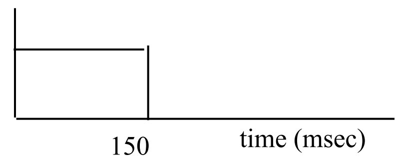
Lab #1 – Neuron models

due Tuesday, Sept. 16 (beginning of class)

1. Membrane model. Simulate the RC circuit of the cell membrane to determine how the voltage across the cell membrane will change in response to the following current inputs. Assume V_r (resting potential) = -70 mV and C_m=100 pF and consider two different values of G_{leak}: (i) 10 nS, and (ii) 1 nS. Plot the resulting membrane voltage $V(t)$ for a duration of 500 milliseconds, with initial condition $V(0) = V_r$.

(a) input: $I_{in}(t) = \begin{cases} I_0 & 0 \le t < 150ms \\ 0 & t < 0, t > 150ms \end{cases}$ (Choose I_0=100 pA.)



(b) Sinewave: $I_{in}(t) = A\sin(2\pi ft)$. Choose A=100 pA, and three values of f (frequency): 1, 10 and 100 Hz. You should make two different figures, one for each value of G_{leak}. Each figure should show the response to the three different frequencies of input current superimposed.

2. Shunting inhibition. Now let's investigate the non-linear interactions that occur as a result of shunting inhibition. Consider a local compartment with sodium and chloride channels (in addition to G_{leak}=10 nS, and assume V_r = -70 mV). First, plot how the membrane voltage will change as you increase the sodium channel conductance alone, with the chloride channel closed. Then do the same for the chloride channel conductance, with the sodium channel closed. Now try increasing both together – i.e., for each setting of the chloride channel conductance, plot the membrane voltage as a function of the sodium channel conductance. How does it compare to what you would expect from linear superposition? (plot the latter superimposed as a dashed line)

3. Linear neuron. Let's say we have a linear neuron with two inputs x_1, x_2 whose corresponding weights are $\begin{pmatrix} -0.5 \\ 1 \end{pmatrix}$. Plot the weight vector within the 2D space x_1, x_2, and shade the portion of the input space for which the neuron would have a positive output value. (It may be easier to just do this by hand rather than in Matlab.)

4. Pattern discrimination. For this part you will need to download the data in `data.mat` on the class website. This contains two arrays of data, `X` and `O`. Plot each of them out using the corresponding symbol. Now let's say we have a McCulloch-Pitt's neuron – i.e., a linear neuron with thresholded output – and we wish to have the neuron discriminate among these patterns by outputting 1 in response to the X's and 0 in response to the O's. Is this possible? What setting of the weights would achieve this? If not, what setting would minimize the error? (an approximate solution is fine) If you were allowed to combine the inputs nonlinearly, what combination rule and setting of weights would allow for the patterns to be correctly discriminated?