Lab 4: Synapses

This lab is intended to make clear how neuronal connectivity works: a neuron has synapses, when it fires the spikes go to its synapses and they in turn cause a change in conductivity for the post-synaptic neuron.

Use a LIF model to simulate two single-compartment ("point") neurons that have reciprocal synaptic connections between each other (the first neuron projects to the second, and the second neuron projects to the first). Both model neurons should have the same parameters[1]:

$$\begin{aligned} R_m &= 10\ \mathrm{M}\Omega && \text{membrane resistance} \\ C_m &= 2\ \mathrm{nF} && \text{membrane capacitance} \\ \tau_m &= R_m C_m = 20\ \mathrm{ms} && \text{membrane time constant} \\ E_L &= -70\ \mathrm{mV} && \text{leak reversal (resting) voltage} \\ V_r &= -80\ \mathrm{mV} && \text{reset voltage} \\ V_\theta &= -54\ \mathrm{mV} && \text{threshold voltage} \\ I_e &= 1.8\ \mathrm{nA} && \text{externally applied current.} \end{aligned} \tag{1}$$

Use an exponential model of the synapse[2], in which

$$\begin{aligned} \tau_s \dot{s} &= -s && \text{the postsynaptic gating variable decays exponentially (time constant } \tau_s\text{)} \\ s &\leftarrow s + P && \text{and increments by } P \text{ whenever a spike arrives.} \end{aligned} \tag{2}$$

Both synapses should have the same parameters:

$$\begin{aligned} P &= 0.5 && \text{Increase in postsynaptic conductance when spike arrives,} \\ \tau_s &= 10\ \mathrm{ms} && \text{Decay time,} \\ R_m \bar{g}_s &= 0.15 && \text{Maximal rate of postsynatpic voltage change.} \end{aligned} \tag{3}$$

Simulate two cases:

a) assuming that the synapses are excitatory with $E_s = 0$ mV, and
b) assuming that the synapses are inhibitory with $E_s = -80$ mV.

For each simulation set the initial membrane potentials of the neurons V to different values chosen randomly from between V_r and V_t and simulate 1 s of activity. For each case plot the voltages of the two neurons on the same graph (with different colours).

[1] An absolute refractory period as in lab 1 is optional, up to you.

[2] This model that lumps together neurotransmitter release, binding, and clearance into a single time-varying conductance, and that τ_s in this case *does not* have the interpretation of a capacitance times a resistance.