bondarenko_szigeti_bett_kim_rasmusson_2004_version04_variant02

1 "environment" component

This component has no equations.

2 "membrane" component

$$i\_stim = \begin{cases} -(80); & \text{if } (time \geq 20) \wedge (time \leq 20.5), \\ 0 & \text{otherwise.} \end{cases}$$

$$\frac{\mathrm{d}(V)}{\mathrm{d}(time)} = \frac{-((i\_CaL + i\_pCa + i\_NaCa + i\_Cab + i\_Na + i\_Nab + i\_NaK + i\_Kto\_f + i\_Kto\_s + i\_K1 + i\_Ks + i\_Kur + i\_Kss + i\_Kr + i\_ClCa + i\_stim))}{Cm}$$

3 "calcium_concentration" component

$$\frac{\mathrm{d}(Cai)}{\mathrm{d}(time)} = Bi * \left((J\_leak + J\_xfer) - \left(J\_up + J\_trpn + \frac{((i\_Cab + i\_pCa) - 2 * i\_NaCa) * Acap * Cm}{2 * Vmyo * F}\right)\right)$$

$$\frac{\mathrm{d}(Cass)}{\mathrm{d}(time)} = Bss * \left(\frac{J\_rel * VJSR}{Vss} - \left(\frac{J\_xfer * Vmyo}{Vss} + \frac{i\_CaL * Acap * Cm}{2 * Vss * F}\right)\right)$$

$$\frac{\mathrm{d}(CaJSR)}{\mathrm{d}(time)} = BJSR * (J\_tr - J\_rel)$$

$$\frac{\mathrm{d}(CaNSR)}{\mathrm{d}(time)} = \left(\frac{(J\_up - J\_leak) * Vmyo}{VNSR} - \frac{J\_tr * VJSR}{VNSR}\right)$$

$$Bi = \left(\left(1 + \frac{CMDN\_tot * Km\_CMDN}{((Km\_CMDN + Cai))^2}\right)\right)^{-(1)}$$

$$Bss = \left(\left(1 + \frac{CMDN\_tot * Km\_CMDN}{\left((Km\_CMDN + Cass)\right)^2}\right)\right)^{-(1)}$$

$$BJSR = \left(\left(1 + \frac{CSQN\_tot * Km\_CSQN}{\left((Km\_CSQN + CaJSR)\right)^2}\right)\right)^{-(1)}$$

4 "calcium_fluxes" component

$$J\_rel = v1 * (P\_O1 + P\_O2) * (CaJSR - Cass) * P\_RyR$$

$$J\_tr = \frac{(CaNSR - CaJSR)}{tau\_tr}$$

$$J\_xfer = \frac{(Cass - Cai)}{tau\_xfer}$$

$$J\_leak = v2 * (CaNSR - Cai)$$

$$J\_up = \frac{v3 * (Cai)^2}{\left((Km\_up)^2 + (Cai)^2\right)}$$

$$J\_trpn = ((k\_plus\_htrpn * Cai * (HTRPN\_tot - HTRPN\_Ca) + k\_plus\_ltrpn * Cai * (LTRPN\_tot - LTRPN\_Ca)) - (k\_minus\_htrpn * HTRPN\_Ca + k\_minus\_ltrpn * L$$

$$\frac{\mathrm{d}(P\_RyR)}{\mathrm{d}(time)} = \left(-(0.04) * P\_RyR - \frac{0.1 * i\_CaL}{i\_CaL\_max} * e^{\frac{-(((V-5))^2)}{648}}\right)$$

5 "calcium_buffering" component

$$\frac{\mathrm{d}(LTRPN\_Ca)}{\mathrm{d}(time)} = (k\_plus\_ltrpn * Cai * (LTRPN\_tot - LTRPN\_Ca) - k\_minus\_ltrpn * LTRPN\_Ca)$$

$$\frac{\mathrm{d}(HTRPN\_Ca)}{\mathrm{d}(time)} = (k\_plus\_htrpn * Cai * (HTRPN\_tot - HTRPN\_Ca) - k\_minus\_htrpn * HTRPN\_Ca)$$

6 "ryanodine_receptors" component

$$\frac{d(P\_O1)}{d(time)} = ((k\_plus\_a * (Cass)^{n} * P\_C1 + k\_minus\_b * P\_O2 + k\_minus\_c * P\_C2) - (k\_minus\_a * P\_O1 + k\_plus\_b * (Cass)^{m} * P\_O1 + k\_plus\_c * P\_O1))$$

$$P\_C1 = (1 - (P\_C2 + P\_O1 + P\_O2))$$

$$\frac{d(P\_O2)}{d(time)} = (k\_plus\_b * (Cass)^{m} * P\_O1 - k\_minus\_b * P\_O2)$$

$$\frac{d(P\_C2)}{d(time)} = (k\_plus\_c * P\_O1 - k\_minus\_c * P\_C2)$$

7 "L_type_calcium_current" component

$$i\_CaL = g\_CaL * O * (V - E\_CaL)$$

$$\frac{d(O)}{d(time)} = ((alpha * C4 + Kpcb * I1 + 0.001 * (alpha * I2 - Kpcf * O)) - (4 * beta * O + gamma * O))$$

$$C1 = (1 - (O + C2 + C2 + C3 + C4 + I1 + I2 + I3))$$

$$\frac{d(C2)}{d(time)} = ((4 * alpha * C1 + 2 * beta * C3) - (beta * C2 + 3 * alpha * C2))$$

$$\frac{d(C3)}{d(time)} = ((3 * alpha * C2 + 3 * beta * C4) - (2 * beta * C3 + 2 * alpha * C3))$$

$$\frac{d(C4)}{d(time)} = ((2 * alpha * C3 + 4 * beta * O + 0.01 * (4 * Kpcb * beta * I1 - alpha * gamma * C4) + 0.002 * (4 * beta * I2 - Kpcf * C4) + 4 * beta * Kpcb * I3) - (3 * beta * C4 +$$

$$\frac{d(I1)}{d(time)} = ((gamma * O + 0.001 * (alpha * I3 - Kpcf * I1) + 0.01 * (alpha * gamma * C4 - 4 * beta * Kpcf * I1)) - Kpcb * I1)$$

$$\frac{d(I2)}{d(time)} = ((0.001 * (Kpcf * O - alpha * I2) + Kpcb * I3 + 0.002 * (Kpcf * C4 - 4 * beta * I2)) - gamma * I2)$$

$$\frac{d(I3)}{d(time)} = ((0.001 * (Kpcf * I1 - alpha * I3) + gamma * I2 + gamma * Kpcf * C4) - (4 * beta * Kpcb * I3 + Kpcb * I3))$$

$$alpha = \frac{0.4 * e^{\frac{(V+12)}{10}} * \left(\left(1 + 0.7 * e^{\frac{-(((V+40))^2)}{10}}\right) - 0.75 * e^{\frac{-(((V+20))^2)}{400}}\right)}{\left(1 + 0.12 * e^{\frac{(V+12)}{10}}\right)}$$

$$beta = 0.05 * e^{\frac{-((V+12))}{13}}$$

$$gamma = \frac{Kpc\_max * Cass}{(Kpc\_half + Cass)}$$

$$Kpcf = 13 * \left(1 - e^{\frac{-(((V+14.5))^2)}{100}}\right)$$

8 “calcium_pump_current” component

$$i\_pCa = \frac{i\_pCa\_max * (Cai)^2}{\left((Km\_pCa)^2 + (Cai)^2\right)}$$

9 “sodium_calcium_exchange_current” component

$$i\_NaCa = \frac{\frac{\frac{k\_NaCa*1}{((K\_mNa)^3+(Nao)^3)}*1}{(K\_mCa+Cao)} * 1}{\left(1 + k\_sat * e^{\frac{(eta-1)*V*F}{R*T}}\right)} * \left(e^{\frac{eta*V*F}{R*T}} * (Nai)^3 * Cao - e^{\frac{(eta-1)*V*F}{R*T}} * (Nao)^3 * Cai\right)$$

10 “calcium_background_current” component

$$i\_Cab = g\_Cab * (V - E\_CaN)$$

$$E\_CaN = \frac{R * T}{2 * F} * \ln \frac{Cao}{Cai}$$

11 “sodium_concentration” component

$$\frac{\mathrm{d}(Nai)}{\mathrm{d}(time)} = \frac{-((i\_Na + i\_Nab + 3 * i\_NaK + 3 * i\_NaCa)) * Acap * Cm}{Vmyo * F}$$

12 “fast_sodium_current” component

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

$$E\_Na = \frac{R * T}{F} * \ln \frac{(0.9 * Nao + 0.1 * Ko)}{(0.9 * Nai + 0.1 * Ki)}$$

$$C\_Na3 = (1 - (O\_Na + C\_Na1 + C\_Na2 + IF\_Na + I1\_Na + I2\_Na + IC\_Na2 + IC\_Na3))$$

$$\frac{\mathrm{d}(C\_Na2)}{\mathrm{d}(time)} = ((alpha\_Na11 * C\_Na3 + beta\_Na12 * C\_Na1 + alpha\_Na3 * IC\_Na2) - (beta\_Na11 * C\_Na2 + alpha\_Na12 * C\_Na2 + beta\_Na3 * C\_Na2))$$

$$\frac{\mathrm{d}(C\_Na1)}{\mathrm{d}(time)} = ((alpha\_Na12 * C\_Na2 + beta\_Na13 * O\_Na + alpha\_Na3 * IF\_Na) - (beta\_Na12 * C\_Na1 + alpha\_Na13 * C\_Na1 + beta\_Na3 * C\_Na1))$$

$$\frac{\mathrm{d}(O\_Na)}{\mathrm{d}(time)} = ((alpha\_Na13 * C\_Na1 + beta\_Na2 * IF\_Na) - (beta\_Na13 * O\_Na + alpha\_Na2 * O\_Na))$$

$$\frac{\mathrm{d}(IF\_Na)}{\mathrm{d}(time)} = ((alpha\_Na2 * O\_Na + beta\_Na3 * C\_Na1 + beta\_Na4 * I1\_Na + alpha\_Na12 * IC\_Na2) - (beta\_Na2 * IF\_Na + alpha\_Na3 * IF\_Na + alpha\_Na4 * IF\_Na +$$

$$\frac{\mathrm{d}(I1\_Na)}{\mathrm{d}(time)} = ((alpha\_Na4 * IF\_Na + beta\_Na5 * I2\_Na) - (beta\_Na4 * I1\_Na + alpha\_Na5 * I1\_Na))$$

$$\frac{\mathrm{d}(I2\_Na)}{\mathrm{d}(time)} = (alpha\_Na5 * I1\_Na - beta\_Na5 * I2\_Na)$$

$$\frac{\mathrm{d}(IC\_Na2)}{\mathrm{d}(time)} = ((alpha\_Na11 * IC\_Na3 + beta\_Na12 * IF\_Na + beta\_Na3 * IC\_Na2) - (beta\_Na11 * IC\_Na2 + alpha\_Na12 * IC\_Na2 + alpha\_Na3 * IC\_Na2))$$

$$\frac{\mathrm{d}(IC\_Na3)}{\mathrm{d}(time)} = ((beta\_Na11 * IC\_Na2 + beta\_Na3 * C\_Na3) - (alpha\_Na11 * IC\_Na3 + alpha\_Na3 * IC\_Na3))$$

$$alpha\_Na11 = \frac{3.802}{\left(0.1027 * e^{\frac{-((V+2.5))}{17}} + 0.2 * e^{\frac{-((V+2.5))}{150}}\right)}$$

$$alpha\_Na12 = \frac{3.802}{\left(0.1027 * e^{\frac{-((V+2.5))}{15}} + 0.23 * e^{\frac{-((V+2.5))}{150}}\right)}$$

$$alpha\_Na13 = \frac{3.802}{\left(0.1027 * e^{\frac{-((V+2.5))}{12}} + 0.25 * e^{\frac{-((V+2.5))}{150}}\right)}$$

$$beta\_Na11 = 0.1917 * e^{\frac{-((V+2.5))}{20.3}}$$

$$beta\_Na12 = 0.2 * e^{\frac{-((V-2.5))}{20.3}}$$

$$beta\_Na13 = 0.22 * e^{\frac{-((V-7.5))}{20.3}}$$

$$alpha\_Na3 = 7e-7 * e^{\frac{-((V+7))}{7.7}}$$

$$beta\_Na3 = (0.0084 + 0.00002 * (V + 7))$$

$$alpha\_Na2 = \frac{1}{\left(0.188495 * e^{\frac{-((V+7))}{16.6}} + 0.393956\right)}$$

$$beta\_Na2 = \frac{alpha\_Na13 * alpha\_Na2 * alpha\_Na3}{beta\_Na13 * beta\_Na3}$$

$$alpha\_Na4 = \frac{alpha\_Na2}{1000}$$

$$beta\_Na4 = alpha\_Na3$$

$$alpha\_Na5 = \frac{alpha\_Na2}{95000}$$

$$beta\_Na5 = \frac{alpha\_Na3}{50}$$

13 "sodium_background_current" component

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

14 "potassium_concentration" component

$$\frac{\mathrm{d}(Ki)}{\mathrm{d}(time)} = \frac{-(((i\_Kto\_f + i\_Kto\_s + i\_K1 + i\_Ks + i\_Kss + i\_Kur + i\_Kr) - 2 * i\_NaK)) * Acap * Cm}{Vmyo * F}$$

15 “fast_transient_outward_potassium_current” component

$$i\_Kto\_f = g\_Kto\_f * (ato\_f)^3 * ito\_f * (V - E\_K)$$

$$E\_K = \frac{R * T}{F} * \ln \frac{Ko}{Ki}$$

$$\frac{\mathrm{d}(ato\_f)}{\mathrm{d}(time)} = (alpha\_a * (1 - ato\_f) - beta\_a * ato\_f)$$

$$\frac{\mathrm{d}(ito\_f)}{\mathrm{d}(time)} = (alpha\_i * (1 - ito\_f) - beta\_i * ito\_f)$$

$$alpha\_a = 0.18064 * e^{0.03577*(V+30)}$$

$$beta\_a = 0.3956 * e^{-(0.06237)*(V+30)}$$

$$alpha\_i = \frac{0.000152 * e^{\frac{-((V+13.5))}{7}}}{\left(0.0067083 * e^{\frac{-((V+33.5))}{7}} + 1\right)}$$

$$beta\_i = \frac{0.00095 * e^{\frac{(V+33.5)}{7}}}{\left(0.051335 * e^{\frac{(V+33.5)}{7}} + 1\right)}$$

16 “slow_transient_outward_potassium_current” component

$$i\_Kto\_s = g\_Kto\_s * ato\_s * ito\_s * (V - E\_K)$$

$$\frac{\mathrm{d}(ato\_s)}{\mathrm{d}(time)} = \frac{(ass - ato\_s)}{tau\_ta\_s}$$

$$\frac{\mathrm{d}(ito\_s)}{\mathrm{d}(time)} = \frac{(iss - ito\_s)}{tau\_ti\_s}$$

$$ass = \frac{1}{\left(1 + e^{\frac{-((V+22.5))}{7.7}}\right)}$$

$$iss = \frac{1}{\left(1 + e^{\frac{(V+45.2)}{5.7}}\right)}$$

$$tau\_ta\_s = \left(0.493 * e^{-(0.0629)*V} + 2.058\right)$$

$$tau\_ti\_s = \left(270 + \frac{1050}{\left(1 + e^{\frac{(V+45.2)}{5.7}}\right)}\right)$$

17 "time_independent_potassium_current" component

$$i\_K1 = \frac{\frac{0.2938*Ko}{(Ko+210)} * (V - E\_K)}{\left(1 + e^{0.0896*(V-E\_K)}\right)}$$

18 "slow_delayed_rectifier_potassium_current" component

$$i\_Ks = g\_Ks * (nKs)^2 * (V - E\_K)$$

$$\frac{\mathrm{d}(nKs)}{\mathrm{d}(time)} = (alpha\_n * (1 - nKs) - beta\_n * nKs)$$

$$alpha\_n = 0.00000481333 * (V + 26.5) * \left(1 - e^{-(0.128)*(V+26.5)}\right)$$

$$beta\_n = 0.0000953333 * e^{-(0.038)*(V+26.5)}$$

19 "ultra_rapidly_activating_delayed_rectifier_potassium_current" component

$$i\_Kur = g\_Kur * aur * iur * (V - E\_K)$$

$$\frac{\mathrm{d}(aur)}{\mathrm{d}(time)} = \frac{(ass - aur)}{tau\_aur}$$

$$\frac{d(iur)}{d(time)} = \frac{(iss - iur)}{tau\_iur}$$

$$tau\_aur = \left(0.493 * e^{-(0.0629)*V} + 2.058\right)$$

$$tau\_iur = \left(1200 - \frac{170}{\left(1 + e^{\frac{(V+45.2)}{5.7}}\right)}\right)$$

20 "non_inactivating_steady_state_potassium_current" component

$$i\_Kss = g\_Kss * aKss * iKss * (V - E\_K)$$

$$\frac{d(aKss)}{d(time)} = \frac{(ass - aKss)}{tau\_Kss}$$

$$\frac{d(iKss)}{d(time)} = 0$$

$$tau\_Kss = \left(39.3 * e^{-(0.0862)*V} + 13.17\right)$$

21 "rapid_delayed_rectifier_potassium_current" component

$$i\_Kr = g\_Kr * O\_K * \left(V - \frac{R * T}{F} * \ln \frac{(0.98 * Ko + 0.02 * Nao)}{(0.98 * Ki + 0.02 * Nai)}\right)$$

$$C\_K0 = (1 - (C\_K1 + C\_K2 + O\_K + I\_K))$$

$$\frac{d(C\_K2)}{d(time)} = ((kf * C\_K1 + beta\_a1 * O\_K) - (kb * C\_K2 + alpha\_a1 * C\_K2))$$

$$\frac{d(C\_K1)}{d(time)} = ((alpha\_a0 * C\_K0 + kb * C\_K2) - (beta\_a0 * C\_K1 + kf * C\_K1))$$

$$\frac{d(O\_K)}{d(time)} = ((alpha\_a1 * C\_K2 + beta\_i * I\_K) - (beta\_a1 * O\_K + alpha\_i * O\_K))$$

$$\frac{d(I\_K)}{d(time)} = (alpha\_i * O\_K - beta\_i * I\_K)$$

$$alpha\_a0 = 0.022348 * e^{0.01176*V}$$

$$beta\_a0 = 0.047002 * e^{-(0.0631)*V}$$

$$alpha\_a1 = 0.013733 * e^{0.038198*V}$$

$$beta\_a1 = 0.0000689 * e^{-(0.04178)*V}$$

$$alpha\_i = 0.090821 * e^{0.023391*(V+5)}$$

$$beta\_i = 0.006497 * e^{-(0.03268)*(V+5)}$$

22 "sodium_potassium_pump_current" component

$$i\_NaK = \frac{\frac{i\_NaK\_max*f\_NaK*1}{\left(1+\left(\frac{Km\_Nai}{Nai}\right)^{1.5}\right)} * Ko}{(Ko + Km\_Ko)}$$

$$f\_NaK = \frac{1}{\left(1 + 0.1245 * e^{\frac{-(0.1)*V*F}{R*T}} + 0.0365 * sigma * e^{\frac{-(V)*F}{R*T}}\right)}$$

$$sigma = \frac{1}{7} * \left(e^{\frac{Nao}{67300}} - 1\right)$$

23 "calcium_activated_chloride_current" component

$$i\_ClCa = \frac{g\_ClCa * O\_ClCa * Cai}{(Cai + Km\_Cl)} * (V - E\_Cl)$$

$$O\_ClCa = \frac{0.2}{\left(1 + e^{\frac{-((V-46.7))}{7.8}}\right)}$$