Biol635 / Math635 / Biol432 / Math430
Fall 2023
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Assignment 2

Answer the following questions.

- Justify your answers.
- Explain your results.
- Provide the necessary calculations in a clear way.
- Provide the necessary supporting graphs and codes.
- Make sure the graphs are properly labeled and include the information (title and parameter values) necessary to understand your explanations.
- You may write your own code or adapt the template code provided in class.

1. Consider the following passive membrane equation

$$\tau \frac{dV}{dt} = -(V - E_L) + R\, I_{app}(t) \tag{1}$$

with $E_L = -60$ mV, $C = 1$ μF/cm^2, $G_L = 0.1$ mS/cm^2, Write a Matlab code (or use the template code) to solve eq. (1). Use $V(0) = -60$ mV and the following units for V, t and I_{app} respectively: $[V]$ = mV,$[t]$ = msec, $[I_{app}] = \mu$A/cm^2.

   (a) Calculate the time constant τ.

   (b) Consider the following two time-independent applied currents $I_{app} = -0.5$ and $I_{app} = 0.5$. For each these values of I_{app}, compare the numerical and analytical solutions to the passive membrane equation (1) by

      i. Plotting superimposed graphs of these solutions

      ii. plotting the error (absolute value of the difference between these two solutions).

(c) Consider a square pulse of current

$$I_{app}(t) = I_0\, Heav(t - t_i) * Heav(t_f - t)$$

with $I_0 = 0.5$, $t_i = 100$ msec and $t_f = 200$ msec.

i. Plot both the numerical and analytical solutions to the passive membrane equation (1)

ii. compare them as in (b).

Run your simulation for 400 msec.

(d) Consider the following current

$$I_{app}(t) = I_0\ \sin(2\,\pi\,\omega\,t/1000).$$

with $I_0 = 0.5$. The input frequency ω is given in Hz (number of cycles per second).

i. Plot the numerical solution to the passive membrane equation (1) for $\omega = 1$, $\omega = 5$, $\omega = 10$, $\omega = 20$, and $\omega = 100$.

ii. Plot a graph relating the output frequency (y-axis) vs. the input frequency (x-axis)

iii. Plot a graph relating the amplitude of the output oscillations (y-axis) vs. the input frequency (x-axis)

2. (Graduate level)

Find examples in the literature of both biological neuronal systems and models that behave like low-pass filters and band-pass filters. Speculate on the differences between them.