

Power Distribution Architectures: The Evolution Continues

The inevitable mix of lower voltages and higher currents is driving the industry toward new and improved power distribution schemes.

by Andrew Hilbert
Vicor

With each generation of processor, memory chip, DSP and ASIC, the trend to lower voltages at higher currents continues to challenge the infrastructure needed to support these contemporary loads. This trend has exposed, in turn, the limitations of known distribution architectures, including Centralized Power Architecture (CPA), Distributed Power Architecture (DPA) and Intermediate Bus Architecture (IBA). The newest of the power architectures—Factorized Power Architecture—promises to provide the performance needed to meet these challenges today.

Centralized Power Architecture

The classic CPA, which is simple and cost effective, continues to be applied wherever appropriate. Starting with communications systems applications, however, centralized power ran into a brick wall because of its inability to effectively deliver lower voltages at higher currents.

A centralized power supply contains the entire power supply in one housing—from the front end through the DC-DC conversion stages (Figure 1). It converts the line voltage to the number of DC voltages needed in the system and buses each voltage to the appropriate load. It's cost effective and doesn't consume valuable board real estate at the point of load with the power conversion function. It is fairly efficient because it avoids serial power transformations, and it concentrates the thermal and EMI issues into one box. In the past, the centralized system, usually a custom design, was often chosen because it was the least expensive approach. These systems, in general, work well when the power requirements, once defined, are not likely to change and space is not an issue.

In order to minimize I^2R distribution losses, the central supply should be located near the load. For safety and EMI reasons, it should be located as close as possible to the AC entry point. This is often a difficult trade-off. Although centralized power works well for many applications, it becomes most unsuitable when it is necessary to distribute the hundreds of amps common with low voltage loads today. Centralized power is also not scalable. Many systems can be configured with varying numbers of function cards representing widely varying loads—such as line cards in a PBX. With centralized power, the power supply must be sized to handle the maximum configured system, which could put the small configurations at a cost disadvantage.

What's more, the remoteness of the supply from the load negatively impacts its transient response—the ability of the supply to react to rapidly changing loads. Also, thermal management can be a special challenge in a centralized architecture, where excess heat could amount to hundreds of watts all in one concen-

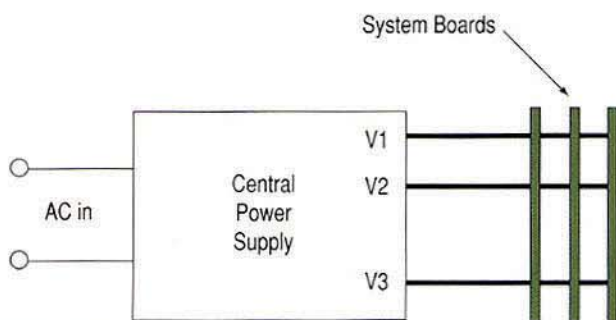


Figure 1 A centralized power supply contains the entire power supply in one housing and buses each voltage to the appropriate load.

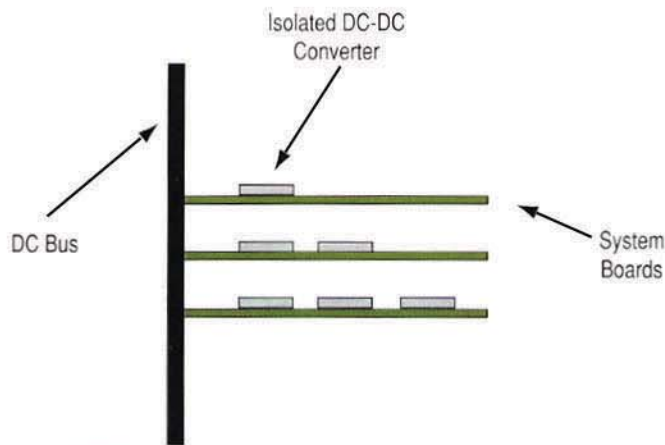


Figure 2 Distributed power is a decentralized power architecture consisting of DC-DC converters located near the load they serve.

trated area. Large heat sinks and fans are often needed to keep the power supply from becoming overheated. System hotspots are a source of reduced reliability.

Distributed Power Architecture

As low voltage loads proliferated, bricks and distributed power came of age. Distributed power put DC-DC converter “bricks” on system boards near the loads they were powering. Since the 1980s, the bricks of DPA have delivered the classic

functions of the DC-DC converter (isolation, voltage transformation and regulation) to the point of load. But as the number of voltages required at the board level continued to increase, DPA began to take up too much valuable real estate and the cost of duplicating the full converter functionality many times over became too much.

Distributed power is a decentralized power architecture characterized by busing a “raw” DC voltage, usually 48 or 300 Vdc depending on the power source, which is then converted by on-board DC-DC converters located near the loads they serve (Figure 2). On-board isolated DC-to-DC converters are matched to the load requirement. This helps with dynamic response and eliminates the problems associated with distributing low voltages around the system.

A distributed approach spreads the heat throughout the system, greatly reducing or eliminating the need for heat sinks or high velocity airflow. With temperatures more evenly maintained throughout the system, reliability specifications are easier to meet. Also, since the power is located on the board, configuring system variations and options is much more cost-effective than in a centralized architecture, which requires the power supply to be sized for worst-case loading.

Redundancy is easy to implement for any critical load by simply paralleling additional DC-DC converters where required. DPA, however, can also be more costly. Since isolation, regulation, transformation, EMI filtering and input protection are repeated at every load, as the loads proliferate, both the costs and board area for power conversion increase.

Intermediate Bus Architecture

To deal with the multiplicity of low voltages more cost-effectively, IBA relies on non-isolated point of load regulators (niPOLs), reducing the POL function to regulation and transformation. The niPOLs operate from an intermediate bus voltage provided by upstream isolated converters. IBA can be a more cost-effective solution because niPOLs, being non-isolated, are less expensive than complete DC-DC converters. But typical niPOL buck converters are in constant conflict

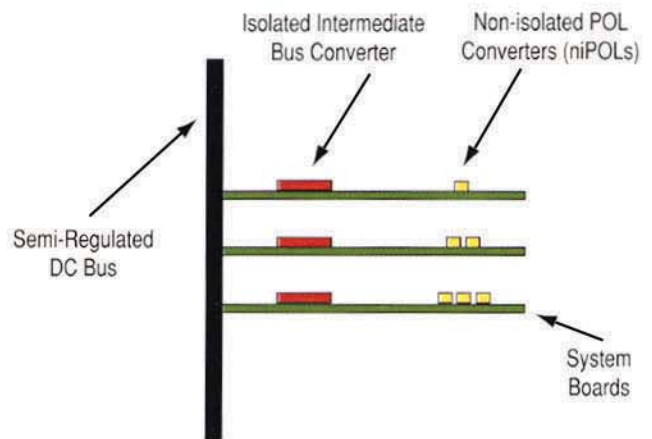


Figure 3 The intermediate bus architecture uses an isolated intermediate bus converter to provide an unregulated voltage to power non-isolated and relatively inexpensive POL converters.

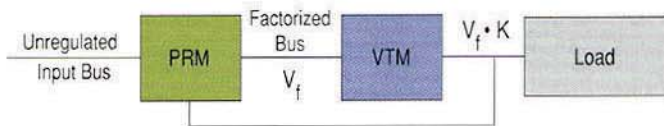


Figure 4 Basic FPA block diagram

between efficient power distribution and efficient power conversion duty cycle.

The intermediate bus architecture differs from the distributed power architecture in that it converts the raw DC voltage—48 or 300 Vdc—to an intermediate voltage, typically 9.6 or 12 Vdc, to feed non-isolated and relatively inexpensive POL converters (Figure 3). The niPOLs are also likely to be smaller and lighter than DC-DC converters, providing the benefits of a small footprint and consuming correspondingly less board real estate. Non-isolated POL converters within the Intermediate Bus Architecture forego isolation and high voltage transformation ratios to improve cost-effectiveness.

The niPOLs of IBA depend upon a bus converter to provide isolation and voltage step-down from the raw DC bus. This is accomplished by the intermediate bus converter, which is usually either a complete DC-DC converter operating from a wide range DC source, or an unregulated IBC operating from a narrow range input. The conversion to the intermediate bus voltage intrinsically reduces efficiency of the system. Also, the intermediate bus converter really does need to be located close to the load, because, even with a 12-volt intermediate bus, four times the current needs to be moved around the board as compared to a 48V distributed power system, so larger traces or shorter runs are needed.

The 12-volt intermediate bus is also too high for efficient conversion to low voltage outputs (under 2 Vdc) as the transformation ratio becomes too high, and the switch duty cycle becomes too low. Lowering the bus voltage to overcome this limitation simply increases the problems associated with the previous issue.

Since the niPOL includes regulation, it needs an inductor in series with its output. These same low voltage loads generally need fast transient response, but now inertia has been imposed right where agility is most needed. These are the fundamental limitations of IBA when it comes to powering today's sophisticated low-voltage, high-speed loads. Another disadvantage with niPOLs is their lack of isolation: loads are vulnerable to deadly faults and the entire system is susceptible to ground-loop and noise coupling problems.

Factorized Power Architecture

FPA reorganizes the basic power conversion functions—voltage transformation, isolation and regulation—and implements them in IC-style packages. A buck/boost Pre-Regulator Module (PRM) provides a stable voltage from an unregulated DC bus, and a Voltage Transformation Module (VTM) steps the voltage up or down and provides isolation at the point of load. High-frequency FPA V•I Chips using zero-current/zero-voltage soft switching topologies, offer designers a number of advantages such as small size, high efficiency, low noise and fast transient response combined with extremely high power density—greater than 1,000 W/in³ at the point of load.

Benefits of Sine Amplitude Converters

Characteristic	Benefit
3.5 MHz fixed switching frequency	The high switching frequency significantly reduces the size of all reactive components, is very easy to filter and decreases the response time.
Zero-voltage and zero-current soft switching	Lossless switching increases efficiency, reducing power losses and heat dissipation. It also reduces—by as much as an order of magnitude—dV/dt and dI/dt, resulting in low noise.
Minimal serial energy storage (no output inductor)	There is no power loss associated with an output inductor, a loss element in a typical converter. There is no current inertia to overcome, contributing to very fast dynamic response.
100% switch duty cycle at any transformation ratio	The high duty cycle results in efficient power train utilization.
Bi-directional power processing	Load dump energy is recycled to the input, improving transient response.
Capacitance reflection and multiplication	This SAC characteristic results in high effective point-of-load capacitance without the physical presence of bulk capacitance.
Power train symmetry	Symmetry produces cancellation of common mode noise.

Table 1 Listed here are the characteristics of the Sine Amplitude Converter (SAC) that contribute to these benefits and that overcome the limitations of IBA.

Figure 4 shows the FPA modules in a basic arrangement, but the PRM and VTM can be operated alone, together, open loop, local loop, adaptive loop, remote loop, co-located, separated, paralleled, or combined with conventional power conversion devices—DC-DC converters, point-of-load converters, charge pumps—to achieve the desired power solution.

The VTM is enabled by a new class of power conversion topologies called Sine Amplitude Converter (SAC), which offers designers a number of benefits that include, for example, high power density, high efficiency, fast transient response and low noise. Characteristics of the SAC that contribute to these benefits and that overcome the limitations of IBA are shown in Table 1. ■

Vicor
Andover, MA.
(978) 470-2900.
[www.vicr.com].