Design Challenges for high-performance GaN based converters in multi-MHz applications

Abstract – Nowadays Silicon (Si) semiconductors present high reliability and maturity, however, the limits in terms of power density, operation temperature, and switching frequency are close to being reached. Gallium Nitride (GaN) power devices promise superior operation at higher junction temperatures, in harsh conditions such as the space, and superior conduction and switching properties than traditional Si technology. Although the theoretical electrical properties of GaN devices are far superior to those of Silicon, all their benefits have not been exploited yet. In order to fully empower the emerging GaN based power electronics applications and unleash the full potential of GaN devices, it is necessary to fully understand what is behind (or inside) a GaN HEMT, as well as their design and reliability challenges.

We were expecting to move the switching frequencies to MHz range, but it looks like that it is more complex than expected. What are the design challenges if you want to design a 20 MHz inverter? How the single event failures influence the health of your GaN converter? How to proceed with further application development? These are the questions in front of us, and this Tutorial will try to respond them. It will cover two fundamental aspects, device theory and practical design issues, starting with a comprehensive introduction to GaN devices and their applications, to provide the attendees with the fundamental knowledge of GaN devices advantages, as well as basic know-how related to practical GaN based circuit design. Afterwards we will present the applications which can clearly benefit from GaN employment, clearly identifying the problems that we have seen during the development.

The tutorial is based on the results published by the speakers and other researchers in the field, as well as on our latest designs and accomplished experimental results.

1. Basic GaN HEMT physics

- GaN and SiC high expectations
- How does a HEMT work?
- Gate engineering
- Dynamic channel resistance

2. Practical challenges

- Package parasitics
- Device driver
- Layout and PCB issues
- Thermal management

3. High Frequency Applications of interest

- High frequency PA – Envelope Tracking
- Ultra-Compact Power Converters
- High Speed PA
- High Frequency challenges
    - PWM generation
    - Delay effect
    - Magnetic material
    - CM noise

4. Reliability challenges

- GaN HEMT characterization
- Building the setup
- Measuring channel resistance
- Characterization under short-circuit events

5. Conclusions