USING GALLIUM NITRIDE TO INCREASE POWER SUPPLY EFFICIENCY

WHITEPAPER

Using Gallium Nitride to Increase Power Supply Efficiency

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A growing number of designers are using GaN-based flyback AC/DC power supplies in a wide variety of applications. GaN is important because it facilitates power transistors that are more efficient, resulting in smaller and cooler power supplies.

Transistors, whether made from silicon or GaN, are non-ideal devices and have two significant sources of inefficiency (in a simplified model): series impedance, called $R_{DS(ON)}$, and parallel capacitance known as C_{OSS}. These two transistor parameters limit the performance of power supplies. GaN is a new technology that designers can use to reduce the impact of these performance-limiting transistor characteristics. In all transistors, as the $R_{DS(ON)}$ is reduced, the die size increases and that causes the parasitic C_{OSS} to also increase. In GaN transistors, the ratio of C_{OSS} increase to $R_{DS(ON)}$ decrease is an order of magnitude lower.

RDS(ON) is the resistance of the switch when it is on, and it causes conduction losses. C_{OSS} power loss is equal to CV2/2 (Figure 1). Turn-on losses result from C_{OSS} discharging through the $R_{DS(ON)}$ as the transistor is turned on. The turn-on losses are equal to (CV2/2) x f, where f is the switching frequency. Replacing silicon switches with GaN switches results in lower values for both $R_{DS(ON)}$ and C_{OSS} and enables the design of more efficient power supplies or operation at higher frequencies with less penalty in efficiency, which aids in transformer size reduction.

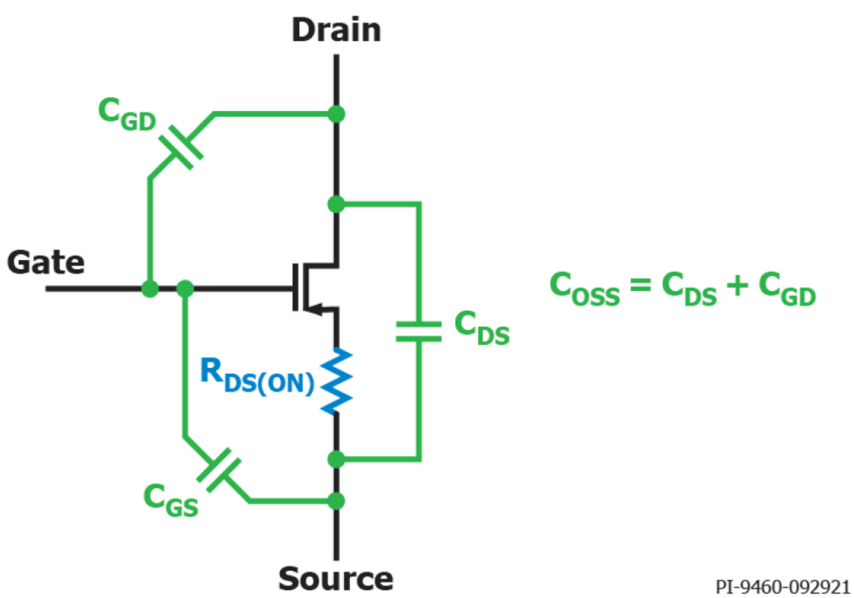

Figure 1. Parasitic capacitances in the primary power switch.

How GaN reduces conduction and switching losses

We touched on the consequences of increasing the size of the transistor; as the transistor gets larger, $R_{DS(ON)}$ decreases. That's good. However, as the transistor gets larger there's (obviously) more area so parasitic C_{OSS} increases. That's not good. The optimal transistor size is the one that minimizes the combination of $R_{DS(ON)}$ and C_{OSS}. That point typically occurs where the curve for decreasing $R_{DS(ON)}$ losses crosses the curve of increasing C_{OSS} losses. When the curves cross, the combination of resistive and capacitive losses is the lowest (Figure 2).

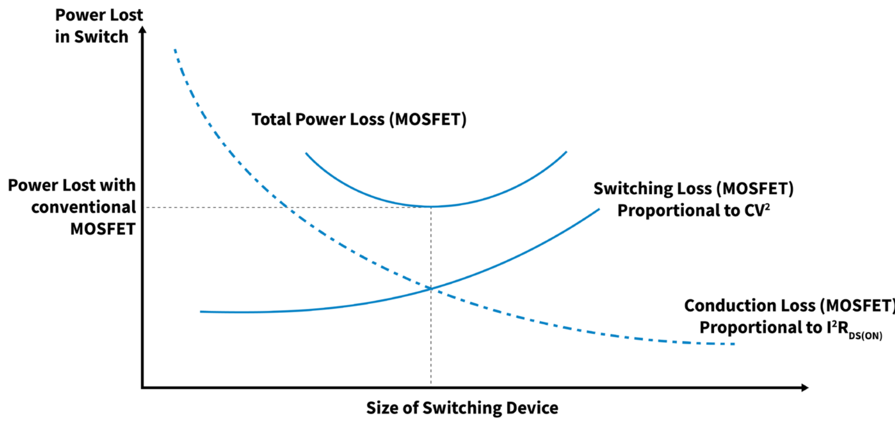

Figure 2. Simplified representation of power loss in a silicon MOSFET compared to device size.

In addition to total $R_{DS(ON)}$, there is a parameter called "specific $R_{DS(ON)}$" that relates the total on-resistance relative to die unit area. Compared with silicon, GaN has a very low specific $R_{DS(ON)}$, resulting in smaller switches and consequently lower C_{OSS}. That means that a smaller GaN device can handle the same power level as a larger silicon device.

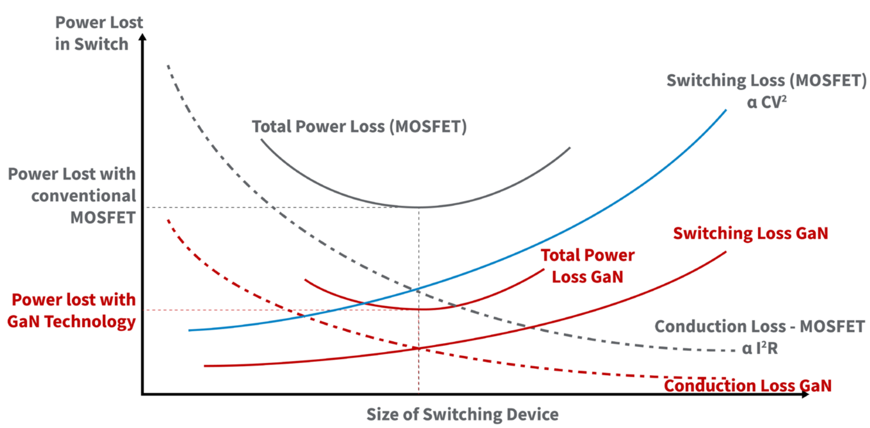

Figure 3. GaN devices have lower total losses compared with silicon MOSFETs.

The combination of lower $R_{DS(ON)}$ and reduced C_{OSS} losses makes it possible to design higher efficiency power supplies with GaN, which reduces heat dissipation. This reduced thermal loading also contributes to making the power supplies smaller. Frequency is another tool the designer can use to reduce size and optimize performance of power supplies using GaN. Since GaN is inherently more efficient than silicon, it is possible to increase the switching frequency of GaN-based power supplies. While that increases the losses, they will still be significantly lower than the losses from a silicon MOSFET and result in smaller magnetics.

Practical limits on transformer construction and parasitic elements in the circuit place limits on how far the switching frequency can be usefully increased. In practical designs, the switching frequency that delivers the best combination of efficiency, size and low cost for a GaN-based flyback adapter rated for ≤100 W can be under 100 kHz. With GaN, the limiting factor is not the speed of the switch. With the dramatic reduction in C_{OSS} designers have increased flexibility to optimize the switching frequency against losses and arrive at a superior solution.

Power supply efficiency improvements with GaN

How does this translate into power supply efficiency improvements? A 65 W flyback adapter using a silicon MOSFET will have an efficiency curve that starts off in the low 85% range at 10% load and will reach 90%+ at full load (Figure 4). A 65 W flyback adapter using a GaN-based InnoSwitch™ product from Power Integrations (PI) will be approximately 88% efficient at 10% load. And at full load, the GaN design will reach about 94%. Replacing the silicon MOSFET with a GaN device can be assumed to provide an improvement of approximately 3% in efficiency across load.

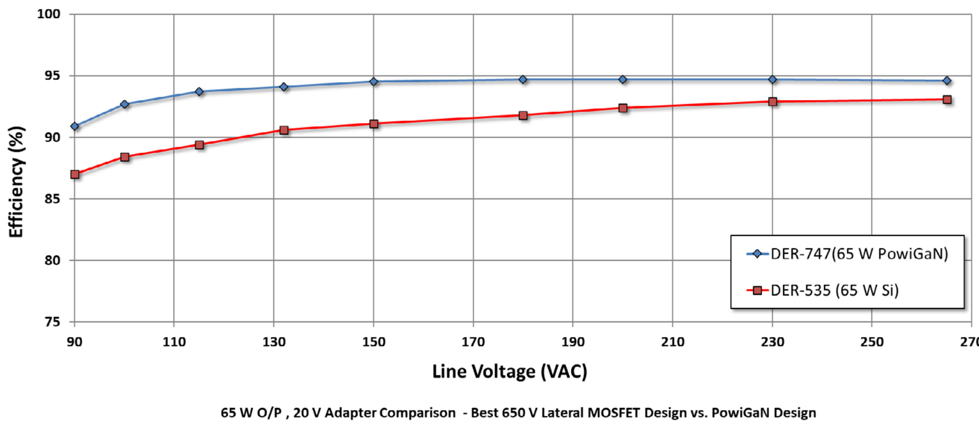

Figure 4. SiC vs. GaN adapters efficiency comparison at full load

That 3% improvement in efficiency equates to at least 35% reduction in losses. The GaN design consumes less energy and produces 35% less heat. This is doubly important as the primary power switch is typically the hottest component in a conventional power supply. The GaN power supply will need less heatsinking. It will be much smaller and lighter in weight making it easier to carry, and it will be cooler running and have a longer operating life as a result of lower component temperatures.

How to design with GaN transistors

Discrete GaN transistors cannot be used as direct substitutes for silicon devices in power converter designs. GaN transistors are more challenging to drive, especially if the driver is not located close to the transistor. GaN devices turn on very fast, and without a carefully optimized drive circuit, this can result in significant problems with electromagnetic interference and even destructive oscillation. GaN devices are normally on, which is not ideal for a power switch, so the discrete GaN switch is often paired with a low-voltage silicon transistor in a cascode arrangement.

To support robust designs and speed time-to-market, PI offers the InnoSwitch3 product family. These fully integrated flyback switcher ICs include controllers for the primary side for the GaN and for the secondary side synchronous rectifier. InnoSwitch3 ICs have low no-load power consumption and feature a high bandwidth communication technology called FluxLink™ which enables feedback information to be delivered across an isolation barrier that complies with international safety standards.

InnoSwitch3-PD, the newest addition to the InnoSwitch3 family, features a primary and secondary controller and a GaN primary switch. This device provides complete USB PD and PPS interface capability, eliminating the microcontroller typically required for USB PD + PPS power supplies. Other PI products with GaN include: InnoSwitch3-Pro which uses digital control and supports dynamic adjustment of power supply voltage and current; a multiple output version called InnoSwitch3-MX; and an LED driver IC, LYTSwitch™-6.

Figure 5. InnoSwitch3 integrated solutions leverage GaN technology to deliver high-performance flyback power supplies and speed development time.

Summary

GaN is ready to use today. A growing variety of applications, including USB PD adapters, televisions, white goods and LED lighting – more than 60 different applications – are already enjoying the benefits that GaN brings. When a flyback AC/DC power supply of 100 W or less can be used, more and more designers are choosing GaN for power supplies that are smaller, lighter in weight, run cooler and deliver increased reliability.

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