Article

Bidirectional bridge converters tackle 12V/48V DC-power transition

VICOR

The $12V_{DC}$ bus has served engineers well for decades, becoming a de facto standard for both battery-based and AC-line designs. This widespread use was largely due to the automobile industry's adoption of the six-cell, 12.6V lead-acid battery in the 1950s, which drove high manufacturing volumes, low costs, and broad availability.

However, system power needs have increased dramatically in the 21st century due to their increasingly ambitious goals. Diverse applications such as industrial installation, robotics, light electric vehicles, self-guided vehicles, solar power systems, and automated test equipment need more power.

As a result, the amount of power that a 12V source can deliver efficiently to loads has reached a practical limit and become unacceptable. Due to higher currents, resistive (IR) losses in cabling result in excessive voltage drop between source and load, while I^2R power dissipation wastes energy and adds to thermal challenges. Both the voltage drop and power dissipation are a consequence of the laws of physics and cannot be avoided.

Until recently, the solution to this dilemma has been to use thicker cables and connectors. However, that approach incurs a high cost with respect to cable weight, routing options, and connectors. Therefore, it is no longer an acceptable approach for many applications.

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In this blog, we outline why transitioning to a 48V power distribution system is more advantageous than redesigning legacy 12V designs to meet the increased power demands of today's electronics. Additionally, we explain how a bidirectional bridge converter solution can help designers tackle the 12V-to-$48V_{DC}$ power transition.

The higher voltage solution

Considering the limitations of upgrading or even redesigning 12V systems, a much better solution is to increase the bus voltage, with 48V as the logical choice for several reasons:

- 48V is a direct 4× multiple of the 12V system, so four batteries can be used in series for applications not powered by the AC line (and even dual-power AC/battery applications);
- 48V-based architecture maximizes power network efficiency while staying well below the safety-limit threshold (typically 60V in most regulatory situations), so no special precautions are needed;
- there are no problems with insulation breakdown or flashover at this relatively modest yet higher voltage; and
- although it exceeds 12V, many semiconductor processes can easily handle this value.

The electrical benefits are clear. At a given power level in an existing cable, the current at 48V is one-quarter that of 12V, so resistive losses are reduced by 75 percent. Alternatively, much thinner cables can be used while keeping losses within acceptable limits. From a power perspective, dissipation in the cabling is reduced to one-sixteenth of the previous value using existing cabling; otherwise, thinner cables can be used while keeping dissipation and self-heating to much lower values.

However, it's not practical to design systems to force a complete switchover to 48V. There are simply too many legacy $12V_{DC}$ sources, loads, and components in place that cannot be abandoned—nor should they. The challenge is to ease the transition and allow legacy 12V busses to be used to create new 48V busses, as well as new 48V electronics to power legacy 12V systems.

In many of these designs, there will be a mix of legacy 12V systems and newer 48V systems requiring high-efficiency, high-density conversion between the two voltages. Fortunately, Vicor offers power modules that bridge 48V and 12V power buses.

Begin with step-down

As more applications adopt 48V bus architectures, Vicor 48V-to-12V DC-DC converters provide a straightforward way to support and interoperate with legacy 12V systems. For example, the 1000W continuous DCM3717 and similar 2000W continuous DCM3735 units operate from a $40V_{DC}$ to $60V_{DC}$ input and generate a regulated 12V output, adjustable from 10V to 12.5V (Figure 1). Up to four of these modules can be connected in parallel to support higher power levels. These non-isolated modules also incorporate a PMBus® interface for control and telemetry.

Figure 1: The 1000W DCM3717 (right) and 2000W DCM3735 (left) are compact, highly efficient 48V-to-12V step-down non-isolated DC-DC converters.

Their sophisticated designs require few external components, enhancing their high board-level power density (Figure 2). Operating at a switching frequency above 1MHz, their peak efficiency of up to 96 percent is a clear indicator of the modest thermal load they impose on the system. These converters can be used independently or with downstream point-of-load (PoL) products to support efficient power distribution networks.

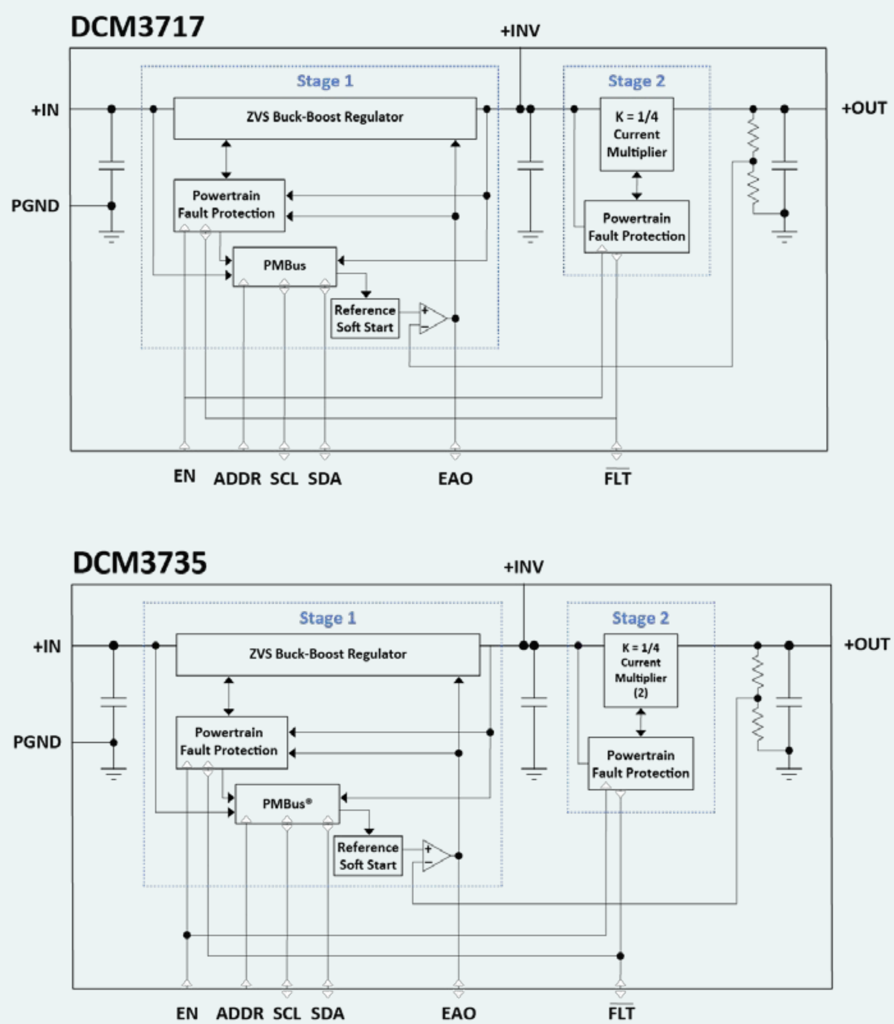

Figure 2: The high level of integration of the DCM3717 and similar DCM3735 minimizes design-in challenges and issues.

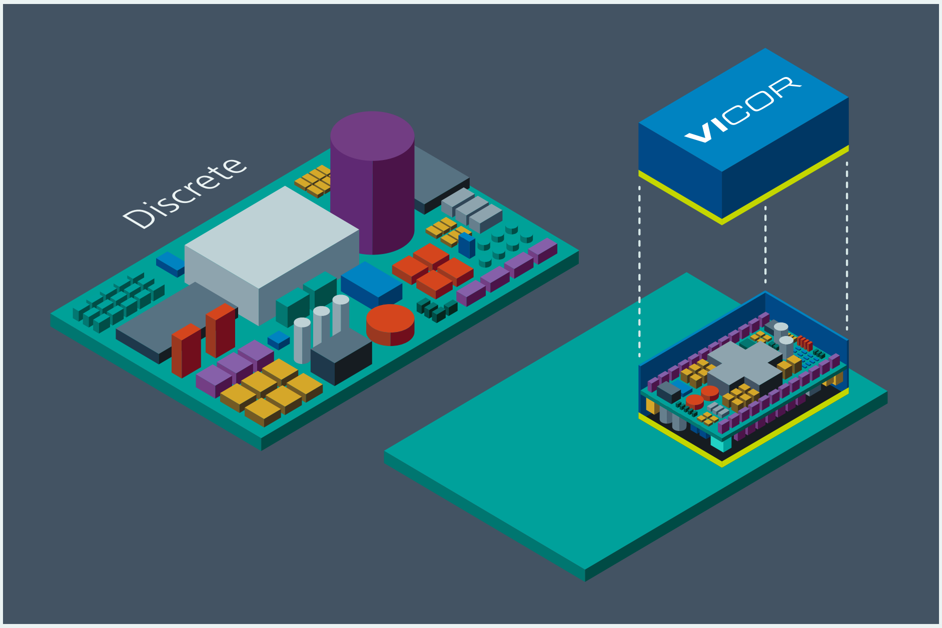

Figure 3: Compared to a discrete approach (left), the SM-ChiP™ implementation (right) results in a far more compact power solution at the board level.

The surface-mount converter housed in package (SM-ChiP™) enclosure with a plated, over molded package results in a converter that is far more compact than a discrete solution (Figure 3). The numbers tell the story: the 1000W DCM3717 is 36.7mm × 17.3mm × 5.2mm, while the 2000W DCM3735 is 36.7mm × 35.4mm × 5.2mm. Despite their small size, these packages offer excellent thermal performance with uniform and predictable heat dissipation, as they provide low thermal impedance to both the top and bottom of the package, facilitating easy thermal management.

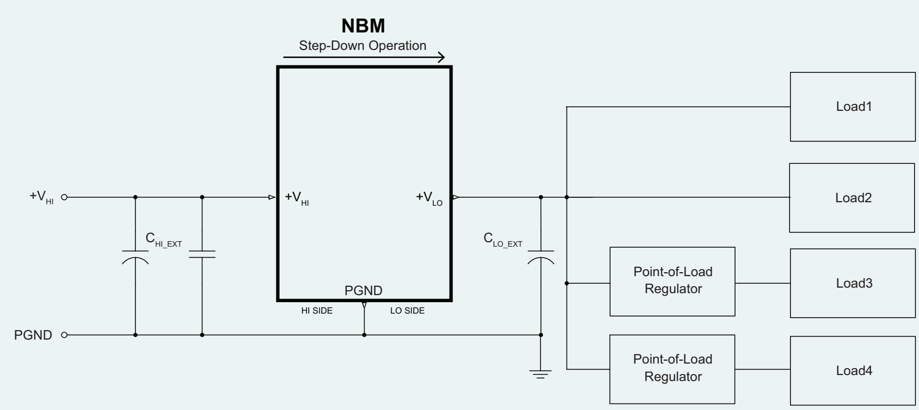

Figure 4: The NBM2317 bidirectional DC-DC converter can be used to step a nominal 48V rail down to 12V to support legacy components.

Add step-up capabilities

To support the complementary step-up path, the Vicor NBM2317, a 1.7MHz bidirectional 12V/48V DC-DC converter, bridges modern and legacy systems for both new and old bus voltages. In step-down mode, it operates from a 40V to 60V high-side voltage bus and delivers a ratiometric low-side voltage between 10V and 15V (Figure 4). In this way, it supports legacy hardware as well as components that are currently available only in 12V versions, of which there are many.

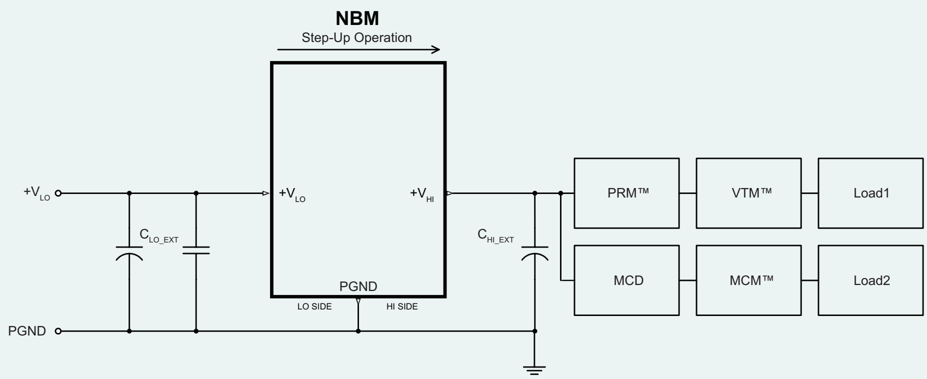

Figure 5: The NBM2317 bidirectional DC-DC converter can also be used to step 12V up to directly supply a 48V rail and other localized DC-DC converters.

The same unit can also be used in step-up mode to create a 48V bus from legacy 12V busses to support new hardware from systems with a lower-voltage bus (Figure 5).

The SM-ChiP™ board-mount packaging enables a high-density, high-efficiency, and low-cost solution to the old or new bus voltage challenge. At just 23mm × 17mm × 5.2mm high, it requires only a fraction of the space occupied by conventional, slower-switching (sub-1MHz) converters.

This non-isolated bridging converter delivers 1000W continuous and 1.5kW peak power, with 97.9 percent peak efficiency at 800W. Its rated output current (step-down operation) is 60A continuous and 100A transient (up to 2ms), while the corresponding values for step-up operation are 15A continuous and 25A transient. Its internal filtering provides a low-noise output without the need for additional components, and it responds to load-side transients in under 1µs, while maintaining its output within a narrow voltage band.

Conclusion

The rationale for transitioning to 48VDC power distribution networks from legacy 12V designs is compelling. Doing so addresses growing issues of efficiency, cable size and management, and losses. At the same time, there are legacy 12V buses that remain in use, as well as 12V loads and components that are not going to be replaced in the foreseeable future. Modules such as the Vicor step-down units and bidirectional step-down converters provide the flexibility needed to handle the possibility of multiple dual bus scenarios.

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