Expert View

by Stephen J. Allen

Capacitive-Based Power Architectures Gain Ground

In traditional single-stage power architecture, the inductor typically dominates the bill of materials, often occupying 50% of the total circuit area and dictating the solution height and footprint. Given that inductor size is dictated by switching frequency, most of the power industry has been focused on pushing switching frequencies higher and exploring alternative FET technologies such as gallium nitride (GaN) that promise much lower figures of merit (FOM). However, while GaN has made substantial inroads to high-voltage applications such as off-line ac-dc inverters, it has yet to show any substantial performance improvements in low-voltage (< 60-V) applications. This market area is dominated with requirements for nonisolated bucks to provide output voltages below 1 V, with currents of 100 A or more, and where space is critical.

Many challenges must be resolved before GaN becomes mainstream in low-voltage applications. These include a lack of inductors suited to 10 MHz and above, how to resolve electromagnetic interference (EMI) issues that surface above 5 MHz in nonisolated applications, and the cost of GaN devices. GaN also competes against extremely good silicon MOSFET transistors today that deliver very low FOMs and are combined with advanced packaging technology to decrease conduction losses and increase conversion efficiency.

How can we disrupt this current market dynamic? Inductors are about 60 times less efficient from an energy storage density perspective compared to capacitors. Essentially, an inductor doing the same work as a capacitor needs to be about 60 times larger by volume. If capacitors can be used to do most of the work, the problem can be solved another way, using off-the-shelf passive components and staying with standard CMOS.

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Toward that goal, Murata has developed an innovative hybrid architecture comprising a novel phase-interleaved charge pump coupled with either a buck or boost stage with all switches and control in a single monolithic CMOS die. In its simplest form, this architecture breaks down voltage transformation into many small voltage steps between input and output using capacitors to do the work, rather than the traditional single-step transformation across an inductor.

This architecture flips "on its head" the whole concept of power conversion. In a traditional single-stage buck or boost, the main switching FETs are rated to hold off the maximum voltage seen in the circuit. In contrast, the hybrid architecture uses capacitors to hold off voltage, and the FETs only see a much lower voltage at each stage in the power transformation. These low-voltage FETs have a significantly better FOM with lower gate capacitance and lower switching losses. For a 12-V point-of-load (POL) buck, the company uses standard 5-V or 3-V CMOS FETs available as library elements within a standard CMOS process. This approach compares with typical 20-V-rated FETs used in a single-stage architecture, allowing the maker's hybrid buck to run at three or four times higher switching frequency with the same efficiency as a single-stage buck, achieving commensurately better light load efficiency and helping to reduce the inductor size.

Furthermore, since the charge pump does most of the work, the inductive stage is presented with a much higher duty cycle, which in turn reduces the amount of inductance required. The duty cycle in Murata's solution is typically three to four times lower than a standard buck, which also makes the buck stage much more suited to multiple-phase output, because more time is available for control.

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What is the result of all this complexity? It means dramatically smaller inductors are needed. For example, at 6 A, we need 3.2 × 2.5 × 1.2 mm chip inductors in place of 4 × 4 × 2.5 mm wire-wound inductors, thus halving the space occupied by the inductors, and with the lower profile, making the whole powertrain much easier to assemble in an advanced 3D semiconductor packaging process. As a result, combining this unique circuit architecture with in-house 3D packaging technology and passive components, Murata is now bringing to market products that are typically one-half the footprint and two-thirds the height. These products demonstrate higher efficiency (typically 95%), lower EMI (typically 10–20 dB lower noise floor across the entire frequency band), far lower input ripple (typically 5× reduction), and better transient performance.

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While Murata was the first to market a soft-switching hybrid architecture, other companies are catching on to using capacitors for power transformation. A number of new products have entered the market in the last six months. Google has presented its switched-tank capacitive-based architecture for use in datacenters, which is available as an open source IP. Murata confidently expects capacitive-based power conversion to become mainstream in low-voltage conversion, and the company has a slew of new product introductions based on this concept planned throughout 2020.

About the Author

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