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Silent and slim DC-DC converters for the CMS MTD BTL and ECAL Barrel for HL-LHC.

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The MIP Timing Detector (MTD) is introduced in the CMS experiment to measure the production time of MIPs. Power Conversion Cards (PCCs) regulate low-voltages in the MTD barrel region. They host three radiation and magnetic field tolerant DC-DC converters. The height of the PCC is limited to 7 mm. This necessitated the development of custom inductors and shields. Additionally, the CMS Electromagnetic Calorimeter is upgraded. On-detector Low Voltage Regulator (LVR) cards host six DC-DC converters and one linear regulator. We will present for both cards their design evolution, stack-up and layout optimization, noise filtering choices, reliability and performance evaluations.

Summary (500 words)

The High Luminosity Large Hadron Collider (HL-LHC) will deliver up to 200 proton-proton interactions, with 14 TeV center-of-mass energies, over an estimated period of 190 ps per bunch-crossing. With an initial resolution of 30-40 ps, the new Minimum Ionizing Particle (MIP) Timing Detector (MTD) will measure production time of MIPs. This will improve identification and event reconstruction capabilities of the CMS experiment in the increased pile-up conditions. The functional building block of MTD's Barrel Timing Layer (BTL), called Readout Unit (RU), is powered by two Power Conversion Cards (PCCs). Design of BTL utilizes 864 PCCs. Additionally, the Electromagnetic Calorimeter Barrel (EB) will undergo an upgrade of electronics to cope with the increased luminosity effects on the resolution of particles'energy measurements. The EB is powered via 2448 Low Voltage Regulator Cards (LVRs).

The PCCs will operate in a magnetic field of 3.8 T and at -35°C. Estimated radiation levels reach a fluence of 1.90×1014 neq/cm2 and a total dose of 32 kGy. BTL as a single layer sub-detector requires high reliability of its components. The reliability goal for PCCs allows for 0.5% failures in 10 years of operation. Implemented design technics include redundancy of components and vias and conservative layout parameters. Current RU allocates the vertical space for the PCC of 7.0 mm and positions the cooling interface below the PCBs. These constraints exclude the use of FEASTMP modules and imply a custom development. The environment of LVRs is less harsh, with lower radiation levels and operating temperature of +8°C. Nevertheless, equal care was taken when engineering this card and identical solutions applied as in the PCCs. The measurements of the prototypes show improved efficiency and similar near field emission while maintaining slimmer form factor compared to FEASTMP.

To comply with the height limit, a flat toroid was designed. This decreases the emitted magnetic field and reduces noise emission w.r.t. solenoidal inductor solution. Implemented layout techniques include hermetic shielding with double-layer via guard-rings and avoidance of through vias in the shielded region, reducing the EM field leaks. The 4.4 mm high toroid's design is a 34-winding topology made of 0.6 mm copper wire. Measurements on a production lot of 650 pieces show an average inductance of 440 nH at 2 MHz in air, 435 nH when shielded and a DCR of 25.5 mΩ compared to 407 nH and 30.3 mΩ measured with FEASTMP toroid. PCC hosts three, and LVR six, DC-DC converters based on radiation tolerant switching ASICs. Two ASIC choices: FEAST2 and bPOL12 were assembled on a set of prototype cards and their performance measured. Additionally LVR card hosts one LinPOL12 ASIC. The thermal contact of the packages was improved using blind&buried vias under the ASICs. The optimization of the input inductance to the decoupling capacitors leads to switching spikes reduction, necessary for reliable operation of bPOL12 ASIC.

The designs of PCC and LVR have matured to a production ready state, offering a compact DC-DC converter design. In this contribution, design choices, simulation, and measurement results will be presented.

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