Week 6

Challenges

ECE 410/510
Spring 2025

Instructions

- The challenges below are for you to delve deeper into the subject matter and to test your own knowledge.
- I'd suggest you try to solve at least one problem per week. More is obviously better.
- Practice "vibe coding" if necessary.
- Post your solution(s) in the `#weekly-challenges` Slack channel so everybody can appreciate what you did, ask questions, and make comments.
- Document everything for your portfolio and make your code available on Github.

Challenge #19: Implement a binary LIF neuron

Learning goals:

- Learn how a binary Leaky Integrate-and-Fire (LIF) neuron works.
- Implement such a neuron in Verilog or any other HDL.

Binary LIF neuron:
The binary LIF neuron can be formulated as:

- State representation: The neuron's state S(t) is either 0 (not spiking) or 1 (spiking)
- Simplfied update rule:
  - Accumulate input: $P(t) = \lambda P(t-1) + I(t)$
  - Where $P(t)$ is a potential variable, λ is a leak factor (between 0 and 1)
  - $I(t)$ is the binary input at time t
- Threshold function:
  - $S(t) = 1$ if $P(t) \geq \theta$ (threshold)
  - $S(t) = 0$ otherwise
- Reset mechanism:
  - If $S(t) = 1$, then $P(t)$ is reset to a lower value

Tasks:

1. Write a Verilog implementation of a simple binary LIF neuron (using the formulation above) with a single input.
2. Write a testbench that demonstrates the following scenarios:
   - Constant input below threshold
   - Input that accumulates until reaching threshold
   - Leakage with no input
   - Strong input causing immediate spiking

Challenge #20: Crossbar matrix-vector multiplication

Learning goals:

- Learn how to simulate a resistive crossbar in SPICE
- Learn how matrix-vector multiplication in a resistive crossbar works

Tasks:

1. Write SPICE code for a 4x4 resistive crossbar (with fixed resistances)

2. Demonstrate that the resulting output currents represent the product of the 4x1 input vector and the 4x4 weight matrix.