WHITE PAPER

Building a smarter ultra-wide DC-DC converter solution with multiple parts

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Finding DC-DC converters with ultra-wide voltage inputs (>5:1 V_{IN} to V_{OUT} ratio) can present a challenge. Some applications, particularly railway and hold-up power supplies, require input voltage ranges that extend well beyond what most DC-DC converters can accept. DC-DC converters that can cover the ultra-wide input range often have several significant drawbacks. Ultra-wide input DC-DC converters require MOSFETs rated for higher voltages, which have inherently higher resistance and will dissipate much more power when the converter is running at low input voltages and higher input currents. The result is a lower current rating for the DC-DC converter which results in lower power density and ultimately a higher cost per watt.

Typical Downsides of Ultra-Wide Input Voltage Range DC-DC Converters:

- Lower efficiency
- Lower power density
- Higher cost

Why use two converters to span the input voltage range?

When a single wide-input-range DC-DC converter results in unacceptable performance and cost, a combination of two or more DC-DC converters with overlapping input voltage ranges may be an effective alternative. Combinations of DC-DC converters with narrower but complementary input voltage ranges will typically operate at higher efficiencies and higher power densities allowing the total design to be smaller, more efficient and less costly than a single-converter solution.

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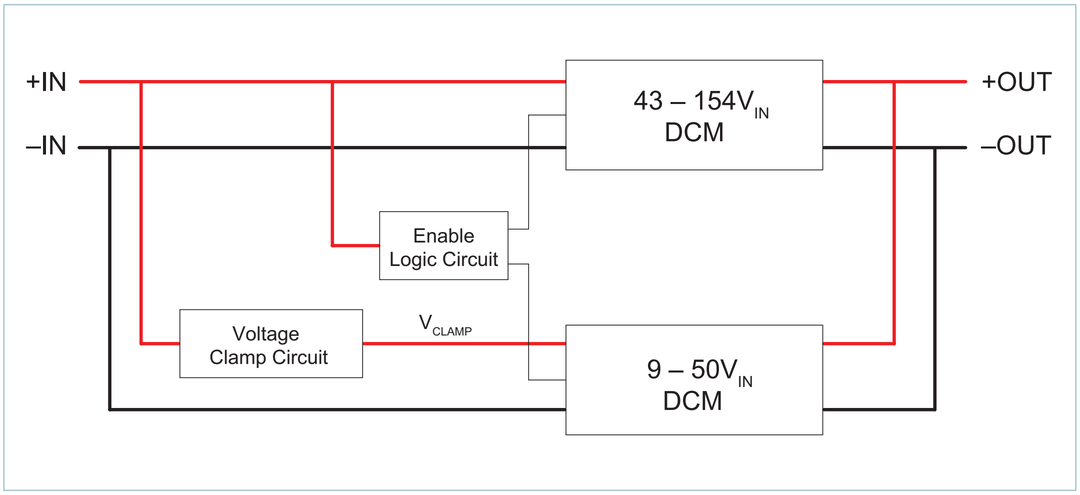
Figure 1 is an example block diagram of a Vicor 9 – 50V_{IN} DCM™ converter paired with a 43 – 154V_{IN} DCM converter to create an ultra-wide-input DC-DC converter with an input voltage range of 9 – 154V. Because both the 9 – 50V_{IN} and the 43 – 154V_{IN} DCM converters are extremely power dense, a combination of the two provides a solution that has a smaller footprint than a single half-brick converter with a similar input voltage range.

1.524 x 0.898 x 0.284in [38.72 x 22.8 x 7.21mm]

Figure 1
Block diagram of ultra-wide-input power supply



In addition to the advantage of board space savings, consider the power and efficiency improvements of using two complementary DCM™ products. A competing off-the-shelf half-brick solution with a 12 – 155V_{IN} range is capable of providing only 100W at 12V with peak efficiency of 85%. In contrast, the two-DCM converter solution delivers a 9 – 154V_{IN} range and is capable of providing 160W at 12V with peak efficiency of 91.5%.

Table 1
Comparing one vs. two DC-DC Converters

Power Supply	V_{IN}	P_{OUT}	V_{OUT}	Efficiency
1 Half-Brick	12 – 155V	100W	12V	85%
2 DC-DC Converters	9 – 154V	160W	12V	91.5%

Using three converters in applications that require hold-up power

Another application that can benefit from using overlapping DCMs is an ultra-wide-range power supply requiring hold up. Instead of a single wide-input-range discrete-converter approach, which is bulky and low-efficiency (70 – 75%), a three-DCM solution offers significantly better efficiency and a small form-factor.

Take, for example, a 400V input with a large hold-up capacitor and a 48V output. Three converters (a 16 – 50V_{IN}, a 43 – 150V_{IN}, and a 120 – 420V_{IN} DCM) will allow the hold-up capacitor to discharge down as far as 16V and still provide 48V to the load. During normal operation, the 120 – 420V_{IN} DCM will supply the load current while the 16 – 50V_{IN} and 43 – 154V_{IN} DCMs will be disabled. But during loss of input power, the hold-up capacitor will supply power to each of the high-efficiency (85 – 90%) DCMs in succession as it discharges.

Figure 2
Three Vicor DC-DC Converters

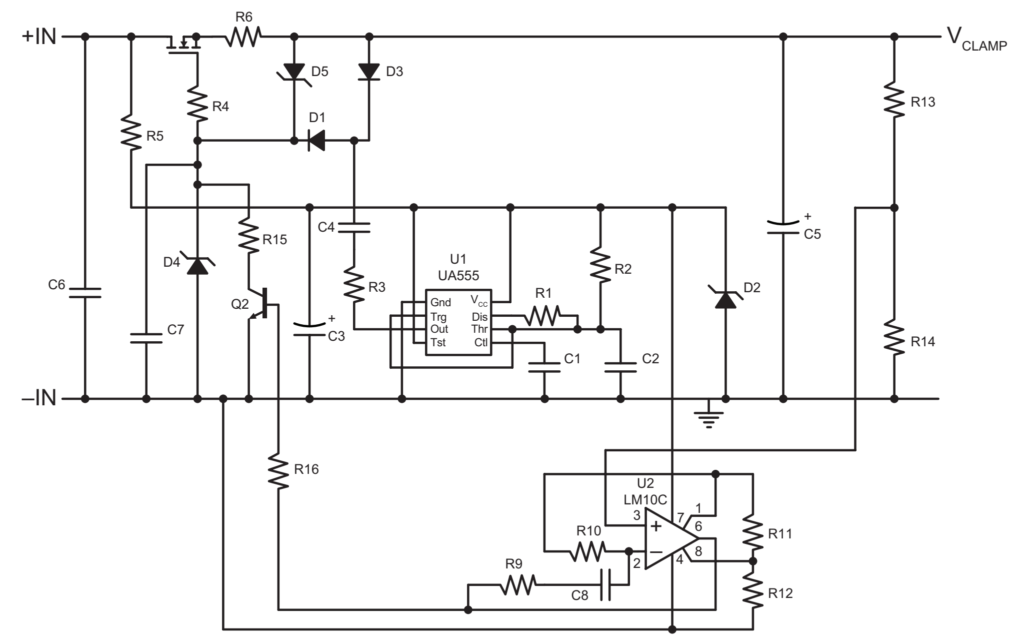
Part Number	Vin (V)	Vout (V)	Power (W)	Package
DCM3623x50M53C2y0z »	28.0 (16.0 - 50.0)	48.0 (28.8 - 52.8)	320.0	3623 ChiP
DCM3623xA5N53B4y0z »	100.0 (43.0 - 154.0)	48.0 (28.8 - 52.8)	240.0	3623 ChiP
DCM4623xD2N53C8y0z »	275.0 (120.0 - 420.0)	48.0 (28.8 - 52.8)	375.0	4623 ChiP

Design considerations

Voltage clamp circuit

In order to prevent the input voltage from damaging the low-voltage DCM™, a voltage-clamping circuit is required (reference Figure 3). [More information about this circuit can be found in application note AN:214 Meeting Transient Specifications for Electrical Systems in Military Vehicles]. This reference circuit will clamp the voltage to a level below the maximum operating voltage of the low-voltage DCM and above the minimum operating voltage of the high-voltage DCM.

Figure 3
Example of a voltage-clamping circuit



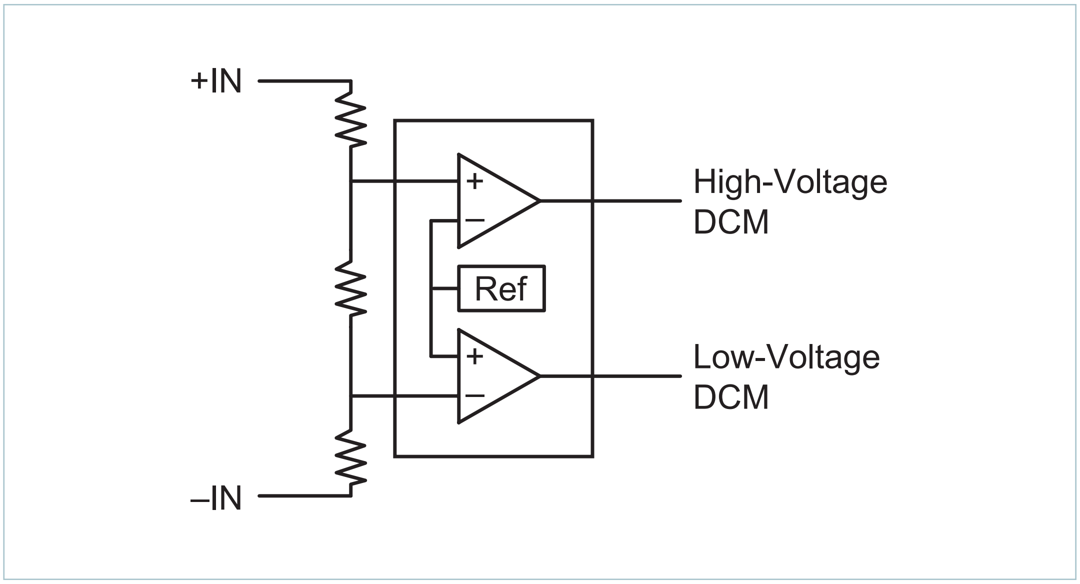
In the case of the hold-up power application, the two lower input voltage DCMs will each require their own voltage clamp circuit and the enable circuit will require three comparators instead of two.

Enable the correct converter for the input voltage

To reduce no-load power consumption and power dissipation in the voltage-clamp circuit MOSFET it is necessary to use circuitry to enable the DCMs separately based on the input voltage. This circuitry can be as simple as comparators with internal references (see Figure 4), or as complex as a circuit with a microcontroller. Enabling and disabling of the DCMs must be accomplished in the overlap range, which is 43 – 50V (Figure 1). The 43 – 154V_{IN} DCM is enabled when the input voltage is above 44V and the 9 – 50V_{IN} DCM must be disabled before the voltage clamp circuit is active. In this example the clamp voltage is 49V; as a result, the 9 – 50V_{IN} DCM should be disabled when the input voltage is above 46.5V.

In designing the system ensure that the disable voltage level is not set higher than the voltage clamp level, after accounting for component tolerances. In addition, the MOSFET in the clamp circuit should be adequately sized to handle the voltage drop across the MOSFET (V_{IN_MAX} – V_{CLAMP}), the current through the MOSFET, and the quiescent current of the disabled 9 – 50V_{IN} DCM.

Figure 4
Example of an enable logic circuit



Switching between converters as the input voltage range changes

There are a few more considerations when using this approach. Depending on the input voltage slew rate and the enable control method used, there may be a short period of time between disable of the low-voltage DCM™ and enable of the high-voltage DCM. The output capacitors of both the 9 – 50V_{IN} and the 43 – 154V_{IN} DCMs must be sized correctly in order to supply the appropriate load current during this brief period. In addition, it is important to have 100ms between disabling a DCM and re-enabling the same DCM to guarantee a predictable soft start. To optimize performance, the input voltage should monotonically rise or decay through the overlap region. Finally, if there is a voltage range where both DCMs are enabled, trim the voltage higher on whichever of the DCMs will be providing the load current during this region of operation.

Don’t settle for average performance

In applications that require ultra-wide-voltage input ranges, using a single DC-DC converter often forces a power system designer to accept significant reductions in available power, power density and system efficiency, while increasing overall system cost. Leveraging the efficiency, power density, ease-of-use and wide variety of Vicor DCM DC-DC converters, it is possible to create a smaller, more efficient and potentially less costly solutions.

References:

AN:214 Meeting Transient Specifications for Electrical Systems in Military Vehicles

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