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Development of the radiation and magnetic field tolerant DC/DC converter system for the ATLAS ITk Strip Detector.

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The custom design, radiation and magnetic field tolerant step-down DC/DC converter system was developed to supply LV power for the ATLAS ITk Strip Detector segments. The system is modular and consists of custom frames with embedded cooling plates and insertable boards containing two or four output channels. Each channel comprises a 48-to-11 V DC/DC converter, hardware overcurrent and overvoltage protection, correction circuitry to compensate for the voltage drops along the cables, and control and monitoring functionality based on the AMAC chip. This contribution presents the design and performance of the DC/DC converters system, including radiation tolerance evaluation.

Summary (500 words)

The existing Inner Detector in the ATLAS experiment will be replaced with an all-silicon detector named the Inner Tracker (ITk) for the High Luminosity LHC upgrade. The outer region of the ITk is composed of the Strip Detector, which consists of a four-layer barrel and two end-caps with six discs each. The power distribution system for Strip Detector will include an intermediate step-down DC/DC (48 V to 11V) converters localized inside the ATLAS detector between muon chambers and calorimeter in the regions called Patch Panel 2 (PP2). The paper presents the development and current status of the custom design DC/DC converter system. There will be two types of DC/DC boards, one with two DC/DC channels providing 11V output voltage and up to 10 A current, and the second one with four DC/DC channels, providing 11V and up to 5 A. Each channel comprises a 48-to-11 V DC/DC converter, hardware overcurrent and overvoltage protection, correction circuitry to compensate for the voltage drops along the cables, and control and monitoring functionality based on the AMAC chip. In addition, the crate controller board provides a control and monitoring interface between DC/DC channels and ATLAS Detector Control System. The distribution of the input and output power lines is organised using a custom-designed crate backplane, which is also used to distribute the e-links for the communication between the crate controller and the DC/DC boards.
Two critical requirements drive the system's development: tolerance to radiation and the magnetic field. The magnetic field up to 0.5 Tesla precludes using the ferrite core inductors, and the air-core inductors have to be used. The expected radiation levels in the PP2 regions are moderate: total ionising dose up 20 Gy, 1 MeV n_{eq}/cm^{2} fluence up to 3x10^{11}/cm^{2} , and fluence of hadron above 20 MeV up to 3x10^{11}/cm^{2}. Still, the effects of radiation damage to electronics are not negligible. The development of the system is based on the Components of the Shelf (COTS) approach. Thus, evaluating the radiation tolerance of critical semiconductor devices was an essential part of the development program. More than ten different types of key semiconductor devices were tested in several irradiation campaigns, including irradiation with proton beams of energy ~230 MeV, neutron irradiation, and gamma irradiation.
The Two further requirements driving the elaborated system design are the thermal management and the grounding and shielding rules. The system has to be thermally neutral to the surrounding environment, and the magnetic field precludes using any fans. The thermal management on the DC/DC board level and the crate level, combined with the requirement of keeping each channel completely floating with respect to the crate and cooling interfaces, appeared to be other driving issues for the elaborated concept.

In the paper, we will present the design of the DC/DC converter, the prototype's performance, and the results of irradiation tests for the components as well as for the complete prototype boards.

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