Unconventional EDA for Mixed-Signal Circuits: A Graphene FET based LC-VCO Case Study

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Abstract

In order to explore ultra-fast design and simulation of mixed-signal circuits and systems, this paper presents a non-EDA design, which is completely based on Simscape®. As a case study, a Graphene Field Effect transistor (GFET) based cross coupled LC oscillator is used where the GFET behavioral model is implemented in the Simscape® physical modeling language. The model is based on the drift-diffusion conduction mechanism of a dual-gate device and the kink region in the I-V characteristics is modeled via a displacement current. The results obtained from the Simscape® simulation matche well with the results obtained from EDA based flows such as SPICE, VHDL-AMS and other Analog Hardware Description Language (AHDL) models. To the best of the authors' knowledge, this is the first attempt to present a Simscape® model a of GFET device and the exploration of GFET based RF circuits using Simscape®.

Introduction

- To meet the demand for smaller, cheaper and low power consumption electronic products, focus has shifted towards analog mixed signal system on chip (AMS-SoC) and alternative technologies.
- Graphene, as an alternative fabrication material, possesses some exceptional properties such as very high carrier mobility and current density, immunity to electromigration, excellent thermal conductivity, mechanical toughness and flexibility and fabrication process compatibility with silicon.
- With increase in the level of integration, the cost and time-to-market increases proportionally.
- SPICE simulation needs fab data or TCAD simulations to derive compact models, which posses serious limits for emerging technologies like graphene based devices where fab data are not yet available.

Case Study: Graphene FET based LC-VCO

- Due to high carrier mobility and high intrinsic voltage gain, GFETs can be very useful for very high speed communication components.
- To start oscillation, the transconductance of the active device should follow:

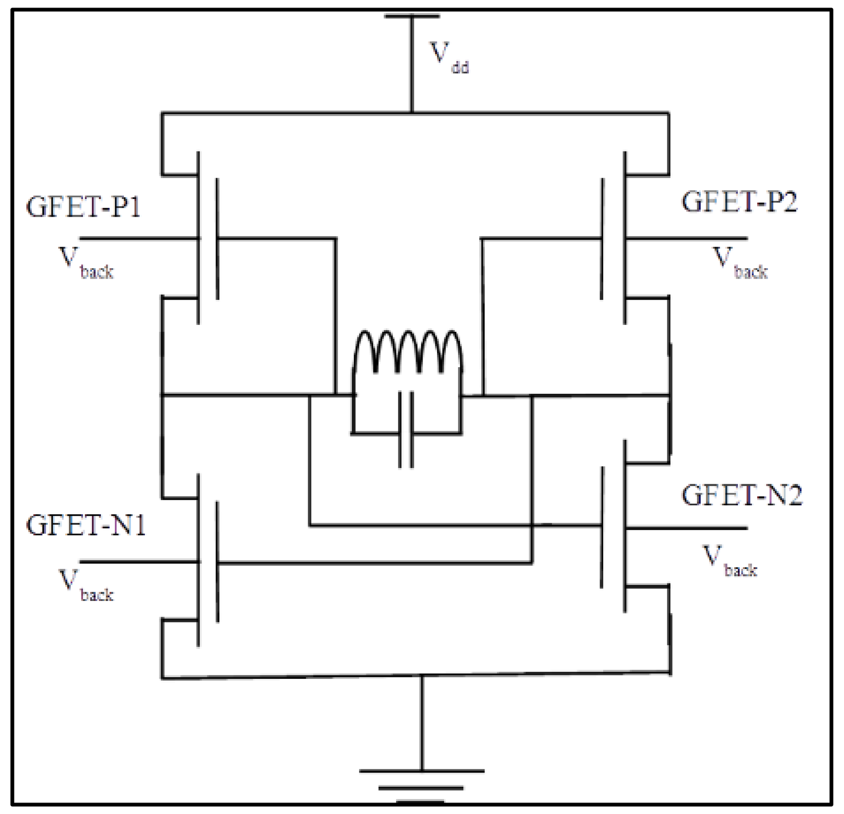
$$g_{active} > \frac{RC}{L}$$

- To limit the current within the tolerable limit, the bias current should be less than the maximum current:

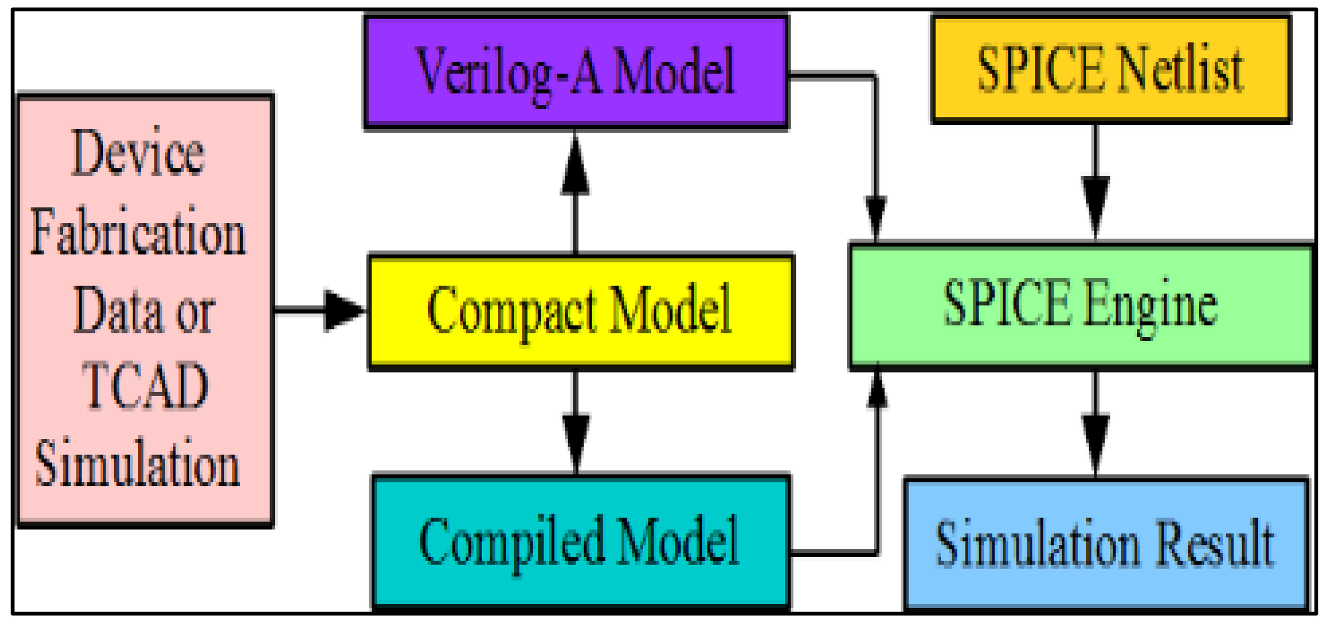
$$I_{bias} \leq I_{max}$$

- The output voltage swing is given by:

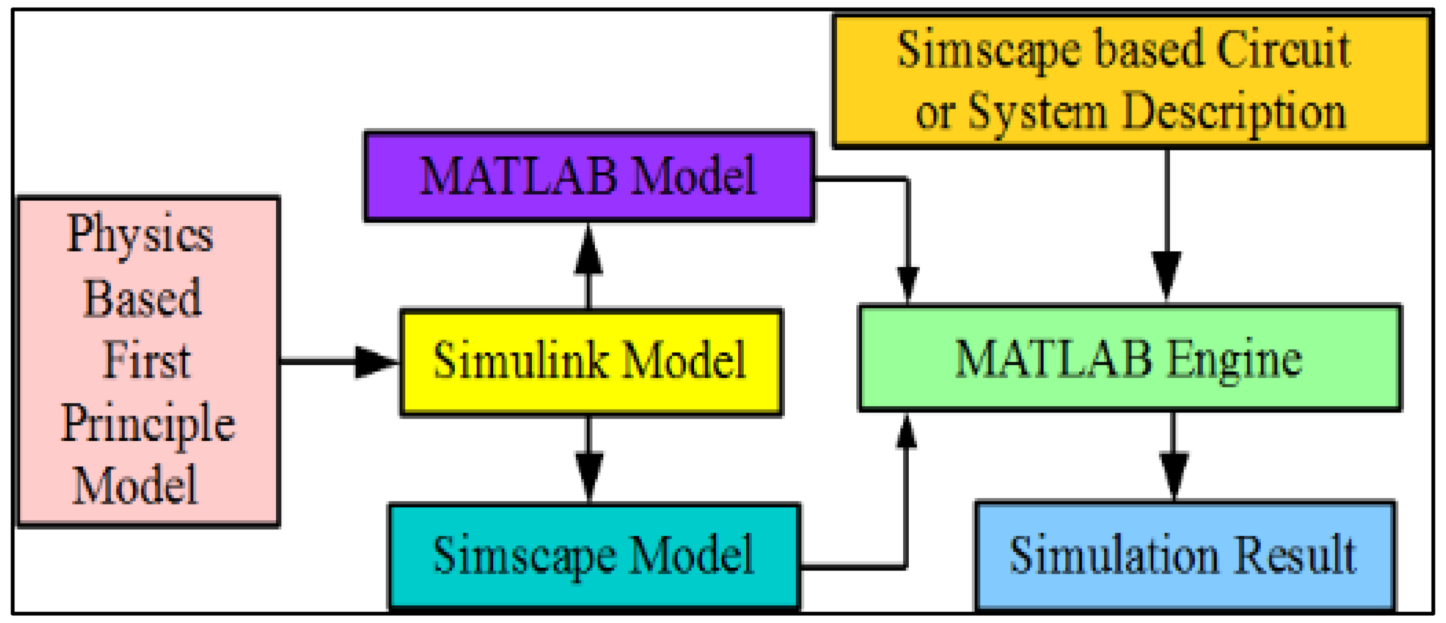
$$v_{tank} = \frac{I_{bias}}{g_{tank}}$$



Proposed Unconventional Mixed-Signal Design Flow

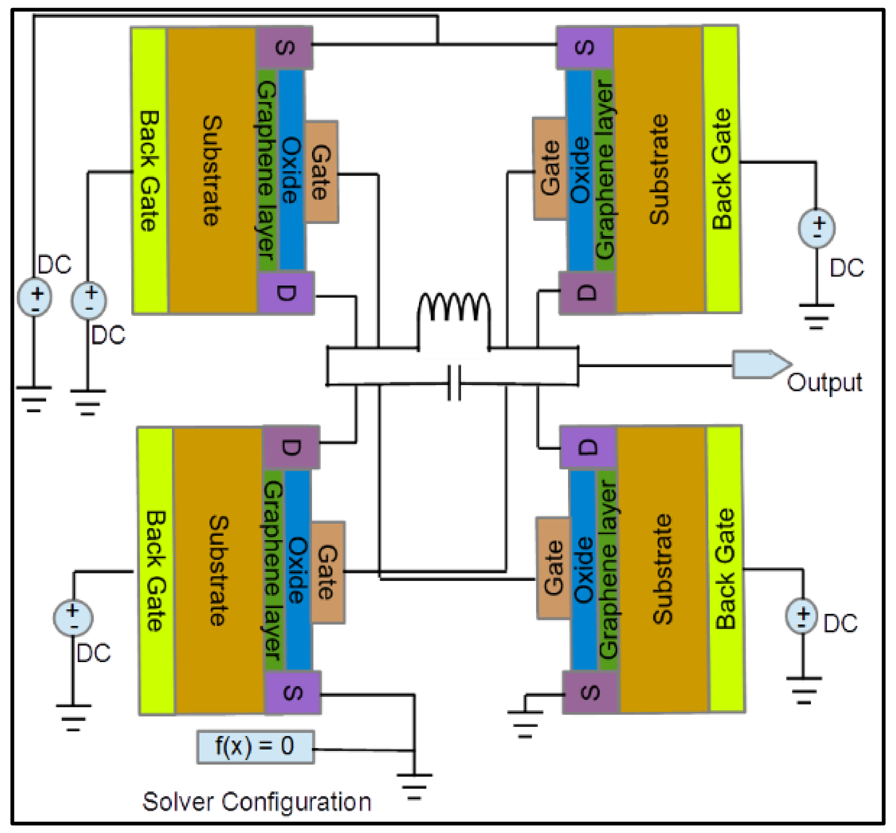


Conventional EDA based design flows need fab data or process information to extract the compact model for the SPICE or analog simulation engine. Besides being effort intensive and computationally slow, these are not well suited to emerging technologies for which fab data are not yet available.



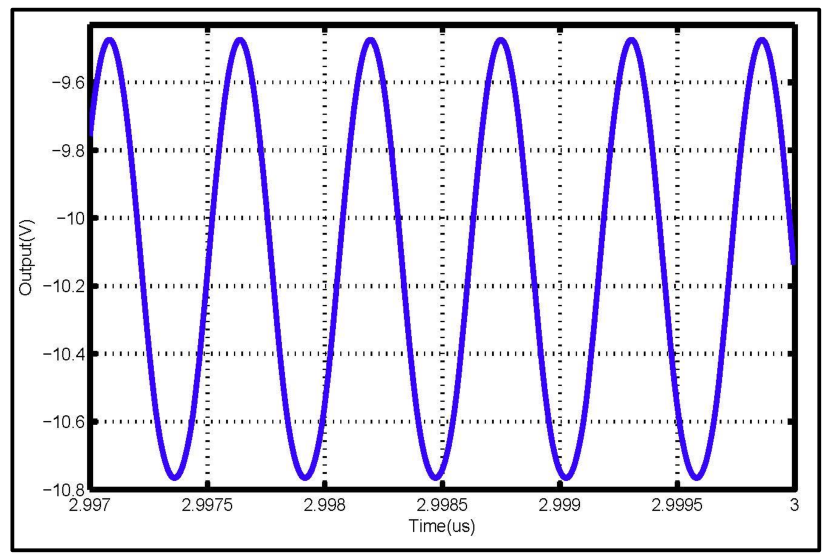
The proposed Simscape® based non-EDA design flow does not need any fab data but instead relies on first principle models published in the literature. This enables the Simscape® based design to be easily applicable toemerging technologies. In addition, the availability of optimization options in MATLAB® makes it easier to fine tune the critical parameters, without additional computational overhead.

Experimental Setup and Results



- By applying appropriate top and back gate voltages, the threshold voltage can be controlled.
- With top gate voltage biased positively (negatively) as compared to the threshold voltage, an n-type (p-type) channel can be formed.
- The transconducatnce of the active device is controlled by modifying the width while keeping the channel length of both PFET and NFET fixed.

- To perform accurate simulation, ODE14X (Extrapolation) solver is used which has the minimum possible step size.
- The oscillator is designed to operate at 1.8 GHz having tank voltage swing of 1.286 Vp-p.



Conclusion and Future research

- A Simscape® based behavioral model suitable for design exploration at high level of abstraction is presented.
- The results obtained from the Simscape® model matche very well with well-accepted EDA models.
- The Simscape® based model can be used as a substitute for more detailed but time consuming EDA models.
- Future work could incorporate additional functionality for noise, transfer function and non-linear RF analyses.
- Optimization techniques using particle swarm optimization algorithm such as artificial bee colony and ant colony optimization can be explored for GFET based circuits within the Simscape® domain.