Power Systems Architectures

What's In? What's Out?

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Distributed power has been a viable design approach for decades, albeit almost exclusively in the telecommunications domain. Board-mounted DC-DC converters, for example, were constructed with discrete components and used to convert power from a centralized supply to more usable power, typically at a backplane. Subsequently, the advent of high-density DC-DC converter modules paved the way to more widespread use of the idea in EDP, industrial, military and medical applications. Since that time, the chorus of articles in the trade press extolling the virtues of Distributed Power Architecture has been increasingly loud and clear: centralized architecture is going or gone and DPA is king.

Wait a minute. A recent article[1] underscored the idea that power architectures don't exactly take the industry by storm. Centralized architectures 3/4 although they have lost three percentage points of share since 1997, 3/4 still account for 44 percent of power systems. Earlier, in the spring, an article[2] declared that designers (unquantified) of military electronic systems prefer centralized power. Intermediate Bus Architecture (IBA), seemingly everywhere in the news over the past year or so, actually accounts for only about 2.8 percent[1] of power systems. Distributed Power Architecture apparently dominates, but not by much. The recently announced Factorized Power Architecture adds to the complexity of the picture.

The structure and operation of each of these power architectures is summarized in Figure 1, and they are discussed in subsequent paragraphs.

Centralized Architectures

The evolution of power architectures began with the centralized architecture. A centralized power supply contains the entire power supply in one housing ¾ from the front end through the DC-DC conversion stages. 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 very cost effective. It doesn't consume precious board real estate at the point of load with the power conversion function. It's relatively simple to manage thermals and EMI. It is fairly efficient because it avoids serial power transformations. In the past, the centralized system, usually a custom design constructed of discrete components, was often chosen because it was less expensive. These systems, in general, work well when the power requirements, once defined, are not likely to change and space is not an issue.

The central supply should be located near the load to minimize I2R losses, and it should also be located as close as possible to the AC entry point to reduce noise radiated from the unshielded AC lines. This is often a difficult trade-off with the input cables requiring shielding to minimize common and differential mode currents that produce noise.

Centralized power works well in many respects, but the most obvious problem is how to distribute hundreds of amps common with low output voltages. Centralized power also lacks scalability. Many systems can be configured with varying numbers of PC cards representing widely varying loads (e.g., 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 can negatively impact the ability of the supply to react to a rapidly changing load (i.e., transient response). Also, thermal management can be a special challenge in a centralized architecture, where excess heat could amount to hundreds of watts all in one concentrated 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.

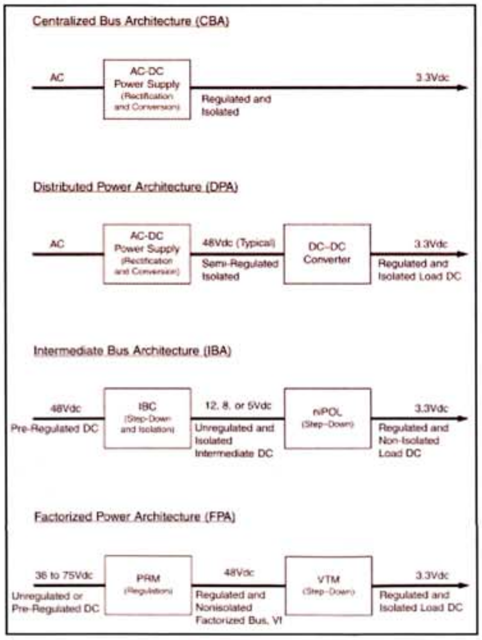

Figure 1. A comparison of the structure and operation of major power architectures

Distributed Power Architecture

DPA addresses some of the shortcomings of a centralized architecture. Distributed power is a decentralized power architecture usually consisting of an AC-DC converter at the AC mains serving DC-DC converters located elsewhere. The AC-DC converter might provide regulation, isolation, noise suppression, and power factor correction as well as an intermediate DC voltage, frequently 48 V. This intermediate voltage is converted by DC-DC converters located at the point of the load they serve. Typically, power in a telecom system is distributed on a 48 volt bus. 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. DPA was actually enabled by the development of high-density bricks.

A distributed approach spreads the heat throughout the system, greatly reducing or eliminating the need for heat sinks or high velocity airflow. With temperature more evenly maintained throughout the system, reliability specifications are easier to meet.

DPA, however, can be more costly in a number of ways. For example, isolation, regulation, transformation, EMI filtering and input protection are all done at every brick. And coming from an offline source, rectification and conversion to the distributed bus voltage are needed so that's an additional power-processing step that reduces overall system efficiency.

Furthermore, if a single DC-DC converter cannot provide adequate power or fault tolerance for a particular output voltage, multiple DC-DC converters will need to be paralleled, creating additional complexity owing to the need to connect remote sense leads from each paralleled converter to a single, common, point and the need for additional circuitry within each paralleled converter to force power sharing among the units.

Intermediate Bus Architecture

The Intermediate Bus Architecture (IBA) was first to separate the DC-DC converter functions of isolation, transformation and regulation and allocate them to two devices. The IBC (Intermediate Bus Converter) provides intermediate voltage transformation and isolation and the niPOL (nonisolated Point of Load) converter provides final transformation and regulation.

IBA can be a very cost-effective solution because point-of-load converters don't require any isolation and tend to be a lot less expensive. Non-isolated POL converters within the Intermediate Bus Architecture forego isolation and high ratio voltage transformation to improve cost-effectiveness, but they depend upon a nearby bus converter to supply power at a low input voltage. On the negative side, the lack of isolation in niPOL converters make over-voltage sensitive loads vulnerable to deadly faults and and the entire system to potential ground loop problems.

The intermediate bus converter introduces a power-processing step to go from, say, the 48 to 12 volts that intrinsically reduces efficiency of the system. Also, the bus converter really does need to be located close to the load, because even at 12 volts, fairly high currents need to be moved around the board so large traces or short runs are needed. The 12 volt bus itself is a bit low for efficient distribution of a lot of power. But it's too high to step down to a very low voltage because of the very low duty cycle on the switch. As a result, it is difficult to make a highly IBA system.

Factorized Power Architecture

Factorized Power Architecture (FPA) also separates conventional converter functionality into two power building blocks. This new architecture, in concert with IC-style chip devices (see Figure 1), provides power system designers with high performance at low cost. FPA is enabled by the power conversion chips, which efficiently process over 200 watts of power in a small (less than 0.25 cubic inch) and light (less than 13 grams) power Ball Grid Array (BGA) or J-level package, with power densities over 800 Watt/in^3. These functional building blocks are deployed as surface mount (SMD) components to create a flexible factorized power system.

One building block, the Pre-Regulator Module (PRM), is designed to accept a wide-range supply voltage and convert it to a factorized bus 3/4 a controlled voltage source 3/4 with 97 percent to 99 percent efficiency. Another building block, the voltage transformation module (VTM), is designed to convert the factorized bus to the voltage levels required by the load with efficiencies as high as 97 percent. The VTM will also provide input to output galvanic isolation.

The combination of FPA and IC chips give the power designer the flexibility to use only what is needed where it is needed. The minimal complement of PRMs and VTMs depends upon the multiplicity of outputs, power levels, individual regulation and power system fault tolerance requirements. VTMs and PRMs may be paralleled with accurate sharing for higher power or redundancy; in fact, VTMs inherently current share when inputs and outputs are paralleled. This avoids the need for a power-sharing protocol, interface signals and a multiplicity of remote sense connections.

By exploiting a zero-voltage switching and zero-current switching topology, the VTMs limit the common-mode and differential-mode noise at the point of load. For example, the output of a VTM configured to convert 48 V to 12 V exhibits about 12 mV p-p of high-frequency ripple with just 1 μF of bypass capacitance. That noise voltage amounts to only 0.1 percent of the DC output.

Reference

[1] Darnell.com, July 21, 2003, Lies, Statistics and IBAs, Linnea Brush; 2 COTS Journal, April 2003, Distributed Power Knocks at Military's Door, Jeff Child.