Power Electronics Moves Forward With New Tools

by Ken Coffman, Faraday Press and Vicor, Phoenix Ariz.

Steve Sandler, DesignCon's latest Engineer of the Year award winner, has been involved with power-system engineering for over 40 years. He is the founder of Picotest, a company specializing in instruments and accessories for high-performance power and distributed-system testing. He frequently lectures and leads workshops internationally on the topics of power integrity and distributed power-system design and is a Keysight Certified EDA expert.

Steve helps engineers around the world to architect, design, troubleshoot and optimize advanced power-delivery networks. In his prominent position, he's exposed to some of the world's toughest design challenges. Over the years, load currents have evolved from tens of amps to thousands of amps at voltages commonly less than 1 V, with output impedances now measured in hundreds of microohms or less. Daily, he devises new methods and test equipment to analyze tough problems, interpret test results and guide engineers toward optimum solutions.

I recently spoke with Steve about the ways in which power supply design has changed in recent years and how it may continue to evolve in the future. Steve shared his thoughts on why design tools such as ADS and Spice are changing, the roles of hard switching versus resonant and quasi-resonant topologies in modern applications, and the design challenges that lie ahead for him and the industry at large.

Ken Coffman: Forty years ago, we could troubleshoot a power supply with an analog voltmeter. Things are much different now. With an analog voltmeter measuring a modern power supply, we wouldn't even know if a power supply output voltage is within specification. Let's just talk about recent history. What power technology changes have you seen in the last ten years?

Steve Sandler: In the last 10 years, it has been mostly two things: the expansion of digital control and all that entails (PMBus, programmable compensation, real time optimization, etc.) and wide-bandgap semiconductors (SiC and GaN) becoming essentially mainstream.

Ken: Thinking back to 40 years ago, a power supply could have been designed and evaluated with a pencil, a four-function calculator and a pad of paper. From a simulation and evaluation point of view, how have the computer tools changed?

Steve: It's evident that in the modern world of power electronics, the PCB is a component, impacting everything from ripple to transient response and even power supply crosstalk. With extremely narrow operating voltage margins, control loops are optimized via simulation and worst-case corner cases, including the potential for rogue waves. Thermal gradients, current densities and even EMI are evaluated with software. The highly increased power density (1 W/in^3 in the 1970s to > 5,000 W/in^3 in 2022) leaves almost no margin for error.

Another interesting evolution is magnetics design. Today, most magnetics are designed using 3D FEM software. This is due to the higher switching frequencies and higher operating efficiencies that make it essential to optimize proximity loss, skin effect loss, etc.

Ken: Several years ago, quite controversially, you declared the death of the Bode plot as a central metric for evaluating a power supply. Slowly, our industry caught up with what you were saying. Now you're saying SPICE in its various versions is equally obsolete for simulating a modern power supply. What does SPICE miss? How does it mislead us?

Steve: This took a while. Finally, this year, the non-invasive loop-evaluation method (NISM) is available in both ADS and PSPICE. It isn't that SPICE itself is dead, it still has a place, but there are a few concerns to address. First, SPICE is not inclusive of EM and so if we believe, as I stated above, that the PCB is a component, it has to be simulated inside an EM environment. Second, SPICE is inherently slow.

I published an article with National Semiconductor in 2005 as they were bringing up WebBench that showed the limitations of time point calculation and also how to resolve it using layered simulation. In 2015, I brought the Harmonic Balance solver to power electronics. This is inherently much faster, as it solves in native Fourier, and so doesn't need to come to steady-state, but can solve for it instantly. This also brought the ability to simulate

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ac, dc, time, spectral content and EMI within a unified model, which is inclusive of full EM simulation (including the PCB). The model runs in about one second, allowing real-time simulation with optimization.

In a DesignCon panel discussion this year, one thing all of us panelists agreed on is the need for interoperability between platforms. So more important than the solver is the ability to import/export the simulation model. This means if an engineer simulates his voltage regulator in Simplis or LTSpice (please don't) the effort isn't wasted if the model can be brought into a simulator like Pathwave ADS.

As it stands now, a power electronics engineer develops a design and a (mostly useless) model in SPICE. This model was an expensive development, despite its lack of accuracy. Rather than wasting this effort, if it can be brought into an EM platform with much more capability; the effort is recovered.

Ken: Recently, I've been thinking that hard-switching power FETs is cruel and abusive. We're asking a lot of our FETs by hard switching them at higher and higher frequencies...particularly the high-side switch in a bridge or buck converter. And, the harmonic series has a lot of high-frequency content which challenges the EMI filter. Do you have a preference? Given a blank sheet of paper to deliver 1,000 W at a low voltage with 48-V input, would you favor a resonant topology, a hard-switched converter or some hybrid?

Steve: Preference is a difficult question. Resonant and quasi-resonant reduce EMI, but typically this comes with higher parts count, higher circulating currents and higher ripple. Typically, hard switching is much more efficient, so I think for most applications, I would choose that.

Having said that, the 48-V input presents a challenge. 48 V to 1 V doesn't work well with the non-isolated stepdown, so a transformer is typically required, or a dc-dc bus converter to get the 48 V to the intermediate voltage. Historically, the intermediate voltage has been 12 V, but there are opportunities for optimization at lower voltages—say 5 V to 7 V, where we can optimize efficiency.

Ken: I feel like I understand a key characteristic of your Picotest company. Due to your prominence at the leading edge of power integrity problems, engineers come to you with problems that can't be solved with existing equipment and you design, build and then sell these unique new solutions. How did I do with describing your business model?

Steve: This is perfect! And we love the challenge. Most companies prefer high-volume applications, shying away from this type of specialty business. We thrive on it, loving the brain stretching involved in unique applications unconstrained by the desires of the masses.

Ken: Let's say present trends continue and in 10 years we're asked to deliver 0.1 V at 10 kW to serve some monster ASIC. How in the world are we going to do it?

Steve: That's the fun part—we have no idea, yet. When there is a void, rest assured that engineers will find a way to fill it! There are sub-threshold devices now operating at several hundred millivolts. Devices are slow there, and so the current isn't high. But who knows what the future will bring?

Today there is an explosion of immersive devices, running them in liquid to keep them cool. That's inefficient, so we push for smaller geometries to reduce the current. But then the devices are faster, so we run them faster and the current climbs back up. It's a never ending cycle and *I love it*! Bring it on.

More About Steve Sandler

Steven Sandler is the managing director of Picotest, a company specializing in precision test and measurement equipment. Sandler is also the founder and chief engineer of AEi Systems, where he leads development of high-fidelity simulation models for all types of simulators as well as the design and analysis of both power and RF systems.

Steve publishes articles and books related to power supply and power distribution network (PDN) performance. His latest book, co-authored with Anto K. Davis, is called Power Integrity Using ADS. Other books from Steve include Switched-Mode Power Supply Simulation with SPICE and Power Integrity: Measuring, Optimizing and Troubleshooting Power-Related Parameters in Electronics Systems.

He's the recipient of DesignCon and EDICON Best Paper Awards and the Jim Williams

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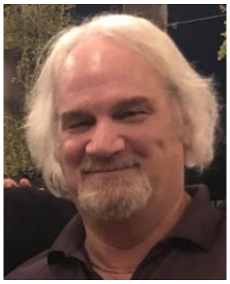
ACE Contributor of the Year Award presented by Linear Technology co-founder, Bob Dobkin. He's also a two-time Test & Measurement Test Engineer of the Year Finalist and was recognized as a "Trailblazer" by Electronic Design magazine. Most recently he was honored by DesignCon 2023 as its Engineer of the Year.

About The Author



Ken Coffman is a senior field applications engineer working for Vicor. One of his side hustles is publishing technical books at Faraday Press, an imprint of Stairway Press. Among the titles that may be familiar to readers of How2Power Today are "Power Distribution Network Design Methodologies: The Faraday Press Edition" co-written and edited by István Novák, "Transfer Functions of Switching Converters" by Christophe Basso, and "Switched-Mode Power Supply Simulation with SPICE" by Steve Sandler. How2Power's reviews of these books are available here. Ken can be reached at Ken@StairwayPress.com and can easily be found on LinkedIn.

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