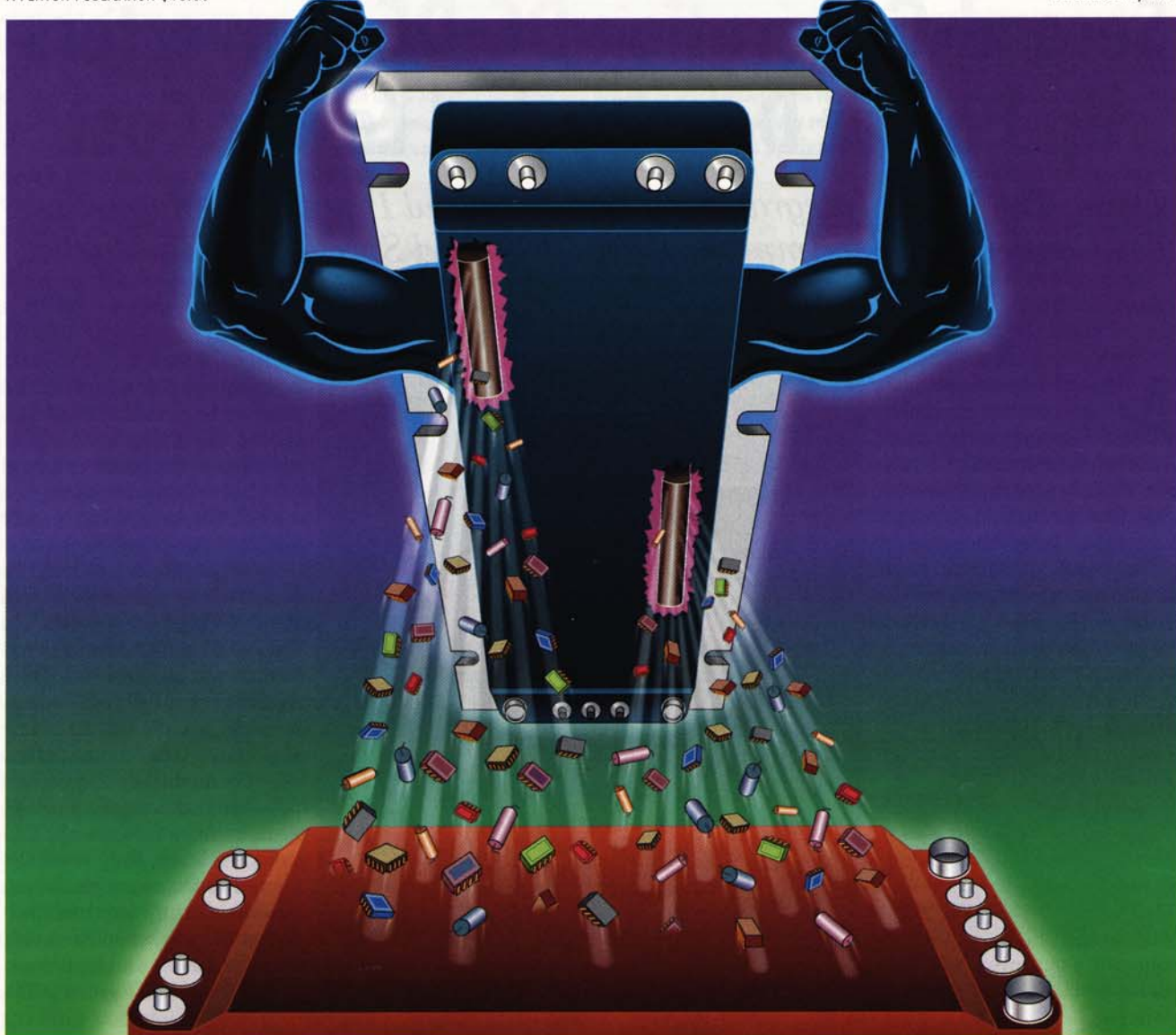


ELECTRONIC DESIGN

FOR ENGINEERS AND ENGINEERING MANAGERS - WORLDWIDE

A PENTON PUBLICATION \$10.00

SEPTEMBER 2, 1997



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TECH INSIGHTS

■ Exploring advances in power conversion for high-end, high-volume applications

Second-Generation DC-DC Converters Up Power Density And Lower Cost

Using The Latest Integration Technology And Innovative Magnetics, The Converters Also Improve Reliability And Speed Time-To-Market.

Patrick Mannion

Although high-density dc-dc converter modules have been popular since their introduction in the mid-80s, the inherent limitations of their basic designs have been a major handicap in terms of power density, cost, and turn-around time. To exacerbate the situation, the rocketing demand for these devices in increasingly varied and demanding applications has maxed out the original design to the extent that nothing short of a complete redesign is required.

Stepping up to the challenge, Vicor Corp., Andover, Mass., has introduced what it defines as the "second generation" of dc-dc power modules, called the VI-300 series. Based on the company's patented zero-current-switching (ZCS) and zero-voltage-switching (ZVS) power-processing architectures, the modules incorporate recent advances in control integration, packaging, magnetics, and noise and thermal management. The end result brings the devices closer to the "ideal power component" with a tripling in power density, higher reliability, lower cost, and faster time to market.

The converters come in a number of standard versions, and are an integral part of the company's overall Concept 300 strategy, which includes advanced factory and design automation. Plans for the near future include making the



modules available in an unlimited variety of standard versions, to the extent that the line between custom and standard modules will become almost indistinguishable.

First-Generation Power

While first-generation converters, or power components, provided many benefits at the time, including reduced size and faster time-to-market, their relatively high cost and inability to break the 100-W/in.³ barrier limited their widespread use in mainstream markets. In addition, first-generation power-converter manufacturers had

to adapt the concept of the product to available manufacturing technologies. As a result, few of the processes used in their manufacture are specifically tailored for power devices. For example, the surface-mount technology used to mount the over 200 components in a typical first-generation converter has been borrowed from mainstream electronic manufacturing, while the magnetic structures used are often slightly modified, 30-year-old pot-core technologies and carryovers from telecom applications. As such, they were designed to process signals, not power, so they tend to limit power density while adversely affecting noise and heat management.

In addition, the generic TO-220 packages used for the switching devices limit mounting options and are plagued with excessive parasitic inductance and capacitance, again leading to high noise levels.

The limits of first-generation power components were stretched and pulled to suit popular applications such as telecom, industrial, ground-based military, and high- to mid-range electronic data procession (EDP), and other areas that could afford the custom modifications. As applications expand into other systems, including low-end, high-volume EDP and busi-

ness equipment, the unsuitability of these devices, in terms of power density, ruggedness, cost, and turnaround, has become obvious.

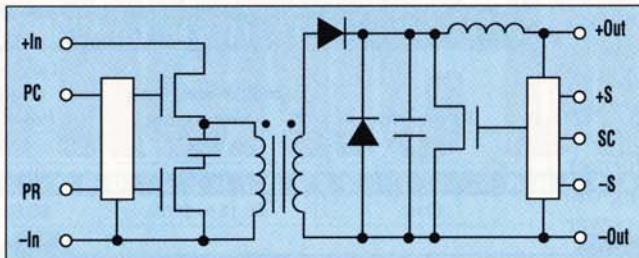
Complete Redesign

To overcome the constraints of first generation power components, Vicor started from scratch with a design based on its patented ZCS/ZVS high-efficiency, low-noise, high-frequency power-processing architecture (Fig. 1). A complete redesign of the control, magnetic, switching, and packaging elements of the modules has resulted in a component with a power density of up to 120 W/in.³ in three package sizes—maxi (4.6 by 2.2 by 0.5 in.); mini (2.28 by 2.2 by 0.5 in.); and micro (2.28 by 1.45 by 0.5 in.).

The modules have one-third the number of parts of their predecessors and can be ordered pre-configured in nine input ranges, and nine output voltages. Resistors can be used to trim up or trim down the output voltage if necessary. Custom models can be ordered with any input voltage from 4.5 to 450 V, any output voltage from 1 to 100 V, and at any power level up to 600 W. Two pin styles, four baseplate options, and a variety of data collection and reporting options are available. The devices have an operating temperature range of -55° to over 110°C and come in three product grades—C, T, and M. User-defined grades also are available.

Other specifications include a no-load to full-load regulation of 0.1%, a programmable output of 10% to 100%, conversion efficiencies of up to 92% depending on the voltage combination and power level chosen, and an input-to-output isolation voltage of 3000 V rms. All models are parallelable with N+M fault tolerance and current sharing, and are phased-array-control compatible. Paralleling architectures include dc- and ac-coupled single wire.

The end result, as far as the power-supply designer is concerned, is a high-power-density component, with a wide range of options, and with high reliability, that reduces the cost of a power supply from \$0.50 to \$2/W down to \$0.25 to \$1/W (see the table).



1. The VI-300's ZCS/ZVS power-processing architecture enables efficient, low-noise, high-frequency operation. The main switch is common drain for improved thermal and noise management, the reset switch is common source for ease of control, while a secondary reverse boost switch narrows the frequency range and allows for synchronous rectification.

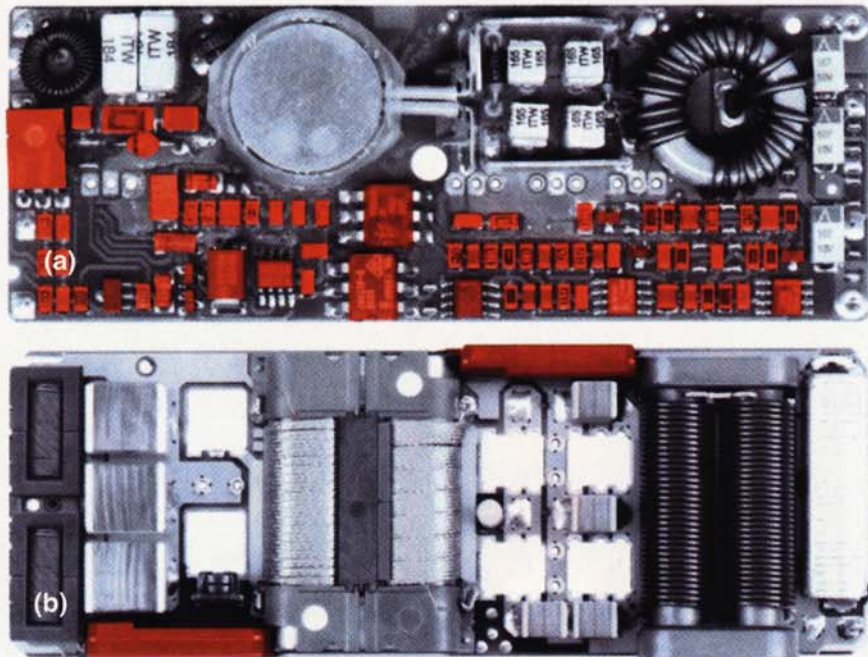
Key to the VI-300 converter's design is its high level of component-level integration (Fig. 2). With the aid of hybrid technology and a Class 10,000 clean room, the device packs all control functions and active circuitry into two (primary and secondary side) ICs occupying a total volume of less than 1/10 in.³ each. As a result, the parts count has been slashed from the typical 115 to 200 parts of first-generation components of down to 35. The ICs, or "brains," are molded and include a copper plate that is soldered directly to the baseplate to provide a thermal escape path to the baseplate. The devices are

subjected to a full 100% burn-in, while cycling from -65° up to 125° C.

While the natural by-products of this cut in parts count are improved reliability and lower cost, the extra space also means that the bulk of the converter can now be devoted almost exclusively to the power train (i.e., the magnetic and switching elements at the core of the design).

The most noticeable aspect of the revamped and enlarged power train is the absence of the traditional potted-core magnetics with their primary and secondary windings laid concentrically on top of one another (Fig. 3). This close proximity of input to output, necessary for efficient magnetic coupling, also can lead to electrical coupling of primary to secondary windings via parasitic capacitance. This coupling can result in unacceptable levels of common-mode noise.

With second-generation devices, the potted-core design has been replaced by proprietary plated-cavity cores that use copper armor, plated onto the ferrite core, to more closely confine the magnetic flux to couple widely sepa-



2. The control circuitry in the first-generation power module, marked red in (a), has been integrated into two (primary and secondary side) ICs, or "brains," marked red in the second-generation module, (b). The end result is a reduction in parts from a typical 115 to 200 down to 35, with the ensuing savings in cost and increase in reliability. The scheme also provides extra room for the power train.

rated primary and secondary windings. The wider separation provides greater isolation and therefore lowers input-to-output parasitic capacitance and noise. The plated cavity also serves to conduct heat away from the transformer to the baseplate, thus increasing the power-handling capability of the power train allowing the transformer to handle a power density of 1000 W/in.³, with a 30°C rise.

The power-train assembly itself is contained between the baseplate and a terminal block assembly, with input and output pins recessed. The modules may be wave-soldered or plugged into inboard or surface-mount terminals. Proprietary sockets handle up to 100 A.

Switching Elements

The switching elements, mounted to the baseplate, have done away with the TO-220 package with its high parasitic inductance and capacitance and high thermal impedance. Instead, the VI-300 devices use a proprietary, low-noise, integrated power device (IPD) that has an order of magnitude lower parasitic effect.

The IPDs are soldered to 20-mil-thick, electrically and thermally conductive, primary and secondary shields, inset within the grounded aluminum baseplate. In addition, the thermal path from the MOSFET die to the baseplate has been reduced through the elimination of a number of layers and the use of materials such as kapton, in place of epoxy and a Faraday shield. This shortening of the path has helped reduce the thermal impedance from junction to baseplate

BENEFITS OF COMPONENT POWER

Parameters	Custom-switching power supply	1st-Generation-Component Power System	2nd-Generation-Component Power System
Size	3 W/in. ³	10 W/in. ³	20 W/in. ³
Development time	Six months	Two months	0.5 months
Cost	\$0.15 to \$1/W	\$0.50 to \$2/W	\$0.25 to \$1/W

The advances made in the converters are backed by equally significant advances in the methods used to manufacture them.

($R_{\theta JB}$) from the 3°C/W typical of the VI-200, to 1.5°C/W for the VI-300.

The advances made in the overall design of the VI-300 have been complemented by equally significant advances in the technology used to manufacture them. Instead of the generic assembly lines that have simply been adapted for power components, Vicor has invested in a custom, fully automated assembly line specifically designed for the assembly of second-generation power components.

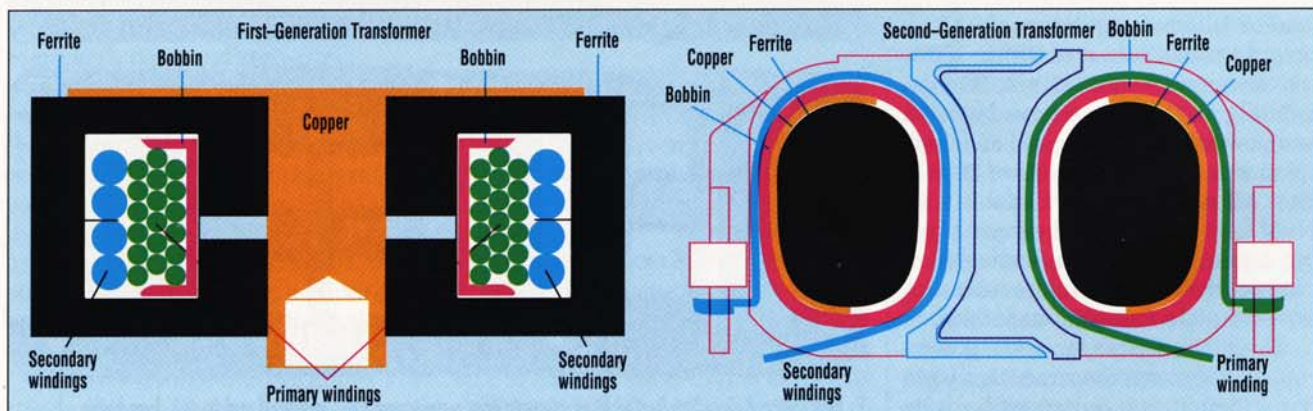
The second-generation factory is designed to accommodate four lines and ancillary processes, with a theoretical total capacity of one module every two seconds. According to Vicor, the total cycle time, when the line

is fully up and running, is predicted to be approximately four hours.

To further augment its VI-300, and follow through on its Concept 300 strategy, Vicor has created a user interface, called the Vicor Design Assistance Computer (VDAC), that will run from the customer's site and give the customer the flexibility to spec components from a remote location at any time of the day or night. Between the factory floor and VDAC lies the ABM which automatically generates the necessary bill of materials. The ABM communicates directly with the computer-integrated manufacturing process to produce the required product, in quantity, in a matter of days.

PRICE AND AVAILABILITY

The maxi module, 600 W, 375-V (250 to 425 V) input, 48-V output, is priced at \$248. The mini module, 300 W, 375-V (250 to 425 V) input, 12-V output, is priced at \$148; The micro module, 150 W, 48-V (36 to 75 V) output, is priced at \$112. Standard modules are shipped in four to eight weeks in quantity. For more information, contact Vicor Express at (800) 735-6200.



3. With primary and secondary windings concentrically on top of each other, first-generation transformers achieved adequate magnetic coupling. However, electric coupling due to parasitic capacitance can lead to excessive common-mode noise. To avoid this, second-generation transformers place the primary and secondary windings far apart, but contain the magnetic flux using a copper armor plated onto the ferrite core. The armor also conducts excess heat to the baseplate.