

VLSI Low Power Design Analysis Modeling Strategies

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Abstract—Complex simulation models are an important tool in the decision-making process. To increase the ability to efficiently explore broader subspaces of these models, this dissertation presents a series of experimental designs for searching over as many as 22 variables in as few as 129 runs. These unique designs blend an orthogonal Latin hypercube with uniform patterns to generate designs that are both space-filling and nearly orthogonal. Multiple metrics are utilized to assess the quality of candidate designs and select the best one. When more than the required number of runs is available, the designs can be permuted and appended to create additional design points, which increase the design's orthogonality and space-filling qualities. Two alternative surfaces are investigated using the designs.

Index Terms— Circuit simulation, statistical modelling, integrated circuit testing circuit modelling, analysis.

I. INTRODUCTION

The high cost of production testing capital equipment, combined with the amount of time an analogue circuit spends on a tester, has made it critical to reduce average chip testing time throughout production. The number of tests that must be done on a circuit can be reduced, as well as the sequence in which they must be performed. This can be accomplished by analysing performance data for a subset of chips or by using simulation data. The benefit of simulation data is that it does not require a large number of circuits to be tested in an inefficient manner in order to obtain the data set. Because of the computational cost of simulating a large system, the large number of random variables needed to model the manufacturing process, and the need to model and simulate not only random parameter variations but also spot defects, generating simulation data for very large-scale integration (VLSI) analogue circuits has been considered extremely difficult.

Decomposing a circuit into numerous blocks, which are linked together by a behavioural model of the system, solves these challenges. We show our statistical simulation methods for a VLSI analogue circuit in this work. The electrical and physical properties of transistors and interconnects, the building blocks of integrated circuits, are subject to large changes that have a direct impact on the fabricated devices' performance and power consumption, significantly reducing manufacturing yield. However, the huge number of transistors on a single chip makes analysing variation effects, a vital task in diagnosing the reason of failure and designing for yield, considerably more difficult. In order to forecast the yield before embarking on such an expensive fabrication

process, reliable and effective statistical analytic approaches in various design phases are essential. The variability analysis of three critical sub-blocks of today's system on chips, namely digital circuits, memory cells, and analogue blocks, is being focused at the circuit level. Within the electronic design automation community, accurate and efficient yield analysis of circuits is considered as a difficult task. At the device level, an approach is presented for developing MOS devices in aggressively scaled geometries using a variation-aware design perspective. The approach offers a yield metric at the device level that addresses a MOS transistor's saturation and leakage currents. To achieve the highest device-level yield, a statistical technique is devised to optimise the advanced doping profiles and geometry aspects of a device.

II. LITERATURE SURVEY

An approach for modelling of production test data is one way to properly constructing test sets for big analogue circuits. A significant number of circuits are created and thoroughly tested in this method. The data's correlations are examined, and a small collection of basis vectors is determined that explains the majority of the observed correlations. Another option is to examine the yield of subgroups of the test set. In this method, the tests that detect the most errors that none of the other tests can detect are gradually added to the test set until the requisite fault coverage is obtained. The remaining tests are removed from the test set since they are considered redundant. The tests in the final test set are then ideally organized to ensure that testing time is kept to a minimum [5]. When data on observed circuit performances is utilized to minimize testing time in either way, a somewhat large sample is required, and as a result, circuits must be in high volume production in order for either strategy to be practicable. Simulated data is an option, as the cost of getting computational data is substantially lower than the expense of obtaining measurable performance data. Furthermore, such information can be gathered even before a circuit is put into production [7]. To do so, you'll need an exact simulation model of the circuit as well as a trustworthy model of the process. One of the fundamental goals of computer experiments is to build a metamodel for estimating the response at untried inputs. In computer experiments, appropriate optimality criteria for selecting a design should be based on the prediction error. The minimization of the mean squared error over the design space is a frequent optimality criterion [6]. Due to the difficulty of directly minimizing this requirement, designs that uniformly fill the entire design space have historically been chosen. The output values of a computer model are frequently utilized to generate a metamodel for prediction. The parameters of this metamodel must be estimated [9]. It's worth noting that the uniform designs chosen do not take this goal into account. Furthermore, in computer studies, more equally distributed sampling does not lead to more accurate modelling. These authors, on the other hand, have yet to discover a better design.

III. TERMINOLOGY

Statistical system simulation is achievable thanks to behavioural modelling. Behavioural models are analytic models of system performance as a function of block performance characteristics, with block performance parameters derived by electrical stimulation of the blocks. The system can then be statistically simulated by creating a statistical model of the block performance characteristics and integrating it with a behavioural simulator to get system performance statistics.

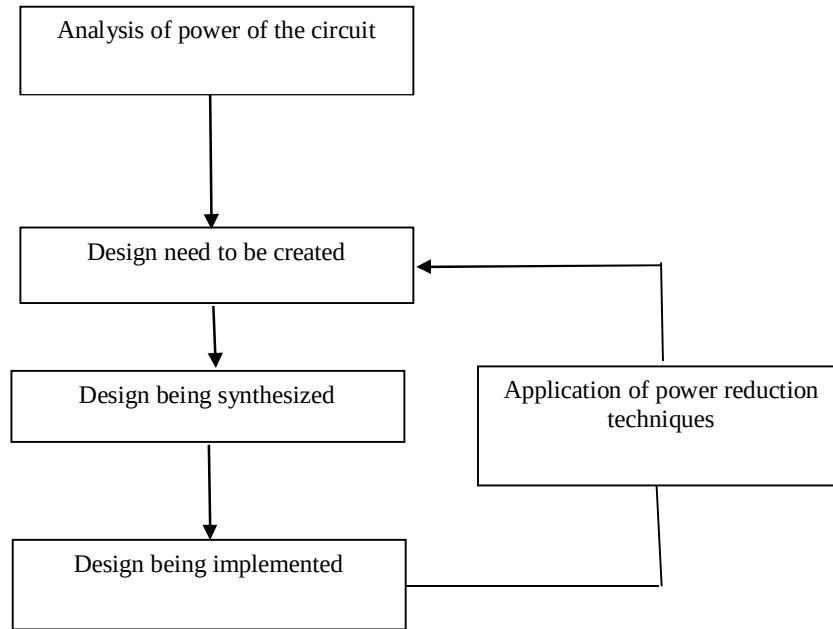
Simulated data is an option since the cost of collecting computational data is substantially lower than the expense of acquiring measured performance data. Furthermore, such information can be gathered even before a circuit is put into production. To do so, you'll need an exact simulation model of the circuit as well as a trustworthy model of the process. Not only the influence of random parameter fluctuations, but also the impact of spot faults, must be represented. Furthermore, statistical simulation for very large-scale integration (VLSI) analogue circuits is thought to be problematic due to the high computational cost of simulating a big system and the enormous number of random variables required to describe the manufacturing process. All of these issues, however, may be solved by partitioning and modelling a circuit properly, and the goal of this study is to show how to do so.

We try to construct a statistical model for the block performance factors in particular. The performance of nonuniform experimental designs is explored, which locate more points towards the design space's boundary. The one-dimensional projections of commonly used space-filling designs are quantile transformed to produce these patterns. Using notation from computer experiment design, and provide heuristic reasoning for introducing generalised maximin Latin hypercube designs, which are derived by changing the one-dimensional projections of a maximin Latin hypercube design by the quantile function of a Beta distribution.

The most important feature is that the uniform design has design points that are fairly evenly distributed across the entire experimental domain. In the uniform design, each variable has eight levels, whereas in the factorial design, each variable has just two levels. A uniform design allows an analyst more flexibility when fitting complex models to the important variables, such as high-degree polynomials, if it turns out that just a few variables influence the answer. In the extreme case where only one variable turns out to be relevant, a Latin hypercube design contains 'n' alternative (equally spaced) input values for the significant variable. It is desirable to have an orthogonal design since it ensures that the coefficient estimates in a regression model are independent. Orthogonality aids in evaluating and estimating as many effects, interactions, and jump discontinuities as possible. Two methods are used to determine the degree of orthogonality.

The experimental designs should contain the following desirable properties to efficiently explore these simulations:

- (i) the input variables near orthogonality,
- (ii) the collection of experimental instances should be a representative subset of the points in the hypercube of explanatory variables, and it should be space-filling.
- (iii) ability to efficiently evaluate a large number of variables (20 or more),
- (iv) as many effects, interactions, and thresholds as feasible can be analysed and estimated with as much flexibility as possible
- (v) require only the most basic a priori assumptions
- (vi) the ease with which the design can be created,
- (vii) ability to manage unnecessary experiment termination



One metric is the maximum pairwise correlation among the columns of a design matrix. The highest pairwise correlation is obtained by calculating the absolute value of (1.4) for all pairs of column vectors in the design matrix and then selecting the maximum of these values. A design matrix with significant space-filling properties is desirable because design points are scattered across the entire experimental region. As a result, you'll have a greater chance of recognising contours that demarcate zones with unusual behaviour. Two methods are used to evaluate the space-filling of a design matrix. The first metric is the ML2 discrepancy. d_1 is the Euclidean Mm distance, with a larger number signifying a greater distance. No two points are within d_1 of each other, as shown by a large d_1 number. Other distance metrics used by practitioners include Euclidean and rectangular, with rectangular and Euclidean being the most common. In this dissertation, the Euclidean Mm distance is employed since it emphasises the shortest distance between locations. Furthermore, the phrase "Mm distance" refers to the Euclidean Mm distance whenever it is used. Both metrics are utilised in this dissertation because in some cases, a single measure is insufficient for differentiating between candidate designs.

IV. CONCLUSION

Each experiment's main purpose is to collect as much high-quality data as possible while utilizing the fewest resources possible. The relevance of space-filling is highlighted, as well as the building of orthogonal Latin hypercube. The methods for evaluating near orthogonality and space-filling ideas are described in depth. These two key traits are combined in the proposed designs, which gives them an advantage over competing systems. The OLHC approach has been extended to incorporate a significantly higher number of variables. If some orthogonality is surrendered, a large increase in space-filling can be achieved. A case is presented for looking at both the maximum pairwise correlation and the condition number when evaluating the quality of a suggested design matrix. The principle of space-filling is highlighted. We use uniform design theory, which previously ignored the issue of orthogonality, using the ML2 discrepancy in conjunction with the Mm distance. All of this was done in order to improve the ability to differentiate between various candidate designs. A list of possible designs can be found in the appendices. The advantages of the proposed designs are illustrated by comparing them to existing designs. Reduction of the number of variables in the proposed designs. The nearly orthogonal and space-filling experimental approaches described in this dissertation have proven effective in high-dimensional difficult models. A noteworthy addition is the coupling of Latin hypercubes with uniform designs, while simultaneously taking into accounts multiple orthogonality and space-filling metrics.

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