Solving Structured Electronic Design of Negative Feedback Amplifiers as Nonlinear Programming Problems

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Abstract

This paper searches the best solution for the stages of noise and bandwidth of negative feedback amplifiers by resorting to Structured Electronic Design, through optimization methods. On one side, noise optimization is achieved by establishing the noise-characteristic as a function of bias current. On the other side, bandwidth optimization is obtained by establishing the equation for the open loop gain pole-product (LP product). Both aspects are defined as nonlinear programming (NLP) problems, where the design variables are related with the parameters of the device (bipolar transistors) used to synthesize the amplifiers. Differential Evolution is used to solve the noise NLP problem and the Hooke-Jeeves method is used to solve the bandwidth NLP problem. The obtained results are presented and some conclusions are established.

1 Introduction

Nowadays, some activities in engineering design are still lead by experience. Regarding Electronics, Structured Electronic Design is a methodology that starts from a set of assumptions and rules. A step-by-step modification of an ideal solution is performed until a real solution, which satisfies all initial requirements, is generated. In the present work, we will focus in the case of negative feedback amplifiers.

The negative feedback amplifiers are composed of an active circuit connected to a feedback network built by passive devices (see Figure 1). The active circuit is implemented by a nullor, which is synthesized by transistors, while the spec's are kept [8]. The main aspects of design to be considered are: noise, distortion and bandwidth. The way a so-

lution (design) is found rests on a search based on an ideal solution (the nullor), and by applying a synthesis procedure, the ideal solution is converted into a real one that fulfills the specifications [9]. Noise, distortion and bandwidth are the user specifications; subsequently these have to be satisfied when the new amplifier is designed.
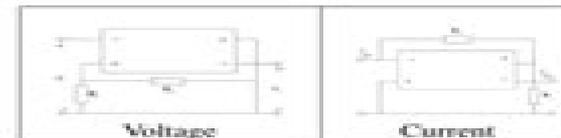

Figure 1. Voltage and current amplifier with resistive devices on the feedback network.

In this work, two of the three design stages: (1) noise and (2) bandwidth are modeled as NLP problems and solved with two techniques. The aim is to avoid designer-participation in the process and to let the optimization techniques do the search for the best design values (this activity is typically made by the designer) in Structured Electronic Design. To the best of our knowledge, this is the first attempt to solve Structured Electronic Design stages as NLP problems.

This paper is organized as follows: Section 2 presents an introduction to Structured Electronic Design, Section 3 includes the steps followed to define the elements of the optimization problems for noise and bandwidth stages. Furthermore, the two complete NLP problems are detailed. The two techniques used to solve each one of the problems and their corresponding results are presented in Section 4. Finally, some conclusions and future work are established in

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   Structured Electronic Design Chris J.M. Verhoeven,Arie van Staveren,G.L.E. Monna,M.H.L. Kouwenhoven,E. Yildiz,2007-05-08 Analog design is one of the more difficult aspects of electrical engineering The main reason is the apparently vague decisions an experienced designer makes in optimizing his circuit To enable fresh designers like students electrical engineering to become acquainted with analog circuit design structuring the analog design process is of utmost importance Structured Electronic Design Negative Feedback Amplifiers presents a design methodology for negative feedback amplifiers The design methodology enables to synthesize a topology and to at the same time optimize the performance of that topology Key issues in the design methodology are orthogonalization hierarchy and simple models Orthogonalization enables the separate optimization of the three fundamental quality aspects noise distortion and bandwidth Hierarchy ensures that the right decisions are made at the correct level of abstraction The use of simple models results in simple calculations yielding maximum performance indicators that can be used to reject wrong circuits relatively fast The presented design methodology divides the design of negative feedback amplifiers in six independent steps In the first two steps the feedback network is designed During those design steps the active part is assumed to be a nullor i e the performance with respect to noise distortion and bandwidth is still ideal In the subsequent four steps an implementation for the active part is synthesized During those four steps the topology of the active part is synthesized such that optimum performance is obtained Firstly the input stage is designed with respect to noise performance Secondly the output stage is designed with respect to clipping distortion Thirdly the bandwidth performance is designed which may require the addition of an additional amplifying stage Finally the biasing circuitry for biasing the amplifying stages is designed By dividing the design in independent design steps the total global optimization is reduced to several local optimizations By the specific sequence of the design steps it is assured that the local optimizations yield a circuit that is close to the global optimum On top of that because of the separate dedicated optimizations the resource use like power is tracked clearly Structured Electronic Design Negative Feedback Amplifiers presents in two chapters the background and an overview of the design methodology Whereafter in six chapters the separate design steps are treated with great detail Each chapter comprises several exercises An additional chapter is dedicated to how to design current sources and voltage source which are required for the biasing The final chapter in the book is dedicated to a thoroughly described design example showing clearly the benefits of the design methodology In short this book is valuable for M Sc curriculum Electrical Engineering students and of course for researchers and designers who want to structure their knowledge about analog design further   **Structured Electronic Design** C.J.M. Verhoeven,TU Delft, Faculty of Information Technology and Systems. Department of Electrical Engineering,1999   **Structured Electronic Design** Arie van Staveren,Chris J.M. Verhoeven,Arthur H.M. van Roermund,2006-04-18 Analog design still has unfortunately a flavor of art Art can be beautiful However art in itself is difficult to teach to students and difficult to transfer

from experienced analog designers to new trainee designers in companies Structured Electronic Design High Performance Harmonic Oscillators and Bandgap References aims to systemize analog design The use of orthogonalization of the design of the fundamental quality aspects noise distortion and bandwidth and hierarchy in the subsequent design steps enables designers to achieve high performance designs in a relatively short time As a result of the systematic design procedure the effect of design decisions on the circuit performance is made clear Additionally the use of resources for reaching a specified performance is tracked This book therefore describes the structured electronic design of high performance harmonic oscillators and bandgap references The structured design of harmonic oscillators includes the maximization of the carrier to noise ratio by means of tapping i e an impedance adaption method for noise matching The bandgap reference a popular implementation of a voltage reference is studied via the unusual concept of the linear combination of base emitter voltages The presented method leads to the design of high performance references in CMOS and Bipolar technology Using this concept on a high level of abstraction the quality with respect to for instance noise and power supply rejection can be identified In this book it is shown with several design examples that this method provides an excellent starting point for the design of high performance bandgap references Auxiliary to the harmonic oscillator and bandgap reference design are the negative feedback amplifiers In this book the systematic design of the dynamic behavior is emphasized By means of the identification of the dominant poles it is possible to give an upper limit of the attainable bandwidth even before the real frequency compensation is accomplished Structured Electronic Design High Performance Harmonic Oscillators and Bandgap References is a valuable book for researchers and designers as well as students in the field of analog design It helps both the experienced and trainee designer to come to grips with the design of analog circuits The presented method is illustrated by several well described design examples   EMI-Resilient Amplifier Circuits Marcel J. van der Horst,Wouter A. Serdijn,André C. Linnenbank,2013-07-23 This book enables circuit designers to reduce the errors introduced by the fundamental limitations noise bandwith and signal power and electromagnetic interference EMI in negative feedback amplifiers The authors describe a systematic design approach for application specific negative feedback amplifiers with specified signal to error ratio SER This approach enables designers to calculate noise bandwidth EMI and the required bias parameters of the transistors used in application specific amplifiers in order to meet the SER requirements   **Trade-Offs in Analog Circuit Design** Chris Toumazou,George S. Moschytz,Barrie Gilbert,2007-05-08 As the frequency of communication systems increases and the dimensions of transistors are reduced more and more stringent performance requirements are placed on analog circuits This is a trend that is bound to continue for the foreseeable future and while it does understanding performance trade offs will constitute a vital part of the analog design process It is the insight and intuition obtained from a fundamental understanding of performance conflicts and trade offs that ultimately provides the designer with the basic tools necessary for effective and creative analog design Trade offs in Analog Circuit Design which is devoted to the understanding of trade offs in analog

design is quite unique in that it draws together fundamental material from and identifies interrelationships within a number of key analog circuits The book covers ten subject areas Design methodology Technology General Performance Filters Switched Circuits Oscillators Data Converters Transceivers Neural Processing and Analog CAD Within these subject areas it deals with a wide diversity of trade offs ranging from frequency dynamic range and power gain bandwidth speed dynamic range and phase noise to tradeoffs in design for manufacture and IC layout The book has by far transcended its original scope and has become both a designer s companion as well as a graduate textbook An important feature of this book is that it promotes an intuitive approach to understanding analog circuits by explaining fundamental relationships and in many cases providing practical illustrative examples to demonstrate the inherent basic interrelationships and trade offs Trade offs in Analog Circuit Design draws together 34 contributions from some of the world s most eminent analog circuits and systems designers to provide for the first time a comprehensive text devoted to a very important and timely approach to analog circuit design   Low-Power Wireless Infrared Communications Rob Otte,Leo P. de Jong,Arthur H.M. van Roermund,2013-04-17 Today wireless infrared transmission has entered our homes offices industry and health care with applications in the field of remote control telemetry and local communication This book is about the underlying technology As it is an outgrowth of my Ph D thesis the emphasis is on fundamental aspects rather than industrial aspects like the standardization effort by the IrDA 7 I guess that this is not a drawback as eventually the laws of physics apply to all of us As the applied radiation is not necessarily in the infrared throughout the book we usually prefer the term optical transmission As most equipment is battery powered the emphasis is on power optimiza tion of the optical transmission system System parameters as well as environ mental parameters that determine the eventual transmission quality are iden tified to facilitate well reasoned system design Many design rules based on calculations measurements and simulations are presented to help the designer push the performance close to the limits set by nature and the available tech nology The first chapters introduce the subject and the present the scope of the book Then the basic transmission link is introduced in chapter 3 and strate gies to optimize its signal to noise ratio are discussed Lighting flicker is identi fied as a possible source of interference Then receiver noise and bandwidth are discussed in chapter 4 mainly based on the material presented in 66 67 69   **High-performance Frequency-demodulation Systems** Michael Hendrikus Laurentius Kouwenhoven,1998   **IEEE International Conference on Electronics, Circuits and Systems** ,2002   Proceedings ,2004   *Low-power Wireless Optical Transmission* Rob Otte,1998   Structured Electronic Design Arie van Staveren,Chris J.M. Verhoeven,Arthur H.M. van Roermund,2001 Analog design still has unfortunately a flavor of art Art can be beautiful However art in itself is difficult to teach to students and difficult to transfer from experienced analog designers to new trainee designers in companies Structured Electronic Design High Performance Harmonic Oscillators and Bandgap References aims to systemize analog design The use of orthogonalization of the design of the fundamental quality aspects noise distortion and bandwidth and

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Table of Contents Structured Electronic Design Negativefeedback Amplifiers

1. Understanding the eBook Structured Electronic Design Negativefeedback Amplifiers
    - The Rise of Digital Reading Structured Electronic Design Negativefeedback Amplifiers
    - Advantages of eBooks Over Traditional Books
2. Identifying Structured Electronic Design Negativefeedback Amplifiers
    - Exploring Different Genres
    - Considering Fiction vs. Non-Fiction
    - Determining Your Reading Goals
3. Choosing the Right eBook Platform
    - Popular eBook Platforms
    - Features to Look for in an Structured Electronic Design Negativefeedback Amplifiers
    - User-Friendly Interface
4. Exploring eBook Recommendations from Structured Electronic Design Negativefeedback Amplifiers
    - Personalized Recommendations
    - Structured Electronic Design Negativefeedback Amplifiers User Reviews and Ratings
    - Structured Electronic Design Negativefeedback Amplifiers and Bestseller Lists
5. Accessing Structured Electronic Design Negativefeedback Amplifiers Free and Paid eBooks
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