PRELIMINARY DISCUSSION OF A WORLD-WIDE-WEB BASED ANALOG CIRCUIT DESIGN TOOL AND DESIGN KNOWLEDGE REPOSITORY

by

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Abstract

A prototype network-centric circuit design tool and design knowledge repository has been developed. It allows a designer with network access to interactively explore a circuit design space of pre-characterized circuit topologies using a convenient graphical user interface. Any user can extend the system to include new or custom circuit topologies without a lot of programming effort by writing their own design specification files.

Designers will benefit from the use of the application as it will enable them to obtain a deeper understanding of the operation of their circuits and the performance tradeoffs that are possible for pre-characterized circuit topologies. The enhanced understanding gained by the designers will result in better design realizations and will accelerate the development of improved topologies in the future.

Several benefits accrue due to the use of the network-centric computing paradigm of which the most significant is the enhanced communication of design knowledge and prevention of reinvention by the use of a centralized *Design Knowledge Repository*.

Introduction

Complex digital systems are commonly synthesized today using automated circuit design systems. Considerable effort has been expended in an attempt to apply design automation concepts to analog systems [1-4]. However, almost all commercial analog circuits are still designed by hand. The limited success of analog design automation is often attributed to the complexity of the analog design problem itself. Analog design is a very knowledge-intensive task that is presently best performed by humans.

Most of the design automation systems reported in the literature complete the entire design process with little or no human interaction. They are often criticized for their complicated nature and steep learning curves. Due to the complex nature of the general analog design problem, rather than attempting to solve the entire design problem in one automated step, it may be advantageous to not completely remove human interaction from the process at the outset. Rather, more practical benefit may be derived from small, easily used, interactive design tools that analog designers can use to make their jobs easier. With this approach, each utility will be used for only a small portion of the overall design task and humans will still guide the process.

Accelerated Assimilation of Designer Knowledge

The standard technique that is commonly taught for solving a multidimensional circuit design problem is to define an application specific cost-function and subsequently use an optimization routine to determine the design parameters that minimize it. Practically, circuits are seldom designed using this methodology because writing a cost-function that realistically represents a designer's priorities is a complicated and time-consuming task that depends upon the application under consideration. Attempting to short-circuit or approximate the cost function results in circuit designs that are sub-optimal.

As a side effect, the use of mathematical optimization tools does not substantially contribute to the designer's understanding of the relationships among the performance parameters and the design parameters. This is problematic because coming up with improved circuit designs and circuit topologies is a creative process that draws upon all of a designer's experience and understanding. The use of automated optimization procedures may actually impede the development of improved circuit topologies because the non-interactive nature of an automated optimization approach results in slower assimilation of designer knowledge.

Designers can more rapidly deepen their understanding of a design by interactively exploring a design space and observing the corresponding effects on and the relationships between the performance parameters. The benefits are especially clear for designs that are too complicated to derive tractable analytical relationships for the performance parameters. The additional insight into design performance gained by manual exploration of the design space will aid the designer in creating improved design topologies in the future.

Duplication of Effort

Reinvention is another problem that plagues the analog circuit design community. Many of the same circuit problems arise over and over again in slightly different contexts. In most cases, the resultant solutions are not sufficiently generalized to be easily applied to future applications, and if they are, there is often not a practical mechanism to communicate the results to the larger design community. Even groups within the same organization commonly duplicate each other's efforts.

Aggregation of generalized design knowledge in one central location that is accessible to everyone within an organization through a standardized interface could result in substantial productivity gains.

The Prototype Application

To address the problems previously discussed, a prototype application consisting of a network-centric circuit design tool and a design knowledge repository have been developed. A block diagram of the prototype system is presented in Figure 1.

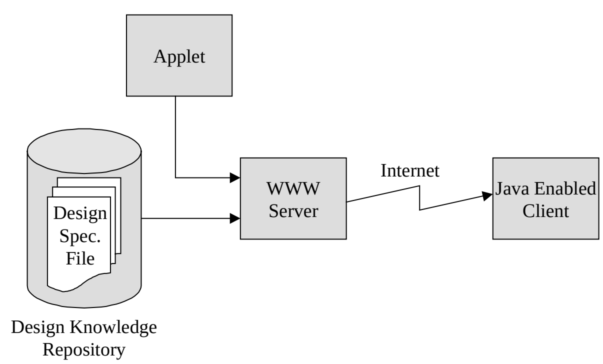

Figure 1 Block diagram of the proposed system

As depicted in Figure 1, the prototype system conforms to the emerging network-centric computing paradigm. The executable, in the form of a Java applet, is transmitted to any Java capable web browser via a network connection. A repository of pre-defined design specification files is maintained at the server. Each of the design specification files embodies the design knowledge available for a specific circuit topology that can be downloaded and used to program the applet at the request of the client.

The downloadable applet is used to interactively explore a design space through a graphical user interface. The required design information is defined by loading a text-based design specification file that contains a list of equations used to characterize the behavior of the circuit and a list of constraints that restrict the solution to the domain of viable solutions.

The application is similar in concept to the equation manipulator developed by Swings, Gielen, and Sansen called DONALD in [4]. As described in their publication, this tool could eventually become part of a larger overall automated analog design system. Our realization differs from theirs in that the system architecture was chosen to be network-centric and the equations are required to be declared in imperative form.

The application's interactive nature will allow designers to more quickly obtain a deeper understanding of how their circuits operate and what performance tradeoffs are possible for a given circuit topology. The additional insight gained through the use of the tool will accelerate the development of improved circuit topologies in the future. Reinvention is avoided because the design specification file for a given circuit topology is developed once by one author and then "published" for others to use.

Downloadable design specification files can be quickly used to investigate the characteristics of certain pre-characterized circuit topologies. Any user can extend the system to include new circuit topologies by developing their own custom design specification files that upon completion can be published for others to use by submission to a centralized design knowledge repository.

Figure 2 contains an example screen snapshot of a Design Space Explorer application window. This example focuses on the design of a common source amplifier. The window is divided horizontally into two resizable panes. The lower pane, called the *feedback pane*, contains a text area used for providing interactive feedback to the user while the upper pane contains a table of design parameter data.

The first row in the table is a special row that holds the *present value* of all the parameters. The table cells with white backgrounds are independent modifiable parameters while those with a gray background are either declared as constants or computed and not modifiable.

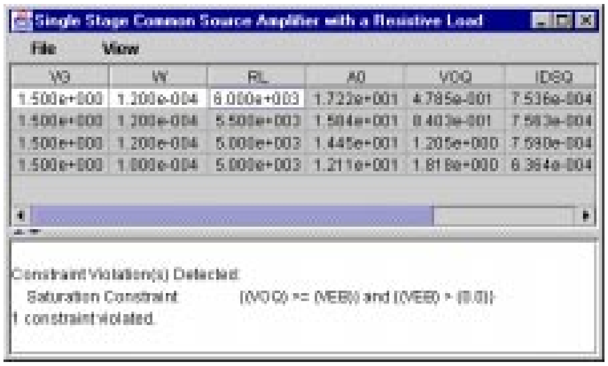

Figure 2 Example snapshot of the Design Space Explorer Application Window

When a user changes one of the modifiable cells, the values of the affected dependent parameters are recomputed and all of the design constraints are evaluated. If any one of the constraints is not satisfied, the design is not viable and an error message indicating the constraints that were violated is presented in the feedback pane. If all the constraints were satisfied following the modification of a parameter, then the design is considered *viable* and a row containing the values of all the viable design's parameters is added to the table. In this manner, the application automatically maintains a history of all of the viable designs encountered. This is a valuable feature for designers because they can review and compare the effects of the various parameter adjustments throughout their entire session.

In the screen snapshot of Figure 2, three viable designs were present in the table in rows 2 through 4 at the time the snapshot was taken. Each of the three viable designs satisfies all of the applicable constraints but since the independent parameters for each of the three designs differ, they have slightly different values of the performance parameters. As indicated in the feedback pane, the *present design* in row 1 is not viable because it does not satisfy all of the design constraints.

The interface has been designed to enhance productivity by allowing the user to control parameter visibility and display order. This feature allows the user to focus only on the parameters of interest, shielding them from unnecessary complexity. Additionally, the user is given the ability to reorder the rows of the table based upon a column-wise sorting criterion. This allows the user to quickly rank the viable designs based upon the parameters of interest.

Advantages of Network-Centric Paradigm

Network-centric applications are becoming increasingly viable as networking technology matures. In this application, several advantages accrue due to the use of the network-centric paradigm:

- Facilitates organization-wide (or worldwide) accumulation, sharing, and archiving of design knowledge by making well-documented design specification files available in a *Design Knowledge Repository*. Due to the fact that users can search the repository for circuit topologies that have already been characterized, the use of one centralized knowledge repository prevents duplication of work already performed.
- Software is available for use anytime, from any networked location, worldwide.
- Other than a Java capable web browser, no special application software is required.
- Cross-platform compatibility is assured by the use of Java. This is especially beneficial for large enterprises with multiple platforms because it helps facilitate communication of design knowledge between disparate groups.
- Since the computation occurs on the client-end, the system is scalable to support virtually any number of clients.
- Lower administration costs. Once the required Java capable browser is installed, users do not need to spend time acquiring, installing and updating software on their machine(s). Since the most recent software version resides in one place on the server, revision maintenance becomes trivial.

Conclusion

Many attempts at analog design automation focus on completing the entire design process with little or no human interaction. The lack of interactivity slows the assimilation of designer knowledge and the advancement of new circuit topologies in general. Additionally, circuit designers within an organization and throughout the world are duplicating each others work over and over again. The use of organization-wide or worldwide platform-independent design knowledge repositories offers potential for reducing the frequency of reinvention.

To address these problems, a prototype network-centric circuit design tool and design knowledge repository has been developed. It allows a designer with network access to interactively explore a circuit design space of pre-characterized circuit topologies using a convenient graphical user interface. Any user can extend the system to include new or custom circuit topologies without a lot of programming effort by writing their own design specification files.

Designers will benefit from the use of the application as it will enable them to obtain a deeper understanding of the operation of their circuits and the performance tradeoffs that are possible for pre-characterized circuit topologies. The enhanced understanding gained by the designers will result in better design realizations and will accelerate the development of improved topologies in the future.

Several benefits accrue due to the use of the network-centric computing paradigm of which the most significant is the enhanced communication of design knowledge and prevention of reinvention by the use of a centralized, platform-independent *Design Knowledge Repository*. Other benefits include reduced system administration costs, system scalability, and improved mobile computing ability.

Acknowledgements:

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