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FLEXIBLE PARAMETER IDENTIFICATION TOOL FOR SEMICONDUCTOR DEVICE DESIGN

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Abstract. This paper presents an efficient parameter identification approach for the simulation of semiconductor devices. In the first part, a methodology to generate the parameter identification tool is proposed for behavioural simulations. This methodology is then implemented and validated on an integrated lateral MOSFETs. The approach presented here allows an accurate parameter identification, which can be used for an efficient optimization of integrated semiconductor devices.

Keywords: Automatic differentiation tool, least square curve fitting method, parameter identification methodology, genetic optimization algorithms, semiconductor device design.

INTRODUCTION

The simulation of semiconductor devices is always a requirement while designing and optimizing such components [2]. As far as power semiconductor devices are concerned, the monolithic integration of advanced functions (eg. control) within high voltage devices gives a high stress on the design [1] and the modelling for both the integrated functions and the main high power switch. The stress on the modelling here deals with the big size of model and the computation time. The parameter identification approach (PIA) for an integrated low voltage function in a high power device is proposed in this paper. This approach provides the analytical model with the best fit to the made device characteristics for an accurate behavioural simulation. In order to achieve this inverse problem, the PIA has to be an efficient, flexible and reliable tool, which can allow to change easily the model equations and to identify the parameter values. This approach allows here to easily identify the model parameters of different function components.

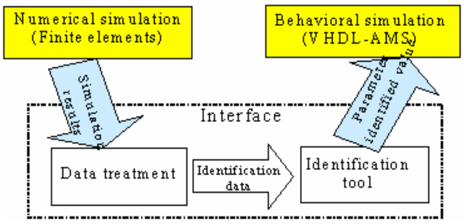

Figure 1: Identification approach

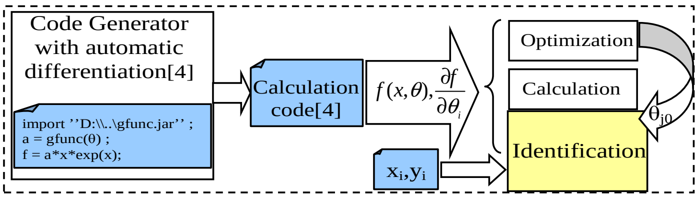

Figure 2. Process to transform a model to a computation code to compute the model and its jacobian

This paper proposes to use the least square curve fitting Levenberg Marquardt method to solve the identification problem, as it compares the approach with generic optimization algorithms [2]. The carrying out of the parameter identification tool, the static characteristic modelling and the parameter identification results with different approaches of a lateral MOSFET are presented in order to validate this approach.

STATE OF THE ART

In the design framework of power semiconductor devices, the designer can use numerical methods such as Finite Elements or Finite Difference Methods in order to solve the differential equations of the semiconductor physics in all the simulated dimensions. Although, these numerical simulations are accurate, two major drawbacks are associated with these methods: the resource requirements and the difficulty to simulate several semiconductor devices in the same time. Analytical models are also not suited for the device sizing because major effects cannot be taken into account such as 1D or 2D Gaussian doping profiles, avalanche phenomenon and other implicit and non linear equations. As a consequence and in order to provide an efficient tool for the pre-sizing of complex semiconductor devices, the paper proposes an interface between numerical and behavioural simulators, by extracting the parameters of behavioural models only from a few numerical simulations.

IDENTIFICATION METHOD

In this identification tool, the least square curve fitting Levenberg Marquardt (LM) method of the non linear problem is used. The principle of this method is to minimize the following quantity $S(\theta)$ [3]:

(1) $$S(\theta) = \sum_{i=1}^{n} \left[y_i - f_i(x_i, \theta)\right]^2 = \sum_{i=1}^{n} r_i^2$$

where y_i, x_i are the measurement points. $f(x_i,\theta)$ is the analytical model with a set of unknown parameters θ. The algorithm and the principle of this method will be developed in the full paper. To minimize the quantity $S(\theta)$, LM method requires the function $f(x_i,\theta)$, the measurement points (x_i, y_i),the partial derivatives of $f(x_i,\theta)$ with respect to its parameters $\theta_j \in \theta$ and also the initial values of unknown parameters θ_{j0}.

A semiconductor model is always complicated, with many unknown parameters and conditions. Therefore, the partial derivative definition in the direction of its parameters is difficult to determine symbolically. On the other hand, the initial unknown parameters values θ_{j0} are not simple to determine in the case of many parameters. Wrong values of θ_{j0} can lead to divergence problems. With the aim of solving these particular problems, an automatic differentiation tool and an identification strategy are proposed in the paper. The partial derivatives generation is gotten automatically by code generation [4]. Then, the identification tool can be applied on first result given bye the ES(Evolution strategies) [5], RTS(Restricted Tournament Selection) [6] optimization algorithm in CADES[4] (as in Fig. 2).

APPLICATION AND RESULT

The PIA is applied on the static model of an integrated lateral MOSFET (NMOS) in Fig. 3. Additional details of the developed model of this NMOS will be presented in the full paper. Two generic optimization algorithms (ES, RTS), and LM method are used to identify the unknown parameters of the NMOS model. Two results of the ES algorithm (with 1000 generations, 100 populations and 15 individuals), two results of the RTS algorithm(with 1000 generations, 100 populations and 0,1 probability mutation) and one result of LM method are compared in Tab. I by the minimal quantity $S(\theta)$ and the model parameter values.

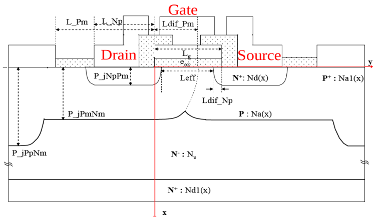

Figure 3. NMOS structure with its physical parameters

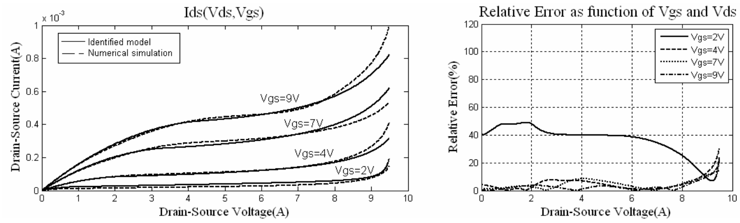

Figure 4. Comparison between the identified model and numerical simulation in the left side, absolute relative error in the right side in the case of RTS-LM

Table 1. Identification results with different algorithm methods

	Method						
	ES(1000x100x15)		**LM**	**RTS(1000x100x0.1)**		**ES - LM**	**RTS - LM**
$S(\theta)$. 10^{-6}	**3,6465**	**3,4154**	**2,8650**	**2,4639**	**2,4019**	**3,2840**	**2,189**
a. 10^{-5}	3,1906	3,9587	4,1692	3,8240	3,423	3,353	3,423
V_{th}	1,781	1,752	0,0734	0,910	0,300	1,64	0,300
M	0,899	0,892	0,888	0,983	1,037	0,859	1,037
K_1	0,909	0,7959	0,6134	0,6122	0,529	0,910	0,53
b_1	0,0905	0,0936	0,2366	0,0437	0,072	0,0848	0,072
b_2	48,87	49,90	1394,5	50	96,5	183,2	96,5
K	0,704	0,638	0,542	0,534	0,458	0,72	0,46
V_{th0}	-0,83	-0,99	0,6345	0,423	0,512	-0,36	0,512
b_5	3,95	3,793	2,7912	2,773	2,437	4,04	2,44
b_4	5,628	5,698	6,269	3,015	3,057	5,63	3,06

In these results, RTS algorithm provides the best result with $S(\theta)$ = 2,4019.10-6. In the first identification of the LM method, the result is not better than the RTS algorithm by reason of the initial parameter values. So, in the next identification step, the best result of the ES and the RTS algorithm are used as the starting point for the LM algorithm. This chaining gives better minima of $S(\theta)$. RTS-LM gets a best result. This best result of parameter identification is shown in Fig. 4. In the full paper, the parameter values and the differences between these results will be fully discussed.

CONCLUSION

In the paper, a methodology of a flexible parameter identification tool is presented to generate an analytical model through the accurate characteristic component in the numerical simulation for the semiconductor component design. An autonomous identification tool integrated into CADES framework is implemented which allow a generic use of the implemented method. Integrated NMOS analytical model is developed. The parameter identification tool is used to identify the parameters of an NMOS.

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