The Case For High-Capacity Analog Optimization

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Analog, mixed-signal and custom integrated circuit design topology selection and device sizing is currently a very manual process. Tools used to aid in these processes include schematic capture environments and simulators. This note looks at key requirements for an automation toolset, termed a high capacity optimizer, to provide value to the designer and how this differs from past low-capacity and medium-capacity optimization offerings.

Introduction

The manual analog front-end design methodology involves topology design, topology selection and finally sizing devices of the selected topology to meet specifications robust to manufacturing and environmental variations. Much of this front-end design process involves manual iterations between the designer and his simulator. However, this tends to be a very time consuming process since there are often a dozen or more specifications that must be achieved across up to 60 manufacturing and environmental variations. Furthermore these specifications tend to tradeoff against one another as, for example, one could achieve better phase margin by compromising gain or achieve better gain by compromising phase margin. Coming to the market are high capacity toolsets to automate the manual, time consuming processes.

A high capacity optimization toolset has the following the attributes:

- Handles any custom topology
- Has an automation environment to allow designers to quickly import topologies and set up their design intent
- Handles 30 design specifications simultaneously
- Flexibility to vary variables of up to 200 devices
- Flexibility to handle up to 60 different manufacturing and environmental variations
- Final design performance is validated with designer’s simulator using his foundry process information
- Multiple circuit solutions are generated depicting performance tradeoffs among specifications

So, through a high-capacity optimization toolset the designer is quickly able to specify his design intent, optimize realistic commercial problem sizes, optionally guide the optimization with designer knowledge, and review an archive of simulator-validated circuit designs generated to choose the performance tradeoffs most desirable for the current application.

This note looks at these attributes and contrasts them to low- and medium-capacity optimization tools.

Custom Topology

Designers spend significant effort in designing their own proprietary topologies that offer advantages over the competition and, consequently, the algorithms employed within the optimization toolset need to be capable of being general enough to handle any analog, mixed-signal and custom integrated circuit topology. Low- and medium-capacity optimization tools often incorporate linear gradient, simulated annealing, or geometric programming type algorithms which are often tuned to particular classes of topologies or require a comprehensive set of equations describing the topology to be defined. Research into the area of intelligent systems has allowed for the development of a high-capacity optimization engine which, incorporated into high-capacity optimization tools, provides the designer the flexibility to use any custom and proprietary topology with any set of foundry process files.

Automation Environment

For automation to become useful, capturing designer intent needs to be a relatively quick process and in low- and medium-capacity optimization tools this has been quite time consuming or lacks the ability to capture all design requirements. The high-capacity optimization toolset provides a full automation environment that includes:

- Ability to import test benches, measurements and topology from the manual design environment
- Automatically imports device size constraints and default ranges from the schematic
- Allows for easy transistor matching set up, device cross-probing and back-annotation to the design entry tool
- Easy setup and validation of measurements, allowing waveform plotting for test bench set up and inter-test bench connections
- Ability to specify device operating constraints
- Ability to specify all performance specifications
- Ability for designer to steer optimizer during an optimization run providing designer-controlled automation

With these capabilities, a designer can quickly, accurately and comprehensively specify his design intent within the automation environment.

Handle 30 Design Specifications Simultaneously

Unlike digital design, which may have two or three design specifications, analog, mixed-signal and custom integrated circuit design often has a dozen or more objectives that must be met simultaneously. Low- and medium-capacity optimizers, differing in the number design specifications they can handle, both often use a weighted-sum approach of having the user specify a weight for each of the specifications, and a weighted sum determining the goodness of a particular circuit. The weights, of course, have a dramatic impact on the regions that the optimizer searches and it is not intuitive for the user as to how to specify weights. The high-capacity optimizer does not require the user to specify weights. Rather, it provides the user with the option of setting priority groups for the specifications, thus specifying the high, medium and low priority design objectives. This, coupled with the high-capacity optimizer's output of an archive of multiple circuit solutions (described below) provides the user with the ability to determine what the capabilities are of a particular topology around the specification region of interest. Furthermore, the ability to handle 30 design specifications simultaneously ensures the tool is useful for commercial circuit designs.

Flexibility To Vary Up To 200 Device Variables

Low- and medium-capacity optimizers have been limited to being able to handle 10 and 30 transistor variables, respectively. This is often limiting when optimizing commercial designs. High-capacity optimizers, incorporating a high-capacity optimization engine, provide the flexibility for designers to input up to 200 variables. Of course the ability to handle this size of designs gives the ability to handle a much larger variety of circuit problems.

Flexibility To Handle Up To 60 Manufacturing And Environmental Variations

The final design must be robust to manufacturing and environmental conditions which could include process, temperature, and supply voltage variations, etc. Low-capacity optimization tools are incapable of handling any variations whereas medium-capacity optimization tools can only handle 3 of these variations. This is limiting and without running the design across all variations, there is the risk that the final design produced by the optimizer is very sensitive to particular manufacturing and environmental conditions. A high-capacity optimizer, through its algorithms, provides the capacity to handle up to 60 manufacturing and environmental variations ensuring robust designs for commercial grade circuits.

Simulator-Validated Results

Some medium-capacity optimization tools use an equation-based technique for optimization. This limits their ability to only handle particular topologies where the equations characterizing the topology's behavior are predefined. Most companies will create custom topologies to differentiate their end product from competitors, so equation-based optimization will not support these topologies - unless of course the company wants to divulge their highly-valuable and confidential custom topology to these optimization companies, and allows them to optimize it.

A high-capacity optimization tool is different in that it is topology-independent, and any custom topology could be optimized. It does not use equations to optimize, but rather uses simulators as the feedback agent to the optimizer. This methodology allows for easy process migration since, by simply importing the new set of process files into the simulator, a design can be quickly migrated to the new foundry.

Multiple Circuit Solutions

Low-capacity and medium-capacity optimization tools generally use a linear gradient or simulated annealing algorithm engine to come up with a single design solution. Needless to say ending up with only one design solution does not give analog designers the flexibility that they need when choosing a circuit for their designs.

This is sometimes called the “black box” approach since a designer has limited control over the optimization process with low- and medium-capacity optimization tools. A designer will submit his topology into the low- or medium-capacity optimization tool, and have one solution come out.

High-capacity optimization, on the other hand, offers a multiple solution approach which offers designers more control before and during the optimization process. Before an optimization designers can guide the optimization process in a broader fashion, specifying corners and device sizing guidelines, etc. During the optimization designers can observe the results coming in, quickly see trends and options, and “steer” the optimization process to find even more optimal results. The multiple solutions give a broader understanding of what is possible with the designer’s topology, and empower the designer far more than a simple one-solution option. Furthermore, multiple solutions among different topologies can be compared to determine the various benefits to aid in the selection process.

Conclusions

To be beneficial in a commercial setting, high-capacity optimizers have been developed to provide designers the ability to quickly specify his design intent, handle small or large designs with small or large number of manufacturing and environmental variations, generate multiple optimal simulator-validated solutions, and control the optimization. With these features significant savings on time-consuming design tasks can be achieved with more novice designers involved in complex device-sizing tasks.

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