Simscape Design Flow for Memristor Based Programmable Oscillators

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Abstract

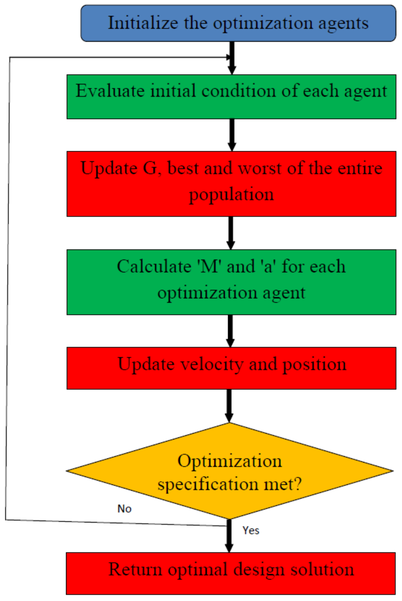
A design optimization flow is proposed for memristor based oscillators. The proposed flow uses Gravitational Search Algorithm (GSA) for the optimization of the oscillator to achieve a reduction in power consumption. For use in the design flow, this paper presents for the first time a memristor behavioral model in the Simscape physical modeling language. This research provides an alternative way to simulate memristor based circuits in addition to existing SPICE and behavioral models. Using this Simscape model, a memristor based programmable Wien oscillator is studied. The oscillator is completely characterized within the MATLAB/ Simscape framework. The oscillation frequency and power consumption of the oscillator under various configurations are explored. The Simscape results and the calculated values from mathematical formulas show a high degree of accuracy.

Introduction and Novel Contributions

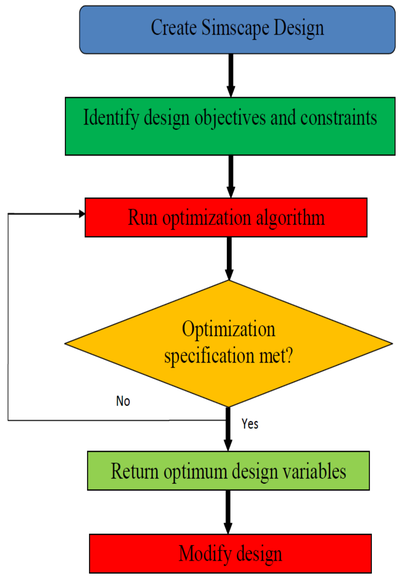
Memristor related research covering analog as well as digital circuits started growing rapidly since the introduction of the variable resistor memristor model. In order to aid the design exploration of memristor integrated circuits and systems, models and design flows in various frameworks are needed. Memristor models have been proposed for SPICE, MATLAB/Simulink, and Verilog-A. Simscape is an integral part of the MATLAB framework. It can model multiple-discipline systems including mechanical and electrical. Simulink uses the signal-flow approach which is suitable for high-level system modeling.
As a case study, the design and optimization of a Wien oscillator is presented with the memristor assisted programmability using the proposed Simscape memristor model.

The novel contributions of this paper to the state-of-the-art include the following: (1) The first ever flow for design optimization of Memristor -based oscillators. (2) A Gravitational Search Algorithm(GSA) based optimization algorithm for memristor -based Wien oscillators. (3) A programmable oscillator using a memristor is presented. As a case study, circuit design exploration of the oscillator under five memristor configurations is presented in terms of power consumption and frequency. (4) The first ever Simscape based models for titanium oxide memristors.

Proposed Design Optimization Flow for Memristor Oscillator



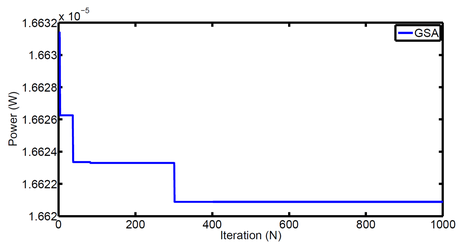
Gravitational Search Algorithm



Design optimization flow

Experimental Results

The GSA algorithm is applied to the Simscape Model. The algorithm is ran for 1000 iteration with 20 optimization agents. The optimized result is presented below. The algorithm took 302 iterations to achieve the optimal power consumption. As presented in the Table below, the power consumption is reduced by 32 % at a cost of 35 % reduction in frequency. The cost of power reduction in terms of frequency is very high but it is beneficial if power is crucial and loss of frequency can be ignored.

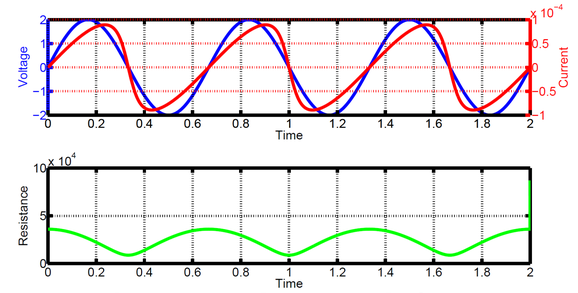


Memristor-based oscillator optimization with GSA

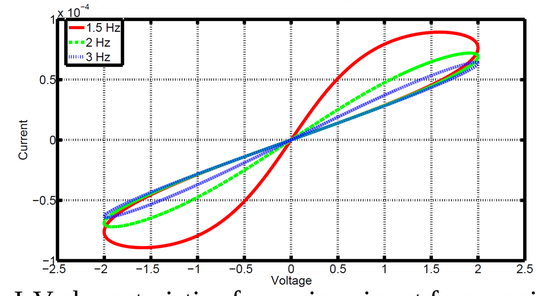
Metric	Power(W)	Frequency(Hz)
Baseline Design	2.43E-05	88.5
Optimal Design	1.66E-05	57.6
Reduction	32%	35%

Optimization Results for Wien Oscillator

Simscape Memristor Simulation

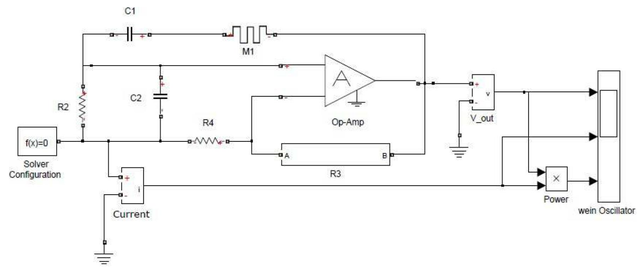


(a) Time-domain simulation result for a 2-V, 1.5 Hz applied sinusoidal voltage.



(b) I-V characteristics for various input frequencies

Experimental setup in simscape



Conclusion

- The model is in accordance to known properties of memristors and was verified in the MATLAB/Simscape simulation environment.
- The simulated oscillation frequencies have been verified with the calculated values from analytical results.
- As a final step in the design process, the optimization of the memristor-based Wien oscillator circuit using the GSA algorithm is done and the results obtained show that reduction in power consumption can be achieved at the cost of frequency reduction.