

Memory Intensive Computing

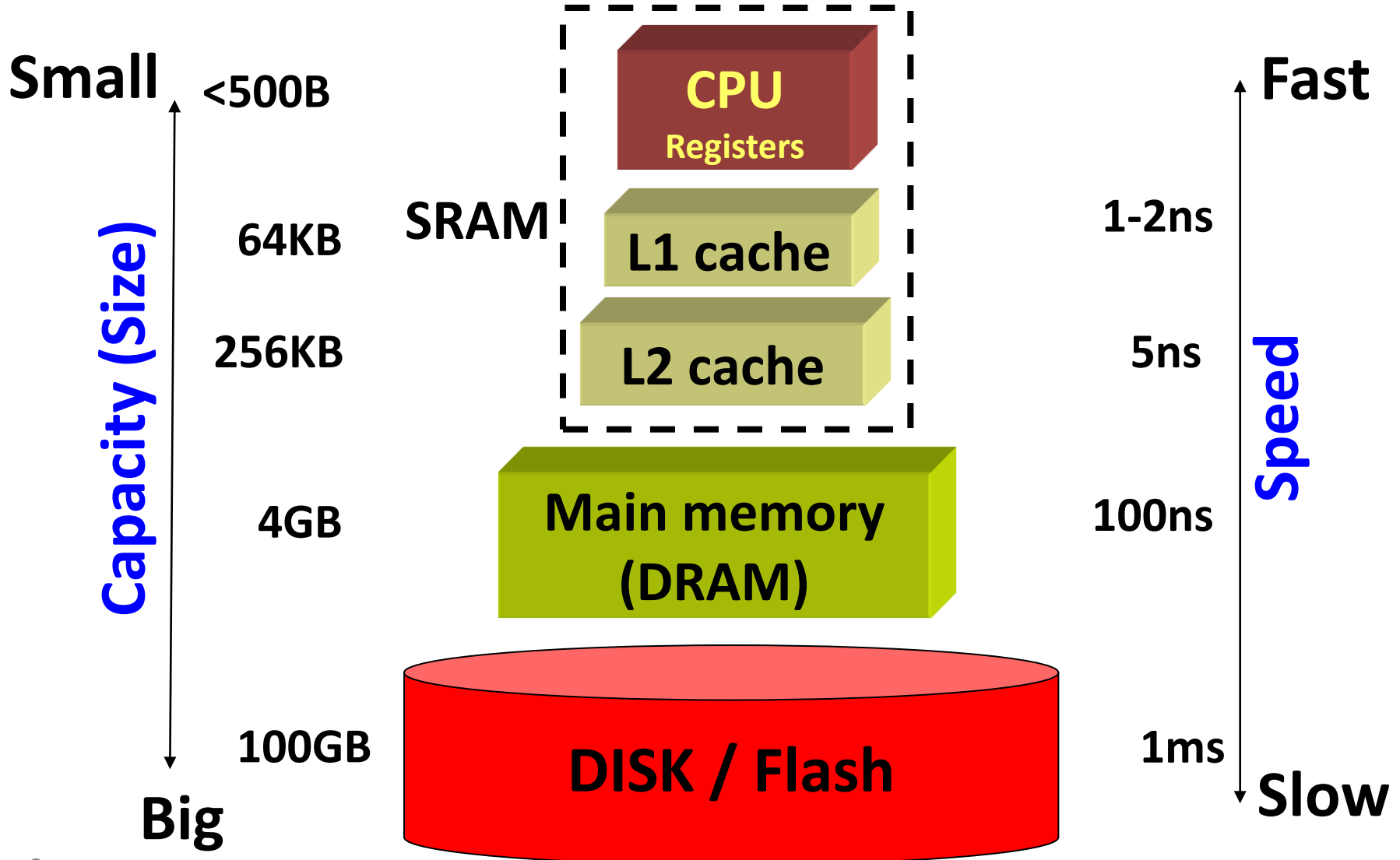
Shahar Kvatinsky

Advisors: Eby Friedman, Avinoam Kolodny,
Uri Weiser

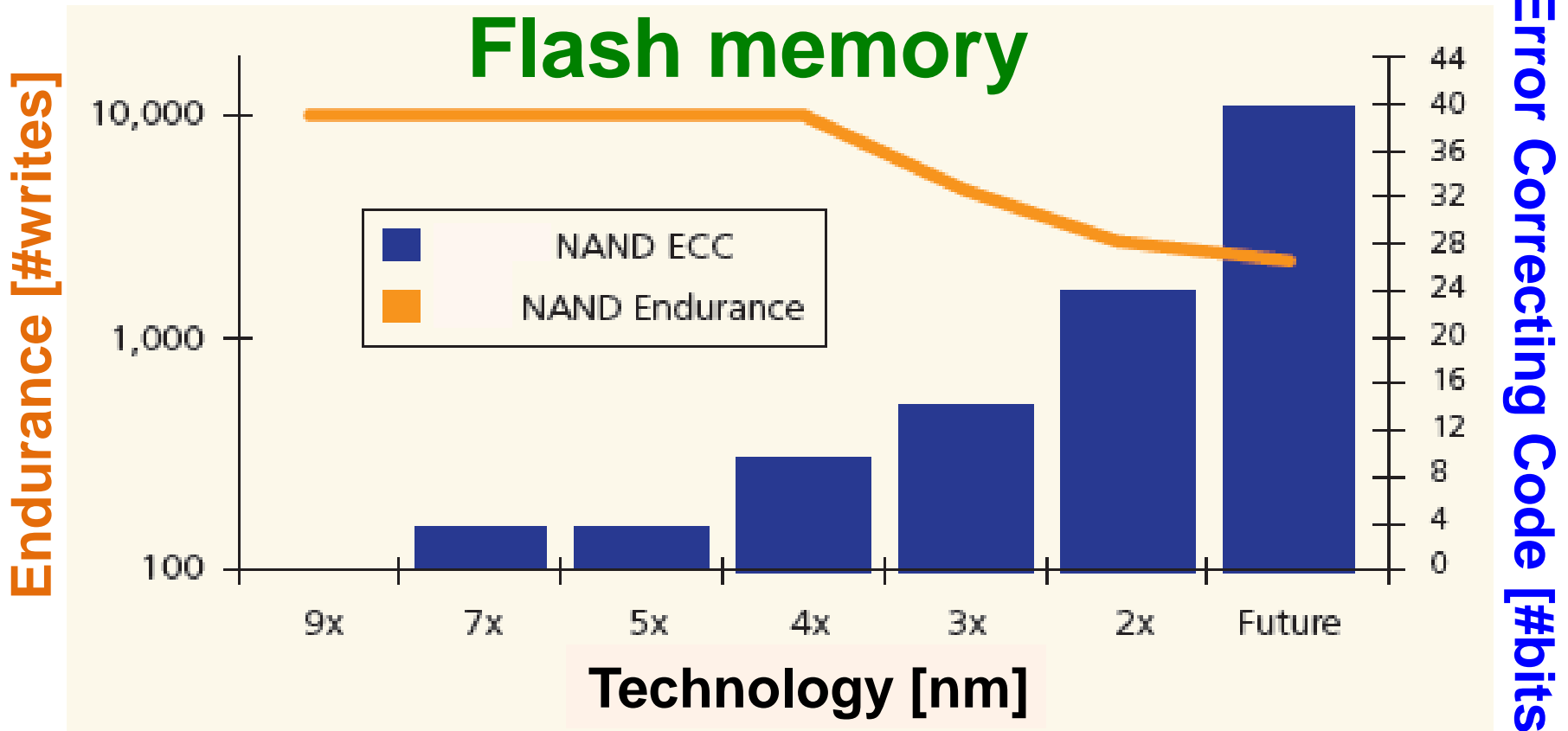


Technion – Israel Institute of Technology
Electrical Engineering Department
January 2014

Memory Hierarchy



Flash is Dead

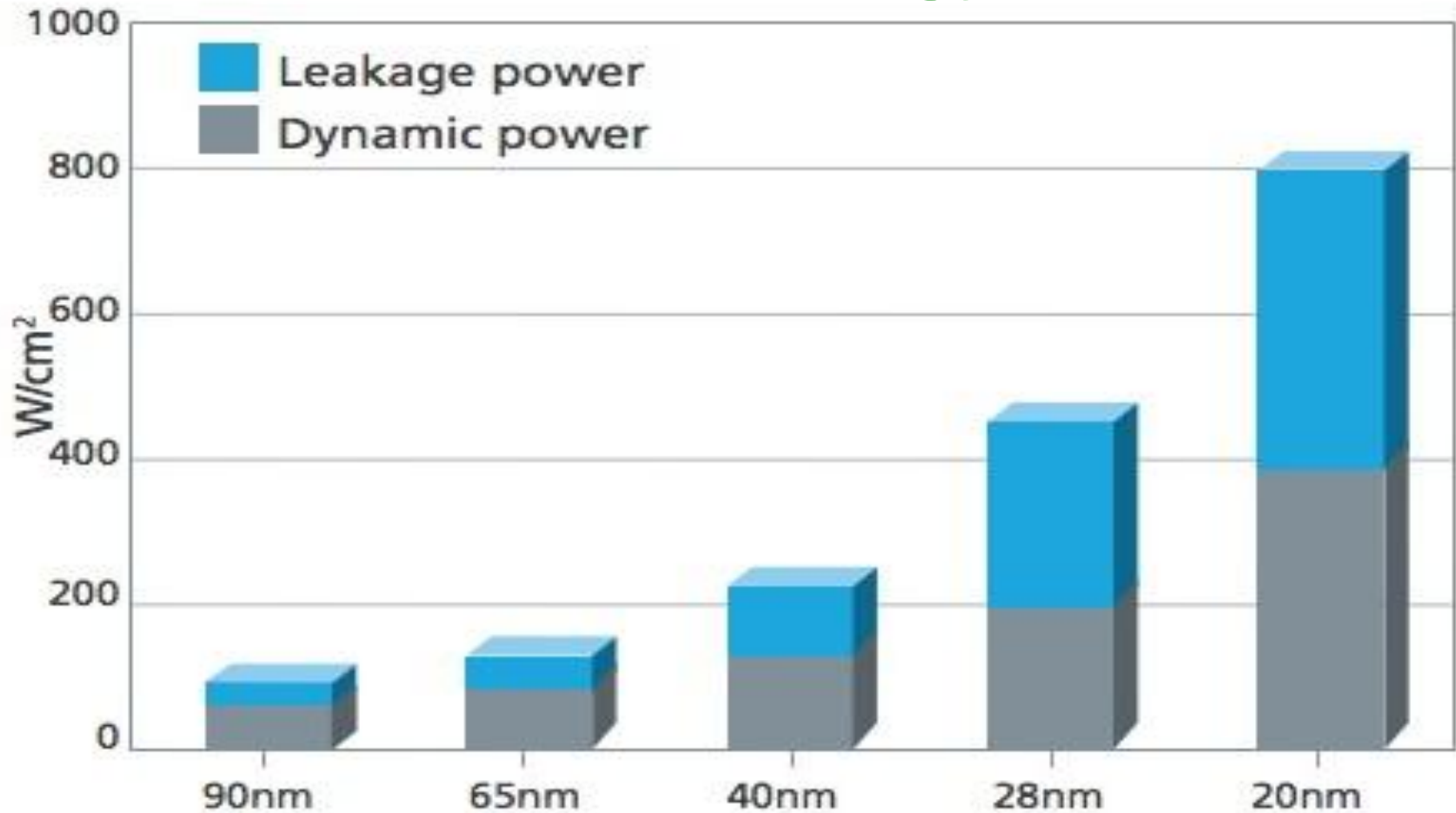


SanDisk's 1Y flash stays at 19-nm

Peter Clarke

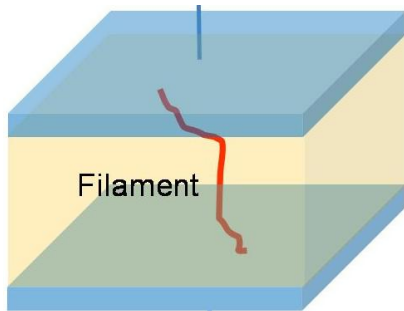
High Leakage in Volatile Memories

Chip energy

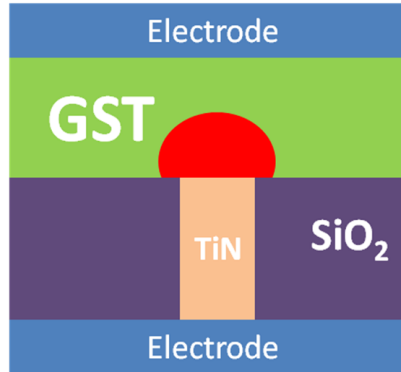


Emerging Memory Technologies

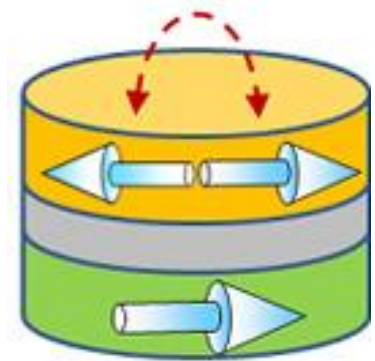
All of Them are Memristors



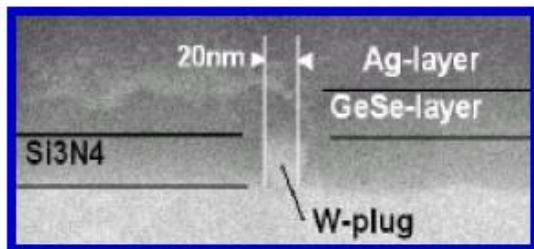
**Resistive RAM
(RRAM)**



**Phase Change
Memory
(PCM)**



STT MRAM



PMC/CBRAM



**Carbon
Nano Tubes**

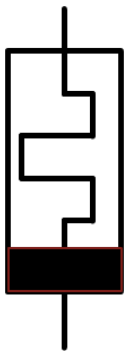
Memristors are the Next Memory!

- Nonvolatile
- Low power
- High endurance
- Fast
- CMOS compatible
- Dense



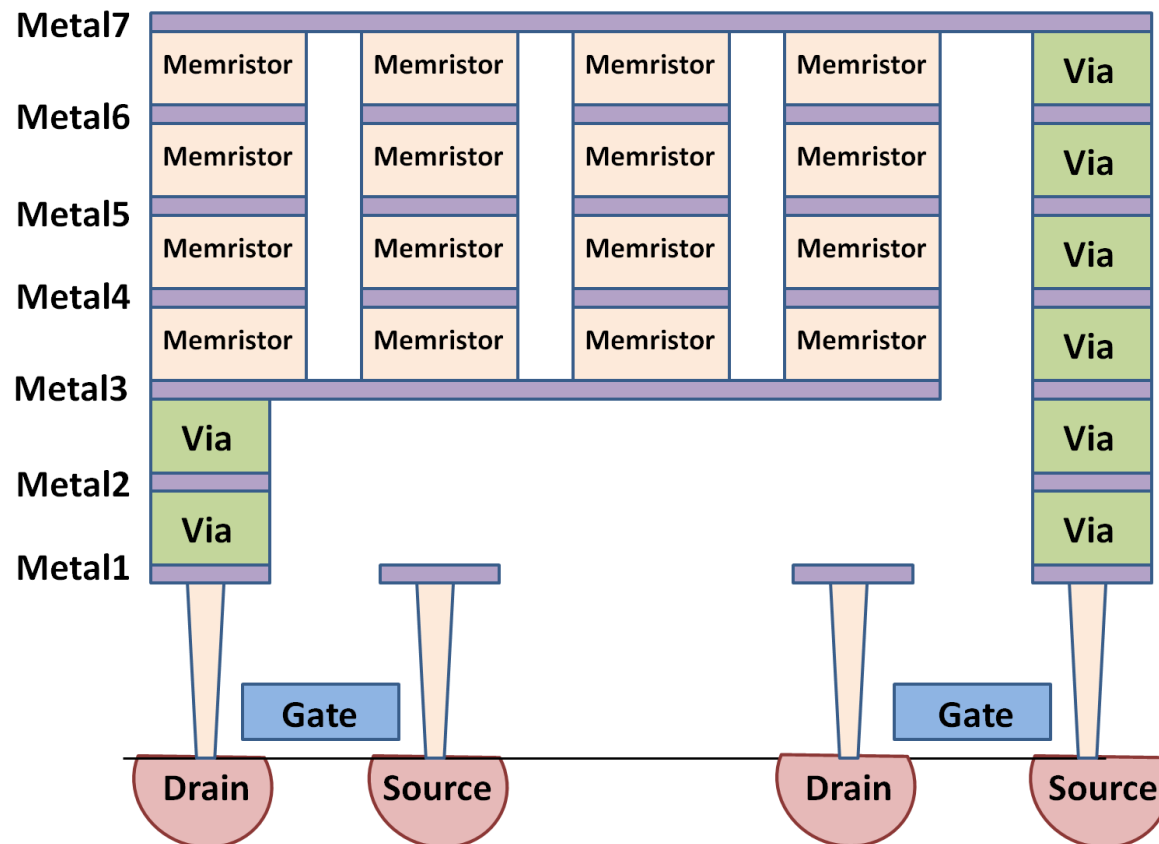
Agenda

- Are memristors the next memory?
- **Memory intensive computing**
- Enhancing computation
 - Continuous Flow Multithreading (CFMT)
 - Memristor Ratioed Logic (MRL)
- Beyond von Neumann
 - Logic within memory
 - Neural networks
- Summary



Memristors Add New Capabilities to CMOS

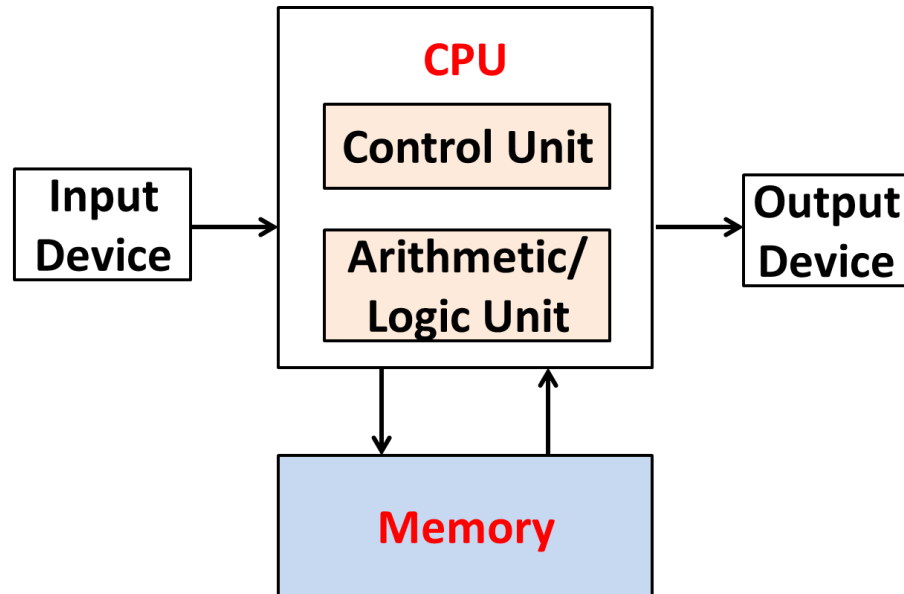
- Sea of memory above the logic



- Dense, fast, and CMOS compatible

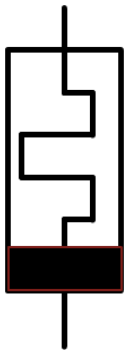
Memory Intensive Architectures

- Combine memory and logic
 - Enhance computation
 - Processing within memory

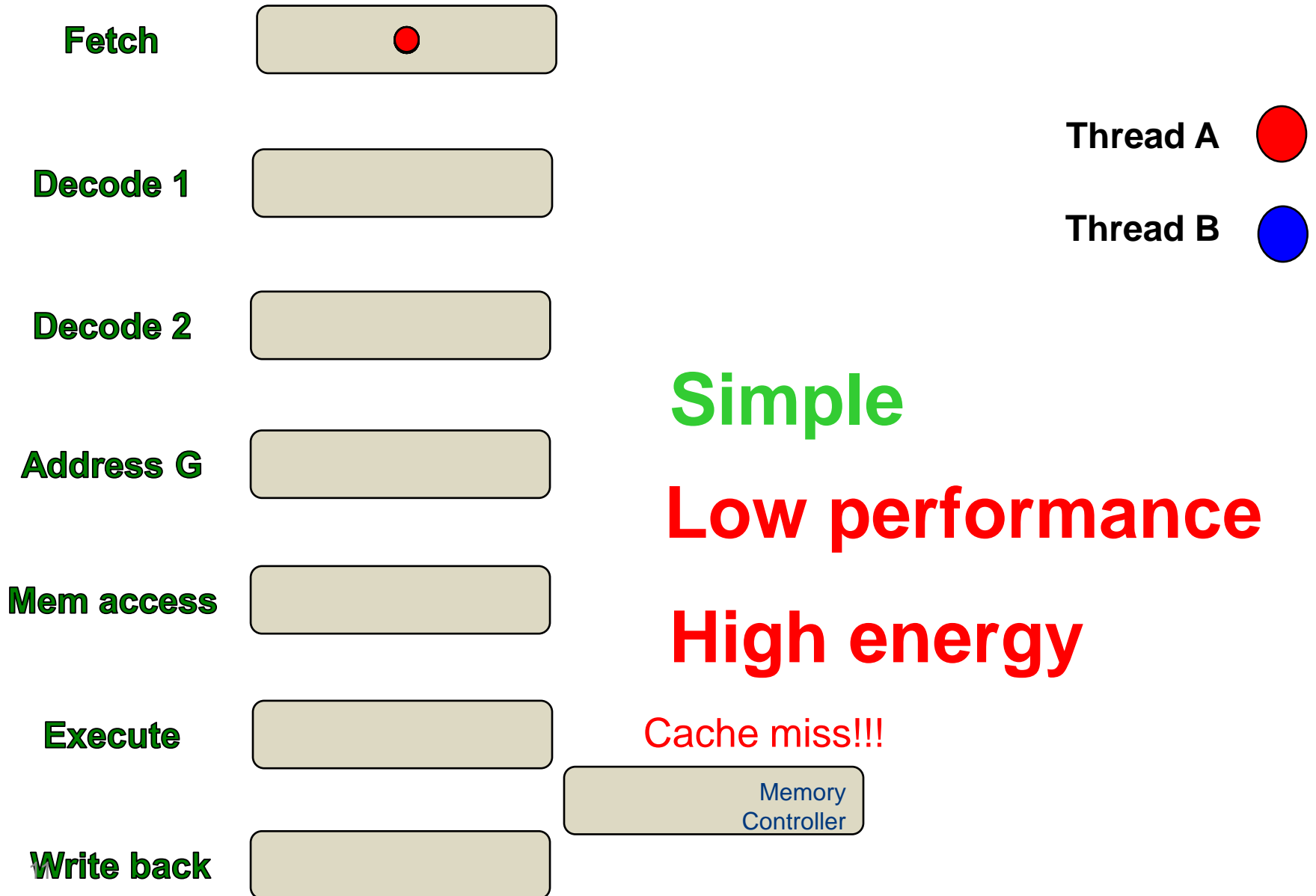


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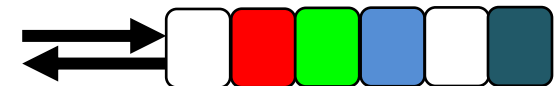
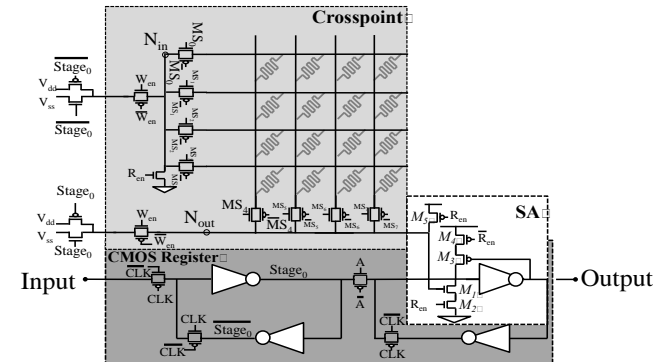
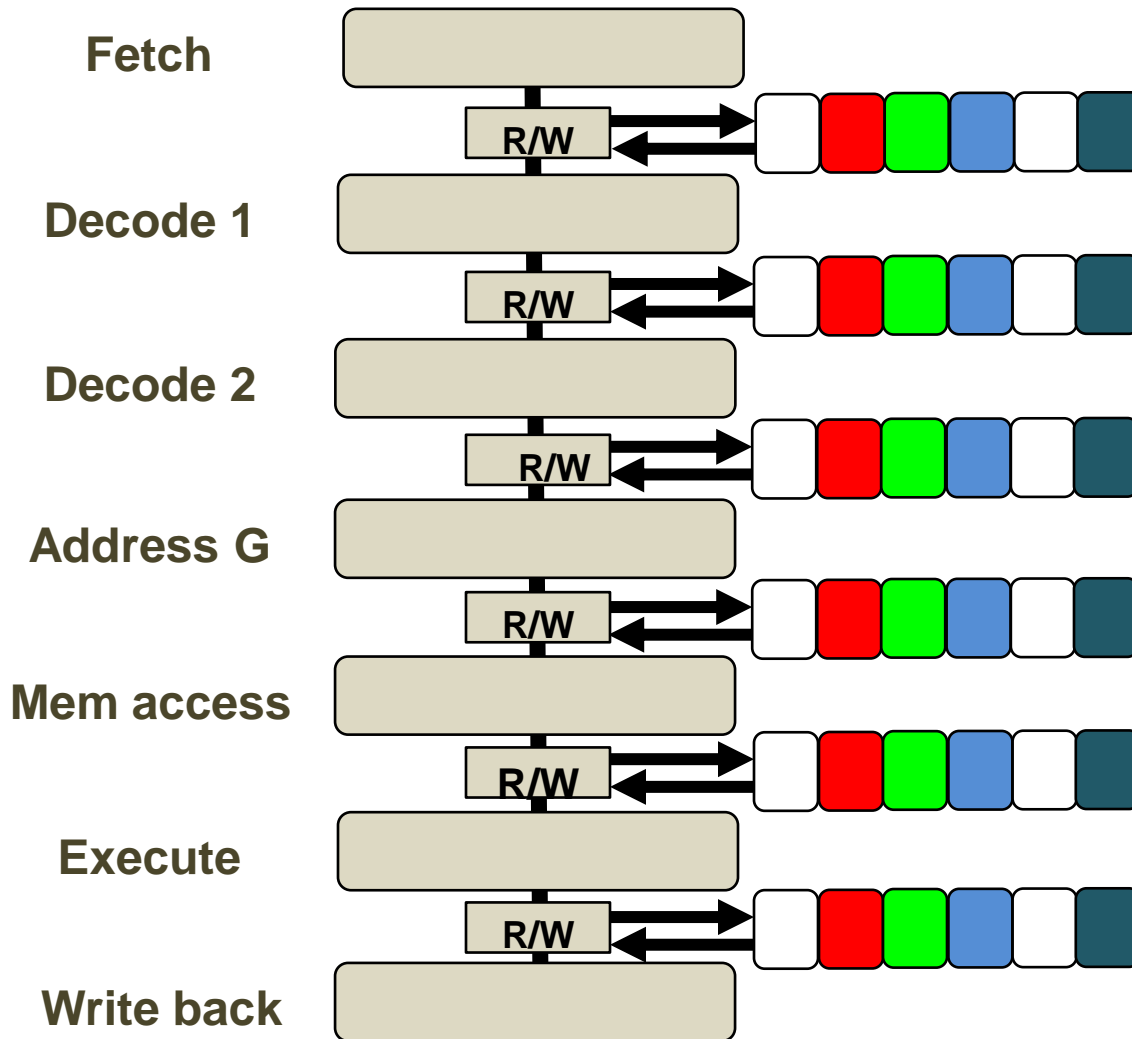


Switch on Event Multithreading



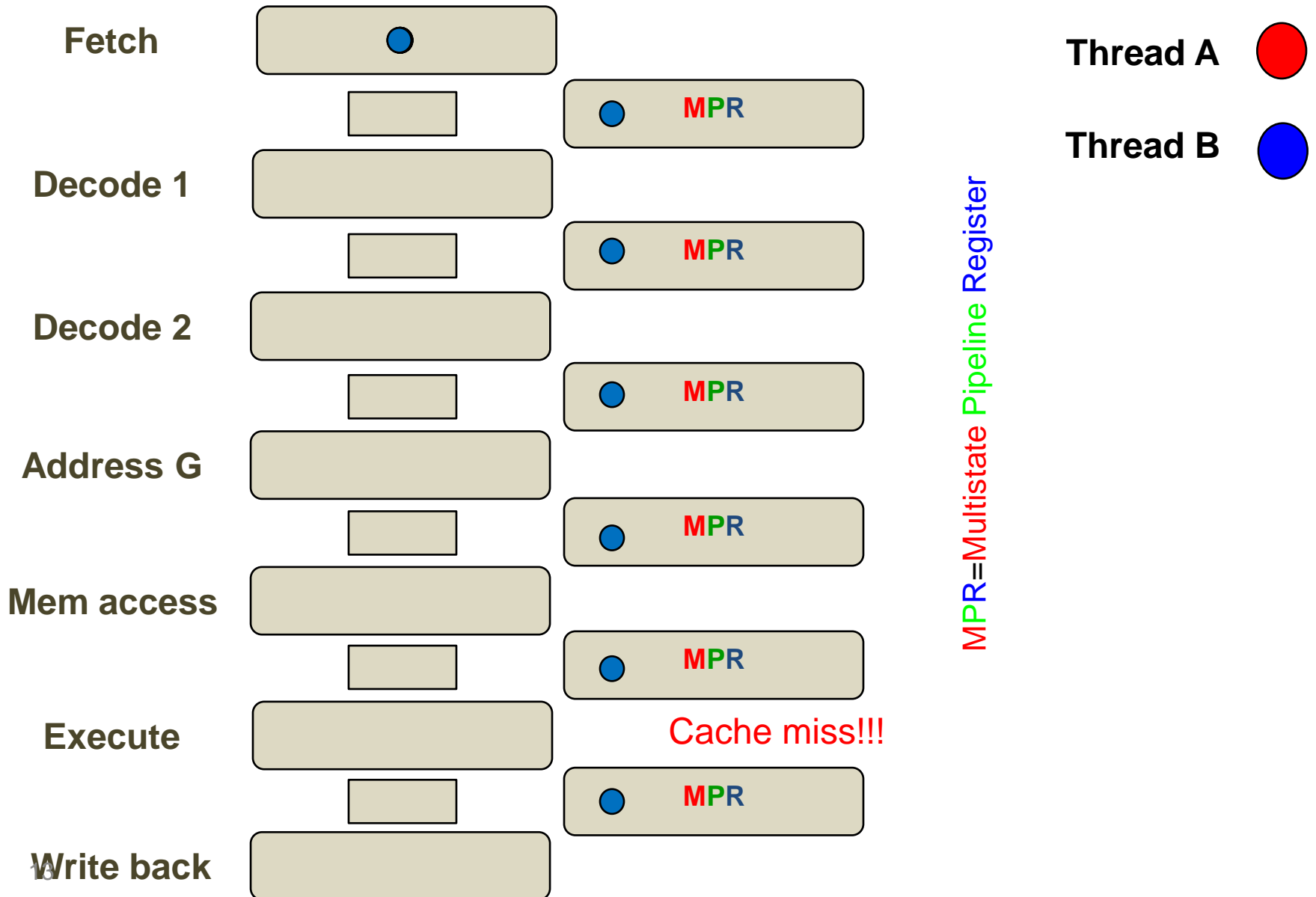
Multistate Pipeline Register

Novel Memory Structure



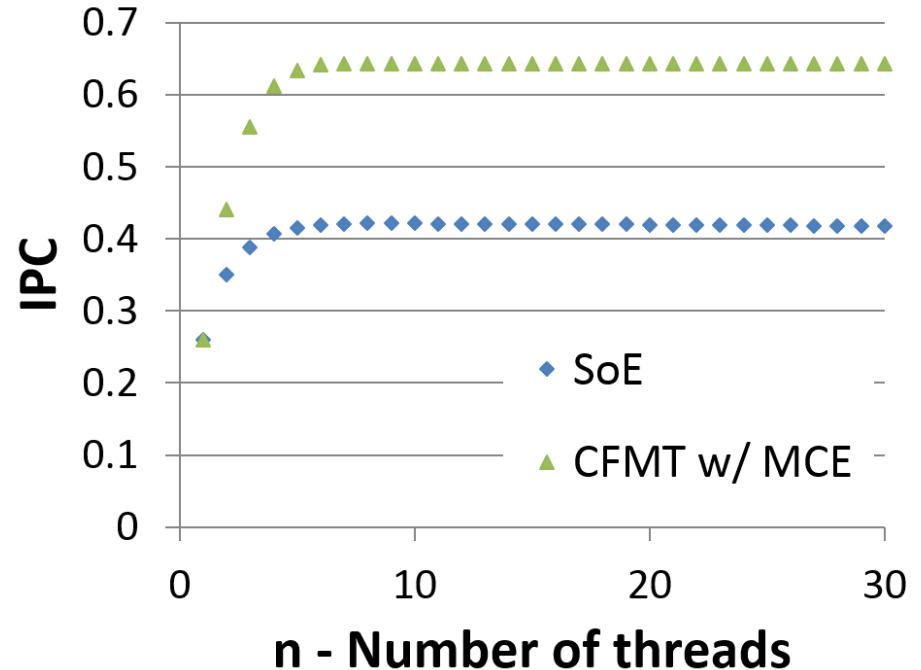
Multistate
Pipeline
Register (MPR)

Continuous Flow MT (CFMT)



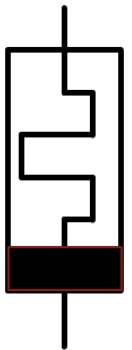
CFMT – A Novel μ Architecture

- Simplicity of SoE MT
- Novel memory structure - MPR
- No pipeline flush
 - Enhance performance (40% avg. improvement)
 - Reduce energy (6.5% avg. reduction)



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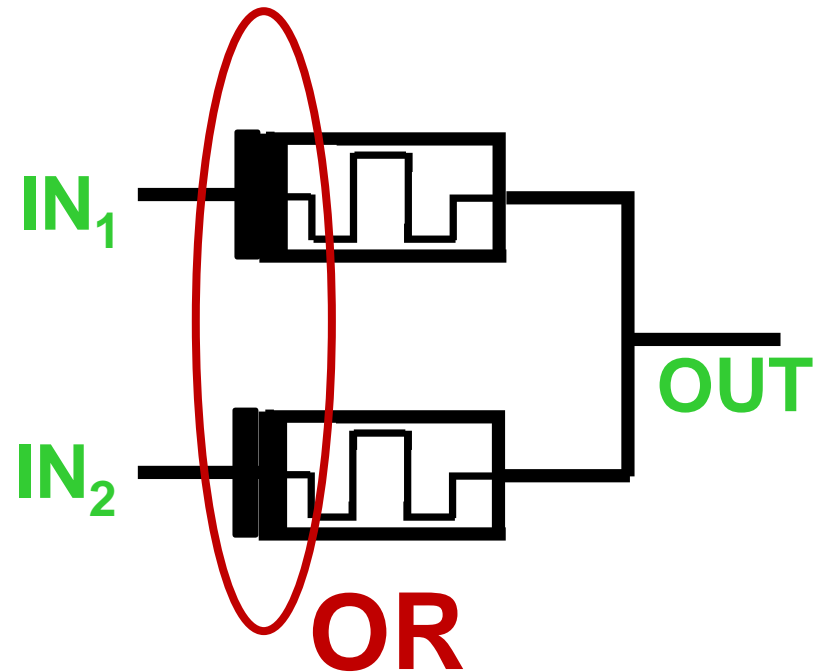
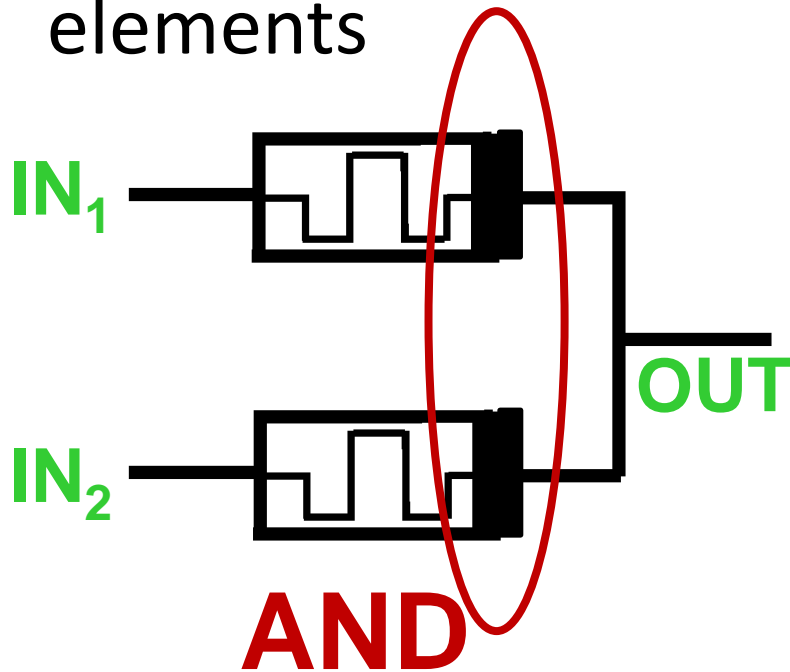
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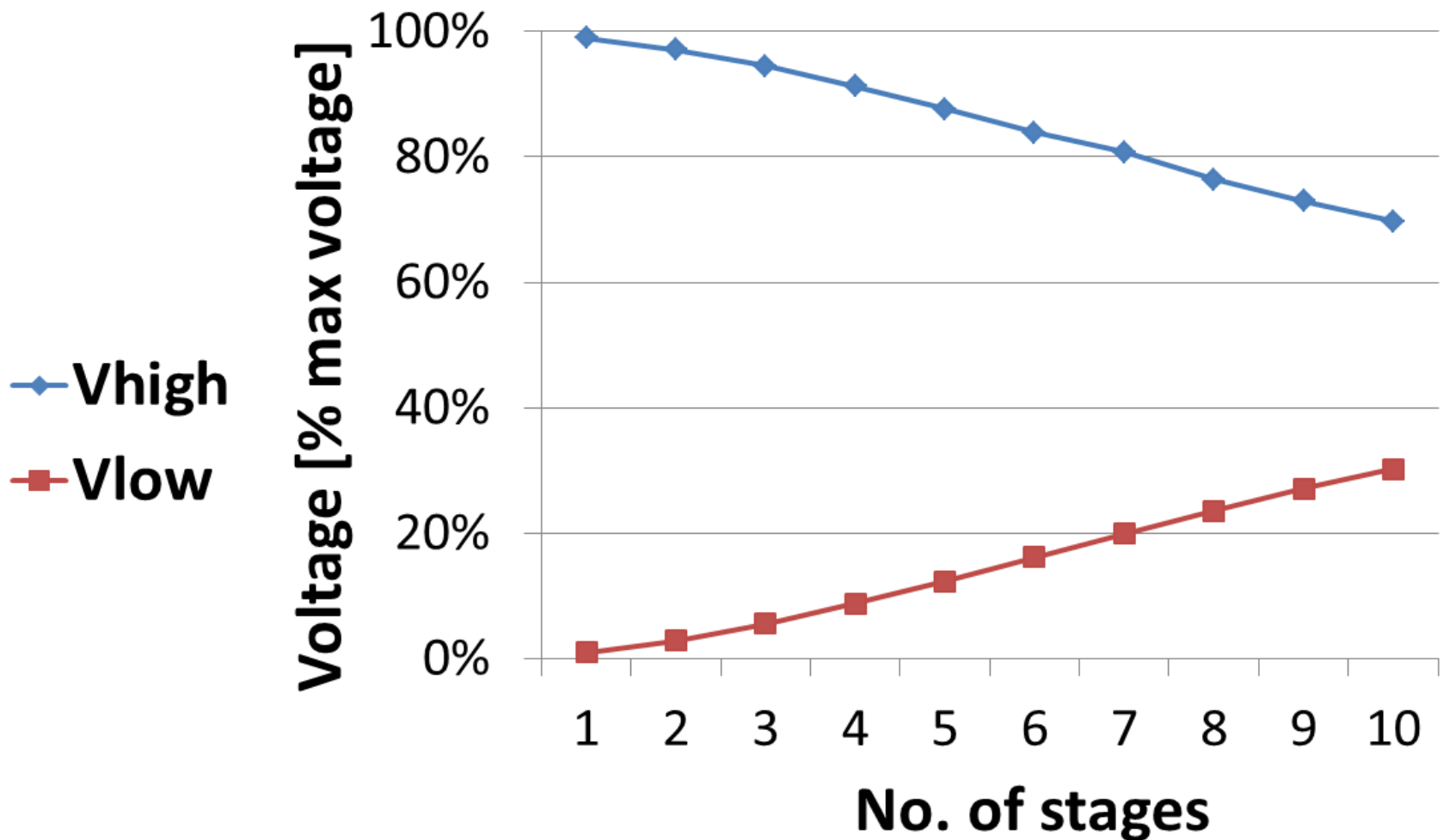
Memristor Ratioed Logic (MRL)

Enhancing computation

- Similar to CMOS logic
- Using CMOS for inversion and amplification
- Memristors operate only as computational elements

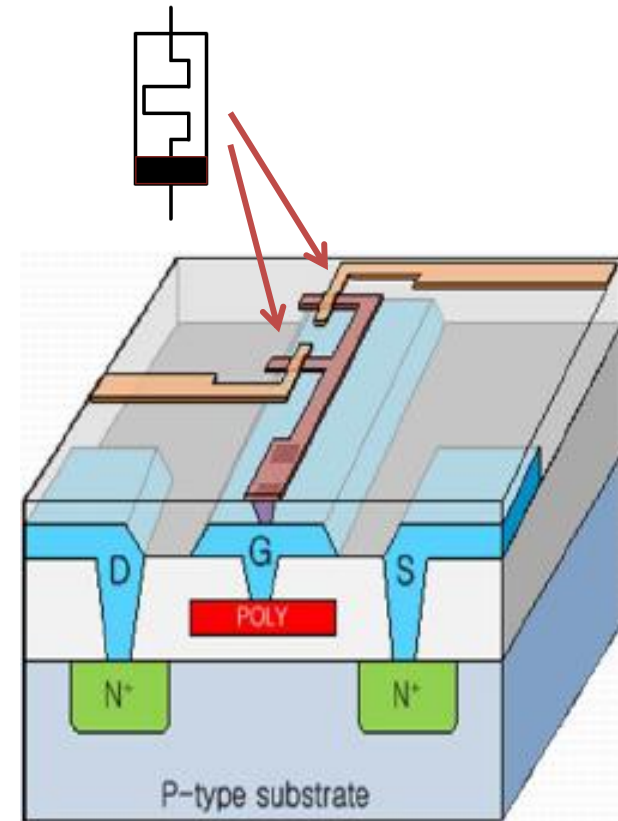
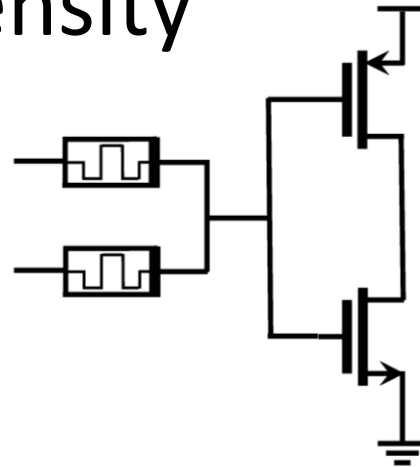


Need for Amplification



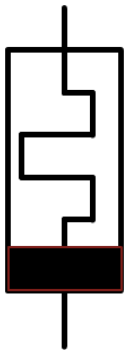
Extending CMOS Technology

- Integrating MRL with CMOS logic:
 - Signal restoration
 - Inversion
- Increase logic density



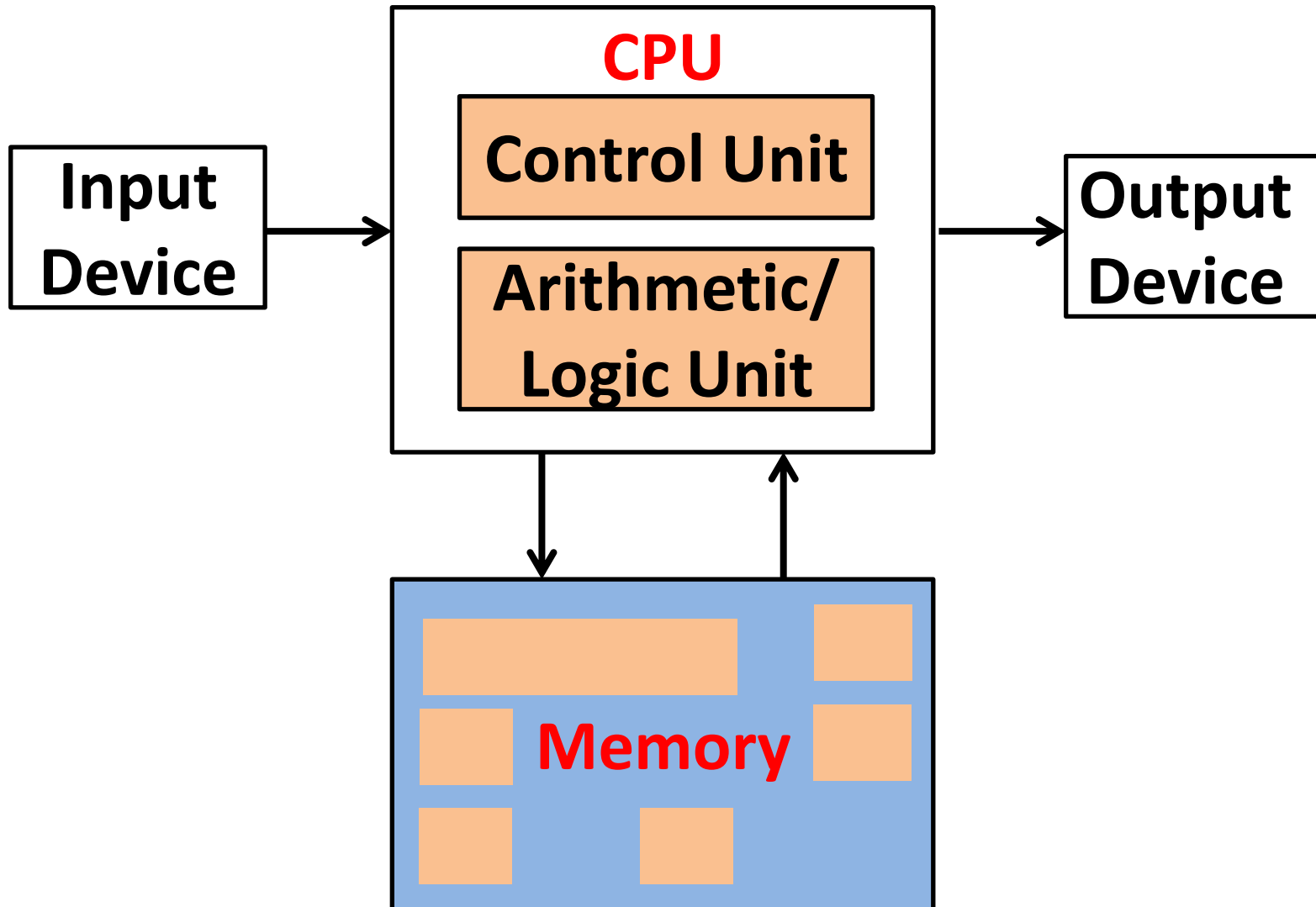
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Logic within the Memory

Beyond von Neumann Architecture



Logic within the Memory

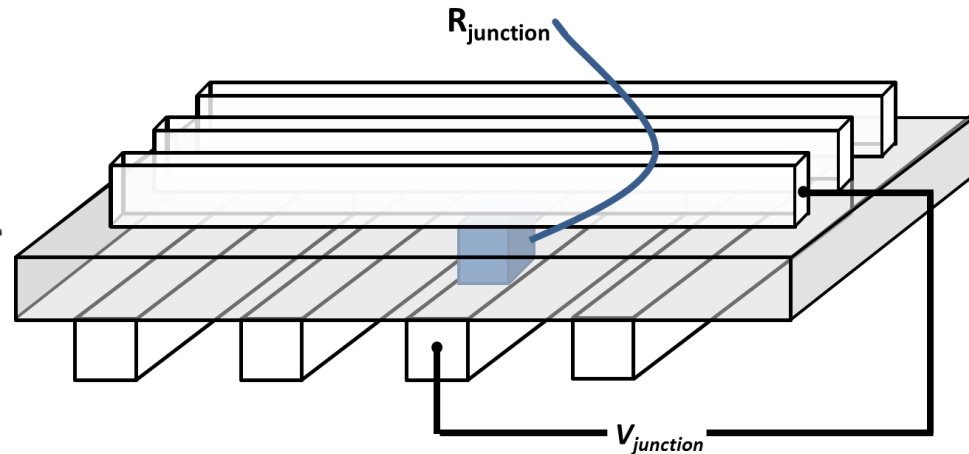
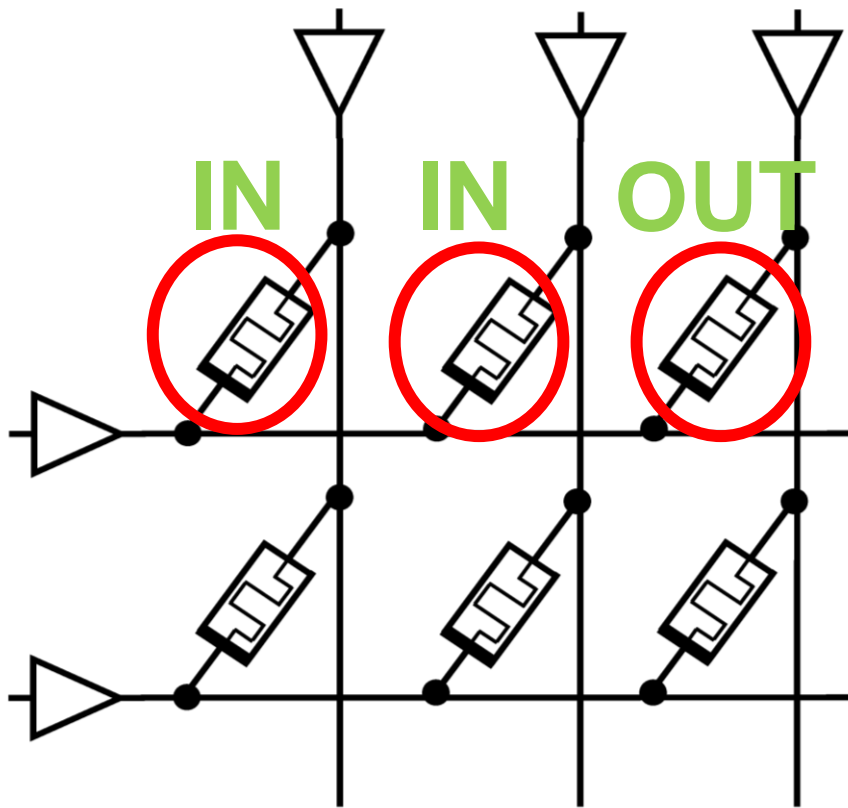
Example – Image Processing

- CPU
- Accelerators – GPU
- Logic within the memory



Logic within Memristor Memory

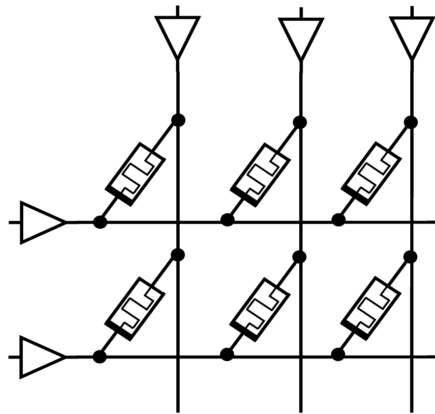
- Based on memristor-based crossbar memory
- $R_{ON} \rightarrow$ logical '1', $R_{OFF} \rightarrow$ logical '0'



Logic within Memory

Our Contribution

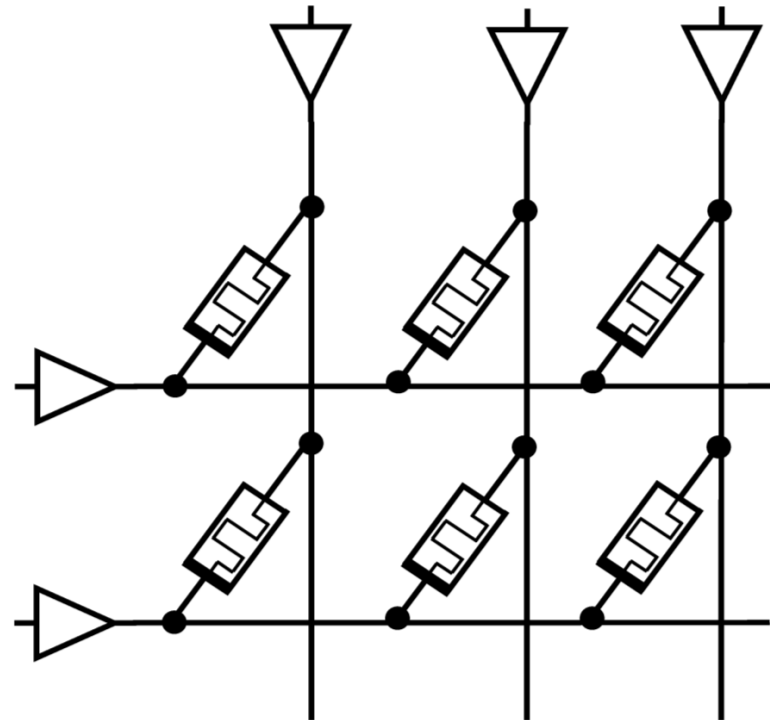
- Crossbar circuit analysis and design
- Coding for memristive crossbars
- Design methodology for material implication



Logic within Memory

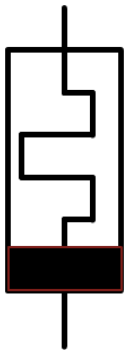
Current Research

- Parallel and dynamic computation within memory
- New logic families
 - MAGIC
 - Systolic arrays



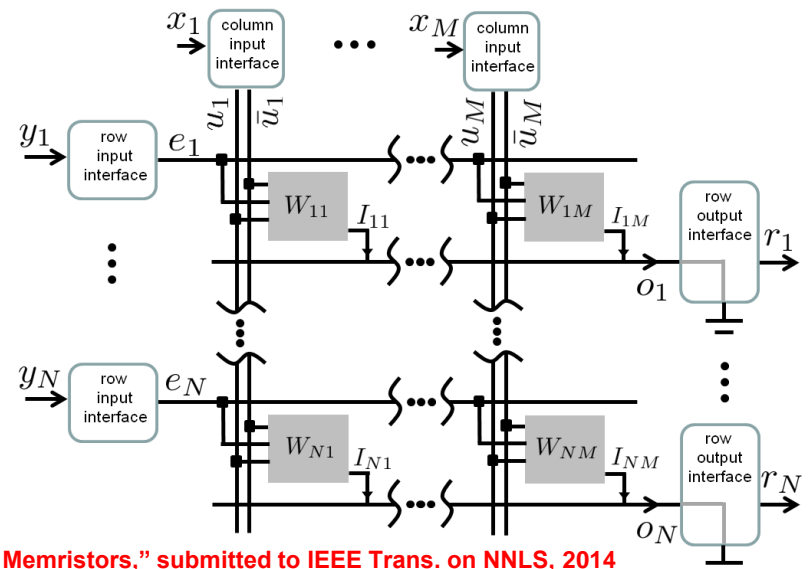
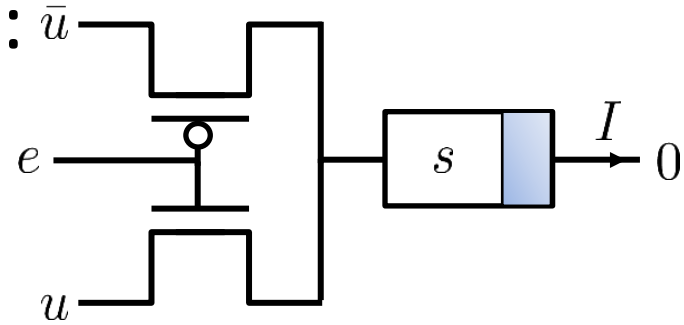
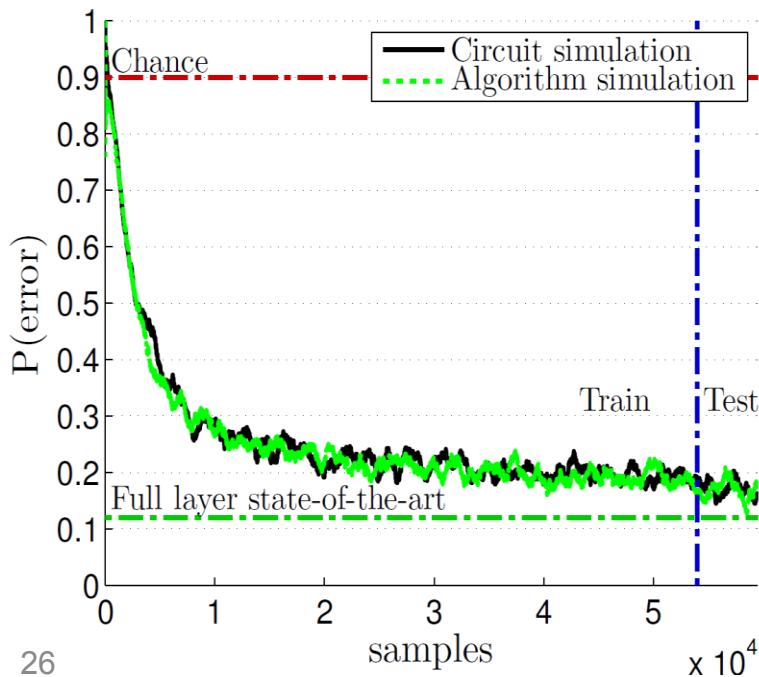
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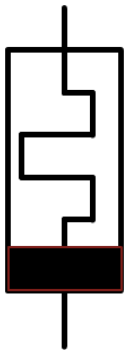
Learning with Memristors

- Implementing many learning algorithms (gradient descent training)
- Significant reduction in area:
 - 3 components vs. 70



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Summary

- Memristors are **not just** memory

Enhancing CPU performance

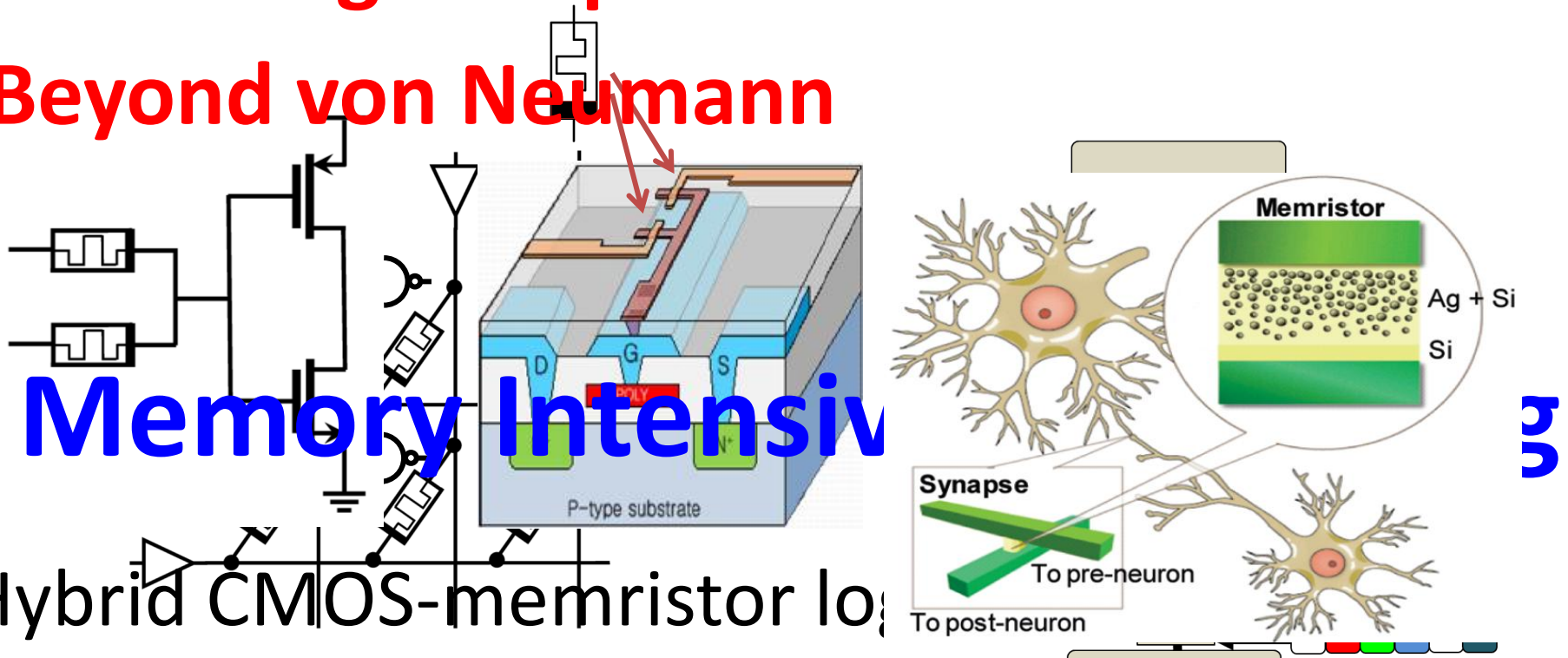
Beyond von Neumann

Memory Intensive

Hybrid CMOS-memristor logic

Logic within memory

Neuromorphic
Novel memory structures



Thanks!

<http://memristor.shorturl.com>

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