Contribution ID: **24** Type: **Poster**

A prototype ASIC buck converter for LHC upgrades

Thursday 18 September 2008 16:15 (20 minutes)

Given the larger number of channels and the need for reduced material budget in the SLHC trackers, alternatives to the present power distribution scheme have to be explored. In this context we are envisaging a new architecture based on custom switching converters able to work in the high radiation and high magnetic field environment of the experiments. A prototype of the converter has been designed and integrated in an ASIC. This includes the fundamental building blocks of a buck converter that can be used in later and more complete designs and even in different topologies. Design techniques, functional and radiation tests of the prototype will be discussed.

Summary

The number of channels in SLHC trackers will increase and the front-end (FE) circuits will probably require larger supply currents at lower voltage. Since the efficiency of the present power distribution scheme is around 50% due to the power lost on cables, any increase in the supply current will dramatically affect the efficiency. It is therefore necessary to evaluate alternative power distribution schemes.

A promising approach consists in the distribution of power through a higher voltage bus (up to 24V) to DC-DC converters positioned closed to the FE electronics. These locally convert the bus voltage to the low voltage needed by the FE, reducing the current in the bus by a factor close to the voltage conversion ratio, hence decreasing the power lost in the cables.

Since the converters should be placed as close as possible to the FE electronics to reduce the high current path, they need to work properly in the harsh environment of the experiments characterized by high level of radiation (up to hundreds of Mrd) and intense magnetic field (up to 4T). These constraints make commercial switching converters, using ferromagnetic materials saturating well below 4T and not rated for reliable radiation hardness, unusable for this purpose.

In this context we are developing a custom inductor-based switching converter where tolerance to radiation and magnetic field are specifically addressed. Radiation tolerance up to 200Mrd has been demonstrated on custom-modified layouts (results presented in TWEPP 2007) for a high voltage 0.35 um CMOS technology usually employed in automotive applications. Magnetic tolerance can be achieved using air core inductors that avoid magnetic core saturation, although at the price of introducing constraints in the design of the converter.

In this contribution, we present a prototype converter that has been developed in the selected 0.35 um technology. The prototype includes the fundamental building blocks of a buck converter that can be used in later and more complete designs and in different converter topologies. It contains the two power switches and the control circuit.

The dimension of the two switches is optimized to reduce the switching and conductive losses as much as possible. The resistance of each switch is 165mOhm and the gate capacitance is 2nF.

The control circuit allows the converter to supply a constant voltage to the load even if the load current is varying. This local regulation capability is a very attractive feature of the power distribution scheme using converters, since it allows for providing the FE electronics with the appropriate power at any time with minimum losses. The control circuit topology used in this design is the voltage mode control.

Our prototype needs some external components that will be integrated in a later version of the converter. This was done in order to have more freedom for testing purposes, as it enables to vary the switching frequency, the compensation network to stabilize the feedback loop, the input and load voltage and the load current.

Design techniques used for the stability of the feedback loop will be presented and layout specificities will be discussed. The prototype shall be delivered in July and functional and radiation tests will therefore be available for the workshop and will be presented.

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Session Classification: POSTERS SESSION