

## Neurodynamics 2023

### HOMEWORK: (LEAKY-)INTEGRATE-AND-FIRE.

In this second homework, we will turn from the biophysical model of a patch of membrane developed by Hodgkin and Huxley to phenomenological models of spiking neurons: Simple Leaky-Integrate-and-Fire models. Additionally, we will be looking at implementing a conductance based synapse.

**Hand-in for this sheet is end of day on June, 2nd**

**Question 1.** Implement the following simple leaky-integrate-and-fire model in `brian2`:

$$\frac{dV}{dt} = -\frac{1}{\tau_M} \left( (V - V_R) - \frac{I}{g_L} \right)$$

$$t_{\text{spike}} : V(t_{\text{spike}}) > V_t \ \& \ V \rightarrow V_R$$

Set  $\tau_M = 20\text{ms}$ ,  $V_R = -70\text{mV}$  and  $g_L = 0.1\mu\text{S}$ . When the membrane potential hits the threshold  $V_t = -50\text{mV}$ , emit a spike and reset the membrane potential to resting. In `brian2`, thresholds and resets are part of a `NeuronGroup` definition. You can also attach a `SpikeMonitor` to the model neuron to easily collect all spike times.

Your task is to setup multiple experiments with 50 varying currents  $I$  from 0.0 to 20.0nA. For each value, record how many spikes the neuron fires in one second. Plot the f-I curve, frequency against current, to characterize the neuron's input-output function.

**Question 2.** Amend the model and include synaptic transmission.

In `brian2`, modelling synaptic conductance in response to spikes is easier as a dynamic variable. The equations for the integrate-and-fire model extend to:

$$\frac{dV}{dt} = -\frac{1}{\tau_M} \left( (V - V_R) + \frac{g_S}{g_L} (V - E_S) \right)$$

$$\frac{dg_S}{dt} = -\frac{g_S}{\tau_S}$$

$$t_{\text{spike}} : V(t_{\text{spike}}) > V_t \ \& \ V \rightarrow V_R$$

Set  $\tau_S = 5.0\text{ms}$  and  $E_S = 10\text{mV}$ .  $g_L$  changes to 3mS

Additionally, use `PoissonGroup` to create 10 input neurons, and then use the `brian2.Synapse` to connect them to the neuron. On each spike, add 0.6mS to the synaptic conductance  $g_S$  (use the option `on_pre += 0.6mS`).

Now, setup the previous experiment – but instead of varying the current  $I$ , vary the firing frequency in Hertz that the `PoissonGroup` input neurons fire at from 0 to 200Hz in 20 steps. Record and plot the firing frequency the neuron responds with.