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FACTORIZED-POWER MODULE COMPLETES BASIC PICTURE

The PRM enables a higher bus voltage than the intermediate bus architecture.

The missing element in the factorized-power architecture that Vicor Corp. announced in April 2003 has been an efficient buck-boost converter that operates well when V_{OUT} is close to V_{IN} . That final piece is now available in what Vicor calls its pre-regulator module, or PRM (Fig. 1). These PRMs provide a controlled, non-isolated factorized bus voltage to supply the required voltage-transformation module (VTM) output voltage. PRM V_{OUT} may be controlled by either local, adaptive, or remote feedback loops, with or without galvanic isolation.

The PRM must work efficiently not only when its buck or boost function is clearly called for, but also when its output voltage is approximately equal to its input voltage (Fig. 2). This is where ordinary buck-boost regulators tend to dither and lose efficiency. The unique feature of the PRM control architecture is that its switching sequence does not change in either buck or boost mode. Only the relative duration of phases within an operating cycle is controlled.

UPSTREAM REGULATION WITH A BUCK-BOOST • To understand the role of the PRM, some background on factorized power is essential. Factorized power uses isolated VTMs deployed at the load and PRMs that can be located, or "factorized," away from the load. The PRM generates a controlled bus voltage that is typically several times higher than an intermediate bus voltage. The VTM simply transforms this by its "K-factor" (turns ratio), less a lumped-impedance resistive loss, to deliver a tightly regulated and isolated lower (or higher) voltage to the point-of-load (see "Inside The VTM," p. 43). Regulation is performed using feedback to the upstream PRM, the PRM being the element that adjusts its output voltage to maintain the load voltage from the VTM in regulation.

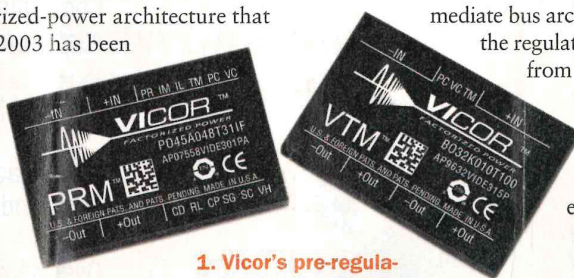
Several things make factorized power very different from other distributed-power approaches, including the popular inter-

mediate bus architecture (IBA). One is shifting the regulation function upstream away from the load converter. This gives system designers flexibility in where they locate the regulation function. It no longer has to be right next to the load, and it can even be off the board. The second is that the bus voltage that is distributed from the PRM can be as high as practical, reducing voltage drop and I^2R loss on the bus.

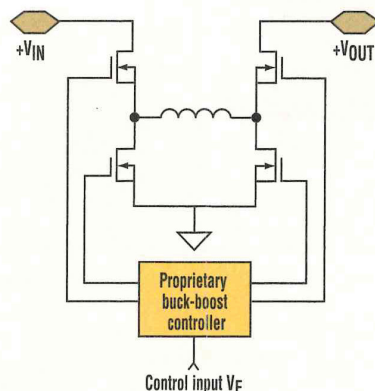
Third, thanks to the design of the VTM, it can handle much

larger ratios of V_{IN} to V_{OUT} than conventional POLs without a loss of efficiency. (VTM topology is described at length in "Sine Amplitude Converters: A New Class Of Topologies For DC-DC Conversion," ELECTRONIC DESIGN, Oct. 27, 2003, p. 49.) Fourth, the VTM topology allows bulk capacitance to be shifted upstream to the output of the PRM where it can be reduced by the square of the VTM step-down ratio, relative to what would have to be provided if the bulk capacitance were located at the output of the point-of-load converter. (Bypass capacitors may still be necessary at the VTM output to deal with noise and coupling impedance.)

PRM ROADMAP • Vicor's first PRMs will address the 48-V requirements of telecom, IT, and distributed-power system applications. With a nominal 48-V input, their outputs range from 26 to 55 V dc, depending on what it takes to maintain the proper voltage at the output of the VTM as its load requirements vary. PRMs for 24 V in telecom and indus-



1. Vicor's pre-regulator module (left) provides the voltage-transformation module (right) with a regulated high output voltage in FPA distribution schemes.



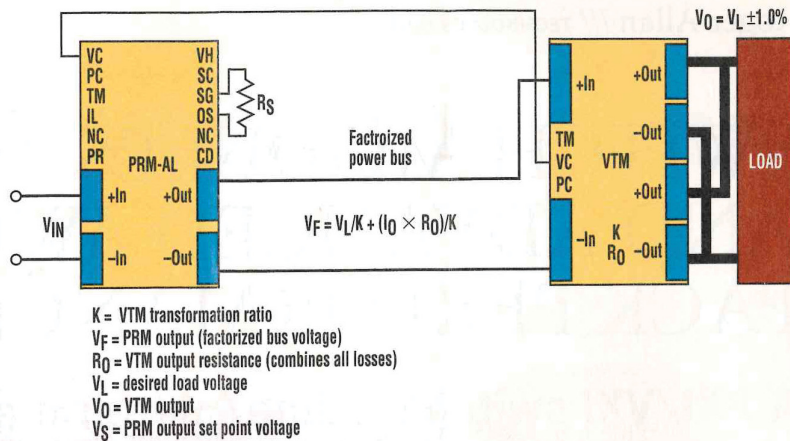
2. The PRM is based on a ZVS Buck-Boost regulator control architecture. Operating frequency is typically fixed at 1.5 MHz. It can step up or step down, with a conversion efficiency up to 98%. A single PRM can put out up to 300 W, and like VTMs, PRMs may be paralleled to achieve increased output power. Vicor's ZVS Buck-Boost engine is capable of input voltages from 1.5 to 400 V.

trial apps, for 18 V in ac adapters, for 12 V in silver boxes and IBA apps, and for 28-V military and aerospace systems will follow.

There will be two versions of the PRM. An adaptive loop version provides the ability to precisely control the load voltage through the isolation barrier without long, noise-sensitive feedback lines or opto- or magnetic couplers. In one feedback approach that takes the greatest advantage of factorized power's fast system response time, the PRM can simply monitor its own output current and voltage and compensate for losses in the VTM and bus (Fig. 3).

In Figure 3, R_S , an external resistor, sets the PRM output voltage on the factorized bus. The VC port on each of the modules serves three purposes. First, it allows the PRM to supply an enable signal to the VTM. Next, it synchronizes the output rise of the VTM to the output rise of the PRM. Third, it enables the VTM to "tell" the PRM its temperature-compensated equivalent output resistance, R_O . (Since the PRM monitors its own output current, it can adjust its output voltage to compensate for R_O .)

In local- or adaptive-loop feedback, the PRM only knows what its output must be. In local-loop, this voltage is held constant. In adaptive-loop, this voltage is varied dependent on R_O . (Also in adaptive loop, this voltage can be varied to include compensation for the distribution resistance in the intercon-



3. Factorized-power architecture regulation can be achieved via local-, remote-, or adaptive-loop feedback. The illustration shows adaptive-loop feedback.

nects between PRM and VTM and between VTM and the load. When implemented, this is handled via the CD pin.) In remote-loop feedback, the load voltage is monitored directly and the PRM compensates for both R_O and the interconnect resistances (equivalent to remote sense on a dc-dc converter). This is the "tightest" regulation (a few tenths of a percent).

Both PRMs and VTM modules share the same 0.85- by 1.26-in. (21.5- by 32.0-mm) footprint and come in ball-grid or J-lead packages. **ED Online 9092**

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INSIDE THE VTM

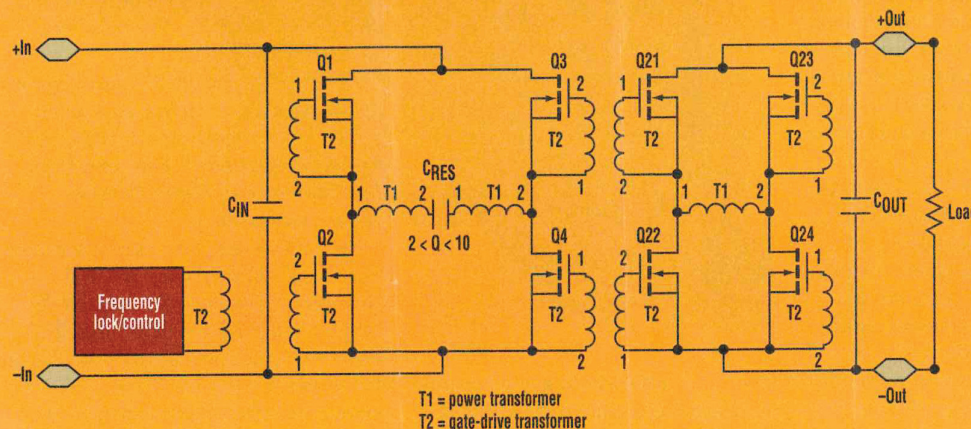
A VTM employs a zero-voltage switching and zero-current switching (ZVS/ZCS) topology called a sine amplitude converter (SAC) (see the figure). The power train is a low-Q, high-frequency, controlled oscillator, with high spectral purity and common-mode symmetry, so it generates very little noise.

The VTM control architecture locks the operating frequency to the power-train resonant frequency. The reactive components of loss are cancelled out. Remaining losses can be treat-

ed as a lumped resistance R_O . So, the SAC-based VTM is a linear voltage/current converter with a flat output impedance up to about 1 MHz. Characterization data shows R_O can be as low as 0.8 mΩ. If that's not low enough, or if more power is needed, VTMs can be paralleled with accurate current sharing.

A SAC VTM's secondary current is a pure sinusoid. The very low, non-inductive R_O allows an almost instantaneous response to a 100% step change in load current. There is no

internal regulation circuitry in a VTM and none of the attendant loop delays and stability issues, so no internal control action is required to respond to the change in load. The internal ASIC controller continues controlling and synchronizing the operation of the switches to maintain operation at resonance.



The efficiency of the VTM at all stepdown ratios is derived from its SAC architecture.

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