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The radiation-hard low-Voltage LDO for HGCAL in the CMS Phase-2 upgrade

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The CMS detector will see the replacement of its existing endcap calorimeter with a new high granularity calorimeter (HGCAL), which will need to withstand much higher radiation levels than the present endcaps. This poses tight constraints on the front-end electronics, including the powering chain. As part of this chain, a low-dropout linear regulator (LDO) has been designed and prototyped for post-regulation for HGCAL, providing extremely low noise stable power to the analog front-end. We present results from tests of the LDO, including from a detailed irradiation campaign (TID, SEE, neutrons).

Summary (500 words)

The HGCAL calorimeter, which will replace the endcap calorimeters in the CMS detector, will undergo unprecedented luminosity and radiations levels due to collisions from the HL-LHC. A radiation-hard adjustable high current custom low-dropout regulator (LDO) has been designed for the post-regulation and powering of sensitive analog front-end devices for the HGCAL electronics system. The LDO offers an excellent transient response at a current of 3000 mA, maintaining a low dropout of under 200 mV. The functional characterization of the LDO showed full compliance with the strict design specifications. The LDO will be placed in all regions of HGCAL facing a dose of up to 200 Mrad and a fluence of up to 8 x 10ˆ15 MeV neq cmˆ-2. A comprehensive irradiation study of the LDO took place to validate its design for mass production and radiation hardness for the duration of the HL-LHC operation. Three different radiation characterization tests were devised, including total ionizing dose (TID), a heavy-ion Single Event Effect (SEE), and a neutron beam exposure. The TID test, performed at CERN with X-Rays, is necessary to estimate the ageing effects on the performance of LDO after an accumulation of dose from 10 years of HL-LHC operation. The LDO was irradiated up to 1 Grad. The output adjustment functionality and internal monitoring indicators of the LDO also showed flawless function even after such a high TID exposure. A voltage drift smaller than 20 µV/Mrad was observed within 2% deviation over the entire TID range. An SEE test was conducted at the Cyclotron in Louvain-La-Neuve (Belgium) with various heavy-ion beams. To enhance the radiation robustness, no digital block is used in the LDO design except one latch in the test block. The SEE test allows the observation of transients at the output of the LDO caused by a single, energetic particle hit and temporary malfunction of status pins. This test also excludes the occurrence of possible latch-up and gate rupture in the device. A fast trigger-based test system is designed to detect and record eventual Single Event Transients (SET) due to the presence of sensitive nodes in the design. Lastly, to test the foreseen large neutron flux in the experiment, LDO samples were sent to the Jozef Stefan Institute (Slovenia), and exposed to 1.0 x 10ˆ16 and 2.0 x 10ˆ16 MeV neq cm-2 of neutron fluence. The post-irradiation analysis would reveal any displacement damage caused by neutrons in the internal atomic structure of the LDO.

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