Thesis proposal: DC bias point analysis of analogue circuits through quadratic fitting techniques

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I. Justification of this thesis proposal

In current engineering practise, computer methods for circuit simulation and design are ubiquitously used. SPICE-like simulators are applied for the evaluation of DC bias points of electronic circuits. With this information, the calculation of their frequency and time-domain responses can be carried out as well. Hence, analysis of DC bias point is essential in simulation. Traditionally, the Newton-Raphson (NR) method with appropriate modifications has been used to determine the bias point of nonlinear circuits [1], [2]. This method is defined in terms of a first-order approximation of a static nonlinearity and has quadratic convergence. Other methods than the NR one are known, e.g. simple iteration, *regula falsi*, secant [1]. They are described in most circuit simulation monographs, e.g. [3], [4]. In large scale circuits with strong nonlinearities and high accuracy requirements, these methods need usually between ten and a few tens of iterations before achieving convergence. It would be advantageous to replace the NR method by a second-order method with cubic convergence. Tests show that quadratic fitting used for DC simulation reduces a number of iterations about two times. This quadratic fitting idea is simple and probably not new. However, this idea has not been yet used because of implementation difficulties.

II. Aim of this project

In the frame of this thesis proposal, research work must be carried out to formulate a suitable extension of the Newton-Raphson method using a second-order approximation of a nonlinear element of the form $i = f(v)$ in the vicinity of the preceding iteration v_0. Such approximation takes the form

$$i \approx f(v_0) + f'(v_0)(v - v_0) + \frac{1}{2} f''(v_0)(v - v_0)^2.$$

This model leads to iterative matrix quadratic equations of the circuit. The main problem is its efficient solution analytically (without iterations). In the project we propose such a solution for a class of algebraic nonlinear circuits.

The project comprises the following stages:

- Preliminary implementation of the algorithm in the Matlab environment together with exhaustive testing.
- Implementation of the proposed method in a C++ circuit simulation program. The main skeleton of the simulator is already available and it has been equipped with a basic NR routine, an input language processing block and almost all the data structures required for its operation.

III. Expected products

The following products are expected from this thesis project

- A MSc degree thesis report which describes the results of the research work carried out during the project. The thesis will be defended in front of a thesis committee *not later than* August 2013. This report must be written in English language.
- Computer code in Matlab and C++ with the new method implemented.

IV. Additional information

Any interested student should contact Dr. M.Á. Gutiérrez de Anda (office 1422) to obtain further information.

References

[1] J.M. Ortega and W.C. Rheinboldt, *Iterative solution of nonlinear equations in several variables*, Academic Press, New York, 1970.

[2] C.W. Ho, D.A. Zein, A.E. Ruehli, and P.E. Brennan, "An algorithm for dc solutions in an experimental general purpose interactive circuit design program," *IEEE Transactions on Circuits and Systems*, vol. 24, no. 8, pp. 416–422, August 1977.

[3] D.A Zein, "Solution of a set of nonlinear algebraic equations for general purpose cad programs," in *Circuit Analysis, Simulation and Design: General Aspects of Circuit Analysis and Design*, A.E. Ruehli, Ed. North Holland, Amsterdam, 1986.

[4] J. Ogrodzki, *Circuit simulation methods and algorithms*, CRC press, Boca Raton, Florida, 1994.