Characterization and Measurement of the SET Pulse Duration of the DARE65T Standard Cell Library

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Tracks:

- Radiation-hardened technologies
- Radiation Test Results

To properly and optimally harden a design for a specific space mission, it is crucial to identify the critical parts of the circuit (e.g., reset and clock signals, PLL configuration signals, critical state machines, ...) and the associated SEE probability (cross section). For low error rate requirements, certain parts of the circuit may need specific hardening. Digital design hardening can be achieved through various methods:

- Drive strength increase
- Triplication (local, distributed, global TMR, etc.)
- Error Correction Codes (ECC)
- SET filtering
- ...

SET filtering is the most efficient way to harden a digital signal in terms of area and power, but it comes at the cost of speed reduction as SET filters operate as a delay cell, decreasing setup and hold margin in the paths where they are inserted. To minimize the margin lost due to SET filtering, it is important to have an accurate value for the SET duration.

SET characterization test structure

The test structure used to measure the cross-section and the SET duration is shown in Figure 1. On the left are the victims: chains of 16 or 32 cells. Each chain is limited to 32 cells connected in series to avoid significant pulse broadening (evaluated at 1-2 ps per victim on such technology) affecting the measurement result. All victim chains are combined using a NAND/NOR combiner, designed to be well-balanced to avoid pulse distortion. The combiner drives an array of SET filters with filtering windows increasing from 50 ps to 2 ns in steps of 50 ps. This approach allows for simultaneous measurement of the SET duration and validation of the SET filter.

As the combiner is sensitive to SET, a second combiner has been added in parallel to detect if the captured event originates from the victims or the combiner.

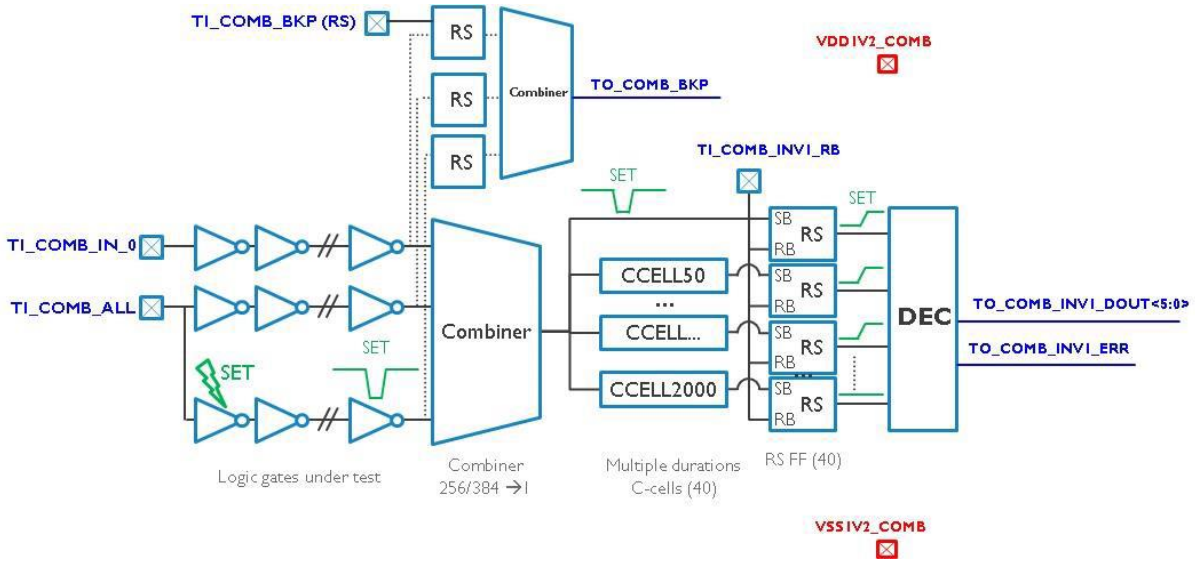

Figure 1: test structure to measure the cross section and the SET duration

The pulses propagating through the filter bank are captured with RS-latches, which are compressed into a 6-bit value with a thermometric encoder. The RS latch content is read and reset every 10 ms (100Hz). This sampling rate balances the readout bandwidth and the probability of a double hit between consecutive readings. The sensitive area of each set of victims is approximately 1100 µm², resulting in around 100 hits after 15 minutes irradiation with a flux of 10k ions/(s*cm²), equating to 1 hit on the sensitive area every 9 seconds. As each strike is independent, the probability of a double strike during 10 ms can be calculated using the Poisson distribution:

$$P(k = 2, 10ms) = \frac{\lambda^k e^{-\lambda}}{k!} = 6.04 \times 10^{-7}$$

The estimated number of the double strikes appearing for 15 minutes of beam is equal to $6.04 \times 10^{-7} \times \frac{900}{0.01}$ =0.054, this number is well below the number of single events expected (100) and thus can be neglected.

<u>Cross section results</u>

Here below are the some measurement results for the inverter INVD1. Other results will be shared in the final version of this paper.

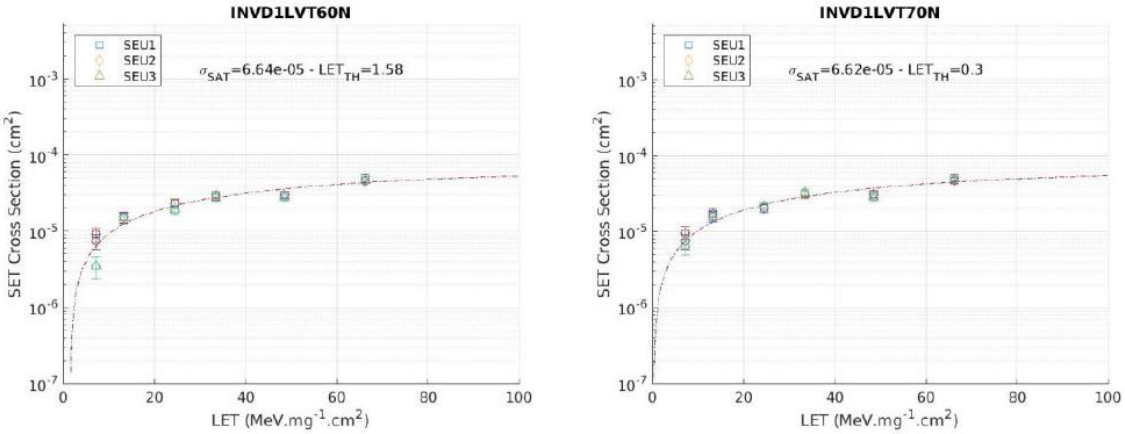

Figure 2: INVD1 Low Vth cross section (L=60nm on the left, L=70nm on the right)

LET	Cross section (cm²)					
(MeV.mg⁻¹.cm²)	HVT60N	HVT70N	LVT60N	LVT70N	SVT60N	SVT70N
7.2	1.14E-05	1.18E-05	6.65E-06	7.85E-06	9.52E-06	1.11E-05
13.3	1.88E-05	1.80E-05	1.51E-05	1.63E-05	1.79E-05	1.80E-05
24.5	2.40E-05	2.51E-05	2.04E-05	2.07E-05	2.12E-05	2.23E-05
33.5	3.64E-05	3.55E-05	2.89E-05	3.20E-05	3.12E-05	3.34E-05
48.5	3.42E-05	3.54E-05	2.95E-05	2.99E-05	3.19E-05	3.26E-05
66.3	5.49E-05	5.34E-05	4.75E-05	4.92E-05	5.09E-05	5.03E-05

Table 1: Cross section (N.U.) of the INVD1 versus gate length and Vth flavor

Pulse width measurement distribution

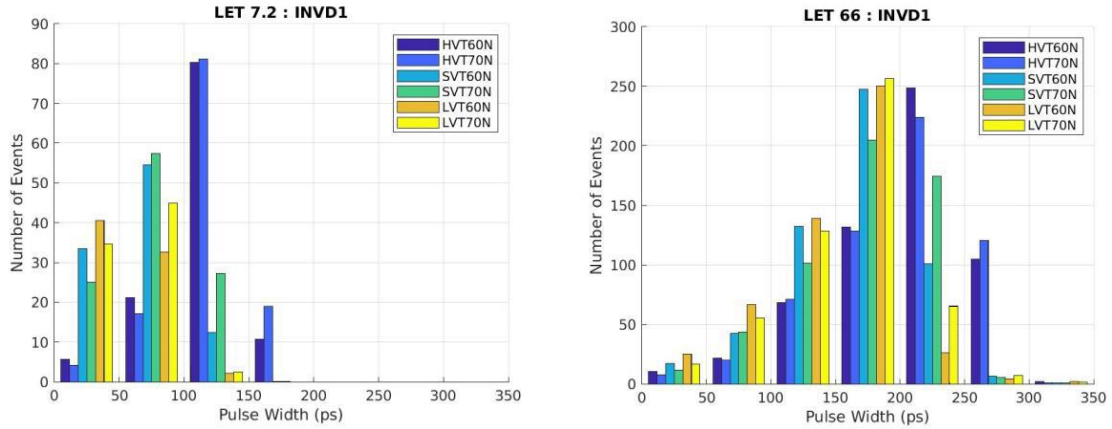

Figure 3: INVD1 pulse width distribution for different gate length (60nm and 70nm) and for different Vth flavor (low, standard and high)

The Figure 3 show the distribution of pulse width for different flavor of the DARE65 INVD1 at 7.2 and 66 Mev*cm^2/mg. The first group HVT60N till LVT70N show the number of SET observed having a duration between 0 and 50 ps, the second group show the number of SET observed having a duration between 50 and 100 ps.....

Conclusion

The test structure proposed in this abstract provide an accurate distribution of the SET pulse width and validate at the same time the SET filter cell to use to filter it.

In the complete paper, other measurement results will be added (e.g. more LET: 7.2, 13.3, 24.5, 33.5, 48.5 and 66.3 Mev*cm^2/mg and gates) and a comparison of the SET duration between the different gates flavor will be detailed.