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Experimental Characterization of Gallium-Nitride Field-Effect Transistors at Cryogenic Temperatures and Application in Multilevel Inverter

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GaN-based field-effect transistors have shown great potential in the development of high-density power converters and also hold promise for cryogenic applications. In order to explore this potential, the cryogenic performance of an EPC gallium-nitride (GaN) power field-effect transistors (FETs) has been evaluated. At -195 C, an 85 % reduction in on-state resistance, and a 16 % increase in threshold voltage were experimentally measured without observing carrier freeze-out effects. Moreover, using a double-pulse test, no major changes in switching characteristics were noted.

Building on these results, a 1 kW, GaN-based, 3-level power converter was designed and successfully tested from room temperature down to -140 C, using a custom milled cold-plate. At -60 C, a 16% reduction in losses was achieved at rated power. An estimated power loss breakdown was performed by taking into account the decreasing conduction losses of the GaN FETs and estimates of losses for the passive components. It is clear that there is significant opportunity for additional gains in efficiency by combining high-performing GaN FETs with passive components optimized for low temperature operation. This work is the first demonstration of a flying capacitor multi-level converter and associated components at such low temperature, and highlights opportunity for further gains in density and efficiency in liquefied natural gas applications which offer readily available low temperature cooling.

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