GaN vs. Silicon in Power Management

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Efficient Power Conversion Corporation (EPC) recently introduced the first enhancement-mode GaN-on-silicon power transistors designed specifically as power MOSFET replacements. These products were designed to be produced in high-volume at low cost using standard silicon manufacturing technology and facilities.

Our 30 year silicon power MOSFET journey taught us there were four key variables controlling the adoption rate of a superior technology.

1. Does it enable new capabilities?
2. Is it easy to use?
3. Is it cost effective to the user?
4. Is it reliable?

New Capability: The most significant new capabilities enabled by enhancement mode GaN HEMT devices stem from the quantum improvement in switching performance and overall device bandwidth. GaN also has a much higher critical electric field than silicon which enables this new class of devices to withstand greater voltage with less penalty in on-resistance. Expect end products using GaN transistors to appear shortly with greater battery life, less power consumption, smaller size, and lower costs.

Easy To Use: How easy a device is to use depends on the skill of the user, how different the device is compared with devices within the experience of the user, and the tools available to help the user apply the device

The new generation of GaN transistor is very similar in behavior to existing power MOSFETs and therefore users can leverage their past design experience. Two areas stand out as requiring special attention: relatively low gate dielectric strength and relatively high frequency response. The first of these two differences, relatively low maximum gate voltage that can, be improved as the technology matures. The second difference, relatively high frequency response, is both a step function improvement over any silicon device, and an added consideration for the user when laying out circuits. For example, small amounts of stray inductance can cause large overshoot in the gate-to-source voltage that could potentially damage devices.

On the other hand, there are several characteristics that render these devices easier to use than their silicon predecessors. For example, the threshold voltage is virtually independent of temperature over a wide range, and the on-resistance has a significantly lower temperature coefficient.

User-friendly tools can also make a big difference in how easy it is to apply a new type of device. EPC has developed a complete set of SPICE device models and a library of applications notes and reference designs available at www.ecp-co.com.

Cost Effective: Since EPC’s transistors are built in a standard silicon foundry and the technology allows for a significant die “shrink” compared with silicon MOSFETs, cost comparisons should quickly favor the new technology. As we progress down the learning curve, GaN will be able to dramatically outperform silicon in cost effectiveness to the average user.

Reliable: The cumulative reliability information on power MOSFETs is staggering. Many years of work has gone into understanding failure mechanisms, controlling and refining processes, and designing products that have distinguished themselves as the highly-reliable backbone of any power conversion system.

GaN on silicon transistors are just beginning this journey. Preliminary results, however, are encouraging. As of the date of this writing, EPC has established the basic capability of enhancement mode GaN on silicon transistors. A full reliability report with greater statistics is expected to be published in March 2010.

The power MOSFET is not dead, but is nearing the end of the road of major improvements in performance and cost. GaN is destined to become the dominant technology over the next decade due to its large advantages in both performance and cost; advantage gaps that promise to widen as we quickly climb the learning curve.