# Circuits and Computational Neuroscience
# Neurosci 613 Fall 2014
# Computer Lab 4

## Due: Thursday, December 11, 2014 by 5pm

1. **Investigate the effects of cell heterogeneity and synaptic strength on synchronous firing in networks of fast spiking inhibitory neurons.** Run the matlab code ConnectivityMatrix.m to construct the connectivity matrix for a 1-dimensional ring network of 50 cells with all-to-all coupling (set n=50, uncomment the section of code for all-to-all coupling, comment out the other portions of the code). In ILIFnetwork_syn.m, set cell parameters to those modeling a fast spiking neuron (a = 0.1; b = 0.2; c = -65; d = 2;). Set simulation end time tend = 1000 msec, synaptic decay time constant taus = 40 msec and random initial values (v = -70*ones(n,1) + 10*rand(n,1); u = -14*ones(n,1) + 5*rand(n,1);). To be able to consider weak synaptic strength, consider gsyn values of negative integers divided by n (for example, gsyn = -2/n;). We introduce cell heterogeneity by setting the applied current to each cell slightly different, with the degree of difference governed by the parameter sigma. Let applied current values vary in the interval [6, 6+sigma] (Iapp = 6*ones(50,1)+sigma*rand(50,1);).
    a. Set synaptic strength to gsyn = -2/n and investigate the effect on network synchrony of increasing the heterogeneity of the cells by increasing sigma from 0. Formulate your own quantitative measure of "synchronous network firing" that can be derived from the spike time histogram which plots the number of cells firing in each 2 msec time window across the simulation. Explain and justify your measure. Describe the breakdown of synchrony as heterogeneity increases using your measure. Identify a "threshold" value of your measure above which "synchrony" occurs and below which "synchrony" does not occur. At what sigma value does the network fall below this threshold? Provide raster plots and spike time histograms to illustrate your measure and findings.
    b. Set sigma to the value which results in "threshold" synchronous firing according to your measure and investigate the effect of increasing synaptic strength on network behavior. Describe network synchrony and behavior as gsyn is set to values more negative than -2/n. How does the pattern of cell firing change? How does cellular heterogeneity determine a cell's participation in network activity? To investigate this, generate plots of the average frequency of each cell as a function of its applied current value (plot(Iapp,freqs,'*');). Provide raster plots and spike time histograms to illustrate your findings.
    c. In a few sentences, summarize your findings on the effect of neuronal heterogeneity and synaptic strength on synchronization by inhibition.

For Problems #2 and #3, use the matlab files in the zipped folder PING_CODE to simulate a network of excitatory (E) cells and inhibitory (I) cells. Parameters for the cells and network are set in the numbered params*.m (* = 0, 1, 2 or 3) files. We will consider a network of 80 E cells and 20 I cells with the following synapse types: E-to-I, I-to-E and I-to-I (the E cells do not synapse on each other). The file description_of_gamma_code.pdf describes the cell and network parameters in the params*.m files. To run the code, set parameter values in the appropriate params*.m file and save the file; in lines 7-10 of gamma_simulator .m uncomment the name of the correct params*.m file; save and run gamma_simulator.m using the RUN (green arrow) button in the matlab editor.

2. **Investigate the effect of the time constant for decay of the inhibitory synapses on the frequency of PING synchronous firing of the E cells.** In the file params2.m, increase the time constant for the decay of the inhibitory synapses tau_d_i_value from 9 to 60 (set g_hat_ie = 0.5), running the file gamma_simulator.m for each value. Plot the average network frequency of the E cell network as a function of tau_d_i_value. Describe the relationship between E cell frequency and the duration of synaptic inhibition.

3. **Contrast the importance of the density of I-to-E synapses and E-to-I synapses in generating coherent PING synchronous firing of the E cells.** The parameters p_ie and p_ei set the connection probability for the I-to-E and E-to-I synapses, respectively. To see the effects of only the I-to-E and E-to-I synapses, set synaptic strength for the I-to-I and E-to-E synapses to 0 (g_hat_ii = 0, g_hat_ee = 0).
   a. In the file params3.m, decrease the density of I-to-E synapses by decreasing p_ie from 1 (keeping all p_ei = 1) and investigate the effect on synchrony of the E cells. Use your measure of “synchronous network firing” formulated in Problem #1 applied to the spike time histogram for the E cells plotted in Figure 2. Determine the value of p_ie at which synchronous firing of the E cells does not occur. Provide raster plots and spike time histograms to illustrate the effect of p_ie on E cell firing.
   b. In the file params3.m, decrease the density of E-to-I synapses by decreasing p_ei from 1 (keeping p_ie = 1). Using your synchrony measure, determine the value of p_ei at which synchronous firing of the E cells does not occur. Provide raster plots to illustrate the effect of p_ei on E cell firing.
   c. In a few sentences, contrast the importance of I-to-E and E-to-I synaptic density in generating PING synchronous firing of the E cells.