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Verilog-A for Memristor Models

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***Abstract* — Memristors are novel devices, which can be used in applications such as memory, logic, and neuromorphic systems. Several models for memristors have been developed – the linear ion drift model, the nonlinear ion drift model, the Simmons tunnel barrier model, and the ThrEshold Adaptive Memristor (TEAM) model. In this technical report a Verilog-A implementation for these models and the relevant window functions is presented, suitable for EDA tools, such as SPICE.**

Keywords – memristor; memristive systems, SPICE, Verilog-A;

I. Introduction

Memristors are passive two-port elements with variable resistance (also known as a memristance) [1]. Changes in the memristance depend upon the history of the device (*e.g.*, the memristance may depend on the total charge passed through the device, or alternatively, on the integral over time of the applied voltage between the ports of the device).

To use EDA tools for simulations of memristor-based circuits, a specific memristor model is needed. Several memristor models have been proposed. In this technical report a Verilog-A code for different memristor models is presented. A complementary GUI MATLAB program is also available in [3], useful for initial work with these memristor models.

II. Memristor Models

All the memristor models have been implemented in the Verilog-A model are presented in [2]. In this technical report only a brief description is provided. The equations and main characteristics of the memristor models are listed in Table 1 and 2.

A. Linear Ion Drift Model

In the linear ion drift model, two resistors are connected in series, one resistor represents the high concentration of dopants region (high conductance) and the second resistor represents the oxide region (low conductance). It is also assumed a linear ion drift in a uniform field and that the ions have equal average ion mobility μ_V.

B. Nonlinear Ion Drift Model

The nonlinear ion drift model is assumed a voltage-controlled memristor with nonlinear dependence between the voltage and the internal state derivative. In this model, the state variable w is a normalized parameter within the interval [0, 1]. This model also assumes asymmetric switching behavior.

C. Simmons Tunnel Barrier Model

This model assumes nonlinear and asymmetric switching behavior due to an exponential dependence of the movement of the ionized dopants, namely, changes in the state variable. In this model, rather than two resistors in series as in the linear drift model, there is a resistor in series with an electron tunnel barrier. In this model, the state variable x is the Simmons tunnel barrier width.

D. ThrEshold Adaptive Memristor (TEAM) Model

The TEAM model is a general memristor model; assume that the memristor has a current threshold and polynomial dependence between the memristor current and the internal state drift derivative. The current-voltage relationship can be in a linear or exponential manner. It is possible to fit the TEAM model to the Simmons tunnel barrier model or to any different memristor model and gain a more efficient computational time.

III. Window Functions

To force the bounds of the device and to add nonlinear behavior close to these bounds, several window functions have implemented in the Verilog-A model. The implemented window functions are: Jogelkar, Biolek, Prodromakis, and TEAM (named Kvatinsky in the Verilog-A model). The window functions are presented in [2] and their main characteristics are listed in Table 3.