OPTIMAL SIZING OF TRANSISTOR'S PARAMETER USING GENETIC ALGORITHM

YAP YUNG LIN

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Faculty of Electronic and Computer Engineering
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Specially…

To my beloved parents

To my kind brothers and sisters

And not forgetting to all friends

For their

Love, Sacrifice, Encouragements, and Best Wishes

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ABSTRACT

This project report presents the design and development of genetic circuit optimizer. Initially, genetic circuit optimizer is based on the Simple Genetic Algorithm (SGA) to perform the optimization function. Genetic algorithm is the programming concept that mimics the mutation concept of biological evolution. Genetic circuit optimizer tends to use the transistor width and length in the selected circuit to tune circuit performance near to optimal. Genetic Circuit Optimizer developed by using Pspice and Matlab. SGA was written in Matlab environment to perform the optimization task. The random transistor width and length named chromosome are generated in Matlab by uing SGA. Chromosomes are decoded into format that recognized by PC Simulation Program with Integrated Circuit Emphasis (PSpice) to simulating corresponding output. Interfacing part is essential part of the project. The output with the transistor's width and length are encoded into chromosome to perform genetic operation. Genetic operation performed to optimal the chromosome. Previous research had concluded the GA optimization process. Moreover, researcher had found the way to decode and encode the transistor sizing into chromosome. Improved Non-dominate Sorting Genetic Algorithm was used to upgrade the Genetic Circuit optimizer. Hence, the Genetic Circuit Optimizer manages to optimization more circuit parameters. The capabilities of Genetic Circuit Optimizer are proved by optimizing the inverter circuit, four stage amplifier circuit and Operational Transconductance Amplifier circuit. Furthermore, the speed and accuracy of Genetic Circuit Optimizer are improved by changing the simulator into Disk Operation Mode (Dos) and using Hspice respectively. Finally, verification and validation of Genetic Circuit Optimizer are statistically showed and studied.

ABSTRAK

Project ini membincangkan pendekatan dan ciptaan Pengoptimasi Litar Genetik. Pada permulaan, Pengoptimasi Litar Genetik terdiri daripada Mudah Litar Pengotimasi Genetic untuk optimasikan parameter yang ditujukan. Genetic algorithm adalah konsep pengaturcaraan yang meniru konsep mutasi evolusi biologi. Pengoptimasi litar genetik cenderung menggunakan transistor lebar dan panjang di litar yang dipilih untuk prestasi tune litar berdekatan ke tahap optimum. Pengoptimasi Genetik dikembangkan dengan Pspice dan Matlab. Litar Pengotimasi Genetic ditulis di dalam Matlab untuk melaksanakan tugas pengoptimuman. Lebar dan panjang transistor dinamakan kromosom dihasil dalam Matlab oleh Mudah Pengoptimasi Genetic secara rawak. Kumpulan data yang dihasilkan dipanggil kromosom. Kromosom diperihal dalam format Komputer peribadi Program Simulasi Penekanan dengan litar bersepadu untuk mensimulasikan keluaran yang sesuai. Interaksi merupakan bahagian penting dalam projek ini untuk menunjukkan menukaran and penghantaran data. Seterusnya, keluaran dengan lebar dan panjang transistor dikodekan menjadi kromosom untuk melakukan operasi genetik. Operasi genetik akan mengoptimumkan kromosom. Kajian dahulu telah menyimpulkan proses optimasi GA. Selain itu, Ahli pengkajian telah menyediakan cara untuk membaca kata laluan dan menyandi saiz transistor sebagai kromosom. Peningkatan Non-mendominasi Sortasi Algoritma Genetik digunakan untuk meningkatkan optimasi Genetik Circuit. Oleh itu, Genetik Circuit Pengoptimal berjaya pengoptimumkan lebih parameter litar yang ditujukan. Kemampuan Pengoptimal Genetic Litar terbukti dengan mengoptimumkan rangkaian inverter, empat tahap penguat litar and litar transkonduktansi operasi penguat. Selanjutnya, kelajuan dan ketepatan Genetic Litar Pengoptimal ditingkatkan dengan menukarkan simulator ke Mode Operasi Disk and menggunakan Hspice. Akhirnya, pengesahan and validasi Genetic Litar Pengoptimal secara statistic ditunjuk dan dipelajari.

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LIST OF ABBREVIATIONS

GA	-	Genetic Algorithm
AI	-	Artificial Intelligent
SPICE	-	Simulation Program with Integrated Circuit Emphasis
SGA	-	Simple Genetic Algorithm
NSGA_2	-	Improved Non-dominate Sorting Genetic Algorithm
MOS	-	Metal-Oxide-Semiconductor
CMOS	-	Complementary Metal-Oxide-Semiconductor
GUI	-	Graphic User Interface
NAND	-	Number of Individual
MAXGEN	-	Maximum generation
NVAR	-	Number of variable
PRECI	-	Precision of variables
GGAP	-	Generation gap
SBX	-	Simulated Binary Crossover
DC	-	Direct Current
MOSFET	-	Metal Oxide Semiconductor Field Effect transistor
DOS	-	Disk Operation System
OTA	-	Operational Transconductance Amplifier
IBM	-	International Business Machine
LM	-	Levenberg – Marguardt

LIST OF SYMBOLS

g_m	-	Gain
w_c	-	Gain bandwidth
$ø$	-	Phase margin
L	-	Length
W	-	width
$I.$	-	Input current
K_n	-	Transistor ratio constant
V_{GS}	-	Voltage between Gate and Source
V_{TN}	-	Threshold voltage
B	-	W/L ratio
U_T	-	thermal voltage
C_{max}	-	Maximum Width allowed by technology
C_{min}	-	Minimum Width allowed by technology
W_{max}	-	Maximum Width chosen by user
W_{min}	-	Minimum Width chosen by user
k_1, k_2	-	Conversion constant
m	-	Number of objective
μ_n	-	Surface mobility of electrons
C_{ax}	-	Thickness of the oxide

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CHAPTER I

INTRODUCTION

Chapter one states the objectives of optimal sizing of transistor parameter by using Genetic Algorithm (GA). A roughly background in this research field will be introduced. Next, scopes of thesis listed in this chapter will layout related topic and literature excluded. Problem statement will clarify problem faced in this field. Lastly, organization of thesis describes structure of all seven chapters.

1.1 Background

Nowadays, many designers struggle in optimizing the transistor's width and length. Usually, optimization process is done by trial and error technique. Therefore, fast and reliable artificial intelligent (AI) tools have become a pressing demand for analog designers.

Transistor size will determine the speed of circuit, energy consumption, total area of circuit, and the delay constraints. So, analog designers are tasked with taking large and small signal models of transistor, and in order to fulfill certain performance requirements, changing the transistors input parameters in accordance with output

constraints. A given output performance measurements like gain, g_m, unity gain bandwidth, w_c, phase margin, $\acute{o}$, they must correspondingly produce the input MOSFET parameters such as the length, L, and width, W and the input current, I. circuit sizing is the process to translating these parameters into performance measurement. In a modern analog design process, designers need to specify between 10 to 100 input parameters in order to achieve up to 20 output performance measurements.

Automated and manual methods for circuit sizing are in practice. The manual method of circuit sizing will be more time consume. It involves a designer using his or her own accumulated knowledge of circuit behavior to iteratively adjust the component parameters such that they satisfy a set of first order transistor models, and then test the accuracy of these models.

GA programming uses the length and width variables of MOSFET to optimize the size of transistors. From the optimal transistor's size, obtain the optimal output. An algorithm by using GA optimization for transistors sizing was created. Hence, a fast and productive automated circuit analyze and optimization tool help circuit designer to obtain optimal parameters of transistor in the shortest time. Ability of GA, one of the AI will help in automate the optimization. It automatically inserts the input parameter to the respective circuit and generates the corresponding output. From the Input and output generated, circuit parameters are optimized.

Besides, analog design optimization encompasses a large set of specifications. The design mostly relies on the solution from equation of the system. However, thousand of solution may exist when tons of objectives included in the system. The designer will assess which solution fits better according to the relative importance of each objective. Hence, a new strategic formulated by GA to tackle multi-objective optimization [1].

1.2 Problem Statement

Transistor's size optimization will involve numbers of transistors and single transistor's width and length. GA will randomly generate data set and optimal it base on output response from Pspice. So, a large search space will be need for GA to optimal large set of parameters. Limitation of the search space and narrow it up to a direction will be an important task. Search space always the main problem for optimal large set of parameter. If the direction of the searching technique wrong, then GA will never found the best parameter. It took time to search for the best solution.

Next, encoding technique for chromosome will be the main consideration. Binary encryption is produce precise data, decoding will be easy and process of genetic evolution more reliable. Disadvantage of binary encryption is data too precise and lead to large mutation rate. There are three more encryption techniques such as floating point encryption, gray code encryption and symbol encryption. Different data set or application will use different encryption method and it highly influences optimization result. Choosing these techniques to encode data in chromosome will be a huge problem to create GA optimization system. Reduction of selection error in GA analysis is the second priority problem. The accuracy of GA in selecting proper data set to create best chromosome need to be investigated. When selection processes occur in GA, different techniques applied to avoid certain bad condition and guide GA select better individual to perform evolution. These are the problem faced when the genetic algorithm is developed. Accuracy of output and precision of GA in analyzing data to produce output will be focus in the developed algorithm as well.

There are few circuit performance need to be optimized. Hence, this project will discuss the multi-objective optimization technique. Relationship between two or three objective function are created. Some of the optimal parameter will toward maximum while some will go to minimum. So, intermediate function is created to relate all the parameters to ensure the GA heading toward right direction. Time consumed in the optimization process is one of the concerns of algorithm developed.

1.3 Objective

Main objective of this thesis is to study the artificial intelligent (AI) technology to transistor size optimization. GA will be the main AI technology to be study here. Basic concept of GA will be understood and elements of GA are investigated. Genetic evolution process of GA which contains the basic element of selection, crossover, and mutation are concerned. Suitable technique for encrypt data into chromosome will concentrated also. Different encryption technique produces different optimization quality.

Secondly, after understood GA well, a GA optimization system will be created base on the study. This system wills optimal transistor's width and length in a specific circuit. GA optimization system consists of three stages. There are collect input stage, interface between software stage and optimization stage. GA will first analyze different set of transistor's parameter corresponding to different output by using Pspice simulator. Results from Pspice will feedback to GA to evaluate it fitness value. Fitness value will decide optimal parameter set.

Thirdly, automated and interfacing between Pspice and Matlab will be apriority task. In GA optimization system, interfacing between software are essential. Matlab which contain GA need output data from Pspice. Pspice is one of the accurate circuit simulators which can provide significant output result due to changing of transistor's parameter. Circuit output need to feedback to Matlab in order to continue GA execution. So, a lot of step need in this process. In order to make GA optimization system fast, automate interfacing will be an important task.

Fourth, develop multiple objective optimization algorithm are needed to optimal few specific circuit parameter. There are few outputs of the circuit will be optimized instance of one. In this study, multiple parameters selected are circuit total width, power and output gain. Matlab will be the core system of GA. Hence, different set of Matlab coding need to understand and explore. Matrix presentation, interfacing between data point and mathematic calculation will be use in GA.