Introduction to Computational Neuroscience (Fall 2023)

Neural Models

Model for the A Current

- The current was described as having 3 activation gates (a=probability of gate activated) and an inactivation gate (b=probability of gate not inactivated). The conductance is then

$$g_{\mathrm{A}} = \bar{g}_{\mathrm{A}} a^3 b \tag{1}$$

and the current is

$$I_{\mathrm{A}} = g_{\mathrm{A}}(V - V_{\mathrm{K}}) \tag{2}$$

- The activation time constant for A current is V-dependent, and is near 3 ms when $V = -45$ mV. The inactivation time constant is also V-dependent, and is near 40 ms when $V = -45$ mV.

Pinsky-Rinzel Model

- The ODE for voltage dynamics in the soma is:

$$C_{\mathrm{m}}\frac{dV_{\mathrm{s}}}{dt} = -\bar{g}_{\mathrm{L}}(V_{\mathrm{s}} - V_{\mathrm{L}}) - g_{\mathrm{Na}}(V_{\mathrm{s}} - V_{\mathrm{Na}}) - g_{\mathrm{DR}}(V_{\mathrm{s}} - V_{\mathrm{K}}) + \frac{g_{\mathrm{c}}}{p}(V_{\mathrm{d}} - V_{\mathrm{s}}) + \frac{I_{\mathrm{s}}}{p} \tag{3}$$

and for the voltage dynamics in the dendrite compartment is:

$$C_{\mathrm{m}}\frac{dV_{\mathrm{d}}}{dt} = -\bar{g}_{\mathrm{L}}(V_{\mathrm{d}} - V_{\mathrm{L}}) - g_{\mathrm{Ca}}(V_{\mathrm{d}} - V_{\mathrm{Ca}}) - g_{\mathrm{AHP}}(V_{\mathrm{d}} - V_{\mathrm{K}}) - g_{\mathrm{K(Ca)}}(V_{\mathrm{d}} - V_{\mathrm{K}}) - \frac{g_{\mathrm{c}}}{1-p}(V_{\mathrm{d}} - V_{\mathrm{s}}) + \frac{I_{\mathrm{syn}}}{1-p} \tag{4}$$

with V-dependent conductances

$$g_{\mathrm{Na}} = \bar{g}_{\mathrm{Na}} m_{\infty}^2 h \tag{5}$$

$$g_{\mathrm{DR}} = \bar{g}_{\mathrm{DR}} n \tag{6}$$

$$g_{\mathrm{Ca}} = \bar{g}_{\mathrm{Ca}} s^2 \tag{7}$$

$$g_{\mathrm{K(Ca)}} = \bar{g}_{\mathrm{K(Ca)}} c \chi(\mathrm{Ca_i}) \tag{8}$$

$$g_{\mathrm{AHP}} = \bar{g}_{\mathrm{AHP}} q \tag{9}$$

Parameter I_{s} is current applied to the soma, I_{syn} is synaptic input, and p is the fraction of the total area comprised by the soma.

- There is also a variable for the concentration of free (i.e., unbound) intracellular Ca^{2+} in the dendrites, Ca_i, with time dynamics given by:

$$\frac{d\mathrm{Ca_i}}{dt} = -0.13 I_{\mathrm{Ca}} - 0.075\mathrm{Ca_i} \tag{10}$$

- Both the Ca^{2+}-activated K^+ conductance $g_{\mathrm{K(Ca)}}$ and the afterhyperpolization conductance g_{AHP} depend on $\mathrm{Ca_i}$. The former responds instantaneously to changes in $\mathrm{Ca_i}$, with activation function:

$$\chi(\mathrm{Ca_i}) = \min\left(\frac{\mathrm{Ca_i}}{250}, 1\right) \tag{11}$$

and the infinity function for g_{AHP} and time constants have the Ca^{2+} dependence:

$$q_\infty = \frac{\alpha_q}{\alpha_q + \beta_q} \tag{12}$$

$$\tau_q = \frac{1}{\alpha_q + \beta_q} \tag{13}$$

with $\alpha_q = \min(0.00002\mathrm{Ca_i}, 0.01)$ and $\beta_q = 0.001$.