AMP™ Architects of Modern Power

Digital Power Comes of Age

This article looks at the evolution of distributed power architectures since the introduction of the first high-frequency switching dc-dc converter modules back in 1984. It describes the factors that have driven this evolution and highlights some of the most significant innovations along the way. We then consider advances in digital power in the last few years and where power technology needs to take us if the growing power demands of data networks and storage systems are to be met with minimum environmental impact. Finally, we highlight the opportunities for 'competitive collaboration' to drive innovation in the digital power supply industry - the engineering benefits it brings to power systems designers, the commercial benefits to companies that consume power supplies, and the opportunity to mitigate the potentially negative environmental impact of our growing demand for digital information in all its forms.

Distributed power architectures now dominate in the design of power systems for high performance datacom and telecom networks, and data center equipment. The change from centralized power - a simple ac-dc power supply, perhaps with battery backup, feeding the cards in a system rack - came about by necessity. Semiconductor operating voltages decreased as ever-smaller process nodes were developed to boost the processing power of ICs. The ICs became more powerful and their lower operating voltages meant that higher current was demanded. Long printed circuit board tracks would mean unacceptable I2R losses, reducing power system efficiency, so distributed power architecture became the norm. This trend is continuing. Since the 1980s the power demands of data centers have risen from 300 W to 1200 W per board and some forecast that it will reach 5kW by 2015 as network IP traffic grows dramatically over the next few years.

The economics of creating distributed power systems were transformed back in 1984 when a group within Sweden's part of Ericsson AB, Ericsson Components – RIFA Power (later to become Ericsson Power Modules) launched the PKA series of dc-dc converters. The introduction of the PKA, described by Ericsson as "the world's first high frequency dc-dc switching power supply," meant that engineers no longer had to design relatively expensive and complex circuits from discrete components. They could now use a compact board-mounted module on each card, adding just a few external filtering and decoupling components, to create much more efficient and effective power systems. The use of power modules also delivered marked improvements in system reliability. This was particularly important for those designing communications networks, where the target for operating life was sometimes 25 years or more.

Typically, the front-end ac-dc unit would have a -48 V output and a dc-dc power module on each card would convert this to 12 V or 5 V, or a combination of both, to provide the correct operating voltage for semiconductors in the system. 3.3 V semiconductors then started to appear and today we're down to 0.9 V for many with some processors drawing up to 90 A current at full load.

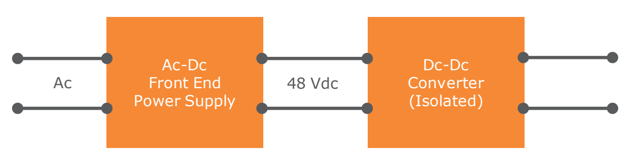

Figure 1. Early distributed power solutions adopted a two-stage conversion with a typical intermediate bus voltage of -48V and a single output at 12V or 5V

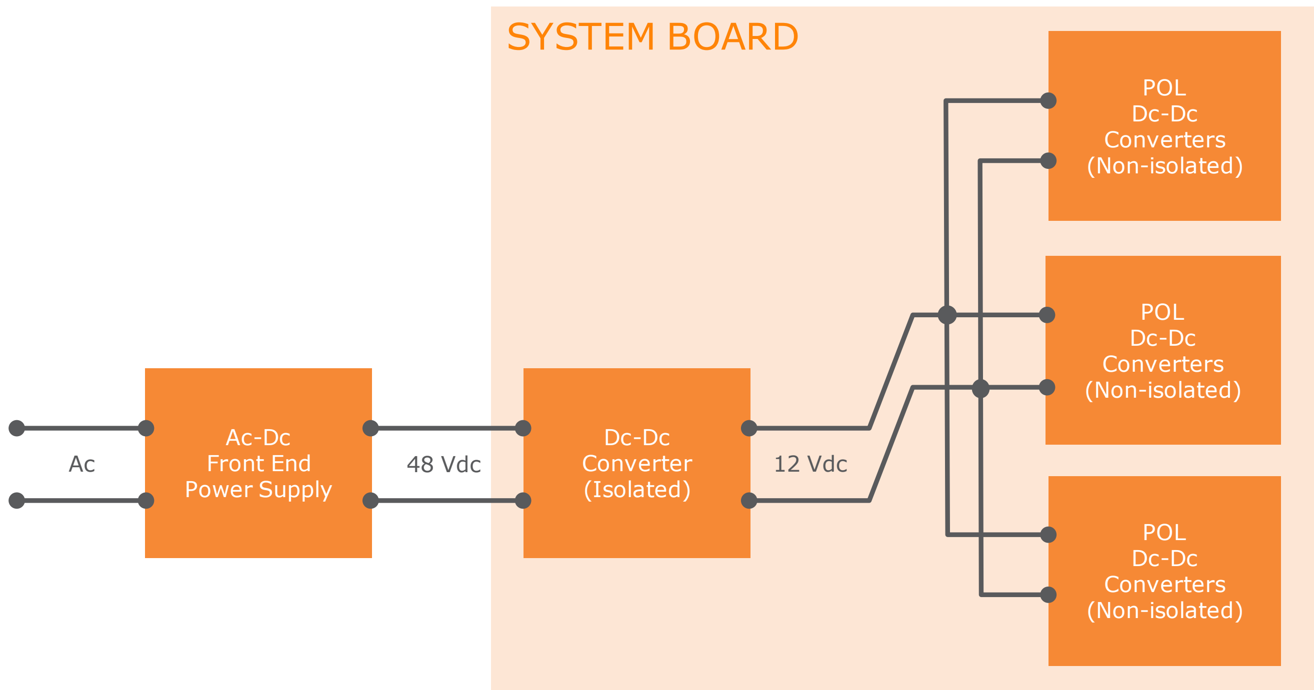

Figure 2. The proliferation of supply rails at the board level has resulted in an intermediate bus architecture (IBA) that requires multiple POL converters on the system board.

The larger the differential between the input and output voltage(s) of a dc-dc converter, the less efficient the conversion process. It soon became clear that for maximum system efficiency it is desirable to handle the last conversion very close to the load i.e. the processor, FPGA or other device. Power supplies used in this final conversion are point of load (POL) converters. In addition to boosting efficiency, placing power converters as close as possible to their loads prevents instability due to stray impedances in long PCB tracks or system wiring. Datel, which was acquired by Murata as part of the Power Electronics Division of C&D Technologies in 2007, was an early pioneer of isolated dc-dc converters and POL modules during the 1980s and 1990s.

Distributed power architectures can be implemented in a number of different ways, using regulated or unregulated bus voltages. As systems became more complex, demanding a number of different voltages, perhaps 12, 5, 3.3, 2.5 and 1.2 V, power system designers began to adopt intermediate bus architectures (IBA) around 15 years ago. Here, the ac-dc power supply feeds an IBA converter at perhaps 24 V or -48 V. The isolated IBA converter outputs 5 to 14 Vdc and feeds the required number of POL converters.

Distributed Goes Digital

The demand to provide sophisticated power management functions, including the sequencing of power supplies with controlled ramp rates as required by large FPGAs, along with a desire to reduce board space and the number of external components are the drivers that have led power system designers to increasingly turn to digital power over the past decade. Key to this are the power management ICs from companies like Texas

Instruments, who introduced the industry's first digital signal processing (DSP) development kit specifically for power supply applications back in December 2002.

However it has been the development of off-the-shelf digital power converter modules that has accelerated the adoption of digital power in the last five years. The first of these came to the market in 2008 in the form of Ericsson's BMR453 intermediate bus converter. Digital converters have much in common with their analog counterparts, including similar power switches and output filters. However, the inner control loop provides digital flexibility for tailoring power delivery to the application and enabling the power systems to dynamically adapt to changes in operating conditions in real time. Communications, monitoring and control are implemented over the industry-standard PMBus.

Digital control is particularly important in improving the efficiency of data network power systems. The power drawn by networking equipment increases with data throughput. At times of low data traffic, the network is operating well below capacity, power supplies are operating well below their maximum load and processors can run at lower clock speeds.

At low loads the power supplies are relatively inefficient, resulting in excessive energy consumption and waste heat generation, with undesirable technical, financial and environmental consequences. By implementing a digital control loop encompassing both intermediate bus and POL converters, the intermediate bus voltage can be varied dynamically in response to varying loads. The input voltage to the POL converters is reduced under low load conditions, which increases conversion efficiency at low loads.

Some digital power devices offer a dynamic voltage scaling (DVS) function to save energy. If the demand for computing power is low, both the clock frequency of the processor and its supply voltage can be reduced. DVS is usually implemented as an open-loop function with a look-up table holding pre-determined combinations of frequency and supply voltage.

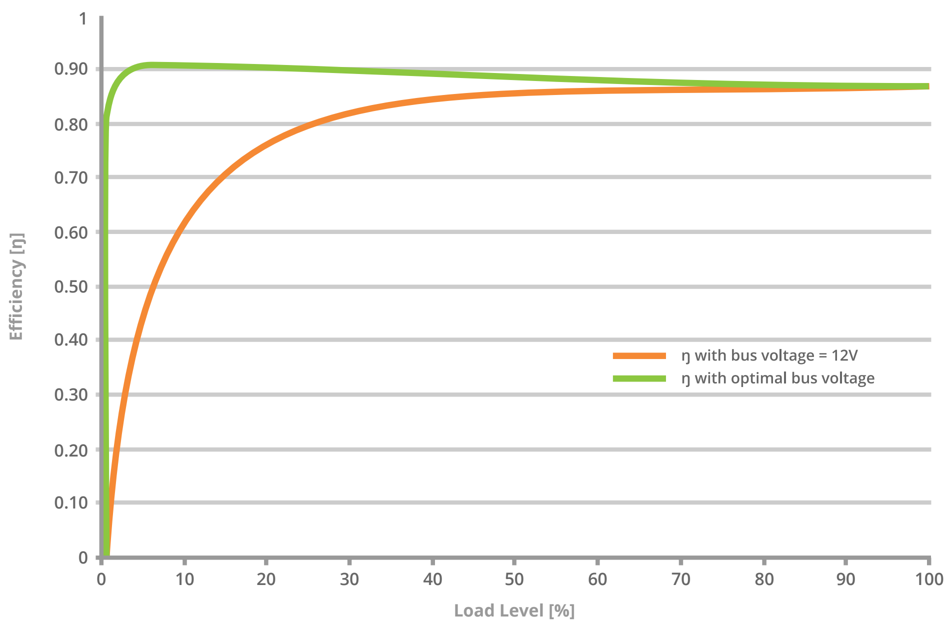

Figure 3. Digital power is particularly effective for improving efficiency under low-load conditions SOURCE - Ericsson (EGG October 2014)

More advanced than DVS, adaptive voltage scaling (AVS), adopts a closed loop, real-time approach that adapts the supply voltage precisely to the minimum required by the processor, depending on its clock speed and workload. This technique also compensates automatically for process and temperature variations in the processor.

Most switching power supplies use a closed control loop with negative feedback from output to input. A compensation network is needed to adjust the frequency response of the loop to achieve the optimum transient response without compromising stability. The design of the compensation network can be a time-consuming task involving considerable trial and error. Even then, the performance of the components in the network can change with variations in temperature or due to ageing. In 2010, CUI Inc, a North American company, was the first manufacturer to develop and launch non-isolated POL converter modules featuring auto-compensation, a digital function that completely eliminates this problem.

Using digital power modules also simplifies or enables many other aspects of power system design including active current sharing, voltage sequencing and tracking, soft start and stop, and synchronization.

The Drive for Standardization

As dc-dc power modules have become more widely adopted, there has been a drive towards some level of standardization of products from different manufacturers. Customers, concerned about supply chain reliability, demanded second sources for products, leading to trade associations being formed by power supply and component vendors to address this issue.

Typically however, the alliances formed in this space succeeded in little more than agreeing to standard footprints and pin-outs for certain categories of power converter, such as non-isolated and isolated dc-dc converter modules. While this has enabled a degree of interchangeability between products from different manufacturers, there has not been full consensus with respect to how all of the electrical functions of converters are implemented, making it less than straightforward to swap out one product for another. This is particularly true for digital power, which adds another layer of complexity to the challenge of ensuring compatibility between solutions.

More significantly, in 2004, Artesyn Technologies, Astec Power, and a group of semiconductor suppliers: Texas Instruments, Volterra Semiconductors, Microchip Technology, Summit Microelectronics, and Zilker Labs, formed a coalition to develop an open standard for a communications with a protocol dedicated to power systems. This was the birth of the industry standard for power subsystem management known as PMBus.

Not all has been 'plain sailing' and despite good intentions and a number of positive moves, there were issues that stalled developments by other manufacturers. Most notable was the patent infringement lawsuit issued by Power One in 2005 to protect the Z-Bus technology used in its POL regulator ICS for monitoring and controlling power supplies. This held back the widespread adoption of PMBus for around four years, until the use of licensing royalty agreements became routine for such technology.

Most recently power supply companies have been coming together once again to address these issues, particularly the more challenging requirements of digital power. In July 2011, CUI announced a cooperative agreement with Ericsson Power Modules and in September that year demonstrated a new family of POL modules that are pin and function compatible with Ericsson's BMR46X series of converters. A year later, CUI entered into a license agreement with Ericsson for the latter's 3E Advanced Bus Converter family, allowing it to offer customers an intelligent intermediate bus converter to pair with its portfolio of POL products. The companies agreed at that time to cooperate on a common standard for digital intermediate bus converters going forward. In July 2014, Murata and Ericsson announced a technical collaboration agreement with the goal of accelerating the adoption of digital power products by offering customers fully compatible products from each company.

Meeting Future Needs

According to the Ericsson Mobility Report, annual IP traffic will reach 7.7 zettabytes by the end of 2017, up from 2.6 zettabytes in 2012. Video communications, cloud-based services and the interconnection of physical objects, dubbed the Internet of Things (IoT), are the primary drivers of this unstoppable growth. This will place even greater demands on data network power system designers and fully exploiting the functional and efficiency benefits provided by digital power devices is the only way that they will be able to rise to the challenge. Furthermore, the technology that started in datacoms and telecoms is proliferating into other industries and applications as advanced processors and FPGAs become commonplace, such as in medical, industrial, and test/measurement equipment. This is creating the need for a simple, intuitive, multisource solution across the board. The challenge is to achieve "perfect power conversion, under all conditions, all of the time". Hence there is pressure on power supply manufacturers to accelerate their rate of innovation to the extent that much deeper collaboration will be needed.

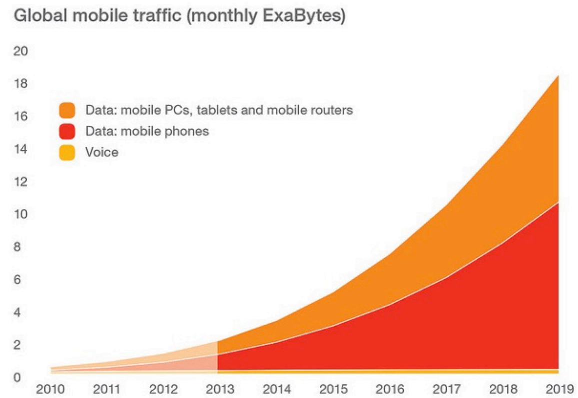

Figure 4. Annual IP traffic will reach 7.7 zettabytes by the end of 2017, up from 2.6 zettabytes in 2012 SOURCE – Ericsson Mobility Report (November 2013)

To this end, CUI, Ericsson Power Modules and Murata, founded the Architects of Modern Power (AMP) Consortium in October 2014. The goals of the Group go far beyond the ambitions or achievements of established trade associations in the power industry. AMP Group will be characterized by deep collaboration between the firms in developing leading-edge digital power technology, in terms of both functionality and efficiency. Common standards will encompass mechanical, electrical, communications, monitoring and control specifications. Members will focus on developing products that deliver high efficiency power conversion under all operating conditions and provide supply chain security to customers through true plug-and-play compatibility between their products.

For more information, please visit:
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