Radiation hardness testing of Low Voltage Distribution Board for CBM-MUCH Experiment

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Introduction

We are involved in building the muon detector (MUCH) for the compressed baryonic matter experiment at FAIR. The goal of this fixed target experiment is to explore the QCD phase diagram in the region of high baryon densities using high energy Au-Au collisions. This experiment requires high position resolution and high rate capabilities of the tracking detectors, which leads to a requirement of higher granularity thus a large number of read out channels [1]. Entire readout for first two stations of MUCH will have 1600 FEE boards to be powered individually. To cope with such requirement Low Voltage distribution Board (LVDB) is planned to be mounted on detector itself so that cable load can be minimized . The experiment will face high intensity and high interaction rate thus there would be a substantial incidence of gamma (20krad for 10 years of operation) around our detectors or electronics. The entire electronics components are therefore required to be radiation hard [2].

Functional description of LVDB

The LVDB is an active system, which divides a single channel high voltage (HV) into several low voltage (LV) channels. In CBM experiment one LVDB is supposed to supply power to eighteen FEE boards , each FEE board requires three voltages 1.6V , 1.8V and 2.2V with the current of 1 A ,7.5 A and 0.25A respectively. The LVDB has over current protection and monitoring facility for voltage and current. The prototype design has been tested for two channels as shown in Fig.1.

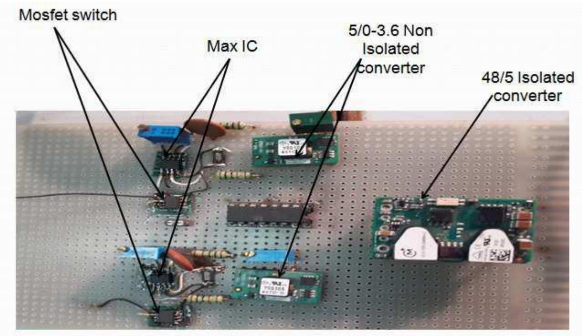

Fig.1: Two channel LVDB prototype.

The LV power supply has very stringent requirement of sector isolation (to avoid sector to sector noise coupling) so in this prototype two DC to DC converters are used. 48V supply has been stepped down to 5V. Using a DC to DC SMPS base isolated converter with forward topology. Output of isolated converter was used to further step down by buck converters (Non-isolated) to meet the require voltages.

Gamma Irradiation

Gamma is an ionizing radiation which generates electron hole-pairs in substrate of semiconductor as well as in depletion region. These ion pairs increase leakage in semi-conductor and lead to failure of the device thus gamma radiation hardness is the prime concern in the design of LVDB (Low voltage distribution box). Gamma irradiation test has been conducted at IUC Kolkata with cobalt 60 gamma irradiation facility with the dose rate of 4krad/minute. Various Components were tested for expected gamma radiation level. As shown in Fig.2 samples (48/5 isolated DC/DC converter) were placed in a cylindrical vessel which was irradiated uniformly inside the radiation facility. For cooling purpose a fan was mounted just on the head of the converter. Converter was irradiated with gamma for an interval of two minutes per session. After being irradiated for two minute, every time converter had been annealed for five minutes. Though fan cooling and very short term operation followed by annealing were there yet just for the sake of safety all the converters were operated at quarter load only.

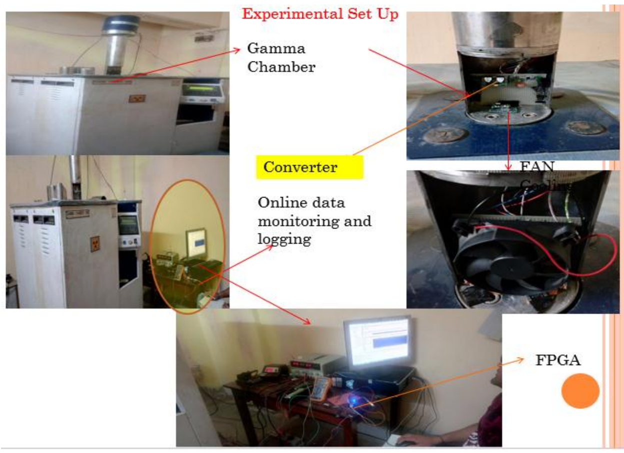

Fig.2: Experimental Setup

Different converters from various manufacturers were irradiated and after multiple failures few of them were qualified our desired radiation tolerance specification.

Real time data acquisition of device under test

During irradiation test voltages of device under test were monitored continuously. As shown in Fig.3, ADC digitized the real time signal from the sensors and fetch that data to Spartan-6 LX9 FPGA board as shown in figure. With the preliminary processing and data segregation. Field Programmable Gate Array (FPGA) send that data to computer via Chip scope pro Software. Mat-lab 2010a is used as back end software. Data segregation, data merging, data plotting scripts were written in mat-lab for thorough inspection of health of the component under irradiation.

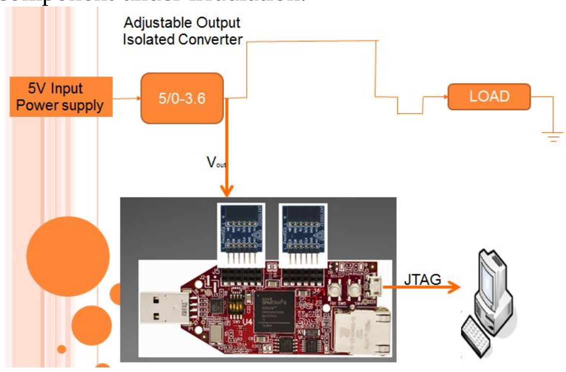

Fig.3: FPGA base monitoring system.

Experimental Results

Voltage response and efficiency of the converter with and without radiation were taken. Voltage response of isolated converter is shown in Fig.4. As expected output voltage without irradiation is stable with 50mV peak to peak ripple.

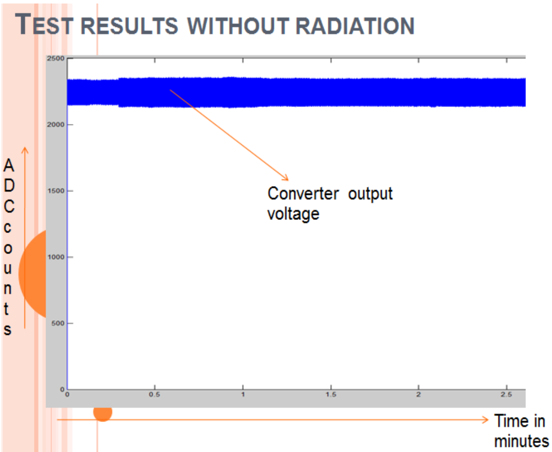

Fig.4: Voltage response without radiation

Voltage response of converter with radiation is shown in Fig.5. By online plotting of converter response it was seen that the converter can withstand 26.25 krad without any appreciable change in DC voltage. Average peak to peak value of ripple is more or less same before and after irradiation. Just before failing converter tries to anneal from the radiation damage but damage rate (proportional to the accumulated dose and present dose rate) is much higher than annealing rate thus momentary restoration of voltages can be seen near the failure dose.

As in CBM experiment whole electronics supposed to be have gamma resistance of 20krad thus after 20krad efficiency had been measured. Fig.6 shows comparative study of efficiency before and after irradiation.

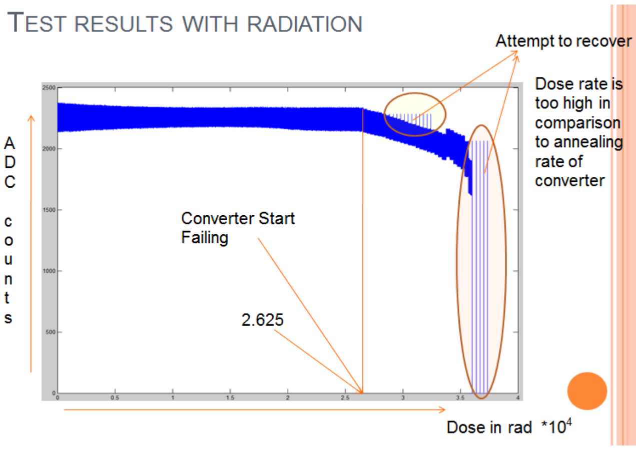

Fig.5: Voltage response with radiation

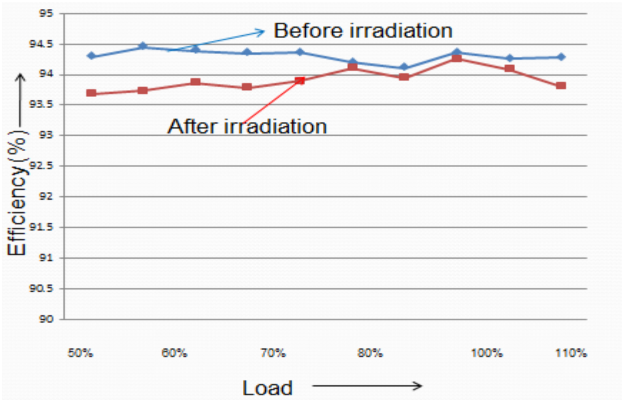

Fig.6: Efficiency curve

Conclusion

As converter can withstand the desire radiation level without any appreciable change in electrical characteristic thus it could be used in CBM electronics and other such high energy physics experiment.

Acknowledgment

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References

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