CERN	European Council for Nuclear Research
ALICE	A Large Ion Collider Experiment
OCL	Oslo Cyclotron Laboratory
UiB	University in Bergen
DUT	Device Under Test
UiO	University of Oslo
RCU	Readout Control Unit
RCU2	Readout Control Unit 2
LHC	Large Hadron Collider
FEE	Front End Electronic
FEC	Front End Card
RAM	Random Access Memory
FPGA	Field Programmable Gate Array
SEE	Single Even Effect
SEU	Single Event Upset
SET	Single Event Transient
SEL	Single Event Latchup
MBU	Multiple Bit Upset
IC	Integrated Circuit
PCB	Printed Circuit Board
LVDS	Low-Voltage Differential Signaling
NI	National Instruments
DAQ	data acquisition
SPI	Serial Peripheral Interface
SF2	SmartFusion2
CML	Current-Mode Logic
TTC	Timing, Trigger and Control
TPC	Time Projection Chamber

LVPECL	Low Voltage Positive Emitter Coupled Logic
RAM	Random access memory
SRAM	static RAM
PM-tube	PhotoMultiplier Tube
TID	Total Ionizing Dose
JTAG	Joint Test Action Group
UART	Universal Asynchronous Receiver/Transmitter
VHDL	VHSIC Hardware Description Language
CHSIC	Very High Scale Integrated Circuit
CPU	Central Processing Unit
MCU	Microcontroller Unit
ADC	Analog to Digital Converter
LET	Linear Energy Transfer
SOC	System On a Chip
CMOS	Complementary Metal Oxide Semiconductor

1 Introduction

At European Council for Nuclear Research (CERN) in Switzerland there are being conducted experiment on fundamental structure of the universe. This is done by accelerating particles up to a energy of 7 TeV per proton, and then crash with a other particles with same energy. This experiment is done by connecting several accelerators with higher and higher energies together, the largest one is called Large Hadron Collider (LHC), and is the largest particle accelerator ever built, installed in a 27 km long tunnel. To detect what is happening to the particles when crashed, there has been build several detectors that is placed in the tunnel. One of these is called the A Large Ion Collider Experiment (ALICE) detector. The ALICE detector is using electronics to measure and detect what is happening under a crash.

The Physics and research group at the University in Bergen (UiB) has been working with CERN on the ALICE project since it started. One of the main boards used in the ALICE detector is the Readout Control Unit (RCU). Now there has been decided that a new RCU board shall be made, that is called Readout Control Unit 2 (RCU2). Everything that are going to be used at CERN has to be made sure that it can survive in the radiation level that can occur there. Therefore every Integrated Circuit (IC) planned to be used for the design of the RCU2 board has to be tested for radiation to be sure that it won't fail when it is installed in the ALICE detector.

1.1 How to test

The radiation in the LHC is dominated by high energetic neutrons and protons, mostly neutrons with a estimated fluence of $(0,6-1,1)\times10^{11}\ neutrons/cm^2$. Therefore it would be preferable to test our electronics with a neutron beam, but since there are few labs who can produce a neutron beam compared to proton beam most of the electronics is only tested at Oslo Cyclotron Laboratory (OCL) with a proton beam. There has been done experiment that compares SEU induced by neutrons and protons [1], and the result shows that it is possible to use a proton beam instead of proton beam with small deviations. By comparing a Proton beam with a neutron beam of 21MeV we see that we get 10-25% less SEU cross section for a proton beam compared to a neutron beam. If we increase the energy to 88MeV then we get close to none deviations.

The tests that are done through this thesis are so called dose-tests. That is irradiation up to a level where an error can clearly be seen or when a high enough dose has been reached without detecting errors. Current consumption and the outputs of the IC are monitored through the whole irradiation process. The dose that we could expect at CERN for a 10 year period in the ALICE detector is estimated to be approximately 0.6 kRad from Pb-Pb collisions that will be run 1 month a year and a little higher for p-p collisions that will be run 10 months a year [3] and [2]. Therefore we could expect a dose of 1-2 kRad during the time it will be used at CERN. If a IC survives more than 5 times of what we would expect at CERN, we could say that it pass the test, that means if it survives more than 5-10 kRad, the device is approved to used in the RCU2 design.

1.2 About this work

When I started working with my thesis in the autumn of 2013 the schematic layout for the RCU2 was basically finished, and most of the component was decided, but not everyone had been tested. So what I have been working on in my thesis are thinking and planing how to test the different IC. In most of the cases I designed a simple test Printed Circuit Board (PCB) which I connected to data acquisition (DAQ) board from National Instruments (NI). By the use of this DAQ the functionality of the IC was tested and current consumption was monitored. For the more advanced IC like the SmartFusion2 (SF2)System On a Chip (SOC)Field Programmable Gate Array (FPGA), I used a starter-kit when designing the test. To measure the low current going into the SF2 chip I also made a current measurement PCB for that purpose. I started my thesis work with making test boards for 8 different ICs. These consist of; power regulators, bus transceivers, limiting amplifier, multiplexer/demultiplexer and buffer. For every each of the different test board that was made I also made labVIEW programs, to control and monitor the tests. After these test board was made working and had been tested, I started working on designing test for the SF2 SOC FPGA. The tests was made on a SF2-starter kit, but with the RCU2 in mind, so that when the hardware for the RCU comes, it will be easy to implement the test on that. I also made two more test board for two IC that was added to the design at a late stage. That was a comparator and a Current Shunt Monitor.

References

[1] Thomas Granlund and Nils Olsson. *A Comparative Study Between Proton and Neutron Induced SEU in SRAMs, 53(4).* 2006.

[2] Ketil Røed. *Single Event Upsets in SRAM FPGA based readout electronics for Time Projection Chamber in the ALICE experiment.* PhD thesis, Norway, 2009.

[3] Georgios Karolos Tsiledakis. *Scale Dependence of Mean Transverse Momentum Fluctuations at Top SPS Energy measured by the CERES experiment and studies of gas properties for the ALICE experiment. PhD thesis.* Technische Universitat Darmstadt, Darmstadt, 2006.