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System Integration Issues of DC to DC converters in the sLHC Trackers

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The upgrade of the trackers at the sLHC experiments requires implementing new powering schemes that will provide an increased power density with reduced losses and material budget. A scheme based on buck and switched capacitors DC to DC converters has been proposed as an optimal solution. The buck converter is based on a power ASIC, connected to a custom made air core inductor. The arrangement of the parts and the board layout of the power module are designed to minimize the emissions of EMI in a compact volume, enabling its integration on the tracker modules and staves.

Summary

1. Introduction.

A power distribution scheme based on the use of on-board DC to DC converters has been proposed to efficiently distribute power to the front-end electronics of the sLHC trackers. The scheme consists of a first stage buck converter located on the front-end modules or staves, followed by a second-stage switched capacitor converter embedded in each front-end ASIC. An overall efficiency above 80% is expected. Beyond the challenge of developing radiation and magnetic field tolerant converters, the proposed buck converter has to be integrated within the front-end modules minimizing the material budget and the board area. At the same time, the converter must be designed such that the emission of electromagnetic interferences is minimized down to a level that is compatible with the front-end noise requirements.

1. Integration of the power converters.

The environmental constrains and the need for a reduced material budget both imposes the need for a custom, integrated design of DC to DC converters. The integration of the first stage buck converter is achieved through the development of a power ASIC that embeds most of the functions and components. The output inductor and the large input and output decoupling capacitors can't be integrated in the ASIC and they required an appropriate optimization of material and size without compromising the need for reduced EMI emissions. Because the second stage handles less power and is inductor-less, it is directly embedded in the front-end ASICs, requiring only a reduced set of external capacitors.

1. Air core inductors.

The output inductor of the buck converter is a critical component that has to meet specific requirements: achievable inductance values, DC and AC series resistance, emission of electromagnetic interferences, component dimensions and effective implementation. To be compatible with the DC magnetic field to which it will be exposed, only air-core inductors were considered. Solenoid and toroid topologies were analyzed and compared by means of electromagnetic simulations and modeling. The optimal solution is represented by PCB air-core inductors, that are easy to manufacture and to shield; DC and AC resistances are expected to be at the same level as for the solenoid inductors. The properties of the selected geometries will be presented.

1. Board layout considerations.

The buck controller ASIC is designed such that it requires very few peripheral components on the board. The integration of the PWM controller, with the power switches, the feedback and the compensation circuits in the ASIC limits the need for external components to only few capacitors and one inductor. The pin assignment of the buck controller ASIC is such that the copper traces are shortened as much as possible, in benefit of a reduced board area and of the subsequent reduction of EMI emissions. With this, the converter finds naturally its place on the edge of the hybrid modules and at the head of staves.

1. EMC performance.

The front-end electronics commonly used in the trackers are sensitive to electromagnetic interferences. Those are minimized with careful board layout. A compact power module that encloses the EMI sources within a shielded enclosure with reduced material budget is proposed, further reducing the noise sources. The noise

characteristics are determined, critical distances are defined between the converter and the front-end circuits, and quantitative measurements are performed.

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