# Equations

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Sum of RMSEs objective function:

$$\sum_{i=1}^{n} \sqrt{\int_{t_i^{(h)}}^{t_i^{(e)}} \frac{(y_i(t) - \hat{y_i}(t))^2}{t_i^{(e)} - t_i^{(h)}} dt} \tag{1}$$

$$\mathrm{I_{Kto}} = [G_{\mathrm{Kto}} a_{\mathrm{Kto}}^3 i_{\mathrm{Kto}} (1 - f_{\mathrm{Kto}}) + G_{\mathrm{Kto,p}} a_{\mathrm{Kto,p}}^3 i_{\mathrm{Kto,p}} f_{\mathrm{Kto}}](V - E_K)$$

$$\frac{da_{\mathrm{Kto}}}{dt} = \alpha_a (1 - a_{\mathrm{Kto}}) - \beta_a a_{\mathrm{Kto}}$$

$$\frac{di_{\mathrm{Kto}}}{dt} = \alpha_i (1 - i_{\mathrm{Kto}}) - \beta_i i_{\mathrm{Kto}}$$

$$\frac{da_{\mathrm{Kto,p}}}{dt} = \alpha_{ap} (1 - a_{\mathrm{Kto,p}}) - \beta_{ap} a_{\mathrm{Kto,p}}$$

$$\frac{i_{\mathrm{Kto,p}}}{dt} = \alpha_{ip} (1 - i_{\mathrm{Kto,p}}) - \beta_{ip} i_{\mathrm{Kto,p}}$$

$$\alpha_a = 0.18064 e^{0.03577(V+33.0)}$$

$$\beta_a = 0.3956 e^{-0.06237(V+33.0)}$$

$$\alpha_i = \frac{0.000152 e^{-(V+15.5)/7.0}}{0.067083 e^{-(V+35.5)/7.0}}$$

$$\beta_i = \frac{0.00095 e^{(V+35.5)/7.0}}{0.051335 e^{(V+35.5)/7.0} + 1}$$

$$\alpha_{ap} = 0.18064 e^{0.03577(V+17.0)}$$

$$\beta_{ap} = 0.3956 e^{-0.06237(V+17.0)}$$

$$\alpha_{ip} = \frac{0.000152 e^{-(V+7.5)/7.0}}{0.067083 e^{-(V+27.5)/7.0} + 1}$$

$$\beta_{ip} = \frac{0.00095 e^{(V+27.5)/7.0}}{0.051335 e^{(V+27.5)/7.0} + 1}$$

$$\mathrm{I_{Kslow1}} = [G_{\mathrm{Kslow1}} f_{\mathrm{Kslow1}} + G_{\mathrm{Kslow1,p}}(1 - f_{\mathrm{Kslow1}})] a_{\mathrm{Kslow1}} i_{\mathrm{Kslow1}} (V - E_K)$$
$$\frac{da_{\mathrm{Kslow1}}}{dt} = \frac{a_{ss} - a_{\mathrm{Kslow1}}}{\tau_{\mathrm{aKslow1}}}$$
$$\frac{di_{\mathrm{Kslow1}}}{dt} = \frac{i_{ss} - i_{\mathrm{Kslow1}}}{\tau_{\mathrm{iKslow1}}}$$
$$a_{ss} = \frac{1}{1 + e^{-(V+22.5)/7.7}}$$
$$i_{ss} = \frac{1}{1 + e^{(V+45.2)/5.7}}$$
$$\tau_{\mathrm{aKslow1}} = \frac{6.1}{e^{0.0629(V+40.0)} + e^{-0.0629(V+40.0)}} + 2.058$$
$$\tau_{\mathrm{iKslow1}} = 803.0 - \frac{18.0}{1 + e^{(V+45.2)/5.7}}$$

$$\mathrm{I_{Kslow2}} = G_{\mathrm{Kslow2}} a_{\mathrm{Kslow2}} i_{\mathrm{Kslow2}} (V - E_K)$$
$$a_{\mathrm{Kslow2}} = a_{\mathrm{Kslow1}}$$
$$\frac{di_{\mathrm{Kslow2}}}{dt} = \frac{i_{ss} - i_{\mathrm{Kslow2}}}{\tau_{\mathrm{iKslow2}}}$$
$$\tau_{\mathrm{iKslow2}} = 5334.0 - \frac{4912.0}{1 + e^{(V+45.2)/5.7}} = 5334.0 - 4912.0 i_{ss}$$

$$\mathrm{I_{Kslow2}} = G_{\mathrm{Kslow2}} a_{\mathrm{Kslow2}} i_{\mathrm{Kslow2}} (V - E_K)$$
$$a_{\mathrm{Kslow2}} = a_{\mathrm{Kslow1}}$$
$$\frac{di_{\mathrm{Kslow2}}}{dt} = \frac{i_{ss} - i_{\mathrm{Kslow2}}}{\tau_{\mathrm{iKslow2}}}$$
$$\tau_{\mathrm{iKslow2}} = 5334.0 - 4912.0 i_{ss}$$

$$\mathrm{I_{Kss}} = G_{\mathrm{Kss}} a_{\mathrm{Kss}} (V - E_K)$$
$$\frac{da_{\mathrm{Kss}}}{dt} = \frac{a_{ss} - a_{\mathrm{Kss}}}{\tau_{\mathrm{aKss}}}$$
$$\tau_{\mathrm{aKss}} = \frac{1235.5}{e^{0.0862(V+40.0)} + e^{-0.0862(V+40.0)}} + 13.17$$

$$
\begin{aligned}
&\mathrm{I_{Kto}} = [G_{\mathrm{Kto}} a_{\mathrm{Kto}}^3 i_{\mathrm{Kto}} (1 - f_{\mathrm{Kto}}) + G_{\mathrm{Kto,p}} a_{\mathrm{Kto,p}}^3 i_{\mathrm{Kto,p}} f_{\mathrm{Kto}}](V - E_K) \\
&\frac{da_{\mathrm{Kto}}}{dt} = \alpha_a (1 - a_{\mathrm{Kto}}) - \beta_a a_{\mathrm{Kto}} \\
&\frac{di_{\mathrm{Kto}}}{dt} = \alpha_i (1 - i_{\mathrm{Kto}}) - \beta_i i_{\mathrm{Kto}} \\
&\frac{da_{\mathrm{Kto,p}}}{dt} = \alpha_{ap} (1 - a_{\mathrm{Kto,p}}) - \beta_{ap} a_{\mathrm{Kto,p}} \\
&\frac{i_{\mathrm{Kto,p}}}{dt} = \alpha_{ip} (1 - i_{\mathrm{Kto,p}}) - \beta_{ip} i_{\mathrm{Kto,p}} \\
&\alpha_a = p_9 e^{p_7 (V + p_1)} \\
&\beta_a = p_{10} e^{-p_8 (V + p_1)} \\
&\alpha_i = \frac{p_{11} e^{-(V + p_2)/p_6}}{p_{12} e^{-(V + p_2 + p_3)/p_6}} \\
&\beta_i = \frac{p_{13} e^{(V + p_2 + p_3)/p_6}}{p_{14} e^{(V + p_2 + p_3)/p_6} + 1} \\
&\alpha_{ap} = p_9 e^{p_7 (V + p_1 - p_4)} \\
&\beta_{ap} = p_{10} e^{-p_8 (V + p_1 - p_4)} \\
&\alpha_{ip} = \frac{p_{11} e^{-(V + p_2 - p_5)/p_6}}{p_{12} e^{-(V + p_2 + p_3 - p_5)/p_6} + 1} \\
&\beta_{ip} = \frac{p_{13} e^{(V + p_2 + p_3 - p_5)/p_6}}{p_{14} e^{(V + p_2 + p_3 - p_5)/p_6} + 1}
\end{aligned}
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\begin{aligned}
&\mathrm{I_{Kslow1}} = [G_{\mathrm{Kslow1}} f_{\mathrm{Kslow1}} + G_{\mathrm{Kslow1,p}} (1 - f_{\mathrm{Kslow1}})] a_{\mathrm{Kslow1}} i_{\mathrm{Kslow1}} (V - E_K) \\
&\frac{da_{\mathrm{Kslow1}}}{dt} = \frac{a_{ss} - a_{\mathrm{Kslow1}}}{\tau_{\mathrm{aKslow1}}} \\
&\frac{di_{\mathrm{Kslow1}}}{dt} = \frac{i_{ss} - i_{\mathrm{Kslow1}}}{\tau_{\mathrm{iKslow1}}} \\
&a_{ss} = \frac{1}{1 + e^{-(V + p_1)/p_4}} \\
&i_{ss} = \frac{1}{1 + e^{(V + p_2)/p_5}} \\
&\tau_{\mathrm{aKslow1}} = \frac{p_6}{e^{p_7 (V + p_3)} + e^{-p_6 (V + p_3)}} + p_8 \\
&\tau_{\mathrm{iKslow1}} = p_9 - \frac{p_{10}}{1 + e^{(V + p_2)/p_5}}
\end{aligned}
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\begin{aligned}
&\mathrm{I}_{\mathrm{Kslow2}} = G_{\mathrm{Kslow2}} a_{\mathrm{Kslow2}} i_{\mathrm{Kslow2}} (V - E_K) \\
&a_{\mathrm{Kslow2}} = a_{\mathrm{Kslow1}} \\
&\frac{di_{\mathrm{Kslow2}}}{dt} = \frac{i_{ss} - i_{\mathrm{Kslow2}}}{\tau_{\mathrm{iKslow2}}} \\
&\tau_{\mathrm{iKslow2}} = p_1 - p_2 i_{ss}
\end{aligned}
$$

$$
\begin{aligned}
&\mathrm{I}_{\mathrm{Kss}} = G_{\mathrm{Kss}} a_{\mathrm{Kss}} (V - E_K) \\
&\frac{da_{\mathrm{Kss}}}{dt} = \frac{a_{ss} - a_{\mathrm{Kss}}}{\tau_{\mathrm{aKss}}} \\
&\tau_{\mathrm{aKss}} = \frac{p_1}{e^{p_2 (V + 40.0)} + e^{-p_2 (V + 40.0 p_3^{\mathrm{Kslow1}})}} + p_3
\end{aligned}
$$