LINC2 Synthesis, Optimization and Yield Analysis – Three Key Components for Successful First Pass Circuit Design (Part 1 of 2)

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As the use of high frequency simulation software became indispensable to the task of designing modern RF and microwave circuits, most EDA (Electronic Design Automation) software packages that addressed this market included at least two core ingredients; circuit simulation and circuit optimization based on a numerical optimizer. These two software tools became so ubiquitous that design methodologies coalesced around their combined use. However, circuit simulation is strictly analysis, not design. Moreover, an optimizer can only make adjustments to the component values of a circuit topology that is already known. It cannot, on its own, come up with a more optimum circuit topology. Although RF and microwave circuit designers exhibit great skill in the application of these tools, the fact that they are often used to "design" circuits even though neither is capable of circuit synthesis has lead to certain undesirable consequences.

First and foremost, circuit design via the simulation/optimization cycle is a trial and error process with no guarantee of success. There are a host of reasons why an optimizer may fail to bring a particular circuit design into compliance with the desired design goals. The process relies heavily on the ability of the practitioner to select a viable circuit topology from a library of pre-existing circuit designs or past experience. The likelihood of successfully designing a circuit by simulation/optimization is directly proportional to the degree that the circuit (and initial component values) presented to the optimizer resembles the desired circuit, i.e. optimization works best when the answer is already known! [1]

For example, it is generally known and accepted that changing the specifications for a filter design may force a change in the filter topology, requiring at least an increase in filter order (increasing the number of components) or a completely new filter type (a radical change in topology) in order to meet the new or improved performance specifications. Most designers would not attempt the futility of trying to use an optimizer to tweak the filter's component values in order to meet a new set of specifications that are substantially more demanding. And yet, for active circuit design, there are practitioners who would attempt to optimize the input and output matching networks of an existing amplifier circuit in order to match to a new device or transistor. One example of where this attempt might fail is if either of the matching networks use one of the eight possible configurations of the common two-element L network. All attempts to optimize the component values to reproduce a match to the new device will fail if the impedance of the new device lies outside the reach of the particular L configuration used. Only a change in topology, such as using a different L network, will solve the problem. Unfortunately, the designer may not realize the futility of the effort until a great deal of time has been spent with the optimizer.

Another problem that can arise with the simulation/optimization procedure is that the optimizer can get stuck in a local minimum in the error function. When this happens, the user is left without any clear idea of how to proceed. Should different weights and con-

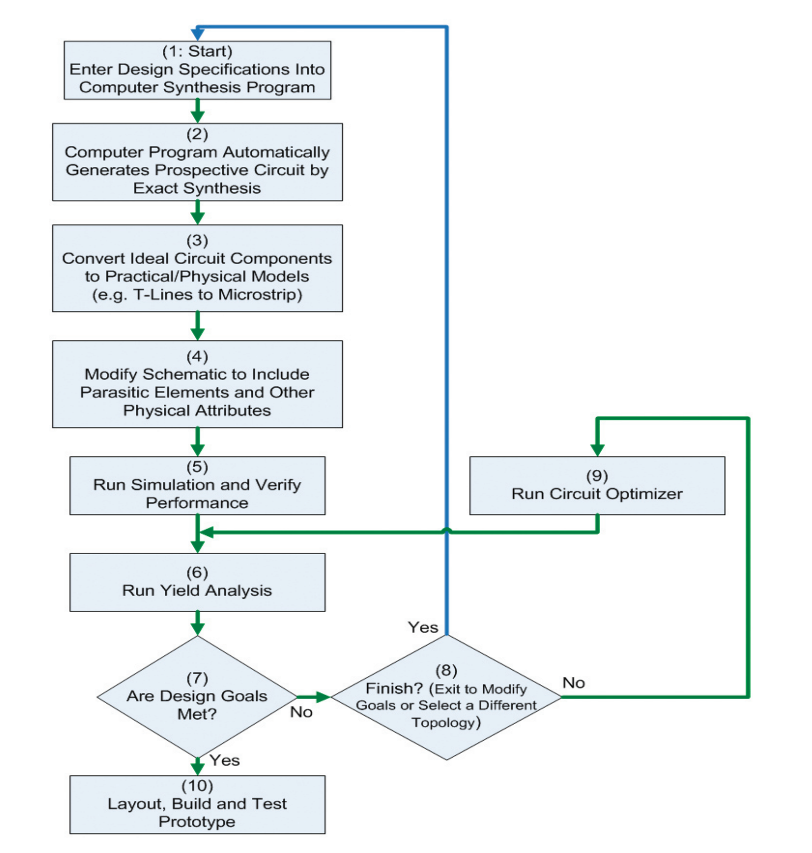

Figure 1: The Design Flow

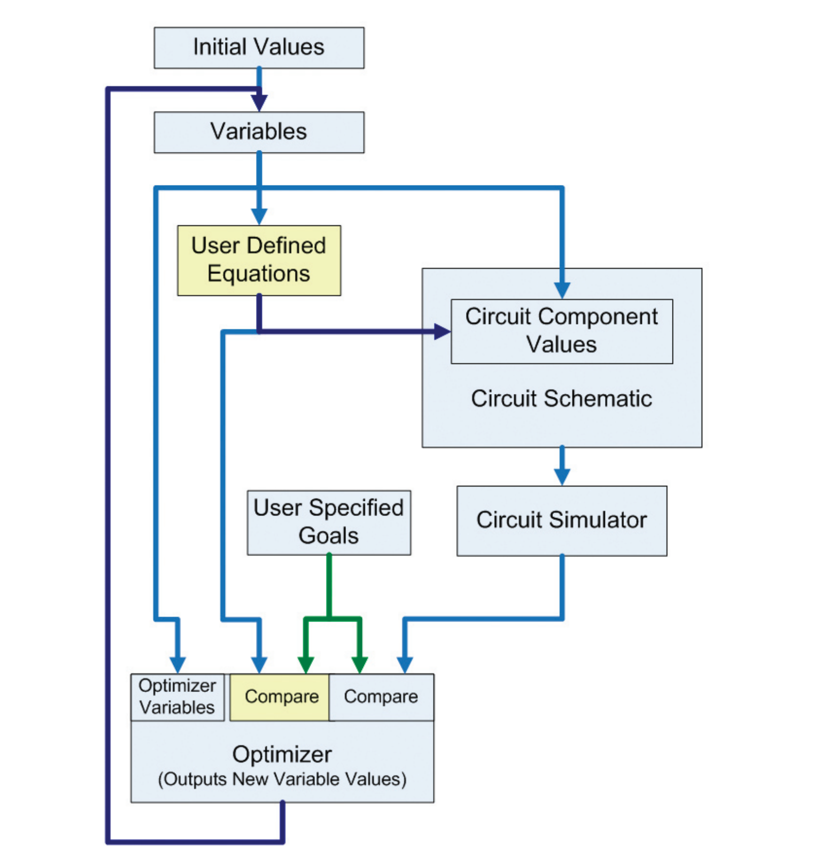

Figure 2: Including User Defined Equations in LINC2 Optimization

straints be placed on variables? Is a different circuit topology required, or simply a different set of initial component values?

To help eliminate these problems, a design procedure is outlined in **Figure 1** that includes synthesis, simulation, and yield analysis. Optimization is included in the design process flow when needed to compensate for the inclusion of parasitic elements or when ideal components are replaced by physical models. For narrowband designs, the synthesis program can produce circuit prototypes that are exact and optimization used near the end of the design process (**Figure 1**) is performing the role of fine tuning (mostly to account for slight performance shifts due to parasitics). In this case the optimizer has virtually a 100% chance of meeting the goals if they are in line with the original synthesis specifications. In the case of wideband design where an exact solution may not be available, the synthesis program can generate an approximate solution or one that meets some specification over a portion of the frequency band (allowing the optimizer to attempt to finish the job of bringing the design to compliance). Even in wideband design where the optimizer is more heavily used, it still benefits greatly from circuit synthesis seeding it with an approximate solution.

Not all optimizers are alike. Some compromise speed for accuracy while others leave it up to the user to figure out (by trial and error process) which type of optimizer is best suited for the problem at hand. The advanced LINC2 optimizer, provided as an integral part of the LINC2 software suite, is powerful, easy to use, and adaptive, thus taking the guesswork out of employing the right type of optimizer. Another reason for using the LINC2 optimizer is that it provides additional capability that may not be found in other optimizers. For example, the new LINC2 optimizer accepts user defined equations that provide additional control over the optimizer above and beyond the usual circuit response goals (see **Figure 2**). The second part of this article will use an amplifier design example to demonstrate how the LINC2 optimizer can take into account an equation that formulates a (user specified) constraint on the physical size of the circuit (e.g. the total length of all microstrip used in the design).

Having the ability to optimize equations is a very powerful tool because it gives the designer control over the outcome of the design in ways that are not necessarily related to electrical performance, and yet may be just as important as the electrical (circuit response) performance. Thus in LINC2, the physical dimensions are one example of an aspect of the design that can be optimized along with the electrical performance. Then lastly, yield analysis provides a final check that the desired performance holds up when component values are allowed to vary over their specified tolerance range.

Therefore, the key to successful first pass circuit design includes circuit synthesis, optimization, and yield analysis in conjunction with simulation. The LINC2 Pro software suite from ACS (Applied Computational Sciences) includes all of these essential program modules. LINC2 integrates filter synthesis, amplifier synthesis (including LNA design and synthesis), matching network synthesis, and component synthesis with a high performance circuit simulator. In an upcoming issue, part 2 of this article will use these essential LINC2 program features to demonstrate the design flow of **Figure 1**.

Summary and Conclusions

A design process was presented that includes synthesis, simulation, optimization and yield analysis. The process outlined in **Figure 1** offers an alternative to the "design by simulation/optimization" cycle. The alternative design method employs circuit synthesis software to produce a prospective circuit design that includes a working topology with computed component values that are exact. In the case where optimization is necessary to tune out the effects of added parasitics (and other practical circuit details), the optimizer may still benefit from a circuit synthesis program seeding it with an initial circuit, complete with component values that are already well along in the process of meeting the design requirements.

Features of the new LINC2 optimizer are presented in **Figure 2**. In part 2, the power of this new optimizer and its capability to control the physical size of the circuit, in addition to optimizing electrical circuit responses, will be demonstrated. As an example, a global equation will be set up that computes the total length of microstrip traces primarily responsible for the overall physical length of the amplifier design. The equation (and thus the physical length of the product) can then become part of the optimizer's goals. It is a powerful new capability that the same optimizer that optimizes RF circuit performance can also be directed to restrain or reduce physical size, seemingly independent from any direct relationship to electrical performance.

The LINC2 Software Suite

LINC2 is a high performance RF and microwave design and simulation program from ACS. In addition to schematic based circuit simulation, optimization and statistical yield analysis, LINC2 Pro includes many value-added features for automating design tasks, including circuit synthesis.

LINC2 offers exact circuit synthesis, schematic capture, circuit simulation, circuit optimization and yield analysis in a single affordable design environment. More information about LINC2 and links to other related articles can be found on the ACS web site at www.appliedmicrowave.com.

References

1. *Designing Microwave Circuits by Exact Synthesis, Brian J. Minnis, Artech House 1996.*

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