EV10AS180A : 10-bit 1.5 Gsps ADC
Radiation test report
Infineon B7HF200

Revision date :	**21/10/2013**
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Scope :	**HI REL SEMICONDUCTOR DIVISION**

1. DOCUMENT AMENDMENT RECORD

Author	Issue	Date	Reason for change
D. BELLIN	A	03/02/2012	Creation
D. BELLIN	B	21/10/2013	Correction of typo in summary chart of last page (modifications in red)

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2. ACRONYMS - DEFINITIONS

- SEU: Single Event Upset = Single conversion errors (self recovered)
  Conversion error in only one conversion

- SEFI (recoverable with reset)
  Single Event Functional Interrupt, could be any type of event where the device "hang". One example could be an internal state machine that goes to an unknown state and the data conversion is interrupted.

- Permanent conversion error (recoverable with reset)
  Sub type of SEFI, where data conversion is still running, but all conversions have some kind of error (e.g. offset error).

- Multi conversion errors (self recovered) or long SEU
  Conversion error in more than one successive conversion.

3. INTRODUCTION

This document summarizes all radiation tests performed on EV10AS180A 10-bit 1.5Gsps ADC designed on Infineon B7HF200 process.

- Total dose tests
- Heavy ions tests
- Proton tests

4. DOCUMENTS

4.1 ADC Specifications

EV10AS180A-prel-OCT2011	EV10AS180A Preliminary Datasheet

4.2 Radiation Test Plan

NE 31S 207332	ADC radiation test plan

4.3 Applicable ESCC specifications

ESCC22900	Total Dose Steady-State Irradiation Test Method
ESCC25100	Single Event Effects Test Method and Guidelines

5. EXECUTIVE SUMMARY

5.1 Total dose

It was concluded that the device under test (P/N EV10AS180A) had neither functional failure nor parameter drift up to 110 Krad (Si). Static and Dynamic results are satisfactory for all parameters.
A total of six devices were tested at 1.5Gsps Clock frequency.
The total irradiation test program was followed by a 24 hr. annealing process at ambient temperature followed by a 168 hr. annealing at 100°C as per ESCC 22900.
The component is not sensitive to 110Krad with very low dose rate (36rad / hr) and it is therefore ELDRS (Enhanced Low Dose Rate Sensitivity) free

5.2 Heavy ions

It was concluded that the devices under test (P/N EV10AS180A) have:

- No SEL (SEL measured up to a LET of 80.72 MeV-cm²/mg at 125degC with a tilt and up to 67.7 MeV-cm²/mg at 125degC without tilt),
- No SEFI
- No permanent error
- Low LET threshold of 0.7 to 1.6 MeV.cm²/mg ➔ device may be sensitive to proton
- Saturated cross-section in the range of 3.8E-5 to 2.1 E-04 cm²
- Worst case long SEU/SET duration is 48 consecutive corrupted data
- For a geostationary satellite:
  - SEE of 2.48E-04 to 8.24E-02/device.day
  - Worst case Multiconversion errors is 1.27E-02/device/day (MTBF > 78 days)
  - Worst case Single conversion errors 8.24E-02/device.day (MTBF > 12 days)

5.3 Proton tests

It was concluded that the devices under test (P/N EV10AS180A) have:

- No SEL (up to 184 MeV),
- No SEFI
- No permanent error
- Energy threshold is lower than 20 MeV
- Saturated cross-section in the range of 1E-10 to 1.3E-09 cm²
- Worst case long SEU/SET duration is 5 consecutive corrupted data
- For a geostationary satellite:
  - SEE of 4.47E-05 to 7.83E-03/device.day
  - Worst case Multiconversion errors is 1.16E-03/device/day (MTBF> 862 days)
  - Worst case Single conversion errors of 7.83E-03/device.day (MTBF>127 days)
- For a LEO JASON satellite:
  - SEE of 7.12E-04 to 8.94E-02/device.day
  - Worst case Multiconversion errors is 1.36E-02/device/day (MTBF> 73 days)
  - Worst case Single conversion errors of 8.94E-02/device.day (MTBF>11 days)

6. TOTAL DOSE TESTS

6.1 Parts references

Type: EV10AS180AGS
Manufacturer: e2v Grenoble
Function: 10-bit 1.5Gsps ADC with integrated DEMUX
Technology: Bipolar SiGeC

Packaging: Ci-CGA 255
Date Code: 1111
Diffusion number: RU039535
Number of parts: 6 irradiated (3 biased ON and 3 OFF) + 3 Reference parts

6.2 Dosimetry and irradiation facility

Source: ^{60}Co (36 rad / hr)
Localization: TRAD/UCL in Louvain La Neuve (Belgium)

6.3 Detailed total dose test report

Refer to document reference NE 31S 207917.

7. HEAVY IONS & PROTONS TESTS

7.1 Methods and patterns

7.1.1 Static tests

Static tests were performed for negative full scale, mid-scale and positive full scale analog input.
In order to avoid saturation and mid-scale where MSB is toggling most of the time an offset was considered:

- **V_{IN} = close to Full Scale+**
  Vin was adjusted in order to have an output code at 32 LSB from Full Scale +, in order to avoid the activation of the overflow function which bypass the decoding circuitry.
  This corresponds to 3E0 (code 992) on ADC output.
- **V_{IN} = close to mid-Scale**
  An offset of 32 LSB is necessary in order to avoid the switching of all bits due to noise (switching from 1FF to 200).
  This corresponds to 21F (code 543).
  Due to an error of the subcontractor, the code finally used was 20F which corresponds to code 527 (offset of 16 LSB)
- **V_{IN} = close to Full Scale –**
  Vin was adjusted in order to have an output code at 32 LSB from Full Scale -, in order to avoid the activation of the underflow function which bypass the decoding circuitry.
  This corresponds to 01F (code 31) on ADC output.

The method used to detect events consists in comparing the acquisition data to the reference code (992, 527 or 31). An event is detected if the difference exceeds 16 LSB (tolerance due to the noisy environment and accuracy of the DC generator used to generate the constant analog input)

Note: tests were done at 100Msps and 600Msps in order to observe long SEU/SET sensitivity to clock rate. The 600 MHz frequency was considered (and not the full speed of 1.5GHz) due to a limitation of the acquisition system.

7.1.2 Dynamic tests

Dynamic tests were performed at 600Msps with Fin=600.02MHz in order that two consecutive samples does not differ from more than 1 LSB. An event is detected if the change between two successive codes is higher than 24 LSBs.

7.2 Parts references

Type:	EV10AS180AGS
Manufacturer:	e2v Grenoble
Function:	10-bit 1.5Gsps ADC with integrated DEMUX
Technology:	Bipolar SiGeC
Packaging:	Ci-CGA 255 (delidded)
Date code front end:	10D
Diffusion number:	RU039535
Number of parts:	2 irradiated + 1 Reference part (spare)

The same parts were used for Heavy Ion and Proton Tests (Heavy Ion first and then Proton tests).

Cumulated dose at the issue of both Heavy Ion & Proton Test is 110 Krad, but is not a problem since it was proven that the device is insensitive to total up to 110 Krad (Si).

7.3 Heavy Ions Tests

7.3.1 Irradiation facility

Tests were performed at U.C.L. (Université Catholique de Louvain) in Belgium in using two cocktails (High LET cocktail and high penetration cocktail)
Tests were subcontracted to TRAD Company (LABEGE, France).

7.3.2 Test setup and results

Please refer to the "Heavy Ions Test Report – Single Event Effects EV10AS180A 10-bit 1.5Gsps ADC from e2v" reference TRAD/EV10A/XXX2/E2V/ELG/1106

7.3.3 Orbital SEE Rate

The following table summarizes Orbital SEE Rate (for a CREME96 cosmic ray environment) for a geostationary satellite

		Width	Shape	Saturated cross section	LET threshold	Rate (Note 1)
		W	S	σ_0	L_0	τ
		-	-	cm^2	$MeV.cm^2.mg^{-1}$	$dev^{-1}.day^{-1}$
Fin=600.02MHz Fclk=600MHz	SEU	10	0.8	8.4e-5	0.8	1.82e-2
	Long SEU and SET	12	1.5	8.6e-5	0.8	4.00e-3
Fclk=600MHz Config. $3E0	SEU	8	1.0	1.1e-4	0.4	5.99e-2
	Long SEU and SET	24	1.2	1.8e-4	0.8	8.67e-3
Fclk=600MHz Config. $20F	SEU	16	1.0	1.3e-4	0.2	8.24e-2
	Long SEU and SET	16	1.3	1.0e-4	0.7	6.00e-3
Fclk=600MHz Config. $01F	SEU	25	0.7	2.1e-4	0.8	3.98e-2
	Long SEU and SET	20	1.0	1.4e-4	0.8	1.27e-2
Fclk=100MHz Config. $3E0	SEU	16	0.9	1.2e-4	0.6	2.50e-2
	Long SEU and SET	18	1.3	4.9e-5	2.8	2.56e-4
Fclk=100MHz Config. $20F	SEU	15	1.0	1.1e-4	0.8	1.22e-2
	Long SEU and SET	16	1.1	3.8e-5	2.7	2.77e-4
Fclk=100MHz Config. $01F	SEU	16	1.0	1.3e-4	0.8	1.41e-2
	Long SEU and SET	18	1.6	5.6e-5	2.5	2.48e-4

Table 1 – Weibull parameters and event rates calculated with OMERE

(Note 1) The rate τ has been calculated for Port ABCD measurement and for a CREME96 cosmic ray environment (without magnetospheric cut-off).

7.3.4 Sensitivity to static pattern

We do not observe any SEU or long SEU/SET rate sensitivity to the 3 static patterns considered (Full Scale+, mid-Scale, Full-scale-):

- SEU rate at 600 Msps are respectively 5.99E-02, 8.24E-02 and 3.98E-02
  ➔ Results are therefore very similar (factor ~2).
- SEU rate at 100 Msps are respectively 2.50E-02, 1.22E-02 and 1.42E-02.
  ➔ Results are therefore very similar (factor ~2).
- Long SEU/SET rate at 600 Msps are respectively 8.67E-03, 6.00E-03 and 1.27E-02
  ➔ Results are quite similar. We only notice a higher sensitivity to long SEU/SET with Full-Scale- (factor ~50)
- Long SEU/SET rate at 100 Msps are respectively 2.56E-04, 2.77E-04 and 2.48E-04.
  ➔ same results for the three considered patterns

7.3.5 Sensitivity to clock rate

We do not observe any significant SEU rate sensitivity to clock rate.

- For Full Scale+, SEU rate at 600Msps and 100Msps are respectively 5.99E-02 and 2.50E-02.
  ➔ Results are therefore very similar (factor ~2)
- For Mid Scale, SEU rate at 600Msps and 100Msps are respectively 8.42E-02 and 1.22E-02.
  ➔ Results are therefore very similar (factor ~7)
- For Full Scale-, SEU rate at 600Msps and 100Msps are respectively 3.98E-02 and 1.41E-02.
  ➔ Results are therefore very similar (factor ~3)

We observe a clock rate sensitivity on long SEU/SET rate:

- For Full Scale+, long SEU/SET rate at 600Msps and 100Msps are respectively 8.67E-03 and 2.56E-04.
  ➔ probability of long SEU/SET increases with clock rate (factor ~25)
- For Mid Scale, long SEU/SET rate at 600Msps and 100Msps are respectively 6.00E-03 and 2.77E-04.
  ➔ probability of long SEU/SET increases with clock rate (factor ~30)
- For Full Scale-, long SEU/SET rate at 600Msps and 100Msps are respectively 1.27E-02 and 2.48E-04.
  ➔ probability of long SEU/SET increases with clock rate (factor ~20)

7.3.6 Static tests for positive full-scale ADC input

The following graphs represent the concatenation of all events acquired for the 3 static input patterns and 2 clock rates in the worst case configuration (with Xe at LET=67.7 MeV.cm².mg-1).
Reminder: when an event is detected, the acquisition of the 120 or 136 points are acquired in order to save the event. All these events are represented below.

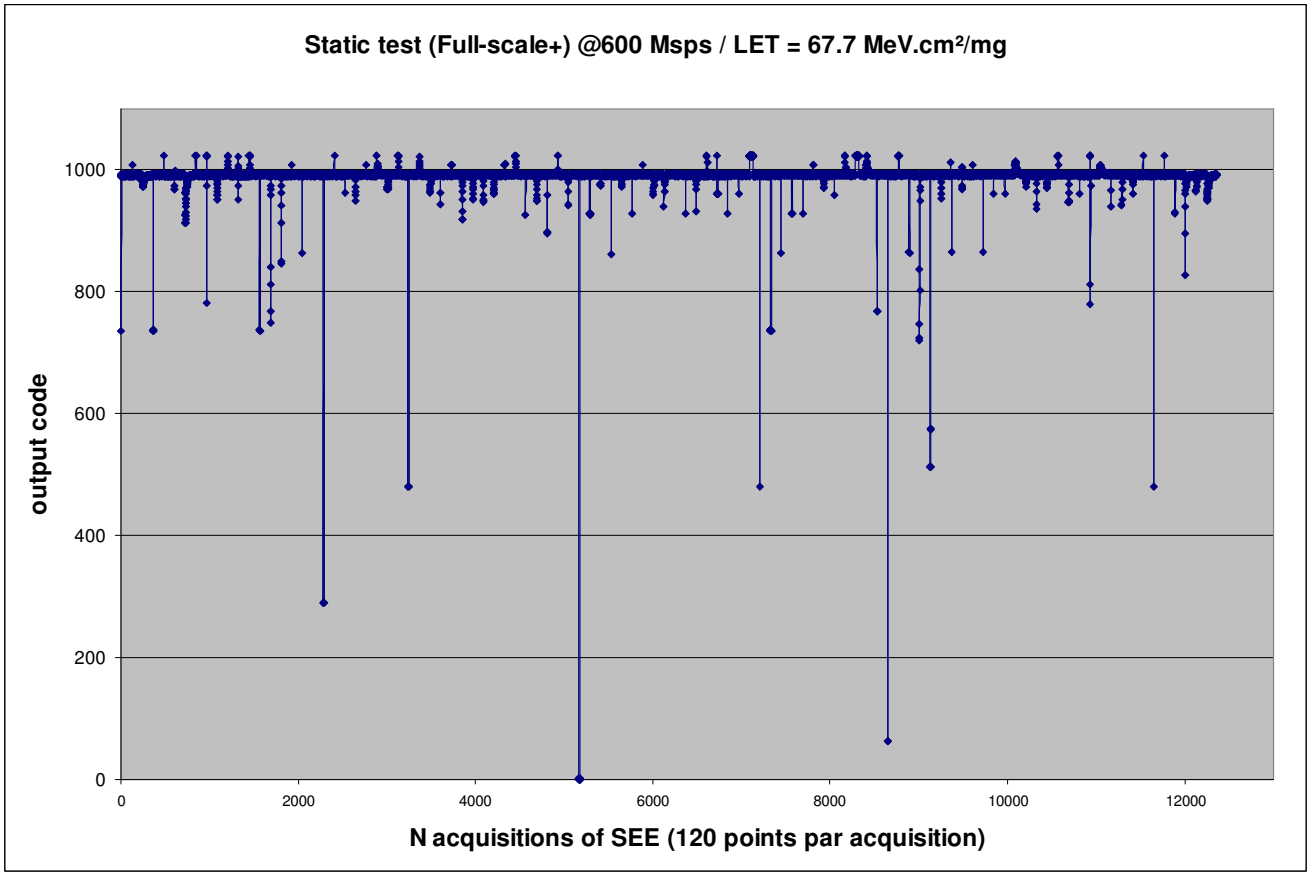

Figure 1 – Concatenation of events for full-scale+ pattern @600Msps / LET=67.7 MeV.cm²/mg

The Figure 1 shows the concatenation of all events detected on run 74 at 600 Msps with positive full-scale pattern (LET = 67.7 MeV.cm²/mg):

- Among the 68 SEUs detected:
  - 15 SEUs are of amplitude 16 LSB
  - 13 SEUs are of amplitude 32 LSB
  - 10 SEUs are of amplitude 64 LSB
  - 7 SEUs are of amplitude 128 LSB
  - 3 SEUs are of amplitude 256 LSB
  - 4 SEUs are of amplitude 512 LSB
- Among the 61 Long SEUs, SETs detected:
  - Most events (51) are SETs whose duration is less than 10 consecutive data
  - There are 3 long SEU with code 1023 (duration of **44,** 39 and 8 consecutive data)
  - Others long SEU have a duration of less than 7 consecutive data.

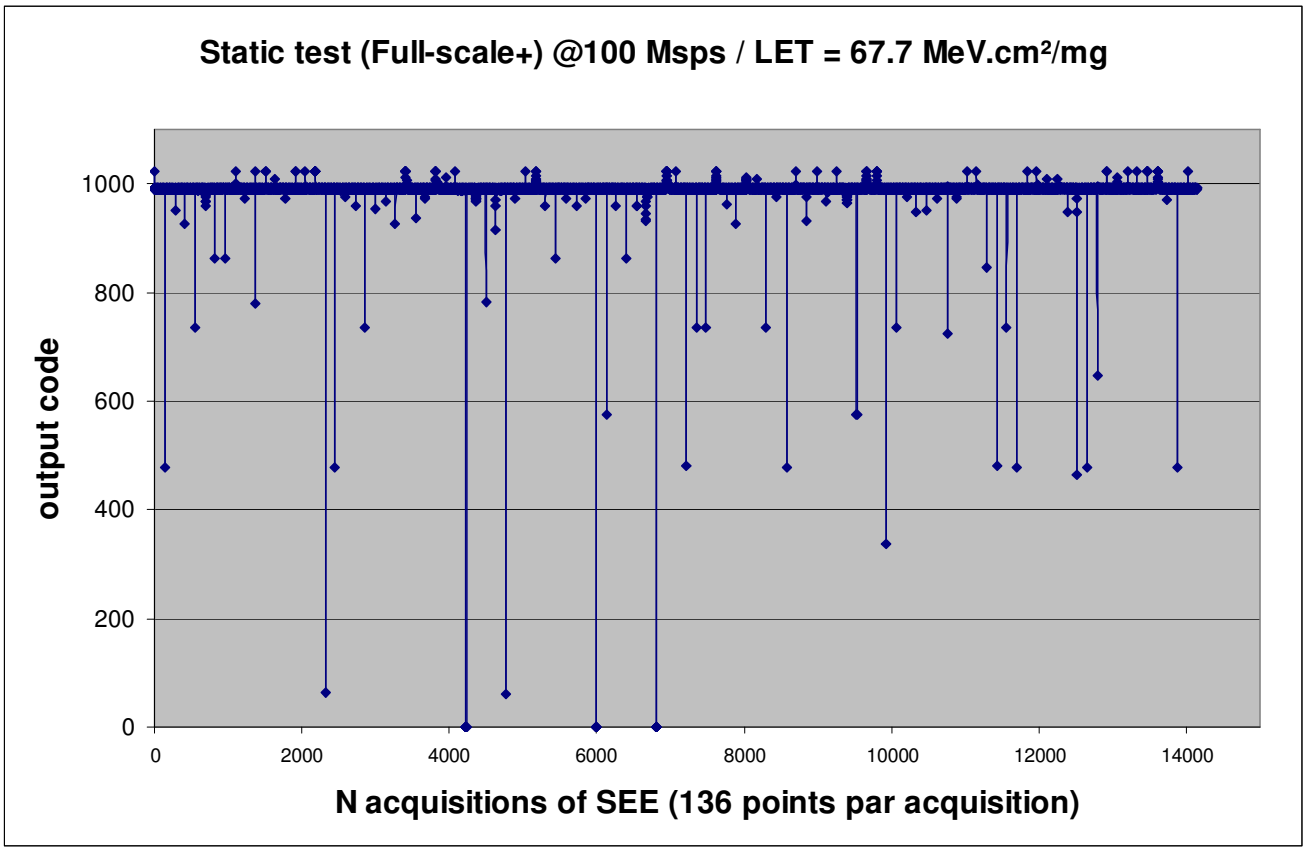

Figure 2 – Concatenation of events for full-scale+ pattern @100Msps / LET=67.7 MeV.cm²/mg

The Figure 2 shows the concatenation of all events detected on run 75 at 100 Msps with positive full-scale pattern (LET = 67.7 MeV.cm²/mg):

- Among the 79 SEUs detected:
  - 15 SEUs are of amplitude 16 LSB
  - 25 SEUs are of amplitude 32 LSB
  - 4 SEUs are of amplitude 64 LSB
  - 5 SEUs are of amplitude 128 LSB
  - 8 SEUs are of amplitude 256 LSB
  - 8 SEUs are of amplitude 512 LSB
- Among the 29 Long SEUs, SETs detected:
  - Most events are SETs whose duration are less than 13 consecutive data.
  - There are 2 long SEU with code 1023 (duration of 5 and 7 consecutive data)
  - There are 3 long SEU with code 0 (duration of 6, 6 and 7 consecutive data)

As a conclusion, we can conclude that the signature of SEUs, long SEUs and SETs are similar for the 2 considered clock rates (100Msps and 600Msps) with positive full-scale pattern.

7.3.7 Static tests for positive mid-scale ADC input

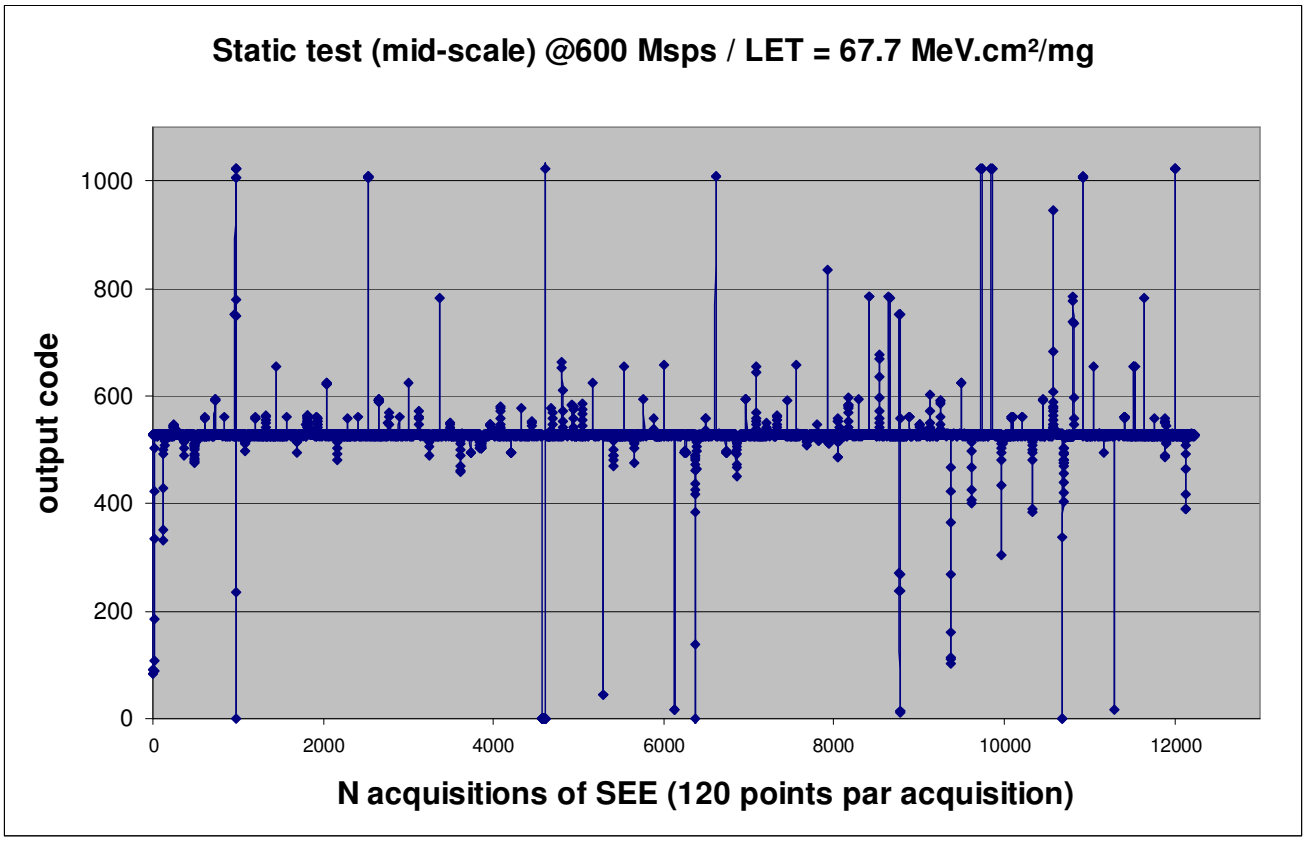

Figure 3 – Concatenation of events for static mid-scale pattern @600Msps / LET=67.7 MeV.cm²/mg

The Figure 3 shows the concatenation of all events detected on run 77 at 600 Msps with mid-scale pattern (LET = 67.7 MeV.cm²/mg):

- Among the 64 SEUs detected:
  - 17 SEUs are of amplitude 32 LSB
  - 12 SEUs are of amplitude 64 LSB
  - 7 SEUs are of amplitude 128 LSB
  - 6 SEUs are of amplitude 256 LSB
  - 4 SEUs are of amplitude 512 LSB
- Among the 64 Long SEUs, SETs detected:
  - Most events (57) are SETs whose duration is less than 10 consecutive data.
  - There are 6 long SEU with code 1023 (duration of 7, 3, 5, 5, 4 and 5 consecutive data)
  - There is 1 long SEU of duration 43 consecutive data with code 0 and final code at 1023.

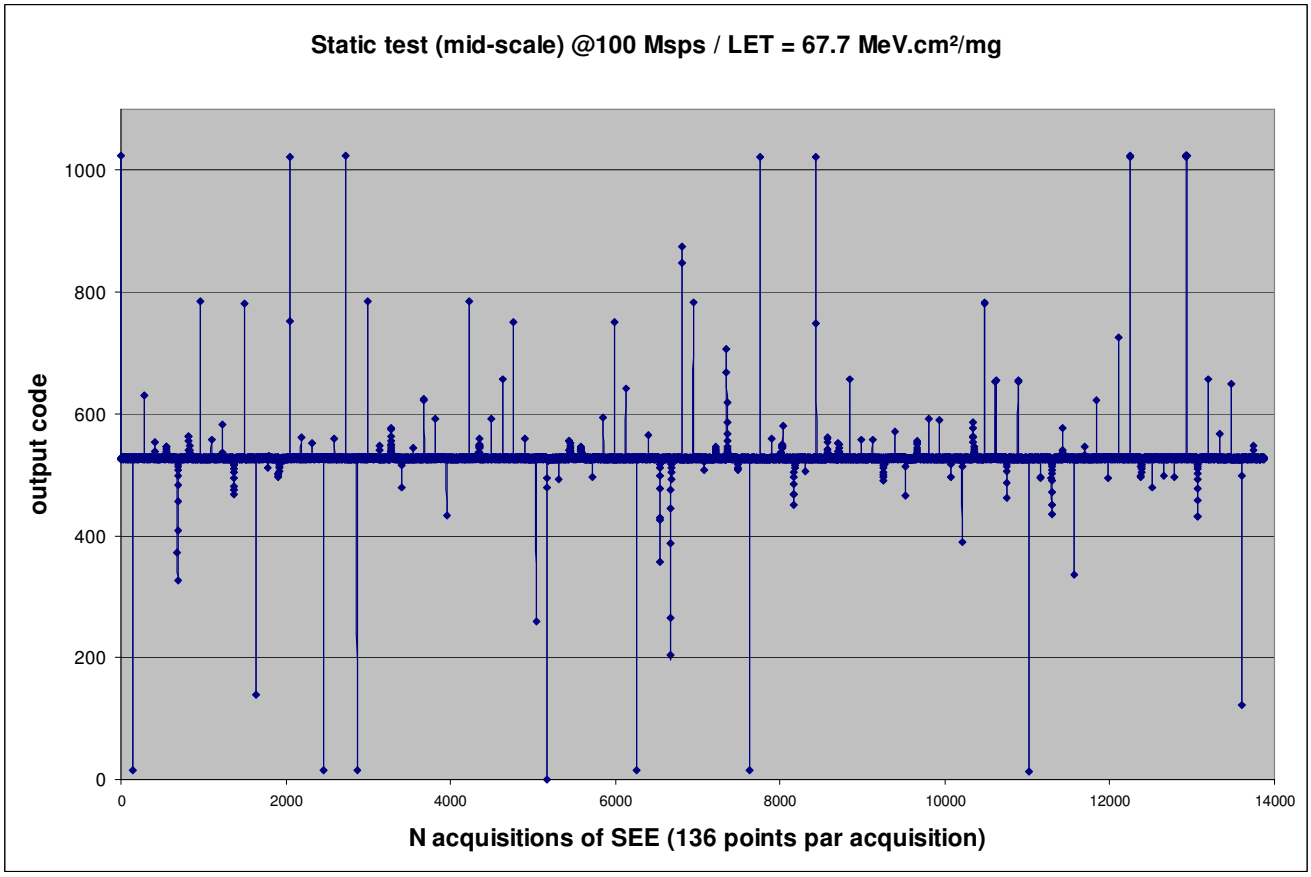

Figure 4 – Concatenation of events for static test at mid-scale @100Msps / LET=67.7 MeV.cm²/mg

The Figure 4 shows the concatenation of all events detected on run 76 at 100 Msps with mid-scale pattern (LET = 67.7 MeV.cm²/mg):

- Among the 71 SEUs detected:
  - 4 SEUs are of amplitude 16 LSB
  - 16 SEUs are of amplitude 32 LSB
  - 7 SEUs are of amplitude 64 LSB
  - 10 SEUs are of amplitude 128 LSB
  - 8 SEUs are of amplitude 256 LSB
  - 7 SEUs are of amplitude 512 LSB
- Among the 32 Long SEUs, SETs detected:
  - Most events (31) are SETs whose duration is either 2 or 3 consecutive data or in the range of 8 to 14 consecutive data.
  - There is 1 long SEU of duration 7 consecutive data with code 1023.

7.3.8 Static tests for negative full-scale ADC input

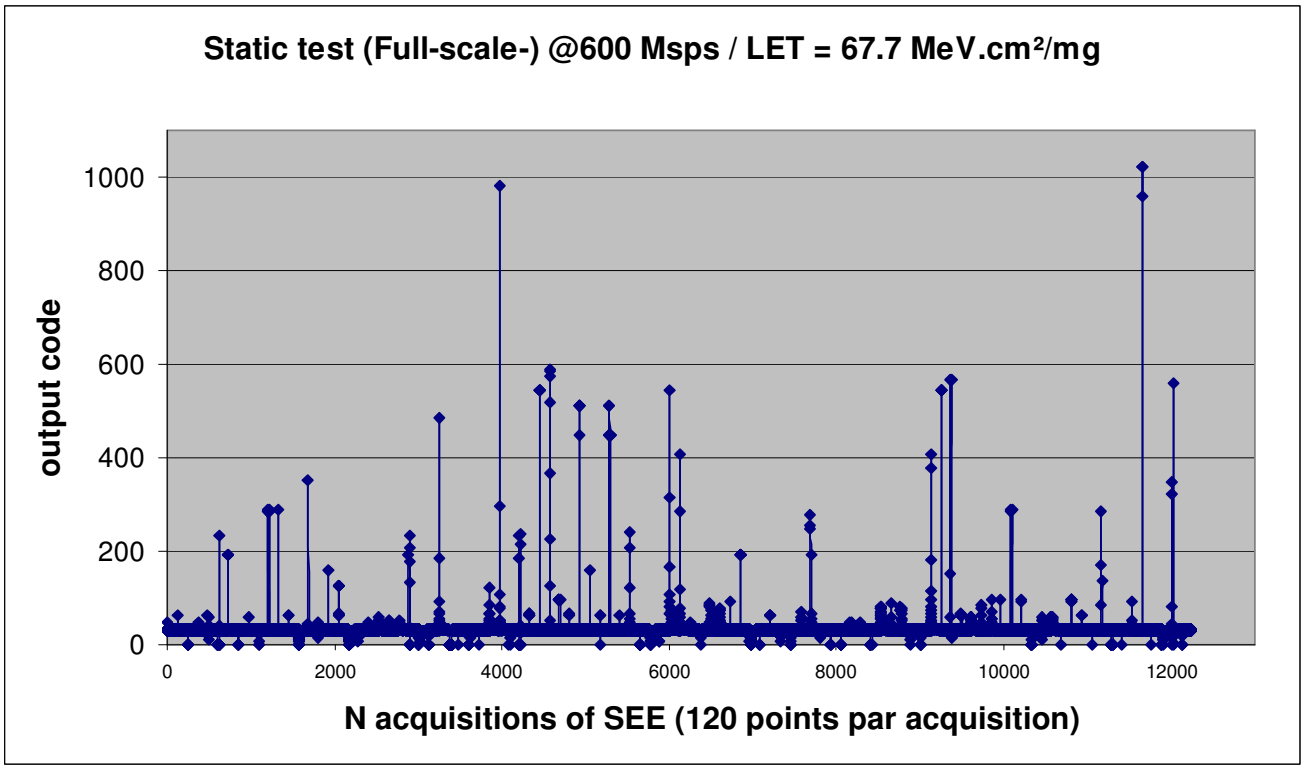

Figure 5 – Concatenation of events for static test at Full-scale- @600Msps / LET=67.7 MeV.cm²/mg

The Figure 5 shows the concatenation of all events detected on run 78 at 600 Msps with negative full-scale pattern (LET = 67.7 MeV.cm²/mg):

- Among the 63 SEUs detected:
  - 13 SEUs are of amplitude 16 LSB
  - 21 SEUs are of amplitude 32 LSB
  - 4 SEUs are of amplitude 64 LSB
  - 2 SEUs are of amplitude 128 LSB
  - 9 SEUs are of amplitude 256 LSB
- Among the 79 Long SEUs, SETs detected:
  - Most events (45) are SETs whose duration is less than 15 consecutive data.
  - 13 events are SETs whose duration is in the range of 16 to 30 consecutive data.
  - There are 10 long SEUs with code 0 (duration of 2 to 11 consecutive data)
  - There are 3 long SEUs with code 192 (duration of 3, 5 and 40 consecutive data)
  - There are 3 long SEUs with code 96 (duration of 2, 5 and 6 consecutive data)
  - There are 2 long SEUs with code 64 (duration of 2 and 7 consecutive data)
  - There are 2 long SEUs with code 543 (duration of 4 and 5 consecutive data)
  - There is 1 long SEU at code 512 of duration 6 consecutive data
  - There is 1 long SEU at code 1023 2 of duration 3 consecutive data

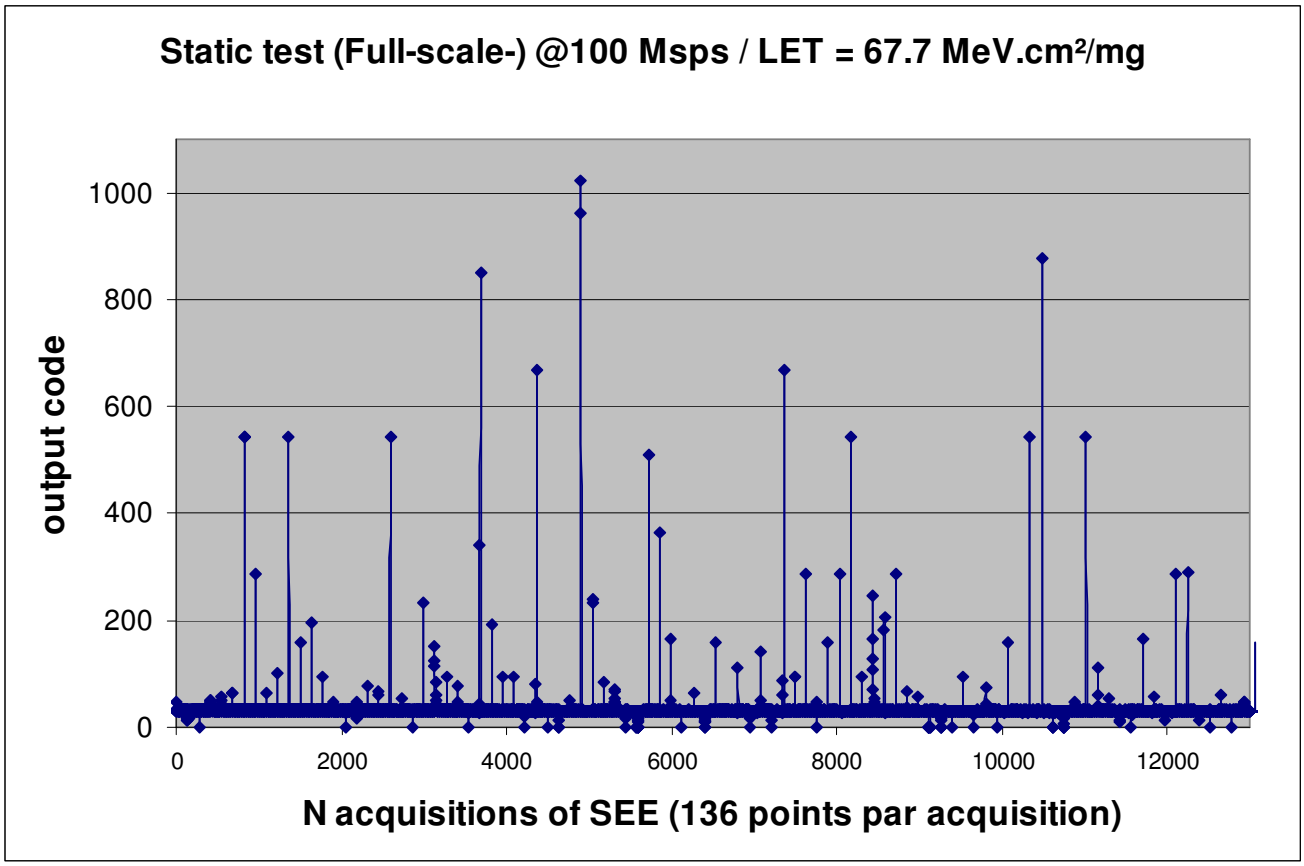

Figure 6 – Concatenation of events for static test at Full-scale- 1600Msps / LET=67.7 MeV.cm²/mg

The Figure 6 shows the concatenation of all events detected on run 78 at 100 Msps with negative full-scale pattern (LET = 67.7 MeV.cm²/mg):

- Among the 77 SEUs detected:
  - 9 SEUs are of amplitude 16 LSB
  - 15 SEUs are of amplitude 32 LSB
  - 10 SEUs are of amplitude 64 LSB
  - 6 SEUs are of amplitude 128 LSB
  - 6 SEUs are of amplitude 256 LSB
  - 5 SEUs are of amplitude 512 LSB
- Among the 27 Long SEUs, SETs detected:
  - Most events are SETs whose duration is less than 15 consecutive data.
  - There are 2 long SEUs with code 0 (duration of 3 and 7 consecutive data)
  - There is 1 long SEU with code 542 of duration of 2 consecutive data
  - There is 1 long SEU with code 64 of duration of 2 consecutive data)

7.3.9 Long SEU/SET duration vs clock rate

The table below summarize the maximum duration of events depending on the pattern and clock rate:

Pattern	Full-Scale -	Mid-Scale	Full-Scale +
600 Msps	40	43	44
100 Msps	15	14	13

Table 2 – Long SEU/SET duration (number of consecutive corrupted data) vs clock rate and pattern

We can therefore conclude that the duration of Long SEU/SETs increases when Fclock is increasing. However, we do not observe a factor 6 on the duration in time domain, that is why we can not

conclude that the duration of event is impendent from the clock rate. We can only conclude that the duration of events (in time domain) decreases not so quickly than clock rate.

7.3.10 Dynamic tests

For a LET of 67.7 MeV.cm²/mg on device 2 (run n°80) we observed:

- Among the 71 SEUs detected:
  - 1 SEU is of amplitude 32 LSB
  - 17 SEUs are of amplitude 64 LSB
  - 12 SEUs are of amplitude 128 LSB
  - 10 SEUs are of amplitude 256 LSB
  - 7 SEUs are of amplitude 512 LSB
- Among the 50 Long SEUs, SETs detected:
  - Most events are SETs whose duration is less than 20 consecutive data.
  - There are 2 long SEUs of amplitude 64 LSB (duration of 3 and 5 consecutive data)
  - There are 5 long SEUs of amplitude 128 LSB (duration of 6, 4, 5, 7 and 7 consecutive data)
  - There are 2 long SEUs of amplitude 96 LSB (duration of 6 consecutive data)
  - There are 2 long SEUs of amplitude 430 LSB (duration of 2 consecutive data)
  - There is 1 long SEU of amplitude 480 LSB of duration 6 consecutive data
  - There is 1 long SEU of amplitude 162 LSB of duration 2 consecutive data
  - There is 1 long SEU of amplitude 386 LSB of duration 5 consecutive data
  - There is 1 long SEU of amplitude 523 LSB of duration **43** consecutive data
  - There is 1 long SEU of amplitude 439 LSB of duration 7 consecutive data

For a LET of 32.6 MeV.cm²/mg on device 2 (run n°15) we observed:

- Among the 70 SEUs detected:
  - 2 SEUs is of amplitude 32 LSB
  - 17 SEUs are of amplitude 64 LSB
  - 19 SEUs are of amplitude 128 LSB
  - 10 SEUs are of amplitude 256 LSB
  - 8 SEUs are of amplitude 512 LSB
- Among the 58 Long SEUs, SETs detected:
  - Most events are SETs whose duration is less than 15 consecutive data.
  - There are 4 long SEUs of amplitude 512 LSB (duration of 4, 3, 5 and 5 consecutive data)
  - There are 2 long SEUs of amplitude 128 LSB (duration of 2 and 7 consecutive data)
  - There are 2 long SEUs of amplitude 64 LSB (duration of 5 and 7 consecutive data)
  - There are 2 long SEUs with code 0 of duration 4 consecutive data.
  - There are 2 long SEUs with code 1023 of duration 4 and **48** consecutive data.
  - There is 1 long SEU of amplitude 256 LSB (duration of 5 consecutive data)

For a LET of 20.4 MeV.cm²/mg on device 2 (run n°23) we observed:

- Among the 57 SEUs detected:
  - 3 SEUs is of amplitude 32 LSB
  - 7 SEUs are of amplitude 64 LSB
  - 18 SEUs are of amplitude 128 LSB
  - 6 SEUs are of amplitude 256 LSB
  - 8 SEUs are of amplitude 512 LSB
- Among the 53 Long SEUs, SETs detected:
  - Most events are SETs whose duration is less than 15 consecutive data.
  - There are 4 long SEUs with code 1023 (duration of 4, 3, 9 and 10 consecutive data)
  - There is 1 long SEU with code 0 of duration 4 consecutive data.

- There are 2 long SEUs of amplitude 128 LSB (duration of 2 and 7 consecutive data)
- There are 2 long SEUs of amplitude 64 LSB (duration of 3 and 3 consecutive data)
- There are 2 long SEUs of amplitude 256 LSB (duration of 2 and 3 consecutive data)

For a LET of 10.2 MeV.cm²/mg on device 2 (run n°45) we observed:

- Among the 40 SEUs detected:
  - 5 SEUs are of amplitude 64 LSB
  - 1 SEUs are of amplitude 128 LSB
  - 5 SEUs are of amplitude 256 LSB
  - 6 SEUs are of amplitude 512 LSB
- Among the 26 Long SEUs, SETs detected:
  - Most events are SETs whose duration is less than 7 consecutive data.
  - There are 4 long SEUs with code 0 (duration of 2 and 3 consecutive data)
  - There are 2 long SEUs of amplitude 64 LSB (duration of 3 and 7 consecutive data)
  - There are 2 long SEUs of amplitude 128 LSB (duration of 2 and 6 consecutive data)
  - There is 1 long SEU of amplitude 256 LSB (duration of 4 consecutive data)

For dynamic tests, around fifty percents of the events detected as long SEU/SET are long SEU. The other fifty percents are SET with exponential recovery shapes. It let thinks that it corresponds to upsets on voltage reference (bandgap).

Still for dynamic tests, the longest long SEU are observed with an output having code 0 or 1023. It means that there is a long SEU on the overflow/underflow bit.

The worst long SEUs and SETs are obtained for the highest LET of 32.6 and 67.7MeV.cm².mg$^{-1.}$ Both amplitude and duration of long SEUs/SETs decrease when LET decreases.

7.3.11 Conclusions on heavy ion tests

Results:

- No SEL (SEL measured up to a LET of 80.72 MeV-cm²/mg at 125degC with a tilt and up to 67.7 MeV-cm²/mg at 125degC without tilt),
- No SEFI
- SEE of 2.48E-04 to 8.24E-02/device.day
- No permanent error
- Low LET threshold of 0.7 to 1.6 MeV.cm²/mg ➔ device may be sensitive to proton
- Saturated cross-section in the range of 3.8E-5 to 2.1 E-04 cm²
- Worst case long SEU/SET is 48 consecutive data.
- Worst case Multiconversion errors is 1.27E-02/device/day (MTBF > 78 days)
- Worst case Single conversion errors 8.24E-02/device.day (MTBF > 12 days)

If we compare the results to the test done the previous version of the 10-bit 1.5Gsps ADC (mask VM81A), we can not that:

- Saturation cross-sections are globally lower (up to 1 decade)
- LET threshold is lower (0.8 MeV.cm²/mg compared to 1.8 MeV.cm²/mg compared on the previous test done at Jyvaskyla. This can be explained by the fact that this new test includes more LET at low energies, and the calculation of LET th is therefore more accurate.
- For a geostationary satellite, the SEE rate is slightly higher on the new mask: this can be explained by the lower LET threshold which is dominant compared to the saturation cross-section which is nevertheless lower on the new mask).

7.4 Protons Tests

7.4.1 Irradiation facility

Tests were performed at K.V.I. (Kernfysisch Versneller Institute) in Netherlands. Tests were subcontracted to TRAD Company (LABEGE, France).

7.4.2 Test setup and results

Please refer to the “Heavy Ions Test Report – Single Event Effects EV10AS180A 10-bit 1.5Gsps ADC from e2v” reference TRAD/EV10A/XXX1/E2V/ELG/1111

Note: The protons test was started with high cocktail energies. As TRAD did not observe events at 100 MeV on device n°2 and as events were observed at 150MeV, an intermediate point was done at 120 MeV to search the threshold. In a second step, events were detected at 100MeV on device n°1, that is why 20MeV and 50MeV energies were then used for both devices.

7.4.3 Orbital SEE Rate

Table 4 summarizes Orbital SEE Rate (for a CREME96 cosmic ray environment) in the following conditions for 2 orbits:

Orbit	GEO 35870 km, 98° JASON 1330 km, 66°
Trapped particules	AP8 MIN Standard magnetic field
Solar particules	ESP (80%) 10 years solar active period
Shielding	1g.cm^{-2}

Table 3 – Calculation parameters

		Width	Shape	Saturated cross section	Energy threshold	GEO 35870 km Rate	LEO 1330 km Rate
		W	S	σ_0	E_0	τ	τ
		-	-	cm²	MeV	$dev^{-1}.day^{-1}$	$dev^{-1}.day^{-1}$
Fin=600.02MHz Fclk=600MHz	SEU	15	2	1e-10	1*	5.03e-3	6.52e-2
	Long SEU and SET	6	1	1e-10	1*	5.91e-4	6.83e-3
Fclk=600MHz Config. S3E0	SEU	5	1	1.3e-9	1*	7.83e-3	8.94e-2
	Long SEU and SET	30	2	2e-10	1*	7.26e-4	1.17e-2
Fclk=600MHz Config. S20F	SEU	5	1	1.1e-9	1*	6.63e-3	7.56e-2
	Long SEU and SET	15	1	1e-10	1*	4.94e-4	6.4e-3
Fclk=600MHz Config. S01F	SEU	10	2	1.3e-9	1*	7.28e-3	8.76e-2
	Long SEU and SET	8	2	2e-10	1*	1.16e-3	1.36e-2
Fclk=100MHz Config. S3E0	SEU	10	2	1.2e-9	1*	6.72e-3	8.08e-2
	Long SEU and SET	10	1	1e-10	150	4.47e-5	7.12e-4
Fclk=100MHz Config. S20F	SEU	10	2	1.3e-9	1*	7.28e-3	8.76e-2
	Long SEU and SET	20	2	2e-10	1*	9e-4	1.26e-2
Fclk=100MHz Config. S01F	SEU	10	2	1.3e-9	1*	7.28e-3	8.76e-2
	Long SEU and SET	20	4	2e-10	20	4.96e-4	1.05e-2

Table 4 – Weibull parameters and SEE rates for 2 orbits

(*) Because of the minimum energy used during test (20 MeV), Energy threshold can not be exactly determined. Then a worst case Energy Threshold of 1 MeV is considered.

Note: In making the assumption that Energy threshold is 1 MeV, Error Rate calculations are pessimistic and correspond to a worst case value.

7.4.4 Static tests for positive full-scale ADC input

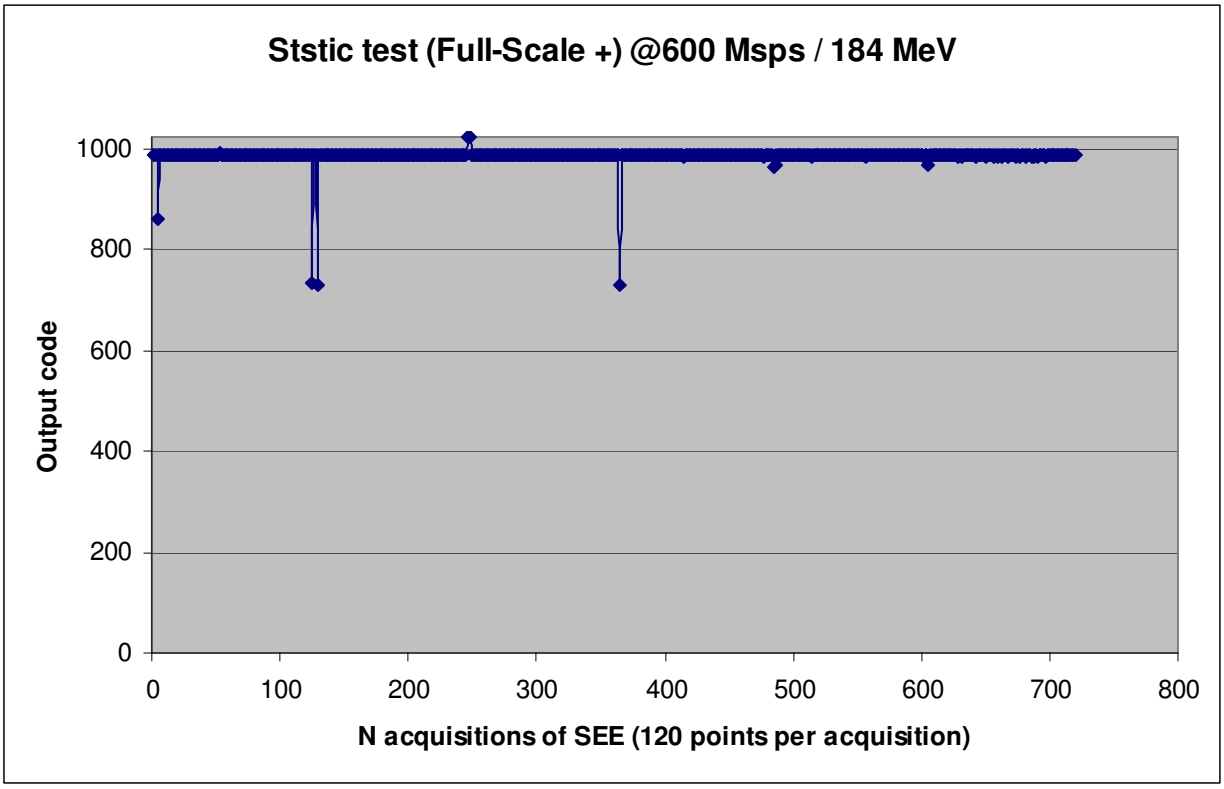

Figure 7 – Concatenation of events for full-scale+ pattern @600Msps / 184 MeV

The Figure 7 shows the concatenation of all events detected on run 1 at 600 Msps with positive full-scale pattern (184 MeV):

- Among the 5 SEUs detected:
  - 1 SEU are of amplitude 128 LSB
  - 4 SEUs are of amplitude 256 LSB
- Among the 2 Long SEUs, SETs detected:
  - There is 1 SET of 2 consecutive data
  - There is 1 long SEU with code 1023 (duration of **3** consecutive data)

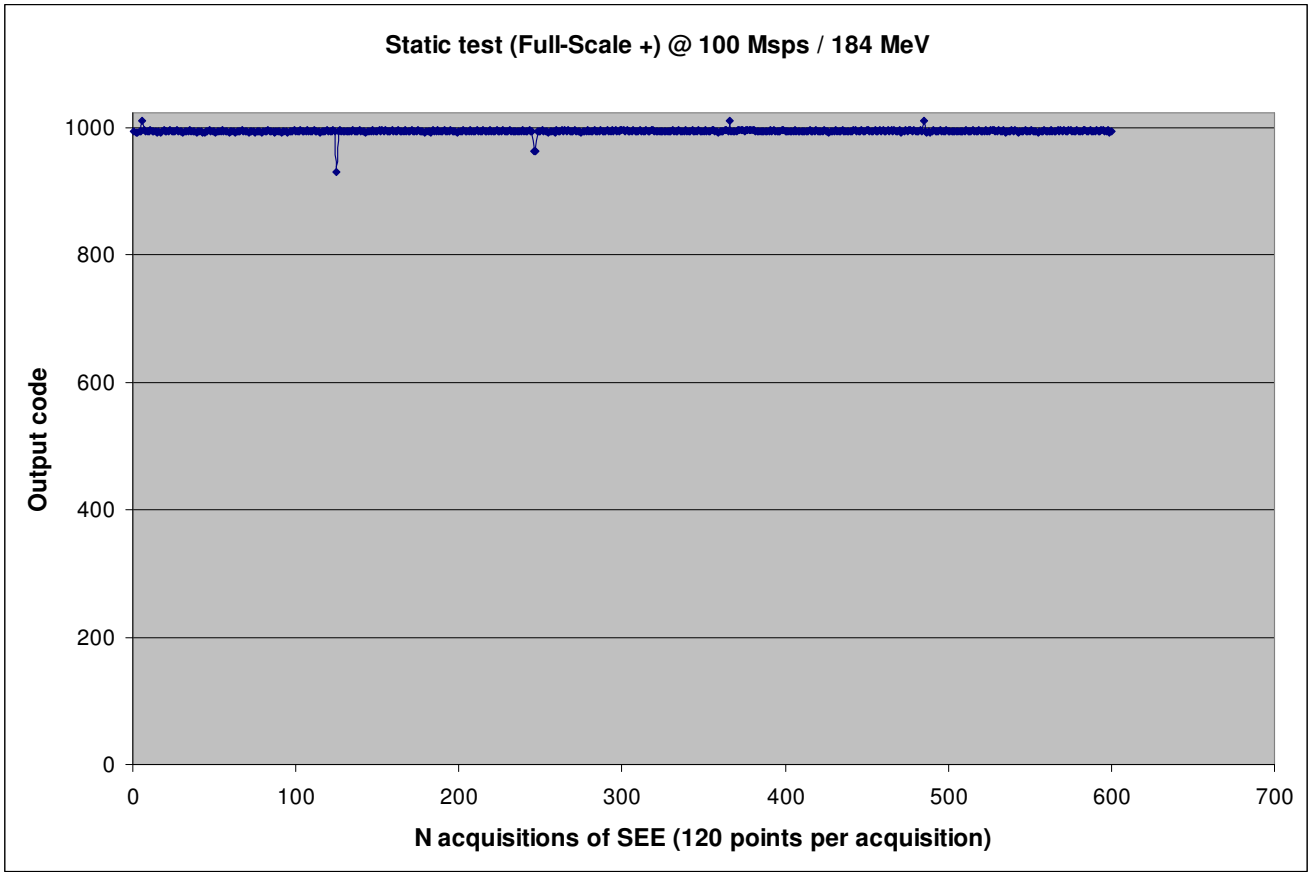

Figure 8 – Concatenation of events for full-scale+ pattern @100Msps / 184 MeV

The Figure 8 shows the concatenation of all events detected on run 2 at 100 Msps with positive full-scale pattern (184 MeV):

- Among the 4 SEUs detected:
  - 3 SEUs are of amplitude 16 LSB
  - 1 SEU are of amplitude 64 LSB
- 1 Long SEUs, SETs detected:
  - It is a long SEU of duration 2 consecutive data and amplitude 32 LSBs

Amplitude and number of events appears to slightly increase when the clock rate is increased. However, the statistic is too small to conclude.

7.4.5 Static tests for mid-scale ADC input

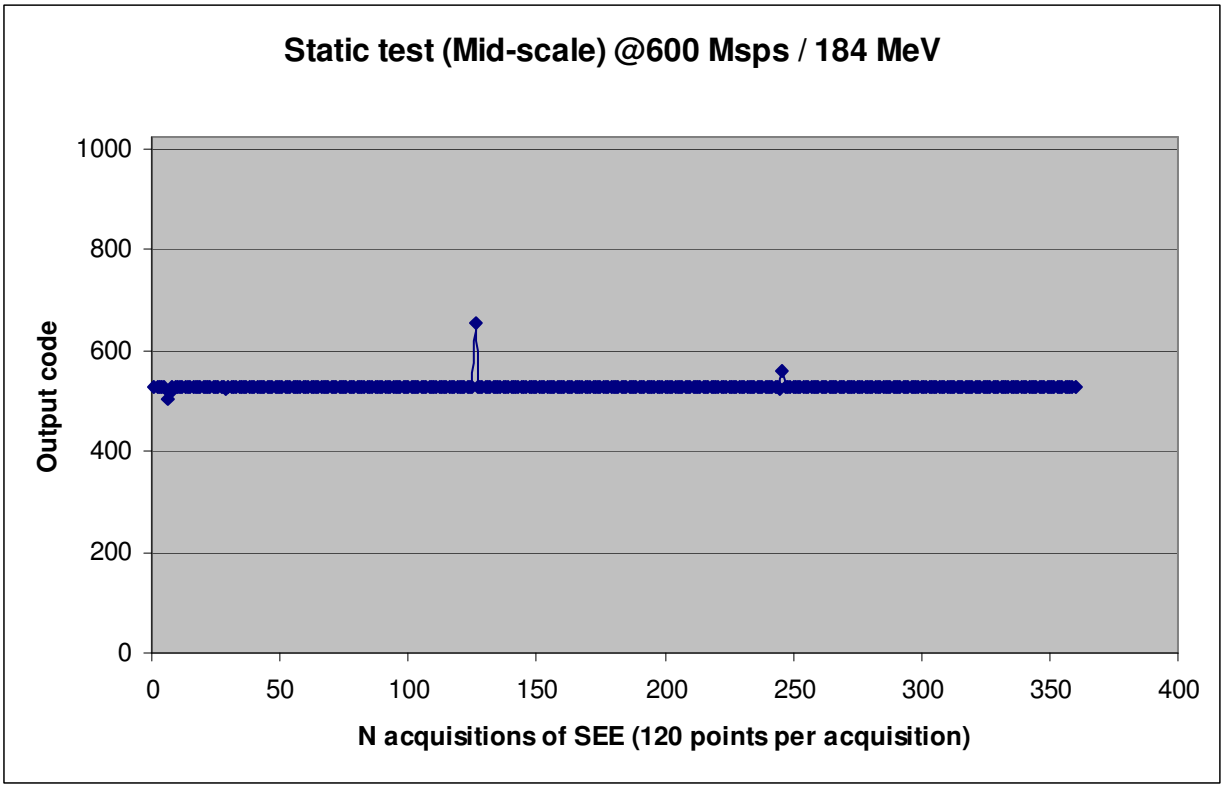

Figure 9 – Concatenation of events for mid-scale pattern @600Msps / 184 MeV

The Figure 9 shows the concatenation of all events detected on run 4 at 600 Msps with mid-scale pattern (184 MeV):

- Among the 3 SEUs detected:
  - 1 SEU are of amplitude 16 LSB
  - 1 SEU are of amplitude 32 LSB
  - 1 SEU are of amplitude 128 LSB
- No Long SEU or SET detected

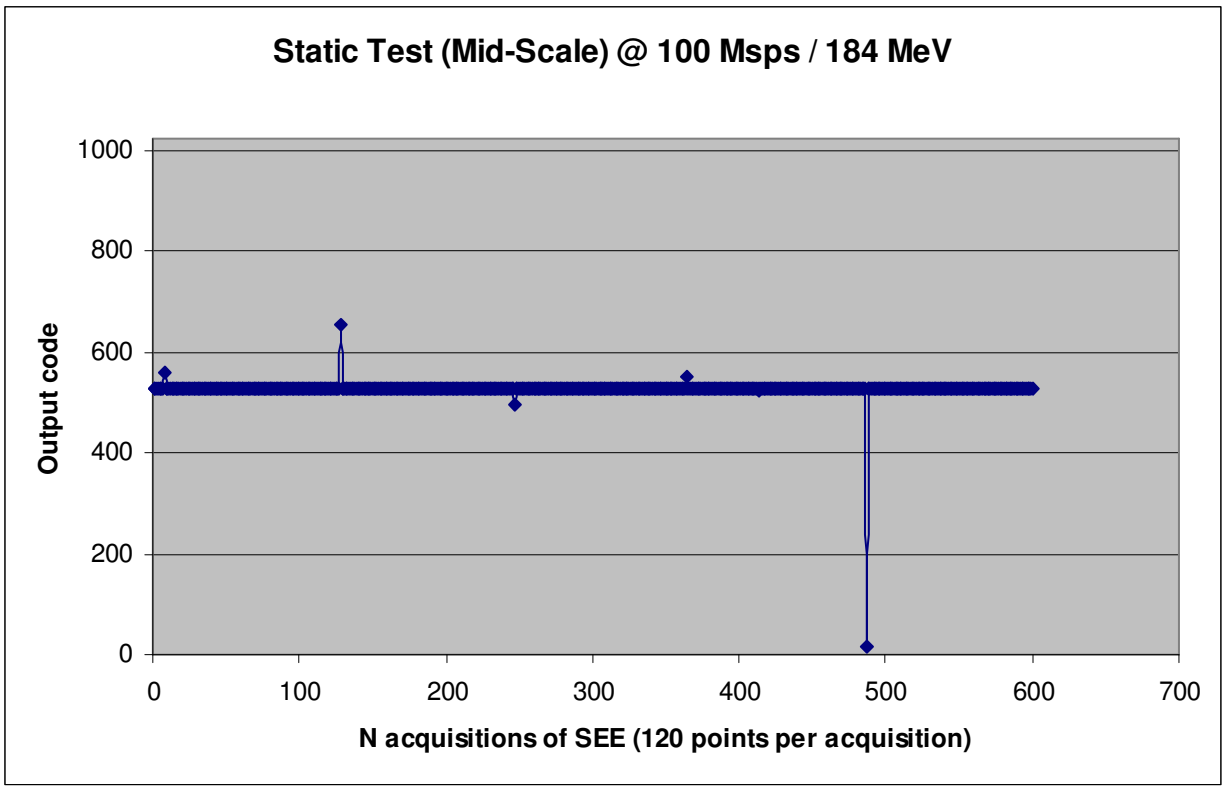

Figure 10 – Concatenation of events for mid-scale pattern @600Msps / 184 MeV

The Figure 10 shows the concatenation of all events detected on run 3 at 100 Msps with mid-scale pattern (184 MeV):

- Among the 5 SEUs detected:
  - 1 SEU are of amplitude 16 LSB
  - 2 SEU are of amplitude 32 LSB
  - 1 SEU are of amplitude 128 LSB
  - 1 SEU are of amplitude 512 LSB
- No Long SEU or SET detected

7.4.6 Static tests for negative Full-scale ADC input

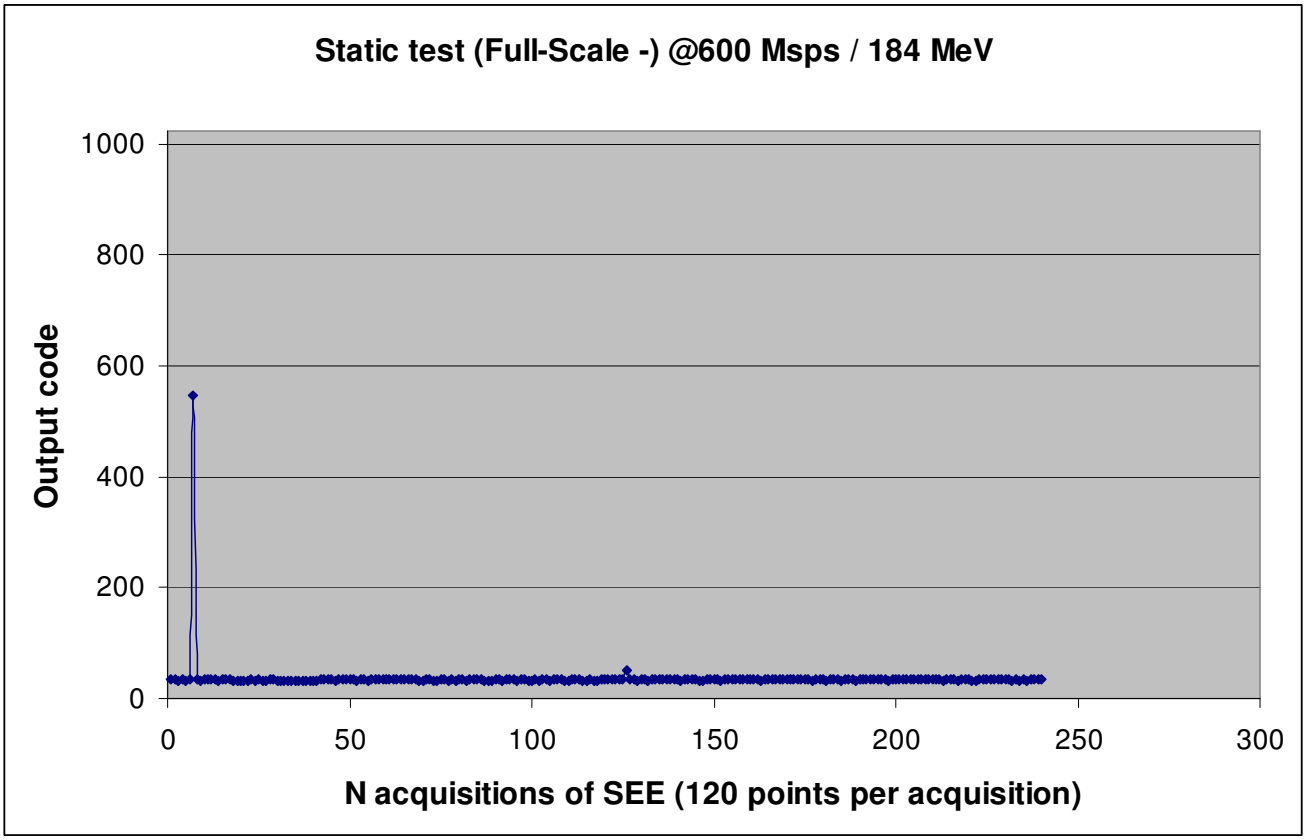

Figure 11 – Concatenation of events for negative full-scale pattern @600Msps / 184 MeV

The Figure 11 shows the concatenation of all events detected on run 5 at 600 Msps with negative full-scale pattern (184 MeV):

- Among the 2 SEUs detected:
  - 1 SEU are of amplitude 16 LSB
  - 1 SEU are of amplitude 512 LSB
- No Long SEU or SET detected:

Figure 12 – Concatenation of events for mid-scale pattern @600Msps / 184 MeV

The Figure 12 shows the concatenation of all events detected on run 3 at 100 Msps with negative full-scale pattern (184 MeV):

7.4.7 Dynamic tests

For 184 MeV.cm²/mg on device 2 (run n°9) we observed:

- Among the 3 SEUs detected:
  - There is 1 SEU is of amplitude 64 LSB
  - There is 1 SEU of amplitude 128 LSB
  - There is 1 SEU of amplitude 512 LSB
- No Long SEU or SET detected

7.4.8 Long SEU/SET duration vs clock rate

The table below summarize the maximum duration of events depending on the pattern and clock rate:

Pattern	Full-Scale -	Mid-Scale	Full-Scale +	Dynamic
600 Msps	2	3	5	2
100 Msps	2	2	4	N/A

Table 5 – Long SEU/SET duration (number of consecutive corrupted data) vs clock rate and pattern

We can conclude that the duration of Long SEU/SETs does not exceed 5 consecutive data for all patterns considered. There is no strong sensibility of long SEU/SET to clock rate.

7.4.9 Conclusions on proton tests

Very few events were detected with proton tests even if the device appears to be sensitive down to the 20MeV Energy. Some additional tests were done at the end of the test with a higher fluence (run 47 to 52) in order to obtain a better statistics.
Most events are SEU and the few long SEU/SET detected are of short duration (always lower than 5 consecutive data).

8. RADIATION TEST RESULTS SUMMARY

Parameter	Symbol	Results	Unit	Comments
Radiation total dose	TID	110	Krad	No issue
Latch up free	SEL	> 80	MeV-cm²/mg	No SEL at 184MeV with protons
SEFI (Single event Functional Interrupt) - Recoverable with Reset	SEFI	NO SEFI		
Permanent conversion errors - Recoverable with Reset		No permanent error		
HEAVY IONS				
LET threshold	LETth	0.7 to 1.6	MeV	Depending on the pattern
Saturated cross-section	Xsat	3.8E-05 to 2.1E-04	Cm²	Depending on the pattern
Long SEU/SET duration	Long SEU	< 48	consecutive corrupted data	48 consecutive data for dynamic tests 44 consecutive data for static tests
SEE performance for a geostationary satellite				
SEE performance	SEE	2.48E-04 to 8.24E-02	SEU/device.day	Depending on the pattern
Multi conversion errors (self recovering)		1.27E-02 / Device.day (>78 days)	MTBF (GEO)	Worst case obtained for static tests $01F at 600Msps Better results with dynamic tests at 600Msps: 4.00 E-03 (250 days)
Single conversion errors (self recovering)		8.24E-02 (12 days)	MTBF (GEO)	Worst case obtained for static tests $20F at 600Msps Better results with dynamic tests at 600Msps: 1.82 E-02 (55 days)
PROTONS				
Energy threshold	Eth	< 20	MeV	
Saturated cross-section	Xsat	1E-10 to 1.3E-09	Cm²	Depending on the pattern
Long SEU/SET duration	Long SEU	< 5	consecutive corrupted data	
SEE performance for a geostationary satellite				
SEE performance	SEE	4.47E-05 to 7.83E-03	SEU/device.day	Depending on the pattern
Multi conversion errors (self recovering)		1.16E-03 / Device.day (>862 days)	MTBF (GEO)	Worst case obtained for static tests $01F at 600Msps. Better results with dynamic tests at 600Msps: 5.91 E-04 (1692 days)
Single conversion errors (self recovering)		7.83E-03 (127 days)	MTBF (GEO)	Worst case obtained for static tests $3E0 at 600Msps Better results with dynamic tests at 600Msps: 5.03 E-03 (198 days)