Integrate-and-Fire

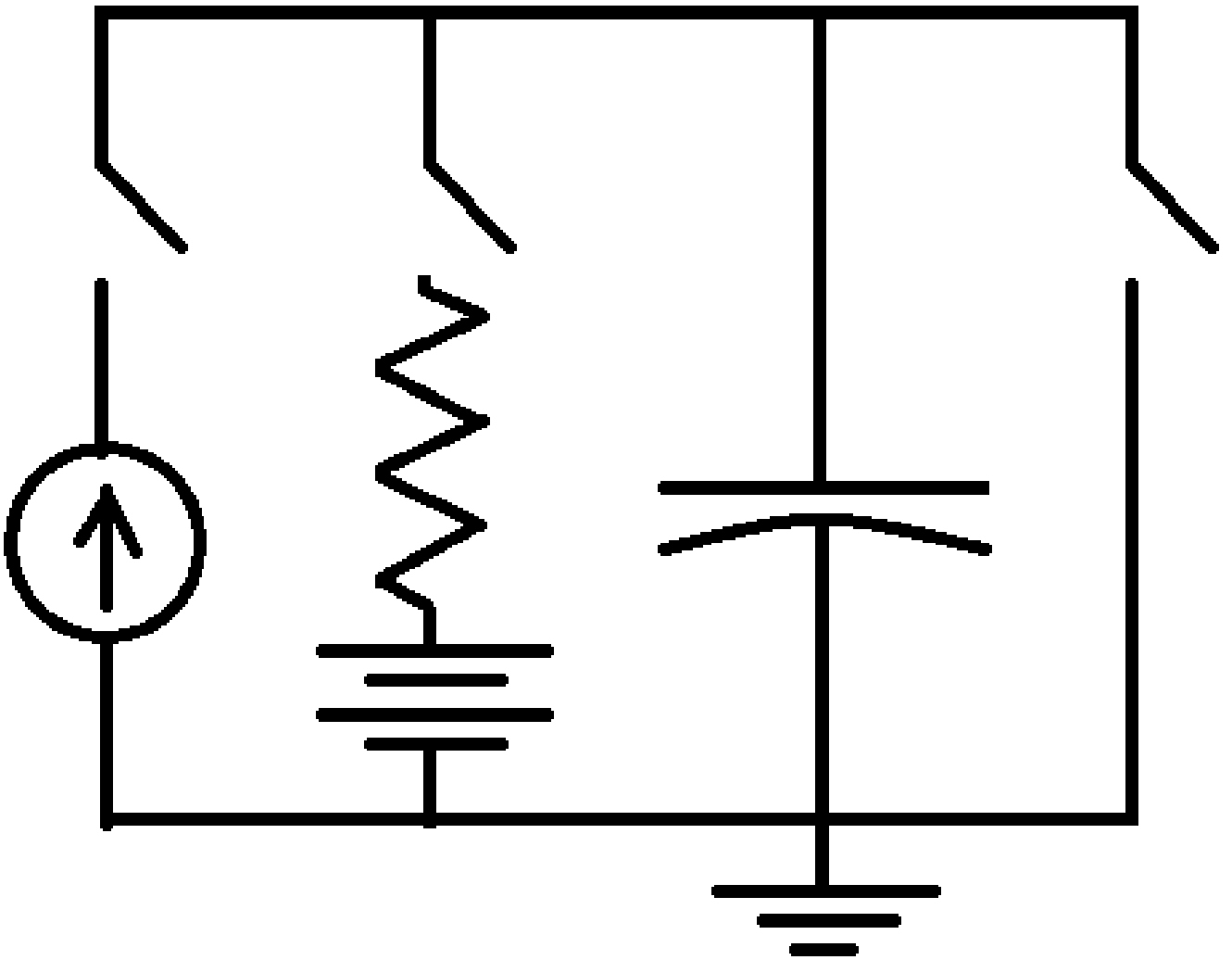
David Wallace Croft, M.Sc.
Atzori Lab, U.T. Dallas
david@CroftSoft.com

2011 Oct 07 Fri

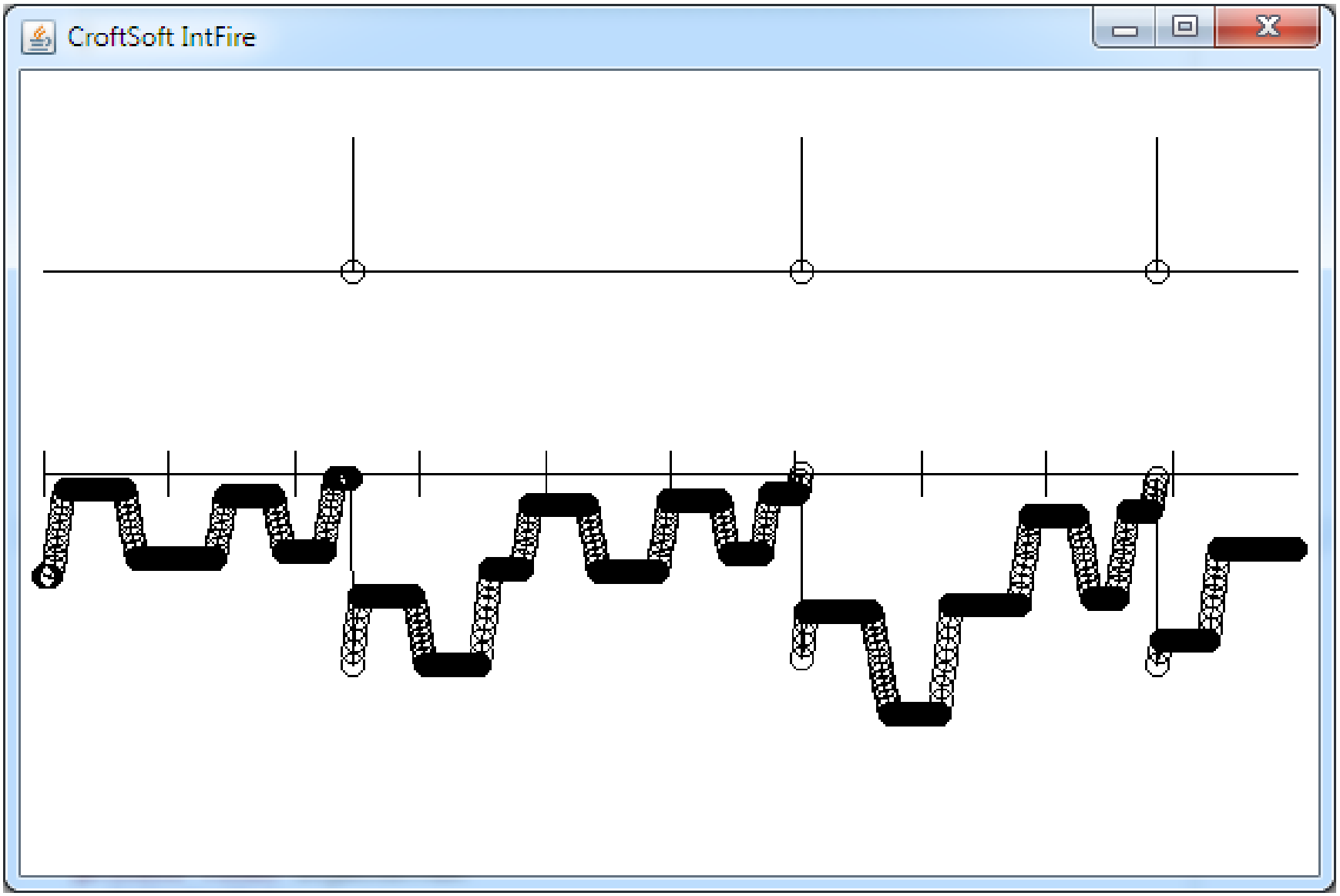
Overview

- Integrate-and-Fire, introduced in 1907, is the simplest model of a spiking neuron
- The Leaky Integrate-and-Fire makes the output sensitive to the timing of inputs by adding a memory loss element
- The Integrate-and-"Tire" adds hyperpolarization to the Leaky Integrate-and-Fire
- Integrate-and-Fire lacks a number of characteristics of the Hodgkin-Huxley model such as a variable threshold

Integrate-and-Fire



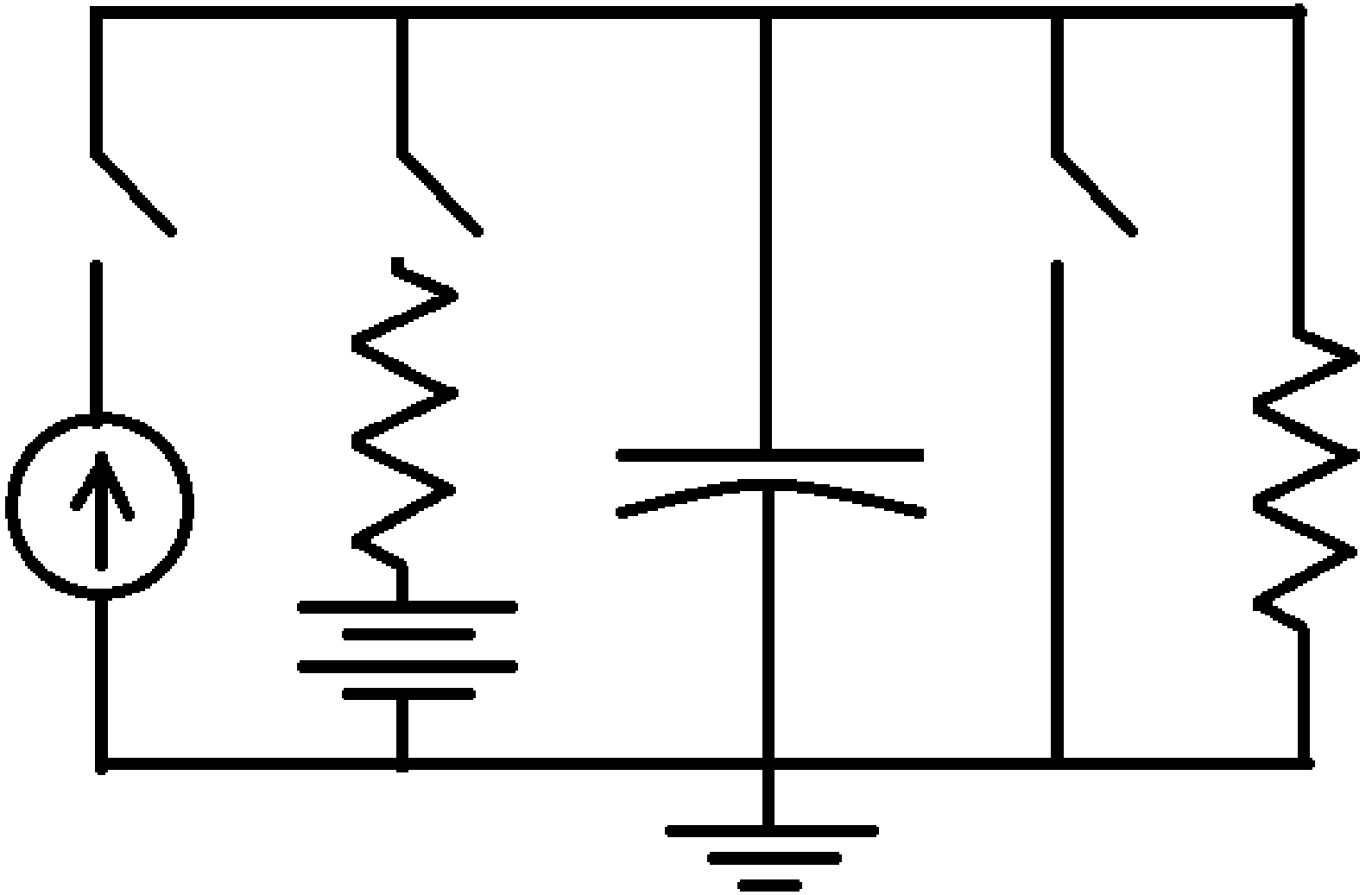
Integrate-and-Fire



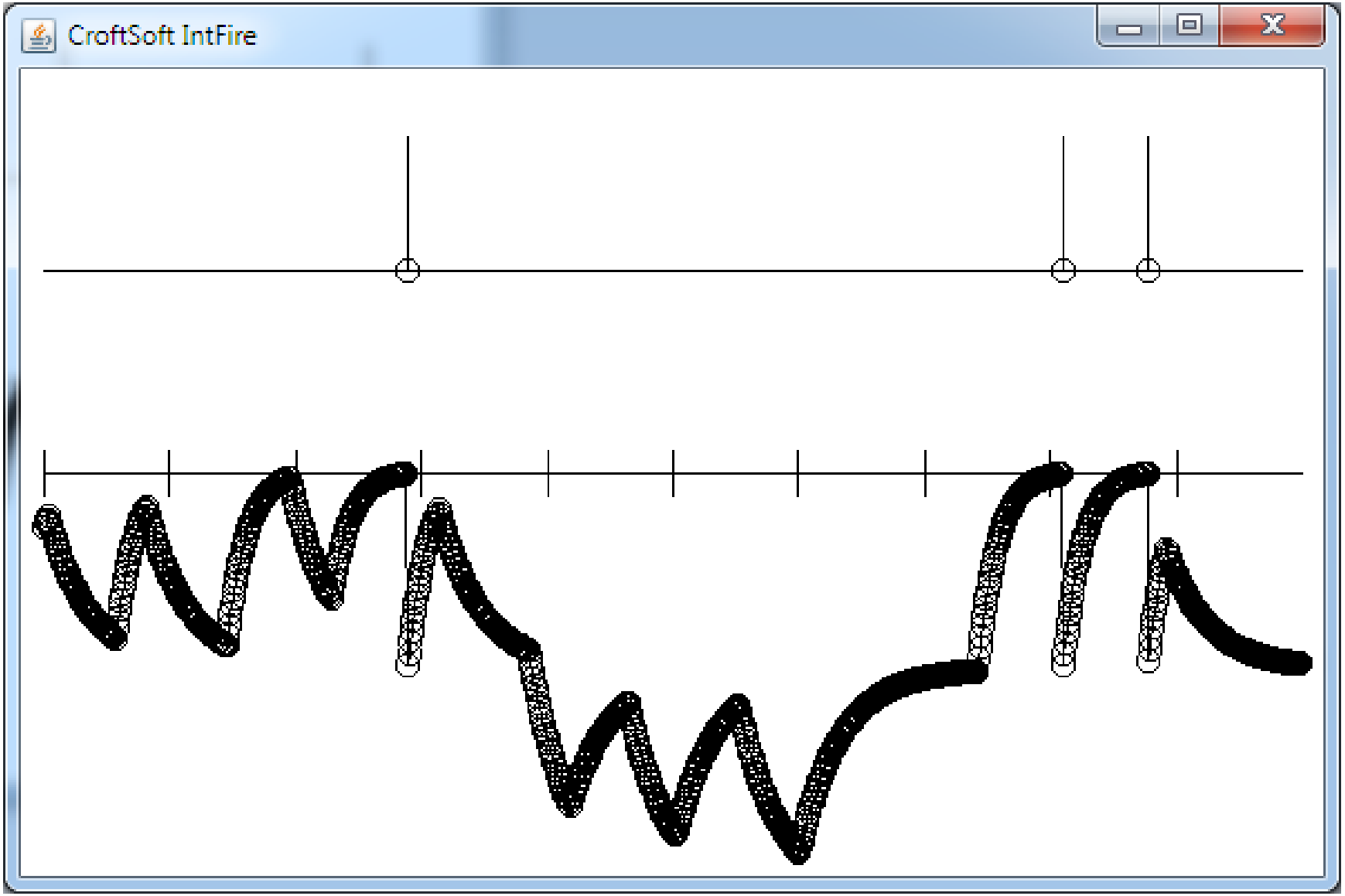
Integrate-and-Fire

- Louis Lapicque, French Neuroscientist, 1907
- Voltage rises as current charges up a capacitor
- Delta function spike at voltage threshold
- Voltage reset to zero at spike
- Spiking rate proportional to injected current
- No refractory period unless added
- No memory loss

Leaky Integrate-and-Fire



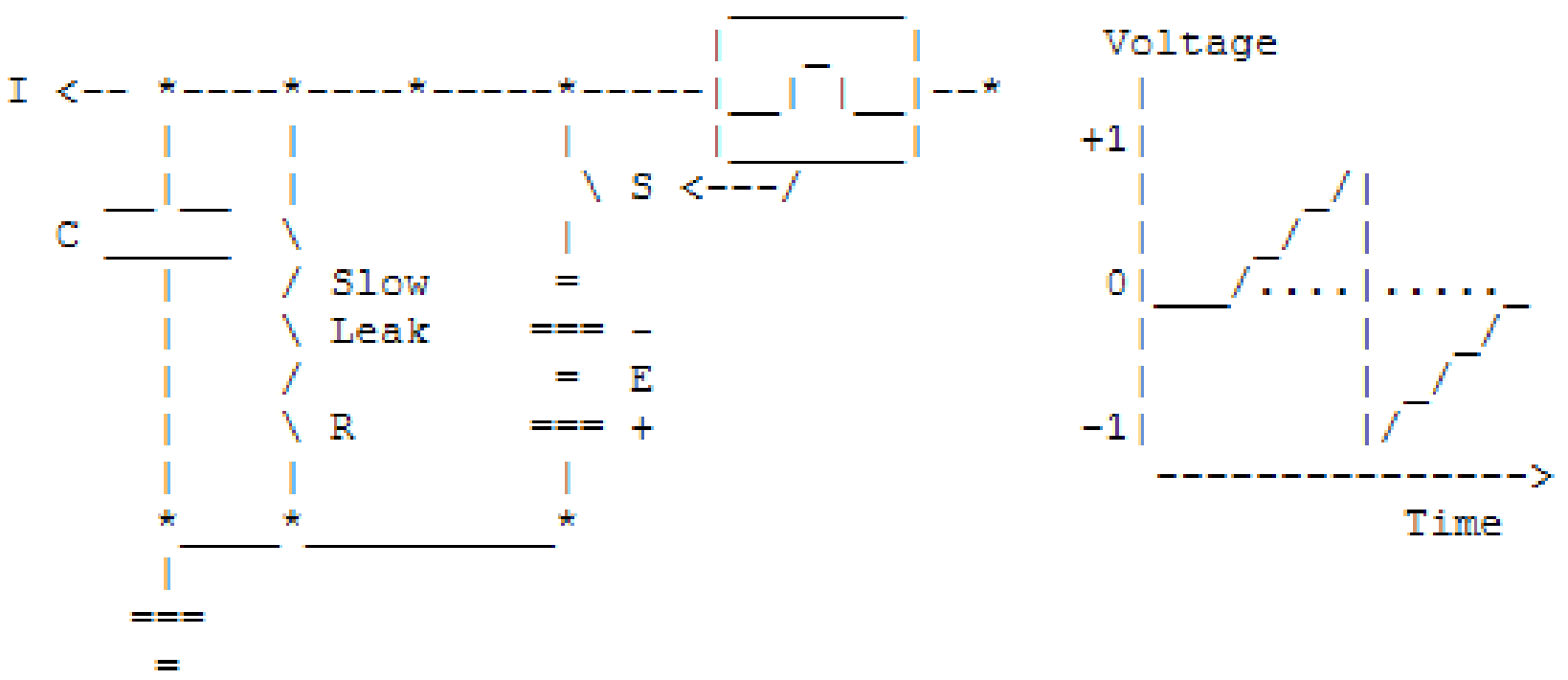
Leaky Integrate-and-Fire



Leaky Integrate-and-Fire

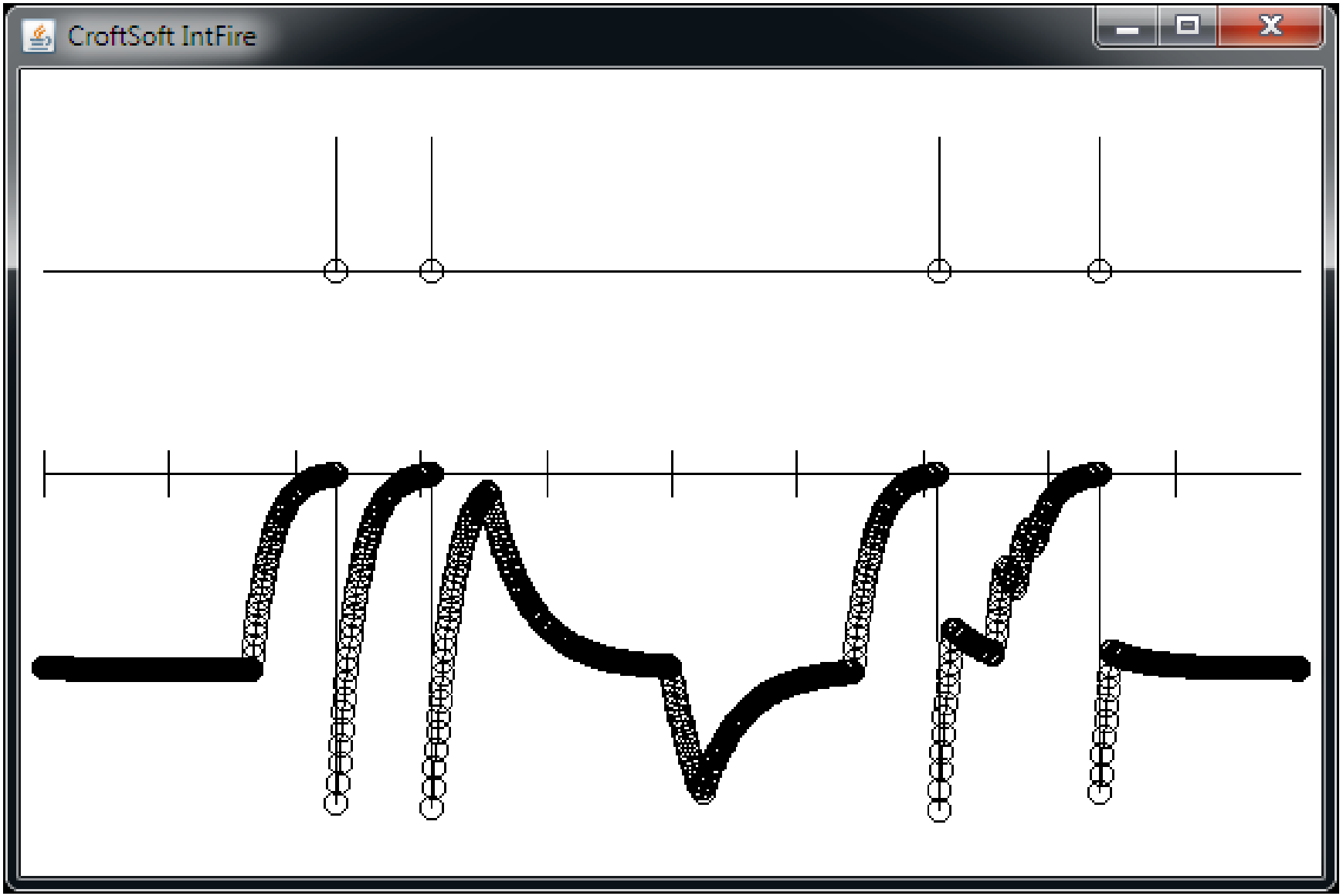
- Adds memory loss to integrate-and-fire
- Conductive (resistive) path to ground
- Leakage current slowly drains voltage difference
- Exponential decay of voltage
- No spiking if injected current too small
- Input spike timing now important
- Asynchronous versus synchronous
- Aperiodic versus periodic
- No refractory period

Integrate-and-"Tire"



Croft (1994) Constructing a Neural Network to Model Self-Timed Circuits

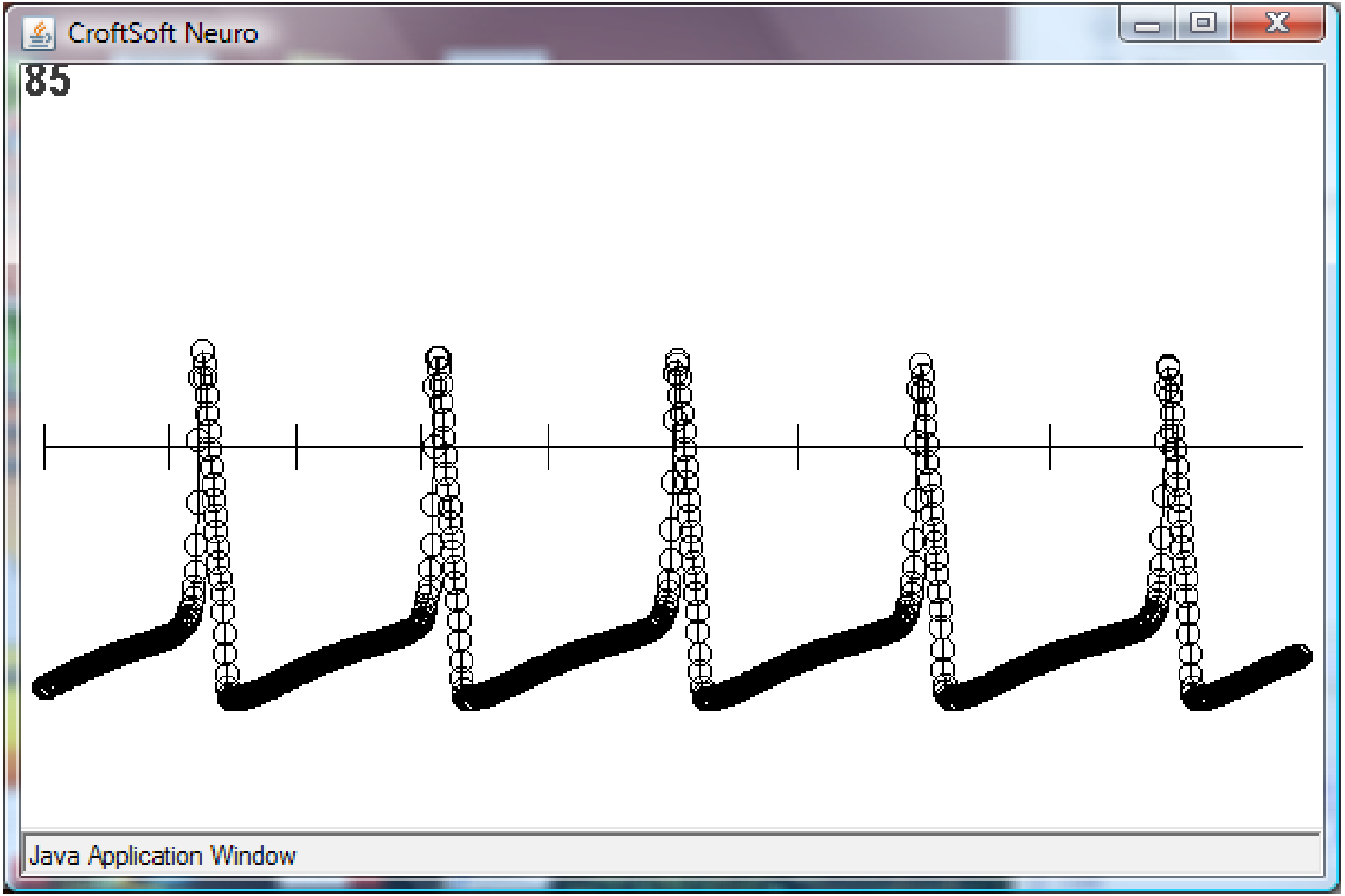
Integrate-and-"Tire"



Integrate-and-"Tire"

- Similar to leaky integrate-and-fire
- Adds a hyperpolarization phase following a spike
- Invented to study spike-timing dependent plasticity
- Voltage reset to negative value instead of zero
- Leakage current reversed during hyperpolarization
- Somewhat like a refractory period
- Requires more current to spike just after a spike

Hodgkin-Huxley Comparison



Hodgkin-Huxley Comparison

- Leaky Integrate-and-Fire lacks a number of characteristics of the Hodgkin-Huxley model
- HH adds voltage-dependent channels which creates non-linearities
- HH has a hyperpolarization
- HH has a refractory period
- The spike threshold for HH varies over time depending on the past input history

Simulation Demonstrations

- Animated Interactive Simulation Java Applets
- Leaky Integrate-and-Fire
  CroftSoft IntFire
  http://www.CroftSoft.com/library/software/intfire/
  - Both channel conductance and current injection inputs
- Hodgkin-Huxley
  CroftSoft Neuro
  http://www.CroftSoft.com/library/software/neuro/

References

- Croft (1994) "Constructing a Neural Network to Model Self-Timed Circuits", http://alumnus.caltech.edu/~croft/archives/academic/cns124b/
- Croft (2011), "CroftSoft IntFire", http://www.CroftSoft.com/library/software/intfire/
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- Wikipedia, "Biological neuron model"