New power components and an innovative power bus architecture improve performance and increase design flexibility

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Demands placed on power supplies continue to grow because of the complex requirements of the systems they power. An increasing diversity of supply voltages, faster load transients, and lower load voltages are forcing designers to look for dc-dc converters that can provide higher efficiencies and current densities in smaller packages—all at a lower cost. But current power products and architectures are becoming stretched beyond their inherent limits. Continuing with incremental improvements and fixes is no longer sufficient to satisfy today's power system requirements.

A new approach to power conversion has been developed by Vicor. Factorized power architecture (FPA) repositions the basic power-conversion functions—voltage transformation, regulation, and isolation—within a distributed power architecture. New power components called V•I Chips deliver unprecedented speed, power density, and efficiency. The resulting power system has significantly improved electrical performance, and offers the benefit of lower cost and greater reliability.

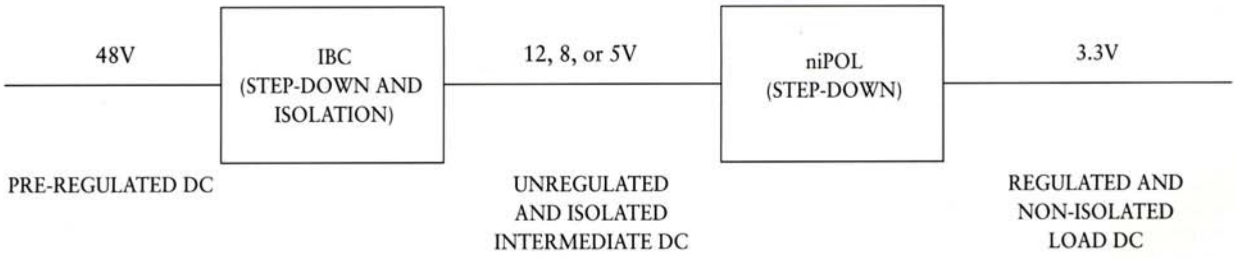
In a conventional brick-based distributed power scheme, isolation, voltage transformation, regulation, filtering, and input protection functions are duplicated at every point of load (POL). An alternative architecture is intermediate bus architecture (IBA) where an isolated brick or bus converter feeds a series of non-isolated point-of-load dc-dc converters. **Figure 1** compares the functional differences between IBA and FPA.

Typically in an IBA, a regulated dc voltage, 48V for example, is fed to an intermediate bus converter (IBC) where it provides an isolated step-down voltage to the intermediate power bus. Typical intermediate voltages are 12, 8, 5, or 3V. At the point of load, the intermediate voltage is again stepped down to its final value. Here a non-isolated buck converter is used—a non-isolated point-of-load converter or niPOL. However, because there is no isolation function within the niPOL, loads sensitive to overvoltage conditions are more vulnerable to faults and the system is more vulnerable to potential ground loop problems.

In contrast, the FPA moves the isolation function to the point of load. Again, as shown in **Figure 1**, the first module in the architecture, the pre-regulator module (PRM), regulates the dc input to the power system, providing a stable bus voltage referred to as the Factorized Bus. The non-isolated PRM operates at efficiencies as high as 99%. Because the PRM is free to produce a higher factorized bus voltage (because isolation is downstream) than found in an IBA system, the voltage can be distributed with lower I^2R losses. This means that the PRM can be mounted farther from the point of loads, even mounted on a different PC board.

The converter at the point of load is called the voltage transformation module (VTM). The VTM takes the regulated but non-isolated output from a PRM and provides galvanic isolation and either a step-up or step-down voltage. The output voltage is determined by the VTM's K factor: $Vout=Vin \times K$. The VTM functions at efficiencies of up to 97% and has exceptional dynamic response and noise characteristics.

For example, when subjected to a 90-percent load step at 50A/µs, the VTM can respond within 200ns with a 1µs settling time. This is fast enough that a designer can consider using a PRM-VTM pair to replace a standard voltage regulator module solution in some microprocessor power applications,



Intermediate Bus Architecture (IBA)

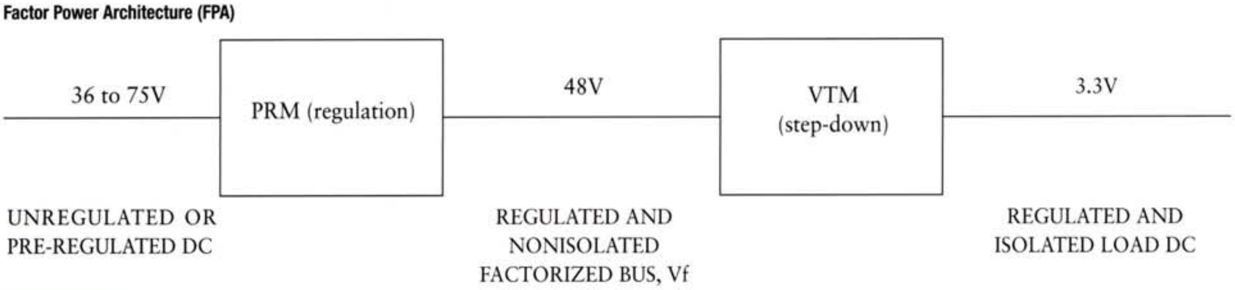


Figure 1 By moving the isolation function to the point-of-load, the voltage level of the intermediate bus may be raised. Several advantages result including improved reliability, fewer components and increased design flexibility.

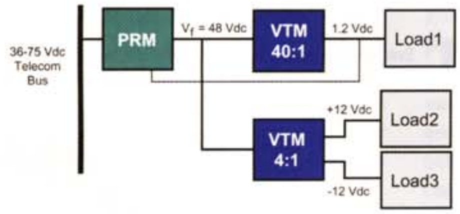
enabling the elimination of large amounts of costly, failure prone load capacitors.

The VTM is based on a zero-voltage and zero-current switching topology. This explains the VTM's ability to limit the common-mode and differential-mode noise at the point of load. For example, the output of a VTM configured to convert 48 to 12V results in about 12mV p-p of high-frequency ripple with only a 1µF ceramic bypass capacitor across the output, or about 0.1% of the dc output. This performance far exceeds that of conventional dc/dc converters.

Because of the VTM's low output impedance, about 1 mΩ on units with low output voltages, the VTM's load regulation is of the order of ±4% when it operates in an open-loop mode. The output of the VTM can be fed back to the PRM for closed-loop operation to improve the load regulation to a few tenths of a percent.

During closed loop operation, the PRM responds to changes in the load by adjusting its regulated output (V_f) up or down as much as needed to compensate for the VTM's output impedance (typically ±4%). Therefore, one PRM can power several VTMs, each with different voltage-transformation ratios, or be combined with multiple PRMs and VTMs for independent voltage regulation on multiple outputs.

One example would be to connect two VTMs to a PRM. (See **Figure 2**.) The VTM powering the load that requires the tightest regulation provides the feedback to the PRM. In this example, this would provide the tight load regulation needed for Load 1. The second VTM, operating in a dual-output mode, would provide 4% regulated voltages to Loads 2 and 3. While perhaps not practical for every application, this example demonstrates the flexibility of FPA. The designer is not forced into using a high-cost, full-function dc/dc converter for every load voltage if it isn't necessary.



FPA application, closed loop with PRM

Figure 2 The PRMs and VTMs can be used in combinations to customize the Factorized Power Architecture to meet system needs, such as one VTM providing feedback to the PRM, so its 1.2V output is tightly regulated. The outputs of the second VTM are regulated to within 4%.

One of the chief advantages of using the FPA mentioned earlier is that the Factorized Bus voltage can be relatively high. Therefore, the point-of-load converters, the VTMs, can be positioned farther away from the PRMs. They can even be positioned on separate PC boards. That's a big advantage in practically applying FPA to your design.

But an even bigger advantage is the fact that the PRMs and VTMs are packaged in BGA devices, called V•I Chips, that are compatible with standard pick-and-place and surface mount assembly processes. The profile for an in-board mounted V•I Chip is less than 4.0mm. This compares with a 12.7mm profile for a through-hole mounted quarter-brick on a pc board.

But power is not sacrificed for size. A two-chip combination (one PRM and one VTM) can produce system-level power densities of 500 W/in.^{3}. At the point of load, the power density is greater than 1,000 W/in.^{3}, equivalent to a current density of nearly 500 A/in.^{3}.

When compared to a conventional quarter-brick dc/dc converter, a PRM-VTM two-chip solution with a smaller footprint and lower profile will deliver 60A at 3.3V. Quarter-bricks typically provide 50A at 3.3V (165W). At 2.5V, the PRM-VTM combination will provide 80A. Today's quarter-brick converters deliver up to 60A. In summary, by reorganizing the basic power conversion functions (voltage transformation, regulation, and isolation) and incorporating these functions in V•I Chip power BGA packages, the FPA significantly improves electrical performance of the power system, improves its reliability, and provides greater design flexibility at a lower cost. ❑

Figure 3 The "semiconductor device" size of the FPA components make their application in highly populated PC boards easier, consuming only 6.5cm^2 of board space versus 21.3cm^2 for a quarter brick.