**Complimentary MOSFET Circuitry for Simulating Neural Ion Channels**

**Keywords:** neuromorphic computing, neuron simulation, MOSFET circuitry

**Introduction:** The ion channel of a neuron is a key functional component to the operation of living organisms, as they allow the cell to react to and generate signals (Llinas, 1988). Modeling this behavior with electronic components is the key to neuromorphic computing, which would advance both neuroscience and computer science. Original silicon models of neurons employed complicated, power-intensive circuitry, until it was realized that the equations guiding subthreshold MOSFET operation are mathematically isomorphic to the voltage-dependent properties of biological ion channels (Hynna and Boahen, 2007). One promising implementation of the silicon neuron requires 8 NMOS transistors, though it has some functional limitations. In this model, only two transistors serve to simulate the actual neuron while the others assist its operation. Reducing the footprint of the silicon neuron is an important factor in building more powerful and effective neuromorphic chips. Using CMOS technology with both PMOS and NMOS transistors is one way to reduce the footprint of a single circuit and more accurately capture the behavior of real neurons.

**Research Questions:** Because half of the transistors in the 8-transistor model are dedicated to inverting the membrane voltage on one of the neuron’s NMOS transistors, it would be advantageous to replace this component with a PMOS transistor to eliminate the need for this inverter. The energy barriers across the channels of the two transistors that comprise the “neuron” should have opposite responses to the same voltage if they are complementary rather than both NMOS.

**Research Plan:** Proving that using a PMOS transistor to replace the 8-transistor circuit with one that only uses four will be done in multiple steps. SPICE software will be used to simulate the behavior of the proposed silicon neuron to assess the feasibility of the design and calculate the optimal intrinsic properties and geometries of each component. Because PMOS transistors transport charge more slowly than NMOS transistors, being based on hole-transport rather than electron-transport, the PMOS must be larger than its NMOS counterparts to compensate, which may lead to unintended consequences. If it can be demonstrated that the alternative circuit is a correct thermodynamic model for a biological neuron, an integrated circuit must be fabricated in order to test that the design works in reality, using the same procedure that tested the 8-transistor model.

**Intellectual Merit & Broader Impacts:** Although we currently understand the chemistry behind how neurons operate and the emergent behavior of the whole brain, we only have theories about what happens in between. Not only will a functioning neuromorphic system that employs silicon neurons give neuroscientists the opportunity to peer into these inner layers for the first time, but it will also enable the next generation of low power supercomputers. One such application of neuromorphic devices is deep space exploration, where radiation and power limitations pose as severe challenges to modern CPUs. Neuromorphic systems would be inherently parallelized and robust to digital corruption, just like the human brain can function despite having noisy analog hardware.

**References:**

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