Challenge #19 – Binary LIF Neuron

Course: ECE 410/510

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Introduction

The binary Leaky Integrate-and-Fire (LIF) neuron is a simplified model of neural computation where input spikes accumulate, decay over time (leak), and trigger an output spike when a threshold is crossed. This model mimics biological neuron behavior and is suitable for digital and neuromorphic designs.

Objective

To design and implement a binary LIF neuron in Verilog HDL, simulate its behavior under multiple test cases, and evaluate how it responds to varying input stimuli.

Neuron Design

The neuron maintains an internal potential variable that updates as follows:
- At each clock cycle, $P(t) = \lambda * P(t-1) + I(t)$, where λ is the leak factor and $I(t)$ is the binary input.
- If $P(t)$ exceeds a fixed threshold θ, the neuron outputs a spike and resets the potential.
- Fixed-point arithmetic (Q1.15 format) was used to approximate real-valued leak and threshold values in Verilog.

Testbench Scenarios

The testbench was used to simulate the following four scenarios:
1. Constant zero input (neuron remains inactive)
2. Repeated low input causing gradual accumulation and eventual spike
3. Leakage over time without any new input
4. Immediate strong input spike exceeding the threshold instantly

Simulation Results

The waveform generated from the simulation confirms the expected neuron behavior. Potential accumulates, leaks over time, and resets on threshold crossing. Each scenario illustrates distinct characteristics of the LIF neuron model.

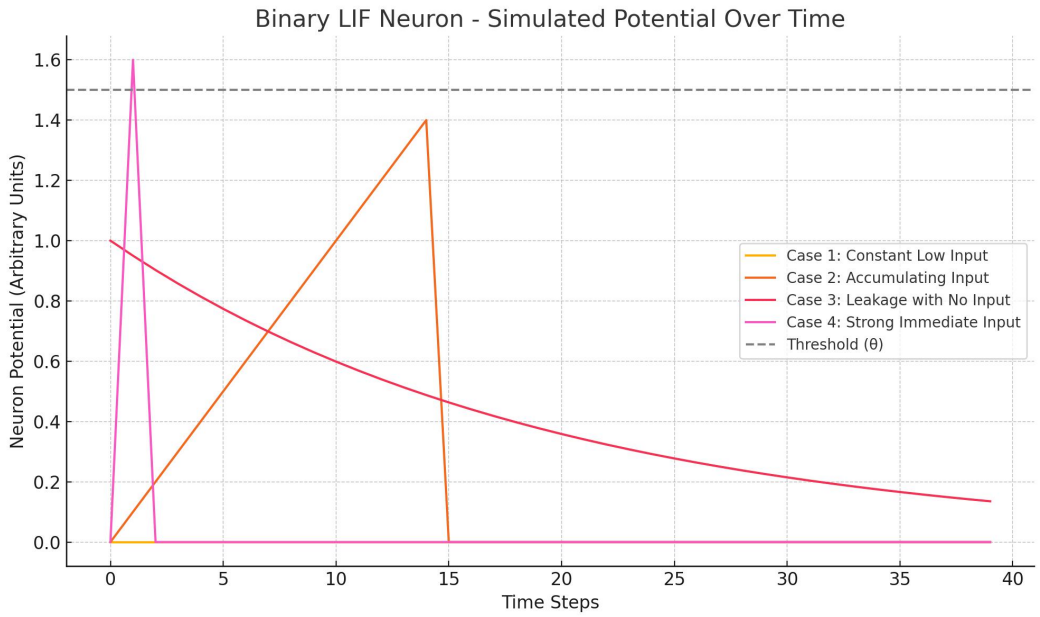

Figure: Simulated neuron potential over time under four input conditions.

Conclusion

This exercise provided insights into how binary LIF neurons operate and how their behavior can be modeled using Verilog. It bridges neuroscience concepts with hardware implementation, highlighting the potential for neuromorphic architectures in digital systems.