neocortix

Event-Driven Simulation of Spiking Neural Networks

NICE Workshop - Sandia National Labs

Lloyd Watts

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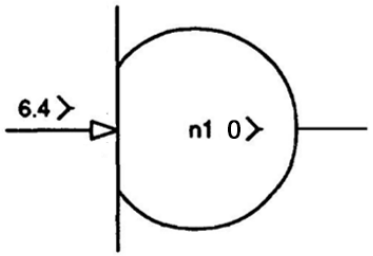
Early History

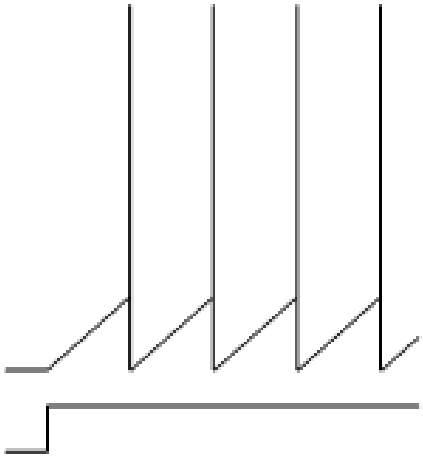
- 1989: Gill Pratt, *Pulse Computation*, MIT Ph.D. Thesis.
- 1992: Lloyd Watts, “Designing Networks of Spiking Neurons and Synapses”, CNS*92.
- 1993: Lloyd Watts, “Event-Driven Simulation of Networks of Spiking Neurons”, NIPS 1993.
- 1993: NeuraLOG and Spike software release: http://www.lloydwatts.com/spike2.html - still available!
- 1993: SYNOD
- 1998: SpikeNET (2003 paper refers to Spike 1993)
- 2001: NEST (formerly SYNOD)
- … many others
- 2009: CARLsim (plasticity, GPU acceleration)

Common belief: point neurons / event-driven simulation are too simple for realistic simulation.

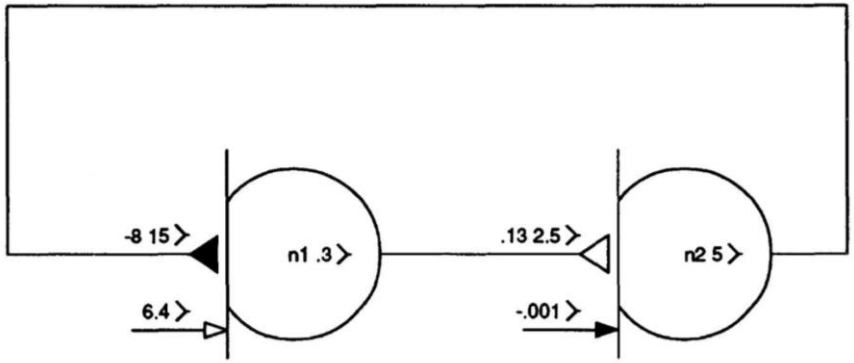
Tonic Spiker



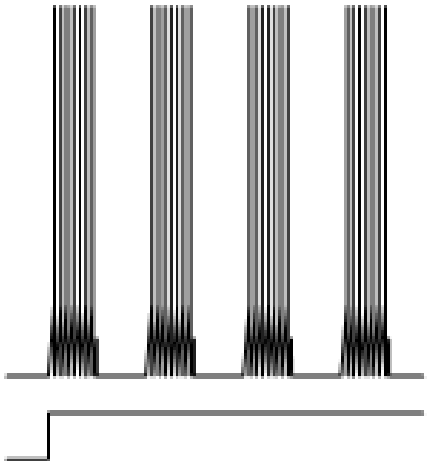
(A) tonic spiking



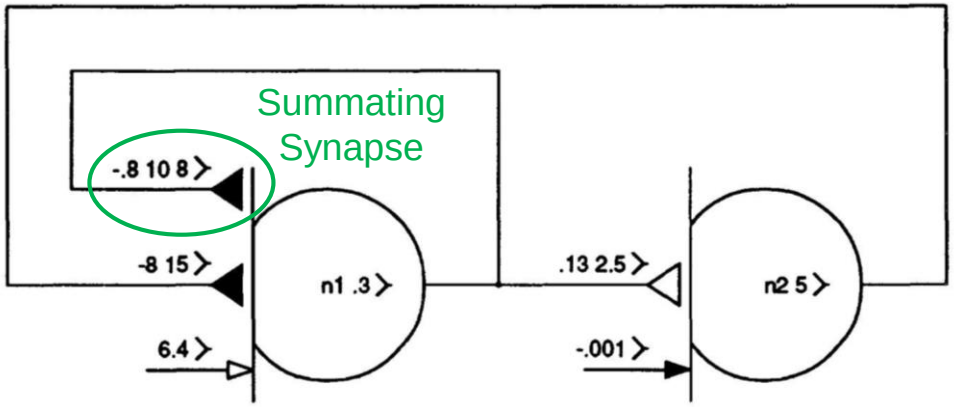
Tonic Burster

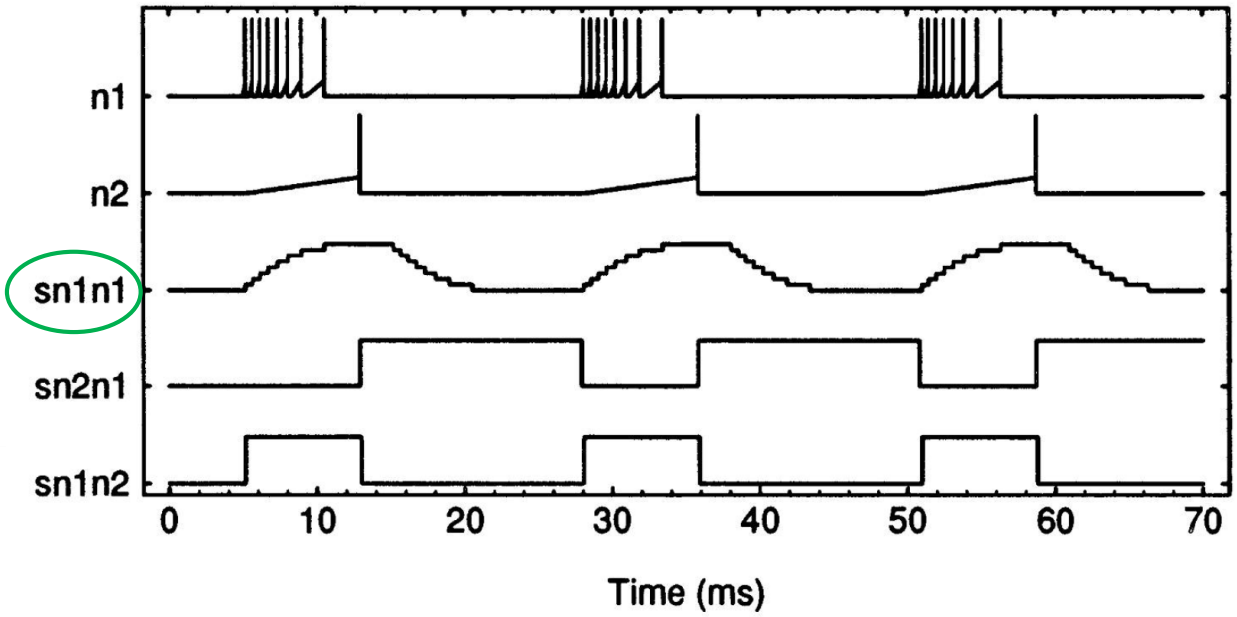


(C) tonic bursting



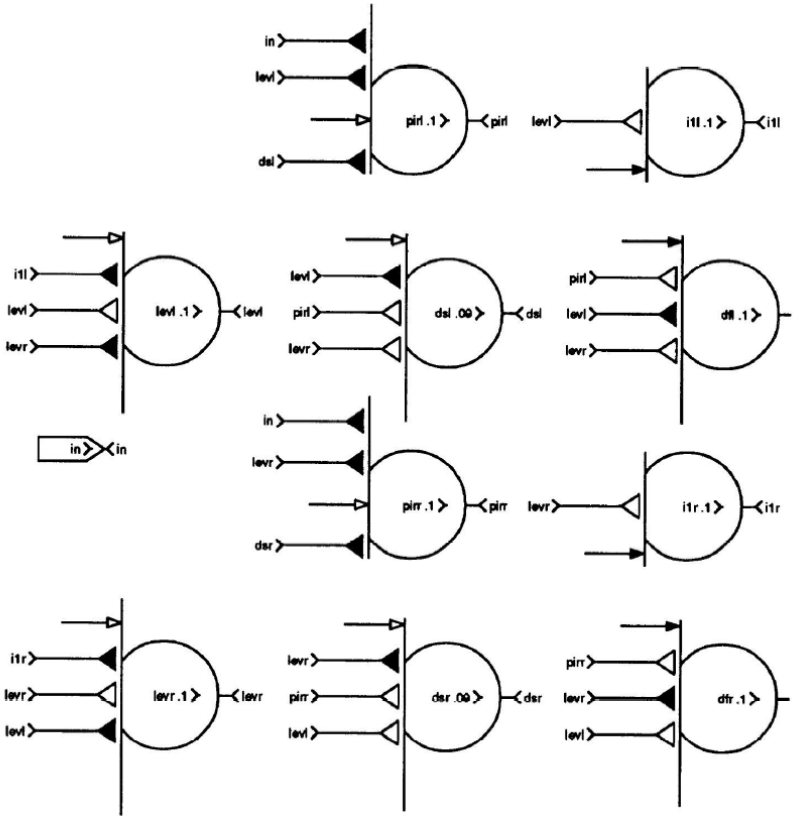
Tonic Burster with Ca^{++} Adaptation

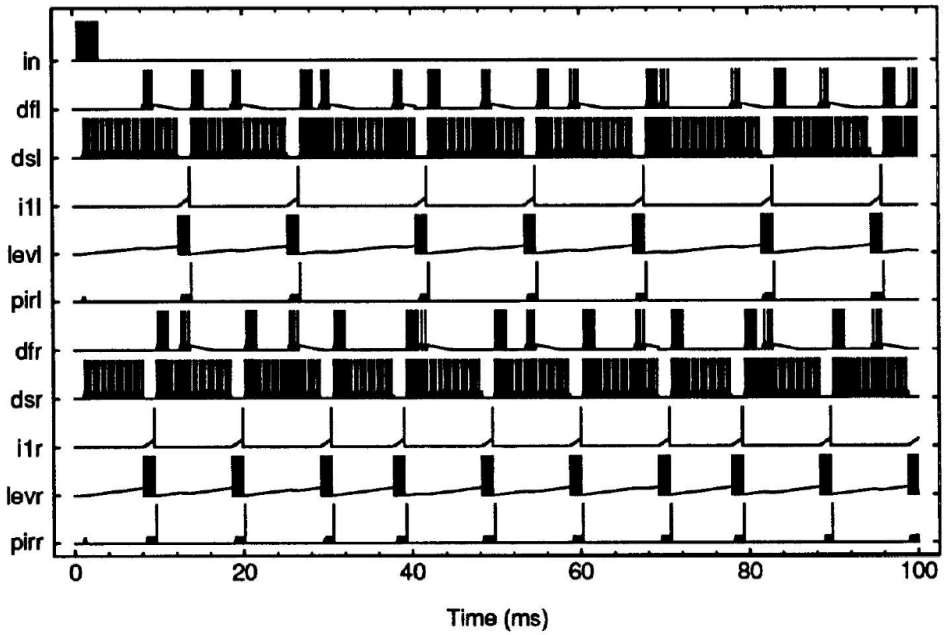




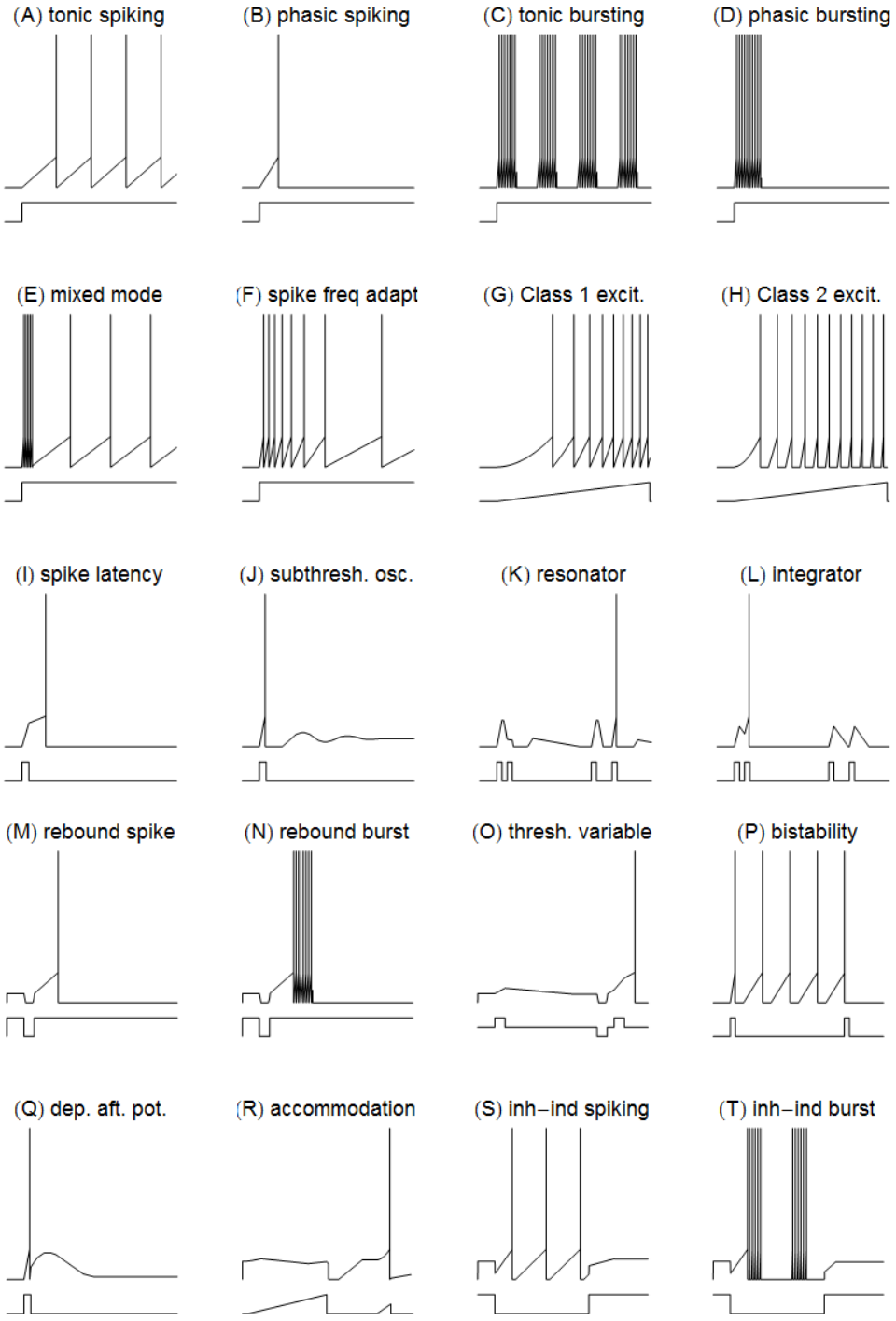
Locust Walking Circuit

Central Pattern Generator (with Sylvie Ryckebusch)



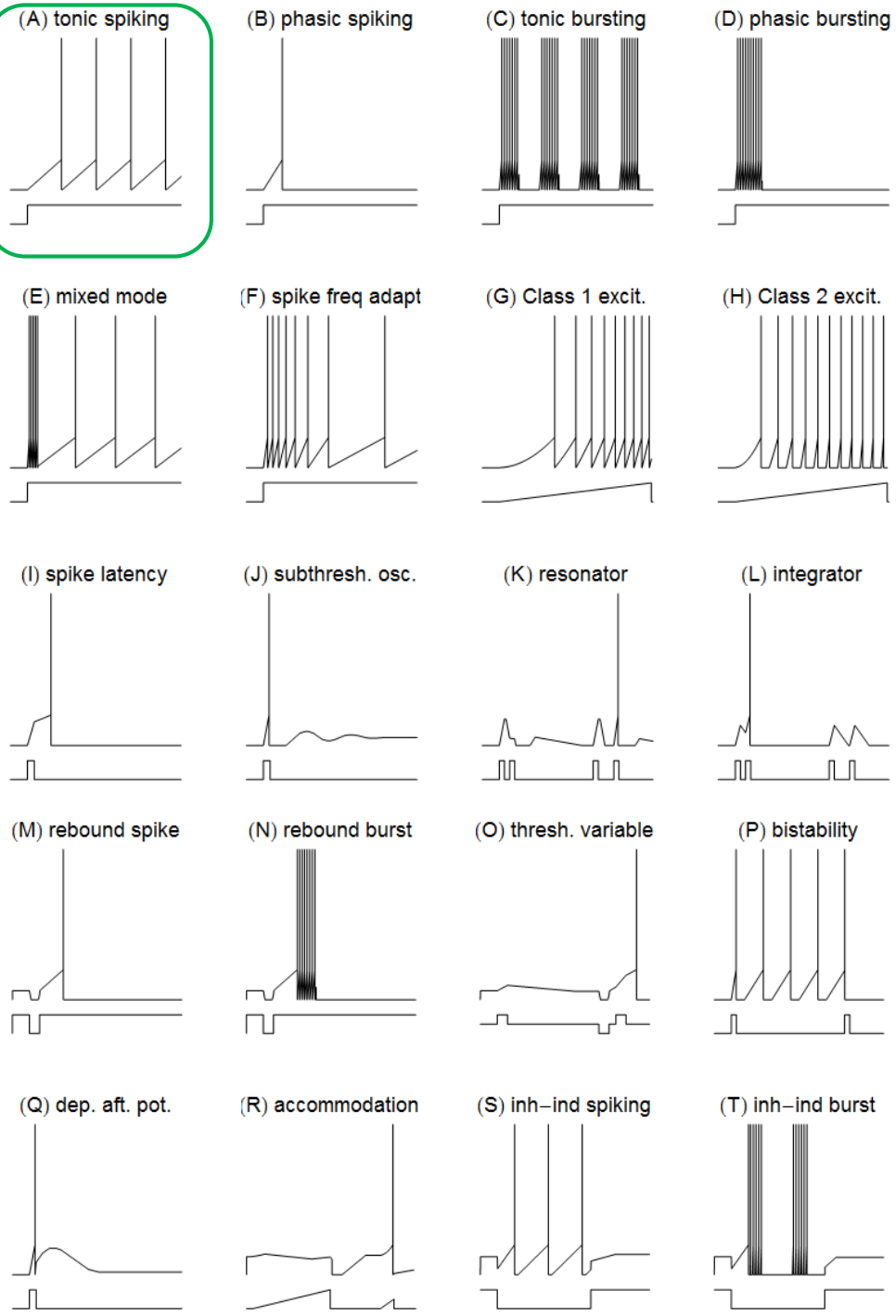


Spike is Izhikevich-complete



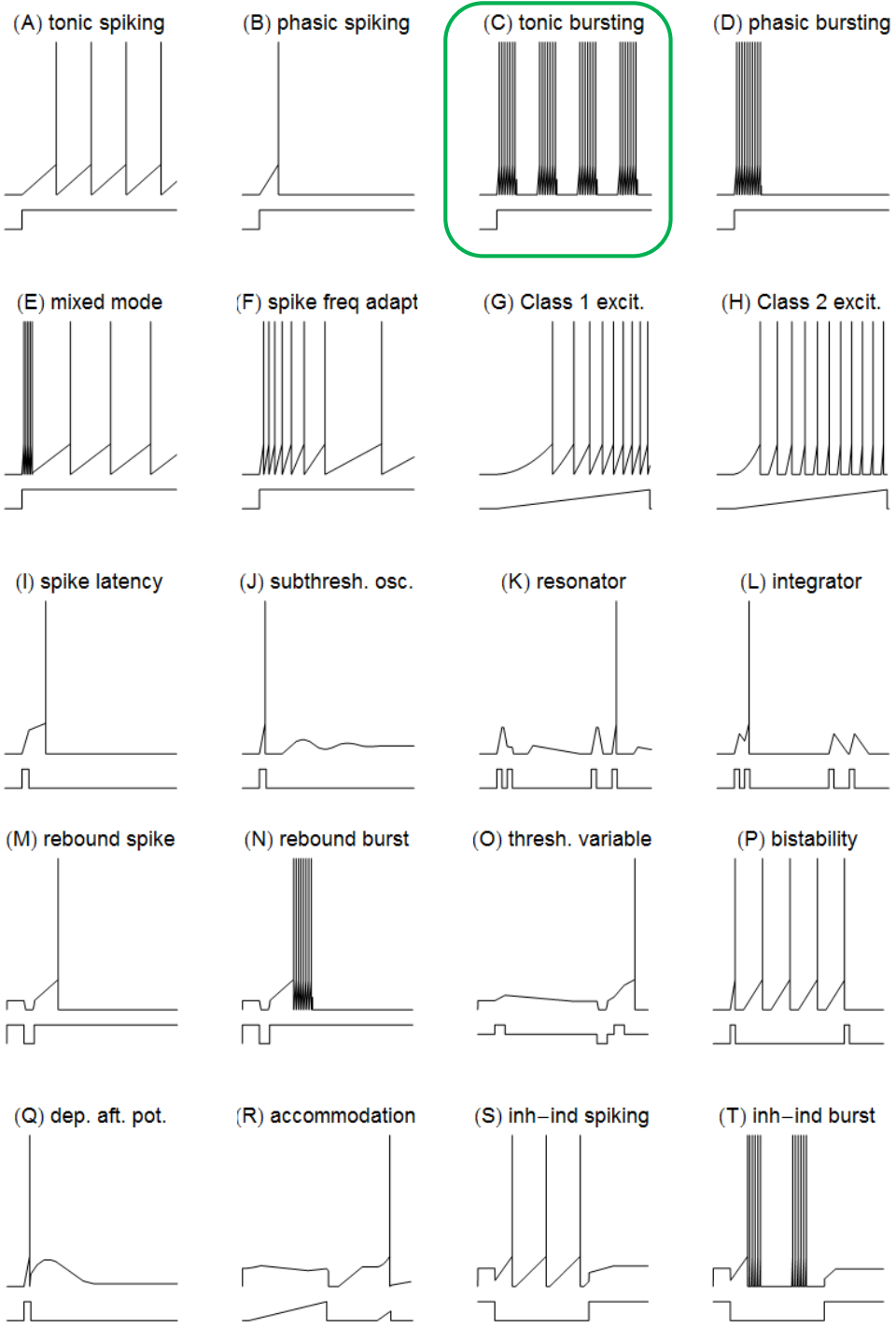
Spike is Izhikevich-complete

```
# Spike Pattern A
begin
INPUT S1 in1
NEURON Dn1 An1 n1 .3
SYNAPSE S1 Dn1 .05 100
end
```



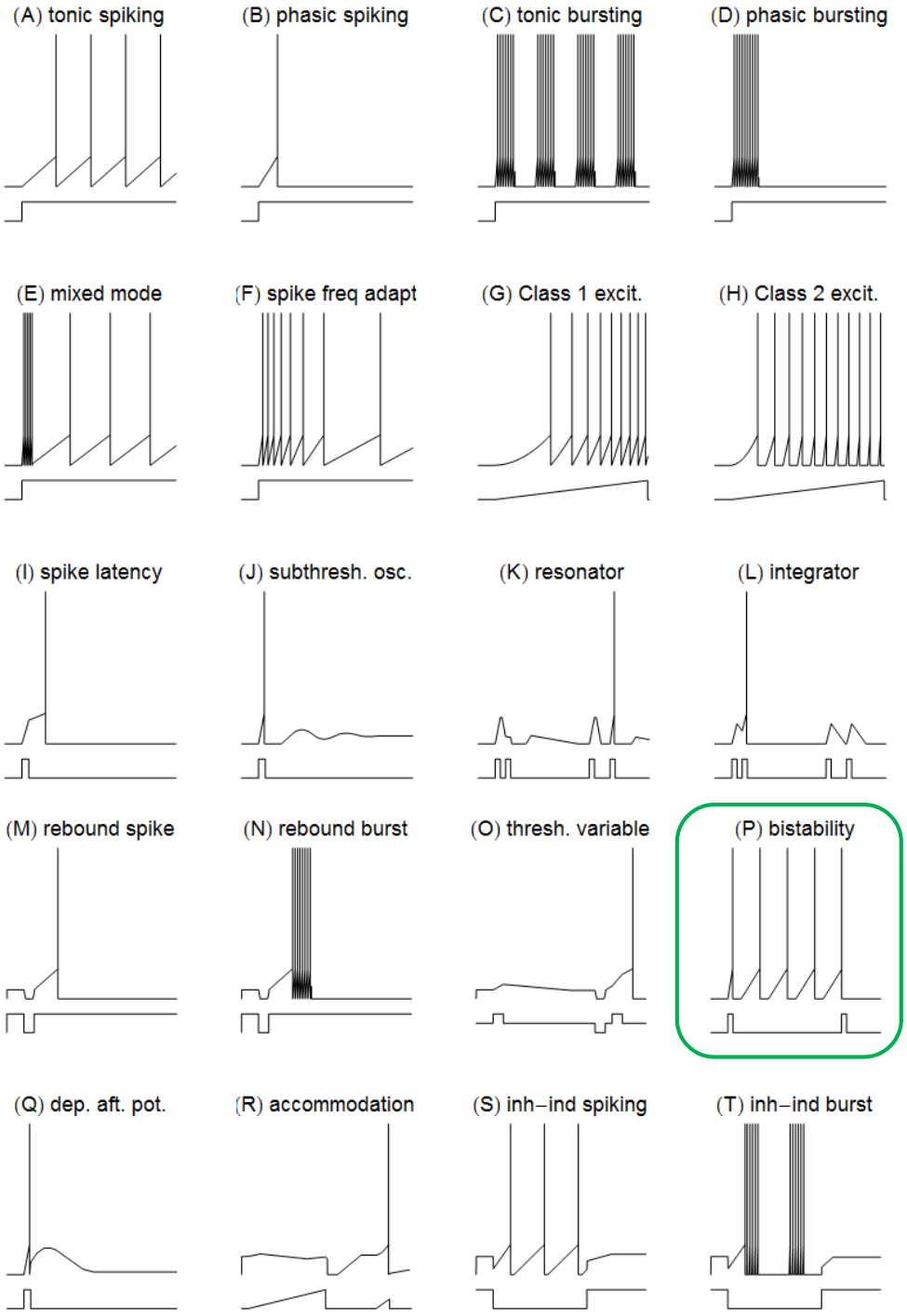
Spike is Izhikevich-complete

```
# Spike Pattern C
begin
INPUT S1 in1
NEURON Dn1 An1 n1 0.1
NEURON Dn2 An2 n2 5
SYNAPSE S1 Dn1 .7 100
SYNAPSE An1 Dn2 .10 2.5
SYNAPSE An2 Dn1 -8 12
end
```



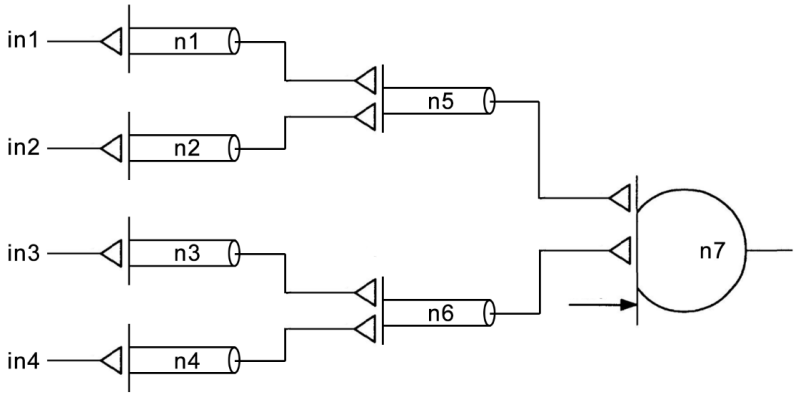
Spike is Izhikevich-complete

```
# Spike Pattern P
begin
INPUT S1 in1
NEURON Dn1 An1 n1 5
NEURON Dn2 An2 n2 .1
SYNAPSE S1 Dn1 .36 3
SYNAPSE An1 Dn1 .1 20
SYNAPSE An1 Dn2 .1 5
SYNAPSE S1 Dn2 .14 5
SYNAPSE An2 Dn1 -10 50
TONIC Dn1 -.01
TONIC Dn2 -0.04
end
```

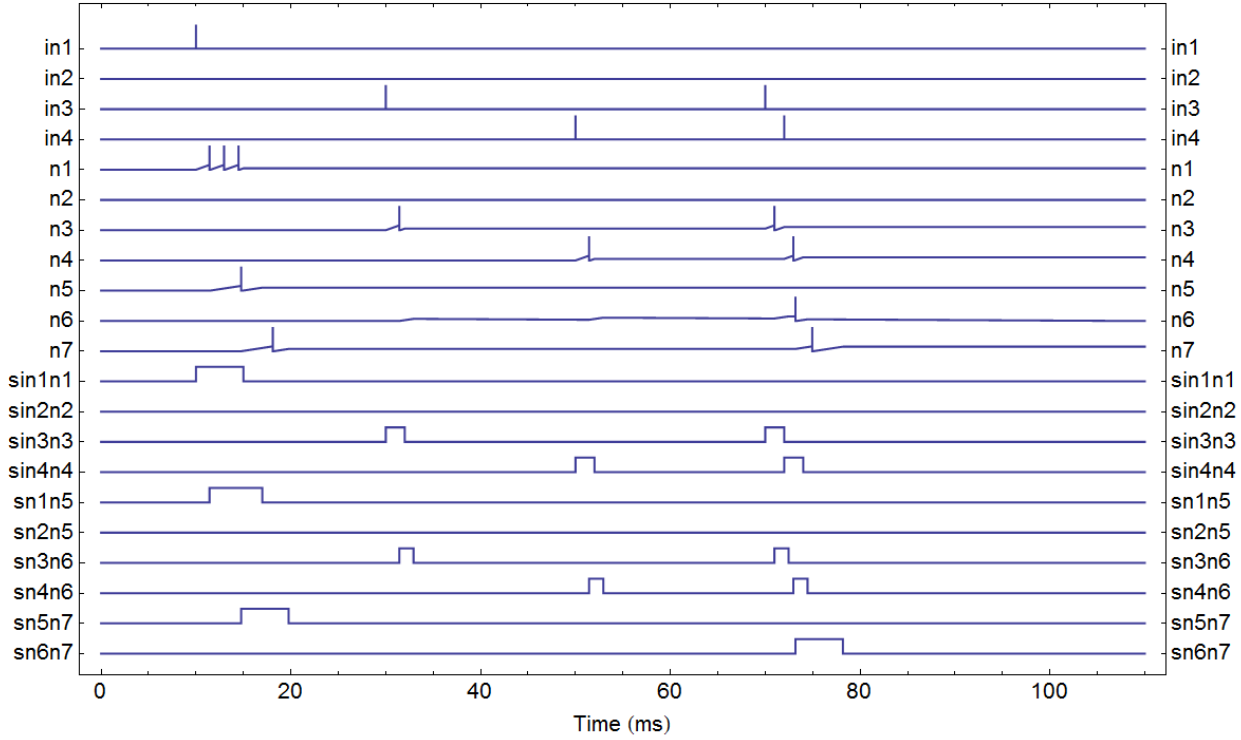


Dendritic Tree (with Paul Rhodes)

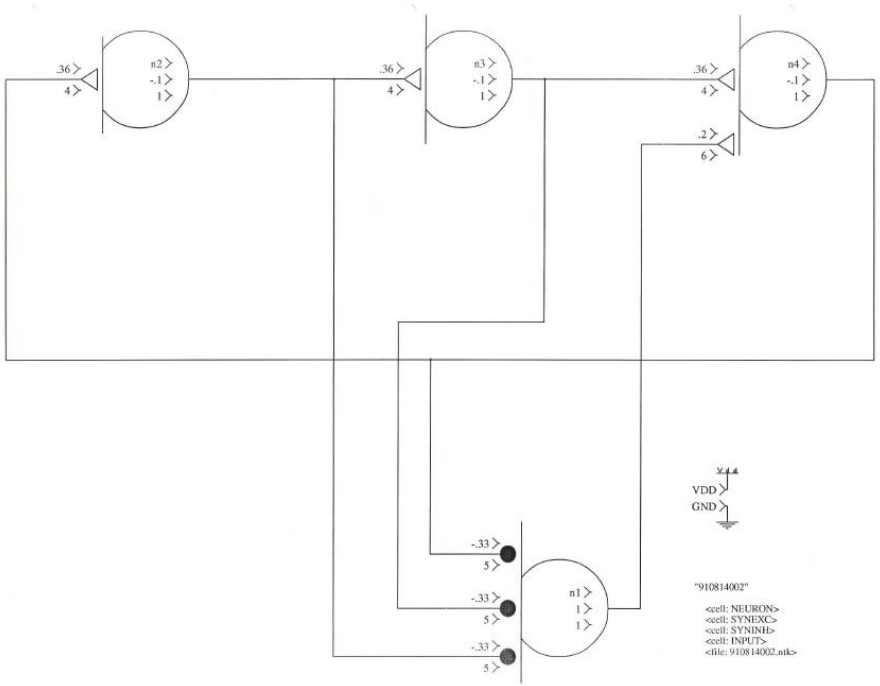
Here, “NEURON” primitives are being used to model dendritic compartments in a dendritic tree.

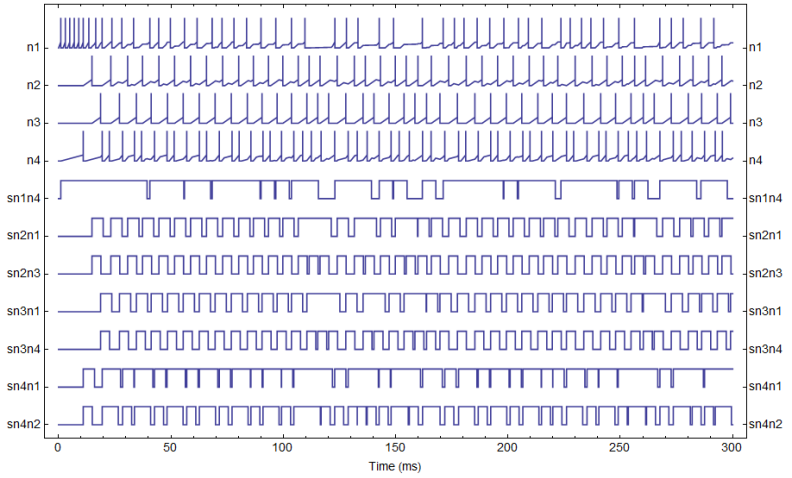



```
begin

INPUT S1 in1
INPUT S2 in2
INPUT S3 in3
INPUT S4 in4

NEURON Dn1 An1 n1 0.1
NEURON Dn2 An2 n2 0.1
NEURON Dn3 An3 n3 0.1
NEURON Dn4 An4 n4 0.1
NEURON Dn5 An5 n5 0.1
NEURON Dn6 An6 n6 0.1
NEURON Dn7 An7 n7 0.1

SYNAPSE S1 Dn1 .7 5
SYNAPSE S2 Dn2 .7 5
SYNAPSE S3 Dn3 .7 2
SYNAPSE S4 Dn4 .7 2
SYNAPSE An1 Dn5 .30 2.5
SYNAPSE An2 Dn5 .30 2.5
SYNAPSE An3 Dn6 .30 1.5
SYNAPSE An4 Dn6 .30 1.5
SYNAPSE An5 Dn7 .30 5
SYNAPSE An6 Dn7 .30 5

TONIC Dn6 -.01

end
```

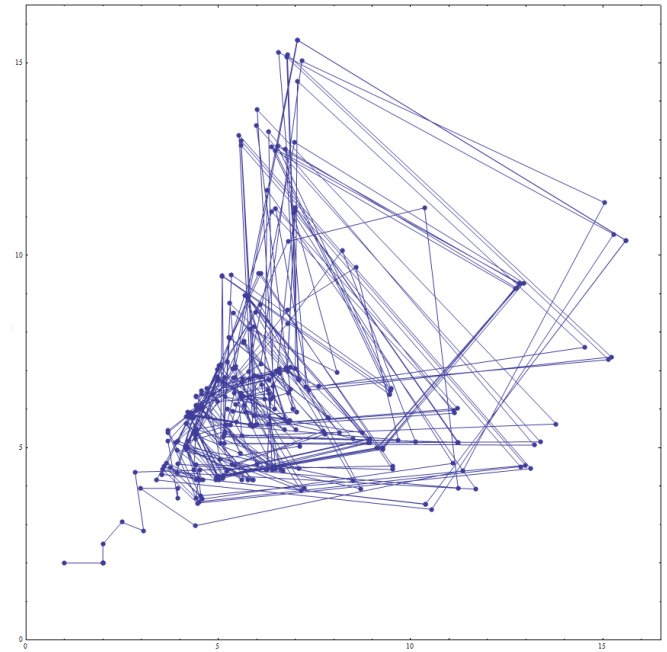


Spiking Neural Chaos






```
# chaos
begin
NEURON Dn1 An1 n1 1
TONIC Dn1 1
NEURON Dn2 An2 n2 1
TONIC Dn2 -.1
NEURON Dn3 An3 n3 1
TONIC Dn3 -.1
NEURON Dn4 An4 n4 1
TONIC Dn4 -.1

SYNAPSE An1 Dn4 .2 6
SYNAPSE An2 Dn1 -.33 5
SYNAPSE An2 Dn3 .36 4
SYNAPSE An3 Dn1 -.33 5
SYNAPSE An3 Dn4 .36 4
SYNAPSE An4 Dn1 -.33 5
SYNAPSE An4 Dn2 .36 4
end
```



Conclusions

- Event-driven simulation is capable of realistic spiking neural behaviors (even with point-neuron integrate-and-fire primitives)
- But we must combine primitives to get realistic behavior
- Requires summating synapse for calcium-like adaptation behavior
- Izhikevich Neurons and Dendritic Trees can be modeled by composing point-neuron primitives
- FAST (1000X faster than full differential equation solvers) – CARLsim even faster with GPU support
- No unwanted synchronization artifacts
- Useful both for fast simulations and for hardware

Thank you!

www.lloydwatts.com
lloydwatts60@yahoo.com

http://www.lloydwatts.com/spike2.html

L. Watts, "Event-Driven Simulation of Networks of Spiking Neurons", *Proceedings of the Sixth Neural Information Processing Systems Conference,* 1993, pp. 927-934.