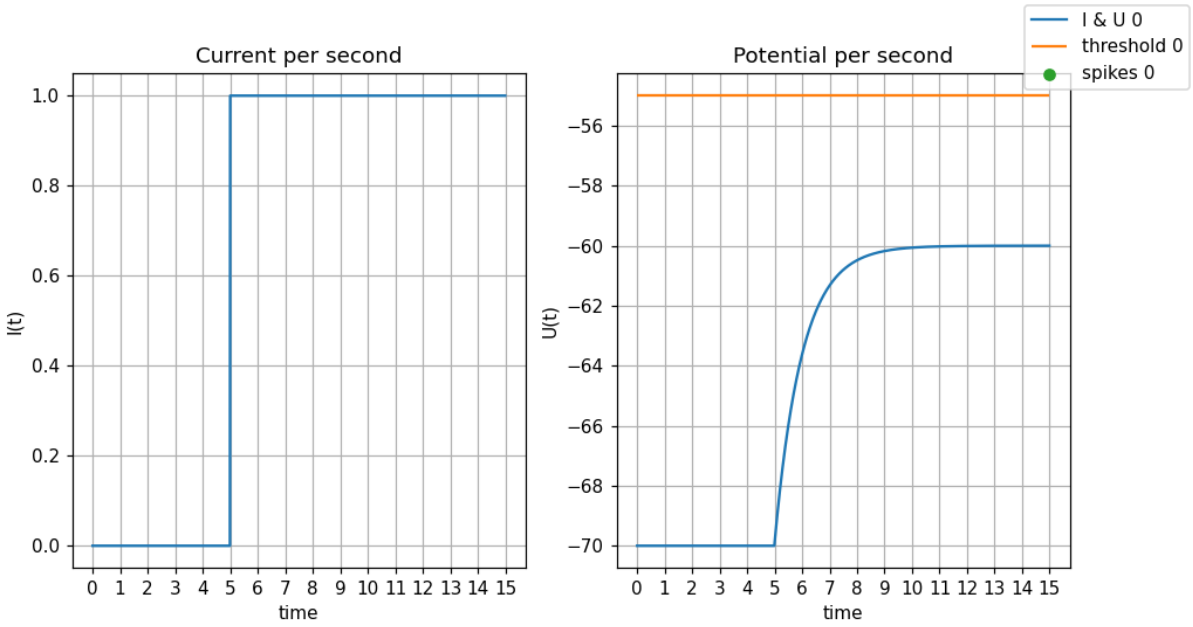
In [7]:
```
for i in range(len(I)):
    neuron.forward(I[i][0])
    monitor.record()
```

After iterating the current, we can get the spike and the potential for each resolution in time.

In [8]:
```
s = monitor.get("s")
s = torch.transpose(s*1, 0, 1)
u = monitor.get("u")
```

For plotting the current and potential, you can use the plotting class which has a initial function (here is `plot_ut_it_init`) that reset and prepare the plot. After initailization, you can update the plot with its relevent function (here is `plot_ut_it_update`). Till the time you initial another plot, you will be able to show multiple plots (with `show` function).

In [9]:
```
plot = plotting()
plot.plot_ut_it_init(time/scale)
plot.plot_ut_it_update(I, u, neuron.threshold, s[0].nonzero(as_tuple=True)[0])
plot.show()
```



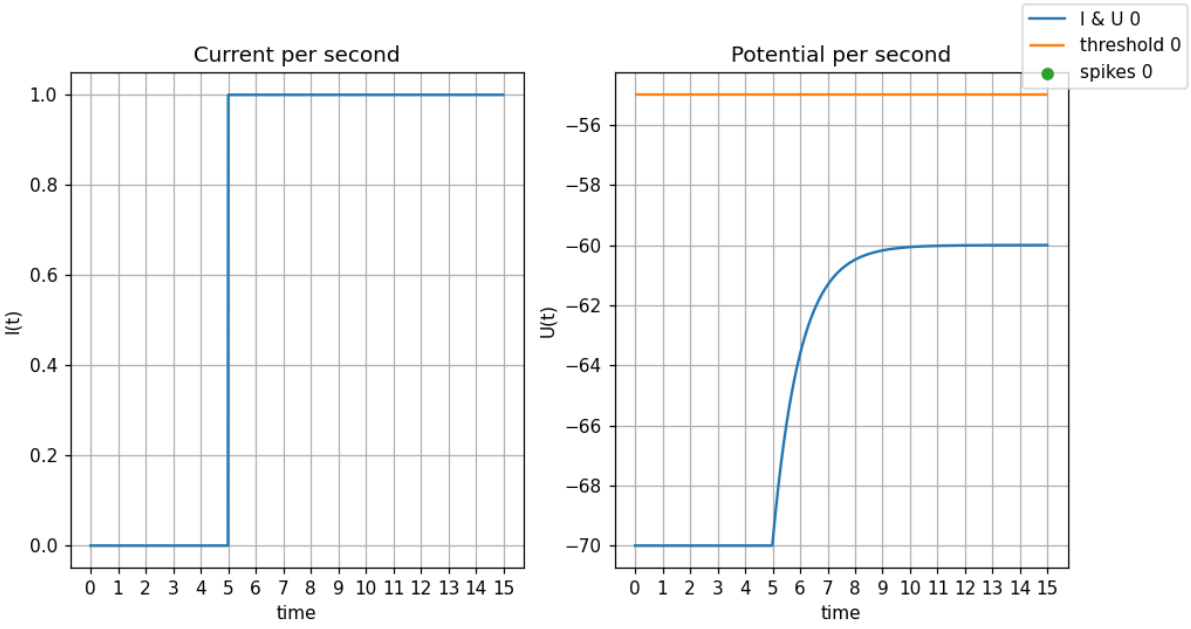
Neuron Behavior

The next function is all the above steps together and return the neuron, current, a list of spikes, and a list of potentials.

In [10]:
```
def single_neuron_time(
        time, dt, scale, step_size, I_function, shape, spike_trace,
        additive_spike_trace, tau_s, trace_scale,
        is_inhibitory, learning, R, C, threshold = -55
    ):

    I = I_function(time, step_size, scale)
    neuron = LIFPopulation(
            shape, spike_trace, additive_spike_trace, tau_s, trace_scale,
            is_inhibitory, learning, R, C, threshold
        )
    neuron.dt = dt
    monitor = Monitor(neuron, state_variables=["s", "u"])
    monitor.set_time_steps(time, dt)
    monitor.reset_state_variables()
    for i in range(len(I)):
        neuron.forward(I[i][0])
        monitor.record()
    return neuron, I, torch.transpose(monitor.get("s")*1, 0, 1), monitor.get("u")
```

The default of the parameters of a neuron is as follow:

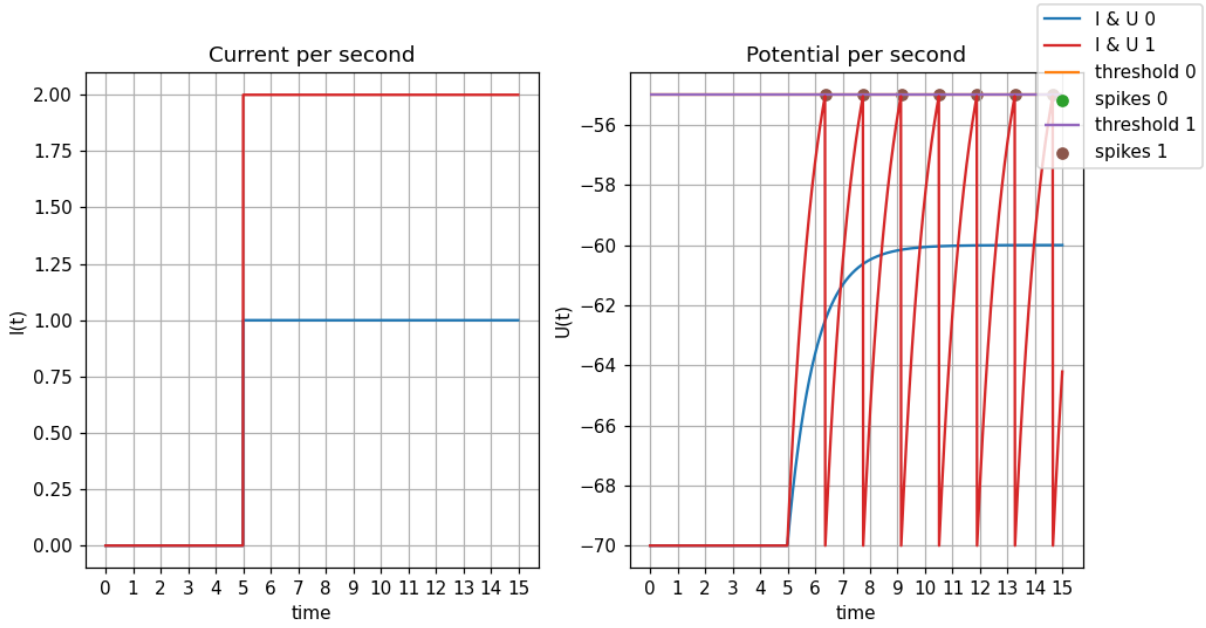
In [11]:
```
%%time
plot = plotting()

neuron, I, s, u = single_neuron_time(
        time, dt, scale, step_size, step_function, shape, spike_trace,
        additive_spike_trace, tau_s, trace_scale,
        is_inhibitory, learning, R, C
    )

plot.plot_ut_it_init(time/scale)
plot.plot_ut_it_update(I, u, neuron.threshold, s[0].nonzero(as_tuple=True)[0])
plot.show()
```




```
CPU times: user 318 ms, sys: 8.49 ms, total: 327 ms
Wall time: 323 ms
```

The next cell is showing how the size of the step function (electric current) affects on a neuron. By increasing the step function value, the growth rate of potential increases.

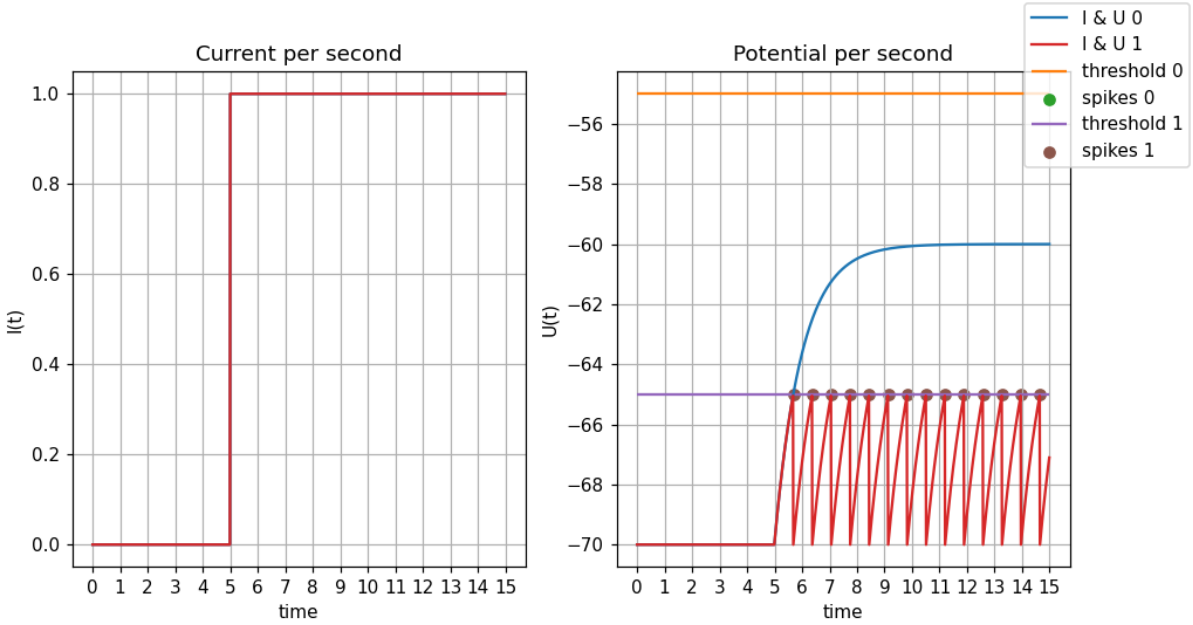
In [25]:
```
%%time

neuron, I, s, u = single_neuron_time(
        time, dt, scale, step_size, step_function, shape, spike_trace,
        additive_spike_trace, tau_s, trace_scale,
        is_inhibitory, learning, R, C
    )

plot.plot_ut_it_init(time/scale)
plot.plot_ut_it_update(I, u, neuron.threshold, s[0].nonzero(as_tuple=True)[0])

neuron, I, s, u = single_neuron_time(
        time, dt, scale, 2, step_function, shape, spike_trace,
        additive_spike_trace, tau_s, trace_scale,
        is_inhibitory, learning, R, C
    )
plot.plot_ut_it_update(I, u, neuron.threshold, s[0].nonzero(as_tuple=True)[0])
plot.show()
```




```
CPU times: user 615 ms, sys: 6.55 ms, total: 622 ms
Wall time: 622 ms
```

The next cell is showing how the threshold affects on a neuron. By decreasing the threshold value, the growth rate of potential won't change and the only difference should be the number of spikes.

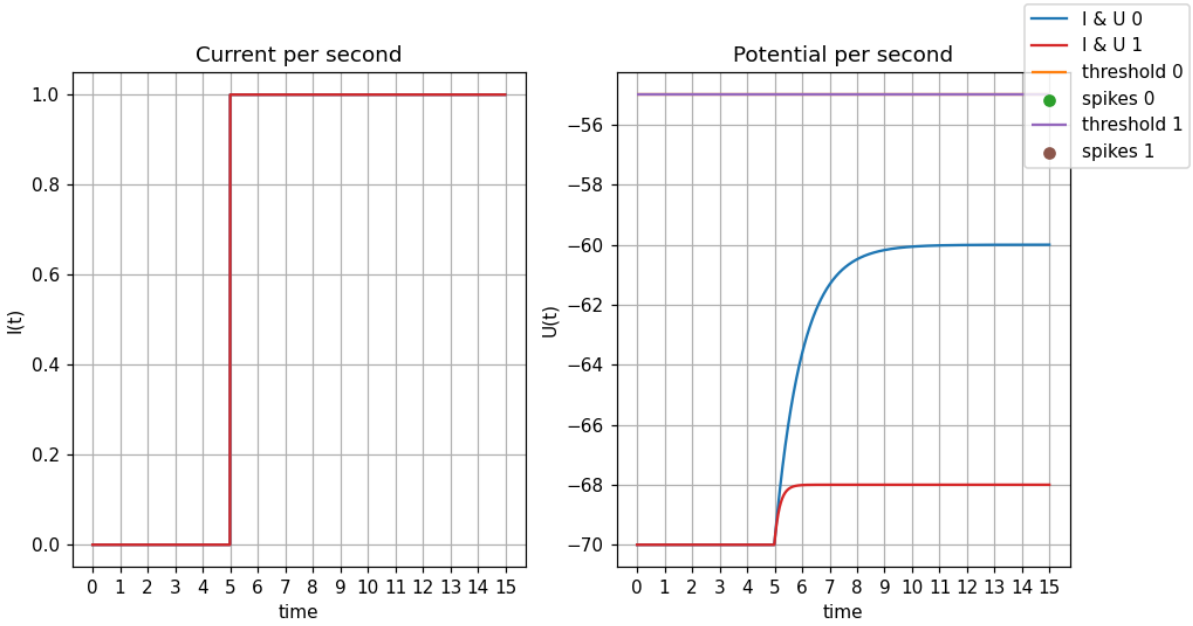
In [21]:
```
%%time

neuron, I, s, u = single_neuron_time(
        time, dt, scale, step_size, step_function, shape, spike_trace,
        additive_spike_trace, tau_s, trace_scale,
        is_inhibitory, learning, R, C
    )

plot.plot_ut_it_init(time/scale)
plot.plot_ut_it_update(I, u, neuron.threshold, s[0].nonzero(as_tuple=True)[0])

neuron, I, s, u = single_neuron_time(
        time, dt, scale, step_size, step_function, shape, spike_trace,
        additive_spike_trace, tau_s, trace_scale,
        is_inhibitory, learning, R, C, threshold = -65
    )
plot.plot_ut_it_update(I, u, neuron.threshold, s[0].nonzero(as_tuple=True)[0])
plot.show()
```




```
CPU times: user 573 ms, sys: 18.9 ms, total: 592 ms
Wall time: 593 ms
```

The next cell is showing how the Resistance (R) affects on a neuron. By decreasing R, the growth rate of potential decreases which it means it will take less time to reach the stable potential and also the stable point decreases.

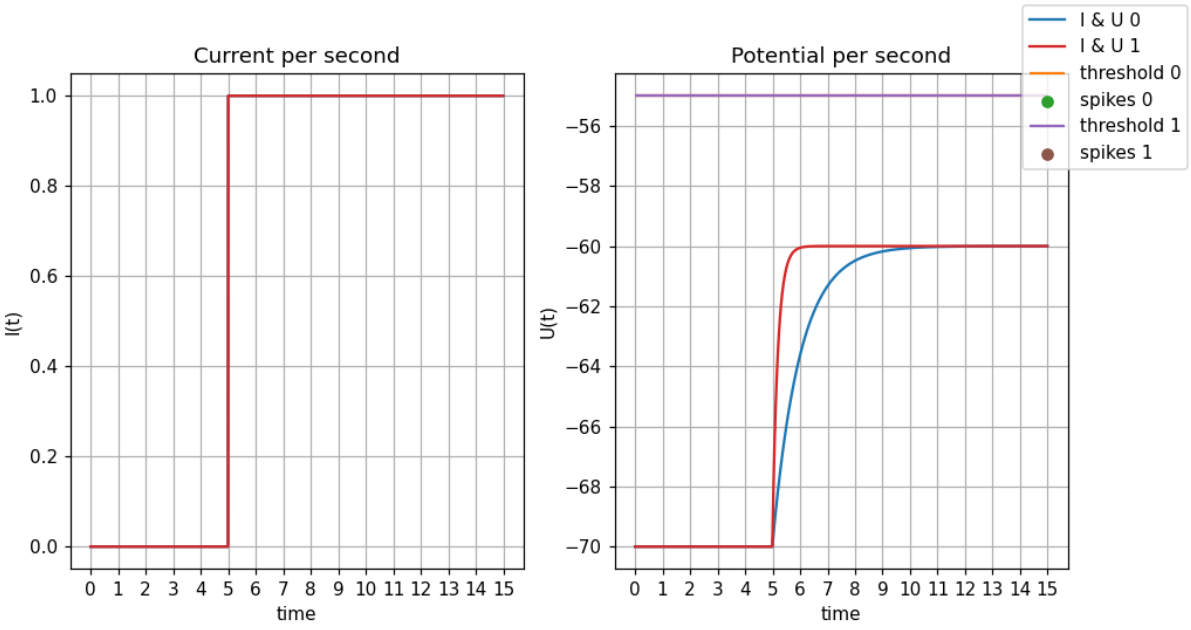
In [23]:
```
%%time

neuron, I, s, u = single_neuron_time(
        time, dt, scale, step_size, step_function, shape, spike_trace,
        additive_spike_trace, tau_s, trace_scale,
        is_inhibitory, learning, R, C
    )

plot.plot_ut_it_init(time/scale)
plot.plot_ut_it_update(I, u, neuron.threshold, s[0].nonzero(as_tuple=True)[0])

neuron, I, s, u = single_neuron_time(
        time, dt, scale, step_size, step_function, shape, spike_trace,
        additive_spike_trace, tau_s, trace_scale,
        is_inhibitory, learning, 2, C
    )
plot.plot_ut_it_update(I, u, neuron.threshold, s[0].nonzero(as_tuple=True)[0])
plot.show()
```




```
CPU times: user 586 ms, sys: 3.49 ms, total: 590 ms
Wall time: 591 ms
```

The next cell is showing how the Capasitor (C) affects on a neuron. By decreasing C, the growth rate of potential increases which it means it will take less time to reach the stable potential but unlike R, the stable point in this situation doesn't change.

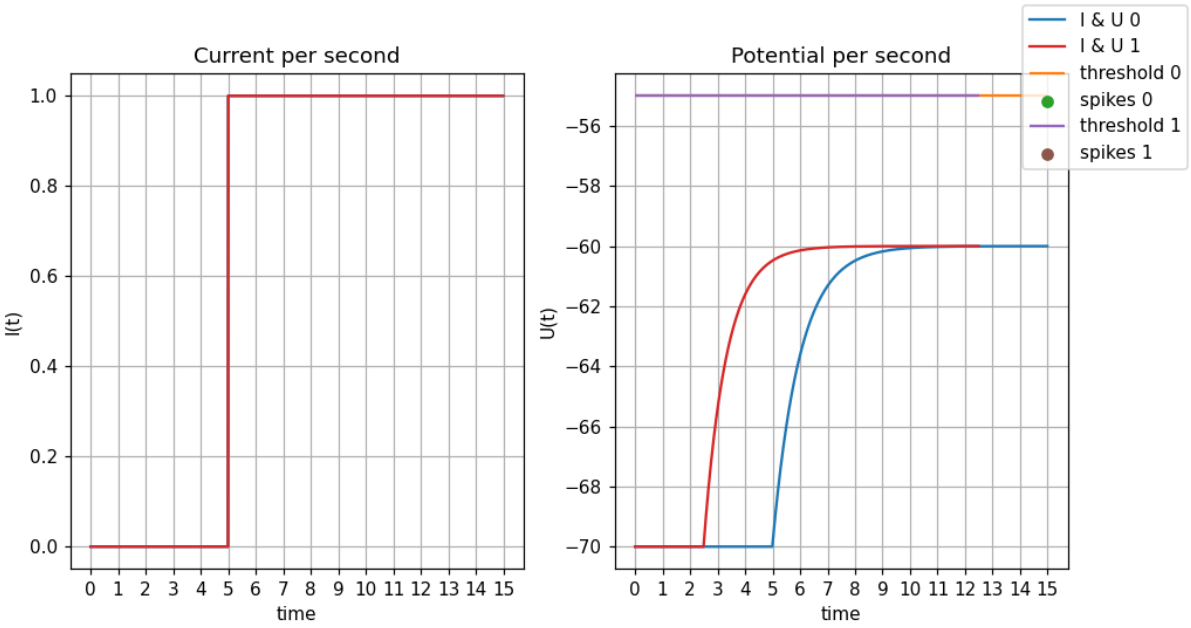
In [14]:
```
%%time
neuron, I, s, u = single_neuron_time(
        time, dt, scale, step_size, step_function, shape, spike_trace,
        additive_spike_trace, tau_s, trace_scale,
        is_inhibitory, learning, R, C
    )

plot.plot_ut_it_init(time/scale)
plot.plot_ut_it_update(I, u, neuron.threshold, s[0].nonzero(as_tuple=True)[0])

neuron, I, s, u = single_neuron_time(
        time, dt, scale, step_size, step_function, shape, spike_trace,
        additive_spike_trace, tau_s, trace_scale,
        is_inhibitory, learning, R, 2
    )
plot.plot_ut_it_update(I, u, neuron.threshold, s[0].nonzero(as_tuple=True)[0])
plot.show()
```




```
CPU times: user 616 ms, sys: 5.99 ms, total: 622 ms
Wall time: 624 ms
```

The next cell is showing how the Δ affects on a neuron. Δ can shift the U/t figure.

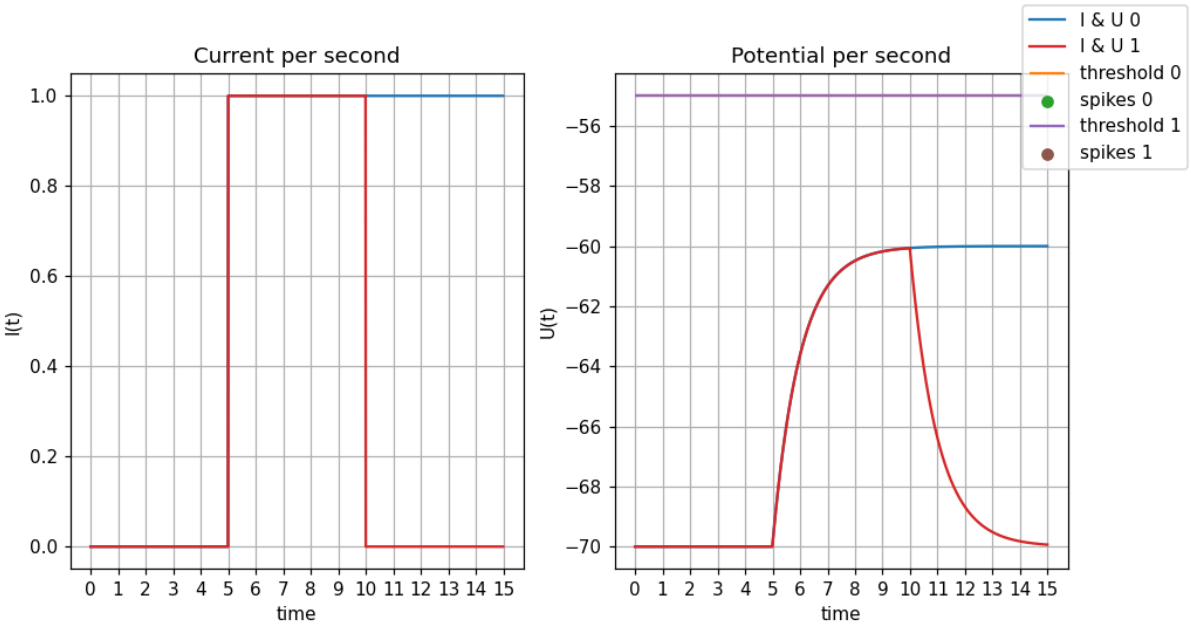
In [15]:
```
%%time
neuron, I, s, u = single_neuron_time(
        time, dt, scale, step_size, step_function, shape, spike_trace,
        additive_spike_trace, tau_s, trace_scale,
        is_inhibitory, learning, R, C
    )

plot.plot_ut_it_init(time/scale)
plot.plot_ut_it_update(I, u, neuron.threshold, s[0].nonzero(as_tuple=True)[0])

neuron, I, s, u = single_neuron_time(
        time, 1.2, scale, step_size, step_function, shape, spike_trace,
        additive_spike_trace, tau_s, trace_scale,
        is_inhibitory, learning, R, C
    )
plot.plot_ut_it_update(I, u, neuron.threshold, s[0].nonzero(as_tuple=True)[0])
plot.show()
```




```
CPU times: user 618 ms, sys: 4.66 ms, total: 623 ms
Wall time: 620 ms
```

The next cell has a different step function (I). which we can see that after the second change, the neuron's potentional is gradually decreasing to its rest potetional.

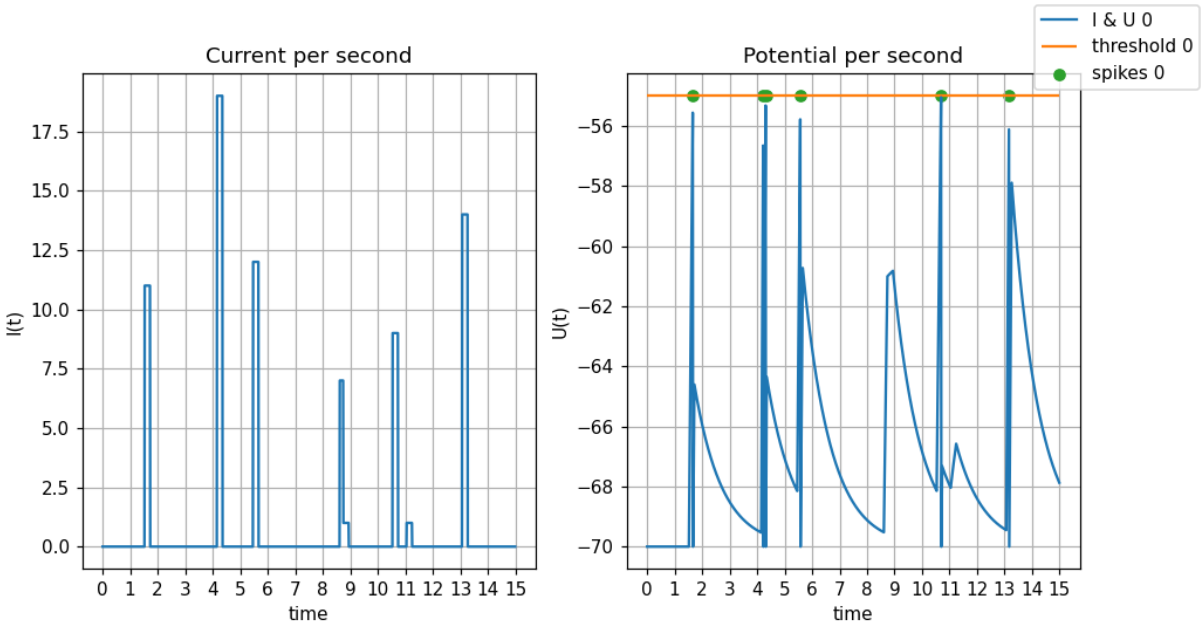
In [16]:
```
%%time
neuron, I, s, u = single_neuron_time(
        time, dt, scale, step_size, step_function, shape, spike_trace,
        additive_spike_trace, tau_s, trace_scale,
        is_inhibitory, learning, R, C
    )

plot.plot_ut_it_init(time/scale)
plot.plot_ut_it_update(I, u, neuron.threshold, s[0].nonzero(as_tuple=True)[0])

neuron, I, s, u = single_neuron_time(
        time, dt, scale, step_size, two_way_step_function, shape, spike_trace,
        additive_spike_trace, tau_s, trace_scale,
        is_inhibitory, learning, R, C
    )
plot.plot_ut_it_update(I, u, neuron.threshold, s[0].nonzero(as_tuple=True)[0])
plot.show()
```




```
CPU times: user 583 ms, sys: 8.16 ms, total: 591 ms
Wall time: 588 ms
```

The next neuron has a random current(I) as input.

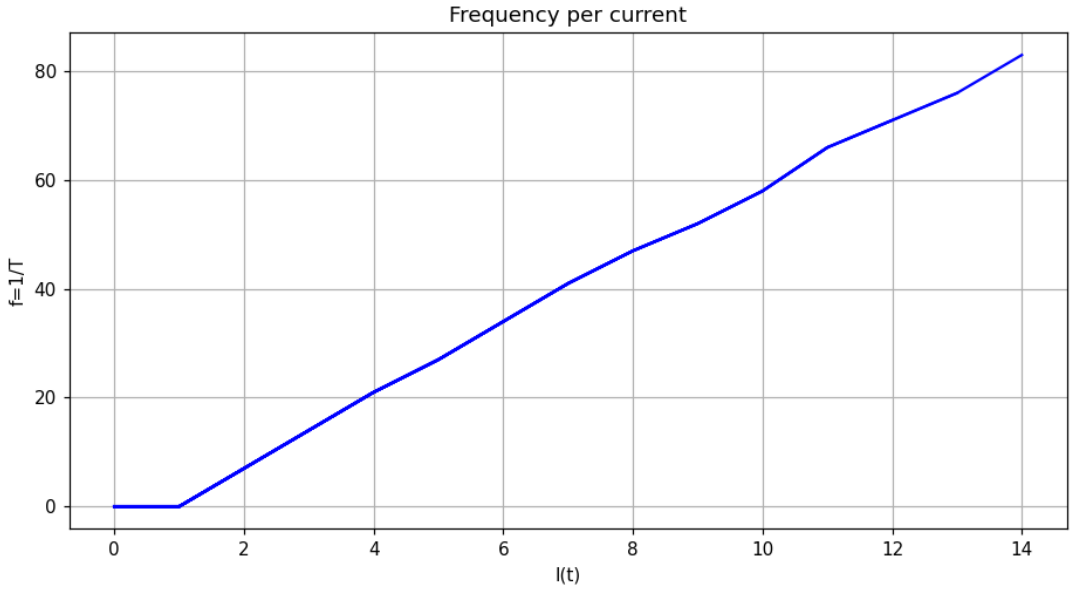
In [17]:
```
%%time
step_size = 20
neuron, I, s, u = single_neuron_time(
        time, dt, scale, step_size, random_step_function, shape, spike_trace,
        additive_spike_trace, tau_s, trace_scale,
        is_inhibitory, learning, R, C
    )

plot.plot_ut_it_init(time/scale)
plot.plot_ut_it_update(I, u, neuron.threshold, s[0].nonzero(as_tuple=True)[0])
plot.show()
```




```
CPU times: user 389 ms, sys: 11.4 ms, total: 401 ms
Wall time: 395 ms
```

In the next cell, we are checking out the behavior of a neuron with different normal step function values. In the end, we plot the figure which shows the spikes frequency in each step function's value.

In [18]:
```
%%time
plot.plot_fi_init()
spikes = []
for x in range(15):
    _, _, s, _ = single_neuron_time(
            time, dt, scale, x, step_function, shape, spike_trace,
            additive_spike_trace, tau_s, trace_scale,
            is_inhibitory, learning, R, C
        )
    spikes.append(s[0].sum())
    plot.plot_fi_update(spikes)

plot.show()
```




```
No handles with labels found to put in legend.


CPU times: user 4.48 s, sys: 80.3 ms, total: 4.56 s
Wall time: 4.73 s
```