Electronic Design

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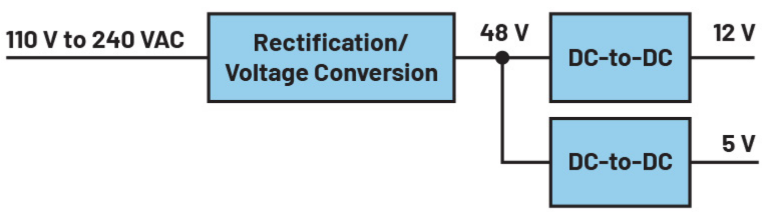
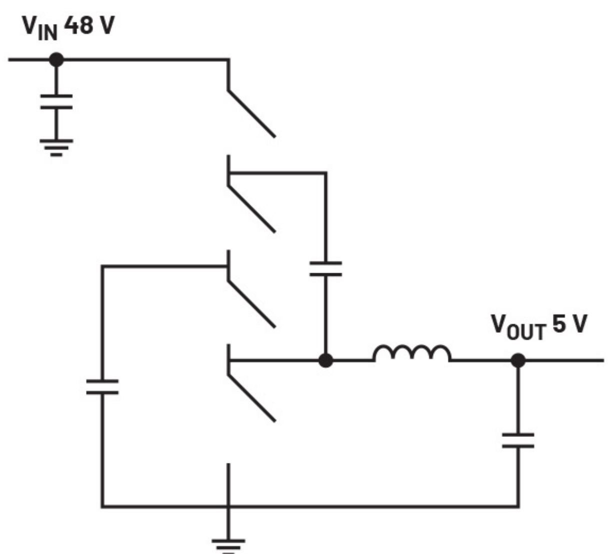
Efficient Power Conversion from an Intermediate Voltage Rail

A hybrid DC-DC converter topology boosts efficiency by combining a buck regulator and a charge pump. Is it the future of intermediate bus conversion?

Different types of switch-mode power-supply topologies can convert an intermediate voltage rail into lower voltages used to power the various loads in a system. If the intermediate voltage is relatively high, e.g., 48 V, and the output voltage needs to be relatively low, e.g., 12 V or even 5 V, existing intermediate bus converter (IBC) topologies can be less than ideal. However, new innovations such as "hybrid converter" architectures may be able to offer higher conversion efficiency than simple heritage buck regulators.



1. A power-supply architecture featuring a DC-link voltage of 48 V. (Credit: Analog Devices)



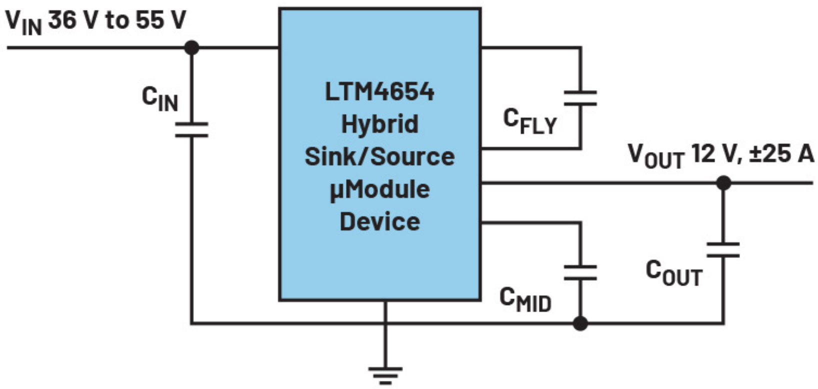
2. A hybrid converter replaces the transformer with a charge pump. (Credit: Analog Devices)

The Challenges of High Step-Down DC-DC Conversion in 48-V Systems

DC-link voltages are employed in many systems. Often these voltages are 24 V, as in the industrial sector, or 48 V, as in the automotive sector. Modern data-center power architectures also use 48 V and, in some cases, 52 V, though several companies are upgrading to bus voltages as high as 800 V to help distribute power to AI server racks more efficiently. Different voltage-converter topologies can be utilized to step down the DC-link voltage to 12 V or 5 V.

Using the buck control concept to convert voltages from high to low is a common approach as long as no galvanic isolation is required for protection against electric shock or other reasons. However, a buck regulator tends to be only moderately efficient when converting a high DC-link voltage, such as 48 V, down to a low output voltage of 12 V or 5 V. As depicted in *Figure 1*, this is due to the necessary operation at a low duty cycle of 9.6%.

With a transformer-based architecture, such as a push-pull or forward converter, the duty cycle can be adjusted by the winding ratio of the transformer. That allows the conversion to take place more efficiently. The drawback, however, is that the transformer itself introduces additional power



3. A highly integrated hybrid µModule regulator in a bus converter application. (Credit: Analog Devices)

losses. Therefore, it's often preferable to eliminate the transformer altogether, particularly in applications that don't require galvanic isolation.

The Hybrid Converter Topology: Combining a Charge Pump and a Buck Regulator

One of the potential solutions to this dilemma lies in the concept of the hybrid converter. This innovative approach to power conversion connects a charge pump topology to a step-down buck regulator. The converter uses a total of four switches that are used to halve a supply voltage with charge pump action. In addition, the lower two switches are used together with an inductor to convert the halved supply voltage to the desired output voltage. *Figure 2* outlines the hybrid voltage converter at a circuit level.

As highlighted in *Figure 2*, the hybrid converter topology combines a charge pump with a step-down power regulator. The building blocks of the power converter can be assembled with a hybrid controller IC, such as the LTC7821.

For a very compact solution, the LTM4654 is a complete hybrid-topology step-down DC-DC power module that belongs to the µModule family from Analog Devices. The solution, the power MOSFETs, the switching controller IC, and the other major building blocks of a bus converter, can step down DC-link voltages as high as 55 V to lower, adjustable voltages of, for instance, 5 or 12 V. The converted power can be up to 300 W continuously.

The power inductor resides on the top of the package so that heat can be dissipated up-and-out of the power module and away from the circuit board. Only flying (charge pump) capacitors, bulk input and output bypass capacitors, and several other passive components for configurations are needed. *Figure 3* shows a solution with the highly integrated LTM4654. It requires very few external components and allows for a conversion efficiency of 96.7% at a conversion of 48-V input voltage to 9-V output voltage at a 15-A load current.

In addition to pure voltage conversion, the module can be used both as a current source and as a current sink. This output source/sink switching mode means that bidirectional operation can take place to work with energy efficiently in a system. The LTM4654 could also be utilized in the negative voltage range to convert, for example, +30 V down to –7 V. This conversion occurs much like a buck regulator in the inverting buck-boost mode.

Furthermore, it's possible to operate several of these hybrid converters in parallel. With two converters, twice the current and thus twice the power can be converted.

The "Hybrid" Future of High-Efficiency Non-Isolated Bus Converters?

For efficient voltage conversion, the usual circuit topologies, such as buck converter or various transformer-based solutions, aren't the only options. Innovative, new solutions such as hybrid converters offer important advantages. These create higher efficiency, especially in bus converters in a range of applications, and they require little space on a circuit board.