Physically Transient True Random Number Generators Based on Paired Threshold Switches Enabling Monte Carlo Method Applications

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Abstract

Here we demonstrate a novel physically transient true random number generator based on magnesium oxide volatile threshold switches, using the intrinsic variation in resistive switching as a natural source of randomness. Taking advantage of the volatile nature in switching, a reset operation is not required in each cycle and the operation is largely simplified. It is demonstrated that such random number generators can be applied for complex numerical calculations, and the value of π was successfully calculated in Monte Carlo method based on the random number generators. Such random number generators based on physically transient threshold switches can have a great prospect in Monte Carlo computing and secure electronics.

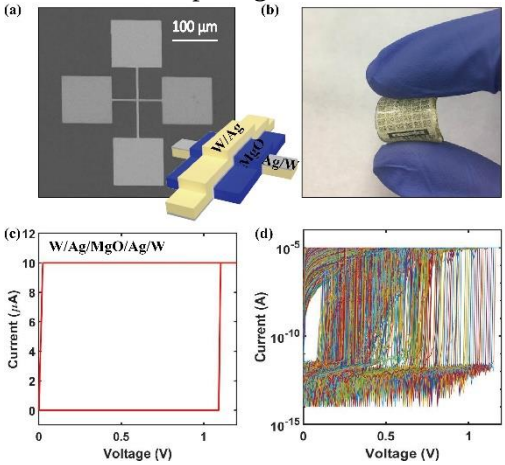

Figure. 1. (a) An SEM image of the W/Ag/MgO/Ag/W threshold switches and schematic diagram of the device. (b) Transferred devices on PDMS substrates. (c) I-V characteristics of the W/Ag/MgO/Ag/W devices in linear scale. (d) Cyclic I-V characteristics of the devices with cycle-to-cycle variations.

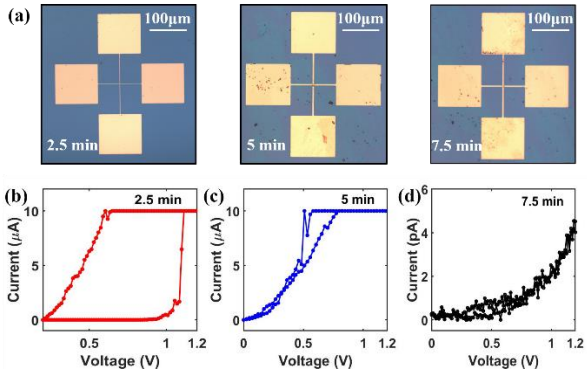

Figure 2. Solution-triggered transient process of the W/Ag/MgO/Ag/W threshold switches. (a) Evolution images of the W/Ag/MgO/Ag/W threshold switching devices in DI water at room temperature for 2.5, 5.0 and 7.5 min. (b-d) Variation in the electrical characteristics of the device after immersing in water for 2.5, 5.0 and 7.5 min.

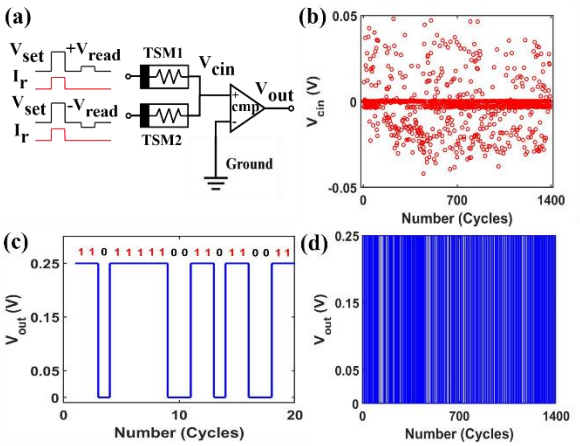

Figure 3. (a) Circuit diagram of the random number generator. (b) Output result of V_{cin}. (c) The generated random bitstream in a short section of 19 cycles. (d) The generated random bitstream in 1400 cycles.

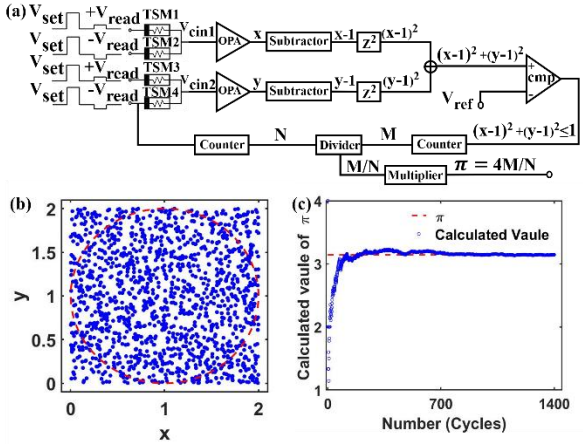

Figure 4. Calculation of the π value in Monte Carlo method. (a) Schematic of the computing module. (b) The distribution of x and y random numbers (blue scatter plots) and the limited range of a circle (red dashed line). (c) Calculated values of π using the TRNG based Monte Carlo computing module.