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Radiation and magnetic field qualification of LVPS – a unified 12 VDC power source for the CMS detector.

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Efforts aiming at consolidating the powering for the CMS detector have led to the development of a Low Voltage Power Supply (LVPS). The LVPS converts 380 VDC to 12 VDC, suitable for powering the widely used bPOL12V Point-Of-Load DC-DC converter. To limit cables size, the LVPS must be hosted in the CMS experimental cavern, being exposed to ionizing radiation and stray magnetic field of up to 120 mT. The device is made of Commercial Off-The-Shelf (COTS) components, therefore thorough qualifications at various design stages were performed to ensure its reliable operation in the harsh environmental conditions for the HL-LHC era.

Summary (500 words)

The decision to consolidate the CMS detector's powering scheme by using DC-DC converters at the point-of-load (POL) [1][2] presents an opportunity to standardize the upstream power source, supplying electrical power to these POL converters. Electromagnetic Calorimeter Barrel, High-Granularity Calorimeter and Minimum Ionizing Particle Timing Detector, >500kW of power must be brought to them at 9-12VDC. A common Low Voltage Power Supply (LVPS) is being developed, which will be hosted in the CMS experimental cavern, limiting size and cost of cables, but being exposed to ionizing radiation and stray magnetic field of up to 120mT. Consequently, a custom development was launched for an appropriate LVPS using Commercial Off-The-Shelf components (COTS). This contribution describes the process of thorough qualification at various design stages to ensure compliance with this operating environment and reliable operation.

Radiation tolerance was first evaluated at the component level. Crucial components were selected, including Analog-to-Digital Converter (ADC), Digital-to-Analog Converter (DAC) and gate driver. Subsequently, system-level tests of the main building blocks were conducted, followed by a system-level radiation test of an LVPS prototype. The reason for multiple testing stages is that COTS components can exhibit effects under elevated radiation levels that are not typically encountered in terrestrial radiation environments. Mitigation methods are employed to manage the observed radiation-induced effects. One practical example is the presence of radiation-induced voltage spikes at the output of a voltage amplifier, used for the measurement of output current by means of shunt resistance [Figure 1]. This issue was identified thanks to careful test planning and continuous high-rate (500kS/s) monitoring, employing a simultaneous-sampling acquisition system [Figure 2]. The high-quality data demonstrated that the shape of the spikes remains consistent over time. Thus, their amplitude may be attenuated by a lowpass filter, mitigating the undesired effect.

Magnetic field tolerance was an equally crucial qualification element. To enhance efficiency and meet power density requirements, the LVPS incorporates an LLC conversion stage with a shielded transformer reducing the input voltage from 380VDC to an intermediate level of ˜30VDC, regulated further with a step-down stage to 7-13VDC. The magnetic shield is a cubic box with 5mm thick walls made of high-purity steel (ARMCO) aiming to prevent excessive magnetic flux penetration to a transformer [Figure 3].
The test in a magnetic field revealed that the shield is insufficient, and the transformer core saturates. The reason for that was insufficient magnetic permeability of the shield in comparison to ferrite material used in the core with its peak relative permeability of 3000. This situation was reproduced with electromagnetic simulations using COMSOL. The simulation demonstrated that thermal annealing of the ARMCO, improving

its magnetic properties, will reduce the flux density penetrating the core of the transformer by an order of magnitude [Figure 4], solving the problem.

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