Models of Neural Systems, WS 2009/10
Computer Practical 8
Solutions to hand in on: January, 4th, 2010

Background

In the Hodgkin-Huxley formalism, currents flowing through a large number of ion channels are modelled. The behaviour of single ion channels is more complex. Today you model the state of single channels using state diagrams and transition rates. In the end you should compare the fraction of open channels from your simulations with the respective fraction given by the Hodgkin-Huxley model.

Potassium-channel model

1. General Methods

   (a) Recapitulate Section 5.7 from the book of Dayan and Abbott. Make sure you understand the state diagrams and the equations describing the state transitions.

   (b) The transitions rates (ms^{-1}) we need are the same we used for the Hodgkin-Huxley model before:

   $$\alpha_n = 0.01 \frac{V + 55}{1 - \exp(-0.1(V + 55))}, \quad \beta_n = 0.125 \exp(-0.0125(V + 65))$$

   where V is the voltage in mV.

2. Assignments

   We assume that the K^+ channel consists of four individual subunits, which all open and close independently. Thus the channel can be in five different states: with 0, 1, 2, 3, or 4 subunits being open. Current is conducted only in the last state, where all subunits are open.

   (a) Implement a model of K^+ channels using the state diagramm shown in Figure 5.12. In general, you start with x channels in some starting state

(e.g. all closed). Then at each time step Δt you draw for each channel a random number between 0 and 1 and determine via the state transition rates whether this channel stays in its state or changes to another state. The probability of changing to a given new state, is its transitions rate times Δt. Make sure that Δt is small enough so that the probability is always much smaller than 1!

(b) Test your model by setting an initial membrane voltage and ensure that the channel state distributions reaches an equilibrium. Then set a new holding potential for some time and observe how the channel state distribution changes until the new equilibrium is reached. Finally you return to your initial membrane potential. Plot the number of open channels as a function of time.

(c) Vary the total number of channels and produce graphs similar to the ones in Figure 5.12. Note that the figure shows actual currents, while you compare the fraction of open channels. What would you have to change to get currents as well?
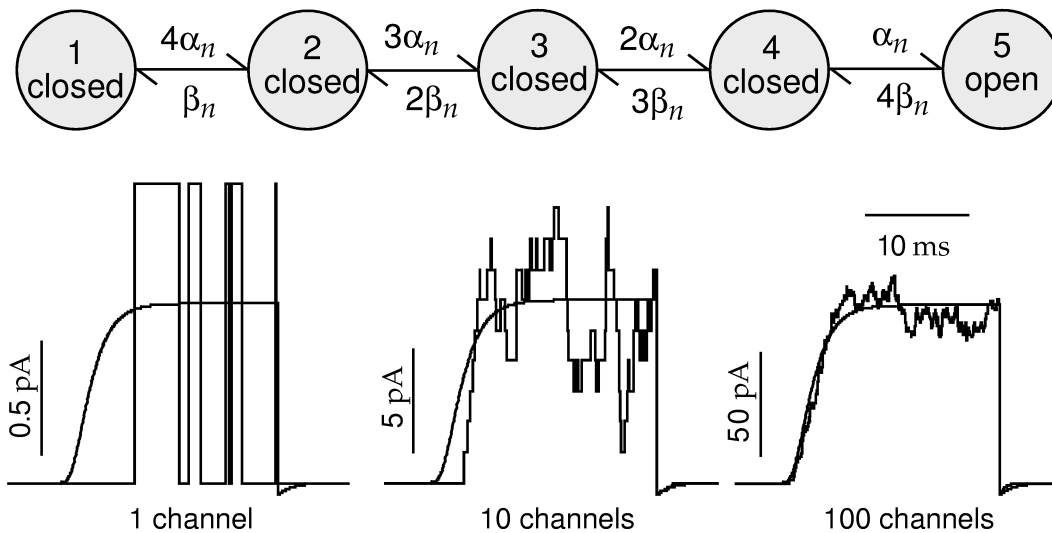
Figure 5.12 (from Dayan and Abbott). Potassium channel model. (Top) State diagram with transition probabilities. (Bottom) Effect of the number of modelled channels on the potassium current.

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