SBML Model Report

Model name: "Noble1998_VentricularCellModel_ModelC"

May 5, 2016

1 General Overview

This is a document in SBML Level 2 Version 4 format. This model was created by the following three authors: Penny Noble[1], Penny Noble[2] and Penny Noble[3] at February second 2012 at 1:30 p. m. and last time modified at February second 2012 at 9:19 p. m. Table 1 gives an overview of the quantities of all components of this model.

Table 1: Number of components in this model, which are described in the following sections.

Element	Quantity	Element	Quantity
compartment types	0	compartments	1
species types	0	species	0
events	0	constraints	0
reactions	0	function definitions	0
global parameters	229	unit definitions	18
rules	106	initial assignments	0

Model Notes

This a model from the article:
Improved guinea-pig ventricular cell model incorporating a diadic space, IKr andIKs, and length- and tension-dependent processes.

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Noble D, Varghese A, Kohl P, Noble P. Can J Cardiol 1998 Jan;14(1):123-34 9487284 ,
Abstract:
The guinea-pig ventricular cell model, originally developed by Noble et al in1991, has been greatly extended to include accumulation and depletion of calciumin a diadic space between the sarcolemma and the sarcoplasmic reticulum where,according to contempory understanding, the majority of calcium-induced calciumrelease is triggered. The calcium in this space is also assumed to play themajor role in calcium-induced inactivation of the calcium current. Delayedpotassium current equations have been developed to include the rapid (IKr) andslow (IKs) components of the delayed rectifier current based on the data of ofHeath and Terrar, along with data from Sanguinetti and Jurkiewicz. Length- andtension-dependent changes in mechanical and electrophysiological processes havebeen incorporated as described recently by Kohl et al. Drug receptorinteractions have started to be developed, using the sodium channel as the firsttarget. The new model has been tested against experimental data on actionpotential clamp, and on force-interval and duration-interval relations; it hasbeen found to reliably reproduce experimental observations.

This model was taken from the CellML repository and automatically converted to SBML.
The original model was: **Noble D, Varghese A, Kohl P, Noble P. (1998) - version=1.0**
The original CellML model was created by:
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2 Unit Definitions

This is an overview of 23 unit definitions of which five are predefined by SBML and not mentioned in the model.

2.1 Unit micrometre

Name micrometre

Definition μm

2.2 Unit per_micrometre

Name per_micrometre

Definition μm^{-1}

2.3 Unit per_second

Name per_second

Definition s^{-1}

2.4 Unit millivolt

Name millivolt

Definition mV

2.5 Unit per_millivolt

Name per_millivolt

Definition mV^{-1}

2.6 Unit per_millivolt_second

Name per_millivolt_second

Definition $mV^{-1} \cdot s^{-1}$

2.7 Unit microS

Name microS

Definition μS

2.8 Unit microF

Name microF

Definition μF

2.9 Unit nanoA

Name nanoA

Definition nA

2.10 Unit nanoA_per_millimolar

Name nanoA_per_millimolar

Definition $\mathrm{nA} \cdot \mathrm{mmol}^{-1} \cdot \mathrm{l}$

2.11 Unit millimolar

Name millimolar

Definition $\mathrm{mmol} \cdot \mathrm{l}^{-1}$

2.12 Unit millimolar4

Name millimolar4

Definition $\mathrm{mmol}^{4} \cdot \mathrm{l}^{-4}$

2.13 Unit millimolar_per_second

Name millimolar_per_second

Definition $\mathrm{mmol} \cdot \mathrm{l}^{-1} \cdot \mathrm{s}^{-1}$

2.14 Unit per_millimolar_second

Name per_millimolar_second

Definition $\mathrm{mmol}^{-1} \cdot \mathrm{l} \cdot \mathrm{s}^{-1}$

2.15 Unit joule_per_kilomole_kelvin

Name joule_per_kilomole_kelvin

Definition $\mathrm{J} \cdot \mathrm{kmol}^{-1} \cdot \mathrm{K}^{-1}$

2.16 Unit coulomb_per_mole

Name coulomb_per_mole

Definition $\mathrm{C} \cdot \mathrm{mol}^{-1}$

2.17 Unit micrometre3

Name micrometre3

Definition μm^3

2.18 Unit litre_micrometre3

Name litre_micrometre3

Definition $l \cdot \mu m^{-3}$

2.19 Unit substance

Notes Mole is the predefined SBML unit for `substance`.

Definition mol

2.20 Unit volume

Notes Litre is the predefined SBML unit for `volume`.

Definition l

2.21 Unit area

Notes Square metre is the predefined SBML unit for `area` since SBML Level 2 Version 1.

Definition m^2

2.22 Unit length

Notes Metre is the predefined SBML unit for `length` since SBML Level 2 Version 1.

Definition m

2.23 Unit time

Notes Second is the predefined SBML unit for `time`.

Definition s

3 Compartment

This model contains one compartment.

Table 2: Properties of all compartments.

Id	Name	SBO	Spatial Dimensions	Size	Unit	Constant	Outside
COMpartment			3	1		☑	

3.1 Compartment COMpartment

This is a three dimensional compartment with a constant size of one litre.

4 Parameters

This model contains 229 global parameters.

Table 3: Properties of each parameter.

Id	Name	SBO	Value	Unit	Constant
V_membrane	V		−92.849		⊟
R	R		8314.472		☑
T	T		310.000		☑
F	F		96485.342		☑
Cm	Cm		$9.5 \cdot 10^{-5}$		☑
i_Stim	i_Stim		0.000		⊟
stim_start	stim_start		0.100		☑
stim_end	stim_end		10000.000		☑
stim_period	stim_period		1.000		☑
stim_duration	stim_duration		0.003		☑
stim_amplitude	stim_amplitude		−3.000		☑
E_Na	E_Na		0.000		⊟
E_K	E_K		0.000		⊟
E_Ks	E_Ks		0.000		⊟
E_Ca	E_Ca		0.000		⊟
E_mh	E_mh		0.000		⊟
P_kna	P_kna		0.030		☑
i_K1	i_K1		0.000		⊟
K_mk1	K_mk1		10.000		☑
g_K1	g_K1		0.500		☑
i_Kr	i_Kr		0.000		⊟
g_Kr1	g_Kr1		0.002		☑
g_Kr2	g_Kr2		0.001		☑

Id	Name	SBO	Value	Unit	Constant
xr1	xr1		$1.03 \cdot 10^{-5}$		⊟
V_rapid-_delayed-_rectifier-_potassium-_current_xr1-_gate	V		0.000		☑
alpha_xr1	alpha_xr1		0.000		⊟
beta_xr1	beta_xr1		0.000		⊟
time_rapid-_delayed-_rectifier-_potassium-_current_xr1-_gate	time		0.000		☑
xr2	xr2		$2 \cdot 10^{-7}$		⊟
V_rapid-_delayed-_rectifier-_potassium-_current_xr2-_gate	V		0.000		☑
alpha_xr2	alpha_xr2		0.000		⊟
beta_xr2	beta_xr2		0.000		⊟
time_rapid-_delayed-_rectifier-_potassium-_current_xr2-_gate	time		0.000		☑
i_Ks	i_Ks		0.000		⊟
g_Ks	g_Ks		0.003		☑
xs	xs		0.001		⊟
V_slow-_delayed-_rectifier-_potassium-_current_xs-_gate	V		0.000		☑
alpha_xs	alpha_xs		0.000		⊟
beta_xs	beta_xs		0.000		⊟

Id	Name	SBO	Value	Unit	Constant
time_slow-_delayed-_rectifier-_potassium-_current_xs-_gate	time		0.000		☑
i_K_ATP	i_K_ATP		0.000		⊟
g_K_ATP	g_K_ATP		0.000		☑
K_ATP	K_ATP		0.100		☑
ATP	ATP		0.000		☑
i_KNa	i_KNa		0.000		⊟
g_K_Na	g_K_Na		0.000		☑
K_kna	K_kna		20.000		☑
i_Na	i_Na		0.000		⊟
g_Na	g_Na		2.500		☑
m	m		0.002		⊟
alpha_m	alpha_m		0.000		⊟
beta_m	beta_m		0.000		⊟
V_fast-_sodium-_current_m-_gate	V		0.000		☑
time_fast-_sodium-_current_m-_gate	time		0.000		☑
delta_m	delta_m		10^{-5}		☑
E0_m	E0_m		0.000		⊟
h	h		0.994		⊟
alpha_h	alpha_h		0.000		⊟
beta_h	beta_h		0.000		⊟
V_fast-_sodium-_current_h-_gate	V		0.000		☑
time_fast-_sodium-_current_h-_gate	time		0.000		☑
i_p_Na	i_p_Na		0.000		⊟
g_pna	g_pna		0.004		☑
i_b_Na	i_b_Na		0.000		⊟

Id	Name	SBO	Value	Unit	Constant
g_bna	g_bna		$6 \cdot 10^{-4}$		☑
i_Ca_L_Ca_cyt	i_Ca_L_Ca_cyt		0.000		⊟
i_Ca_L_K_cyt	i_Ca_L_K_cyt		0.000		⊟
i_Ca_L_Na_cyt	i_Ca_L_Na_cyt		0.000		⊟
i_Ca_L_Ca_ds	i_Ca_L_Ca_ds		0.000		⊟
i_Ca_L_K_ds	i_Ca_L_K_ds		0.000		⊟
i_Ca_L_Na_ds	i_Ca_L_Na_ds		0.000		⊟
i_Ca_L	i_Ca_L		0.000		⊟
P_Ca_L	P_Ca_L		0.100		☑
P_CaK	P_CaK		0.002		☑
P_CaNa	P_CaNa		0.010		☑
Km_f2	Km_f2		100000.000		☑
Km_f2ds	Km_f2ds		0.001		☑
R_decay	R_decay		20.000		☑
FrICa	FrICa		1.000		☑
d	d		0.000		⊟
alpha_d	alpha_d		0.000		⊟
beta_d	beta_d		0.000		⊟
V_L_type_Ca-_channel_d-_gate	V		0.000		☑
time_L_type-_Ca_channel-_d_gate	time		0.000		☑
E0_d	E0_d		0.000		⊟
speed_d	speed_d		3.000		☑
f	f		1.000		⊟
alpha_f	alpha_f		0.000		⊟
beta_f	beta_f		0.000		⊟
V_L_type_Ca-_channel_f-_gate	V		0.000		☑
time_L_type-_Ca_channel-_f_gate	time		0.000		☑
speed_f	speed_f		0.300		☑
delta_f	delta_f		10^{-4}		☑
E0_f	E0_f		0.000		⊟
f2	f2		0.935		⊟
Ca_i_L_type-_Ca_channel-_f2_gate	Ca_i		0.000		☑

Id	Name	SBO	Value	Unit	Constant
V_L_type_Ca_channel_f2_gate	V		0.000		☑
time_L_type_Ca_channel_f2_gate	time		0.000		☑
f2ds	f2ds		0.965		⊟
Ca_ds_L_type_Ca_channel_f2ds_gate	Ca_ds		0.000		☑
V_L_type_Ca_channel_f2ds_gate	V		0.000		☑
time_L_type_Ca_channel_f2ds_gate	time		0.000		☑
i_b_Ca	i_b_Ca		0.000		⊟
g_bca	g_bca		$2.5 \cdot 10^{-4}$		☑
i_to	i_to		0.000		⊟
g_to	g_to		0.005		☑
g_tos	g_tos		0.000		☑
s	s		0.995		⊟
alpha_s	alpha_s		0.000		⊟
beta_s	beta_s		0.000		⊟
V_transient_outward_current_s_gate	V		0.000		☑
time_transient_outward_current_s_gate	time		0.000		☑
r	r		0.000		⊟
V_transient_outward_current_r_gate	V		0.000		☑

Id	Name	SBO	Value	Unit	Constant
time_transient_outward_current_r_gate	time		0.000		☑
i_K_ACh	i_K_ACh		0.000		⊟
g_KACh	g_KACh		0.000		☑
ACh	ACh		5.000		☑
K_D	K_D		$1.3 \cdot 10^{-4}$		☑
x_ACh	x_ACh		0.000		⊟
alpha_ACh	alpha_ACh		0.500		☑
beta_ACh	beta_ACh		0.500		☑
time_ACh_dependent_potassium_current_xACh_gate	time		0.000		☑
i_NaK	i_NaK		0.000		⊟
i_NaK_max	i_NaK_max		0.700		☑
K_mK	K_mK		1.000		☑
K_mNa	K_mNa		40.000		☑
i_NaCa	i_NaCa		0.000		⊟
i_NaCa_cyt	i_NaCa_cyt		0.000		⊟
i_NaCa_ds	i_NaCa_ds		0.000		⊟
k_NaCa	k_NaCa		$5 \cdot 10^{-4}$		☑
n_NaCa	n_NaCa		3.000		☑
d_NaCa	d_NaCa		0.000		☑
gamma	gamma		0.500		☑
FRiNaCa	FRiNaCa		0.001		☑
i_up	i_up		0.000		⊟
K_1	K_1		0.000		⊟
K_2	K_2		0.000		⊟
K_cyca	K_cyca		$3 \cdot 10^{-4}$		☑
K_xcs	K_xcs		0.400		☑
K_srca	K_srca		0.500		☑
alpha_up	alpha_up		0.400		☑
beta_up	beta_up		0.030		☑
i_trans	i_trans		0.000		⊟
i_rel	i_rel		0.000		⊟
VoltDep	VoltDep		0.000		⊟
RegBindSite	RegBindSite		0.000		⊟
CaiReg	CaiReg		0.000		⊟

Id	Name	SBO	Value	Unit	Constant
CadsReg	CadsReg		0.000		☐
ActRate	ActRate		0.000		☐
InactRate	InactRate		0.000		☐
K_leak_rate	K_leak_rate		0.005		☑
SRLeak	SRLeak		0.000		☐
K_m_rel	K_m_rel		250.000		☑
K_m_Ca_cyt	K_m_Ca_cyt		$5 \cdot 10^{-4}$		☑
K_m_Ca_ds	K_m_Ca_ds		0.010		☑
PrecFrac	PrecFrac		0.000		☐
ActFrac	ActFrac		0.002		☐
ProdFrac	ProdFrac		0.285		☐
SpeedRel	SpeedRel		0.000		☐
gama_SR_SL	gama_SR_SL		2.500		☑
gama_SR_IT	gama_SR_IT		2.500		☑
Na_o	Na_o		140.000		☑
Na_i	Na_i		7.332		☐
Ca_o	Ca_o		2.000		☑
K_o	K_o		4.000		☑
K_i	K_i		136.564		☐
Ca_i_intracellular_calcium_concentration	Ca_i		$1.4 \cdot 10^{-5}$		☐
Ca_ds_intracellular_calcium_concentration	Ca_ds		$1.88 \cdot 10^{-5}$		☐
Ca_up	Ca_up		0.453		☐
Ca_rel	Ca_rel		0.448		☐
Ca_Calmod	Ca_Calmod		$5.555 \cdot 10^{-4}$		☐
Ca_Trop	Ca_Trop		$2 \cdot 10^{-4}$		☐
Calmod	Calmod		0.020		☑
Trop	Trop		0.050		☑
alpha_Calmod	alpha_Calmod		100000.000		☑
beta_Calmod	beta_Calmod		50.000		☑
alpha_Trop	alpha_Trop		0.000		☐
beta_Trop	beta_Trop		200.000		☑
gama_Trop_SL	gama_Trop_SL		1.500		☑
KTrop	KTrop		5000.000		☑
radius	radius		12.000		☑
length	length		74.000		☑
V_i	V_i		0.000		☐

Id	Name	SBO	Value	Unit	Constant
V_Cell	V_Cell		0.000		☐
V_i_ratio	V_i_ratio		0.000		☐
V_ds_ratio	V_ds_ratio		0.100		☑
V_rel_ratio	V_rel_ratio		0.100		☑
V_e_ratio	V_e_ratio		0.400		☑
V_up_ratio	V_up_ratio		0.010		☑
Kdecay	Kdecay		10.000		☑
light_chain	light_chain		$3.32 \cdot 10^{-5}$		☐
cross_bridge	cross_bridge		$8.09 \cdot 10^{-5}$		☐
KCont1	KCont1		12000.000		☑
XCont2	XCont2		0.000		☐
XCont1	XCont1		0.000		☐
KCont2	KCont2		100.000		☑
KCont3	KCont3		60.000		☑
KCont4	KCont4		25.000		☑
sarcomere_length	sarcomere_length		2.000		☑
cross_bridge_density	cross_bridge_density		0.050		☑
tension_rest	tension_rest		0.000		☐
tension_active	tension_active		0.000		☐
overlap	overlap		0.000		☐
cross_bridge_availability	cross_bridge_availability		0.000		☐
isometric_tension	isometric_tension		0.000		☐
i_stretch	i_stretch		0.000		☐
i_Ca_stretch	i_Ca_stretch		0.000		☐
i_K_stretch	i_K_stretch		0.000		☐
i_Na_stretch	i_Na_stretch		0.000		☐
i_An_stretch	i_An_stretch		0.000		☐
gama_SAC_SL	gama_SAC_SL		2.500		☑
gama_SAC_IT	gama_SAC_IT		2.500		☑
SLHST	SLHST		2.000		☑
ITHST	ITHST		1.000		☑
g_Ca_stretch	g_Ca_stretch		0.010		☑
g_K_stretch	g_K_stretch		0.010		☑
g_Na_stretch	g_Na_stretch		0.010		☑
g_An_stretch	g_An_stretch		0.010		☑

Id	Name	SBO	Value	Unit	Constant
E_An_stretch	E_An_stretch		−20.000		☑
f_stretch	f_stretch		0.000		☐
g_fibro_junct	g_fibro_junct		$2.9 \cdot 10^{-4}$		☑
g_fibro	g_fibro		$2 \cdot 10^{-4}$		☑
c_fibro	c_fibro		10^{-5}		☑
g_fibro_stretch	g_fibro_stretch		0.000		☑
E_fibro_stretch	E_fibro_stretch		0.000		☑
V_fibro	V_fibro		−20.000		☐
i_fibro	i_fibro		0.000		☐
i_fibro_junct	i_fibro_junct		0.000		☐

5 Rules

This is an overview of 106 rules.

5.1 Rule V_membrane

Rule V_membrane is a rate rule for parameter V_membrane:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{V\_membrane} = \frac{1}{\mathrm{Cm}} \cdot (\mathrm{i\_Stim} + \mathrm{i\_K1} + \mathrm{i\_to} + \mathrm{i\_Kr} + \mathrm{i\_Ks} + \mathrm{i\_K\_ATP} + \mathrm{i\_K\_ACh} + \mathrm{i\_NaK} + \mathrm{i\_Na} + \mathrm{i\_b\_Na} + \mathrm{i\_p\_Na} + \mathrm{i\_Ca\_L\_Na\_cyt} + \mathrm{i\_Ca\_L\_Na\_ds} + \mathrm{i\_NaCa\_cyt} + \mathrm{i\_NaCa\_ds} + \mathrm{i\_Ca\_L\_Ca\_cyt} + \mathrm{i\_Ca\_L\_Ca\_ds} + \mathrm{i\_Ca\_L\_K\_cyt} + \mathrm{i\_Ca\_L\_K\_ds} + \mathrm{i\_b\_Ca} + \mathrm{i\_stretch}) \tag{1}$$

5.2 Rule xr1

Rule xr1 is a rate rule for parameter xr1:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{xr1} = \mathrm{alpha\_xr1} \cdot (1 - \mathrm{xr1}) - \mathrm{beta\_xr1} \cdot \mathrm{xr1} \tag{2}$$

5.3 Rule xr2

Rule xr2 is a rate rule for parameter xr2:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{xr2} = \mathrm{alpha\_xr2} \cdot (1 - \mathrm{xr2}) - \mathrm{beta\_xr2} \cdot \mathrm{xr2} \tag{3}$$

5.4 Rule xs

Rule xs is a rate rule for parameter xs:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{xs} = \mathrm{alpha\_xs} \cdot (1 - \mathrm{xs}) - \mathrm{beta\_xs} \cdot \mathrm{xs} \tag{4}$$

5.5 Rule m

Rule m is a rate rule for parameter m:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{m} = \mathrm{alpha\_m} \cdot (1 - \mathrm{m}) - \mathrm{beta\_m} \cdot \mathrm{m} \tag{5}$$

5.6 Rule h

Rule h is a rate rule for parameter h:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{h} = \mathrm{alpha\_h} \cdot (1 - \mathrm{h}) - \mathrm{beta\_h} \cdot \mathrm{h} \tag{6}$$

5.7 Rule d

Rule d is a rate rule for parameter d:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{d} = \mathrm{speed\_d} \cdot (\mathrm{alpha\_d} \cdot (1 - \mathrm{d}) - \mathrm{beta\_d} \cdot \mathrm{d}) \tag{7}$$

5.8 Rule f

Rule f is a rate rule for parameter f:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{f} = \mathrm{speed\_f} \cdot (\mathrm{alpha\_f} \cdot (1 - \mathrm{f}) - \mathrm{beta\_f} \cdot \mathrm{f}) \tag{8}$$

5.9 Rule f2

Rule f2 is a rate rule for parameter f2:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{f2} = 1 - 1 \cdot \left(\frac{\mathrm{Ca\_i\_L\_type\_Ca\_channel\_f2\_gate}}{\mathrm{Km\_f2} + \mathrm{Ca\_i\_L\_type\_Ca\_channel\_f2\_gate}} + \mathrm{f2} \right) \tag{9}$$

5.10 Rule f2ds

Rule f2ds is a rate rule for parameter f2ds:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{f2ds} = \mathrm{R\_decay} \cdot \left(1 - \left(\frac{\mathrm{Ca\_ds\_L\_type\_Ca\_channel\_f2ds\_gate}}{\mathrm{Km\_f2ds} + \mathrm{Ca\_ds\_L\_type\_Ca\_channel\_f2ds\_gate}} + \mathrm{f2ds} \right) \right) \tag{10}$$

5.11 Rule s

Rule s is a rate rule for parameter s:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{s} = \mathrm{alpha\_s} \cdot (1 - \mathrm{s}) - \mathrm{beta\_s} \cdot \mathrm{s} \tag{11}$$

5.12 Rule r

Rule r is a rate rule for parameter r:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{r} = 333 \cdot \left(\frac{1}{1 + \exp\left(\frac{(\mathrm{V\_transient\_outward\_current\_r\_gate} + 4)}{5} \right)} - \mathrm{r} \right) \tag{12}$$

5.13 Rule x_ACh

Rule x_ACh is a rate rule for parameter x_ACh:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{x\_ACh} = \mathrm{alpha\_ACh} \cdot (1 - \mathrm{x\_ACh}) - \mathrm{beta\_ACh} \cdot \mathrm{x\_ACh} \tag{13}$$

5.14 Rule ActFrac

Rule ActFrac is a rate rule for parameter ActFrac:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{ActFrac} = \mathrm{PrecFrac} \cdot \mathrm{SpeedRel} \cdot \mathrm{ActRate} - \mathrm{ActFrac} \cdot \mathrm{SpeedRel} \cdot \mathrm{InactRate} \tag{14}$$

5.15 Rule ProdFrac

Rule ProdFrac is a rate rule for parameter ProdFrac:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{ProdFrac} = \mathrm{ActFrac} \cdot \mathrm{SpeedRel} \cdot \mathrm{InactRate} - \mathrm{SpeedRel} \cdot 1 \cdot \mathrm{ProdFrac} \tag{15}$$

5.16 Rule Na_i

Rule Na_i is a rate rule for parameter Na_i:

$$\begin{aligned}\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{Na\_i} = \frac{1}{1 \cdot \mathrm{V\_i} \cdot \mathrm{F}} \cdot (&\mathrm{i\_Na} + \mathrm{i\_p\_Na} + \mathrm{i\_b\_Na} + 3 \cdot \mathrm{i\_NaK} + 3 \cdot \mathrm{i\_NaCa\_cyt} \\ &+ \mathrm{i\_Ca\_L\_Na\_cyt} + \mathrm{i\_Ca\_L\_Na\_ds})\end{aligned} \tag{16}$$

5.17 Rule K_i

Rule K_i is a rate rule for parameter K_i:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{K\_i} = \frac{1}{1 \cdot \mathrm{V\_i} \cdot \mathrm{F}} \cdot (\mathrm{i\_K1} + \mathrm{i\_Kr} + \mathrm{i\_Ks} + \mathrm{i\_Ca\_L\_K\_cyt} + \mathrm{i\_Ca\_L\_K\_ds} + \mathrm{i\_to} - 2 \cdot \mathrm{i\_NaK}) \tag{17}$$

5.18 Rule Ca_i_intracellular_calcium_concentration

Rule Ca_i_intracellular_calcium_concentration is a rate rule for parameter Ca_i_intracellular_calcium_concentration:

$$\begin{aligned}\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{Ca\_i\_intracellular\_calcium\_concentration} = \frac{1}{2 \cdot 1 \cdot \mathrm{V\_i} \cdot \mathrm{F}} \cdot (\mathrm{i\_Ca\_L\_Ca\_cyt} + \mathrm{i\_b\_Ca} - 2 \\ \cdot \mathrm{i\_NaCa\_cyt} - 2 \cdot \mathrm{i\_NaCa\_ds}) \\ + \mathrm{Ca\_ds\_intracellular\_calcium\_concentration} \\ \cdot \mathrm{V\_ds\_ratio} \cdot \mathrm{Kdecay} + \frac{\mathrm{i\_rel} \cdot \mathrm{V\_rel\_ratio}}{\mathrm{V\_i\_ratio}} \\ - \mathrm{Ca\_Calmod} - \mathrm{Ca\_Trop} - \mathrm{i\_up}\end{aligned} \tag{18}$$

5.19 Rule Ca_ds_intracellular_calcium_concentration

Rule Ca_ds_intracellular_calcium_concentration is a rate rule for parameter Ca_ds_intracellular_calcium_concentration:

$$\begin{aligned}\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{Ca\_ds\_intracellular\_calcium\_concentration} = \frac{1 \cdot \mathrm{i\_Ca\_L\_Ca\_ds}}{2 \cdot 1 \cdot \mathrm{V\_ds\_ratio} \cdot \mathrm{V\_i} \cdot \mathrm{F}} \\ - \mathrm{Ca\_ds\_intracellular\_calcium\_concentration} \\ \cdot \mathrm{Kdecay}\end{aligned} \tag{19}$$

5.20 Rule Ca_up

Rule Ca_up is a rate rule for parameter Ca_up:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{Ca\_up} = \frac{\mathrm{V\_i\_ratio}}{\mathrm{V\_up\_ratio}} \cdot \mathrm{i\_up} - \mathrm{i\_trans} \tag{20}$$

5.21 Rule Ca_rel

Rule Ca_rel is a rate rule for parameter Ca_rel:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{Ca\_rel} = \frac{\mathrm{V\_up\_ratio}}{\mathrm{V\_rel\_ratio}} \cdot \mathrm{i\_trans} - \mathrm{i\_rel} \tag{21}$$

5.22 Rule Ca_Calmod

Rule Ca_Calmod is a rate rule for parameter Ca_Calmod:

$$\begin{aligned}\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{Ca\_Calmod} = \mathrm{alpha\_Calmod} \cdot \mathrm{Ca\_i\_intracellular\_calcium\_concentration} \\ \cdot (\mathrm{Calmod} - \mathrm{Ca\_Calmod}) - \mathrm{beta\_Calmod} \cdot \mathrm{Ca\_Calmod}\end{aligned} \tag{22}$$

5.23 Rule Ca_Trop

Rule Ca_Trop is a rate rule for parameter Ca_Trop:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{Ca\_Trop} = \mathrm{alpha\_Trop} \cdot \mathrm{Ca\_i\_intracellular\_calcium\_concentration} \cdot (\mathrm{Trop} - \mathrm{Ca\_Trop}) - \mathrm{beta\_Trop} \cdot \mathrm{Ca\_Trop} \tag{23}$$

5.24 Rule light_chain

Rule light_chain is a rate rule for parameter light_chain:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{light\_chain} = \mathrm{KCont1} \cdot \mathrm{XCont1}^2 \cdot \mathrm{XCont2} \cdot (1 - \mathrm{light\_chain}) - \mathrm{KCont2} \cdot \mathrm{light\_chain} \tag{24}$$

5.25 Rule cross_bridge

Rule cross_bridge is a rate rule for parameter cross_bridge:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{cross\_bridge} = \mathrm{KCont3} \cdot \mathrm{light\_chain} \cdot (1 - \mathrm{cross\_bridge}) - \mathrm{KCont4} \cdot \mathrm{cross\_bridge} \tag{25}$$

5.26 Rule V_fibro

Rule V_fibro is a rate rule for parameter V_fibro:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{V\_fibro} = \frac{(\mathrm{i\_fibro} + \mathrm{i\_fibro\_junct})}{\mathrm{c\_fibro}} \tag{26}$$

5.27 Rule i_Stim

Rule i_Stim is an assignment rule for parameter i_Stim:

$$\mathrm{i\_Stim} = \begin{cases} \mathrm{stim\_amplitude} & \text{if } (\mathrm{time} \geq \mathrm{stim\_start}) \wedge \left(\mathrm{time} - \mathrm{stim\_start} - \left\lfloor \frac{\mathrm{time} - \mathrm{stim\_start}}{\mathrm{stim\_period}} \right\rfloor \cdot \mathrm{stim\_period} \leq \mathrm{stim\_durat} \right. \\ 0 & \text{otherwise} \end{cases} \tag{27}$$

5.28 Rule E_Na

Rule E_Na is an assignment rule for parameter E_Na:

$$\mathrm{E\_Na} = \frac{\mathrm{R} \cdot \mathrm{T}}{\mathrm{F}} \cdot \left(\frac{\mathrm{Na\_o}}{\mathrm{Na\_i}}\right) \tag{28}$$

5.29 Rule E_K

Rule E_K is an assignment rule for parameter E_K:

$$\mathrm{E\_K} = \frac{\mathrm{R} \cdot \mathrm{T}}{\mathrm{F}} \cdot \left(\frac{\mathrm{K\_o}}{\mathrm{K\_i}}\right) \tag{29}$$

5.30 Rule E_Ks

Rule E_Ks is an assignment rule for parameter E_Ks:

$$\mathrm{E\_Ks} = \frac{\mathrm{R} \cdot \mathrm{T}}{\mathrm{F}} \cdot \left(\frac{\mathrm{K\_o} + \mathrm{P\_kna} \cdot \mathrm{Na\_o}}{\mathrm{K\_i} + \mathrm{P\_kna} \cdot \mathrm{Na\_i}} \right) \tag{30}$$

5.31 Rule E_Ca

Rule E_Ca is an assignment rule for parameter E_Ca:

$$\mathrm{E\_Ca} = \frac{0.5 \cdot \mathrm{R} \cdot \mathrm{T}}{\mathrm{F}} \cdot \left(\frac{\mathrm{Ca\_o}}{\mathrm{Ca\_i\_intracellular\_calcium\_concentration}} \right) \tag{31}$$

5.32 Rule E_mh

Rule E_mh is an assignment rule for parameter E_mh:

$$\mathrm{E\_mh} = \frac{\mathrm{R} \cdot \mathrm{T}}{\mathrm{F}} \cdot \left(\frac{\mathrm{Na\_o} + 0.12 \cdot \mathrm{K\_o}}{\mathrm{Na\_i} + 0.12 \cdot \mathrm{K\_i}} \right) \tag{32}$$

5.33 Rule i_K1

Rule i_K1 is an assignment rule for parameter i_K1:

$$\mathrm{i\_K1} = \frac{\frac{\mathrm{g\_K1} \cdot \mathrm{K\_o}}{\mathrm{K\_o} + \mathrm{K\_mk1}} \cdot (\mathrm{V\_membrane} - \mathrm{E\_K})}{1 + \exp\left(\frac{(\mathrm{V\_membrane} - \mathrm{E\_K} - 10) \cdot \mathrm{F} \cdot 1.25}{\mathrm{R} \cdot \mathrm{T}} \right)} \tag{33}$$

5.34 Rule i_Kr

Rule i_Kr is an assignment rule for parameter i_Kr:

$$\mathrm{i\_Kr} = \frac{(\mathrm{g\_Kr1} \cdot \mathrm{xr1} + \mathrm{g\_Kr2} \cdot \mathrm{xr2}) \cdot 1}{1 + \exp\left(\frac{\mathrm{V\_membrane} + 9}{22.4} \right)} \cdot (\mathrm{V\_membrane} - \mathrm{E\_K}) \tag{34}$$

5.35 Rule alpha_xr1

Rule alpha_xr1 is an assignment rule for parameter alpha_xr1:

$$\mathrm{alpha\_xr1} = \frac{50}{1 + \exp\left(\frac{(\mathrm{V\_rapid\_delayed\_rectifier\_potassium\_current\_xr1\_gate} - 5)}{9} \right)} \tag{35}$$

5.36 Rule beta_xr1

Rule beta_xr1 is an assignment rule for parameter beta_xr1:

$$\mathrm{beta\_xr1} = 0.05 \cdot \exp\left(\frac{(\mathrm{V\_rapid\_delayed\_rectifier\_potassium\_current\_xr1\_gate} - 20)}{15} \right) \tag{36}$$

5.37 Rule alpha_xr2

Rule alpha_xr2 is an assignment rule for parameter alpha_xr2:

$$\text{alpha\_xr2} = \frac{50}{1 + \exp\left(\frac{(\text{V\_rapid\_delayed\_rectifier\_potassium\_current\_xr2\_gate} - 5)}{9}\right)} \tag{37}$$

5.38 Rule beta_xr2

Rule beta_xr2 is an assignment rule for parameter beta_xr2:

$$\text{beta\_xr2} = 0.4 \cdot \exp\left(\left(\left(\frac{\text{V\_rapid\_delayed\_rectifier\_potassium\_current\_xr2\_gate} + 30}{30}\right)^3\right)\right) \tag{38}$$

5.39 Rule i_Ks

Rule i_Ks is an assignment rule for parameter i_Ks:

$$\text{i\_Ks} = \text{g\_Ks} \cdot \text{xs}^2 \cdot (\text{V\_membrane} - \text{E\_Ks}) \tag{39}$$

5.40 Rule alpha_xs

Rule alpha_xs is an assignment rule for parameter alpha_xs:

$$\text{alpha\_xs} = \frac{14}{1 + \exp\left(\frac{(\text{V\_slow\_delayed\_rectifier\_potassium\_current\_xs\_gate} - 40)}{9}\right)} \tag{40}$$

5.41 Rule beta_xs

Rule beta_xs is an assignment rule for parameter beta_xs:

$$\text{beta\_xs} = 1 \cdot \exp\left(\frac{\text{V\_slow\_delayed\_rectifier\_potassium\_current\_xs\_gate}}{45}\right) \tag{41}$$

5.42 Rule i_K_ATP

Rule i_K_ATP is an assignment rule for parameter i_K_ATP:

$$\text{i\_K\_ATP} = \frac{\text{g\_K\_ATP} \cdot (\text{V\_membrane} + 80)}{1 + \left(\frac{\text{ATP}}{\text{K\_ATP}}\right)^2} \tag{42}$$

5.43 Rule i_KNa

Rule i_KNa is an assignment rule for parameter i_KNa:

$$\text{i\_KNa} = \frac{\text{g\_K\_Na} \cdot \text{Na\_i}}{\text{Na\_i} + \text{K\_kna}} \cdot (\text{V\_membrane} - \text{E\_K}) \tag{43}$$

5.44 Rule i_Na

Rule i_Na is an assignment rule for parameter i_Na:

$$\text{i\_Na} = \text{g\_Na} \cdot \text{m}^3 \cdot \text{h} \cdot (\text{V\_membrane} - \text{E\_mh}) \tag{44}$$

5.45 Rule E0_m

Rule E0_m is an assignment rule for parameter E0_m:

$$\text{E0\_m} = \text{V\_fast\_sodium\_current\_m\_gate} + 41 \tag{45}$$

5.46 Rule alpha_m

Rule alpha_m is an assignment rule for parameter alpha_m:

$$\text{alpha\_m} = \begin{cases} 2000 & \text{if } |\text{E0\_m}| < \text{delta\_m} \\ \dfrac{200 \cdot \text{E0\_m}}{1 - \exp(0.1 \cdot \text{E0\_m})} & \text{otherwise} \end{cases} \tag{46}$$

5.47 Rule beta_m

Rule beta_m is an assignment rule for parameter beta_m:

$$\text{beta\_m} = 8000 \cdot \exp(0.056 \cdot (\text{V\_fast\_sodium\_current\_m\_gate} + 66)) \tag{47}$$

5.48 Rule alpha_h

Rule alpha_h is an assignment rule for parameter alpha_h:

$$\text{alpha\_h} = 20 \cdot \exp(0.125 \cdot (\text{V\_fast\_sodium\_current\_h\_gate} + 75)) \tag{48}$$

5.49 Rule beta_h

Rule beta_h is an assignment rule for parameter beta_h:

$$\text{beta\_h} = \frac{2000}{1 + 320 \cdot \exp(0.1 \cdot (\text{V\_fast\_sodium\_current\_h\_gate} + 75))} \tag{49}$$

5.50 Rule i_p_Na

Rule i_p_Na is an assignment rule for parameter i_p_Na:

$$\text{i\_p\_Na} = \frac{\text{g\_pna} \cdot 1}{1 + \exp\left(\frac{(\text{V\_membrane}+52)}{8}\right)} \cdot (\text{V\_membrane} - \text{E\_Na}) \tag{50}$$

5.51 Rule i_b_Na

Rule i_b_Na is an assignment rule for parameter i_b_Na:

$$\text{i\_b\_Na} = \text{g\_bna} \cdot (\text{V\_membrane} - \text{E\_Na}) \tag{51}$$

5.52 Rule i_Ca_L_Ca_cyt

Rule i_Ca_L_Ca_cyt is an assignment rule for parameter i_Ca_L_Ca_cyt:

$$\begin{aligned}\text{i\_Ca\_L\_Ca\_cyt} = {} & \frac{\frac{(1-\text{FrICa})\cdot 4\cdot \text{P\_Ca\_L}\cdot \text{d}\cdot \text{f}\cdot \text{f2}\cdot(\text{V\_membrane}-50)\cdot \text{F}}{\text{R}\cdot\text{T}}}{1-\exp\left(\frac{(\text{V\_membrane}-50)\cdot \text{F}\cdot 2}{\text{R}\cdot\text{T}}\right)} \\ & \cdot \left(\text{Ca\_i\_intracellular\_calcium\_concentration}\cdot \exp\left(\frac{100\cdot \text{F}}{\text{R}\cdot\text{T}}\right) - \text{Ca\_o}\right. \\ & \left. \cdot \exp\left(\frac{(\text{V\_membrane}-50)\cdot \text{F}\cdot 2}{\text{R}\cdot\text{T}}\right)\right)\end{aligned} \tag{52}$$

5.53 Rule i_Ca_L_K_cyt

Rule i_Ca_L_K_cyt is an assignment rule for parameter i_Ca_L_K_cyt:

$$\begin{aligned}\text{i\_Ca\_L\_K\_cyt} = {} & \frac{\frac{(1-\text{FrICa})\cdot \text{P\_CaK}\cdot \text{P\_Ca\_L}\cdot \text{d}\cdot \text{f}\cdot \text{f2}\cdot(\text{V\_membrane}-50)\cdot \text{F}}{\text{R}\cdot\text{T}}}{1-\exp\left(\frac{(\text{V\_membrane}-50)\cdot \text{F}}{\text{R}\cdot\text{T}}\right)} \\ & \cdot \left(\text{K\_i}\cdot \exp\left(\frac{50\cdot \text{F}}{\text{R}\cdot\text{T}}\right) - \text{K\_o}\cdot \exp\left(\frac{(\text{V\_membrane}-50)\cdot \text{F}}{\text{R}\cdot\text{T}}\right)\right)\end{aligned} \tag{53}$$

5.54 Rule i_Ca_L_Na_cyt

Rule i_Ca_L_Na_cyt is an assignment rule for parameter i_Ca_L_Na_cyt:

$$\begin{aligned}\text{i\_Ca\_L\_Na\_cyt} = {} & \frac{\frac{(1-\text{FrICa})\cdot \text{P\_CaNa}\cdot \text{P\_Ca\_L}\cdot \text{d}\cdot \text{f}\cdot \text{f2}\cdot(\text{V\_membrane}-50)\cdot \text{F}}{\text{R}\cdot\text{T}}}{1-\exp\left(\frac{(\text{V\_membrane}-50)\cdot \text{F}}{\text{R}\cdot\text{T}}\right)} \\ & \cdot \left(\text{Na\_i}\cdot \exp\left(\frac{50\cdot \text{F}}{\text{R}\cdot\text{T}}\right) - \text{Na\_o}\cdot \exp\left(\frac{(\text{V\_membrane}-50)\cdot \text{F}}{\text{R}\cdot\text{T}}\right)\right)\end{aligned} \tag{54}$$

5.55 Rule i_Ca_L_Ca_ds

Rule i_Ca_L_Ca_ds is an assignment rule for parameter i_Ca_L_Ca_ds:

$$\begin{aligned}\text{i\_Ca\_L\_Ca\_ds} = {} & \frac{\frac{\text{FrICa}\cdot 4\cdot \text{P\_Ca\_L}\cdot \text{d}\cdot \text{f}\cdot \text{f2ds}\cdot(\text{V\_membrane}-50)\cdot \text{F}}{\text{R}\cdot\text{T}}}{1-\exp\left(\frac{(\text{V\_membrane}-50)\cdot \text{F}\cdot 2}{\text{R}\cdot\text{T}}\right)} \cdot \left(\text{Ca\_i\_intracellular\_calcium\_concentration}\right. \\ & \left. \cdot \exp\left(\frac{100\cdot \text{F}}{\text{R}\cdot\text{T}}\right) - \text{Ca\_o}\cdot \exp\left(\frac{(\text{V\_membrane}-50)\cdot \text{F}\cdot 2}{\text{R}\cdot\text{T}}\right)\right)\end{aligned} \tag{55}$$

5.56 Rule i_Ca_L_K_ds

Rule i_Ca_L_K_ds is an assignment rule for parameter i_Ca_L_K_ds:

$$\begin{aligned} \text{i\_Ca\_L\_K\_ds} = & \frac{\frac{\text{FrICa}\cdot\text{P\_CaK}\cdot\text{P\_Ca\_L}\cdot\text{d}\cdot\text{f}\cdot\text{f2ds}\cdot(\text{V\_membrane}-50)\cdot\text{F}}{\text{R}\cdot\text{T}}}{1-\exp\left(\frac{(\text{V\_membrane}-50)\cdot\text{F}}{\text{R}\cdot\text{T}}\right)} \\ & \cdot\left(\text{K\_i}\cdot\exp\left(\frac{50\cdot\text{F}}{\text{R}\cdot\text{T}}\right)-\text{K\_o}\cdot\exp\left(\frac{(\text{V\_membrane}-50)\cdot\text{F}}{\text{R}\cdot\text{T}}\right)\right) \end{aligned} \tag{56}$$

5.57 Rule i_Ca_L_Na_ds

Rule i_Ca_L_Na_ds is an assignment rule for parameter i_Ca_L_Na_ds:

$$\begin{aligned} \text{i\_Ca\_L\_Na\_ds} = & \frac{\frac{\text{FrICa}\cdot\text{P\_CaNa}\cdot\text{P\_Ca\_L}\cdot\text{d}\cdot\text{f}\cdot\text{f2ds}\cdot(\text{V\_membrane}-50)\cdot\text{F}}{\text{R}\cdot\text{T}}}{1-\exp\left(\frac{(\text{V\_membrane}-50)\cdot\text{F}}{\text{R}\cdot\text{T}}\right)} \\ & \cdot\left(\text{Na\_i}\cdot\exp\left(\frac{50\cdot\text{F}}{\text{R}\cdot\text{T}}\right)-\text{Na\_o}\cdot\exp\left(\frac{(\text{V\_membrane}-50)\cdot\text{F}}{\text{R}\cdot\text{T}}\right)\right) \end{aligned} \tag{57}$$

5.58 Rule i_Ca_L

Rule i_Ca_L is an assignment rule for parameter i_Ca_L:

$$\begin{aligned} \text{i\_Ca\_L} = & \text{i\_Ca\_L\_Ca\_cyt} + \text{i\_Ca\_L\_K\_cyt} + \text{i\_Ca\_L\_Na\_cyt} \\ & + \text{i\_Ca\_L\_Ca\_ds} + \text{i\_Ca\_L\_K\_ds} + \text{i\_Ca\_L\_Na\_ds} \end{aligned} \tag{58}$$

5.59 Rule E0_d

Rule E0_d is an assignment rule for parameter E0_d:

$$\text{E0\_d} = \text{V\_L\_type\_Ca\_channel\_d\_gate} + 24 - 5 \tag{59}$$

5.60 Rule alpha_d

Rule alpha_d is an assignment rule for parameter alpha_d:

$$\text{alpha\_d} = \begin{cases} 120 & \text{if } |\text{E0\_d}| < 10\hat{}\text{-4} \\ \dfrac{30\cdot\text{E0\_d}}{1-\exp\left(\frac{\text{E0\_d}}{4}\right)} & \text{otherwise} \end{cases} \tag{60}$$

5.61 Rule beta_d

Rule beta_d is an assignment rule for parameter beta_d:

$$\text{beta\_d} = \begin{cases} 120 & \text{if } |\text{E0\_d}| < 10\hat{}\text{-4} \\ \dfrac{12\cdot\text{E0\_d}}{\exp\left(\frac{\text{E0\_d}}{10}\right)-1} & \text{otherwise} \end{cases} \tag{61}$$

5.62 Rule E0_f

Rule E0_f is an assignment rule for parameter E0_f:

$$\text{E0\_f} = \text{V\_L\_type\_Ca\_channel\_f\_gate} + 34 \tag{62}$$

5.63 Rule alpha_f

Rule alpha_f is an assignment rule for parameter alpha_f:

$$\text{alpha\_f} = \begin{cases} 25 & \text{if } |\text{E0\_f}| < \text{delta\_f} \\ \dfrac{6.25 \cdot \text{E0\_f}}{\exp\left(\frac{\text{E0\_f}}{4}\right) - 1} & \text{otherwise} \end{cases} \tag{63}$$

5.64 Rule beta_f

Rule beta_f is an assignment rule for parameter beta_f:

$$\text{beta\_f} = \frac{12}{1 + \exp\left(\frac{1 \cdot (\text{V\_L\_type\_Ca\_channel\_f\_gate} + 34)}{4}\right)} \tag{64}$$

5.65 Rule i_b_Ca

Rule i_b_Ca is an assignment rule for parameter i_b_Ca:

$$\text{i\_b\_Ca} = \text{g\_bca} \cdot (\text{V\_membrane} - \text{E\_Ca}) \tag{65}$$

5.66 Rule i_to

Rule i_to is an assignment rule for parameter i_to:

$$\text{i\_to} = \text{g\_to} \cdot (\text{g\_tos} + \text{s} \cdot (1 - \text{g\_tos})) \cdot \text{r} \cdot (\text{V\_membrane} - \text{E\_K}) \tag{66}$$

5.67 Rule alpha_s

Rule alpha_s is an assignment rule for parameter alpha_s:

$$\text{alpha\_s} = 0.033 \cdot \exp\left(\frac{\text{V\_transient\_outward\_current\_s\_gate}}{17}\right) \tag{67}$$

5.68 Rule beta_s

Rule beta_s is an assignment rule for parameter beta_s:

$$\text{beta\_s} = \frac{33}{1 + \exp\left(0.125 \cdot (\text{V\_transient\_outward\_current\_s\_gate} + 10)\right)} \tag{68}$$

5.69 Rule i_K_ACh

Rule i_K_ACh is an assignment rule for parameter i_K_ACh:

$$\text{i\_K\_ACh} = \frac{\text{g\_KACh} \cdot \frac{\text{K\_o}}{\text{K\_o+K\_mk1}} \cdot \text{x\_ACh} \cdot \frac{1}{1+\left(\frac{\text{K\_D}}{\text{ACh}}\right)^2} \cdot (\text{V\_membrane} - \text{E\_K})}{1 + \exp\left(\frac{2 \cdot \text{F} \cdot (\text{V\_membrane} - (\text{E\_K}+10))}{\text{R} \cdot \text{T}}\right)} \tag{69}$$

5.70 Rule i_NaK

Rule i_NaK is an assignment rule for parameter i_NaK:

$$\text{i\_NaK} = \frac{\frac{\text{i\_NaK\_max} \cdot \text{K\_o}}{\text{K\_mK+K\_o}} \cdot \text{Na\_i}}{\text{K\_mNa} + \text{Na\_i}} \tag{70}$$

5.71 Rule i_NaCa_cyt

Rule i_NaCa_cyt is an assignment rule for parameter i_NaCa_cyt:

$$\text{i\_NaCa\_cyt} \tag{71}$$
$$= \frac{(1 - \text{FRiNaCa}) \cdot \text{k\_NaCa} \cdot \left(\exp\left(\frac{\text{gamma} \cdot (\text{n\_NaCa}-2) \cdot \text{V\_membrane} \cdot \text{F}}{\text{R} \cdot \text{T}}\right) \cdot \text{Na\_i}^{\text{n\_NaCa}} \cdot \text{Ca\_o} - \exp\left(\frac{(\text{gamma}-1) \cdot (\text{n\_NaCa}-2) \cdot \text{V\_m}}{\text{R} \cdot \text{T}}\right.\right.}{\left(1 + \text{d\_NaCa} \cdot \left(\text{Ca\_i\_intracellular\_calcium\_concentration} \cdot \text{Na\_o}^{\text{n\_NaCa}} + \text{Ca\_o} \cdot \text{Na\_i}^{\text{n\_NaC}}\right.\right.}$$

5.72 Rule i_NaCa_ds

Rule i_NaCa_ds is an assignment rule for parameter i_NaCa_ds:

$$\text{i\_NaCa\_ds} \tag{72}$$
$$= \frac{\text{FRiNaCa} \cdot \text{k\_NaCa} \cdot \left(\exp\left(\frac{\text{gamma} \cdot (\text{n\_NaCa}-2) \cdot \text{V\_membrane} \cdot \text{F}}{\text{R} \cdot \text{T}}\right) \cdot \text{Na\_i}^{\text{n\_NaCa}} \cdot \text{Ca\_o} - \exp\left(\frac{(\text{gamma}-1) \cdot (\text{n\_NaCa}-2) \cdot \text{V\_membrane}}{\text{R} \cdot \text{T}}\right.\right.}{\left(1 + \text{d\_NaCa} \cdot \left(\text{Ca\_ds\_intracellular\_calcium\_concentration} \cdot \text{Na\_o}^{\text{n\_NaCa}} + \text{Ca\_o} \cdot \text{Na\_i}^{\text{n\_NaCa}}\right)\right.}$$

5.73 Rule i_NaCa

Rule i_NaCa is an assignment rule for parameter i_NaCa:

$$\text{i\_NaCa} = \text{i\_NaCa\_cyt} + \text{i\_NaCa\_ds} \tag{73}$$

5.74 Rule K_1

Rule K_1 is an assignment rule for parameter K_1:

$$\text{K\_1} = \frac{\text{K\_cyca} \cdot \text{K\_xcs}}{\text{K\_srca}} \tag{74}$$

5.75 Rule K_2

Rule K_2 is an assignment rule for parameter K_2:

$$\text{K\_2} = \text{Ca\_i\_intracellular\_calcium\_concentration} + \text{Ca\_up} \cdot \text{K\_1} + \text{K\_cyca} \cdot \text{K\_xcs} + \text{K\_cyca} \tag{75}$$

5.76 Rule i_up

Rule i_up is an assignment rule for parameter i_up:

$$\text{i\_up} = \frac{\text{Ca\_i\_intracellular\_calcium\_concentration}}{\text{K\_2}} \cdot \text{alpha\_up} - \frac{\text{Ca\_up} \cdot \text{K\_1}}{\text{K\_2}} \cdot \text{beta\_up} \quad (76)$$

5.77 Rule i_trans

Rule i_trans is an assignment rule for parameter i_trans:

$$\text{i\_trans} = 50 \cdot (\text{Ca\_up} - \text{Ca\_rel}) \quad (77)$$

5.78 Rule VoltDep

Rule VoltDep is an assignment rule for parameter VoltDep:

$$\text{VoltDep} = \exp(0.08 \cdot (\text{V\_membrane} - 40)) \quad (78)$$

Derived unit dimensionless

5.79 Rule CaiReg

Rule CaiReg is an assignment rule for parameter CaiReg:

$$\text{CaiReg} = \frac{\text{Ca\_i\_intracellular\_calcium\_concentration}}{\text{Ca\_i\_intracellular\_calcium\_concentration} + \text{K\_m\_Ca\_cyt}} \quad (79)$$

5.80 Rule CadsReg

Rule CadsReg is an assignment rule for parameter CadsReg:

$$\text{CadsReg} = \frac{\text{Ca\_ds\_intracellular\_calcium\_concentration}}{\text{Ca\_ds\_intracellular\_calcium\_concentration} + \text{K\_m\_Ca\_ds}} \quad (80)$$

5.81 Rule RegBindSite

Rule RegBindSite is an assignment rule for parameter RegBindSite:

$$\text{RegBindSite} = \text{CaiReg} + (1 - \text{CaiReg}) \cdot \text{CadsReg} \quad (81)$$

5.82 Rule ActRate

Rule ActRate is an assignment rule for parameter ActRate:

$$\text{ActRate} = 0 \cdot \text{VoltDep} + 500 \cdot \text{RegBindSite}^2 \quad (82)$$

5.83 Rule InactRate

Rule InactRate is an assignment rule for parameter InactRate:

$$\text{InactRate} = 60 + 500 \cdot \text{RegBindSite}^2 \tag{83}$$

5.84 Rule SpeedRel

Rule SpeedRel is an assignment rule for parameter SpeedRel:

$$\text{SpeedRel} = \begin{cases} 5 & \text{if V\_membrane} < 50 \\ 1 & \text{otherwise} \end{cases} \tag{84}$$

5.85 Rule SRLeak

Rule SRLeak is an assignment rule for parameter SRLeak:

$$\text{SRLeak} = \begin{cases} \text{K\_leak\_rate} \cdot \exp\left(\text{gama\_SR\_IT} \cdot \text{isometric\_tension}\right) & \text{if isometric\_tension} > 0 \\ \text{K\_leak\_rate} \cdot \exp\left(\text{gama\_SR\_SL} \cdot \text{sarcomere\_length}\right) & \text{otherwise} \end{cases} \tag{85}$$

5.86 Rule PrecFrac

Rule PrecFrac is an assignment rule for parameter PrecFrac:

$$\text{PrecFrac} = 1 - \text{ActFrac} - \text{ProdFrac} \tag{86}$$

5.87 Rule i_rel

Rule i_rel is an assignment rule for parameter i_rel:

$$\text{i\_rel} = \left(\left(\frac{\text{ActFrac}}{\text{ActFrac} + 0.25} \right)^2 \cdot \text{K\_m\_rel} + \text{SRLeak} \right) \cdot \text{Ca\_rel} \tag{87}$$

5.88 Rule V_Cell

Rule V_Cell is an assignment rule for parameter V_Cell:

$$\text{V\_Cell} = \frac{3.141592654 \cdot \left(\frac{\text{radius}}{1000}\right)^2 \cdot \text{length}}{1000} \tag{88}$$

5.89 Rule V_i_ratio

Rule V_i_ratio is an assignment rule for parameter V_i_ratio:

$$\text{V\_i\_ratio} = 1 - \text{V\_e\_ratio} - \text{V\_up\_ratio} - \text{V\_rel\_ratio} \tag{89}$$

5.90 Rule V_i

Rule V_i is an assignment rule for parameter V_i:

$$\text{V\_i} = \text{V\_Cell} \cdot \text{V\_i\_ratio} \tag{90}$$

5.91 Rule alpha_Trop

Rule alpha_Trop is an assignment rule for parameter alpha_Trop:

$$\text{alpha\_Trop} = \text{KTrop} \cdot \exp(\text{gama\_Trop\_SL} \cdot \text{sarcomere\_length}) \tag{91}$$

5.92 Rule XCont2

Rule XCont2 is an assignment rule for parameter XCont2:

$$\text{XCont2} = \frac{\text{Ca\_Calmod}}{\text{Calmod}} \tag{92}$$

5.93 Rule XCont1

Rule XCont1 is an assignment rule for parameter XCont1:

$$\text{XCont1} = \frac{\text{Ca\_Trop}}{\text{Trop}} \tag{93}$$

5.94 Rule tension_rest

Rule tension_rest is an assignment rule for parameter tension_rest:

$$\text{tension\_rest} = 2 \cdot 10^{-4} \cdot \exp(2 \cdot \text{sarcomere\_length}) \tag{94}$$

5.95 Rule tension_active

Rule tension_active is an assignment rule for parameter tension_active:

$$\text{tension\_active} = \begin{cases} 1 - \exp(3 \cdot (\text{sarcomere\_length} - 1)) & \text{if sarcomere\_length} > 1 \\ 0 & \text{otherwise} \end{cases} \tag{95}$$

5.96 Rule overlap

Rule overlap is an assignment rule for parameter overlap:

$$\text{overlap} = \begin{cases} 1 - 0.625 \cdot (\text{sarcomere\_length} - 2) & \text{if sarcomere\_length} > 2 \\ 1 & \text{otherwise} \end{cases} \tag{96}$$

5.97 Rule cross_bridge_availability

Rule cross_bridge_availability is an assignment rule for parameter cross_bridge_availability:

$$\text{cross\_bridge\_availability} = \text{tension\_active} \cdot \text{overlap} \cdot \text{cross\_bridge\_density} \tag{97}$$

5.98 Rule isometric_tension

Rule isometric_tension is an assignment rule for parameter isometric_tension:

$$\text{isometric\_tension} = \text{cross\_bridge} \cdot \text{cross\_bridge\_availability} + \text{tension\_rest} \tag{98}$$

5.99 Rule f_stretch

Rule f_stretch is an assignment rule for parameter f_stretch:

$$\text{f\_stretch} = \begin{cases} \dfrac{1}{1+\exp\left(2 \cdot \text{gama\_SAC\_IT} \cdot (\text{isometric\_tension} - \text{ITHST})\right)} & \text{if isometric\_tension} > 0 \\ \dfrac{1}{1+\exp\left(2 \cdot \text{gama\_SAC\_SL} \cdot (\text{sarcomere\_length} - \text{SLHST})\right)} & \text{otherwise} \end{cases} \tag{99}$$

5.100 Rule i_Ca_stretch

Rule i_Ca_stretch is an assignment rule for parameter i_Ca_stretch:

$$\text{i\_Ca\_stretch} = \text{g\_Ca\_stretch} \cdot \text{f\_stretch} \cdot (\text{V\_membrane} - \text{E\_Ca}) \tag{100}$$

5.101 Rule i_Na_stretch

Rule i_Na_stretch is an assignment rule for parameter i_Na_stretch:

$$\text{i\_Na\_stretch} = \text{g\_Na\_stretch} \cdot \text{f\_stretch} \cdot (\text{V\_membrane} - \text{E\_Na}) \tag{101}$$

5.102 Rule i_K_stretch

Rule i_K_stretch is an assignment rule for parameter i_K_stretch:

$$\text{i\_K\_stretch} = \text{g\_K\_stretch} \cdot \text{f\_stretch} \cdot (\text{V\_membrane} - \text{E\_K}) \tag{102}$$

5.103 Rule i_An_stretch

Rule i_An_stretch is an assignment rule for parameter i_An_stretch:

$$\text{i\_An\_stretch} = \text{g\_An\_stretch} \cdot \text{f\_stretch} \cdot (\text{V\_membrane} - \text{E\_An\_stretch}) \tag{103}$$

5.104 Rule i_stretch

Rule i_stretch is an assignment rule for parameter i_stretch:

$$\text{i\_stretch} = \text{i\_Ca\_stretch} + \text{i\_Na\_stretch} + \text{i\_K\_stretch} + \text{i\_An\_stretch} \tag{104}$$

5.105 Rule i_fibro

Rule i_fibro is an assignment rule for parameter i_fibro:

$$\text{i\_fibro} = \text{g\_fibro} \cdot (\text{V\_fibro} + 20) + \text{g\_fibro\_stretch} \cdot (\text{V\_fibro} - \text{E\_fibro\_stretch}) \tag{105}$$

5.106 Rule i_fibro_junct

Rule i_fibro_junct is an assignment rule for parameter i_fibro_junct:

$$\text{i\_fibro\_junct} = \text{g\_fibro\_junct} \cdot (\text{V\_membrane} - \text{V\_fibro}) \tag{106}$$

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