Electronic Design

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The Ever-Evolving DC-DC Converter

Sponsored by Digi-Key and Vicor: An essential part of power-supply architecture, these converters continue to advance to bring more power with greater efficiency in smaller packages.

The heart of the modern electronic power supply is the dc-dc converter. It provides the transitions from one voltage level to multiple other voltage levels. The dc-dc converter is available as an IC that's the core of your own design, as a module, and as a brick (see sidebar below). The latter two types eliminate a considerable amount of original design by delivering a product that's ready to integrate into a larger power supply.

Over the years, the dc-dc converter has become the main component that sets and maintains operational voltages and improves efficiency while increasing power density. This summary update of the venerable devices illustrates how it has changed to meet multiple driving factors.

Modern Power-Supply Architecture

Two main types of architectures are used in today's power systems: the distributed architecture and the intermediate bus architecture. *Figure 1a* shows the distributed arrangement. A traditional ac-dc supply generates a main dc bus that's distributed to all parts of the equipment. The needed dc voltages for ICs and other devices are produced by point-of-load (POL) dc-dc converters/regulators.

The intermediate bus arrangement is shown in *Figure 1b*. The main dc distribution bus from the ac-dc supply is connected to dc-dc converters in each major subsystem or printed circuit board (PCB) that produce an intermediate bus. From there, POL dc-dc converters take over to create the individual supply voltages for the loads.

Trends and Goals

There are several major drivers of dc-dc converter specifications and features. These drivers are the trends impacting power-supply design today:

- *Lower supply voltages:* Large MPUs, FPGAs, and ASICs increasingly have adopted extremely low core supply voltages. The range of voltages is from 0.6 to 1.8 V. At the same time, current draw from these devices has increased dramatically from tens of amperes to hundreds of amps. Some new devices operate at 1 V or less while consuming over 500 A.
- *Higher efficiency:* Efforts to reduce energy consumption and decrease heat levels have pushed efficiency to the top of the priorities list.
- *Transition to 48 V:* Power-supply bus voltages have commonly been 12 V, but 5-, 24-, 28-, and 36-V buses have been used. A major trend is to standardize on 48 V. This higher voltage has multiple benefits that include improved efficiency and the reduction of I^2R losses. Higher voltages reduce the current for the same power level. The result is a power-loss reduction by a factor of 16. Many new products and systems are transitioning to 48 V, such as power tools, industrial devices

WHAT IS A BRICK?

A brick is a complete ac-dc or dc-dc power supply in a brick-shaped configuration. It's designed to be mounted directly on a PCB. The bricks comply with standard sizes as determined by the Distributed-power Open Systems Alliance (DOSA). Bricks are typically switch-mode power supplies in a convenient modular format that lets designers buy their needed power supply rather than creating it from scratch.

Bricks come in a wide range of sizes, voltages, and power ratings. Standard sizes are:

1. Full brick: 4.6 × 2.4 × 0.5 inches
2. Half brick: 2.3 × 2.4 × 0.35 inches
3. Quarter brick: 2.3 × 1.45 × 0.35 inches
4. 1/8th brick
5. 1/16th brick
6. 1/32nd brick

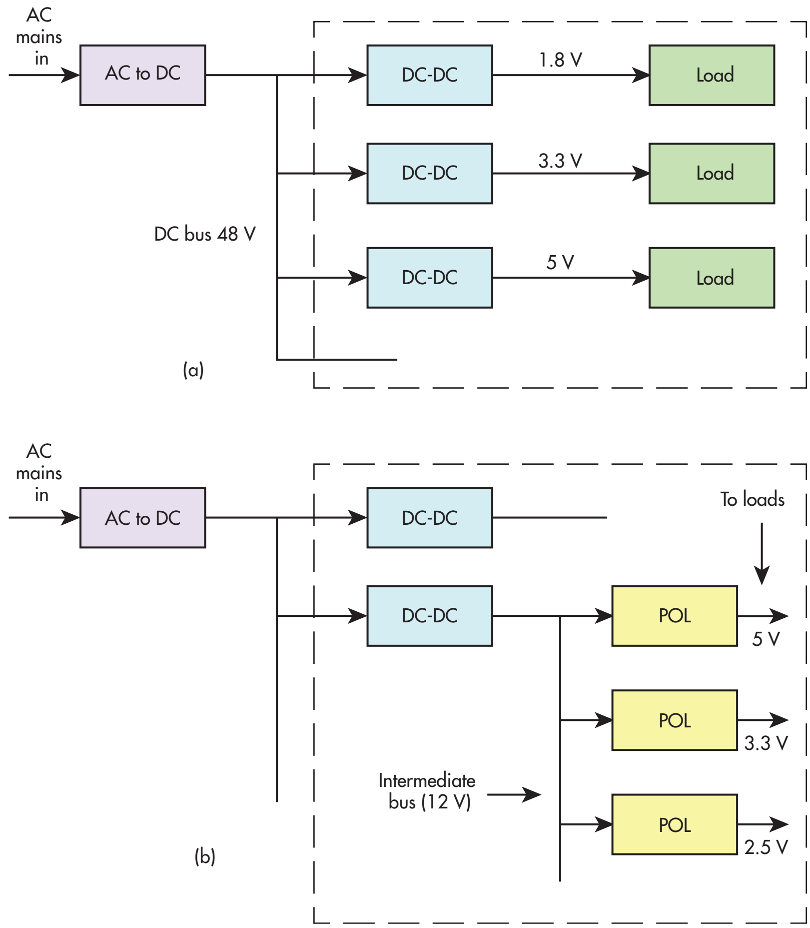
The larger the brick, the greater its power capability. Most standard voltage outputs are available. Technology advances have continuously increased the power density of bricks thanks to more efficient switching components.

(e.g., robots), and forklifts. Data centers are major adopters of 48-V systems. And, of course, automobiles are gradually moving to a 48-V system that will supplement the existing 12-V system.

• *Increased power density:* All designers seem to want the above features in a much smaller package. Increasing the power density is difficult to achieve, though. A common approach is to use higher switching frequencies that decrease inductor and capacitor sizes. Putting all of those components and modules into a smaller space produces thermal problems. Clever mechanical packaging can minimize this problem.

• *Improve reliability:* All of those goals should be achieved, but maintaining or improving the reliability of the equipment is another key challenge for the designer.

A good example of current power-supply design is the rapid and enormous growth of the cloud storage and computing business. This has caused the data centers of the major players (Amazon, IBM, Microsoft, etc.) to add many more rack servers. That increase adds thousands of new servers and in some cases, up to a million servers.



Illustrated are a distributed bus architecture (a) and intermediate bus architecture (b).

Due to that high energy consumption, there's a need to lower electrical service costs as well to reduce the heat level in the data centers and lower air-conditioning costs. Higher efficiency will help control energy costs while smaller packages provide more space in data centers for future expansion.

Some of the other trends and goals are:

• Increased use of wide-bandgap devices like GaN transistors to boost efficiency.
• Improved packaging by way of more 3D designs.
• Increased use of power factor correction (PFC).
• Reduce no-load power consumption.
• Increased use of power management.

Power Management

Power management refers to the use of digital control of dc-dc converters for the purpose of optimizing the power delivery in a product or system and providing protection. Power-management ICs or subsystems regulate, control, and distribute power to the product. Some power-management chips include two or more dc-dc converters and perhaps some LDOs. The converters may also include drivers for using external MOSFET power devices at higher voltages and/or higher currents.

Another feature is the power monitoring and control circuits. These circuits measure and digitize input and output voltages and currents as well as both internal and external temperatures. Other controls may involve the ability to set the output voltage from an external source. Overvoltage and overcurrent detection provide the signals to shut down the device to prevent damage.

Most power-management ICs include a PMBus communications port to provide for external programming as well as monitoring and control functions. The PMBus is a variation of the popular I^2C serial interface.

Some of the most widely used power-management chips are those in cell phones that monitor conditions and provide feedback. Such chips also include a battery charger and other battery-related circuits.

DC-DC Converters for Special Use Cases

An incredible range of applications are possible with dc-dc converters—virtually every electronic product made today has one or more them inside. However, they show up in some very unusual products, equipment, and systems.

One of those special cases is a system that's used to grow coral. A researcher has created a system in which a precise dc voltage between 1.2 and 4 V is applied between two electrodes while the electrodes are immersed in sea water, resulting in the growth of calcium carbonate (limestone). This limestone supports the growth of coral and speeds up the process.

Large systems can be deployed offshore in areas where the coral is depleted fully or partially. Such large-scale systems for offshore deployment need heavy-duty, high-output dc-dc converters. Driven by solar, wind, or wave action, the dc-dc converters will feed high current into the sea water to produce the limestone.

DC-DC Converter Sources

Multiple companies are making an enormous variety of dc-dc converters. One with an extended product line is Vicor. Its BCM, PRM, ZVS, VTM, and other product groups cover an array of converters. Both isolated and non-isolated devices are available in a wide range of input and output voltages and currents as well as power levels.

A special feature of Vicor's new VI Chip PRM dc-dc modules is user-configurable capabilities. In other words, you can take a standard PRM module and quickly customize it to your specific system needs, saving time, money, and resources. Multiple packaging options accommodate your design.

In addition, the company's new line of 48-V converters covers most of the popular output voltages. There's a dc-dc converter for almost any application. Evaluation boards are available for most products; multiple training videos provide guidance; and online design tools help the selection and application process.