Whitepaper

650 V GaN FET technology delivers the best efficiency, and the robustness needed for AEC-Q101 qualification

Dr. Dilder Chowdhury and Dr. Jim Honea

Delivering the highest efficiency in power conversion requires using the best semiconductor devices as the fundamental building blocks. In recent years GaN FET technology has shown that it offers the best possible efficiency. However, for high-current, high-power applications, the question is can 650 V GaN FETs deliver the robustness of operation at high voltages and high temperatures, as well as the quality, reliability and scalability in manufacturing to be successful in markets such as automotive?

Nexperia Power GaN FET solutions

Our GaN FET technology delivers the lowest Rds(on) (source drain on-state resistance) for higher voltages and a significantly better switching FOM (Figure of Merit). It shows significant promise and removes many of the limitations naturally imposed by silicon based IGBT and superjunction (SJ) devices.

Hard-switched application topologies where Si SJ FETs cannot be used due to the diode reverse recovery can instead use GaN FETs and take full advantage of reduced component counts and higher efficiency with simpler control schemes. That's why our 650 V GaN FET technology has been developed primarily for high power (650 V – 900 V) applications like power supplies (AC:DC, PFC, OBC, DC:DC) and traction inverters within automotive, telecom (5G), server (data centres & storage) and industrial markets.

Building a scalable technology

Gallium Nitride (GaN) HEMTs (High Electron Mobility Transistors) are formed on a silicon substrate via a seed layer and a graded layer of GaN and AlGaN layers before the pure GaN layer is grown. A thin layer of AlGaN then forms a 2DEG (2-Dimensional Electron Gas) which provides the high electron mobility due to the combination of spontaneous and piezoelectric polarisation at the interface of GaN and AlxGa1-xN layers.

By using wide bandgap (WBG) materials with higher critical electric field and higher mobility on a silicon substrate, provides Nexperia with a scalable GaN solution. It is ideally suited for ramp-up to large volume mass production as it utilises existing Si-based fab technology and infrastructure. Starting epitaxial material can be grown on Si substrate in metal organic chemical vapor deposition (MOCVD) reactors on diameters up to 200 mm and then processed in Si based fabs.

Delivering rugged robustness

The product parameters shared here are from the GAN063-650WSA, our first generation 50 mΩ 650 V device, but all products will share the same common robustness.

- High reliability gate structure (± 20 V) and high threshold voltage (4 V) provide a high safety margin against gate source transients induced due to the high drain source dv/dt
- High voltage source-drain transient specification can handle switching transients up to 800 V
- Rated operating range of -55 to +175 °C with Tj(max) of 175 °C makes them ideal for harsh environments.
- Very low Vf (1.3 V @ 12 A) enables Si-like freewheeling current capability without complex dead time adjustments

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EFFICIENCY WINS.

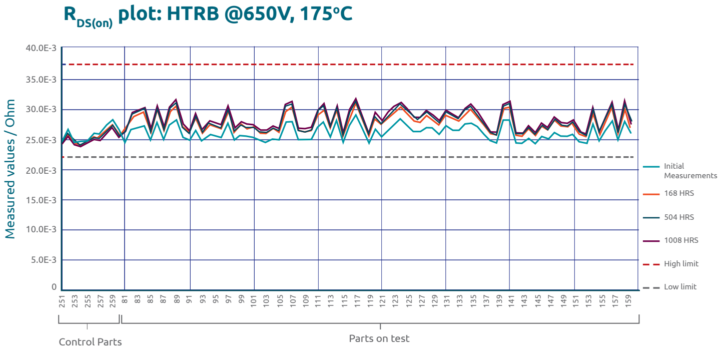
Matching automotive quality and qualification

Nexperia's 650 V GaN FETs are qualified in accordance with AEC-Q101 Rev D level qualification tests. The results shown here are also from testing on a GAN063-650WSA 50 mΩ 650V device and include 650 V, 175 °C High Temperature Reverse Bias (HTRB) tests with dynamic Rds(on) shifts. Temperature cycling tests were performed over the -55 to 150 °C range and included high-temperature (175 °C) gate positive (+20 V) and gate negative (-20 V) bias tests.

Further life tests included high temperature biased and unbiased humidity tests and operating life tests. These are just some of the critical tests that were performed and passed to show the reliability and high quality of the technology.

HTRB

High-Temperature Reverse Bias was performed at the full rated voltage and maximum operating temperature of 650 V and 175 °C. The AEC-Q101 Rev D condition for passing is that Rds(on) does not shift by more than 20%. Figure 1 shows the shift in dynamic Rds(on) for the test device. Note that the maximum shift is less than 15%.



[Fig. 1 Dynamic Rdson measurement during HTRB]

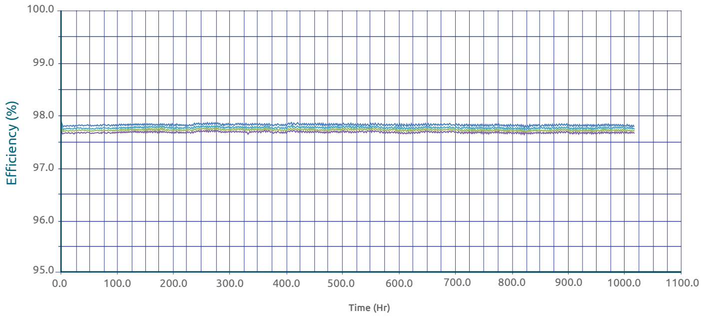
HTOL

While High-Temperature Operating Life (HTOL) tests are not part of the AEC-Q101 standard, they are useful in validating reliability of the parts under actual operating conditions. A basic half-bridge operating in continuous conduction mode provides the most fundamental exercise of switching behaviour. For this test, a number of identical half-bridge circuits were prepared, each using two GAN063-650WSA devices.

These were operated continuously as synchronous-boost converters with the following conditions:

- Vin – 200 V
- Vout – 480 V
- Pout – 800 W
- Tj – 175 °C
- Frequency – 300 kHz

The following graph shows efficiency of all samples during the 1,000-hour test. As can be seen, there is no indication of degradation in any of the sample circuits. Following the tests, all devices were tested for shifts in dynamic Rds(on), leakage current, and threshold voltage. All parameters were found to be stable, with any parametric shift within allowed levels.



[Fig. 2 Efficiency of boost converters (HTOL) over 1000 hours]

Conclusion

Although still at the early stage of technology maturity, Power GaN technology offers significant commercial viability with robustness and reliability. Its efficiency has been proven, and with devices such as the GAN063-650WSA already qualified to AEC-Q101 standard, Power GaN has shown it can deliver the performance and robustness for automotive and other demanding applications. And power GaN technology on Si shows tremendous growth potential to achieve volume mass production, which will enable cost-effective production of the large quantities required for these markets.

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