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48V input rad-hard DCDC converters for HEP experiments: development and results

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Two new radiation-hard DCDC converters are in development, which tolerate a higher input voltage (up to 48V) and provide a larger output power compared to existing solutions. They are called bPOL48V and rPOL48V, and they employ Gallium Nitride devices. bPOL48V can provide 12A of output current with 90% efficiency and is close to production readiness, while rPOL48V is in an early stage of development and is designed to provide an output current up to 30A. A linear regulator (linPOL48V) able step down the voltage from up to 48V with maximum output current of 200mA has been also designed and tested.

Summary (500 words)

In the past, a compact, rad-hard and efficient power distribution strategy for HEP detectors has been presented, based on two cascaded Point-of-Load DCDC converters: a first-stage converter (bPOL12V) having as input a 12V line creates a 2.5V domain, which powers the opto-electronic components. Second-stage converters (bPOL2V5) further step down the voltage from 2.5V to supply the front-end analog and digital circuits. bPOL12V and bPOL2V5 are today in production for HL-LHC.

In this work, a new conversion stage is introduced, able to step down the voltage from up to 48V. It can provide a larger output power compared to existing converters and can be used to supply bPOL12V, allowing to significantly reduce the current in the long cables from the off-detector power supplies.

Two converters with different architectures (bPOL48V and rPOL48V) are in design phase. Both use commercial Gallium Nitride (GaN) devices as power switches, which offer a reduced on-state resistance and a faster switching speed compared to silicon MOSFETs, leading to increased efficiency. In addition, GaN devices are highly tolerant to radiation. In particular, the commercial GaN power stage adopted for bPOL48V has been successfully tested for radiation (Total Ionizing Dose, TID, up to 100Mrad, Linear Energy Transfer, LET, up to 45 MeV*cm2/mg and displacement damage up to 1e15 n/cm2 1MeV eq).*

bPOL48V is a buck converter able to provide a maximum output current of 12A. Its output voltage can be programmed down to 1.2V, making it usable also for the 12V-20V to 1.2V-2.5V conversion. Its controller has been designed at CERN using a high-voltage commercial 0.35µm CMOS technology. It features several internal linear regulators to provide the correct voltages to the control circuitry, a predictive logic to optimize the dead times and a voltage-mode control loop.

*The measured efficiency at full load is around 90% (for Vin=48 and Vout=12V), the converter has been tested up to a TID of 50Mrad without appreciable change in the performance, while single event tests showed that there are no destructive events up to an LET of 40 MeV*cm2/mg. Only rare Single Event Transient on the output voltage have been found, with variations of less than 5% for LET=28.8 MeV*cm2/mg and less than 10% for LET=40 MeV*cm2/mg. Displacement damage tests are ongoing.

rPOL48V is today in an early stage of development. It is based on a resonant architecture, which allows using significantly smaller inductors compared to bPOL48V. It has a fixed conversion ratio of 4 and features very high efficiency and current capability up to Iout=30A. A non-rad-hard version of this converter is under development using commercial components: commercial GaN devices for the power stage, commercial drivers, while the control is implemented in an FPGA. In parallel, a rad-hard version of the drivers and of the controller is being designed at CERN.

A rad-hard linear regulator, linPOL48V, has been also developed. It can provide a selectable voltage (minimum 1.2V) from up to Vin=48V. The maximum current rating is 200mA and it has been already tested for TID and SEE, with similar performance to bPOL48V.

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