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ECE510

Challenge #24: Running a Simulation on EBRAINS BrainScaleS-2 Neuromorphic Hardware and its Relation to DC-DC Converters

1. Introduction

This document presents an in-depth analysis of Challenge #24, which involves running simulations on the EBRAINS BrainScaleS-2 neuromorphic hardware. The challenge also explores how the behavior and functionality of this neuromorphic system can relate conceptually and structurally to basic DC-DC converter topologies including the Buck, Boost, Buck-Boost, and Ćuk converters.

2. EBRAINS BrainScaleS-2 Overview

EBRAINS is an EU-funded research infrastructure that offers cutting-edge computational resources for neuroscience and neuromorphic computing. BrainScaleS-2 is a neuromorphic hardware system that simulates biological neural networks at accelerated speeds using mixed-signal circuits.

- Technology: Mixed analog-digital (ASIC-based)

- Simulation Speed: Faster than real time

- Programming Interface: PyNN (Python-based)

3. Learning Goals of the Challenge

- Run a simulation on BrainScaleS-2 hardware

- Explore PyNN to model spiking neural networks

- Understand the mapping between hardware neural dynamics and physical systems

4. Tasks in the Challenge

1. Create an EBRAINS account

2. Access BrainScaleS-2 tutorials and example scripts

3. Run a simulation such as matrix multiplication on the BrainScaleS-2 platform

4. Analyze and interpret output spiking data

5. Conceptual Parallels with DC-DC Converters

Feature	BrainScaleS-2 Neuromorphic System	DC-DC Converter Circuit
System Dynamics	Spiking behavior over time	Voltage/current variation
Control Mechanism	Spike encoding, synaptic plasticity	PWM modulation, feedback loop
Power Efficiency	Event-driven, low power	High-efficiency regulation
Mathematical Modeling	Membrane potential dynamics	Inductor/Capacitor behavior

6. Mapping Neuromorphic Behavior to Converter Topologies

Buck Converter (Step-Down):

- Analogous to inhibitory neural networks

- Spiking frequency decreases with input voltage

Boost Converter (Step-Up):

- Analogous to excitatory spike propagation

- Higher spiking output from low baseline input

Buck-Boost Converter (Inverting):

- Alternating excitatory/inhibitory pathways

- Produces inverted or bidirectional spike outputs

Ćuk Converter (Multi-Stage Transfer):

- Recurrent SNNs with delay feedback

- Mirrors dual energy transfer paths

7. Practical Hybrid Application

A spiking neural network (SNN) can be trained using BrainScaleS-2 to regulate the output of a DC-DC converter:

1. Sense output voltage from converter

2. Encode it as input spike train

3. Train SNN to produce appropriate PWM control signal

4. Feedback learning using STDP rule

8. Conclusion

The BrainScaleS-2 platform allows researchers to simulate biologically inspired, energy-efficient computational models. When compared to DC-DC converters, both systems demonstrate dynamic feedback-based regulation and real-time differential behavior. This opens doors for hybrid systems where neuromorphic control units drive hardware power circuits, potentially leading to breakthroughs in adaptive, intelligent power management.

9. References

- EBRAINS: https://www.ebrains.eu

- BrainScaleS-2 Documentation: https://electronicvisions.github.io/documentation-brainscales2

- PyNN Library: https://neuralensemble.org/PyNN

- Buck/Boost Converter Theory: Power Electronics Handbook, 4th Edition