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Consolidation of the radiation tolerant programmable power supply cards for the LHC beam screen heaters

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For the next LHC run it is required to install 200 W of heating capacity to regenerate the beam screen by desorption of gas trapped on its walls. In the LHC, there are 272 beam screen heaters and the associated electronics limits the heating capacity to 25 W. These electronics are mostly installed inside the LHC tunnel and exposed to its radiation environment.

This paper describes the basic functionalities of the new card and the work done for designing and qualifying under radiation an analog signal multiplexer and a power switch capable of coping with the grid voltage.

Summary

The beam screens are equipped with resistive heating elements of 100 Ω to provide a power of up to 200 W to raise its temperature up to 90 K. This raise of temperature results in the release of gas molecules trapped on the beam screen. During beam operation, the heating power is limited to 25 W, which is also the limit of the currently installed cards. During the next shutdown, 272 power supply cards will be consolidated to raise their limit from 25 W to 200 W. The increased power will be available for use whenever there is no beam in the LHC.

The consolidation requires the development of a new electronics card reusing parts of the existing design that proved to operate reliably.

The consolidated card supports both DC (0-50 V, 0-2 A) and AC (50-230 VAC, 0-4 A) modes of operation. For the new AC mode, the card uses isolation transformers and power MOSFETs with pulse width modulation (PWM) regulating power from the AC grid. For the selection of the radiation tolerant power MOSFETs, a radiation campaign took place at CERN's CNRAD experimental area during 2012. CNRAD offers a mixed radiation field, similar to the one in the LHC tunnel. Three different commercial power MOSFET electronics were tested at CNRAD for approximately 5 months to simulate LHC operation of many years. The MOSFETs were tested both in passive (standalone) and active (230VAC grid applied) modes. All types of power MOSFETs survived the passive tests and one MOSFET type survived the active tests. The total integrated dose (Gy), equivalent neutrons (>1 MeV) and hadrons (>20 MeV) exceeded the radiation requirements of the design. This is true for all 3 MOSFET types because during LHC irradiation (beam ON) the MOSFETs are disconnected.

The heater power cards provide measurements of the delivered current and voltage (AC and DC), of the protection thermometer (thermocouple or resistive sensor) and of some analog measurements used to correct variations on the amplifiers or the ADC. To reduce cost and simplify the design, it was decided to use analog switches. Two analog switches using a radiation-hard technology and one commercial part were considered. For the commercial switch, two radiation campaigns took place; one at CNRAD exceeding the radiation design target and a second at the Proton Irradiation Facility (PFI) of Paul Scherrer Institute (PSI) in Zurich, CH. No failure was observed up to a tested TID of 2.3 kGy-Si at PSI (230 MeV protons).

The highest priority of the design is the safety of the LHC machine. The card satisfies all identified issues that could result in hazardous situations requiring intervention in the LHC vacuum envelope during LHC shutdowns. Extensive feedback information is available to provide online error identification and diagnostics that could be used, as well, for assessing the ageing of the card components.

The new power card is designed to safely operate in the LHC environment even in close proximity to the higher radiation regions of the dispersion-suppressors.

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