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# Gallium Nitride DC-to-DC Converter

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High efficiency, radiation hard, hybrid GaN and CMOS integrated module DC-to-DC converter has been designed. The integrated, compact, low-mass, single-module DC-DC converter solution has an input voltage of 18V regulated down to an output voltage of 1.4V, with 5A maximum load current. It exhibits >80% efficiency. Discrete GaN transistors are used for the power stage, and the controller circuitry and power device drivers are integrated on a 0.35um CMOS chip. Radiation hardening by design (RHBD) techniques have been implemented and the goal is that the converter functions at total ionizing dose (TID) levels ≥150 megarad(Si).

## Summary

Large high energy physics experiments are currently driving the development of new and more efficient powering schemes to cope with the increase of power demanded by the upgraded high-density front-end electronics boards. Due to the radiation levels up to hundreds of Mrad(Si) at the detector cores, commercial DC-DC converters cannot be used in these powering schemes. Therefore, a critical need exists for custom-designed radiation-hard DC-DC converters. Another requirement for these converters is the ability to function in high magnetic fields.

Gallium Nitride (GaN) material, providing inherent radiation hardness, high switching frequency and large voltage swing is a viable contender for implementing these converter circuits. In the converter that will be presented, discrete GaN transistors are used for the power stage, and the controller circuitry and power device drivers are integrated on a 0.35um CMOS chip. Radiation hardening by design (RHBD) techniques have been implemented and the goal is that the converter functions at total ionizing dose (TID) levels ≥150 megarad(Si) and neutron fluence levels ≥2.0E15 n/cm2, and is immune to Single Event Latchup (SEL). The converter will also be designed to cope with high magnetic field constraints, with low electromagnetic interference (EMI) for operation in the proximity of the noise-sensitive front-end electronic boards.

The hybrid GaN and CMOS integrated module DC-DC converter has the following specifications:

• Input voltage of 18V regulated down to an output voltage of 1.4V, with 5A maximum load current. The 18V input voltage is one of the main benefits of the proposed work (allows higher voltage delivered to the core which significantly helps with the power dissipation and cooling requirements).

• Exhibits >80% efficiency

• Integrated, compact, low-mass, single-module DC-DC converter solution. The components will be integrated to provide a single-package solution to meet the sizing requirements of most of the detectors in large particle physics experiments.

The feasibility of the design has been verified by designing and simulating the whole system, including the CMOS controller/drivers with GaN power stage, and also designing, fabricating and testing the first prototype board-level system of the DC-DC converter. This prototype system includes a candidate GaN power stage and many other components that will be parts of the final, radiation-hard system. A component off the shelf (COTS) driver chip was selected to drive the GaN stage in the prototype hardware system. The COTS driver is not tolerant enough for the extreme levels of radiation present at the detector cores, but allowed to collect important information on the DC-DC converter performance. The test results showing 18V input voltage, 1.4V output voltage, 5A output current and 82% efficiency will be discussed in the conference presentation. Meanwhile, a 0.35um CMOS chip that contains the controller and drivers, as well as radiation effect tests structures has been fabricated in April 2017. Schedule permitting, test results of this chip will also be discussed in the conference.

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