

72V Hybrid DC/DC Reduces Intermediate Bus Converter Size by Up to 50%

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Until now, most intermediate bus converters (IBCs) needed to provide isolation from input to output with the use of a bulky power transformer. IBCs are commonly used in datacom, telecom and medical distributed power architectures, and are available in the industry standard 1/16th, 1/8th and 1/4 brick footprints. A typical IBC has a nominal input voltage of 48V or 54V and produces a lower intermediate voltage between 5V to 12V with an output power from about 50 watts to several hundred watts.

However, in many new applications, called “48V Direct,” isolation is not necessary in the IBC since the upstream 48V or 54V input is already isolated from the hazardous AC mains. In many applications, a hot swap front end device is required to use a nonisolated IBC. As a result, nonisolated IBCs are being designed into many new applications, which significantly

reduce the solution size and cost while also increasing the operating efficiency and providing design flexibility. A typical distributed power architecture is shown in Figure 1.

Now that nonisolated conversion is allowed in some distributed power architectures, one could consider using the single stage buck

converter for this application. It would need to operate over an input voltage range from 36V to 72V and produce a 5V to 12V output voltage. The LTC3891 from Analog Devices can be used for this approach and provides an efficiency of about 97% when operating at a relatively low 150kHz switching frequency. When operating the LTC3891 at higher frequencies results in a lower efficiency due to the MOSFET switching losses that occur with the relative high 48V input voltage.

A New Approach

An innovative approach combines a switched capacitor converter with a synchronous buck. The switched capacitor circuit reduces the input voltage by a factor of two and then feeds into the synchronous buck. This technique of reducing the input voltage in half and then bucking down to the desired output voltage results in a higher efficiency or a much smaller solution size by operating at a much higher switching frequency. Other benefits include lower switching losses and reduced MOSFET voltage stress due the inherent soft-switching characteristic of the switched capacitor front-end converter resulting in lower EMI. Figure 2 shows how this combination has formed the hybrid step-down synchronous controller.

New High Efficiency Converter

The LTC7821 merges a switched capacitor circuit with a synchronous step-down converter, enabling up to a 50% reduction in DC/DC converter solution size compared to traditional buck converter alternatives. This improvement is enabled by a 3X higher switching frequency without compromising efficiency. Alternatively,

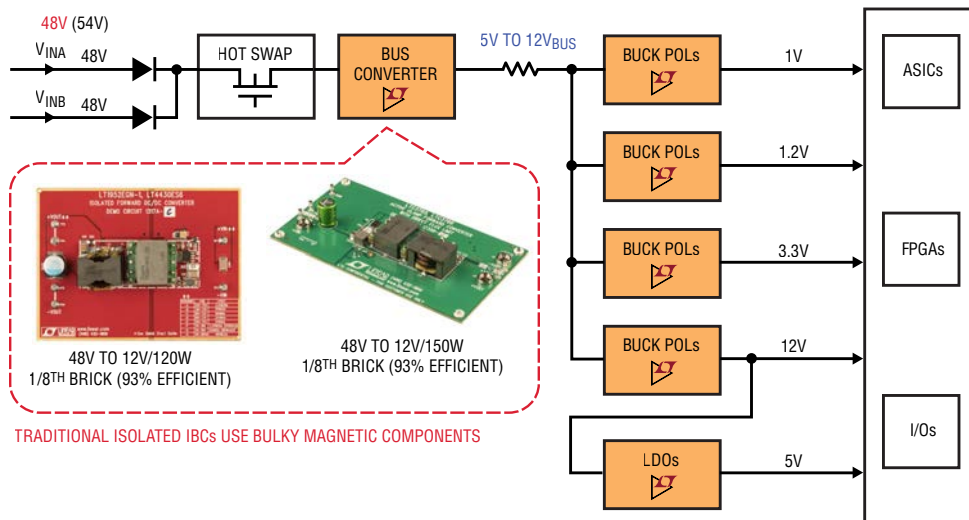


Figure 1. Typical Distributed Power Architecture

when operating at the same frequency, an LTC7821 based solution can provide up to a 3% higher efficiency. Other benefits include low EMI emissions due to a soft-switched front end ideal for the next generation of non-isolated intermediate bus applications in power distribution, datacom and telecom as well as emerging 48V automotive systems.

The LTC7821 operates over a 10V to 72V (80V abs max) input voltage range and can produce output currents in multiple 10s of amps, depending on the choice of external components. External MOSFETs switch at a fixed frequency, programmable from 200kHz to 1.5MHz. In a typical 48V to 12V/20A application, an efficiency of 97% is attainable with the LTC7821 switching at 500kHz. The same efficiency can only be achieved in a traditional synchronous step-down converter by switching at one-third the operating frequency, forcing the use of much larger magnetics and output filter components. The LTC7821's powerful 1 Ω N-channel MOSFET gate drivers maximize efficiency and can drive multiple MOSFETs in parallel for higher power applications. Due to its current mode control architecture, multiple LTC7821's can be operated in a parallel, multiphase configuration with excellent current sharing and low output voltage ripple to enable much higher power applications without hot spots.

The LTC7821 implements many protection features for robust performance in a wide range of applications. A LTC7821 based design also eliminates the inrush current typically associated with switched capacitor circuits by prebalancing the capacitors on start-up. The LTC7821 also monitors the system voltage, current and temperature for faults and uses a sense resistor for overcurrent protection. It stops switching and pulls the $\overline{\text{FAULT}}$ pin low when a fault condition occurs. An onboard timer can be set for appropriate restart/retry times. It's EXTV_{CC} pin permits the LTC7821 to be powered from the lower voltage output of the converter or other available sources up to 40V, reducing power dissipation and improving efficiency. Additional features include $\pm 1\%$ output voltage accuracy over temperature, a clock output for multiphase operation, a power good output signal, short-circuit protection, monotonic output voltage start-up, optional external reference, undervoltage lockout and internal charge balance circuitry. Figure 3 shows the schematic of the LTC7821 when converting a 36V to 72V input to a 12V/20A output.

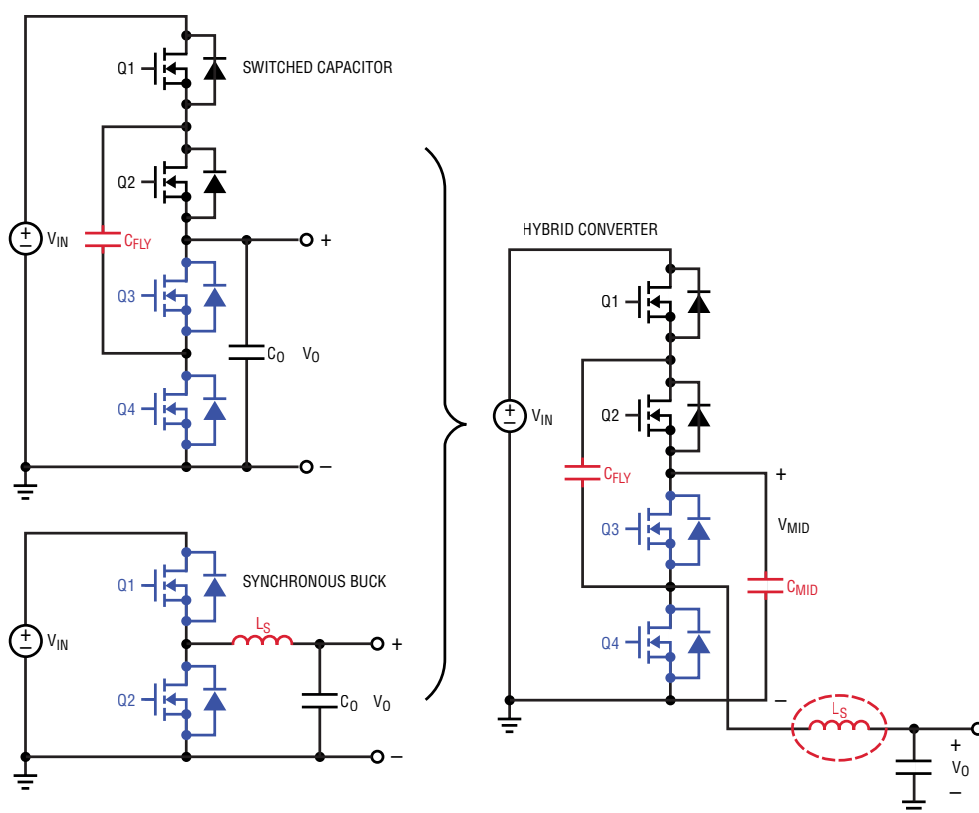


Figure 2. Switched Capacitor + Synchronous Buck = LTC7821 Hybrid Converter

The efficiency curves shown in Figure 4 represent a comparison of three different converter types for the application that converts a 48V_{IN} to a 12V_{OUT} at 20A as follows:

1. A single stage buck running at 125kHz with a 6V gate drive (blue curve)
2. A single stage buck running at 200kHz with a 9V gate drive (red curve)
3. The LTC7821 hybrid running at 500kHz with a 6V gate drive (green curve)

A LTC7821 based circuit running at up to three times the operating frequency of the other converters has the same efficiency as the other solutions. This higher operating frequency results in a 56% reduction of the inductor size and up to a 50% reduction to the total solution size.

Capacitor Prebalancing

A switched capacitor converter usually has a very high inrush current when the input voltage is applied or when the converter is enabled, resulting in the possibility of supply damage. The LTC7821 has a proprietary scheme to precharge all switching capacitors before the converter PWM signal is enabled. Therefore, the inrush current during power-up is minimized. In addition, the LTC7821 also

has a programmable fault protect window to further ensure reliable operation of the power converter. These features result in the output voltage have a smooth soft-start just like any other conventional current mode buck converter. See the LTC7821 data sheet for additional details.

Main Control Loop

Once the capacitor balancing phase is completed, normal operation begins. MOSFETs M1 and M3 are turned ON when the clock sets the RS latch, and turned off when the main current comparator, ICMP, resets the RS latch. MOSFETs M2 and M4 are then turned on. The peak inductor current at which ICMP resets the RS latch is controlled by the voltage on the I_{TH} pin, which is the output of the error amplifier EA. The V_{FB} pin receives the voltage feedback signal, which is compared to the internal reference voltage by the EA. When the load current increases, it causes a slight decrease in V_{FB} relative to the 0.8V reference, which in turn causes the I_{TH} voltage to increase until the average inductor current matches the new load current. After MOSFETs M1 and M3 have turned off, MOSFETs M2 and M4 are turned on until the beginning of the next cycle. During the switching of M1/M3 and M2/M4, capacitor C_{FLY} is alternately connected in series with

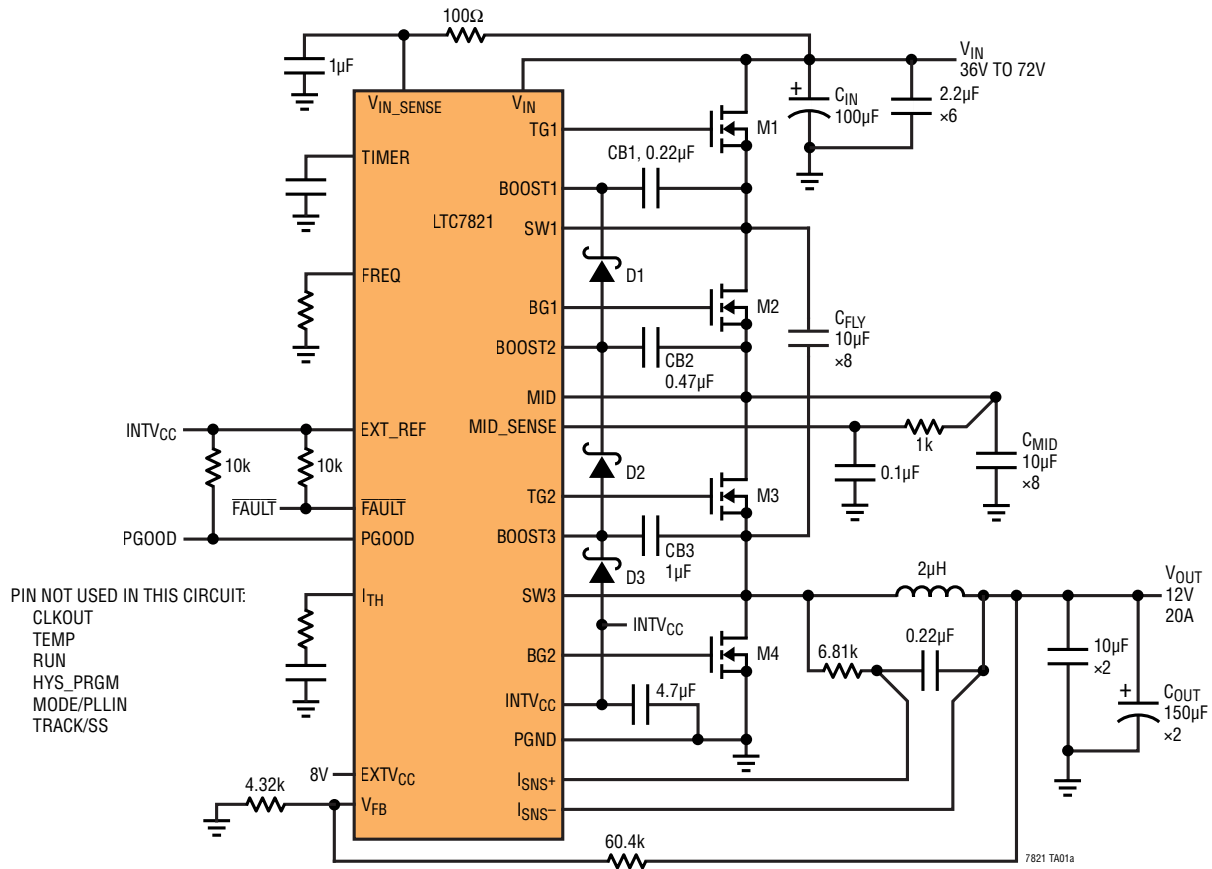


Figure 3. LTC7821 Schematic, 36V_{IN} to 72V_{IN}/12V/20A Output

or parallel to C_{MID}. The voltage at MID will be approximately at V_{IN}/2. So, this converter just operates like a conventional current mode buck converter with fast and accurate cycle-by-cycle current limit and option for current sharing.

Conclusion

The combination of a switched capacitor circuit to halve the input voltage followed by a synchronous step-down converter (hybrid converter) provides up to a 50% reduction in DC/DC converter solution size compared to traditional buck converter alternatives. This improvement is enabled by a 3X higher switching frequency without compromising efficiency. Alternatively, the converter can operate with 3% higher efficiency in a footprint comparable to existing solutions. This new hybrid converter architecture also provides other benefits that include soft switching for reduced EMI and MOSFET stress. Multiple converters can be easily paralleled with active accurate current sharing when higher power is needed.

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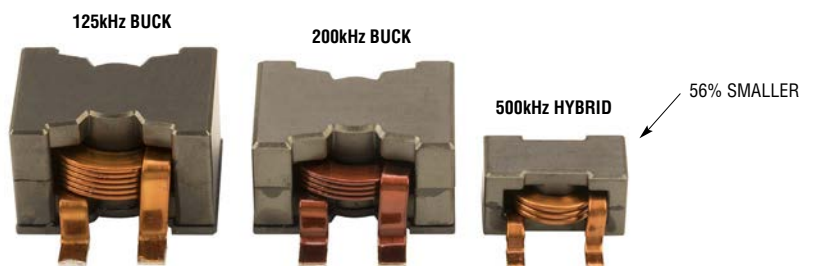
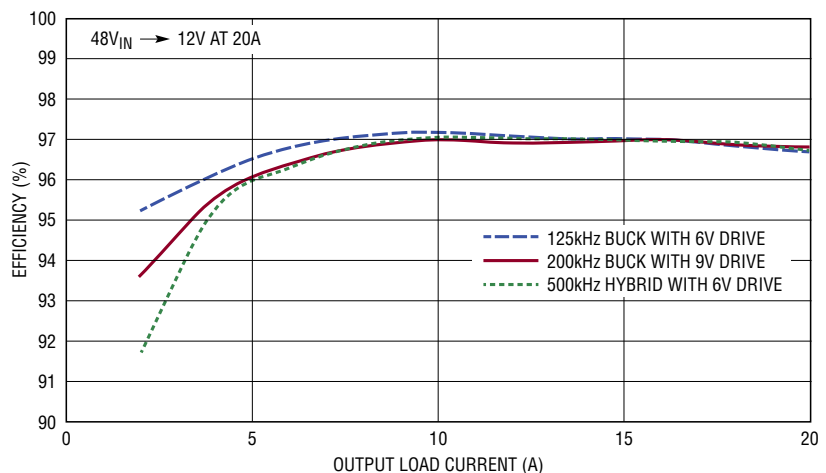


Figure 4. Efficiency Comparison and Transformer Size Reduction