boyett_zhang_garny_holden_2001_version01

1 "environment" component

This component has no equations.

2 "membrane" component

membrane_voltage_diff_eq

$$\frac{d(V)}{d(time)} = \frac{-1.0}{C} * (i\_Na + i\_Ca\_L + i\_Ca\_T + i\_to + i\_sus + i\_K\_r + i\_K\_s + i\_f + i\_b\_Na + i\_b\_Ca + i\_b\_K + i\_NaCa + i\_p + i\_st + i\_Ca\_P)$$

3 "sodium_current" component

i_Na_calculation

$$i\_Na = g\_Na * (m)^{3.0} * h * Na\_o * \frac{(F)^{2.0}}{R*T} * \frac{\left(e^{\frac{(V-E\_Na)*F}{R*T}} - 1.0\right)}{\left(e^{\frac{V*F}{R*T}} - 1.0\right)} * V$$

4 "sodium_current_m_gate" component

m_diff_eq

$$\frac{d(m)}{d(time)} = \frac{(m\_infinity - m)}{tau\_m}$$

m_infinity_calculation

$$m\_infinity = \left(\frac{1.0}{\left(1.0 + e^{\frac{-(V)}{5.46}}\right)}\right)^{\frac{1.0}{3.0}}$$

tau_m_calculation

$$tau\_m = \left(\frac{0.6247e-3}{\left(0.832 * e^{-0.335*(V+56.7)} + 0.627 * e^{0.082*(V+65.01)}\right)} + 0.00004\right)$$

5 "sodium_current_h_gate" component

h_calculation

$$h = ((1.0 - F\_Na) * h1 + F\_Na * h2)$$

h1_diff_eq

$$\frac{\mathrm{d}(h1)}{\mathrm{d}(time)} = \frac{(h1\_infinity - h1)}{tau\_h1}$$

h2_diff_eq

$$\frac{\mathrm{d}(h2)}{\mathrm{d}(time)} = \frac{(h2\_infinity - h2)}{tau\_h2}$$

h1_infinity_calculation

$$h1\_infinity = \frac{1.0}{\left(1.0 + e^{\frac{(V+66.1)}{6.4}}\right)}$$

h2_infinity_calculation

$$h2\_infinity = h1\_infinity$$

tau_h1_calculation

$$tau\_h1 = \left(\frac{0.000003171 * e^{-0.2815*(V+17.11)}}{\left(1.0 + 0.003732 * e^{-0.3426*(V+37.76)}\right)} + 0.0005977\right)$$

tau_h2_calculation

$$tau\_h2 = \left(\frac{0.00000003186 * e^{-0.6219*(V+18.8)}}{\left(1.0 + 0.00007189 * e^{-0.6683*(V+34.07)}\right)} + 0.003556\right)$$

6 "L_type_Ca_channel" component

i_Ca_L_calculation

$$i\_Ca\_L = g\_Ca\_L * \left(f\_L * d\_L + \frac{0.006}{\left(1.0 + e^{\frac{-((V+14.1))}{6.0}}\right)}\right) * (V - E\_Ca\_L)$$

7 "L_type_Ca_channel_d_gate" component

d_L_diff_eq

$$\frac{\mathrm{d}(d\_L)}{\mathrm{d}(time)} = \frac{(d\_L\_infinity - d\_L)}{tau\_d\_L}$$

alpha_d_L_calculation

$$alpha\_d\_L = \left(-14.19 * \frac{(V + 35.0)}{\left(e^{\frac{-((V+35.0))}{2.5}} - 1.0\right)} - \frac{42.45 * V}{(e^{-0.208*V} - 1.0)}\right)$$

beta_d_L_calculation

$$beta\_d\_L = \frac{5.71 * (V - 5.0)}{\left(e^{0.4*(V-5.0)} - 1.0\right)}$$

tau_d_L_calculation

$$tau\_d\_L = \frac{1.0}{(alpha\_d\_L + beta\_d\_L)}$$

d_L_infinity_calculation

$$d\_L\_infinity = \frac{1.0}{\left(1.0 + e^{\frac{-((V+23.1))}{6.0}}\right)}$$

8 "L_type_Ca_channel_f_gate" component

f_L_diff_eq

$$\frac{\mathrm{d}(f\_L)}{\mathrm{d}(time)} = \frac{(f\_L\_infinity - f\_L)}{tau\_f\_L}$$

alpha_f_L_calculation

$$alpha\_f\_L = \frac{3.12 * (V + 28.0)}{\left(e^{\frac{(V+28.0)}{4.0}} - 1.0\right)}$$

beta_f_L_calculation

$$beta\_f\_L = \frac{25.0}{\left(1.0 + e^{\frac{-((V+28.0))}{4.0}}\right)}$$

tau_f_L_calculation

$$tau\_f\_L = \frac{1.0}{(alpha\_f\_L + beta\_f\_L)}$$

f_L_infinity_calculation

$$f\_L\_infinity = \frac{1.0}{\left(1.0 + e^{\frac{(V+45.0)}{5.0}}\right)}$$

9 "T_type_Ca_channel" component

i_Ca_T_calculation

$$i\_Ca\_T = g\_Ca\_T * d\_T * f\_T * (V - E\_Ca\_T)$$

10 "T_type_Ca_channel_d_gate" component

d_T_diff_eq

$$\frac{\mathrm{d}(d\_T)}{\mathrm{d}(time)} = \frac{(d\_T\_infinity - d\_T)}{tau\_d\_T}$$

alpha_d_T_calculation

$$alpha\_d\_T = 1068.0 * e^{\frac{(V+26.3)}{30.0}}$$

beta_d_T_calculation

$$beta\_d\_T = 1068.0 * e^{\frac{-((V+26.3))}{30.0}}$$

tau_d_T_calculation

$$tau\_d\_T = \frac{1.0}{(alpha\_d\_T + beta\_d\_T)}$$

d_T_infinity_calculation

$$d\_T\_infinity = \frac{1.0}{\left(1.0 + e^{\frac{-((V+37.0))}{6.8}}\right)}$$

11 "T_type_Ca_channel_f_gate" component

f_T_diff_eq

$$\frac{\mathrm{d}(f\_T)}{\mathrm{d}(time)} = \frac{(f\_T\_infinity - f\_T)}{tau\_f\_T}$$

alpha_f_T_calculation

$$alpha\_f\_T = 15.3 * e^{\frac{-((V+71.7))}{83.3}}$$

beta_f_T_calculation

$$beta\_f\_T = 15.0 * e^{\frac{(V+71.7)}{15.38}}$$

tau_f_T_calculation

$$tau\_f\_T = \frac{1.0}{(alpha\_f\_T + beta\_f\_T)}$$

f_T_infinity_calculation

$$f\_T\_infinity = \frac{1.0}{\left(1.0 + e^{\frac{(V+71.0)}{9.0}}\right)}$$

12 "four_AP_sensitive_currents" component

i_to_calculation

$$i\_to = g\_to * q * r * (V - E\_K)$$

i_sus_calculation

$$i\_sus = g\_sus * r * (V - E\_K)$$

13 "four_AP_sensitive_currents_q_gate" component

q_diff_eq

$$\frac{\mathrm{d}(q)}{\mathrm{d}(time)} = \frac{(q\_infinity - q)}{tau\_q}$$

q_infinity_calculation

$$q\_infinity = \frac{1.0}{\left(1.0 + e^{\frac{(V+59.37)}{13.1}}\right)}$$

tau_q_calculation

$$tau\_q = \left(10.1e - 3 + \frac{0.006517}{0.57 * e^{-0.08*(V+49.0)}} + 0.000024 * e^{0.1*(V+50.93)}\right)$$

14 "four_AP_sensitive_currents_r_gate" component

r_diff_eq

$$\frac{\mathrm{d}(r)}{\mathrm{d}(time)} = \frac{(r\_infinity - r)}{tau\_r}$$

r_infinity_calculation

$$r\_infinity = \frac{1.0}{\left(1.0 + e^{\frac{-((V-10.93))}{19.7}}\right)}$$

tau_r_calculation

$$tau\_r = \left(0.00298 + \frac{0.001559}{\left(1.037 * e^{0.09*(V+30.61)} + 0.369 * e^{-0.12*(V+23.84)}\right)}\right)$$

15 "rapid_delayed_rectifying_potassium_current" component

i_K_r_calculation

$$i\_K\_r = g\_K\_r * P\_a * P\_i * (V - E\_K)$$

P_a_calculation

$$P\_a = ((1.0 - F\_K\_r) * P\_af + F\_K\_r * P\_as)$$

16 “rapid_delayed_rectifying_potassium_current_P_af_gate” component

P_af_diff_eq

$$\frac{\mathrm{d}(P\_af)}{\mathrm{d}(time)} = \frac{(P\_af\_infinity - P\_af)}{tau\_P\_af}$$

P_af_infinity_calculation

$$P\_af\_infinity = \frac{1.0}{\left(1.0 + e^{\frac{-((V+14.2))}{10.6}}\right)}$$

tau_P_af_calculation

$$tau\_P\_af = \frac{1.0}{\left(37.2 * e^{\frac{(V-9.0)}{15.9}} + 0.96 * e^{\frac{-((V-9.0))}{22.5}}\right)}$$

17 “rapid_delayed_rectifying_potassium_current_P_as_gate” component

P_as_diff_eq

$$\frac{\mathrm{d}(P\_as)}{\mathrm{d}(time)} = \frac{(P\_as\_infinity - P\_as)}{tau\_P\_as}$$

P_as_infinity_calculation

$$P\_as\_infinity = P\_af\_infinity$$

tau_P_as_calculation

$$tau\_P\_as = \frac{1.0}{\left(4.2 * e^{\frac{(V-9.0)}{17.0}} + 0.15 * e^{\frac{-((V-9.0))}{21.6}}\right)}$$

18 “rapid_delayed_rectifying_potassium_current_P_i_gate” component

P_i_diff_eq

$$\frac{\mathrm{d}(P\_i)}{\mathrm{d}(time)} = \frac{(P\_i\_infinity - P\_i)}{tau\_P\_i}$$

P_i_infinity_calculation

$$P\_i\_infinity = \frac{1.0}{\left(1.0 + e^{\frac{(V+18.6)}{10.1}}\right)}$$

19 “slow_delayed_rectifying_potassium_current” component

i_K_s_calculation

$$i\_K\_s = g\_K\_s * (xs)^{2.0} * (V - E\_K\_s)$$

20 "slow_delayed_rectifying_potassium_current_xs_gate" component

xs_diff_eq

$$\frac{\mathrm{d}(xs)}{\mathrm{d}(time)} = \frac{(xs\_infinity - xs)}{tau\_xs}$$

alpha_xs_calculation

$$alpha\_xs = \frac{14.0}{\left(1.0 + e^{\frac{-((V-40.0))}{9.0}}\right)}$$

beta_xs_calculation

$$beta\_xs = e^{\frac{-(V)}{45.0}}$$

xs_infinity_calculation

$$xs\_infinity = \frac{alpha\_xs}{(alpha\_xs + beta\_xs)}$$

tau_xs_calculation

$$tau\_xs = \frac{1.0}{(alpha\_xs + beta\_xs)}$$

21 "hyperpolarisation_activated_current" component

i_f_calculation

$$i\_f = (i\_f\_Na + i\_f\_K)$$

i_f_Na_calculation

$$i\_f\_Na = g\_f\_Na * y * (V - E\_Na)$$

i_f_K_calculation

$$i\_f\_K = g\_f\_K * y * (V - E\_K)$$

22 "hyperpolarisation_activated_current_y_gate" component

y_diff_eq

$$\frac{\mathrm{d}(y)}{\mathrm{d}(time)} = \frac{(y\_infinity - y)}{tau\_y}$$

alpha_y_calculation

$$alpha\_y = e^{\frac{-((V+78.91))}{26.62}}$$

beta_y_calculation

$$beta\_y = e^{\frac{(V+75.13)}{21.25}}$$

y_infinity_calculation

$$y\_infinity = \frac{alpha\_y}{(alpha\_y + beta\_y)}$$

tau_y_calculation

$$tau\_y = \frac{1.0}{(alpha\_y + beta\_y)}$$

23 "sodium_background_current" component

i_b_Na_calculation

$$i\_b\_Na = g\_b\_Na * (V - E\_Na)$$

24 "potassium_background_current" component

i_b_K_calculation

$$i\_b\_K = g\_b\_K * (V - E\_K)$$

25 "calcium_background_current" component

i_b_Ca_calculation

$$i\_b\_Ca = g\_b\_Ca * (V - E\_Ca)$$

26 "sodium_calcium_pump" component

i_NaCa_calculation

$$i\_NaCa = K\_NaCa * \frac{\left((Na\_i)^{3.0} * Ca\_o * e^{0.03743*V*gamma\_NaCa} - (Na\_o)^{3.0} * Ca\_i * e^{0.0374*V*(gamma\_NaCa-1.0)}\right)}{\left(1.0 + d\_NaCa * \left(Ca\_i * (Na\_o)^{3.0} + Ca\_o * (Na\_i)^{3.0}\right)\right)}$$

27 "sodium_potassium_pump" component

i_p_calculation

$$i\_p = i\_p\_max * \left(\frac{Na\_i}{(K\_m\_Na + Na\_i)}\right)^{3.0} * \left(\frac{K\_o}{(K\_m\_K + K\_o)}\right)^{2.0} * \frac{1.6}{\left(1.5 + e^{\frac{-((V+60.0))}{40.0}}\right)}$$

28 “sustained_inward_current” component

i_st_calculation

$$i\_st = g\_st * d\_s * f\_s * (V - 18.0)$$

29 “sustained_inward_current_d_gate” component

d_s_diff_eq

$$\frac{\mathrm{d}(d\_s)}{\mathrm{d}(time)} = \frac{(d\_s\_infinity - d\_s)}{tau\_d\_s}$$

alpha_d_s_calculation

$$alpha\_d\_s = \frac{1000.0}{\left(0.15 * e^{\frac{-(V)}{11.0}} + 0.2 * e^{\frac{-(V)}{700.0}}\right)}$$

beta_d_s_calculation

$$beta\_d\_s = \frac{1000.0}{\left(16.0 * e^{\frac{V}{8.0}} + 0.2 * e^{\frac{V}{50.0}}\right)}$$

tau_d_s_calculation

$$tau\_d\_s = \frac{1.0}{(alpha\_d\_s + beta\_d\_s)}$$

d_s_infinity_calculation

$$d\_s\_infinity = \frac{alpha\_d\_s}{(alpha\_d\_s + beta\_d\_s)}$$

30 “sustained_inward_current_f_gate” component

f_s_diff_eq

$$\frac{\mathrm{d}(f\_s)}{\mathrm{d}(time)} = \frac{(f\_s\_infinity - f\_s)}{tau\_f\_s}$$

alpha_f_s_calculation

$$alpha\_f\_s = \frac{1000.0}{\left(3100.0 * e^{\frac{-(V)}{13.0}} + 700.0 * e^{\frac{-(V)}{70.0}}\right)}$$

beta_f_s_calculation

$$beta\_f\_s = \frac{1000.0}{\left(16.0 * e^{\frac{V}{8.0}} + 0.2 * e^{\frac{V}{50.0}}\right)}$$

tau_f_s_calculation

$$tau\_f\_s = \frac{1.0}{(alpha\_f\_s + beta\_f\_s)}$$

f_s_infinity_calculation

$$f\_s\_infinity = \frac{alpha\_f\_s}{(alpha\_f\_s + beta\_f\_s)}$$

31 "intracellular_calcium_handling" component

U_d_calculation

$$U\_d = \left(1.0 - \frac{B\_d}{(K\_m\_b + Ca\_d + B\_d)}\right)$$

J_Ca_ds_calculation

$$J\_Ca\_ds = alpha\_ds * Vol\_d * (Ca\_d - Ca\_s)$$

i_Ca_P_calculation

$$i\_Ca\_P = i\_Ca\_P\_max * \frac{Ca\_s}{(Ca\_s + 0.0004)}$$

J_Ca_r_calculation

$$J\_Ca\_r = alpha\_r * f\_R * \frac{(Ca\_d)^{2.0}}{\left((K\_m\_r)^{2.0} + (Ca\_d)^{2.0}\right)} * Vol\_r * Ca\_r$$

f_R_diff_eq

$$\frac{\mathrm{d}(f\_R)}{\mathrm{d}(time)} = (-(alpha\_fR) * Ca\_d * f\_R + beta\_fR * (1.0 - f\_R))$$

U_s_calculation

$$U\_s = \left(1.0 - \frac{B\_s}{(K\_m\_b + Ca\_s + B\_s)}\right)$$

J_Ca_P_calculation

$$J\_Ca\_P = J\_Ca\_P\_max * \frac{Ca\_s}{(Ca\_s + 0.0004)}$$

J_Ca_u_calculation

$$J\_Ca\_u = J\_Ca\_u\_max * \frac{(Ca\_s)^{2.0}}{\left((K\_m\_u)^{2.0} + (Ca\_s)^{2.0}\right)}$$

J_Ca_ur_calculation

$$J\_Ca\_ur = alpha\_ur * Vol\_u * (Ca\_u - Ca\_r)$$

J_Ca_1_calculation

$$J\_Ca\_1 = alpha\_1 * Vol\_u * Ca\_u$$

i_Ca_calculation

$$i\_Ca = (i\_Ca\_L + i\_Ca\_T)$$

Ca_d_diff_eq

$$\frac{\mathrm{d}(Ca\_d)}{\mathrm{d}(time)} = \frac{U\_d}{Vol\_d} * \left(J\_Ca\_ds - \frac{0.95 * i\_Ca}{2.0 * F}\right)$$

Ca_s_diff_eq

$$\frac{\mathrm{d}(Ca\_s)}{\mathrm{d}(time)} = \frac{U\_s}{Vol\_s} * \left(\left(J\_Ca\_ds - \left(\frac{((0.05 * i\_Ca - 2.0 * i\_NaCa) + i\_b\_Ca)}{2.0 * F} + J\_Ca\_u\right)\right) + J\_Ca\_r + J\_Ca\_1\right)$$

Ca_u_diff_eq

$$\frac{\mathrm{d}(Ca\_u)}{\mathrm{d}(time)} = \frac{(J\_Ca\_u - (J\_Ca\_1 + J\_Ca\_ur))}{Vol\_u}$$

Ca_r_diff_eq

$$\frac{\mathrm{d}(Ca\_r)}{\mathrm{d}(time)} = \frac{(J\_Ca\_ur - J\_Ca\_r)}{Vol\_r}$$

Vol_u_calculation

$$Vol\_u = f\_u * Vol\_c$$

Vol_r_calculation

$$Vol\_r = f\_r * Vol\_c$$

Vol_d_calculation

$$Vol\_d = f\_d * Vol\_c$$

Vol_s_calculation

$$Vol\_s = (Vol\_c - (Vol\_u + Vol\_d))$$

32 "ionic_concentrations" component

This component has no equations.

33 "reversal_and_equilibrium_potentials" component

E_Na_calculation

$$E\_Na = \frac{R * T}{z * F} * \ln \frac{Na\_o}{Na\_i}$$

E_K_calculation

$$E\_K = \frac{R * T}{z * F} * \ln \frac{K\_o}{K\_i}$$

E_Ca_calculation

$$E\_Ca = \frac{R * T}{z * F} * \ln \frac{Ca\_o}{Ca\_i}$$

E_K_s_calculation

$$E\_K\_s = \frac{R * T}{F} * \ln \frac{(K\_o + 0.12 * Na\_o)}{(K\_i + 0.12 * Na\_i)}$$