CONFIGURING AN EMBEDDED NEUROMORPHIC COPROCESSOR USING A RISC-V CHIP FOR ENABLING EDGE COMPUTING APPLICATIONS

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Neuromorphic technology on-edge

- **Neuromorphic hardware** has been available for a few years
  - Biology-inspired Spiking Neural Networks (SNNs)
  - Promising for **edge computing**
    - Low power
    - High parallelism
    - Real-time
- Suitable **algorithms** for edge applications are just beginning to appear
  - Constraint Satisfaction Problem solvers
  - Robotic controllers + real-time signal analysis systems
    - Processing, classification, pattern matching, etc.
    - Sometimes with neuromorphic sensors

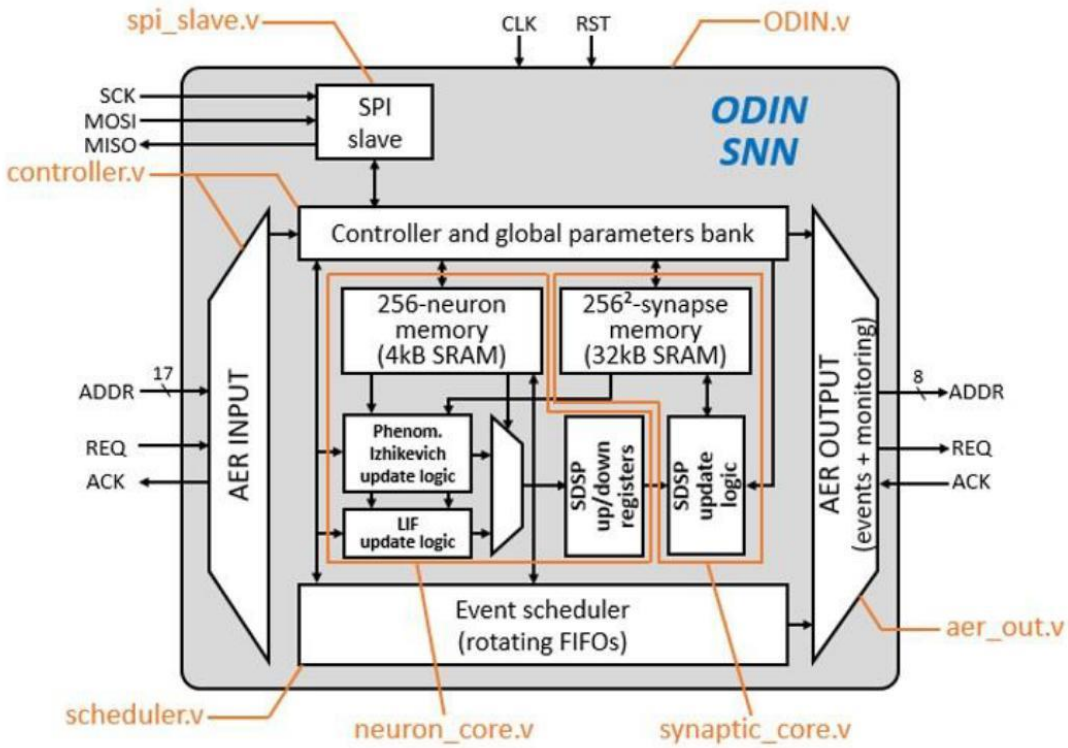
Neuromorphic technology on-edge

- Using neuromorphic devices in edge computing is **still difficult**
  - Need **external hosts** for configuring networks and input data
    - Desktop PC or cloud server
  - Solutions beginning to emerge
    - HW: NeuroEdge (with Raspberry Pi), Intel Loihi (on-chip x86 MCU)
    - SW: NeuroXplorer, Nengo

- **In this work:** a chip-level integrated solution for online configuration of neuromorphic platforms
  - Small, efficient, low-power
  - RISC-V (RocketChip) + neuromorphic (ODIN)
  - Proof of concept for deeper integration of neuromorphic architectures into the edge computing data flow

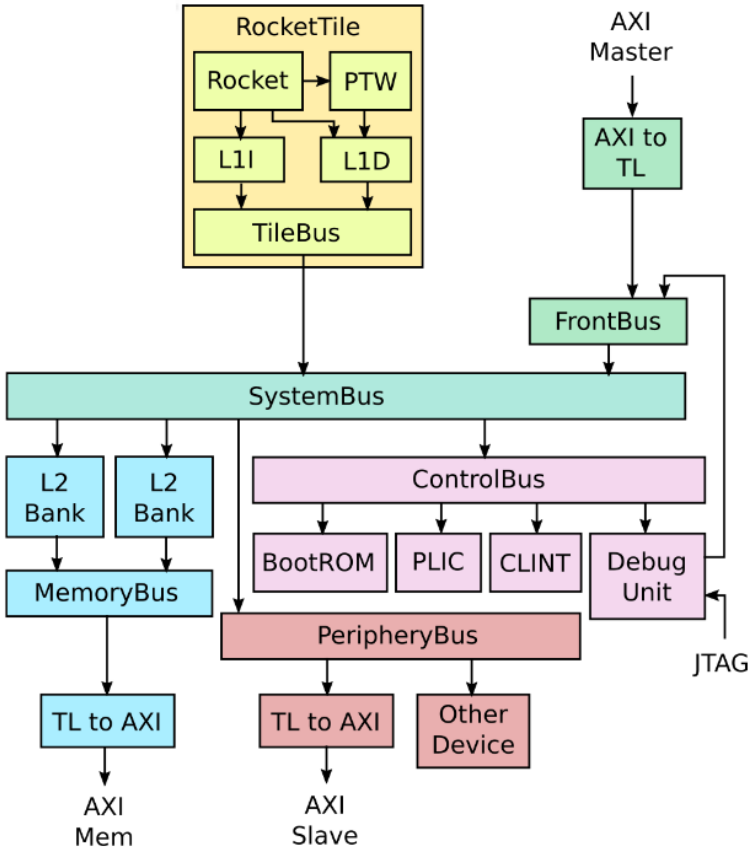
ODIN: a Spiking Neural Network Coprocessor

- **Emergent neuromorphic architecture**
  - 256 neurons, all-to-all synaptic interconnections
  - Address Event Representation (AER) model for communication
  - Leaky Integrate & Fire and Izhikevich models for neurons
- **Freely available as an open-source netlist**
- Registers are configured through SPI
  - Write & read operations on neurons and synapses



HTTPS://GITHUB.COM/CHFRENKEL/ODIN

ODIN integration within Chipyard



- **Chipyard:** RISC-V based SoC framework
  - Driven by a single Rocket core
  - RISC-V: free, open source, architecture-agnostic, extensible ISA
- ODIN entity integrated as a custom Verilog module
  - Top-level I/O signals for the AER protocol

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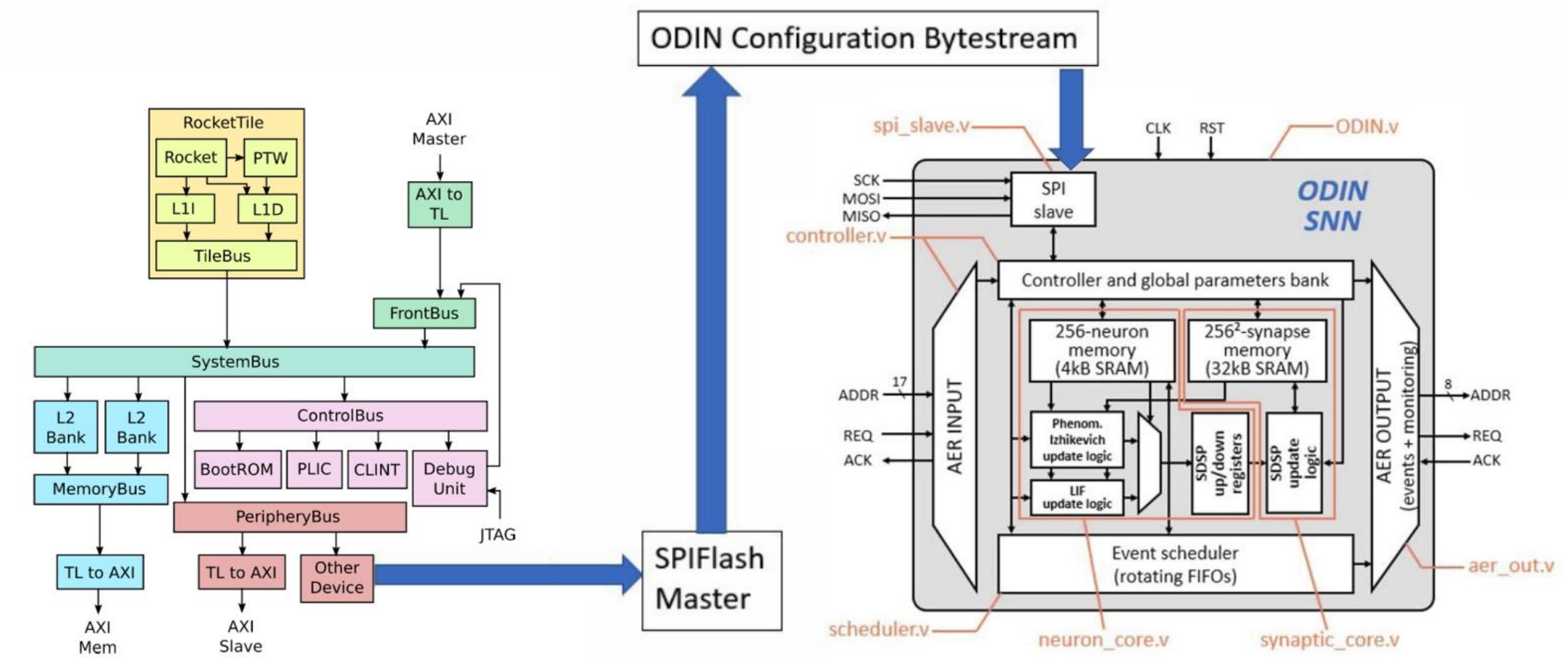
ODIN integration within Chipyard



ODIN Parameters Definition

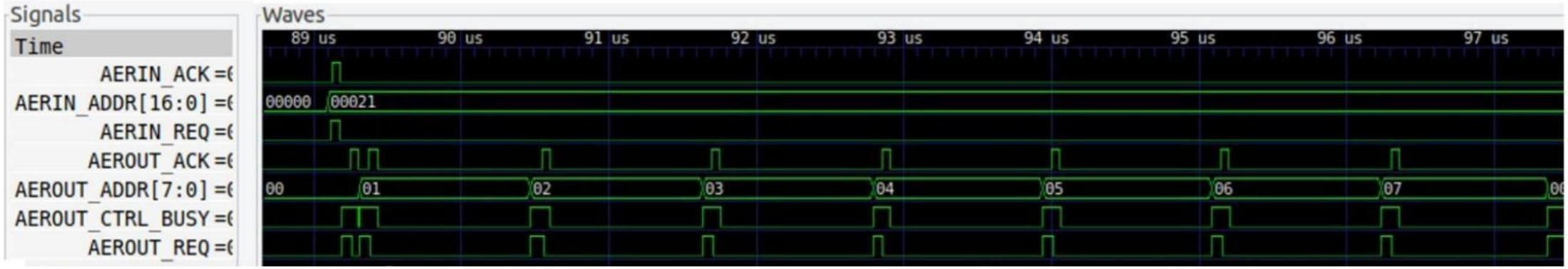
- **Manual configuration** of ODIN **is challenging**
  - Configuration through SPI is long and error-prone
- We developed a C program for **simple configuration of ODIN**'s SPI internal registers and loading the SRAM contents of neurons and synapses

Set SPI Configuration registers	Add Synapse	Add neuron

- In future work, these configuration functions will run on Rocket and enable **fully-online configuration** of the network

RTL Simulation: Synfire Chain

- System test by a simple SNN model
  - 8-neuron **synfire chain**
  1. Setup of ODIN's SPI-slave configuration registers
  2. Configuration of synaptic interconnections by writing into the synapse SRAM
  3. Setup of neuron SRAM
  4. **Synfire chain simulation**



Synthesis results

- Synthesis target: Xilinx PYNQ Z2

Site Type	Scope	Type	Used	Available	Utilization
Slice LUTs			8506	53200	15.99%
	Logic		7928	53200	14.90%
	Memory	Distributed RAM	578	53200	1.09%
Slice Registers		Flip-Flop	4317	106400	4.06%
F7 Muxes			179	26600	0.67%
F8 Muxes			34	13300	0.26%
BRAM Tile			15.5	4140	11.07%
	RAMB36/FIFO	RAMB36E1	15	140	10.71%
	RAMB18	RAMB18E1	1	280	0.36%

Conclusions

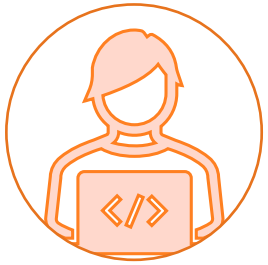
- We have presented a system integrating a **RISC-V CPU** and a **neuromorphic coprocessor** on the **same chip**
- Using **free and open-source** resources
  - RISC-V: well-known, flexible and reconfigurable, can be an **easier interface** for developers to work with than neuromorphic hardware
- Enables **on-edge reconfiguration of a SNN application**
  - No data transfer bottleneck
  - No dependence on external hosts

Conclusions

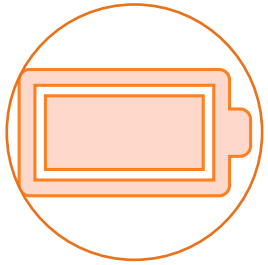
- Overall goal: **the seamless integration of neuromorphic technologies with state-of-the-art processors**

Fully **self-contained** systems

Best of both worlds: can handle **classical computation** + **deep learning**



Easier interface for developers through known ISA



Respecting **low-power** constraints for edge computing

New opportunities for creating applications in IoT and industrial fields

THANK YOU FOR YOUR ATTENTION