# Power Conversion: The End of the Road for Silicon

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**KEY TAKE AWAYS**

- Silicon has reached theoretical limits of performance in power conversion.
- Gallium nitride (GaN) and silicon carbide (SiC) will displace much of the $12B market for silicon power MOSFETs.
- There is product in production today that is 5-10 times better than the theoretical limit of silicon.

Electricity is present in our day-to-day lives in just about everything we do. From cell phones to refrigerators to the cars we drive, electricity is required to perform an intended function in order to achieve a desired result. As the middle class continues to improve their standard of living in the emerging economies, demand for electricity is expected to grow significantly. In fact, the worldwide demand for electricity is expected to grow by approximately 75% over the next 25 years.

**The Power Conversion Process**

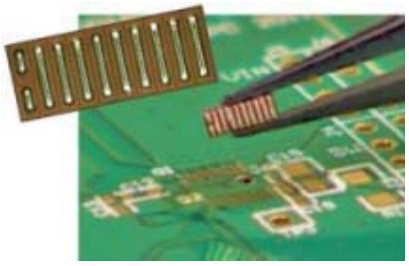
Many electrical devices start with a wall socket and require that AC power be converted and regulated along the path to its end use. This stream of conversion may involve converting from AC to DC, then DC to DC (several times). Each device and each function within each device requires electricity to be precisely reformatted to allow efficient performance. This precise reformatting of electricity is what the "power conversion process" means.

At the heart of power conversion systems are power semiconductor transistors designed with exact specifications to accomplish particular tasks. The more precisely a transistor's specifications are aligned with a particular application, the more efficiently it converts electricity.

**The Invention of the Power MOSFET**

The power transistor had an industry-changing innovation over 35 years ago with the introduction of the power MOSFET. These silicon-based power transistors enabled high efficiency power conversion to become a commercial reality.

Power MOSFETs precisely control electricity by chopping the flow of electrons into small packets of energy with minimum losses. These packets of energy are then reassembled into the exact format needed to supply the exact power demanded by the user. The silicon-based MOSFET has had a great run, but now this technology is close to reaching its performance limits. Silicon cannot switch fast enough nor provide the power efficiencies required for today's demanding applications.



**The Obsolescence of the Power MOSFET**

In the power MOSFET there is a basic tradeoff between conductivity, specified as on-resistance, "R", and the amount of charge required to turn the device from the ON to the Off state (or OFF to ON), typically referred to as "Q". This tradeoff drives the figure of merit called RQ product — the device's on-resistance multiplied by the charge. Emerging applications, as well as evolutionary improvements to existing applications, require an RQ product that significantly exceeds the capabilities of the power MOSFET.

There are several technologies emerging that are destined to replace the silicon power MOSFET as the power semiconductor transistor of choice. Currently, the most promising technologies are GaN (gallium nitride) and SiC (silicon carbide). Both GaN and SiC technologies are wide band gap materials that offer the advantages of higher power densities, higher voltages, lower leakage current, and the ability to operate at higher temperatures.

These wide band gap technologies can theoretically shrink the size of the transistor and the RQ product by more than a factor of 100 compared to silicon. Today there are commercial GaN products already on the market that are 5-10 times better than silicon, and improvements are happening at a pace reminiscent of Moore's Law.

Both GaN and SiC technologies will displace silicon as the base material for power transistors. They will take their respective positions in the next few years by displacing silicon power MOSFETs, and their close cousin the IGBT, in the $12 billion power conversion market.

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