1st IAA Latin American CubeSat Workshop- Brasilia DF, Brazil

Using the NANOSATC-BR1 to evaluate the effects of space radiation incidence on a radiation hardened ASIC

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ABSTRACT

Nanosatellites has expanded the possibilities of testing new design techniques which mitigate the effects of radiation environments (outer space, particle accelerators, nuclear radiations, etc) on integrated circuits (IC). The interaction between radiation and silicon, more specifically MOS devices, gives origin to two classes of problems: a cumulative long term ionization damage denominated Total Ionization Effects (TID) and instantaneous radiation dose effects denominated Single Event Effects (SEE). In order to overcome such problems, two main approaches are usually considered: the usage of a radiation hardened manufacturing process or the employed of commercial CMOS process along Radiation Hardening By Design (RHBD) techniques. Recently, the last one has been more adopted due restrictions and low demand, however it requires an exhaustive design process and testing. The NANOSATC-BR1 is composed by scientific and technological payloads and it is being used for environmental test. One of their technological payloads is the SMDH ASIC, which is intended to detect the fault transient type (bit-flip) related with SEE events along with performance degradation originated by accumulated dose. Data error rate and degradation will be collected over the life of the satellite and sent to Earth for analysis. This work presents a strategy to evaluate the radiation hardened design techniques applied in the SMDH ASIC, providing the qualification and validation of components, which could thus be used with reliability in future projects.

OBJECTIVES

The circuit was designed with the intention of performing functional tests during ionizing irradiation in Earth orbit. The SMDH ASIC, named here as Test Chip 1 (TC1), is composed with two test digital circuits and a set of transistors.

The main objectives of the TC1 are:

- Begin the functional validation of cell library created to enable the design of radiation tolerant circuits, where the on-off driver will be the first of these circuits to be designed;
- Obtain through radiation test in earth the first results of the cell library tolerance to the effects of ionizing radiation, more precisely the TID and SEE effects.

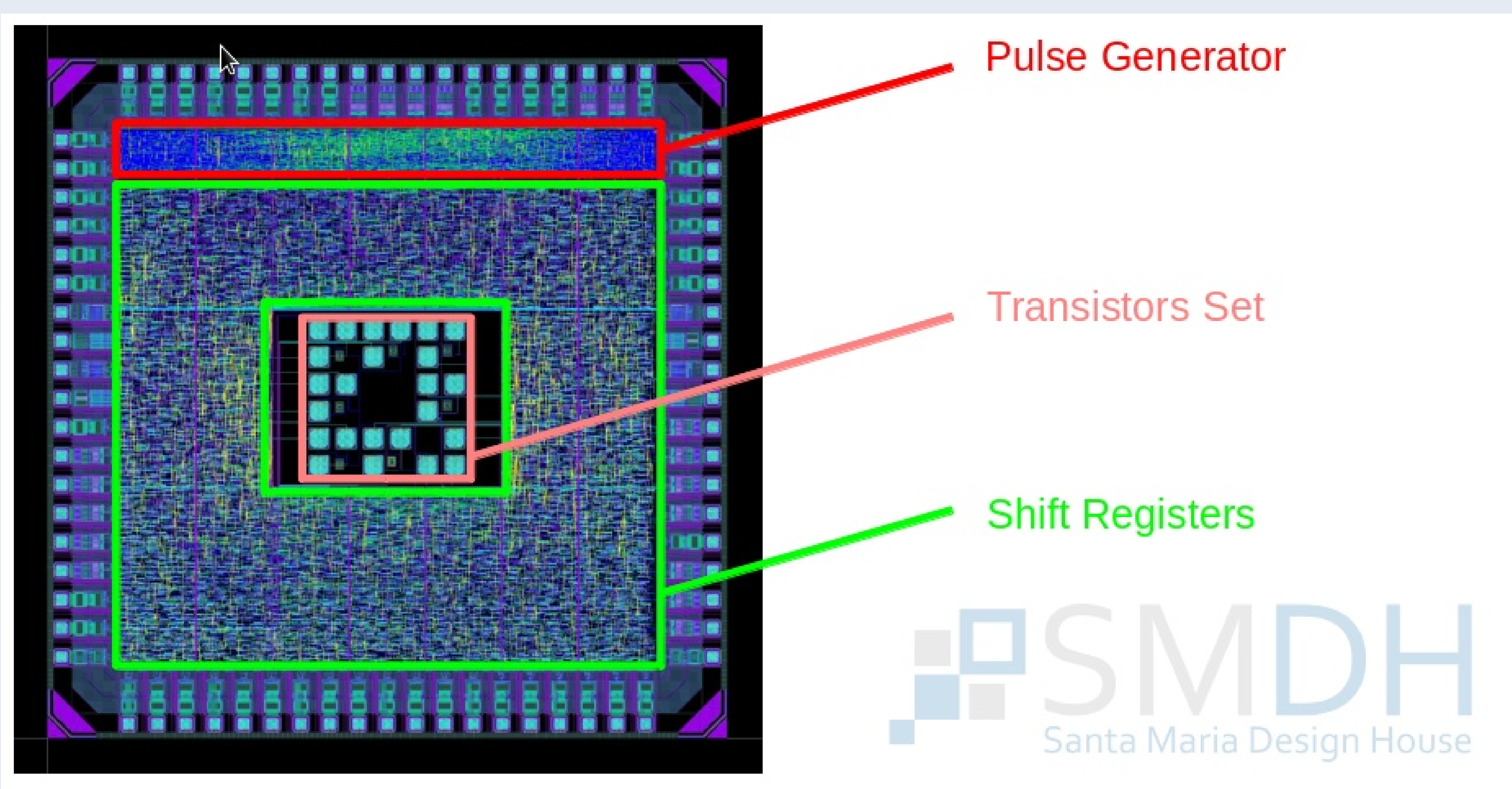

Figure 1: Test Chip Layout.

Pulse Generator

Digital block that controls the pulses generation for activation/deactivation of secondary circuits. Built from the radiation tolerant library cells, is the digital portion of the on-off driver (2x4 mux, counter, reset logic). It could be evaluated in relation to the TID and SEE.

Shift Registers

This block is composed of 10 shift registers circuits with different configurations. There are two shift registers sub-groups: half were designed with standard cells, and the other half were designed with rad-hard cells. The shift registers have two different lengths: 256 and 1024. Some settings have a sequence of 0, 4 or 8 inverters. It permits to analyze the SEE tolerance of the memory cells from the standard and rad-hard library.

SMDH Control

This block is an integral part of the synthesized FPGA circuit and implements the following features:

- Stimuli generation for the TC1;
- Capture and pre-processing of generated responses by TC1;
- Storage control responses on BRAM 1 block

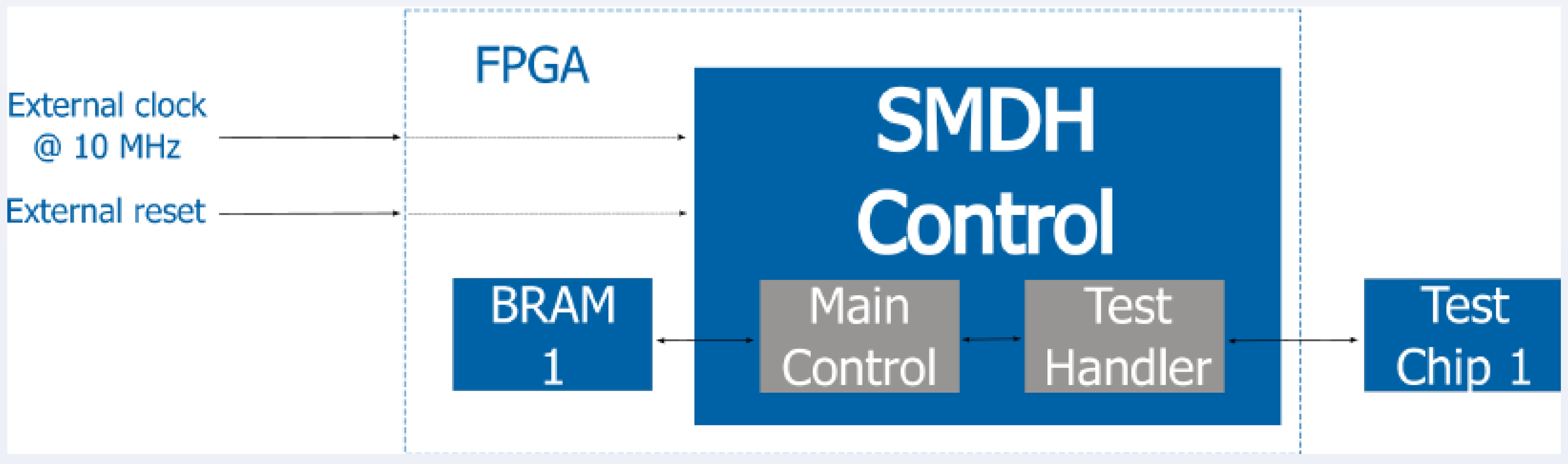

Figure 2: SMDH Control block diagram.

RESULTS

In all tests was possible to observe the errors caused by instantaneous radiation. In Table 1 is shown the relation between SEE and the solar X-ray flux monitored by the Geostationary Operational Environmental Satellite GOES-15. The measurement data shown that the system was exposed to a strong solar flare that took place on 10 September 2014 with proton energies of up to 100MeV.

Data Sets	Dates		#SEE detected	# Events by severity		
	From	To		R1	R2	R3
1	20/06/14	30/06/14	0	0	0	0
2	01/07/14	12/08/14	996	6	1	0
3	12/08/14	13/08/14	297	0	0	0
4	13/08/14	15/08/14	17	0	0	0
5	15/08/14	17/08/14	88	0	0	0
6	17/08/14	19/08/14	146	0	0	0
7	19/08/14	23/08/14	170	0	0	0
8	23/08/14	23/08/14	1089	2	0	0
9	23/08/14	24/08/14	1338	1	0	0
10	25/08/14	27/08/14	1622	1	0	0
11	27/08/14	28/08/14	0	0	0	0
12	28/08/14	01/09/14	0	0	0	0
13	01/09/14	02/09/14	0	0	0	0
14	02/09/14	15/09/14	2529	6	1	1
15	15/09/14	16/09/14	0	0	0	0
16	09/22/14	09/22/14	0	0	0	0

Table 1: SEE events detected.

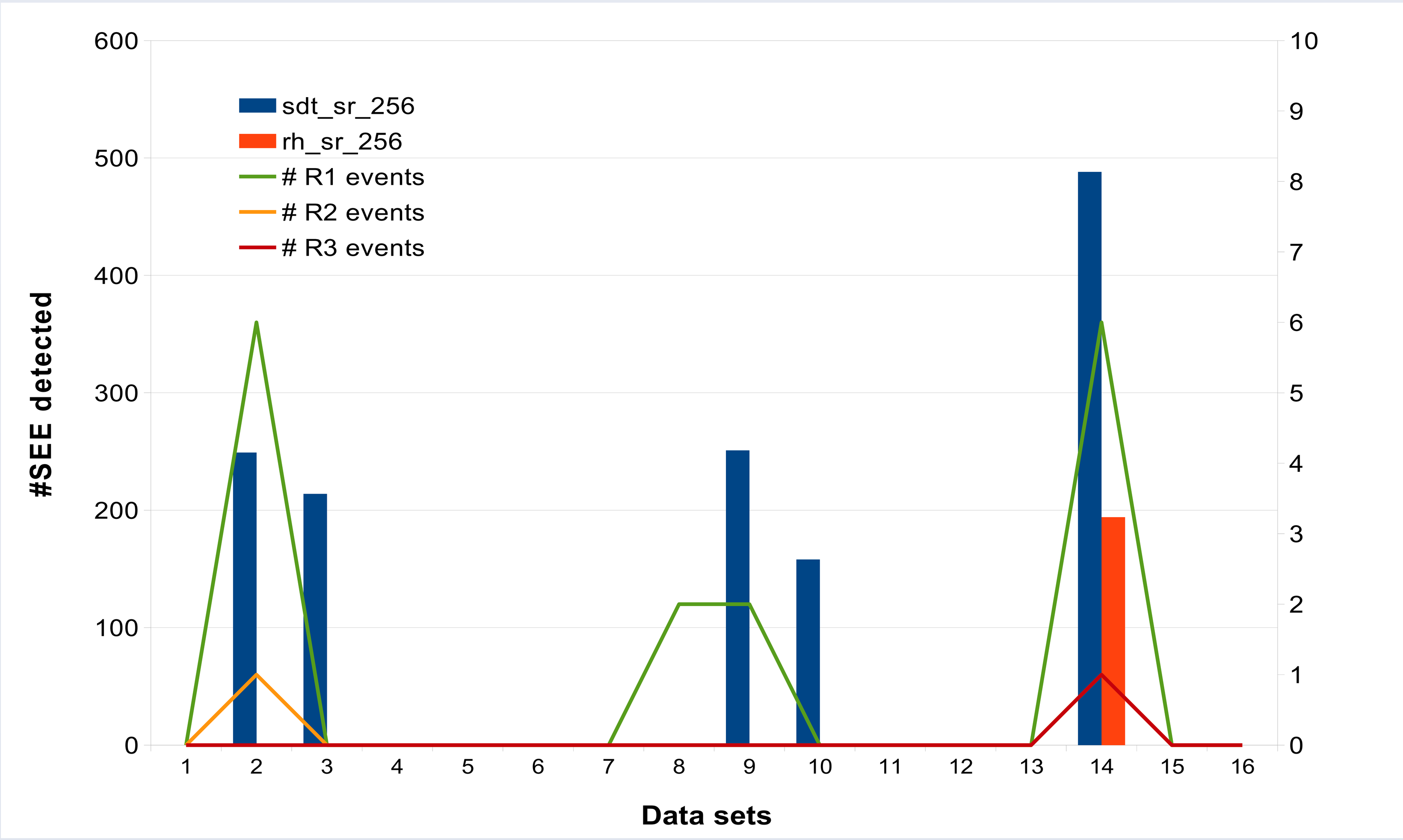

Figure 3: SEE tolerance comparison of the shift-registers (256 FF, 8 INV).

CONCLUSIONS

The amount of errors in the shift-registers designed using the standard cell library is comparatively larger than the shift-registers using rad-hard cell library.

REFERENCES

Poivey, C., Barth, J.L., LaBel, K.A., Gee, G., Safren, H., 2003. In-flight observations of long-term single-event effect (SEE) performance on orbview-2 solid state recorders (SSR), in: Proc. IEEE Radiation Effects Data Workshop. pp. 102–107.

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