The Desired Memristor for Circuit Designers

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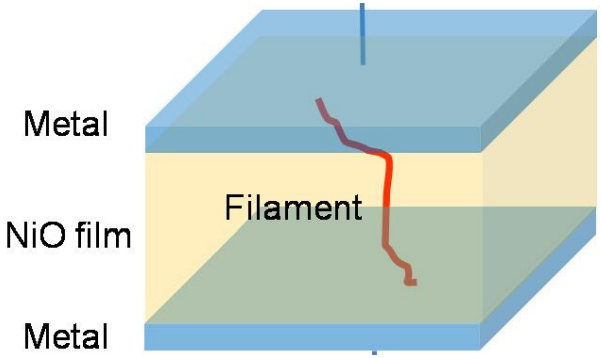
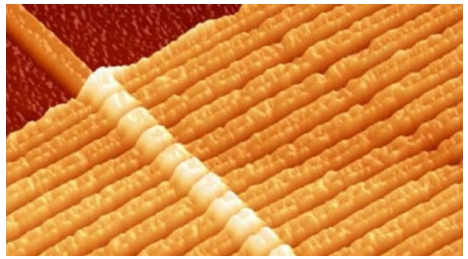
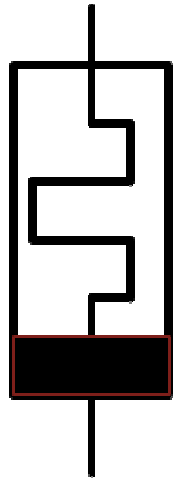
Many Options for Memristive Devices

- Resistive switches
- STT MRAM
- PCM
- CBRAM
- etc.

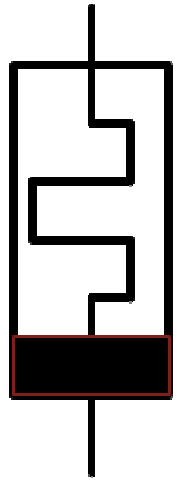






Different Applications Require Different Memristors

- Memristor-based Memory
- Logic gates from memristors
- Analog circuits
- Neuromorphic systems
- More?



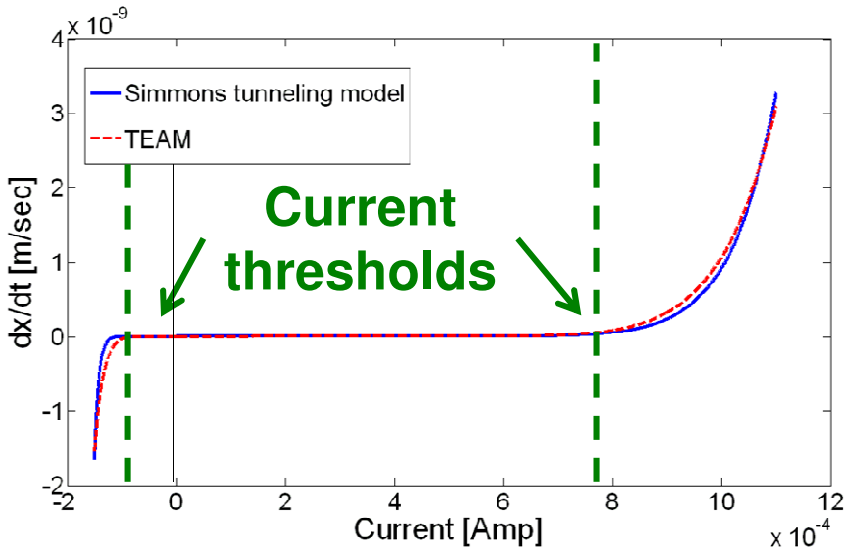
What is the required memristor for circuit design

General Model – TEAM

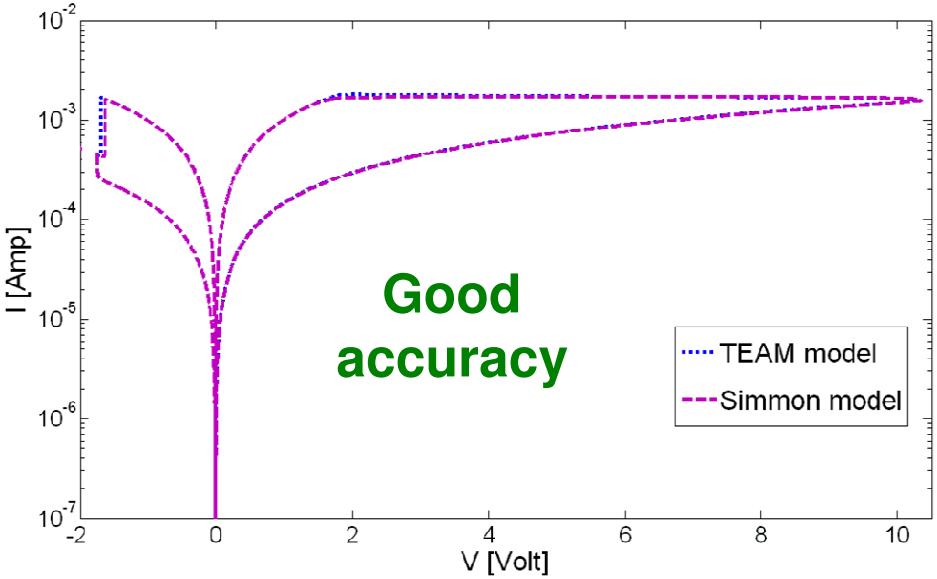
ThrEshold Adaptive Memristor

- Tunable nonlinearity
- Current threshold

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



x – state variable

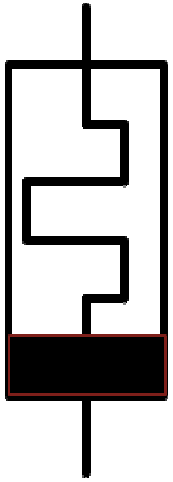


S. Kvatinsky et al, "TEAM: ThrEshold Adaptive Memristor Model," TCAS I, 2012

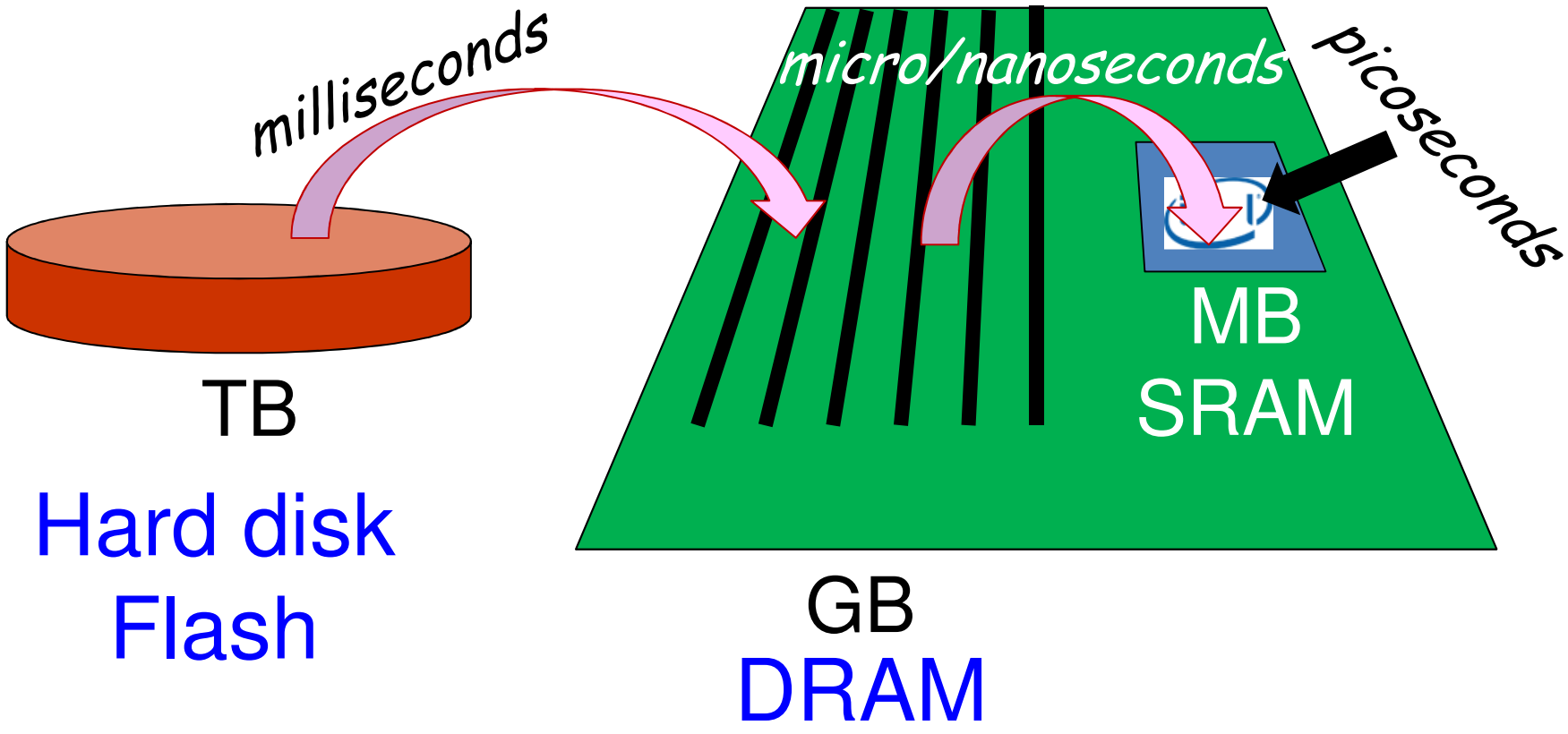
Desired Properties Shared by All Applications

Relative Priority Depends on Application

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



Memristors at Every Level of the Memory Hierarchy



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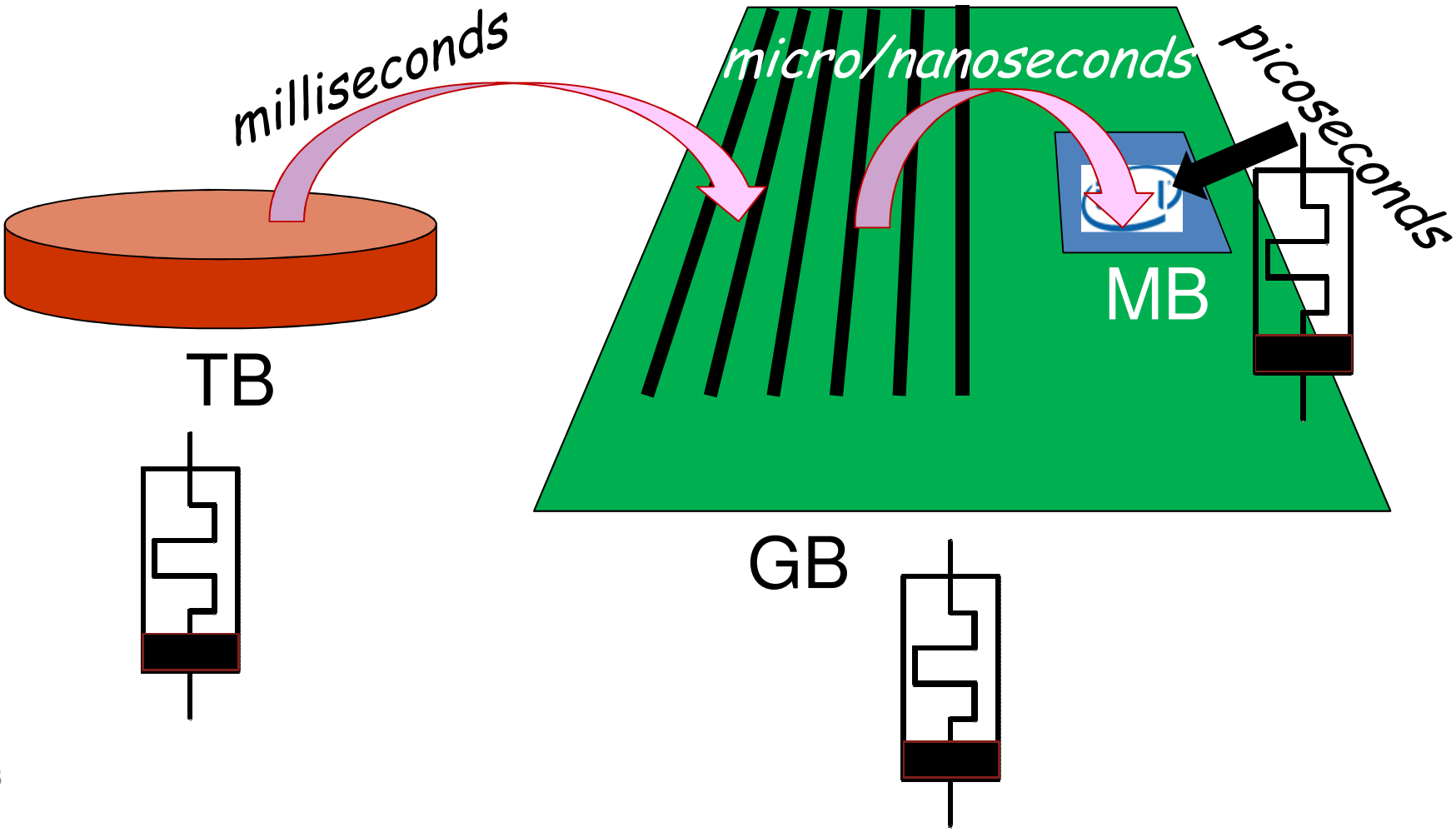

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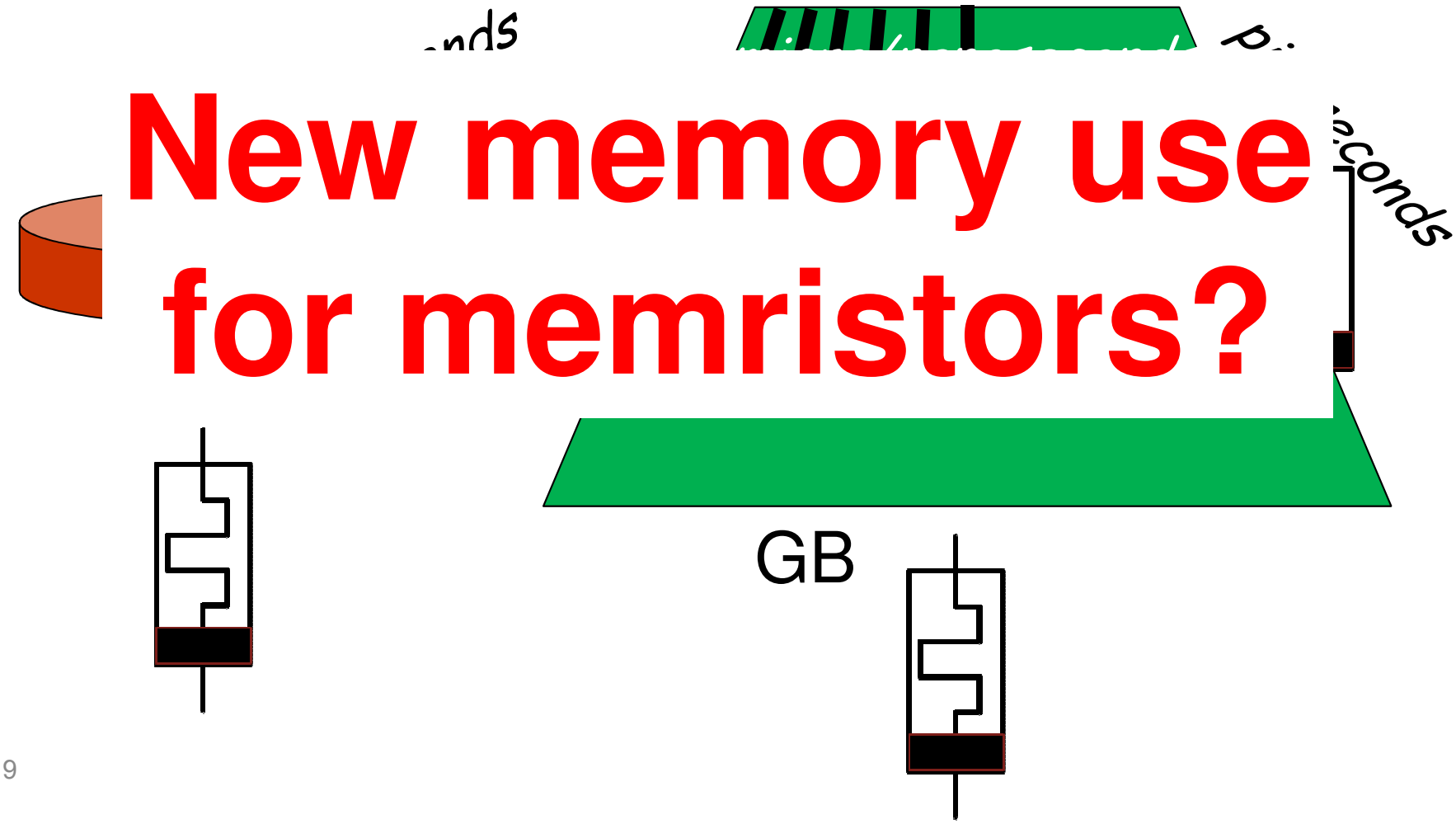
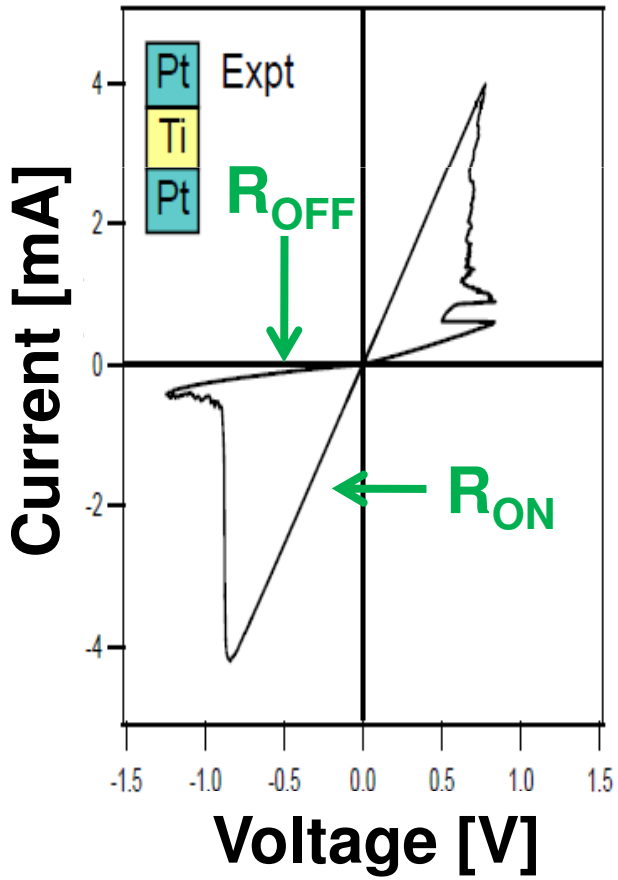


New memory use for memristors?

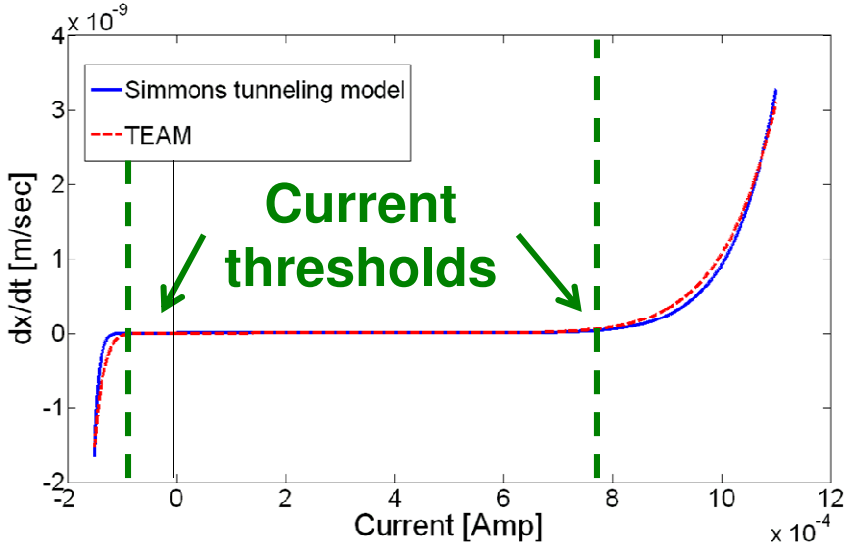
Store Digital Data with Memristors

- Logical value as resistance
- Multi level memory
- Distinct values – high R_{off}/R_{on} ratio



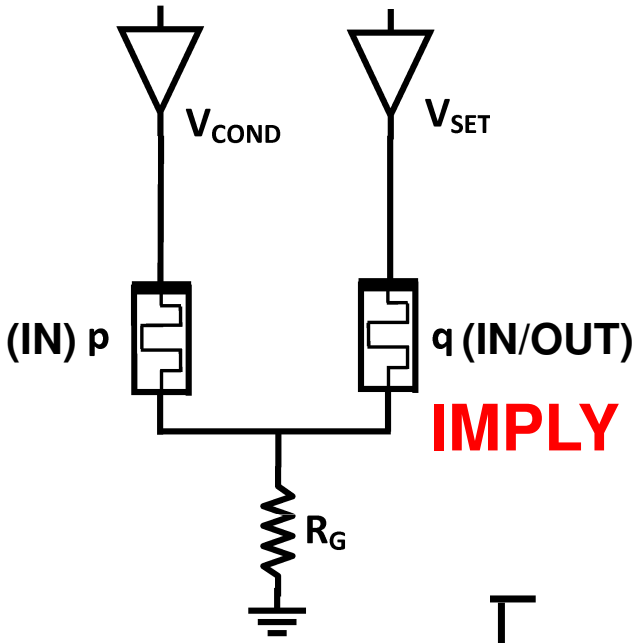
Non-Destructive Read Mechanism

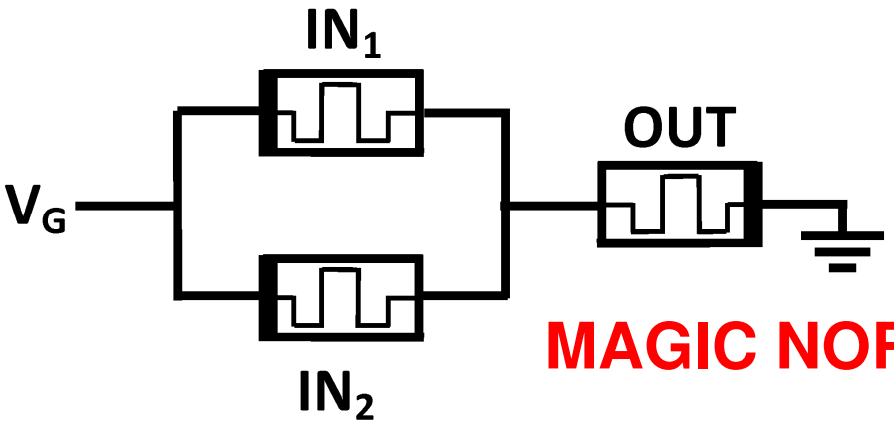
- State drift phenomenon
- Need for highly nonlinear behavior
- Ideally: voltage/current threshold

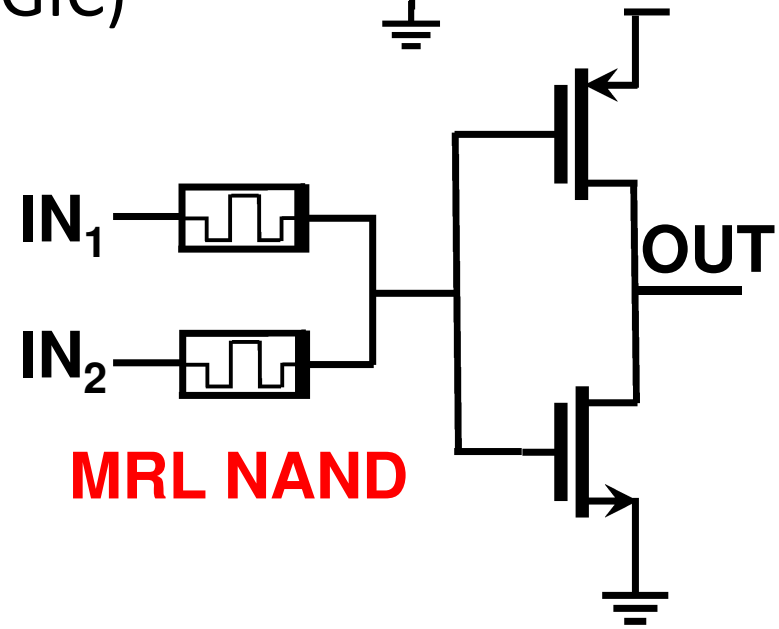


Memristors as Logical Elements

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



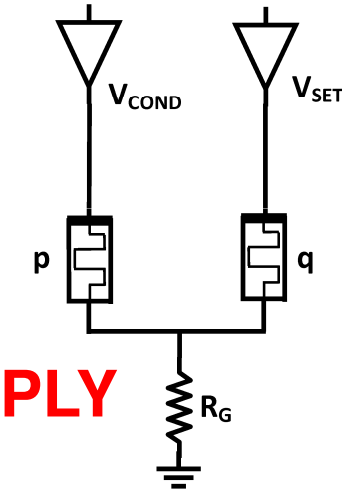




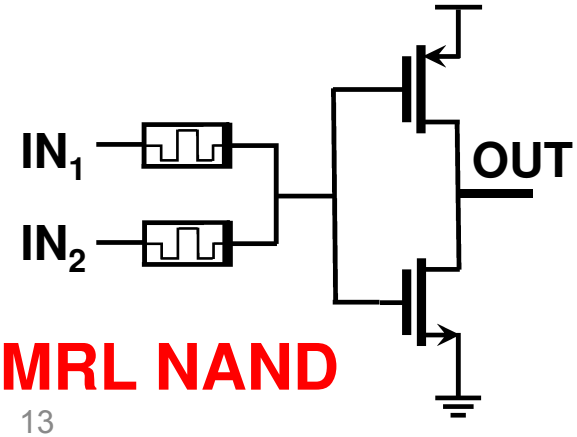
S. Kvatinsky et al, "Memristor-based IMPLY Logic Design Procedure," ICCD, 2011
S. Kvatinsky et al, "MRL: Memristor Ratioed Logic," 2012

Desired Properties for Memristor as Logic Element

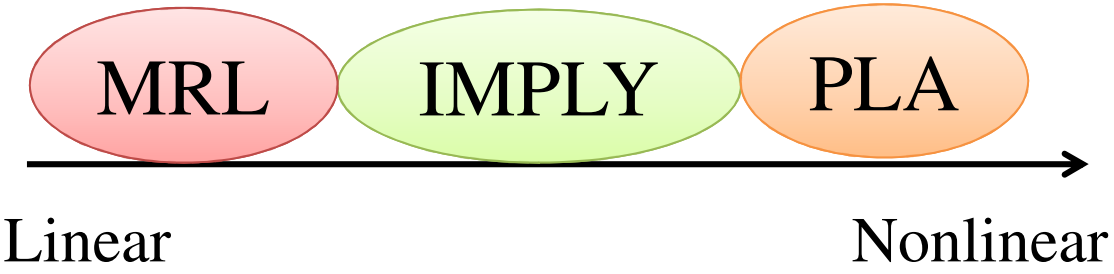
- In addition to memory properties, depends on logic family:
  - MRL – linear memristor
  - IMPLY, PLA – nonlinear memristor



IMPLY

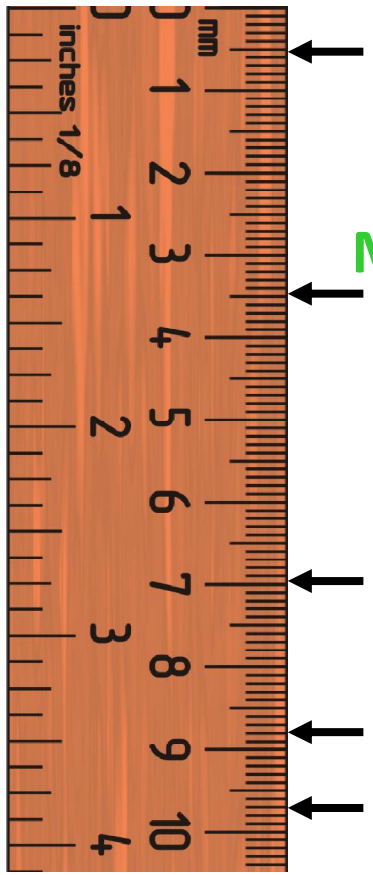


MRL NAND



Conclusion: Different Application - Different Memristor

Linear



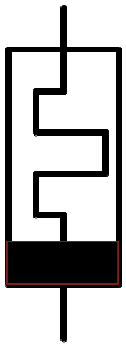
MRL

Multilevel memory

Memory

PLA

IMPLY



Nonlinear

Power
Size
Data retention
CMOS compatibility
Speed
Endurance

Discussion

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http://memristor.shorturl.com/