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Inductor based switching DC-DC converter for low voltage power distribution in SLHC

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In view of a power distribution scheme compatible with the requirements of future trackers in SLHC, we are evaluating the feasibility of on-board inductor based DC-DC step-down conversion. Such converter should be integrated and capable of operating in radiation environments and magnetic field. We present results concerning the choice of the CMOS technology for the integrated circuit, the research of magnetic components properly working in presence of high magnetic field, calculations of the expected efficiency and EM noise emission.

Summary

The distribution of power in future LHC experiments represents a difficult engineering challenge, given the global requirements in terms of power needs, available cooling capacity and limited material budget. The harsh radiation environment (up to several Mrd in Total ionizing Dose) requires all the electronics to be radiation tolerant and the intense magnetic field (up to 4T) makes conventional switching converters unusable in many locations.
In view of LHC upgrades where front-end circuits might require even larger supply currents, it is necessary to evaluate an alternative power distribution scheme. This could be based on the distribution of higher voltage (24 -48V) from external power supplies to converters installed locally inside the detectors that have to convert the power to the low voltage and high current required by the front-end circuits. Due to the vicinity of the switching converter to the sensitive detector elements, EM noise has to be carefully studied.
We are evaluating a solution involving an inductor based switching DC-DC step-down converter. A preliminary analysis is in progress in order to understand the feasibility and availability of the different components of the converter that match the above requirements.
We have selected a 0.35 um CMOS technology usually employed in automotive applications. This technology can stand up to 80V and it can be made radiation tolerant with some modification to the layout. Irradiation results on leakage current and threshold voltage shift up to 80 Mrad will be shown.
As regular ferromagnetic inductor cores saturate in such high magnetic field we are evaluating different air core inductor designs. To avoid EM noise we studied the emitted magnetic field from differently shaped air core inductors (solenoidal and toroidal). Inductors of 500nH made by 32 turns with a volume of 340mmˆ3 were simulated with a 3D finite element program with a current of 1A. The results illustrating the residual magnetic field for different geometries will be shown.
A simulation program was written to evaluate the efficiency of this converter, taking into account the parameters and parasitic values of the CMOS technology, inductor and capacitor and using different values of input voltage, output current and voltage. We will show that an efficiency above 80% could be achieved. In the nominal case of input voltage equal to 24V, output voltage 2.5V, output current 1A, switches on-resistance 110mOhm, inductance 500nH and at a frequency of 1Mhz, the efficiency is 89%.

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