

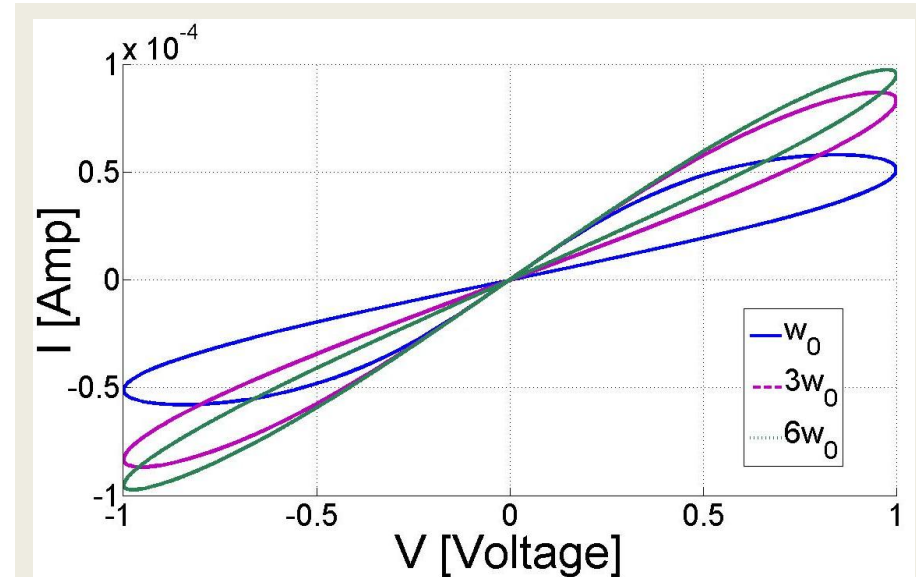
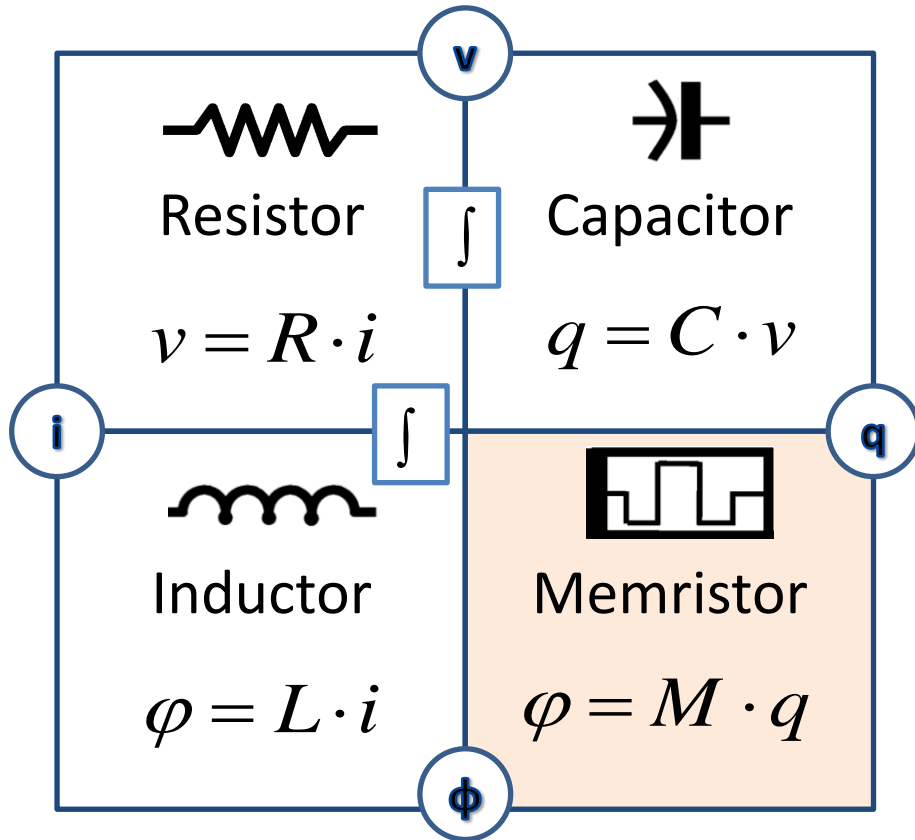
# Memristors: Not Just Memory

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May 2013

# Memristors

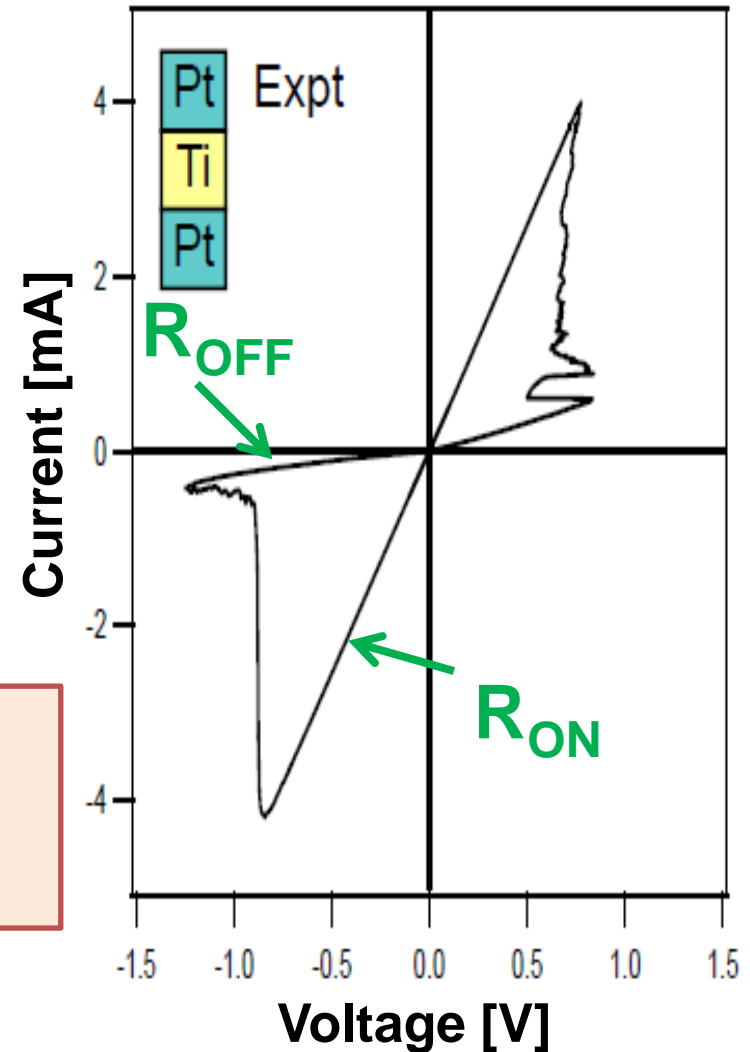
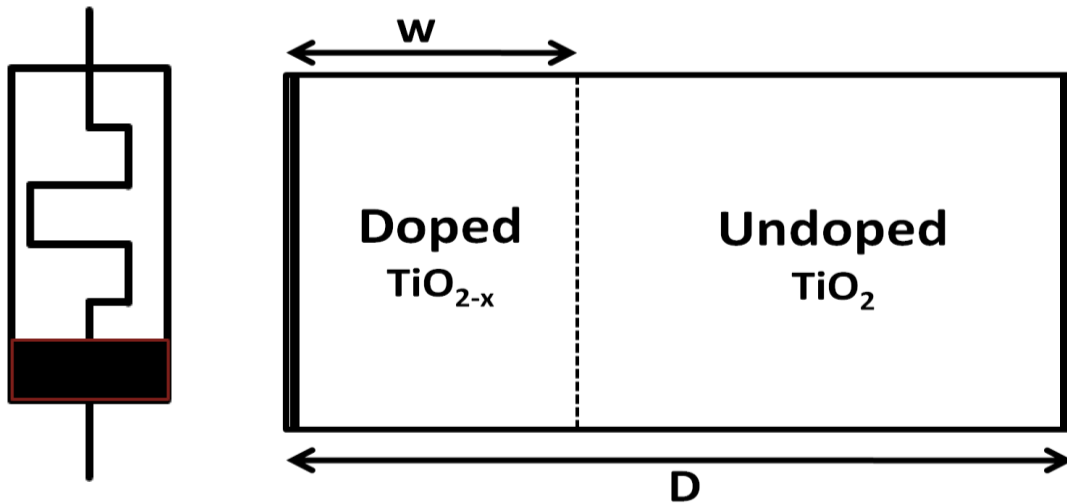


$$v = M(x, i) \cdot i$$

$$\frac{dx}{dt} = f(x, i)$$

# Memristors are Real!

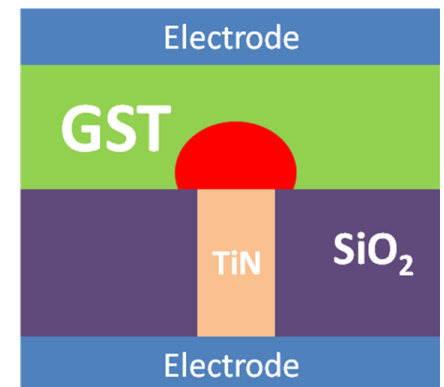
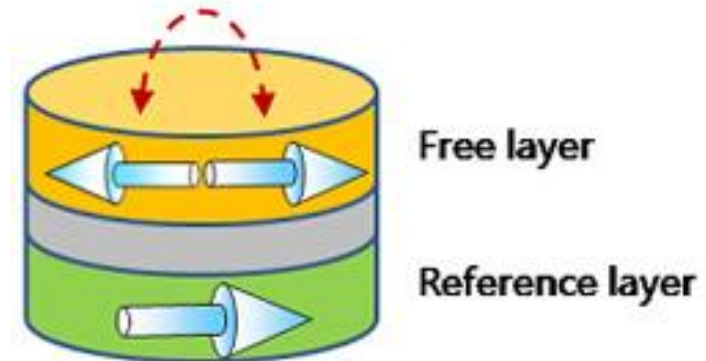
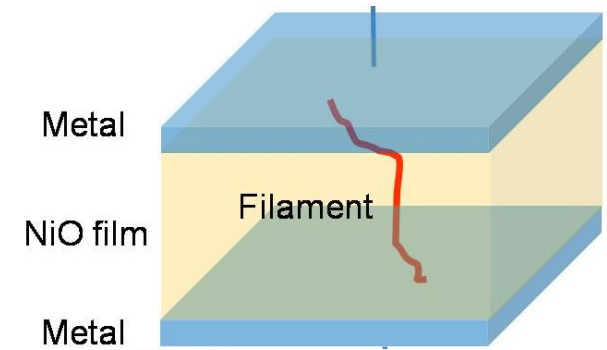
- 2008 Hewlett Packard



$$M(q) = R_{OFF} \left( 1 - \frac{\mu_v R_{ON}}{D^2} q(t) \right)$$

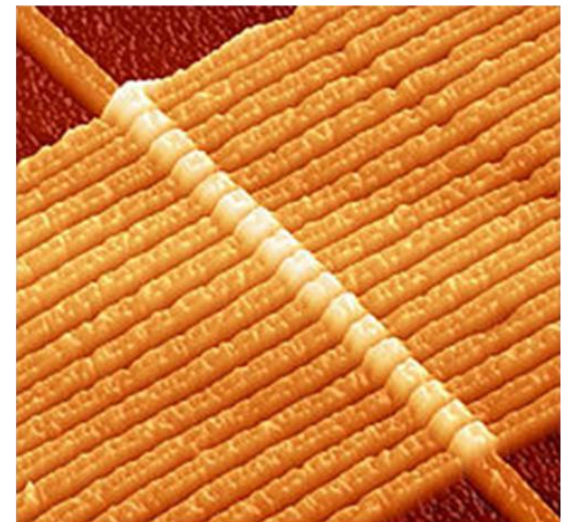
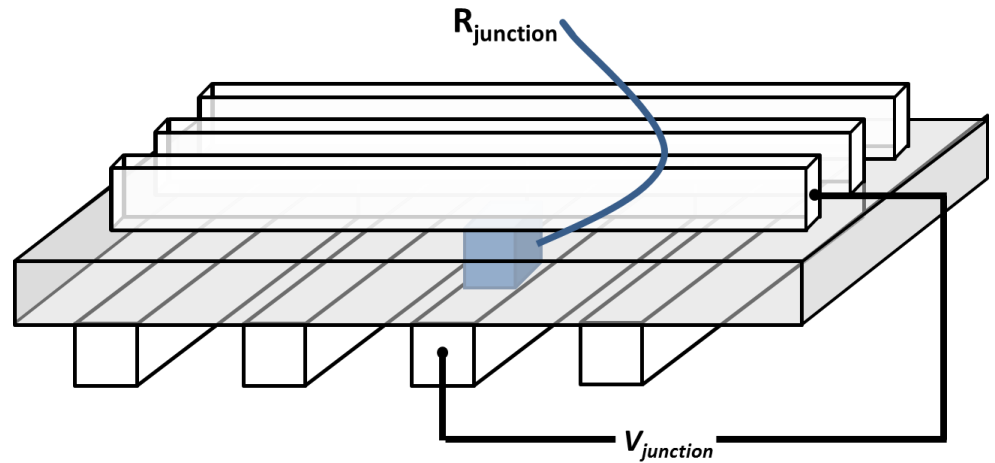
# More Memristors

- ReRAM
- STT-MRAM
- Spintronic memristors
- Organic memristors
- Phase-change memory



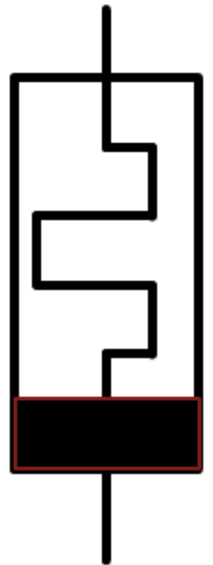
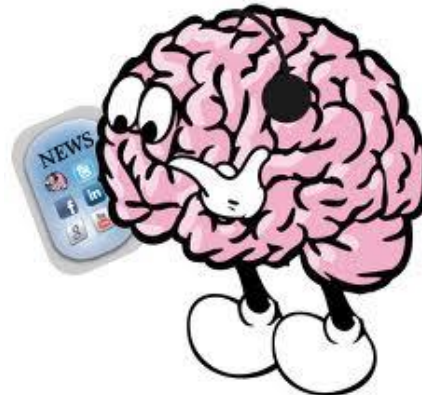
# Memristors are the Next Memory

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

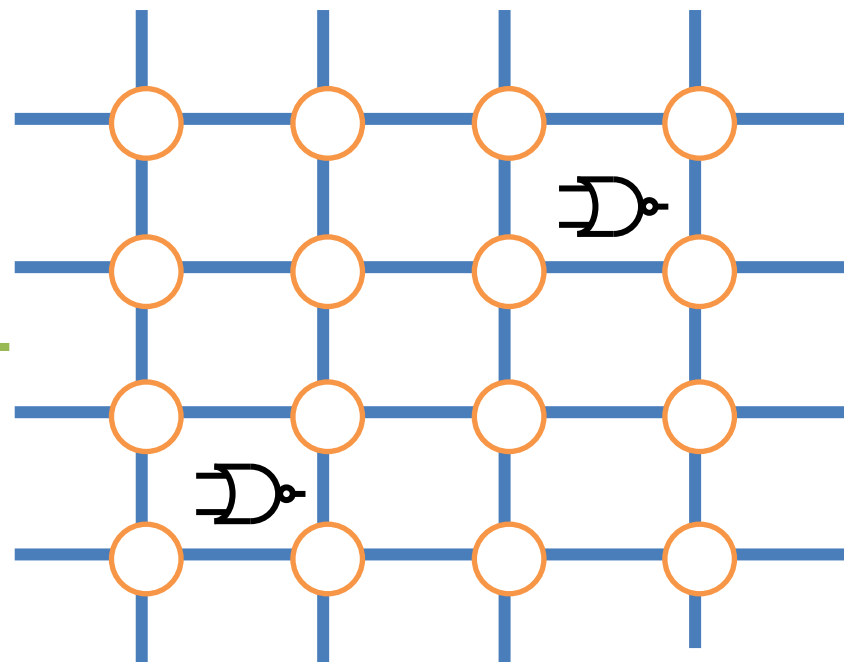
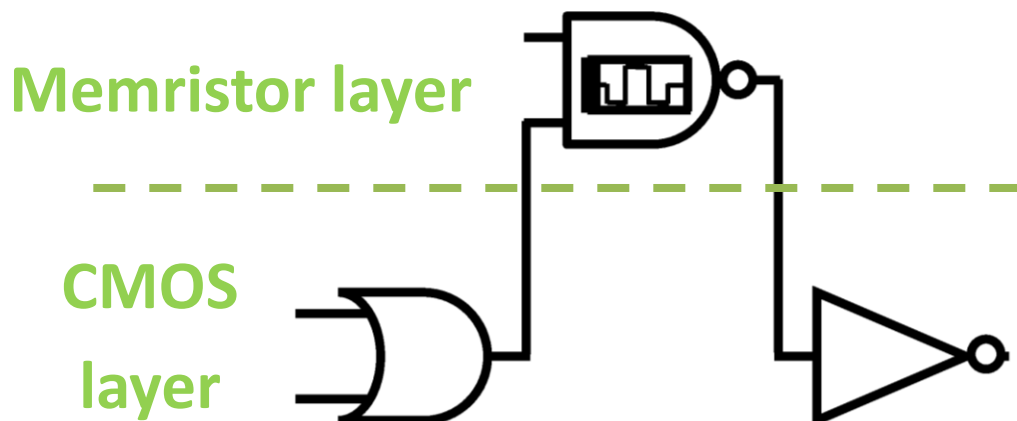


# Not Just Memory

- Logic circuits
- Analog circuits
- Neuromorphic systems
- Sensors
- New architectures



# Why Use Memristors in Logic?



**Integrating memristors  
with standard logic**

**Beyond Moore**

Save die area

More logic on die

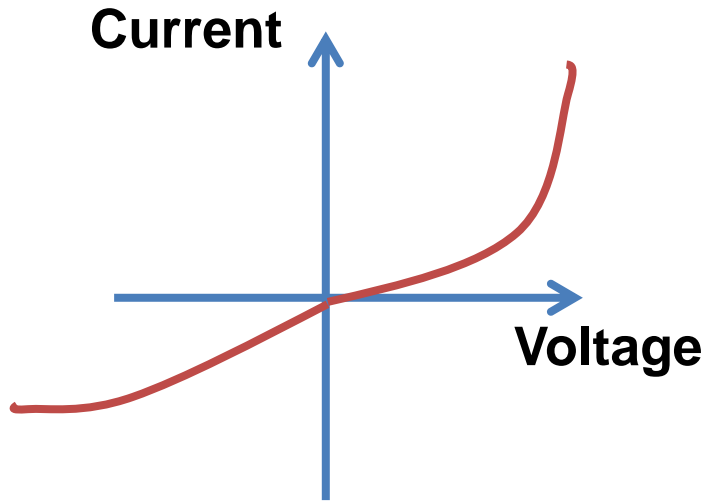
**Logic within the  
memory**

**Beyond Von-Neumann**

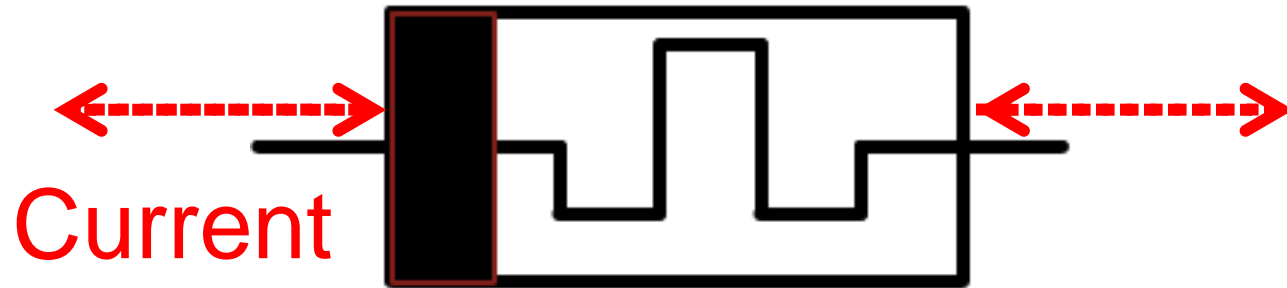
Flexible

Save power, BW

# Memristor Polarity



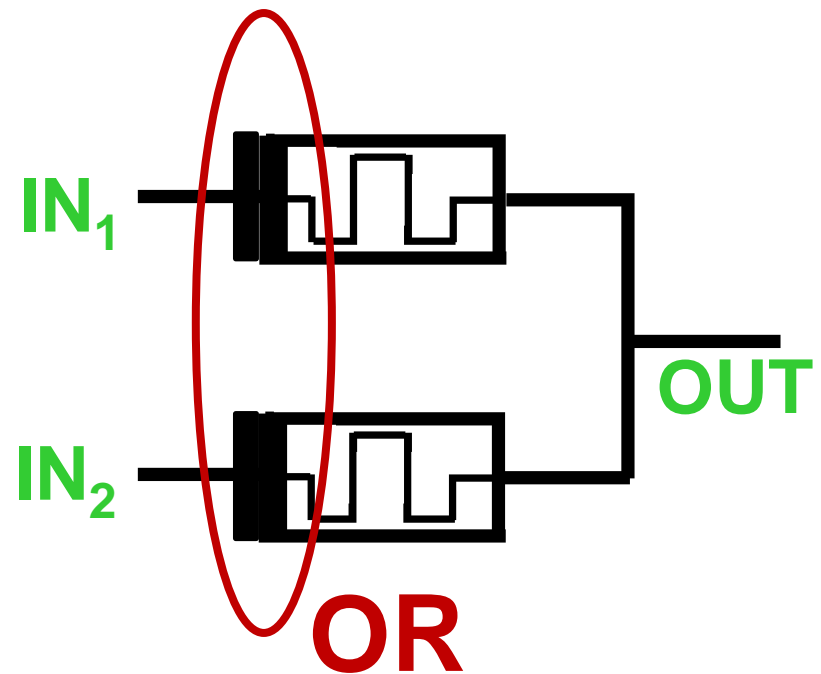
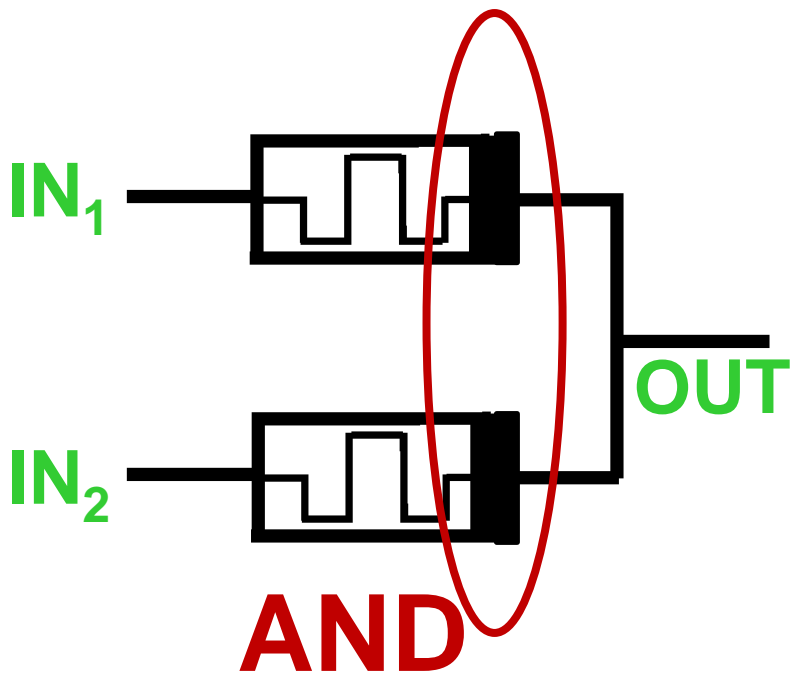
Decrease resistance





# Memristor Ratioed Logic (MRL)

- Voltage as logical state
- Memristors only as computational elements

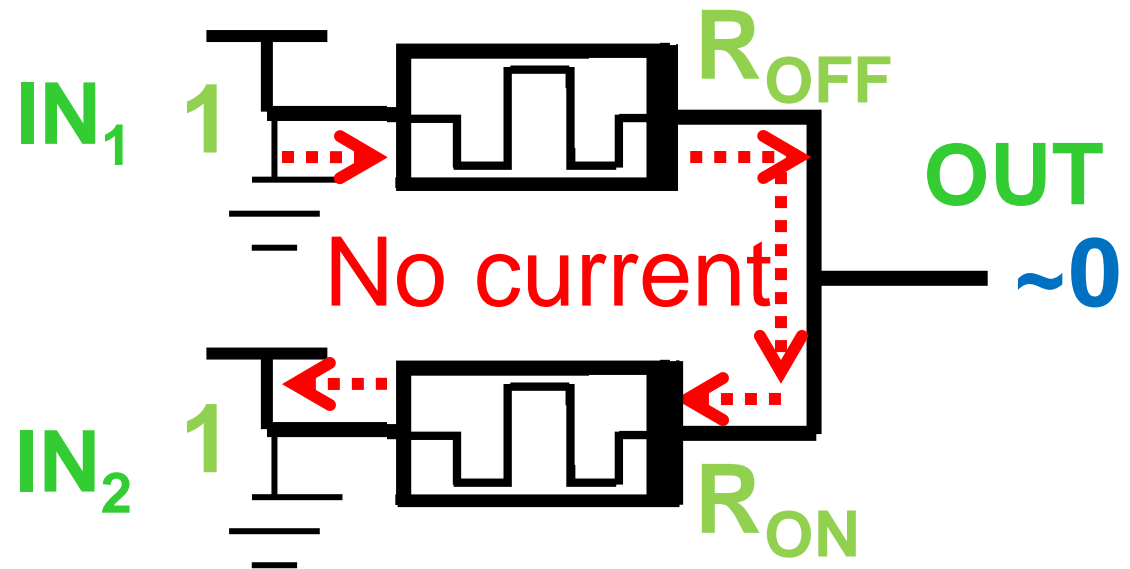


# AND Operation

$$V_{OUT} = V_{CC} \cdot \frac{R_{ON}}{R_{ON} + R_{OFF}} \approx V_{CC} \cdot \frac{R_{ON}}{R_{OFF}} \ll V_{CC}$$

Increase resistance

IN <sub>1</sub>	IN <sub>2</sub>	AND
0	0	0
0	1	0
1	0	0
1	1	1

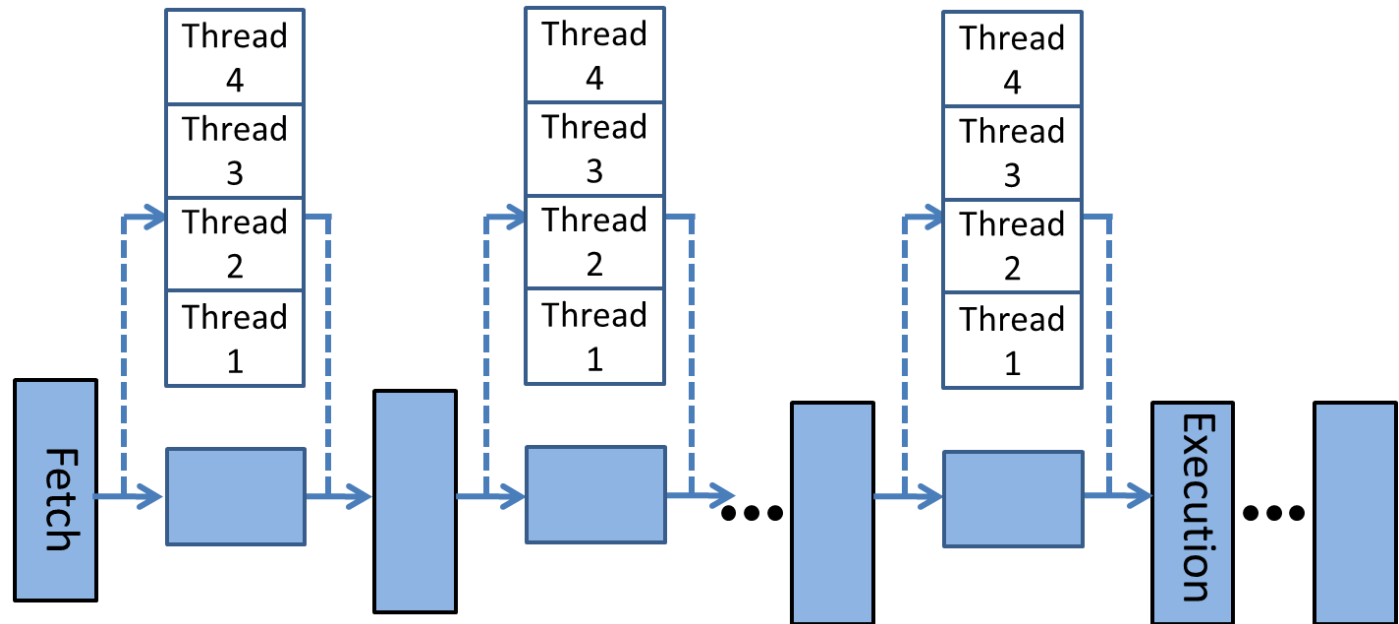


Decrease resistance

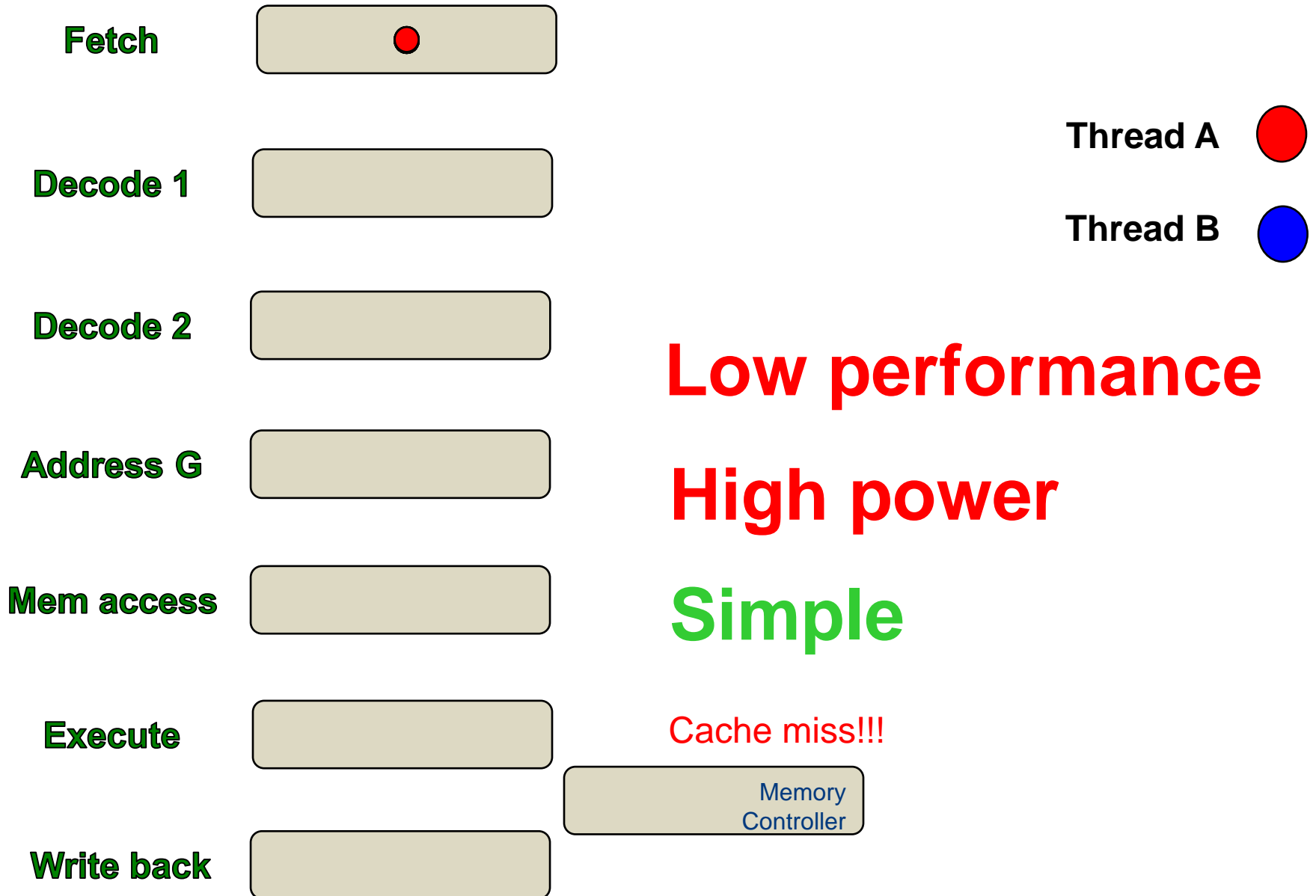
$$R_{OFF} \gg R_{ON}$$

# New Architectures

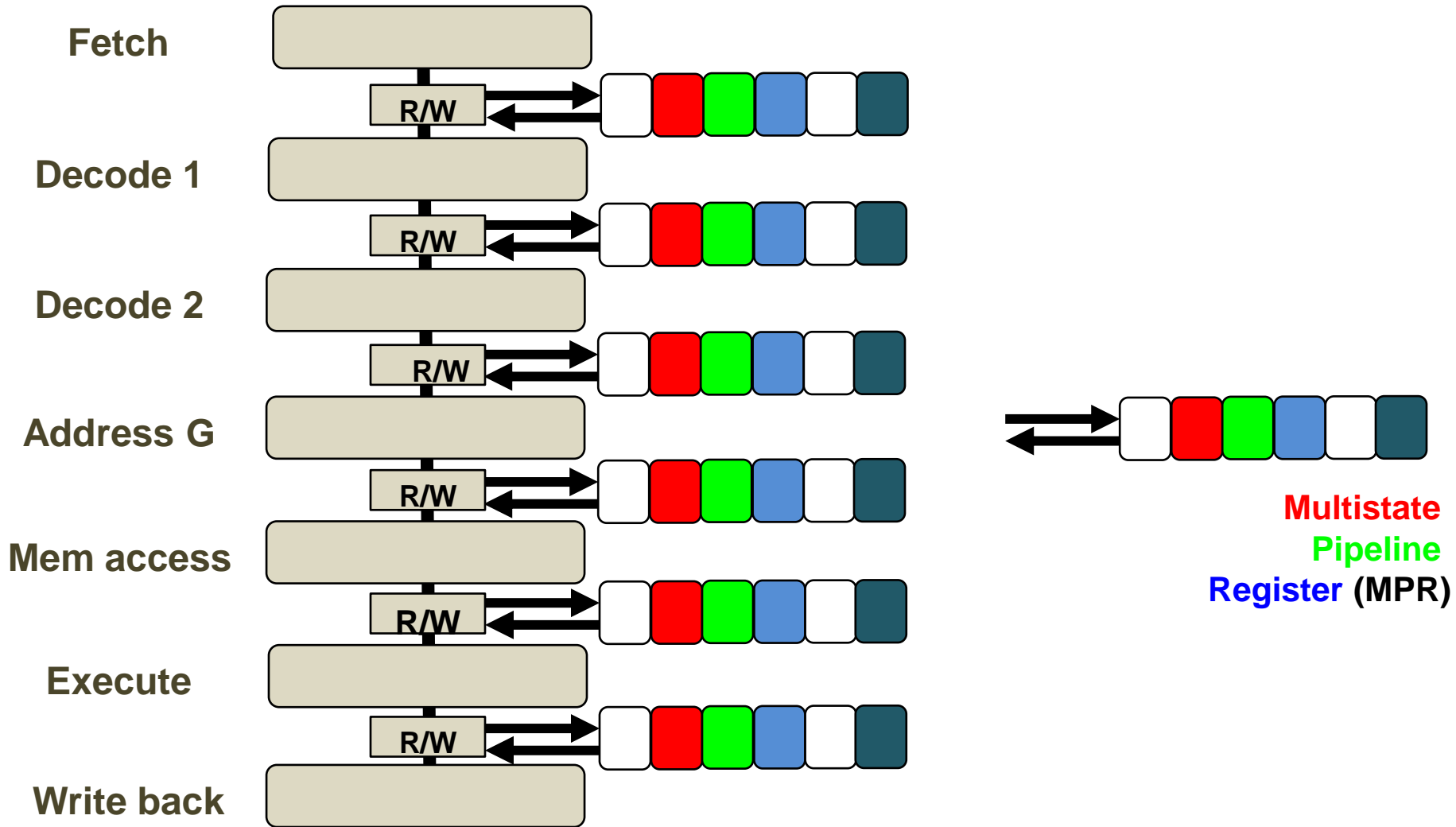
- Memory intensive computing
- Sea of memory



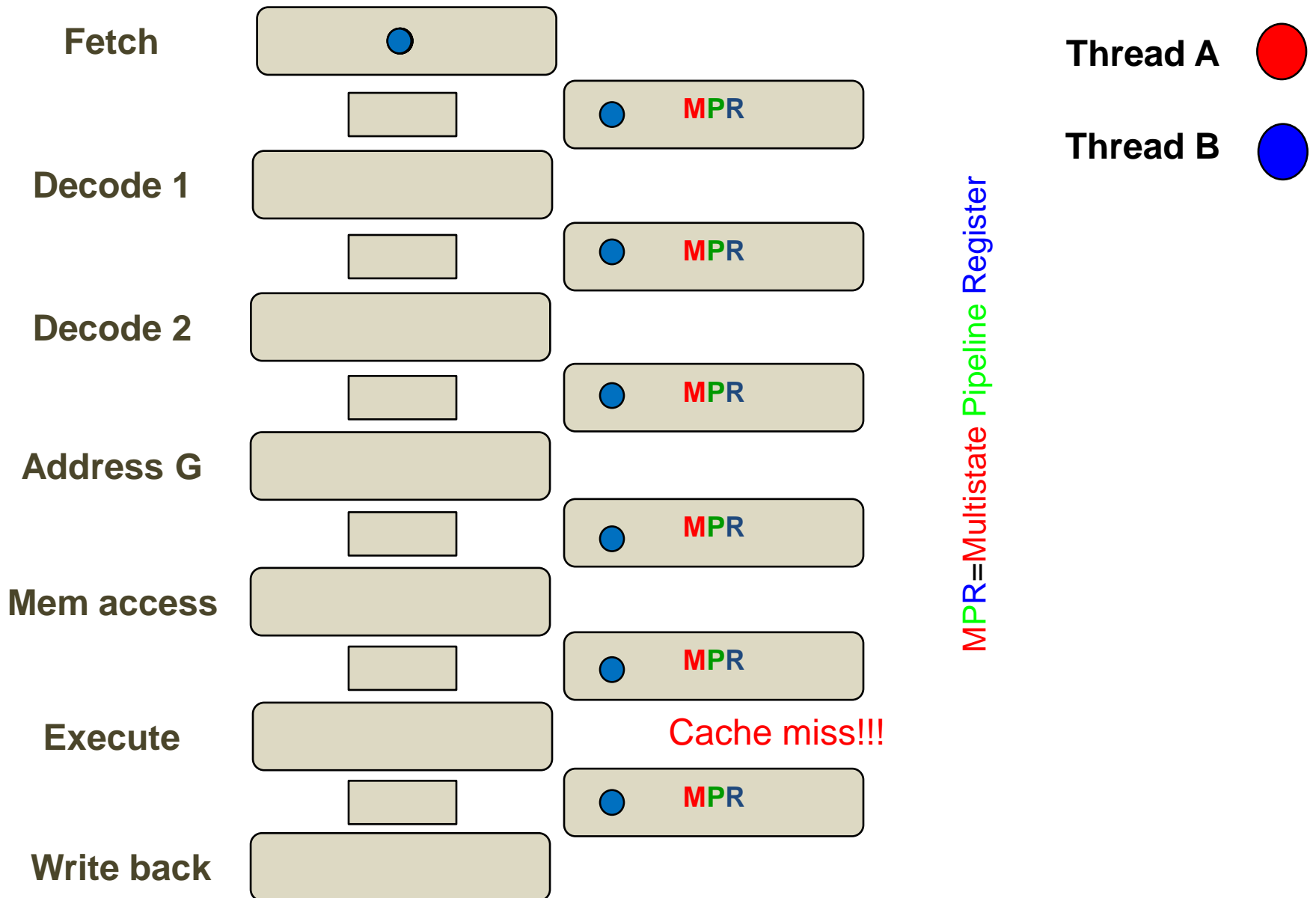
# Switch on Event Multithreading



# Continuous Flow MT (CFMT)

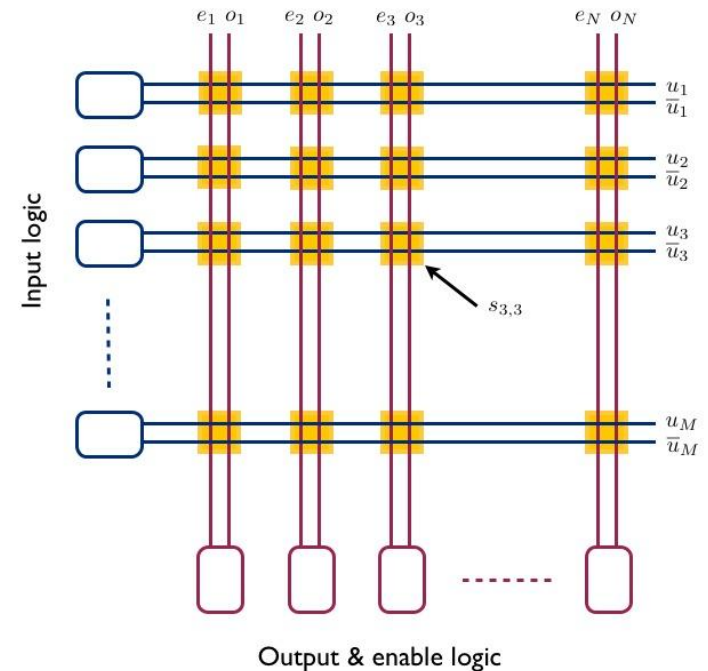
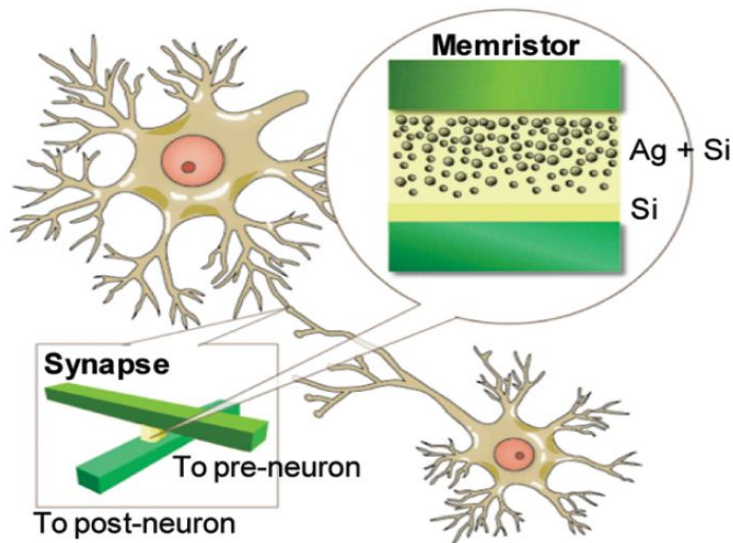


# Continuous Flow MT (CFMT)



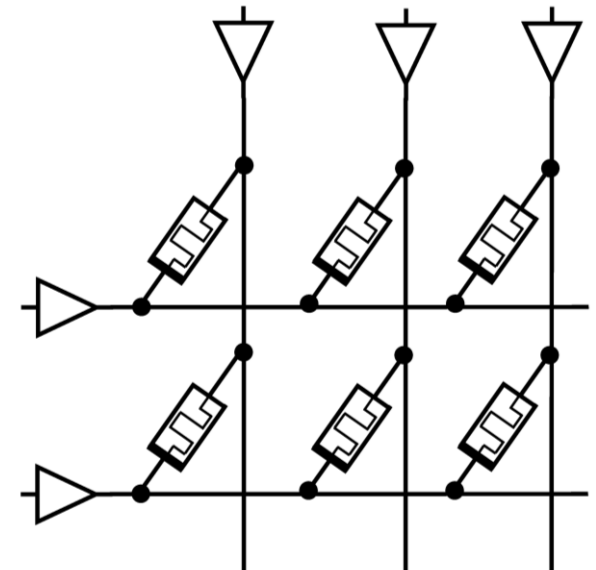
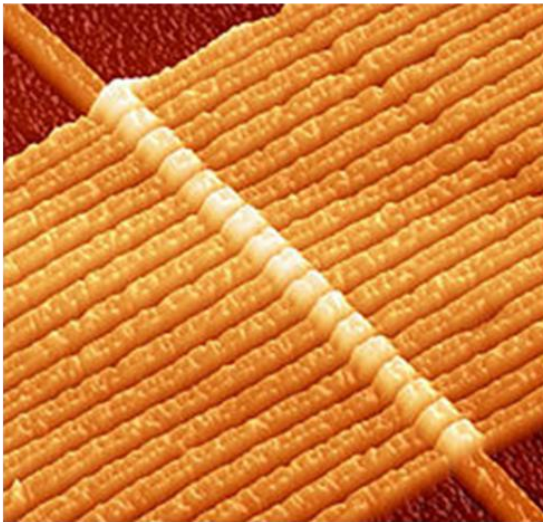
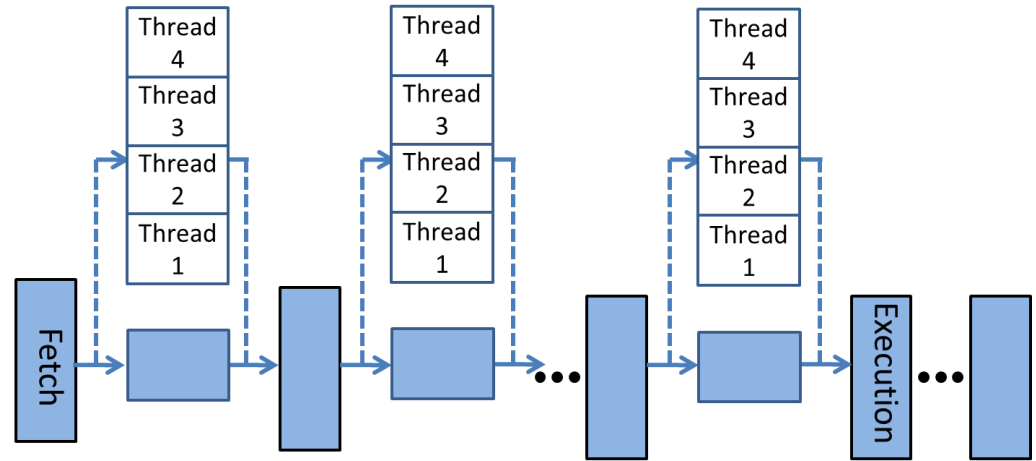
# Neuromorphic

- Memristor as a synapse
- Memristor as a neuron



# Summary

- Next memory
- Think different





# Thanks!

<http://memristor.shorturl.com>