Contribution ID: **488**

Type: **Invited Oral**

M3Or4N-03: [Invited] GaN HEMT and Air Core Magnetics based Power Converters Evaluations at Cryogenic Temperature

Wednesday, 12 July 2023 16:55 (30 minutes)

Cryogenic power electronics is both advantageous and indispensable in many applications, like deep space probe, military electric vehicle, magnetic resonance imaging etc. Among different semiconductors, the gallium nitride (GaN) high electron mobility transistor (HEMT) is the most promising candidate for cryogenic applications with significant conduction loss and switching loss reductions. In this work, the GaN HEMT power converters with different power levels (from several Watts to several kiloWatts) are evaluated at cryogenic temperature. Three different commercial GaN HEMTs are used in these power converters, including the Texas Instruments LMG5200 80 V GaN half-bridge power stage with integrated gate driver, the GaN Systems 650 V bottom cooled GaN HEMT GS66516B, and the 650 V top cooled GaN HEMT GS66516T from GaN Systems. Moreover, different converter evaluation methods are investigated. Three of these power converters are evaluated by using a cryogenic chamber and such that the converter operating environment temperature can be regulated. One of the power converters is evaluated by using liquid nitrogen (LN2) channeled through a cold plate, where the gate driver can be designed to operate at non-cryogenic temperatures. Due to the degraded performance of conventional magnetic components, air core magnetics are used in these power converters to improve the converter efficiency.

All the evaluated GaN HEMT based power converters have demonstrated improved efficiency performance at cryogenic temperatures. The individual converter efficiency performances are summarized as follows: 1) 2.5 MHz 4 W LMG5200 based inductive power transfer (IPT) converter: the converter efficiency at room temperature is 58.56%, while this value is increased up to 78.2% at 93 K; 2) 500 kHz 80 W LMG5200 based Buck converter: the converter efficiency increases from 90.67% at room temperature to 97.53% at 93 K; Further, the integrated gate driver for the LMG5200 works properly at LN2 temperature; 3) 300 kHz 700 W GS66516B based Boost converter: the converter efficiency at rated output power and room temperature is 95.97%, while the converter efficiency increases up to 96.56% at 148 K. The converter is not evaluated at even lower temperatures due to the malfunction of the gate driver; 4) 150 kHz 5 kW GS66516T based Buck converter: a cryogenic power electronics structure is adopted to avoid the malfunction of gate driver and the cold plate is used to achieve cryogenic temperature. Maximum efficiency of 98.5% is achieved at 1.5 kW output power and around 1% efficiency improvement can be achieved when compared with room temperature operation at 130 K.

Loss distribution analysis for the power converters is cataloged. There are two major reasons for efficiency improvement at cryogenic temperatures for these power converters: 1) switching loss and conduction loss reductions for GaN HEMTs; 2) conduction loss reductions for air core magnetics since the copper resistance is reduced at cryogenic temperature. Overall, GaN HEMT and air core magnetics-based power converters are very promising for cryogenic applications. The final paper will discuss the details of power converters performances and loss distribution analysis.

Primary author: WEI, Yuqi

Co-authors: Prof. MANTOOTH, H. Alan (University of Arkansas); HOSSAIN, Md Maksudul (University of Arkansas)

Presenter: Prof. MANTOOTH, H. Alan (University of Arkansas)

Session Classification: M3Or4N: Transportation Symposia IV: Cable, Power Distribution