A Practical Hafnium-Oxide Memristor Model Suitable for Circuit Design and Simulation

Sherif Amer¹, Sagarvarma Sayyaparaju¹, Karsten Beckmann², Nathaniel C. Cady¹ and Garrett S. Rose¹
University of Tennessee, Knoxville¹
SUNY Polytechnic Institute²

Background

- Memristors have become widely used in different applications owing to their peculiar characteristics
- Memristor SPICE modeling is important for efficient circuit simulation
- Many models exist but not always practical
- Multiple switching mechanisms typically contribute to the switching behavior of the device
- This makes it hard to develop physical models
- Practical: based on measurable parameters and converges well
- A model is developed based on empirical data of HfO₂
- The proposed model can be easily fit any memristive device.
- Convergence is considered

Proposed model

- Introduced parametrized nonlinearity to the model
- Captures plateauing effects via smooth sigmoidal functions
- Preserves the simplicity of PWL model
- Uses the Instantaneous resistance “R” as the state variable
- Provides smooth transition around the memristor threshold which helps convergence

\[
d\delta M/dt = \begin{cases} 
-\frac{\Delta V(t)}{\delta \text{ membrane voltage}}, & V(t) > V_{tp} \\
\frac{\Delta V(t)}{\delta \text{ membrane voltage}}, & V(t) < V_{tn} \\
0, & \text{otherwise}
\end{cases}
\]

\[
f(M(t)) = \begin{cases} 
\frac{1}{1 + \exp\left(-\frac{t_{\text{mem}}(t) - \theta_{R}}, \beta_{R}\right)}, & V(t) < V_{tn} \\
\frac{1}{1 + \exp\left(-\frac{t_{\text{mem}}(t) - \theta_{RLS}, R}, \beta_{RLS}, R\right)}, & V(t) > V_{tp} \\
0, & \text{otherwise}
\end{cases}
\]

PWL model

- Uses the instantaneous “R” as the state variable.
- Simple model, based on measurable parameters and suitable for circuit designers.
- Assumes very simple dynamics that deviate significantly from actual memristors.
- Ignores nonlinear switching mechanisms
- Ignores Resistance plateauing

Convergence Test

- Maze structure is used as a benchmark
- Stresses the models since all nodes are modified in the transient analysis
- All memristors are updated
- Includes no other elements but memristors

Convergence Evaluation

- Many models use if...else
- Such models often have smoothness problems
- Smoothness around the threshold is important
- Nonlinearity of the function also matters

Conclusions

- Resistance based approach is easier to fit to measurable parameters
- The proposed model is based on measurable parameters
- It is an improved version of a PWL model that was previously proposed
- The model is general and can be fitted to any general memristive device
- Smoothness around the memristor threshold is crucial for convergence during circuit simulation

Acknowledgement

The authors would like to thank Dr. Mark Dean, Gangotree Chakma, Mesbah Uddin and Md. Badruddoja Majumder at the University of Tennessee, Knoxville for interesting and useful discussions on this topic.

This work was funded in part by the Air Force Research Laboratory, Information Directorate under award number FA8750-16-1-0065.

References


Visit us @ neuromorphic.eecs.utk.edu