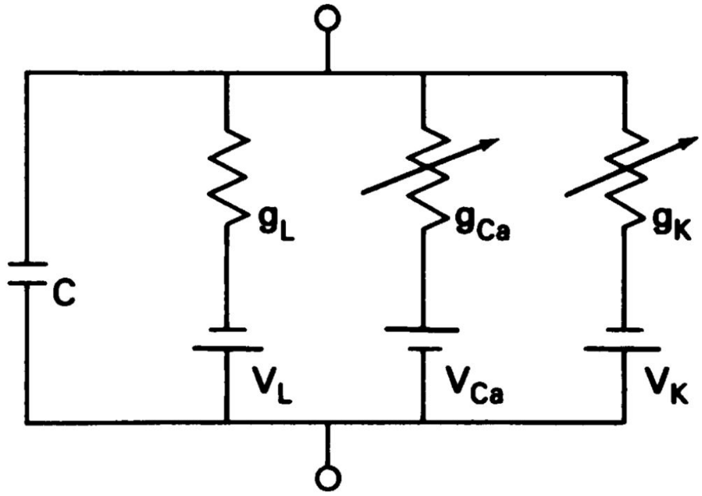


Figure 3.1: TODO + cite ML

# 1 Preface

# 2 Code Usage

# 3 Morris-Lecar Neuron

## 3.1 Circuit Model

The Morris-Lecar description [2] models a neuron as having a membrane potential $v$, defined to be the difference in voltage between the inside and outside of the neuron cell. Current flows through potassium and calcium channels in the membrane, labelled as $I_K$ and $I_{Ca}$, respectively. There is also some current arising form other ions, which is collectively totalled as the leak current $I_L$. The combined potassium, calcium, and leak channels each have an effective conductance (or, taking reciprocals, resistance) and potential. Finally, the membrane has a capacitance $C$. **Figure 3.1** depicts a circuit for this model.

Consequently, the membrane potential obeys the following first order differential equation:

$$C\frac{dv}{dt} = I - g_K(v - V_K) - g_{Ca}(v - V_{Ca}) - g_L(v - V_L) \tag{3.1}$$

Nominally, the potassium and calcium conductances are non-constant. Rather, they obey the following equations:

$$g_K = \bar{g}_K w \tag{3.2}$$

$$g_{Ca} = \bar{g}_{Ca} m \tag{3.3}$$

where $\bar{g}_K, \bar{g}_{Ca}$ are constant.

At constant $v$, the parameters $x = w, m$ are governed by first order differential equations of the following form:

$$\frac{dx}{dt} = \lambda_x(v)(x_\infty(v) - x) \tag{3.4}$$

However, the $m$ timescale is much shorter than the $w$ timescale, so that $m \approx m_\infty(v)$ in (3.1). Furthermore, to be consistent with [1], we may re-arrange the $x = w$ version of (3.4) to be of the following form:

$$\frac{dw}{dt} = \alpha(v)(1 - w) - \beta(v)w \tag{3.5}$$

where

$$\alpha(v) = \frac{1}{2}\phi \cosh\left(\frac{v - V_3}{2V_4}\right)\left(1 + \tanh\left(\frac{v - V_3}{V_4}\right)\right) \tag{3.6}$$

$$\beta(v) = \frac{1}{2}\phi \cosh\left(\frac{v - V_3}{2V_4}\right)\left(1 - \tanh\left(\frac{v - V_3}{V_4}\right)\right) \tag{3.7}$$

Furthermore, we have

$$m_\infty(v) = \frac{1}{2}\left(1 + \tanh\left(\frac{v - V_1}{V_2}\right)\right) \tag{3.8}$$

## 3.2 Morris-Lecar Parameters

The following parameters from [1] were used in this project:

| Variable | Value | Units |
|---|---|---|
| $C$ | 20 | $\mu F/cm^2$ |
| $g_L$ | 2.0 | $mS/cm^2$ |
| $\bar{g}_{Ca}$ | 4.4 | $mS/cm^2$ |
| $\bar{g}_K$ | 8 | $mS/cm^2$ |
| $V_L$ | -60 | $mV/cm^2$ |
| $V_{Ca}$ | 120 | $mV/cm^2$ |
| $V_K$ | -84 | $mV/cm^2$ |
| $V_1$ | -1.2 | $mV/cm^2$ |
| $V_2$ | 18.0 | $mV/cm^2$ |
| $V_3$ | 2.0 | $mV/cm^2$ |
| $V_4$ | 30.0 | $mV/cm^2$ |
| $\phi$ | 0.04 | dimensionless |

Table 3.1: TODO

# 4 Dynamics

# 5 Stochastics

# 6 Interspike Intervals

# 7 Linearized Model

# 8 Poincare-Like Maps

# 9 Patched Model

# 10 Next Steps

# References

[1] Priscilla E. Greenwood, Lawrence M. Ward, SpringerLink (Online service), SpringerLINK ebooks Mathematics, and Statistics. *Stochastic Neuron Models*, volume 1.5. Springer International Publishing, Cham, 1st 2016. edition, 2016.

[2] C. Morris and H. Lecar. Voltage oscillations in the barnacle giant muscle fiber. *Biophysical journal*, 35(1):193–213, 1981.