

# POWER *Systems Design*

Power Control Intelligent Motion

February 2004

## Eliminating Capacitor Drags

Power System Protection  
Programmable Power Management  
Acoustic Evaluation  
Subscriber Line Protection

are stable before the onboard power supplies (Brick, LDO, and FET) are turned on. This makes sure that the system start-up phase won't start while supply voltages are out of the specified range.

Phase 2: The voltages on the device side (V1, V2, V3) are monitored to ensure reliable power is applied to the devices. In multi-voltage systems sequencing specifications can be quite complex, e.g. core voltage first, then core voltage and then auxiliary voltages.

Phase 3. All power supply nodes (input and device side) and digital input signals (Reset\_In& FPGA\_Load\_Complete) are monitored to generate logic control signals (CPU\_Reset and Power\_Good) for the system to start up. The power manager's precise delay capabilities allow the control of delays ranging from a few microseconds to seconds!

Phase 4. All power supply nodes (input and device side) are monitored for power supply faults and to facilitate generation of supervisory signals: Brown\_Out\_NMI, CPU\_Reset, and Power\_Good. Also, the Manual\_Shut\_Down signal is monitored to facilitate the control logic to jump to phase 5.

Phase 5. Monitor supplies to ensure controlled shut down. Integration and Programmability Benefits with Power Manager

The power manager family of Lattice Semiconductor greatly simplifies implementation of complex power-supply sequencing and monitoring systems and reduces design time.

Programmability reduces prototype-debugging time, and by programming the threshold voltages, power supply margining tests can be performed even on the production line.

The power manager family provides the complete collection of functions needed for sequencing and monitoring power supplies in all 5 phases of power supply cycle; it is a highly integrated single-chip solution with all sequencing and monitoring functions in one central place. Its robustness ensures reliable start up of the board; even under noisy power supply start up conditions and the change in supply sequencing and monitoring requirements due to component substi

tutions on the circuit board can be easily addressed through re-programmability.

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# Power systems architectures

## What's in? What's out? What is state of the art?

*The Factorized Power Architecture (FPA), in concert with IC-style chip devices, 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 power Ball Grid Array with power densities over 800 Watt/ cubic inch.*

Robert Marchetti, Vicor

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. 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 æ 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 I<sup>2</sup>R 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

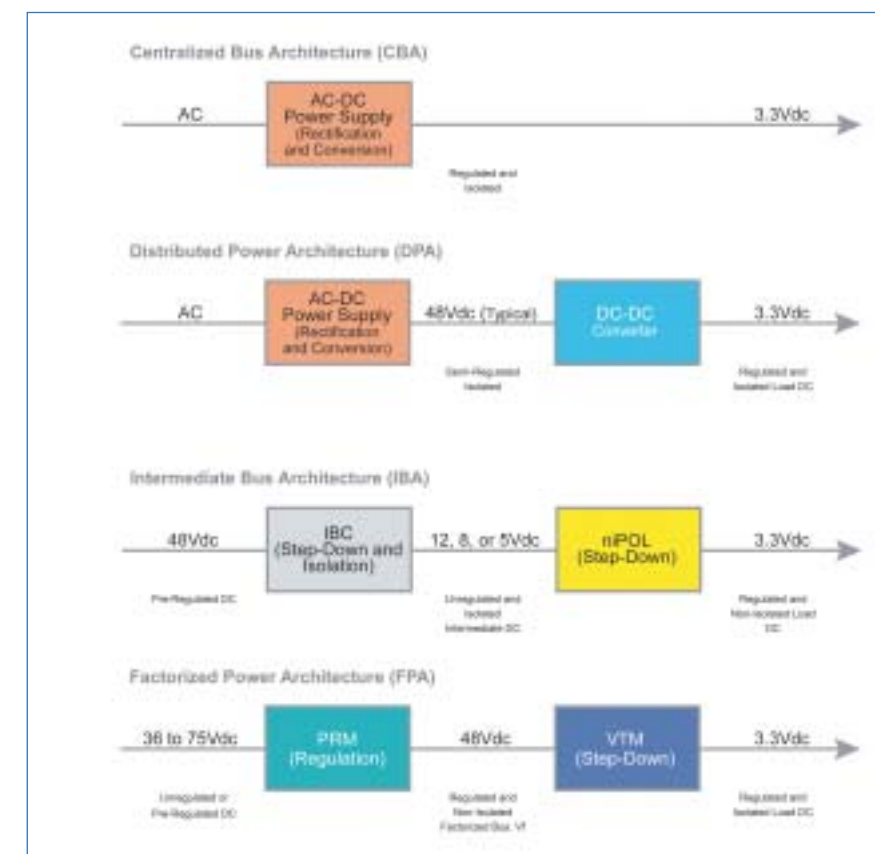


Figure 1: A comparison of the structure and operation of major power architectures.

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.

#### Distributed Power Architecture

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 48V. 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, isola-

tion, 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 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 (non isolated 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 the entire system to potential ground loop problems.

The intermediate bus converter introduces a power-processing step to go from, say, the 48 to 12Volts that intrinsically reduces efficiency of the system. Also, the bus converter really does need to be located close to the load, because even at 12Volts, fairly high currents need to be moved around the board so

large traces or short runs are needed. The 12Volt 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/ cubic inch. These functional building blocks are deployed as surface mount (SMD) components to create a flexible Factorized Power system.



Figure 2: The Factorized Power Architecture converter.

One building block, the Pre-Regulator Module (PRM), is designed to accept a wide-range supply voltage and convert it to a Factorized Bus as a controlled voltage source as with 97% to 99% 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%. 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 48V to 12V exhibits about 12mV p-p of high-frequency ripple with just 1  $\mu$ F of bypass capacitance. That noise voltage amounts to only 0.1% of the DC output.

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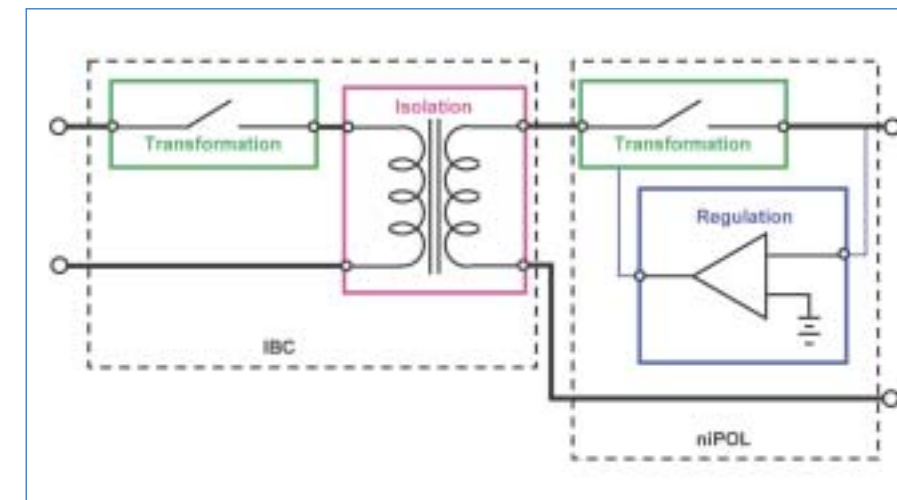


Figure 3: Function blocks of the Factorized Power Architecture converter.

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25 - 27 May 2004  
Exhibition Centre Nuremberg

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