Technical Article

Advantages of Wide Band Gap Materials in Power Electronics – Part 2

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In the first installment of this series, I explored how gallium nitride (GaN) enables operation at higher frequencies and how that allows for smaller component selection. This ultimately shrinks product size while maintaining the same power level: hence the power density increases.

Smaller Products: the Increasing Power Density

As the power density of a power supply increases due to the shrinking of its components, what happens to the heat generated?

Heat management can become challenging as the power-loss density increases. For a given aspect ratio, the area available for heat exchange reduces as the volume reduces, which leads to a higher surface temperature.

Efficiency improvements become necessary to enable shrinking in the size of power systems. From a loss point of view, a 90% efficient system has twice as much power loss as a 95% efficient system: every percentage point counts.

Another driving factor pushing for higher efficiencies are the governing regulations and standards for power supplies, which are becoming increasingly stringent. More marketing-related green certifications also require increasingly higher standards.

Improving Efficiency

In an application using GaN transistors, you can take two main paths to improve a particular application.

The first is to maintain operational frequency close to an equivalent silicon-based system, since the GaN-based FET has less loss.

The second is to shrink the system by increasing the frequency, in which case transition or switching losses become a dominant element again.

In the second case, where the power density increases, there is a need to further improve efficiency.

The best way to reduce switching losses is to adopt a resonant or quasi-resonant scheme. The same basic concept applies: switch the transistors with either zero current or zero voltage across them (or close to zero). A number of such topologies already exist with silicon solutions that you can extend to GaN.

The advantage of using GaN is that the switching frequencies and transition speeds are high enough that you can use the parasitics from passive components as part of the design to tune the resonance. Smaller parasitics will also result in lower circulating currents and enable shorter dead times. This inherently simplifies the design, reducing cost, weight and all of the extra losses associated with extra components.

You can reduce conduction losses by taking advantage of the high frequency to reduce current ripple (lower current peaks generate lower conduction losses). A good example in AC/DC conversion is an active-switch power factor correction (PFC) circuit, where the charging current is sinusoidal rather than pulsed, thus reducing peak-current conduction losses. Similarly, the effectiveness of active switches can be maximized by using very fast controllers, so to present as low impedance through the power stage, thus improving efficiency.

You can further improve the reduction in driving losses coming from the lowered activation voltage and lower gate charge (Qg) with resonant gate-driving techniques.

Conclusion

Size reduction and improved power-conversion efficiency are the two major visible advantages of using GaN in power systems.

Depending on the system, increasing the frequency beyond a certain limit may not be advantageous for size reduction, as the system's non-power-related components might not be able to shrink accordingly (power connectors, motors). In those systems, the reason to push for a higher frequency is to push the electromagnetic interference (EMI) beyond the scope of standards.

GaN is the greatest major paradigm shift in power supplies in decades, and with the extremely high switching speeds achieved (100/ns), a GaN switch is the closest thing to an ideal switch available.

GaN opens up the possibility to revisit classic power supplies, improving performance, efficiency, cost and size. More importantly, it enables designers to explore and invent new topologies that were not conceivable with silicon.

Get to know TI GaN solutions and begin your design.

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