Bulk Capacitor Optimization for Offline Power Supplies Using Galium Nitride-IC

The adoption of USBPD 3.0 and Type-C connectors is expected to standardize power adaptors across previously segmented electronic markets. Gone are the days when travelers needed to carry separate adaptors for their laptops and cell phones. Aftermarket adaptor manufacturers are focusing their efforts on servicing this new market opportunity.

The need for high efficiency, cost-effective solutions for higher power density has never been greater.

By Chris Lee, Product Manager, Power Integrations

Adaptors rated at under 75W can be broken down into: input filter, diode rectifier, input and output capacitors, IC controller, auxiliary power supply, magnetics, power devices and heatsinks. Integrated solutions have come a long way in shrinking and simplifying converters to the point where the largest remaining components are the magnetics, the input 'bulk' capacitors, output capacitors, and the EMI input stage. Significant research and engineering effort has been focused on high frequency AC/DC converter design to reduce the size of the magnetics. However, the input bulk capacitor occupies the same or greater volume as the magnetics within an adaptor.

A new IC from Power Integrations, MinE-CAP, has been designed to address input bulk cap optimization for universal input designs. Using Power Integrations' PowiGaN gallium nitride technology, MinE-CAP safely enables the use of 160 V rated capacitors for universal input designs, reducing bulk capacitor volume by up to 50%.

MinE-CAP is a low impedance switching circuit positioned in series with the low-voltage capacitor (CLV in Figure 1). It monitors the voltage across CLV and connects and disconnects the capacitor as the input line voltage increases/decreases around a threshold. The MinE-CAP circuitry can be paired with a high frequency power conversion stage to maximize space savings.

System Considerations

The rule of thumb for universal power adaptors is that the value of the DC bus capacitance, in µF, is chosen to be 1.5 to 2 times the output power requirement, in watts, when the design considerations is as low as 90 VAC. For high-line-only applications, the total capacitance can be reduced significantly. With this key concept in mind, MinE-CAP enables designers to significantly reduce the input bulk capacitor size. The figure below shows a schematic layout for a typical MinE-CAP application.

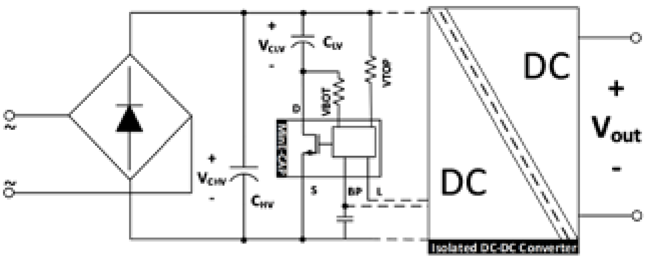

Figure 1: Typical MinE-CAP application

CHV is a high voltage capacitor (rated at 400 V) that typically accounts for around 20% of the total capacitance. CLV is a low voltage capacitor (160 V) that accounts for about 80% of the total capacitance. This split in capacitance enables the capacitor volume to be reduced by up to 50%, leading to an overall reduction in adaptor size of up to 40%.

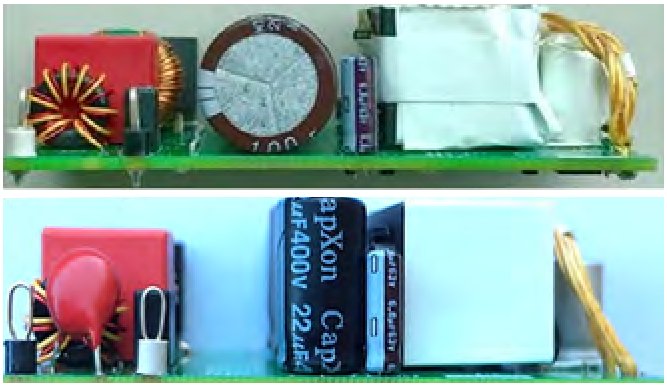

Figure 2: First level optimization of 65 W adaptor

In Figure 2, the top image is a typical 65 W adaptor that requires a single 400 V, 100 µF capacitor. The bottom image shows the space savings achieved by using MinE-CAP in the exact same 65 W adaptor design. The total input capacitance is split into two 160 V, 47 µF capacitors and one 400 V, 22 µF capacitor. The total capacitance is therefore actually increased by 16% while, at the same time, the bulk capacitor volume is reduced by 40%.

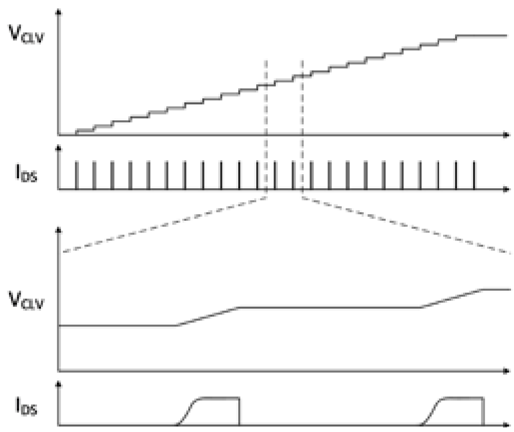

Figure 3: Charging algorithm used for low-Line start-up

Typical Applications

Designers can take existing designs and modify the input bulk capacitor stage to decrease the space occupied by the input stage. This allows them to shrink the enclosure or, conversely, they can add more capacitance in the same enclosure and increase the power.

Another design usage for MinE-CAP is in applications that require peak power delivery. Increasingly, on-board protocol chips are in bidirectional communication with the device being charged. These chips typically monitor and report adaptor temperature, faults and power delivery capabilities. Designers are taking advantage of this bidirectional communication to provide 1.5 to 2 times the nameplate power. These peak power algorithms significantly reduce charging times. However, input bulk capacitance limits the peak power delivery capabilities. With MinE-CAP, the input bulk capacitance can be increased significantly using the same space. This enables prolonged peak power delivery even at low line.

MinE-CAP Basics

MinE-CAP operates by precisely charging and monitoring the voltage across CLV, only introducing this capacitor into the circuit at low AC line when maximum input capacitance is required. MinE-CAP is designed to engage and disengage CLV dynamically during every line AC cycle, as required. The power supply therefore operates smoothly across the entire specified input voltage range. For the design referenced in Figure 2, effective low-line total bulk capacitance is 116 µF while the effective high-line bulk capacitance is 22 µF.

When the system is in high-line, the MinE-CAP measures the differential voltage across CLV via VTOP and VBOT. It regulates the voltage on CLV to support power delivery in the event of a line or load step.

MinE-CAP Start-up

Traditionally, at start-up the inrush current into the bulk capacitors can affect the reliability of the fuse, bridge rectifier and capacitor, as this current is only limited by the line impedance and input filters. As the adaptor power rating increases, the inrush current increases, often requiring the use of an NTC thermistor to protect the fuse and diode bridge. However, the NTC thermistor reduces the overall efficiency of the system and adds a hotspot to the input stage. Therefore, the fuse and diode bridges are often oversized and the thermistor is undersized to limit its impact on system efficiency.

In a MinE-CAP design, 80% of the bulk capacitance is disengaged from the application at start-up. In low-line start-up conditions (V_{IN} < 150 VAC), MinE-CAP performs precisely controlled active charging of C_{LV}. At the low-line start-up condition, it is important to pre-charge C_{LV} to support full power capability prior to enabling the DC/DC converter. The MinE-CAP IC configures the internal high-voltage switch as a current source, to provide precise, constant current, pulse-charging of C_{LV}, see Figure 3. This approach allows fast charging of C_{LV} and ensures the power supply is ready to deliver full power in less than 250 milliseconds from the initial AC line connection. This controlled charging of the C_{LV} allows MinE-CAP designs to eliminate the inrush NTC thermistor, improving the overall system design by removing a thermal hotspot and increasing conversion efficiency.

For high-line applications (V_{IN} > 150 VAC), C_{HV} alone supports the full power delivery. MinE-CAP performs a slow charge-up of C_{LV} and regulates the voltage below the capacitor rated voltage. This improves hold-up time of the power supply due to line drop-out.

Protection Features

In addition to the precision start-up algorithm, MinE-CAP integrates a suite of protection features including over-temperature, pin open/short fault detection, and surge protection. In the event of a fault, MinE-CAP disengages C_{LV} from the system. To prevent further system damage, MinE-CAP communicates the fault information to the power conversion stage via the L-pin. This multipurpose pin is also used to communicate the DC bus voltage information to the power supply controller IC during normal operating conditions.

Summary

The GaN-powered MinE-CAP enables the use of 160 V rated capacitors in universal input designs that are normally restricted to only 400V rated capacitors, resulting in space savings equivalent to those achieved by adopting higher switching frequencies. The precision start-up algorithm eliminates the need for an NTC thermistor without impacting the end user experience. The DC bus voltage and fault information is communicated to the DC/DC converter via the L-pin. Pairing MinE-CAP with the InnoSwitch IC family maximizes integration, minimizes component count, simplifies layout and optimizes power supply size.

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