The Desired Memristor for Circuit Designers

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Currently There is No Standard for Memristive Devices

• Many types:
  – Resistive switches
  – STT MRAM
  – PCM
  – ...

[Images of memristor structures]
Different Applications Require Different Memristors

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

What is the required memristor for circuit design?
General Model – TEAM
ThrEshold Adaptive Memristor

- Tunable nonlinearity
- Current threshold

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


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

New memory use for memristors?

Store Digital Data with Memristors

- Logical value as resistance
- Multi level memory
- Different dosage for different memory hierarchies:
  - Speed
  - Endurance
  - Size
Desired Memristor for Memory

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

Memristors as Logical Elements

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

Desired Properties for Memristor as Logic Element

• Digital application – similar to memory

• Depends on logic family:
  – MRL – linear memristor
  – IMPLY, PLA – nonlinear memristor

Desired Memristor for Analog Circuits

Memristor as a computational element
e.g., analog counters, sensors

Memristor as a configurable device
Initialization and operation
Desired Memristor to Neuromorphic

Linear \rightarrow \text{Unsupervised learning}

Nonlinear \rightarrow \text{Supervised learning}

Conclusion: Different Application - Different Memristor
Discussion

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