EE 591L – Neuromorphic Analog VLSI
Project 6 – Silicon Neurons

Objective
To better understand the operation of a simplistic silicon neuron model, the integrate-and-fire neuron.

Special Directions
Turn in electronic copies of the SPICE decks for all three parts.

You will also need to "use initial conditions" when simulating this neuron, especially with the capacitors. Please see the SPICE manual for details.

You are permitted (but not required) to use XCircuit to generate your SPICE netlists. Please see details on the class website for more information.

Part 1 – Design of an All-Transistor Amplifier
Design an integrate-and-fire neuron that meets the following specifications, assuming that the "membrane" potential is charged with a constant current source of 3nA.

- Duration of the spike is 0.1msec
- Time between spikes is 1msec
- No capacitors larger than 10pF
- V_{mem} stays within the supply rails at all points in time (never goes below ground or above V_{dd})
- All times must be within 5% tolerance

Observe and plot both the membrane potential and the output (V_{spike}) potential.

- How far does the membrane potential jump at the onset and termination of the spike?
- Theoretically, how far should this jump be? Do the two values agree?

Modify the input/injection current.

- How is frequency of spiking affected by the input current?
- Perform at least five simulations (preferably more) and plot the frequency versus input current.
- Theoretically, what should this relationship (frequency versus current) be?

Part 2 – Silicon Axon
Build a silicon axon by cascading together at least ten integrate-and-fire neurons, as was shown in class.

- What is the best way to terminate this cascade of integrate-and-fire neurons?
- How can you modify the duration of the individual pulses?
- Show output from stages 1, 2, 3, 5, and 10 (and any other stages you desire).

Part 3 – "On" Cells Versus "Off" Cells

The integrate-and-fire neuron that we have discussed is considered an "Off" neuron because its resting potential is off, or ground.

- How can you modify this circuit to make this an "On" neuron (its resting potential is on, or V_{dd}, and it spikes down to ground for a short time)?
- Hint – You must sink current from the V_{mem} node (current source from V_{mem} to ground instead of a current source from V_{dd} to V_{mem}). You must also change part of the circuit.
- Simulate the circuit and show that it works.