Neuromorphic Circuit Design: Integrate-and-Fire Neuron with STDP Synapse

SANA
Department of Electronics and Communication Engineering
BVRIT Hyderabad college of Engineering for Women's
Sana20041712@gmail.com

Abstract-

Neuromorphic circuits mimic the behavior of biological neurons and synapses for energy-efficient brain-inspired computing. This work presents the design of an Integrate-and-Fire (I&F) neuron with a Spike-Timing-Dependent Plasticity (STDP) synapse using the SG13G2 PDK in eSim with Ngspice simulation. The neuron integrates pre-synaptic inputs over time, firing when a threshold is reached, while the synapse dynamically adjusts its weight depending on the timing of pre- and post-synaptic spikes. The circuit demonstrates fundamental learning behavior and can serve as a building block for larger neuromorphic systems.

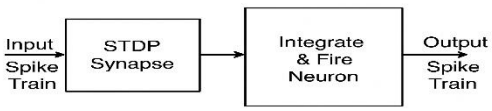
Keywords-

Integrate-and-Fire Neuron, STDP, Neuromorphic Circuits, Synaptic Plasticity, eSim, Ngspice

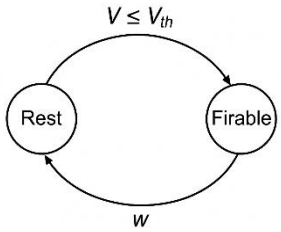
1.Circuit Details-

The proposed neuromorphic circuit is composed of two main sub-blocks:
1. STDP Synapse – Emulates the biological synaptic weight. The weight is stored as a capacitor voltage, which is updated depending on the relative timing of pre-synaptic and post-synaptic spikes. MOSFET switches and simple current mirrors are used for read/write operations.
2. Integrate-and-Fire Neuron – Integrates the weighted input current on a capacitor. When the membrane voltage exceeds a threshold, a comparator generates an output spike and resets the integration capacitor.

2.Block Diagram-

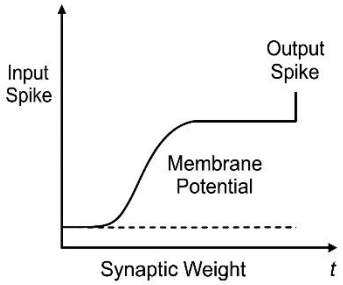


3.State Diagram

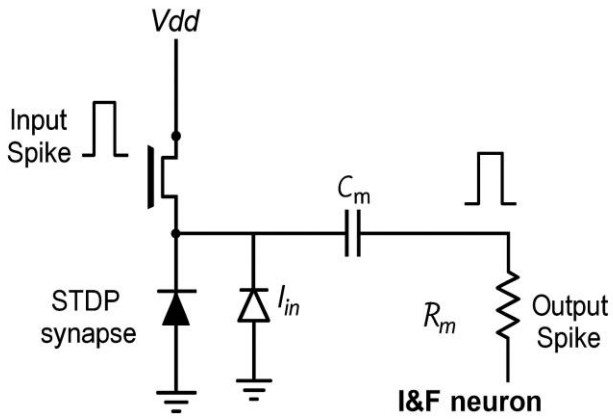


State Diagram

4.Circuit Waveform-



Reference Circuit-



References-

1.eSim FOSSEE Project, https://esim.fossee.in

2. Mead, C., "Neuromorphic Electronic Systems," Proceedings of the IEEE, 1990.