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Models of Neural Systems I, WS 2007/08
Computer Practical 7
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Filter properties of neuronal membranes

Many systems when subjected to small inputs behave approximately linearly and thus they responses can be characterised with linear properties. Here we will analyse filtering properties of simplified neurons in subthreshold regime.
Exercises

1. Analyse responses to an external input I of a passive membrane:

$$\tau \frac{dV}{dt} = -V + RI \qquad (1)$$

where $\tau = 10\,\mathrm{ms}$ and $R = 10^7\,\Omega$.

(a) Simulate membrane potential subjected to a sinusoidal current injection $I(t) = A\sin(2\pi f t)$.

(b) Vary the frequency of the input current in a range 1 Hz - 100 Hz. For each frequency determine the ratio between the amplitude of input and output oscillations. Plot the results as a function of frequency.

(c) The response of a membrane to a wide range of frequency can be analysed by mean of so-called ZAP current:

$$I_{\mathrm{ZAP}}(t) = I_0 \sin(2\pi f(t)t) \qquad (2)$$

with $f(t) = f_m t/2T$. Inject ZAP current with $f_m = 100$ Hz aind $T = 100$ s. Plot the resulting membrane potential.

(d) Calculate the magnitiude and phase of (complex) membrane impedance defined by:

$$Z(f) = \frac{\tilde{V}(f)}{\tilde{I}(f)}, \qquad (3)$$

where $\tilde{V}(f)$ and $\tilde{I}(f)$ denote respectively Fourier transform of membrane potential and external current. Fast Fourier Transform algorithm (FFT) is implemented in SciPy by `fft` (read documentation first!). Plot the results in double logarithmic scale (`loglog`).

2. (Optional) Resonate-and-fire model neuron is described by the following equations:

$$\frac{dx}{dt} = bx - \omega y \quad (4)$$

$$\frac{dy}{dt} = \omega x + by \quad (5)$$

$$(6)$$

Here take $b = -1$ and $\omega = 10$.

(a) Implement the model in Python and plot its response to a current pulse.

(b) Repeat the exercises 1(c)-1(d) for this model. Choose the input amplitude in the subthreshold regime.

(c) Compare the results with passive membrane.

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