DIGITAL INDUSTRIES SOFTWARE

How Siemens EDA's Solido achieved production-grade AI in EDA applications

Executive summary
In this paper, we'll classify the levels of artificial intelligence (AI) maturity/sophistication in EDA today, what it took for Siemens EDA's Solido group to develop production-grade AI in its Solido Design Environment and Solido Characterization Suite tool offerings, and how production-grade AI in these tools greatly enables design teams to get innovations to market faster.

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Introduction

It's hard to miss the hype about AI in just about everything today, so it should be no surprise that this hype has also crept into EDA marketing. But in many cases, AI is truly showing great results in improving engineering productivity and speeding up the IC design process. Perhaps the most advanced group in using AI in all of EDA is the Solido team in Siemens EDA's Custom IC verification division.

In a very compelling webinar, "Getting the right answers with machine learning," by Siemens EDA's Jeff Dyck, Dyck describes the journey Solido took starting fifteen years ago as the EDA startup that pioneered the use of AI to solve the EDA industry problem of accurate variation-aware verification at the SPICE-simulation level. This solution has now been expanded to rapidly finding and fixing variability and characterization-related showstoppers in design and IP, and it is widely deployed in semiconductor and system companies today.

For any new semiconductor design or process, all components of the design, from foundational IP to custom circuits, must be verified at the SPICE level to perform at or beyond specification across all process, voltage, and temperature (PVT) operating corners, as well as local device variation.

Without the correct tools, this is an exhaustive task. For example, from a statistical standpoint, a 6-sigma verification target means one error out of one billion samples, which actually requires approximately 10 billion samples to measure with a reasonable confidence interval.

In addition, Liberty model characterization has also grown into a process that requires hundreds of thousands to millions of simulations to complete. Liberty models are utilized by static timing analysis (STA) tools to perform timing, power, and area analysis on large digital designs using a lookup table approach instead of running SPICE on every transistor in the design. As a result, an exhaustive combination of input and output, as well as PVT conditions must all be pre-simulated in SPICE, which results in an exorbitant amount of simulation required in this step.

Solido leveraged AI to achieve disruptive acceleration in this process while maintaining full production accuracy. Using AI methods that adaptively utilize real simulations to obtain initial results, intelligently select sample points, and fine-tune AI-produced results to arrive at SPICE-accurate measurements even at the tail end of output distributions, Solido's AI technology enables design and verification teams to achieve the same production-accurate SPICE results orders of magnitude faster than brute-force methods. This technology is included in Siemens' Solido Intelligent Custom IC Verification platform, and it enables design teams to accelerate time-to-market by months of schedule time.

The evolution of AI technologies and AI maturity model

The critical elements needed to achieve production-grade AI in engineering tools are as follows:

- **Verifiability –** Can you tell if the AI model is right?
- **Accuracy –** How close are the answers compared to the golden reference?
- **Generality -** Does the AI approach work on everything?
- **Robustness -** Can I bet my next design schedule on it?
- **Usability -** Does it "just work" for my team?

In addition, AI maturity on these critical elements can be measured on a five-level scale (in much the same way as the autonomous industry has categorized five levels of autonomous vehicles).

Level 0: No AI. These are simply brute-force tools that are not AI accelerated. For SPICE simulation, this means using a brute-force Monte Carlo approach to verify designs.

Level 1: Partially-reliable AI. These AI methods work on some cases, but fail on others, with no way to tell. Tools at this level are seldom useful for practical IC design or verification applications since they do not provide reliable indicators of correctness of results. They are used mostly for demonstration purposes.

Level 2: Partially-reliable AI with accuracy-aware self-verification. AI tools at this level have methods to determine when results are correct or incorrect and can prove it automatically. They are usable for certain tasks, but users need a backup plan for when the tools are unable to produce correct results.

Level 3: Adaptive, accuracy-aware AI. Tools at this level can identify when AI models are not delivering sufficiently accurate results and can continue adaptively collecting data and improving models automatically until accuracy criteria are met.

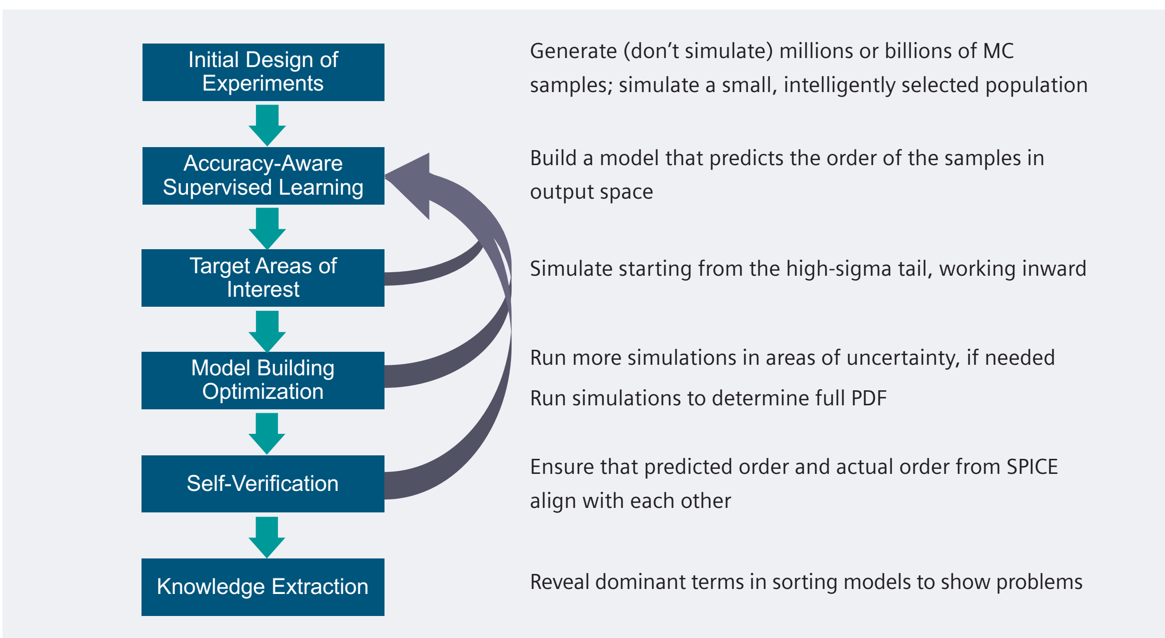

Figure 1: Example of a level 3 adaptive, accuracy-aware AI flow

As illustrated in Figure 1, Level 3 AI typically starts with an initial design of experiments in which the user simulates a small amount of the total space to first find areas of interest. The next step is to start building machine learning models that know their accuracy.

To do this, the tool finds areas that show extremes or worst cases, such as lowest gain or longest delays on an op amp, for example. The tool performs more simulations in those focus areas and uses data gained to improve the accuracy of the models.

The tool then uses a refined model based on more simulation data to analyze the areas of the design where there's the greatest uncertainty or a change in a condition, such as a drop in voltage or a temperature fluctuation. It also performs self-verification so that when a condition is met, it can prove it. If it can't prove it, then it can use the data from areas where it is not correct to improve the model further.

A sufficiently mature model can then be set up to zoom into troubled areas and give insights into not only what areas are having problems, but what potential fixes could be applied to remedy a given problem.

Level 3 is complex because it requires automated data acquisition, automated data cleaning, and automatic rebuilding of models dynamically at runtime.

Tools in level 3 are useful in production if there is good support for occasional corner cases that cannot be automatically solved yet.

Level 4: Full production AI that "just works." Solutions at this level have extended level 3 adaptive technology so that it identifies and supports all corner cases and delivers correct results in every case, every time.

As with most software applications, each tool capability level requires approximately an order of magnitude more development effort than the previous level.

Software engineering time and effort required at each maturity level of AI engineering tools

While level 1 prototypes can be developed in days, level 2 in months and level 3 in years, getting from level 3 to level 4 requires decades of person-years of focused R&D development to achieve production-grade AI.

Solido high-sigma verification technology:
Getting from Level 3 to Level 4

2008: Invented – level 3	2021: Person decades later – level 4
• Capacity: 1M samples	• Capacity: 1M samples
• 1000 process variables	• 100K process variables
• Continuous outputs only	• All outputs (e.g. multi-modal, n-ary)
• 1 failure region	• N failure regions
• Self-verification shown in logs	• Self-verification GUI
• Manual setup and operation	• Full adaptive; no expertise needed
• Required stable simulation	• Handles, recovers from, and corrects sim failures

Figure 2: Solido high-sigma verification technology has gone through person-decades of refinement to achieve level 4 functionality.

To illustrate the complexity of developing a truly sophisticated level 4 tool, Dyck compares the first version of the Solido's High-Sigma Monte Carlo (HSMC) tool released in 2008 (classified as a level 3 AI tool) to the much more sophisticated version offered today, High-Sigma Verifier (classified as a level 4 AI tool). Both versions of this application were designed to provide brute-force accurate, variation-aware SPICE-level verification.

In line with achieving critical elements required for successful AI tool deployment in engineering usage, in over 10 years of refining the algorithm, Solido was not only able to improve the runtime, accuracy, and capacity of the tool, but also improved on the usability, robustness, and verifiability of the tool. Figure 2 shows the comparison on these many fronts.

Pushing EDA AI capabilities further with Additive Learning

One of the newest features of the evolving, level 4 AI algorithm is "Additive Learning" or "Additive AI." Additive Learning enables AI-powered tools to retain and re-use AI models from previous runs, drastically decreasing the number of simulations needed for subsequent runs, all while preserving full accuracy. It also automatically identifies situations where the technique can be applied, so if measurement results of subsequent runs have changed significantly, the software automatically increases the number of simulations needed to always provide the correct answer to the user. This breakthrough allows the user to achieve a 10X to 100X speedup on incremental verification runs, after an initial verification run is completed.

AI enablement in Solido Intelligent Custom IC Verification Platform

Solido has applied its approach to AI development to other tools throughout the Siemens intelligent custom IC verification platform. Let's take a look at the two major tools suites from Solido, how AI is used in them and what results they yield for customers.

Solido Design Environment – High-Sigma Verifier technology in the Solido Design Environment uses AI to accelerate SPICE-level variation-aware verification by orders of magnitude, while preserving full SPICE accuracy. This enables users to achieve 3, 4, 5, 6 and higher target sigma verification in a fraction of runtime compared to brute force verification. For higher sigma targets such as 6 sigma and higher, verification may be simply not feasible without a solution like High-Sigma Verifier.

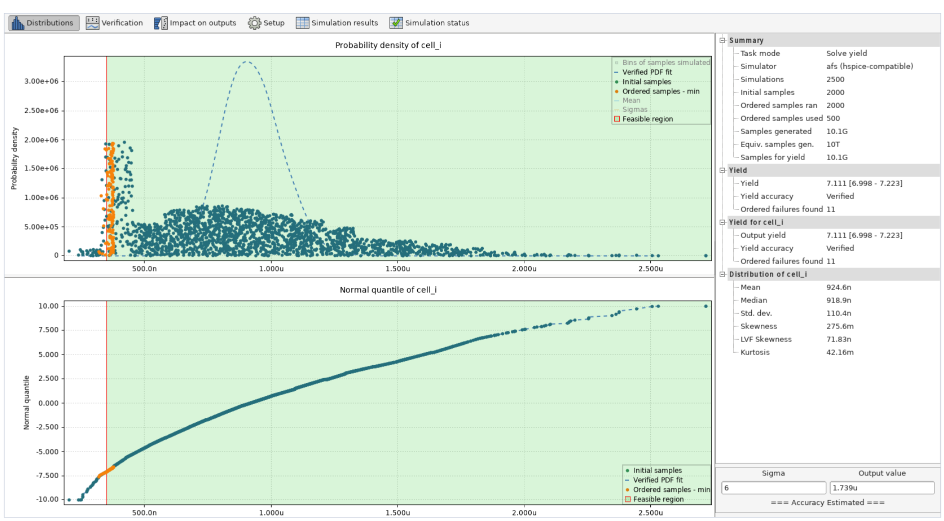

Figure 3: Example of Solido High-Sigma Verifier's output, showing brute-force accurate high-sigma verification performed 4,000,000x faster than traditional brute-force methods.

Solido Characterization Suite – Solido Generator and Analytics, both technologies within the Solido Characterization Suite product line, utilize AI to produce and verify Liberty (.lib) models. Solido Analytics employs AI methods to automatically detect outliers in .lib data, allowing users to accelerate .lib validation cycles from weeks to hours. Solido Generator allows users to produce new PVT corner .libs, using other PVT .libs as anchor data. Both are deployed in many production characterization flows today, helping library teams accelerate time-to-market by shortening .lib development and verification cycles.

The next step in EDA AI evolution is bringing Assistive AI technologies to EDA workloads, leveraging generative AI to enable the tool to assist human users to identify and implement design optimization choices. Figure 5 includes an illustration of the evolution of AI technology and where Solido stands today.

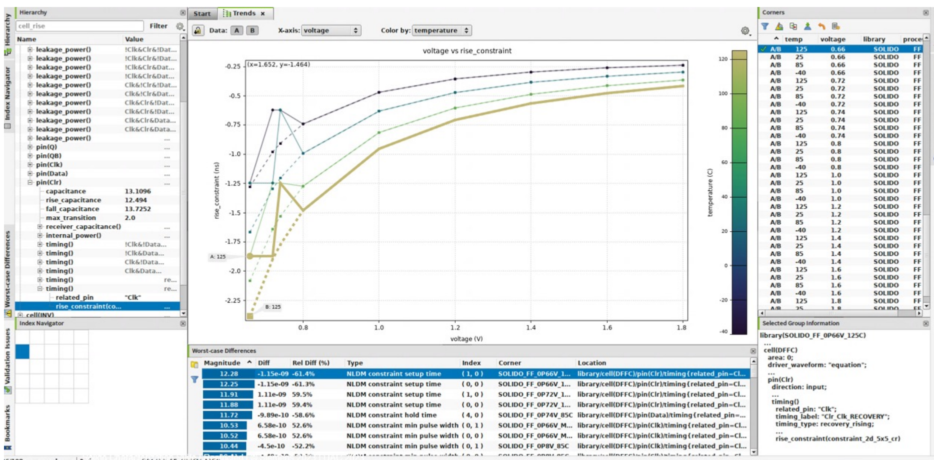

Figure 4: Example results from Solido Analytics, showing AI outlier analysis automatically identifying potential .lib issues.

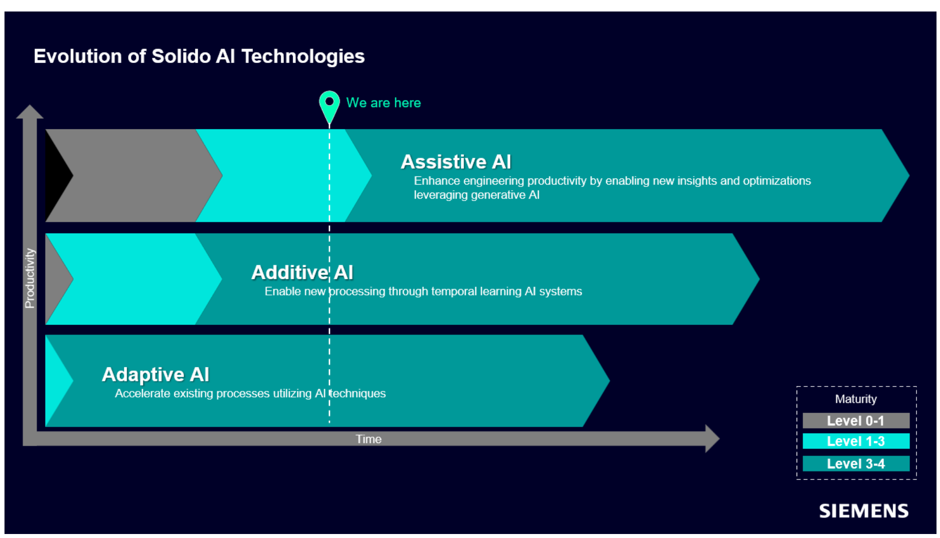

Figure 5: The evolution of Solido AI technologies

Conclusion

Solido's use of AI in EDA tools is already making a profound impact on helping design teams converge on correct results much more quickly and thus enables them to bring their innovations to market faster. As research and further refinement of AI evolves, the Solido team is committed to staying at the forefront of pioneering production-grade AI to help customers stay at the leading edge of IC design innovation.

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