

The Desired Memristor for Circuit Designers

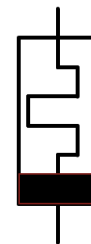
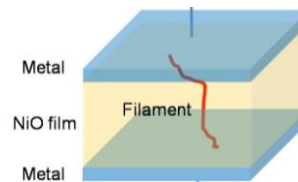
Shahar Kvatinsky, E. G. Friedman,
A. Kolodny, and U. C. Weiser



Technion – Israel Institute of Technology
Nature Conference June 2012

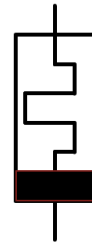
Currently There is No Standard for Memristive Devices

- Many types:
 - Resistive switches
 - STT MRAM
 - PCM
 - ...



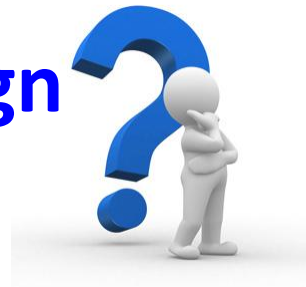
Different Applications Require Different Memristors

- Memory
- Logic
- Analog circuits
- Neuromorphic systems
- More?



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**What is the required
memristor for
circuit design**



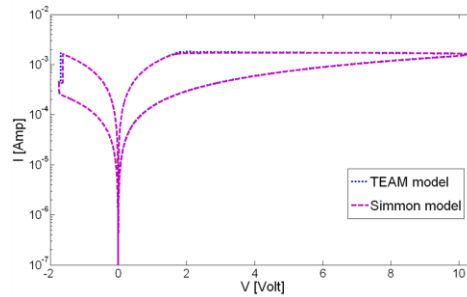
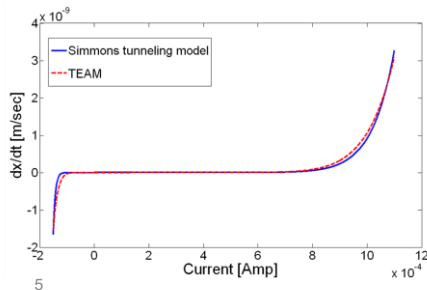
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General Model – TEAM

ThrEshold Adaptive Memristor

- Tunable nonlinearity
- Current threshold

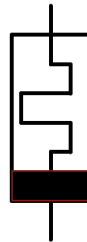
$$\frac{dx(t)}{dt} = \begin{cases} k_{off} \cdot \left(\frac{i(t)}{i_{off}} - 1\right)^{\alpha_{off}} \cdot f_{off}(x), & 0 < i_{off} < i \\ 0, & i_{on} < i < i_{off} \\ k_{on} \cdot \left(\frac{i(t)}{i_{on}} - 1\right)^{\alpha_{on}} \cdot f_{on}(x), & i < i_{on} < 0, \end{cases}$$



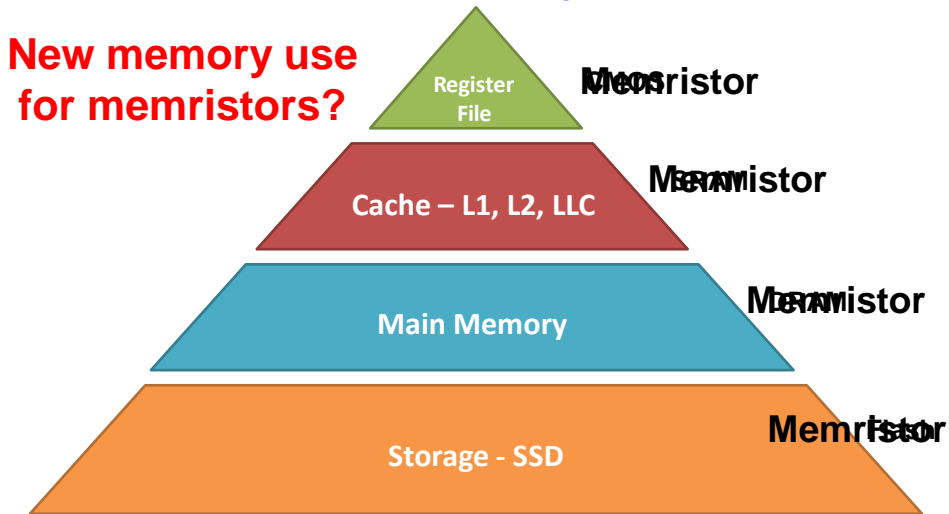
S. Kvatinsky et al, "TEAM: ThrEshold Adaptive Memristor Model," TCAS I, 2012

Desired Properties Shared by All Applications

- Low power consumption
- Good scalability
- Long data retention
- High endurance
- Manufacturing compatibility with CMOS
- Voltage compatibility with CMOS



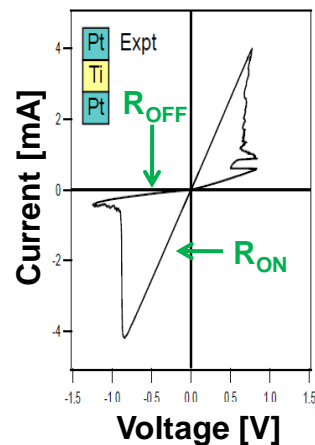
Memristors in Every Memory Hierarchy



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Store Digital Data with Memristors

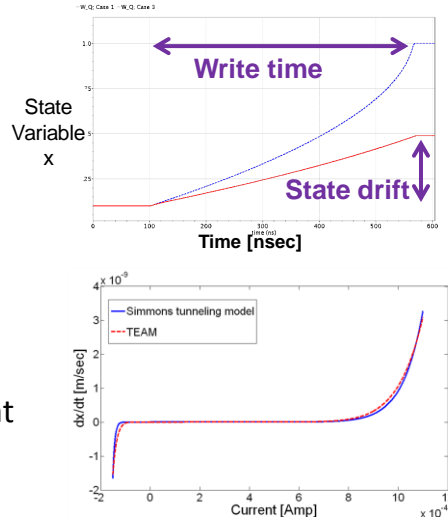
- Logical value as resistance
- Multi level memory
- Different dosage<<<?>>> for different memory hierarchies:
 - Speed
 - Endurance
 - Size



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Desired Memristor for Memory

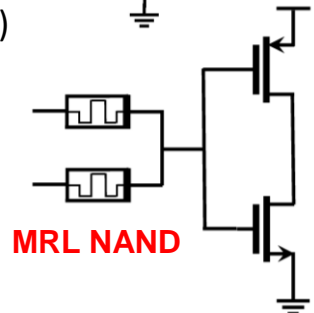
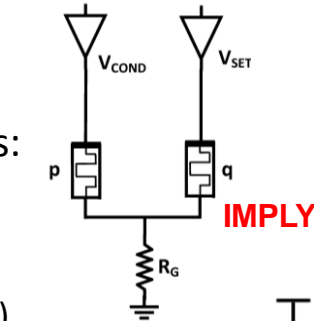
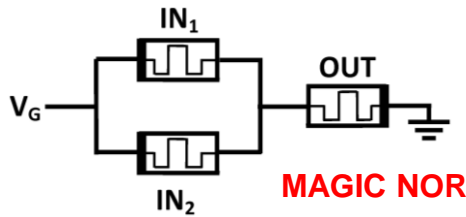
- Distinct values – high R_{off}/R_{on} ratio
- Non-destructive read mechanism:
 - State drift phenomenon
 - Highly nonlinear behavior
 - Threshold – voltage/current



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Memristors as Logical Elements

- Different circuit families of memristor-based logic gates:
 - IMPLY
 - MRL (Memristor Ratioed Logic)
 - MAGIC (Memristor Aided LoGIC)



¹⁰
 S. Kvatinsky et al, "Memristor-based IMPLY Logic Design Procedure," ICCD, 2011
 S. Kvatinsky et al, "MRL: Memristor Ratioed Logic," 2012

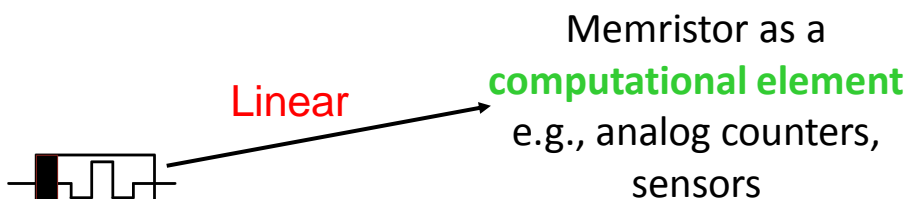
Desired Properties for Memristor as Logic Element

- Digital application – similar to memory
- Depends on logic family:
 - MRL – linear memristor
 - IMPLY, PLA – nonlinear memristor



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Desired Memristor for Analog Circuits



Memristor as a

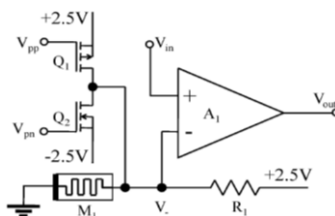
computational element

e.g., analog counters,
sensors

Memristor as a

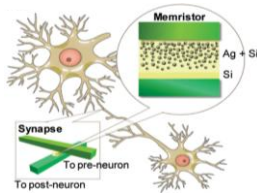
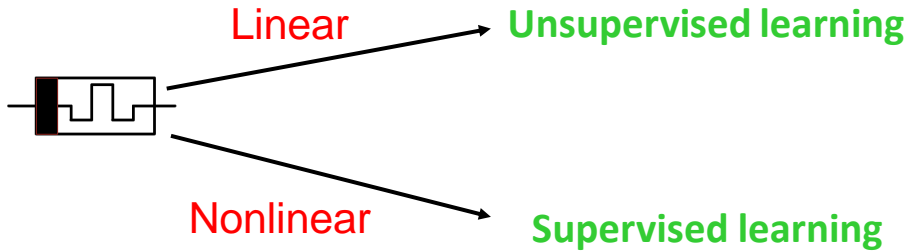
configurable device

Initialization and
operation



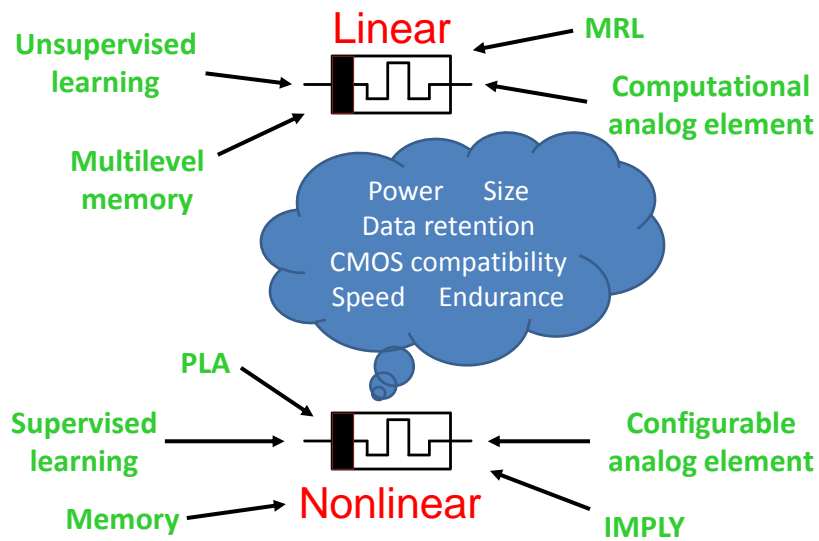
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Desired Memristor to Neuromorphic



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Conclusion: Different Application - Different Memristor



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Discussion

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<http://memristor.shorturl.com/>