Power Adapters Slim Down with GaN

Easy portability and a slim or compact outline are great design goals for external power adapters. In practice, success is always limited by the need for thermal management (large heatsinks) to ensure reliability and relatively large filter components to stabilize and smooth the DC power at the output. Advanced GaN power-semiconductor technology reduce size, weight, and increase energy-efficiency advantages. **Ron Stull, Power Systems Engineer, CUI Inc., Tualatin, USA**

With the arrival of new power transistors based on GaN technology, unlike traditional Silicon-based devices, power adapters are set to become considerably smaller, slimmer, lighter, and generally less intrusive. This is great news for a huge variety of products ranging from laptops to gym equipment such as treadmills that are often positioned in rows comprising several units side by side. Smaller adapters can offer advantages such as reduced clutter, a more pleasant appearance, and easier portability.

What's special about GaN?

GaN (gallium nitride) is one of the emerging groups of so-called wide bandgap (WBG) semiconductors that also includes Silicon Carbide (SiC). After long development, enhancement-mode (normally turned off) GaN transistors that are ready to deploy in commercial power supplies are now available. Compared to Silicon devices, GaN transistors offer a more favorable combination of conduction losses in relation to device voltage rating, fast switching capability with low energy losses, high thermal conductivity, and high-temperature operation, at a price that is cost-effective for consumer and industrial applications.

At the forefront of advanced power supply development, CUI recently launched GaN power adapters that are 32 % lighter than comparable Silicon-based power supplies (Figure 1), resulting in up to 250 % greater power density. The GaN adapters are also lighter and operate up to 96 % efficiency.

The key to these advances lies in GaN's superior efficiency at high operating frequencies, which allows designers to specify a smaller transformer and smaller filtering components such as inductors and capacitors. Bulky heatsinks can also be avoided. These are typically the largest components in the adapter, so trimming or eliminating these can make a significant difference to the overall size and allow more freedom to craft the outline to achieve a desired look.

GaN boost to power supply performance

In any switched-mode power supply, transistors are either turning on, turned on, turning off, or turned off. In each state some energy is lost. An important goal for the power supply designer is to minimize the overall effect of these losses. The chosen transistor parameters, the converter topology, and the switching frequency are major factors that influence the result. As far as transistor selection can help, the parameter $R_{DS(ON)}$ (resistance from drain to source) heavily influences the losses when the device is turned on. Switching performance, on the other hand, is governed by the charge (Q_g) due to the capacitance of the transistor's gate region. The product of $R_{DS(ON)}$ and Q_g is an important figure of merit (FOM) for power transistors.

Transistor designers seek to create devices with low FOM that are attractive for use in switching power supply applications. However, optimizing the device for low $R_{DS(ON)}$ tends to come at the expense of increased Q_g, and vice versa. It's a balancing act that means the transistors with the best FOM, i.e low $R_{DS(ON)}$ and low Q_g, tend to be expensive. Moreover, as far as plain old Silicon transistors are concerned, the technology is nearing its theoretical limit. Engineering the FOM down to a lower number is increasingly difficult and costly while at the same time the

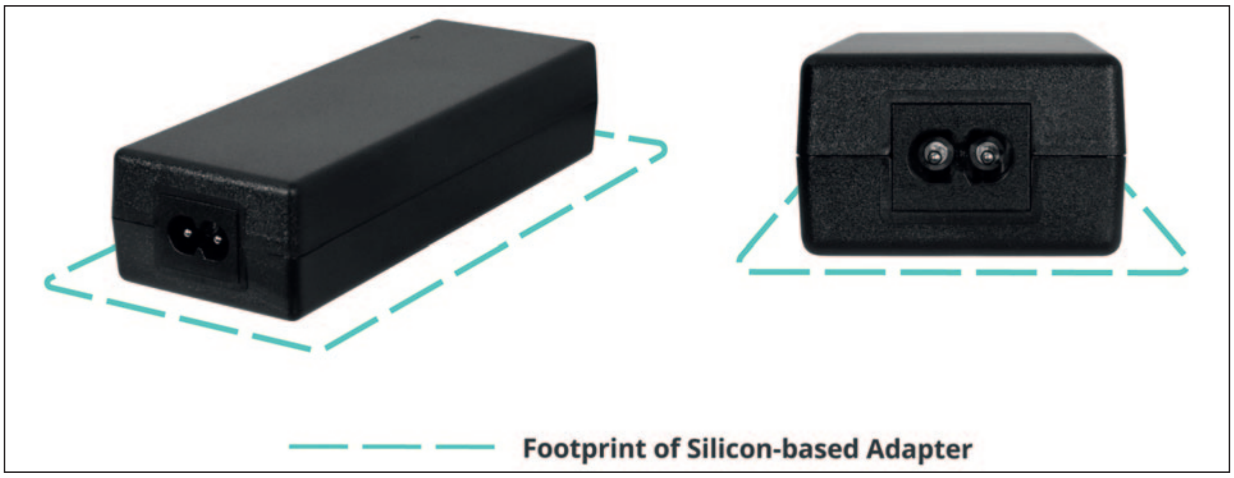

Figure 1: New power adapters built with GaN transistors are 33 % smaller than their predecessors

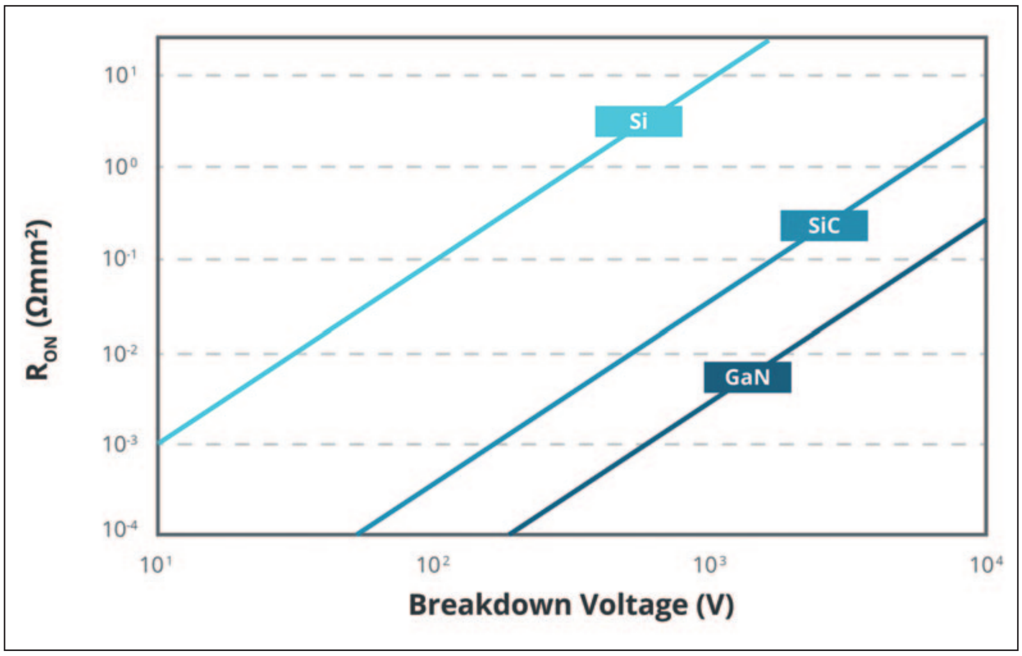

Figure 2: GaN transistors have much lower RDS(ON) in relation to voltage rating (breakdown voltage) than Silicon or SiC devices

potential improvements that can be achieved are diminishing.

GaN technology now introduces a "new deal" for device designers and – by extension – power-supply designers, too. GaN technology allows extremely low $R_{DS(ON)}$ in relation to the breakdown voltage of the device. For typical line-powered applications, GaN offers by far the most favorable combination of device voltage rating and $R_{DS(ON)}$ compared to Silicon and the other wide-bandgap technology in use today, Silicon Carbide (SiC), as Figure 2 illustrates. The switching losses of GaN devices are also naturally lower than those of Silicon devices.

By taking advantage of these characteristics of GaN transistors, power supply designers can save conduction losses thanks to the low transistor $R_{DS(ON)}$ while also using higher switching frequencies without incurring excessive switching losses.

At higher switching frequencies, shorter cycles allow filters comprising lower values of capacitance and inductance to store enough energy for effective smoothing of the output. Hence these components can be physically smaller. The transformer size can also be reduced. Moreover, because GaN has better thermal conductivity than Silicon, and devices can withstand higher operating temperature, the rating and hence the physical size of any heatsinks can also be reduced. In practice, a heatsink-free design is often possible.

Whereas conventional Silicon-based transistors are typically switched at frequencies in the 65-100 kHz range, GaN-based designs can operate at about 600 kHz at light loads, reducing to about 300 kHz for optimum efficiency up to full load.

GaN transistor behavior when turned off is also worth examining. In a conventional Silicon transistor, a parasitic diode in parallel with the main drain-source channel, called the body diode conducts a reverse freewheeling current when the transistor is reverse biased while turned off. The GaN transistor has no such parasitic diode, although freewheel current is allowed to pass through the main channel. The absence of body diode reverse-recovery charge lowers switching losses. Also, there is no diode turn-on noise hence electromagnetic emissions can be lower. In a half-bridge power stage, the fast switching capability allows the dead-time, during which both transistors are turned off, to be extremely short thereby minimizing power dissipation due to freewheel currents.

Meeting efficiency regulations

The efficiency of power adapters for commercial products is, of course, heavily controlled by ecodesign regulations that are in place in major markets worldwide. Today's adapters – whether Silicon or GaN based – must meet strict specifications on maximum power dissipated in standby mode and average operating efficiency, which is measured at various loadings from below 50 % to full load. Depending on the type of adapter and its power rating, the current US Level VI regulations call for maximum allowed standby power as low as 210mW and imposes minimum average efficiency requirements based on measurements at 25 %, 50 %, 75 %, and 100 % of full load.

The conventional Silicon-based units in CUI's portfolio satisfy the toughest ecodesign regulations currently in force worldwide. GaN-based products can surpass these requirements and hence will become increasingly in demand to meet new and tighter specifications in the future.

Into production

In the current timeframe, CUI's GaN strategy focuses on maximizing size and weight savings at comparable or better efficiency than Silicon-based products. The first GaN power adapters to enter production, the SDI200G-U with three-prong (C14) inlet and SDI200G-UD with two-prong (C8) inlet, achieve 210 mW no-load power consumption and efficiency of up to 96 %. Both units meet the current US DoE Level VI and EU Ecodesign specifications for average efficiency and no-load power as well as the more stringent, but voluntary, EU CoC Tier 2 directive.

Measuring 5.91 x 2.13 x 1.3 in. (150 x 54 x 33 mm), the new models have power density of 11.4 W/in^3, which compares with 5.3 W/in^3 for similar conventional silicon power adapters. At 560 g, compared to 820 g, they are also 32 % lighter.

Outlook for the future

CUI's SDI200G models are the first generation of power supplies to take advantage of the exciting new GaN technology and further models are planned. GaN transistors will also allow engineers to unleash the benefits of high-efficiency circuit topologies such as active-clamp flyback and bridgeless totem-pole power-factor correction in future designs. Moreover, as GaN is in its infancy, the long-term outlook promises significant improvements in device performance that will enable future generations of power products to offer even greater efficiency, reliability, and space savings.