Optimal OpAmp Sizing based on a Fuzzy-Genetic Kernel

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ABSTRACT

In this paper an innovative fuzzy-genetic approach is proposed to address the problem of analog circuit sizing. The proposed approach introduces a fuzzy mutation operator which models expert design knowledge and this way not only avoids local minima but also reduces the search dynamically the space. The proposed approach is compared against a state-of-the-art genetic approach, for the optimal operational amplifier sizing, and presents a faster convergence rate.

Categories and Subject Descriptors

J.6 [**Computer-Aided Engineering**]: Computer-aided design (CAD)

General Terms

Algorithms, Design, Performance

Keywords

CAD, Optimization, Fuzzy Model, Genetic Algorithms, Analog Circuit.

1. INTRODUCTION

Designing complex analog and mixed-signal circuits and systems is a complex and cumbersome task that requires extensive design expertise. Despite the evolution of design automation approaches in the last decades, most of the designer effort in the synthesis of an analog system is still dedicated to circuit sizing in order to satisfy a set of predefined performance specifications and parameters constraints. Thus, the development of new design automation procedures to improve the design efficiency is mandatory [1].

Recent approaches [2-4] to analog design automation show an enormous potential of applying soft computing techniques to circuit, system and layout level synthesis, due to their capability of evolving solutions on large search spaces associated to either linear or non-linear design problems.

This work applies a fuzzy-genetic optimization kernel to the analog circuit design flow, particularly, to an optimization based architecture, illustrated in fig. 1, and using a standard electrical simulator as evaluation engine allowing both precise evaluations and generalized application to a broad range of circuit topologies.

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2. FUZZY-GENETIC OPTIMIZATION BASED APPROACH

The proposed IC design optimization approach starts by building a coarse fuzzy model, which describes qualitatively the contribution of each optimization variable, a subset from the whole optimization variables selected by the designer, to the performance parameters or measures. This model will then be stored together with the circuit description, in a circuit database, and will be used during the evolutionary optimization process to implement the mutation operator.

2.1 Modeling Kernel

The modeling kernel, illustrated in fig. 1, is the module dedicated to generate the models, in this case, the fuzzy model. In order to build the fuzzy model a search space sampling is performed using the Design of Experiments (DOE) approach. Then, the samples are evaluated based on precise electrical simulations obtained with HSPICE. Then, the fuzzy rules are defined based simulations results and their general form is given by if-then rules, as the following: "If *input* is low then *output* is max", where low and max are membership function terms. After defining the fuzzy rules the modeling kernel implements a fuzzy inference mechanism, based on a MAX-MIN strategy and a defuzzification process based on the center-of-area approach. Finally, the returned results by the fuzzy model are of three different types, respectively: (1) increase the optimization variable value; (2) decrease the optimization variable value; (3) generate a new random value.

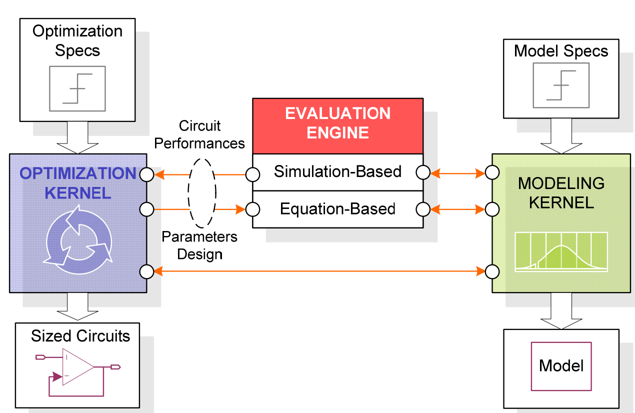

Figure 1. Optimization Based Approach.

2.2 Optimization Kernel

The optimization kernel, illustrated in fig. 1, is based on an evolutionary computation approach, published in [4] and extended by introducing a new mutation operator, illustrated in fig. 2. The new mutation operator in step of just introducing a pure random change on a selected gene, the classical approach, it uses the built-in fuzzy model to determine how the variable, represented by the selected gene, should change in order to increase the probability of improving the solution. The main point is that the overall search space is dynamically reduced and the population receives knowledge information during the evolutionary process, which results in orienting the population movements towards the solution area with a direct impact in terms of a reduction in both the number of evaluations and generations required to obtain the solution.

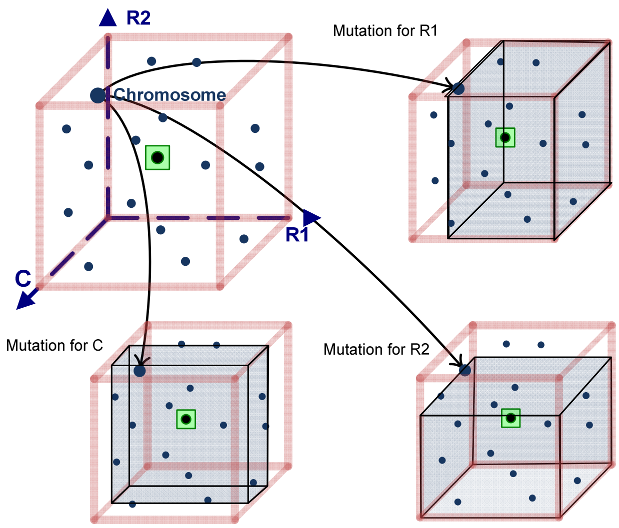

Figure 2. Selective Fuzzy Mutation Operator.

3. CASE STUDY

In order to demonstrate the effectiveness of the proposed approach a classical two-stage operational amplifier, illustrated in fig. 3, were considered as benchmark. In this case study the technology used were 0.35 µm AMS (Austria Mikro Systems International AG) CMOS technology process with a supply voltage of 3.3V. However the proposed approach is fully independent from both circuit topology and technology.

The circuit is composed by 16 devices from where 10 optimization variables and 30 constraints were considered. The design parameters, optimization variables, are within the following ranges Ws [1, 400, 1] and Ls [0.35, 10, 0.1] expressed in µm. The parameters to define these are minimum, maximum and step size. The constraints consist of overdrive voltages and drain-sources voltages margin to guarantee the proper circuit behavior. Finally, the desired specifications or design goals were the ones described in table 1.

The achieved results were compared against a state-of-the-art approach [4]. The results, compiled in table 2, show a success rate of 10 out of 10 for both the reference approach and the proposed approach. Then, the proposed approach reduces the required number of generations in about 1/3 and the number of evaluations in about 1/4 for an extra cost in terms of computational time of less than 1/3. The extra computational cost is due to the fuzzy mutation operator which will be easily diluted for more complex circuits and/or analysis where the electrical simulations can take a substantial amount of time when compared to the execution of the algorithm.

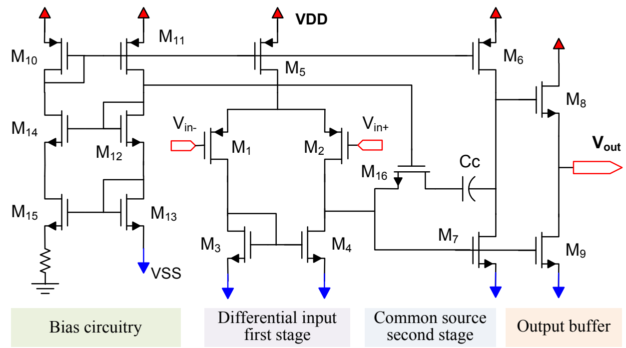

Figure 3. Two-Stage OpAmp.

Table 1. Two-Stage Opamp Specs

Id	Gain	GBW	Phase	Power
TS OpAmp	> 65 dB	>20 MHz	60º<Ph<90º	Min (mW)

Table 2. Comparative Results against a State-of-the-Art Optimization Kernel applied to Analog IC Sizing

Measure\Algorithm	GA-MOD2	GA-FUZZY
Success Rate	10/10	10/10
Generation Avg	31.3	21.1
nEval Avg	282.4	200.8
Time Avg (s)	8.7	11.8

4. CONCLUSIONS

A new fuzzy-genetic optimization kernel were introduced, embedded in an analog IC design flow using electrical simulators as evaluation engines and tested against a state-of-the-art optimization kernel. The presented case study shows extremely promising results for analog circuit benchmarks anticipating good performances for more complex circuit topologies and analysis.

5. REFERENCES

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