Transient Response Options for Power Designers

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For DC-DC converters, fast transient response has become ever more critical because of the increasingly higher speeds of contemporary devices. Telecommunications systems, networking systems, servers, processor-based systems are all good examples of applications that employ these high-speed devices. Microprocessors and custom ASICs, for example, have load requirements that can quickly change from a more or less idle state to full load demanding a rapid increase in current. If a converter is unable to respond to a load change, the output voltage of the converter drops. The voltage drop could cause a microprocessor or ASIC to shutdown or reset.

The typical converter is much slower than a microprocessor, but one may ask: why do conventional power converters respond relatively slowly to a load change? The output stage of a typical converter has a fairly large inductor in series with the load. Basic physics tells us that the current through an inductor cannot change instantaneously.

For most designers, capacitance on the output is the standard solution. A fully isolated DC converter at the point of load gives designers a bit better transient response than a non-isolated point-of-load converter. That’s still not good enough, but they also have additional options, such as active transient attenuation, attention to layout, and power converter selection.

Load Capacitance

The transient response of the typical converter is much slower than desired for many applications. Designers deal with this deficiency by storing a large reservoir of energy in capacitors at the output of the converter. The amount of capacitance needed to provide a large change in load current without very much voltage change for enough time for the converter to get up to speed, is substantial, often many thousands of microFarads. That’s a problem because a capacitor takes up space on a board ? which is precious these days ? and it is a failure-prone device that costs money.

The principal advantage of point-of-load capacitance is that it's easy to adapt to the needs of a standard converter for a specific application; that is, different capacitors can be used to adapt the same converter to a variety of loads.

Consequently, an additional factor to consider is the choice of the output capacitor ? ceramic, electrolytic, film, or tantalum. Ceramic capacitors have low ESR (equivalent series resistance) and low ESL (equivalent series inductance), but they have low capacitance per unit volume. They're low-cost and some may lose capacitance as high voltages are applied. Electrolytic capacitors have high ESR and typically the interconnect used within a device creates high equivalent series inductance. They do have high capacitance per unit volume and they have moderate reliability. The current through the device must not exceed the specifications. A film capacitor has low ESR and very low ESL. They have high voltage tolerance and low capacitance per unit volume. Tantalum capacitors have very low ESR, very low ESL, and very high capacitance per unit volume. They do have low voltage tolerance and low reliability. The RMS currents must be within specifications or catastrophic failure could occur.

Active Transient Attenuation
For active transient attenuation, an active device can be added between the output of the converter and the load. An active filter, when paired with a typical off-the-shelf DC-DC converter, will not only provide filtering that is superior to that of a passive filter, but will also provide improved transient response. This approach can either eliminate the need for load capacitance for noise reduction, or reduce the amount required by as much as a factor of ten for equivalent transient capability. Since attenuation involves a low-pass filter, there is an element of energy storage somewhat mitigating the effects of parasitics. It also allows the standardization of the power converter.

On the other hand, an active filter reduces system efficiency, it does not eliminate all the transient response issues, and it adds complexity to the system.

Layout Considerations
For an application needing fast transient response, designers must minimize trace resistance and inductance. For low trace resistance, only high-grade copper in wide traces should be used for the plus and minus output to the load. It is also important to minimize the distance between the converter and the load and to minimize the number of connectors used between the converter and the load. For low trace inductance, the current loop path from the +OUT to the -OUT should be as small as possible. Twisted pairs should be used if wires are used in interconnecting converter to load. The positive or negative traces should be run in separate planes on top of each other if the PC board traces are used in connecting converter to the load. Traces and/or the wires should be routed away from magnetic fields and components.

Power Converter Design
Finally, the most effective option a designer has to improve transient response is the choice of DC-DC converter. The need for energy storage by using capacitors at the output of the converter can be minimized or avoided by using a converter design that can better match to the requirements of the load.

DC-DC converter components are based on high-frequency switching technologies. Efficient high-frequency operation has long been recognized as the key to achieving high-power density and improved performance in switch-mode converters. High-frequency operation translates into smaller magnetics and capacitors, lower noise levels and smaller filters ? and, more to the point here, faster response times. For a crude comparison, PWM converters operate at about 100 kHz, ZCS converters operate at about 1 MHz, and a converter with a V*I chip inside operates at about 3.5 MHz (Figure 1).

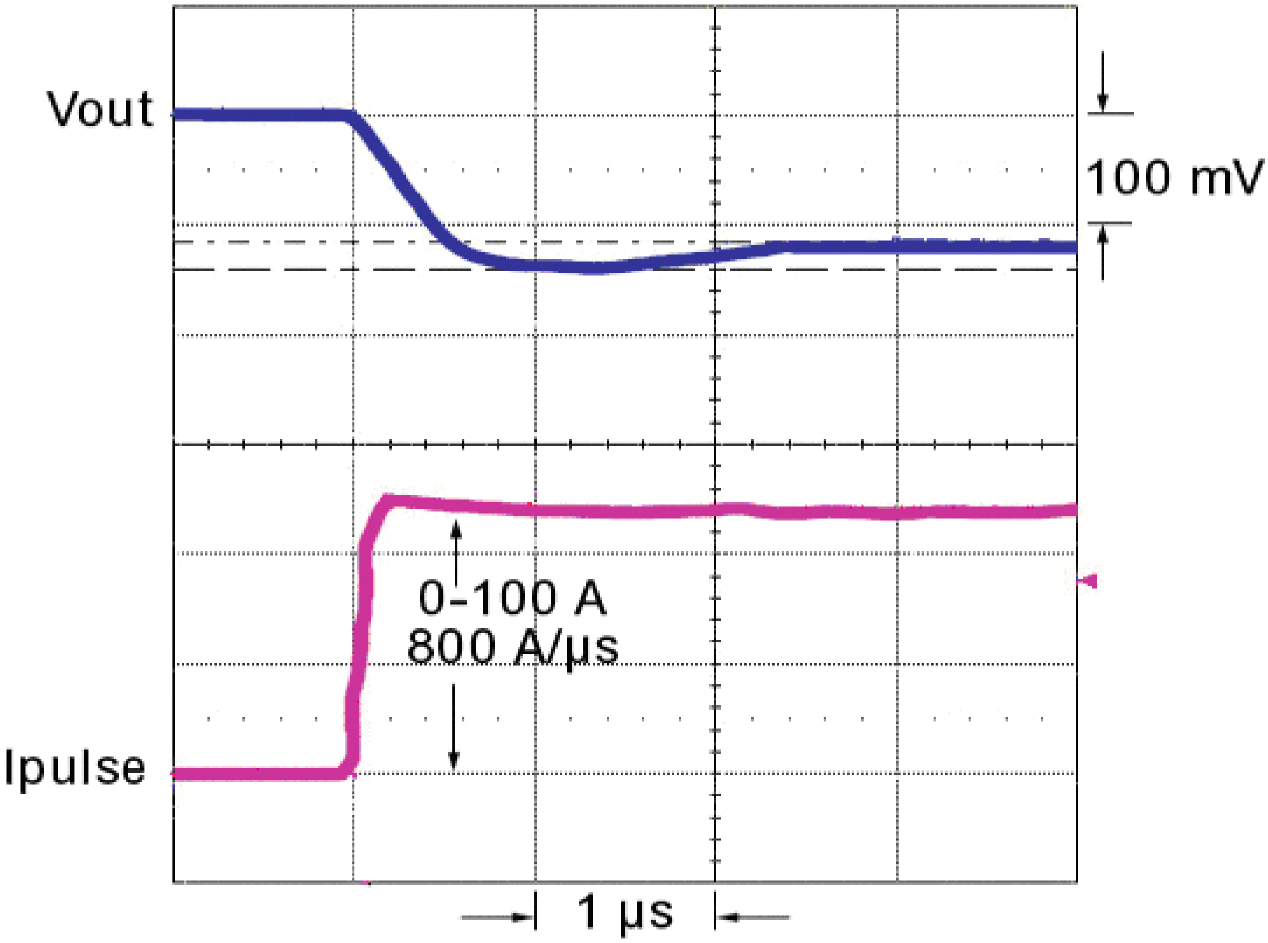

Figure 1. Converters with a V*I chip inside respond to load changes, regardless of magnitude, in less than one microsecond with an effective switching frequency of 3.5 MHz.

A converter that uses isolation at the point of load can better match the output of the converter with the requirements of the load. With an isolated point-of-load converter, such as a VI-brick (Figure 2), energy storage can be moved to the primary side, and because energy is stored at a much higher voltage, much less capacitance is needed. The V2 relationship and the ratio of 48-to-1 results in a multiplication factor of about 2000; so, instead of needing 20,000 microFarads on the secondary side, only about 10 microFarads are needed on the primary side. Fewer and smaller capacitors take up much less space, and the converter can obviously respond much faster.

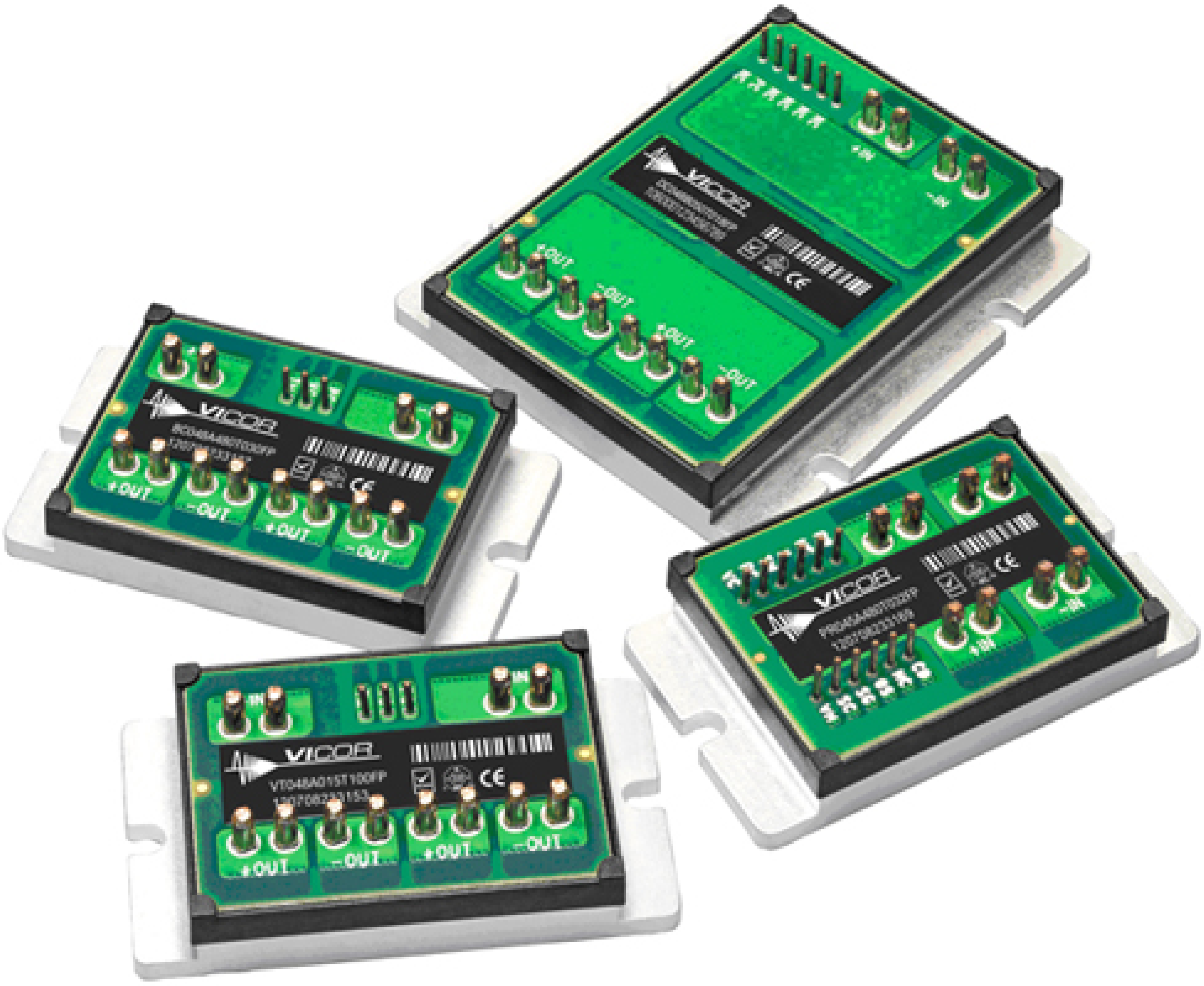

Figure 2. VICBricks are quarter-brick sized DC-DC converters that conform to industry-standard footprints and pin-outs while delivering high performance in power density, efficiency, cost, and transient response.

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