



# Ensuring Reliable and Optimal Analog PCB Designs With Advanced Analysis for **SPICE Simulation**

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**P**CB designs that have been tested for functional Simulation Program with Integrated Circuit Emphasis (SPICE) simulation are not optimal and reliable unless the design components are also optimized for parameter values, tolerances, and power ratings. Although designers can use technologies such as Optimizer and Monte Carlo to analyze circuit simulation behavior and fine-tune designs, they need an integrated environment to make the best design tradeoffs. This article will show how PCB designers can ensure that designs are not only functionally correct but also reliable, optimal, and deliver high yield.

## Introduction

In the traditional simulation flow, a design is iteratively tested with SPICE simulators at typical values. It is sent for PCB prototyping or manufacturing only when the circuit operates with the intended behavior. This practice of prototyping or manufacturing a working circuit often causes problems in the real world because a working circuit is not necessarily a reliable circuit. If the operating conditions are harsh, a working circuit might malfunction when the safe operating limits (SOL) of the circuit devices are violated, thus leading to component breakdown. To prevent stress failures, designers tend to make tolerances unnecessarily tight and use devices with high SOLs. This is known as over-designing, and it not only makes circuits non-optimal but also reduces yield.

SPICE analog circuit simulation software with advanced analysis capabilities

built on top functions beyond the traditional simulation flow. This helps prevent over-designing by allowing designers to meet required performance, reliability, and manufacturability specifications.

Through an easy-to-use, intelligent, multi-simulation environment, designers can import measurements from analog circuit simulation software and conduct optimization (Optimizer), Sensitivity, Smoke, and yield (Monte Carlo) analyses in a methodical yet flexible way. This type of environment further enables designers to process simulation results for the best balance of performance, yield, and safety.

## Traditional Simulation: Unwieldy Approach, Many Iterations, Inadequate Results

A typical design has measurements of interest spread across various output nodes of the circuit and various test stimuli that are applied at different input nodes of the circuit. The designer creates test conditions based on the design specification and simulates the design for each test condition. Each round of simulation is followed by inspection of results and tweaking of design parameters until the design converges across all key measurements. If the design specification takes into account factors such as cost and manufacturability in addition to functional correctness, this iterative simulate-inspect-tweak cycle using a SPICE simulator must be followed by several rounds of arbitrarily adjusting the values of design parameters to make the design optimal, safe, and implementable.

Using traditional simulation technologies,

there is no way the designer can tweak some parameters and immediately determine if the design still meets the specification, nor can the designer modify the specification and see the impact on the parameter values. Furthermore, if multiple specifications have to be solved, there is no easy way to adjust all parameters simultaneously.

In the absence of technologies that address design complexities and implementation and operating realities, traditional simulation relies significantly on over-designing. PCB manufacturing issues—tolerance variations or operating conditions such as device stress—are not tested thoroughly. Instead, the usual tendency is to over-design by tightening tolerances arbitrarily or adding heat-sinks without analyzing their requirements.

## Point Tools: Piecemeal Analysis, Non-Optimal Results

Advanced analysis capabilities such as Optimizer, Sensitivity, and Monte Carlo analyses help designers overcome some of the limitations of traditional simulation practices. Optimizer not only automates the iterative process of adjusting component values but also minimizes the number of iterations by intelligently determining the changes that are likely to deliver results. If the designer runs Sensitivity before running Optimizer, the number of iterations required to optimize the design can be further reduced because optimizing only the sensitive components can achieve optimal results. After the design is optimized, the designer can run Monte Carlo and improve the yield by varying the tolerances.

Reduced iterations, a more methodical

approach, and decisions backed by data are some of the benefits of using available simulation tools. However, when these tools are run independently and the designer does not have a mechanism to handle and visualize measurements across multiple simulations, results are not always optimal. Consider, for example, analyzing a PCB design that is predominantly nonlinear with Monte Carlo, which works with a random pick of values. A random pick of the value within a tolerance range does not guarantee there will be no combination that might cause the desired value to go out of specification. Therefore, to ensure stability in the tolerance zone, the designer needs to carefully examine the sensitive components. In a case like this, designers can make better decisions if the simulation tools are integrated. They can run the tools in any flow that is suitable for applying their simulation strategies and examine the results of multiple simulations through a unified interface.

### **Advanced Analysis Capabilities: Flexible Flows, Maximize Performance**

Advanced analysis is not just a combination of point tools but is a well-integrated environment of key simulation capabilities: sensitivity analysis, optimization, parametric plotting, statistical analysis, and stress analysis. Not only does an integrated environment enable the various software products to talk to one another (therefore offering a comprehensive solution), but each of these technologies packs more power than its standalone counterpart and is designed specifically for the PCB domain.

### **Sensitivity Analysis**

PCB tolerances are large. Circuit measurements can change in a nonlinear manner when parameters change within these large tolerances. Additionally, PCB analog circuits often contain switching elements that further contribute to making the circuit measurements nonlinear. Traditional DC sensitivity analysis available in most SPICE engines is based on delta changes and assumes that test measurements are linearly related to parameter changes. Extrapolating such sensitivity analysis through nonlinearities does not work on actual circuits.

To produce adequate results, a sensitivity analysis based on repeated simulation runs for different values of parameters (within tolerance limits) is needed. Such sensitivity

analysis allows designers to run simulations in the tolerance region of components and provides sensitivity information of parameters with respect to measurements. Refining tolerances based on sensitivity information leads to a better device choice and a higher yield. It also helps minimize simulation iterations when the circuits run through the optimizer. The results of Sensitivity analysis provide useful inputs to Optimizer and Monte Carlo.

### **Optimizer Technology**

Using the traditional least square (LSQ) optimization engine might work for simple circuits but it is likely to fail if designs are complex and nonlinear. Optimizing a design with respect to one type of test vector might actually offset the design outputs against specifications for other test vectors. The need is twofold: the ability to handle different simulations (driven by different test vectors) and a choice of various engines that provides flexibility in applying optimization strategies and helps the designer gradually determine the optimal values. The random engine is needed to obtain an estimate of optimal zones. The seed provided by the random engine can make the LSQ engine more effective. The discrete engine can round off the optimal values to manufacturable values. This approach provides the ability to handle nonlinearities more effectively than the traditional optimization approach and therefore works well in the PCB domain.

Unlike traditional Optimizer tools, technology that supports multiple optimization engines can optimize a design across more than one simulation profile, covering all measurements in one go. This means that if a circuit behaves differently with two different stimuli, this technology will be able to optimize across two simulations simultaneously and provide results that address both circuit profiles.

### **Parametric Plotting**

Once a circuit is created and simulated, the parametric plotter is used for sweeping multiple parameters to help analyze the stability of a solution within the tolerance zone. Parametric plotting provides a solution space around the point suggested by the Optimizer tool. The designer can sweep parameters across various simulation measurements and visualize results as multiple 2D plots or in a spreadsheet. The spreadsheet view supports more than one way of sorting to help examine the solution space.

### **Statistical Analysis**

Monte Carlo statistical analysis predicts the behavior of a circuit statistically when part values are varied within their tolerance range, providing yield for each measurement. If the yield is not acceptable, the designer should reexamine the sensitivity results and tighten the tolerances to suit yield. All measurements across different simulation profiles should be processed in one go, and results should be displayed corresponding to different measurements. Unlike traditional Monte Carlo that supports a single tolerance, advanced analysis options must support both positive and negative tolerances to be completely effective.

### **Stress Analysis**

Stress analysis warns of component stress caused by power dissipation, increases in the junction temperature, secondary breakdowns, or violations of voltage or current limits. It audits all components and flags those that fail stress tests and exceed SOLs. Based on the results, the designer can select components with higher device ratings or apply heatsinks. For long-term circuit reliability, stress analysis is critical.

### **Advantages of Advanced Analysis**

Advanced analysis starts where SPICE analog circuit simulation ends. After a design is simulated to ensure that it is functionally correct, designers can import advanced analysis measurements plus tolerance and safe limit information from component libraries. Using advanced analysis capabilities, designers can automatically maximize the performance of circuits—this eliminates trial-and-error bench testing or piecemeal analysis. Integrating sensitivity analysis, optimization, parametric plotting, stress analysis, and yield analysis into simulation technology enables engineers to create virtual prototypes of designs. It also enables designers to methodically analyze designs from standpoints that range from design nonlinearities to implemented values. The result: a reliable, safe, and optimal design even before any prototype is produced. ■

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