by Ashok Bindra

Patrizio Vinciarelli: A Physicist Leading Power Electronics Industry for More Than Three Decades

Patrizio Vinciarelli, a physicist by education and experience, has been a leader in the power electronics world for more than three decades (Figure 1). From zero-current, zero-voltage switching technology to more efficient power distribution and integrated packaging and products that make power distribution more efficient, Vinciarelli's company, Vicor, has consistently raised the bar in power system design and manufacturing, propelling power electronics to new heights in performance every decade since its inception in 1981. Thanks to its unique business model and strategy, the company has prospered for over 30 years. Today, it has 1,000 employees, and its net revenue has passed US$300 million. The company offers a broad portfolio of high-efficiency, high-density power modules addressing a wide range of high-performance applications that enable customers to efficiently convert and manage power from the wall plug to the point of load (POL).

Vinciarelli was recently awarded the prestigious 2019 IEEE William E. Newell Power Electronics Award for visionary leadership in the development of high-efficiency, high-power-density power conversion components for distributed power system applications.

FIG 1 Dr. Patrizio Vinciarelli, founder and chief executive officer of Vicor.

New Direction

Before venturing into power electronics, Vinciarelli was a fellow at the Institute for Advanced Study in Princeton, New Jersey, and an instructor at Princeton University. Prior to Princeton, he was at the Stanford Linear Accelerator Center and the European Center for Nuclear Research. He spent nearly 10 years doing research in theoretical physics after coming to the United States in 1970 with a doctorate in physics from the University of Rome, Italy. Curiously, he found the field of physics advancing slowly. So he sought new challenges.

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While still working in the field of physics, he had an experience one day that would eventually prove very significant in his life. While listening to classical music at home, one of his passions, his stereo system broke down. Puzzled, he opened the stereo amplifier to find that the power supply was the culprit. He remembered this incident and later took on the challenge of improving power systems. "Unexpected events motivate people to go in new directions, and that's what happened to me," he said.

Thus, Vicor Corp. was launched in 1981, but Vicor was not going to be just another power supply manufacturer. Vinciarelli was embarking on this project to bring about change with fundamental innovations. He was determined to usher in new energy and vision to an industry trying to catch up with advancing semiconductor technologies.

Research showed that power supplies were custom assemblies with little flexibility or scalability, poor efficiency, and low power density. Thus, he decided to develop a modular power system methodology and create high-density building blocks

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for power systems that could be easily scaled with an order-of-magnitude improvement in performance. Vinciarelli explains that Vicor's focus is on modular solutions from the wall plug to the point-of-load: "It was quite different from the mold of power supply companies at the time, and that remains the model today."

FIG 2 The first Vicor product. A megahertz-regulated 75-W dc–dc converter module with a minimum efficiency of 80% and a power density of 25 W/in^3. It was introduced in 1984. (Image courtesy of Vicor Corp.)

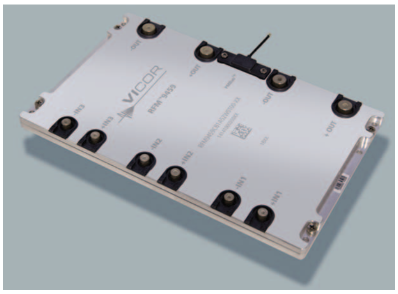

FIG 3 A three-phase ac–dc converter module capable of delivering 10 kW of regulated 48 Vdc from a tablet configuration. (Image courtesy of Vicor Corp.)

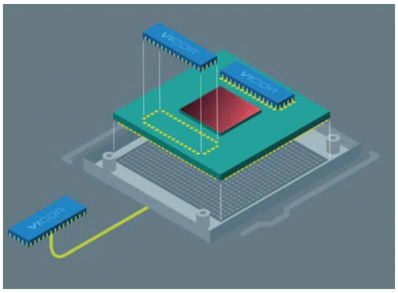

FIG 4 A diagram of Vicor's power-on-package, which is redefining POL regulation for demanding high-performance computing applications. (Image courtesy of Vicor Corp.)

Contributions to the Industry

In the early 1980s, the switching frequencies of power supplies were below 100 kHz. Vicor decided to step up to 1 MHz using its patented zero-current, zero-voltage switching technology. The result was a 75-W dc–dc brick switching at 1 MHz with 80% efficiency and a power density of 25 W/in^3 (Figure 2). Although this performance is low by today's standard, it was way ahead of its time in 1984. Nearly 35 years later, Vicor is delivering products with up to 98% efficiency and 3,000-W/in^3 density. A recent addition is a three-phase ac–dc converter module (Figure 3) capable of delivering 10 kW of regulated 48 Vdc in a 1.5-cm thin power tablet. To achieve this level of performance for a three-phase 10-kW ac–dc module, the converter combines innovations in power conversion topologies, control architectures, and advanced application-specific integrated circuit (ASIC) and packaging technology.

After pioneering zero-current and zero-voltage switching topologies, Vinciarelli went on to develop Factorized Power Architecture (FPA) as an alternative to the industry's intermediate bus architecture (IBA) developed to power state-of-the-art processors, ASICs, and memories. Unlike IBA, FPA does not step down from an intermediate bus voltage to the POL through series inductors. "Instead of averaging down the intermediate bus voltage, FPA uses current multiplier modules with a current gain of 48:1 or higher to provide higher efficiency, smaller size, faster response, and scalability to 1,000 A and beyond," explains Vinciarelli.

Unlike IBA, FPA does not step down from an intermediate bus voltage to the POL through series inductors.

Besides developing power conversion engines for implementing FPA, Vicor develops its own control ASICs and deploys them in advanced packages to create industry-leading products, such as converter-housed-in-package (ChiP) modules. ChiP modules have demonstrated power densities of 3 kW/in^3 at up to 98% peak efficiency. According to Vinciarelli, ChiP technology is an enabling power technology like wafer-scale packaging. It leverages Vicor's power management expertise and world-class manufacturing capabilities.

With the increasing demands of high-performance applications like artificial intelligence (AI), machine learning, and data mining, the CPUs and graphics processing units at the POL are operating at current levels of >500 A at <1-V load. Traditional multiphase voltage regulators and IBA are unable to meet escalating demands for higher currents at lower voltages required by high-performance processors. Vicor's new power-on-package technology incorporating FPA and modular current multipliers enables the conversion of 48 V direct to the processor voltage with unprecedented efficiencies and bandwidth. The power density is more than twice that of comparable products using traditional IBA (Figure 4).

Volume Manufacturing and Expansion

Vicor has pursued automation in manufacturing since the late 1980s. Its world-class manufacturing facilities are in Andover, Massachusetts, where the company is headquartered. Product quality and reliability have been critical to Vicor's success and are emphasized in the company's design and manufacturing methodology. In its early years, the company addressed demanding applications where performance could justify higher costs. In the last 10 years, the company has scaled up high-volume automated manufacturing to become cost competitive with the industry. "We have the cost structure to offer much higher performance products at a very competitive cost," says Vinciarelli.

The decade starting in 2000 after the dot-com bubble burst presented significant challenges and opportunities to Vicor. Until 1999, nearly 70% of Vicor's business was telecom, and the bubble had motivated an escalating number (one every few weeks) of copycat competitors to pursue what had appeared to be an easy path to success. The burst of the bubble prompted Vicor to diversify its business model across a multiplicity of end markets, leveraging major advances in power technology comprehensively protected by intellectual property (IP), in essence, blazing a trail that competitors could not follow.

Consequently, Vicor was forced to enforce its IP, which resulted in substantial licensing and damages revenue. To keep the design and manufacturing team motivated for all of these years, the company provided a stimulating and challenging environment with a career growth and financial incentives linked to its success.

As for developments related to gallium nitride (GaN), Vinciarelli sees a long life ahead for silicon. While certain power semiconductor companies claim that silicon is nearing the end of its road and that GaN field-effect transistors are necessary to meet the demands of advanced power systems, Vinciarelli holds a different view. "GaN is not a magic bullet that can pierce through a multiplicity of power system challenges," he said. "GaN FETs are good for certain applications but lack the right combination of attributes for power system solutions requiring efficient power distribution, conversion topologies, and modular power packaging, and these are the necessary enablers."

With nearly 150 patents assigned to Vicor, Vinciarelli at the helm plays an active role in company management and product development. Delivering 1,000 A at <1 V efficiently to AI processors poses challenges that Vicor has anticipated and overcome. As he's said, "These are very exciting times."

About the Author

Ashok Bindra (bindra1@verizon.net) obtained his M.S. degree from the Department of Electrical and Computer Engineering, Clarkson College of Technology (now Clarkson University), Potsdam, New York and M.Sc. degree in physics from the University of Bombay, India. He is the editor-in-chief of *IEEE Power Electronics Magazine* and a veteran freelance writer and editor with more than 35 years of editorial experience covering power electronics, analog/radio-frequency technologies, and semiconductors. He has worked for leading electronics trade publications in the United States, including *Electronics*, *EETimes*, *Electronic Design*, *Power Electronics Technology*, and *RF Design*.

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