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Design of a Radiation Tolerant System for Total Ionizing Dose Monitoring Using Floating Gate and RadFET Dosimeters

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The necessity to improve the accuracy of the Total Ionizing Dose (TID) measurements at CERNs'radiation zones, has driven the research of new TID-measuring candidates. For this purpose, a TID Monitoring System (TIDMon) is designed, that investigates the effects of the TID on a Floating Gate Dosimeter (FGDOS) compared to Radiation-sensing Field-Effect Transistors (RadFETs). The monitoring system is characterized inside the CERN test facilities where the LHC mixed radiation field is reproduced. The architecture of the TIDMon, the radiation tolerance techniques and the design choices adopted for the system are presented in this work

Summary

The need for upgrading the Total Ionizing Dose (TID) measurement accuracy of the actual version of the Radiation Monitoring system for the LHC complex, drove the development of a TID Monitoring (TIDMon) system based on the Floating Gate Dosimeter (FGDOS). The TIDMon offers a modular platform which allows to study different configurations of the FGDOS, to determine if it's a good candidate compared to the RadFET that has already been used in the RadMon.

The FGDOS is an ionizing radiation sensor based on a floating gate transistor structure. Prior irradiation, the floating gate is charged through an injector. Inside the sensor, an embedded MOS and a Voltage Controlled Oscillator (VCO) read and convert the gate potential into a square wave signal. During irradiation, the negative charge induced neutralizes the positive charge stored in the gate, reducing the gate potential. Two different floating gates can be selected in the sensor, with two different sensitivities –low and high, which allows the adaptation of the monitor sensitivity to the radiation field.

The manual recharge, the automatic recharge, the sensitivity, the recharge and threshold frequencies of the FGDOS are configurable. In automatic mode, when the output frequency goes bellow the defined threshold (and thus the corresponding charge of the gate), the TIDMon automatically charges the floating gate to the desired recharge frequency. These frequencies are defined for each sensitivity level, such that to keep the sensor in its most linear operating range. The TIDMon provides also the possibility to bypass the VCO, and thus obtain on the output the current induced by the floating gate, in order to characterize the floating gate directly.

The architecture of the TIDMon is built around a Flash-based FPGA (Actel ProAsic3) which embeds several custom controllers that manage the peripherals (ADC, sensors). The FPGA allows the remote control of the settings and offers a modular architecture, improving the FGDOS dosimetry data processing. An 8-channel 16 bit ADC is used to acquire the dosimetry from the RadFETs and the other analog signals (power supplies voltages, images of currents sources and temperature) that monitor the status of the board.

The architecture is based on the RadMon V6 whose radiation testing was performed using protons, 60Co, and 1 MeV neutrons at the components level. The TIDMon was tested at the system level with 60Co, and mixed field radiation. It was proven to be operational up to a TID of at least 25-30 krad (Si). The Triple Modular Redundancy (TMR) mitigation technique is applied on the registers automatically by means of a commercial synthesis tool, to increase the robustness of the FPGA embedded controller. The RAM blocks have been triplicated manually in the code because the tool was not able to do it automatically.

The TIDMon system proved the robustness of its TID measurement during several irradiation campaigns and the FGDOS controller design showed good results. Further studies are required to continue to characterize the FGDOS to several environment factors (temperature, dose rate···) and irradiation campaigns have been planned.

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