D2.4 - ADC Radiations Test Report (TID&SEE) - EV12AQ600 - Mask VO03A - J710JSG

Revision date :	**20/07/2021**
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Approved by	Approbation Status	Date
TE2V (OLIVIER BONNET)	OK	20/07/2021
TAS (JEAN-PHILIPPE MAUREL)	OK	20/07/2021

1. DOCUMENT AMENDMENT RECORD

Author	Issue	Date	Reason for change
BONNET Olivier	A	27/05/2021	Creation
BONNET Olivier	B	19/07/2021	Add SEFI contribution §9.6.1

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2. GLOSSARY

ATE Automatic Test System
CRÈME Cosmic Ray Effects on Micro-Electronics
DAC Digital-to-Analog Converter
DC Direct Current
DSP Digital Signal Processor
DUT Device Under Test
ENOB Effective Number of Bits
HF High Frequency
HIF Heavy Ions Facility
HSL Highest Spur Level
IUCM Input Under Clocking Mode
LED Light-Emitting Diode
LET Linear Energy Transfer
MTBF Mean Time Between Failure
MUX MUltipleXer
NRTZ Narrow Return To Zero
NRZ Non Return to Zero
OCDS Output Clock Division Select Function
OMERE Modelization tool for extern radiative environment
PSS Phase Shift Select Function
RADEF RADiation Effects Facility (Jyväskylä University laboratory, Finland)
RIN Input Resistance
RF Radio Frequency
RTZ Return To Zero
SEE Single Event Effect
SEFI Single Event Functional Interrupt
SEL Single Event Latchup
SET Single Event Transient
SFDR Spurious Free Dynamic Range
SFSR Signal to Full Scale Range
SINAD Signal to Noise and Distortion
SNR Signal to Noise Ratio
THD Total Harmonic Distortion
VOH Voltage Output High
VOL Voltage Output Low

3. INTRODUCTION

This report describes the tests performed on the device EV12AQ600 (STMicroelectronics BiCmos9 130nm, mask VO03A) to determine :

- Its sensitivity to the total ionizing dose (TID) at 150Krad with a low dose rate of 36rad/h (10mrad/s)
- Its sensitivity to the heavy ions test (SEE) up to 67 MeV.cm^2/mg

4. APPLICABLE AND REFERENCE DOCUMENTS

[AD01]	TRAD RADIATION ASSISTANCE TEST REPORT TRAD_ATR_AQ600_XXX1_ASI_MF_1904_Rev0
[AD02]	Technical proposal: TRAD/P/ASI/EV12AQ600/FD/190718 Rev1 dated 21/05/2019
[AD03]	Irradiation test plan: TRAD/ITP/ASI/EV12AQ600/ELG/190619 Rev.3 dated 28/10/2020
[RD01]	ESA ESCC Specification 22900 – Total Dose Steady-State Irradiation Test Method
[RD02]	MIL-STD-883J Method 1019.9 – Ionizing Radiation (Total Dose) Test Procedure
[RD03]	ASTM 1892-12 – Standard Guide for ionizing Radiation (Total Dose) Effect Testing of Semiconductors Devices
[RD04]	ESCC Basic specification No. 25100 Issue 2 of October 2014
[RD05]	Datasheet EV12AQ600 1203D-BDC Quad 12-bit 1.6 GSps ADC with embedded cross-point switch, Digitizing up to 6.4 GSps

5. EXECUTIVE SUMMARY

5.1 Lot description

Reference	EVP12AQ600
Package	CBGA323
Function	Quad 12-bit 1.6 GSps ADC
Technology	STMicroelectonics BiCmos9 130nm
Diffusion Lot No.	J710JSG
Mfr. No.	EVP12AQ600SH
Mask Lot	VO03A
Front End Date Code	1822
Manufacturer	Teledyne E2V

5.2 Total dose

Ten devices, five ON, five OFF, were tested, with a dose rate of 36rad/h and up to a total dose of 150Krad(Si).

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 device under test (P/N EVP12AQ600SH) had neither functional failure nor parameter drift up to 150 Krad (Si) with a dose rate of 36rad/h (10mrad/s).

5.3 Heavy ions

The main objective of this test was to evaluate the sensitivity of the EVP12AQ600SH, an Analog to Digital Converter, to Single Event Latch up (SEL) and Single Event Effects (SEU, SEFI, SET).

This test was performed by TRAD for THALES ALENIA SPACE FRANCE at RADEF with a maximum LET at 67 MeV.cm²/mg. Irradiations were performed from November 6th, 2020 to November 7th, 2020. During this test campaign, 3 samples were irradiated.

The behavior of the fours cores is identical.

The SEL test was performed at 125°C ±1°C.

- No SEL was detected with a LET of 67 MeV.cm²/mg.

The SET on SSO test is performed at 92°C:

- SET on SSO were observed with a minimum LET of 1.5 MeV.cm²/mg
- No LET threshold was found with available heavy ions during this test campaign

The SET on SYNCO test was performed at 92°C:

- SET on SYNCO were observed with a minimum LET of 9.0 MeV.cm²/mg.
- No SET on SYNCO was observed with a LET of 1.5 MeV.cm²/mg.

The SEU on core A, B, C and D test was performed at 92°C:

- SEU on core A, B, C and D were observed with a minimum LET of 1.5 MeV.cm²/mg.
- No LET threshold was found with available heavy ions during this test campaign.

The SEU on serial lanes of core A, B, C and D test is performed at 92°C:

- SEU on the serial lanes of core A, B, C and D were observed with a minimum LET of 1.5MeV.cm²/mg.
- No LET threshold was found with available heavy ions during this test campaign.

The SEFI on serial lanes of core A, B, C and D test is performed at 92°C:

- SEFI on serial lanes of core A, B, C and D were observed with a minimum LET of 1.5MeV.cm²/mg.
- No LET threshold was found with available heavy ions during this test campaign.

In the EV12AQ600, 100% of the SEFI were detected by the check of the CLK, CB2 (timestamp) and CB1 (parity bit), and all the SEFI were solved by a simple SYNC.

The EV12AQ600 Quad channel 12 bits 1.6GSps ADC has successfully pass this heavy ions test. The latch-up immunity, the perfect similarity of the four cores, the SEFI easy to manage and the very good performances of both, SSO and SYNCO signals must be particularly noted.

6. TOTAL DOSE TESTS

6.1 Irradiation facility

The tests have been performed at TRAD (Toulouse) by using a Co60 source.

The Co60 irradiation certificate is available in the Annex 1 of this document.

6.2 Part references

12 parts have been used for these tests, 5 part biased ON, 5 parts biased OFF and 2 reference parts.

Serial number	3	4	5	6	7	8	9	10	11	12	1	2
Bias mode	ON					OFF					REF	

6.3 Automatic Test Equipment (ATE) : Pre-irradiation tests

The tests were performed with the test program under development, to assure that the cores were functional and that the static measurements were OK.

6.4 Bias conditions

VccA	3.3V
VccD	1.2V
VccO	2.5V
VccSPI	2.5V
Clock Frequency	6GHz
Input Frequency	2GHz

6.5 Dosimetry and irradiation facility

Irradiation Source	^{60}Co
Source Location	Labège (TRAD, France)
Irradiation equipment	GAMRAY
Dosimetry equipment	PTW

6.6 Target Dose 150KRad

Total Dose Limit (KRad(Si))	152KRad					
Total Dose Steps	0	18	34	88	100	152
Dose rate (Rad(Si)/h)	36Rad/H					

6.7 Annealing

24h at room temperature and 168h at 100°c.

6.8 Intermediate measurements

Conditions:

- Ambient temperature
- Socketed Evaluation board
- Nominal power supplies

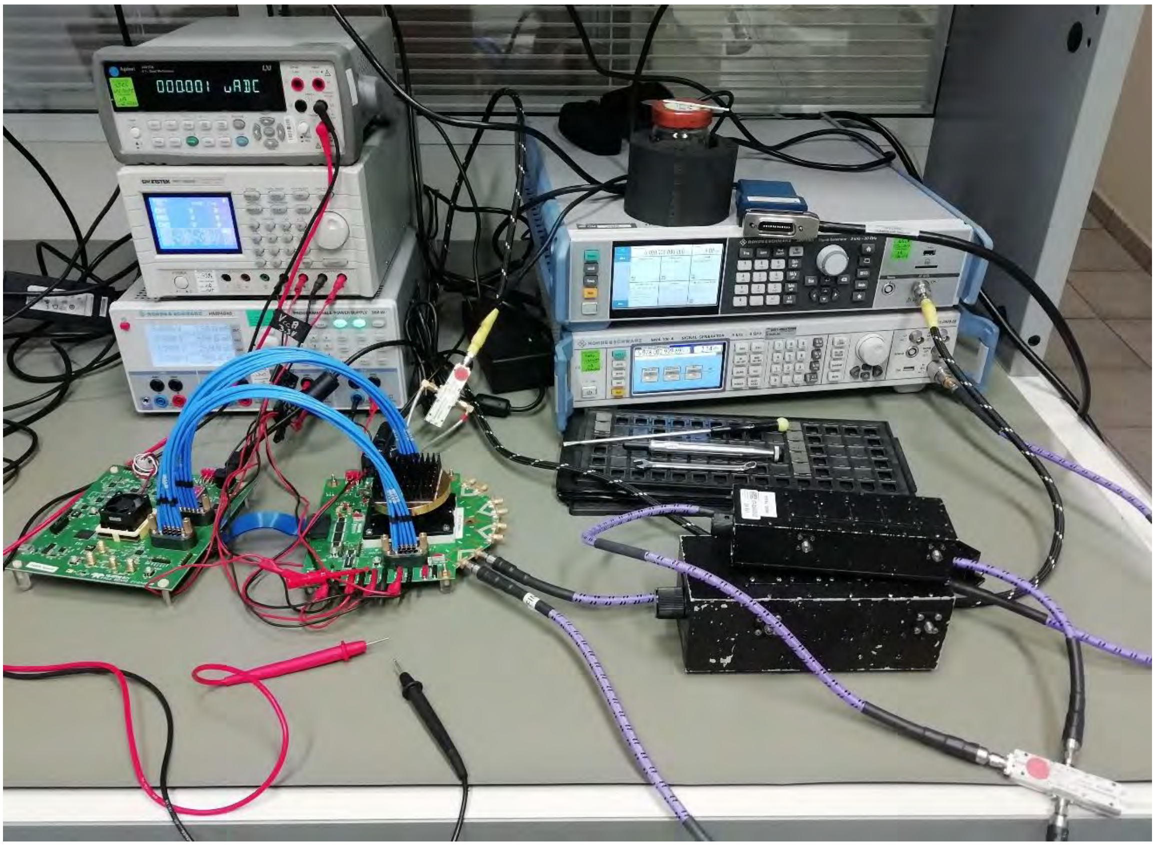
Measurements:

- Power consumption
- Leakage current
- Dynamic measurements

Clock Frequency : 6.4GHz

Input Frequency : 100MHz, 1850MHz, 2230MHz & 5980MHz, by using the IN0 input

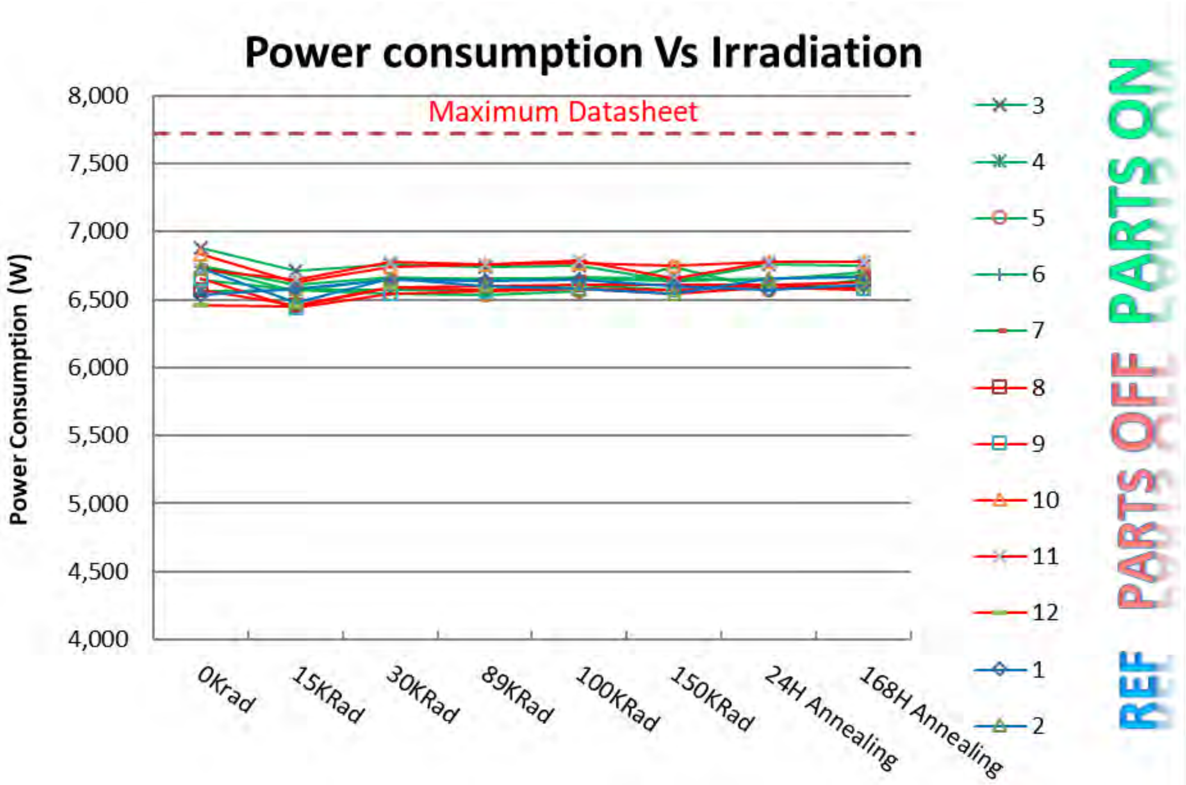
Input power : -1, -3, -8 & -12dBFs



7. TOTAL DOSE RESULTS

7.1 Power Consomption

		Steps							
Part	Power consumption	0Krad	15KRad	30KRad	89KRad	100KRad	150KRad	24H Annealing	168H Annealing
1	(W)	6,53	6,58	6,65	6,64	6,65	6,59	6,57	6,61
2	(W)	6,73	6,48	6,65	6,60	6,58	6,55	6,66	6,67
3	(W)	6,88	6,71	6,76	6,74	6,75	6,64	6,76	6,75
4	(W)	6,56	6,57	6,58	6,57	6,61	6,57	6,61	6,59
5	(W)	6,64	6,57	6,55	6,54	6,56	6,74	6,57	6,65
6	(W)	6,74	6,57	6,66	6,65	6,65	6,63	6,66	6,68
7	(W)	6,75	6,61	6,66	6,65	6,66	6,65	6,65	6,70
8	(W)	6,57	6,46	6,59	6,60	6,61	6,60	6,61	6,62
9	(W)	6,65	6,44	6,55	6,56	6,58	6,57	6,60	6,58
10	(W)	6,83	6,62	6,74	6,76	6,77	6,75	6,78	6,77
11	(W)	6,72	6,64	6,78	6,76	6,79	6,65	6,78	6,78
12	(W)	6,46	6,45	6,59	6,57	6,58	6,54	6,59	6,57

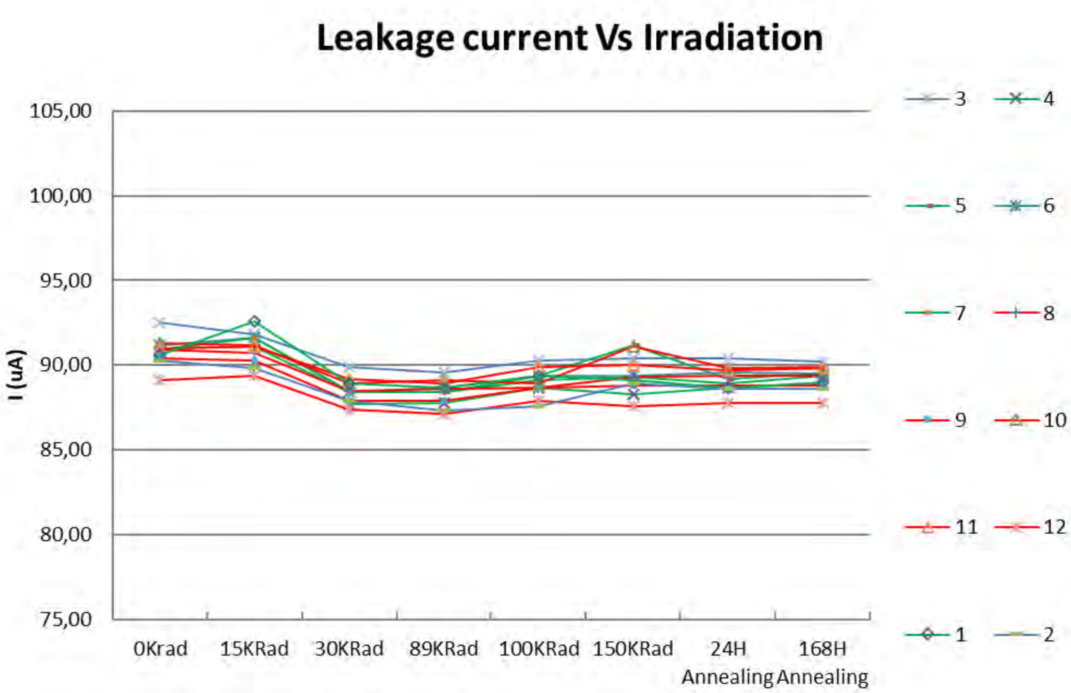


Conclusion:

There is no impact of TID on the power consumption up to 150Krad.

7.2 Leakage Current

Part	Leakage Current	Steps							
		0Krad	15KRad	30KRad	89KRad	100KRad	150KRad	24H Annealing	168H Annealing
1	PSS (uA)	90,60	92,60	88,90	88,70	89,40	89,10	88,70	89,00
2	PSS (uA)	90,30	89,80	87,90	87,30	87,60	88,90	88,60	88,60
3	PSS (uA)	92,52	91,80	89,90	89,60	90,30	90,40	90,40	90,20
4	PSS (uA)	90,80	0,00	87,70	87,80	88,70	88,30	88,70	88,90
5	PSS (uA)	91,00	91,10	88,40	88,40	89,40	91,20	89,20	89,60
6	PSS (uA)	91,20	91,60	88,40	88,70	89,40	89,40	89,60	89,50
7	PSS (uA)	90,90	91,60	88,50	88,40	89,10	89,30	88,90	89,40
8	PSS (uA)	90,90	90,70	88,50	88,60	88,70	89,30	89,40	89,40
9	PSS (uA)	90,40	90,30	87,90	87,90	88,70	88,80	88,80	88,80
10	PSS (uA)	91,30	91,20	88,90	89,10	88,90	91,10	89,80	89,90
11	PSS (uA)	91,00	91,10	89,20	88,90	89,90	90,00	89,70	89,80
12	PSS (uA)	89,10	89,40	87,40	87,10	87,90	87,60	87,80	87,80



Conclusion:

There is no impact of TID on the leakage current up to 150KRad.

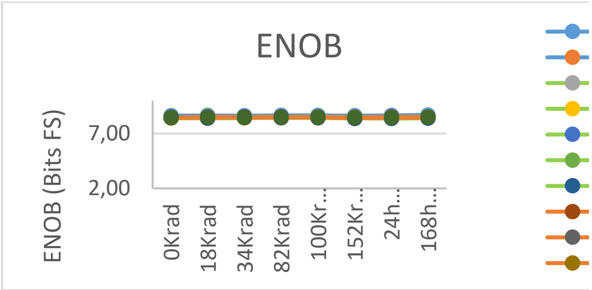
7.3 FFT Results

When the TID start, the final program of the test facilities was not the final one, in particular, the automatic calibration was not available, so the 12 devices were calibrated manually. The consequences are that some configurations have not been optimized, especially for 1_Channel mode and for Fin = 5980MHz.

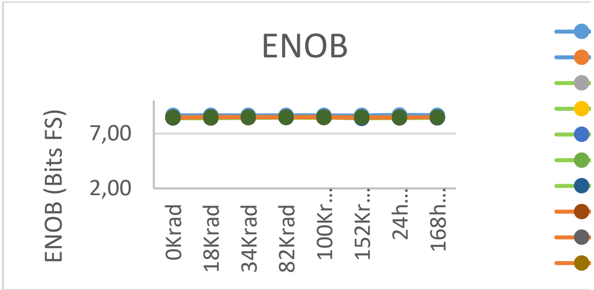
However, the quantity of measurements show that there is no significant variation, the various core have the same behavior during the full campaign.

7.3.1 ENOB for core A, B, C & D @ Fin 100MHz, -1dBFs

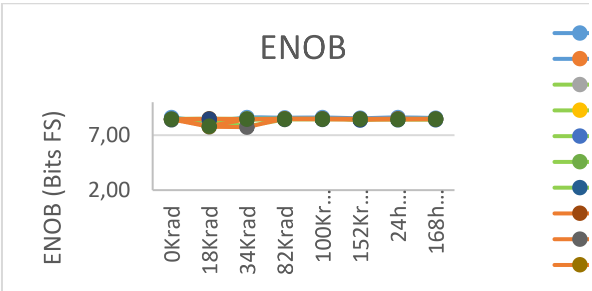
Core A



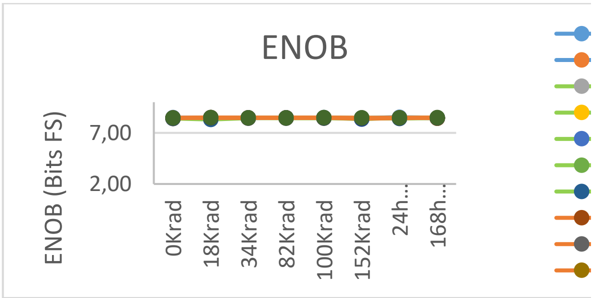
Core B



Core C



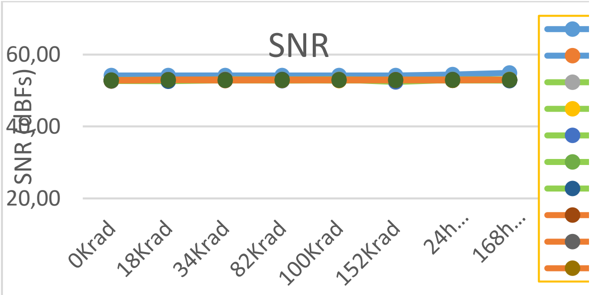
Core D



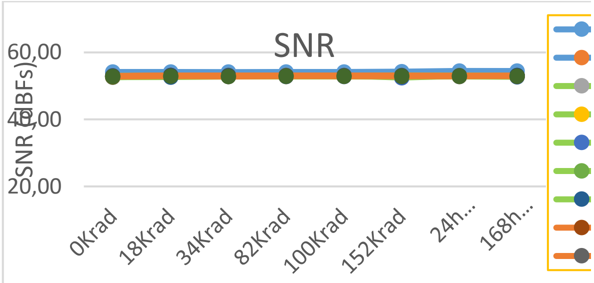
The variations in Core,C at step 18 & 34Krad are the consequence of an acquisition problem, which appears, on some reference devices too. The socket was cleaned and the problem disappears at the following steps.

7.3.2 SNR for core A, B, C & D @ Fin 100MHz, -1dBFs

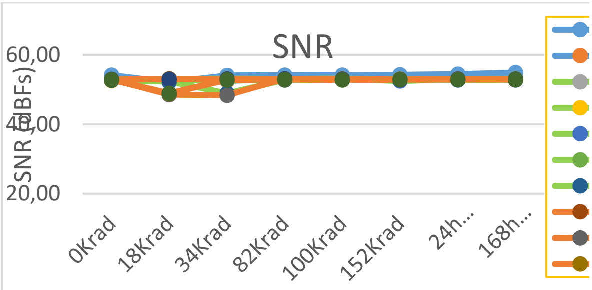
Core A



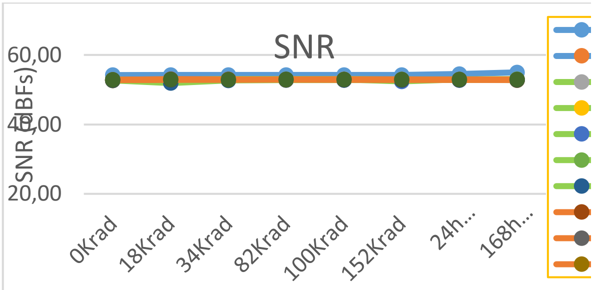
Core B



Core C



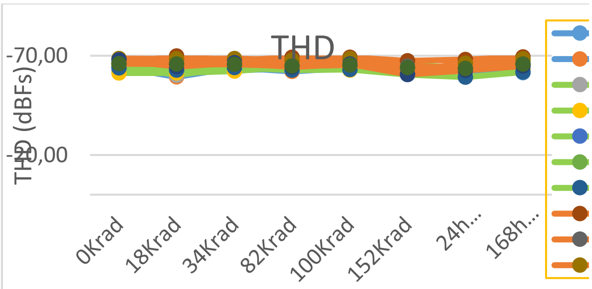
Core D



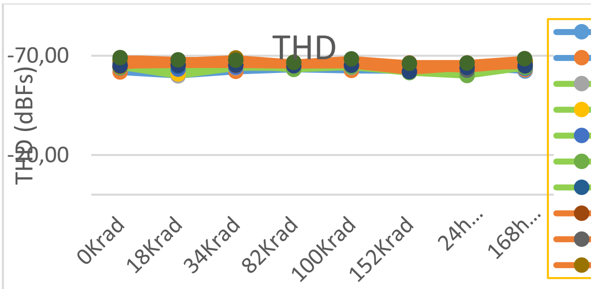
The variations in Core C, at step 18 & 34Krad are the consequence of an acquisition problem, which appears, on some reference devices too. The socket was cleaned and the problem disappears at the following steps.

7.3.3 THD for core A, B, C & D @ Fin 100MHz, -1dBFs

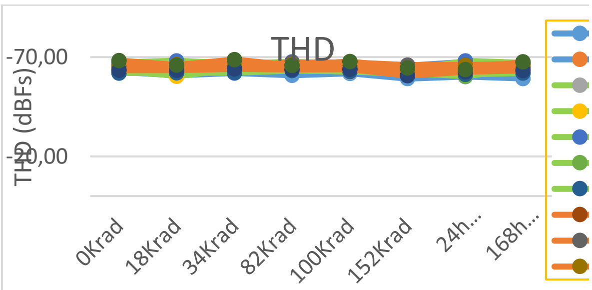
Core A



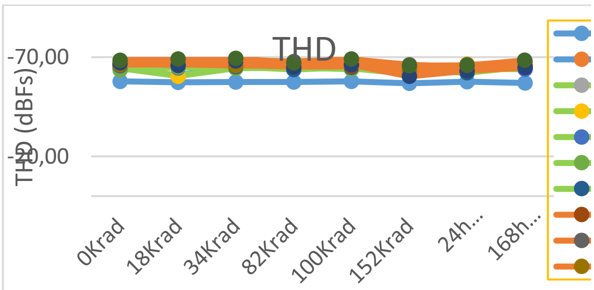
Core B



Core C



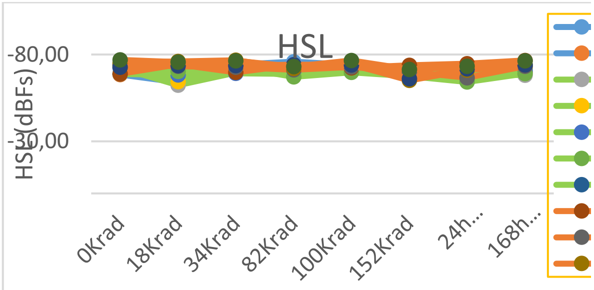
Core D



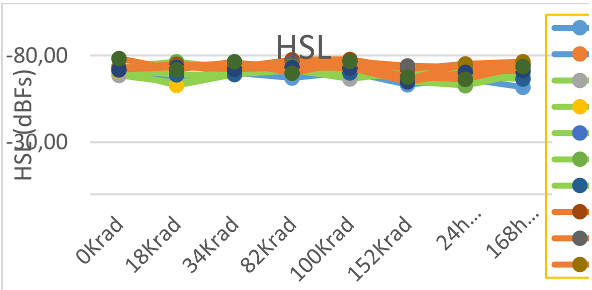
7.3.4 HSL for core A, B, C & D @ Fin 100MHz, -1dBFs

Core A

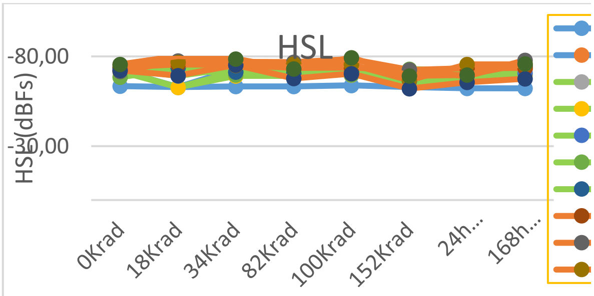
Core B



Core C

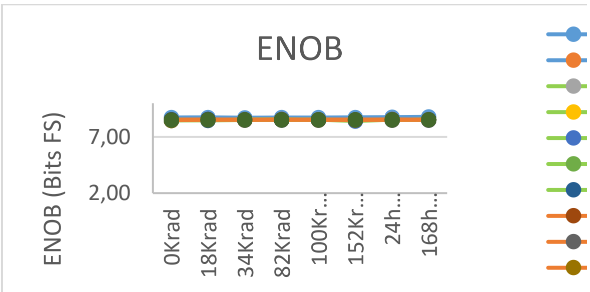


Core D

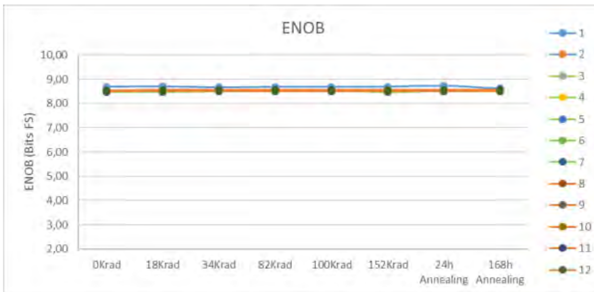


7.3.5 ENOB for core A, B, C & D @ Fin 100MHz, -12dBFs

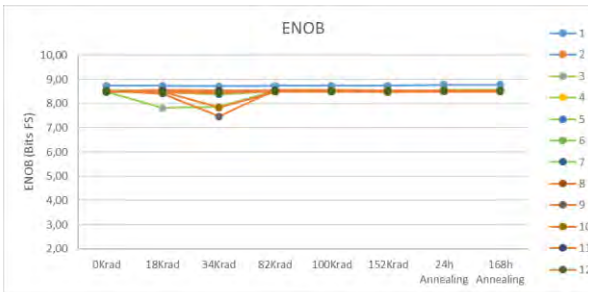
Core A



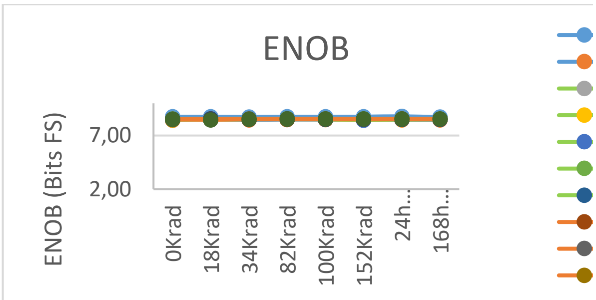
Core B



Core C



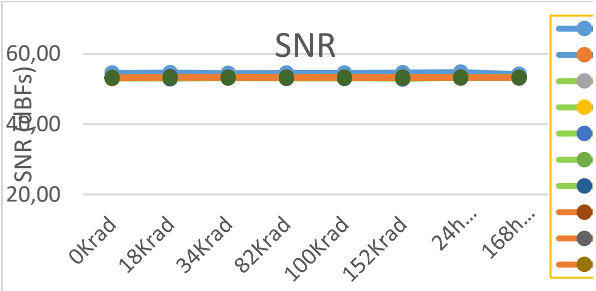
Core D



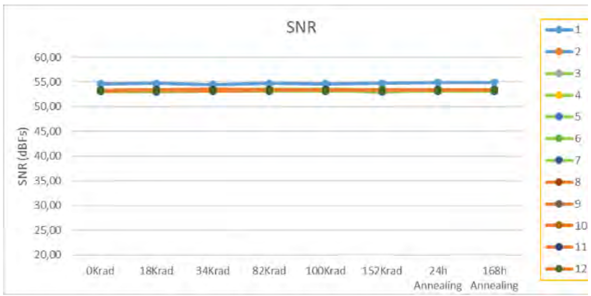
The variations in Core C, at step 18 & 34Krad are the consequence of an acquisition problem, which appears, on some reference devices too. The socket was cleaned and the problem disappears at the following steps.

7.3.6 SNR for core A, B, C & D @ Fin 100MHz, -1dBFs

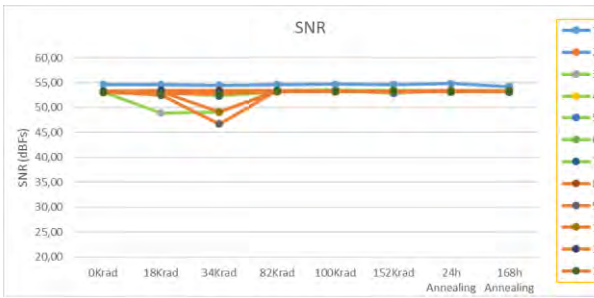
Core A



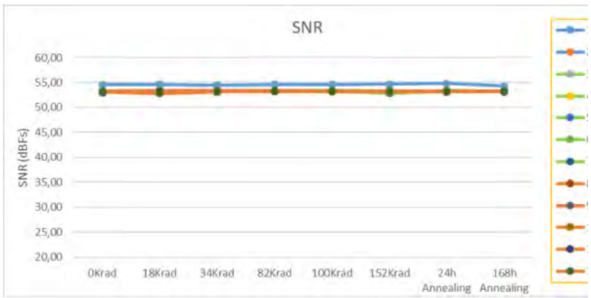
Core B



Core C



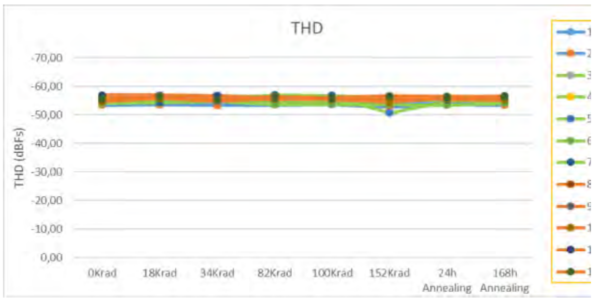
Core D



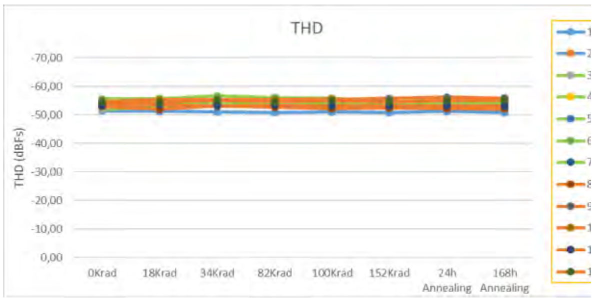
The variations in Core C, at step 18 & 34Krad are the consequence of an acquisition problem, which appears, on some reference devices too. The socket was cleaned and the problem disappears at the following steps.

7.3.7 THD for core A, B, C & D @ Fin 100MHz, -12dBFs

Core A



Core B

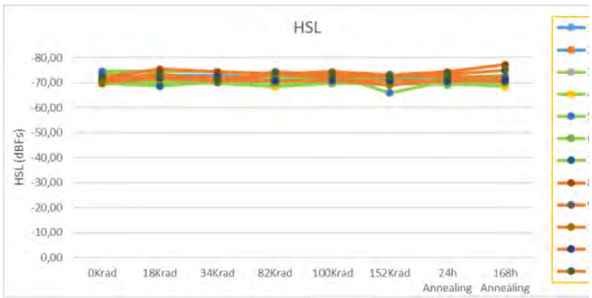


Core C

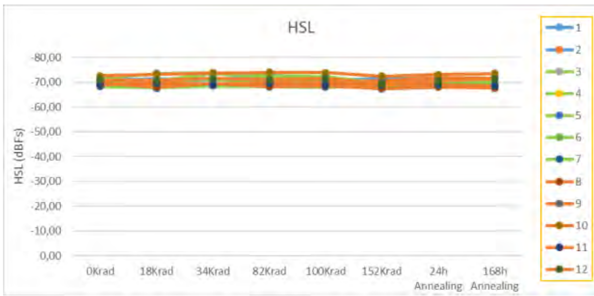
Core D

7.3.8 HSL for core A, B, C & D @ Fin 100MHz, -12dBFs

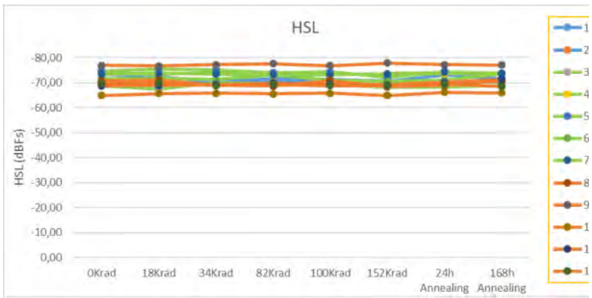
Core A



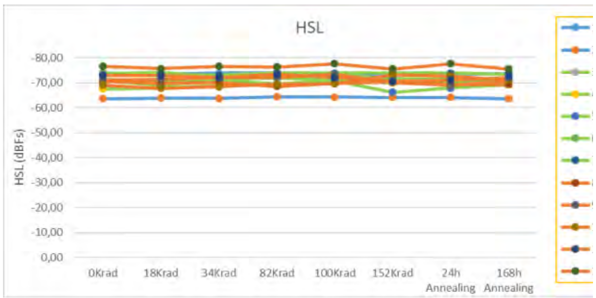
Core B



Core C

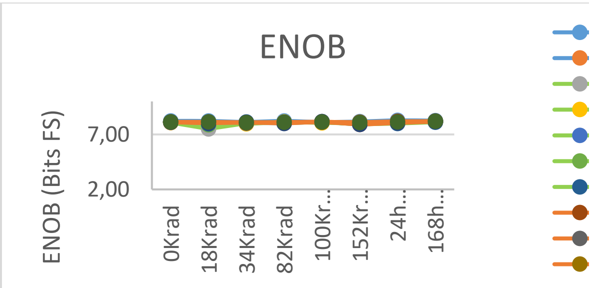


Core D

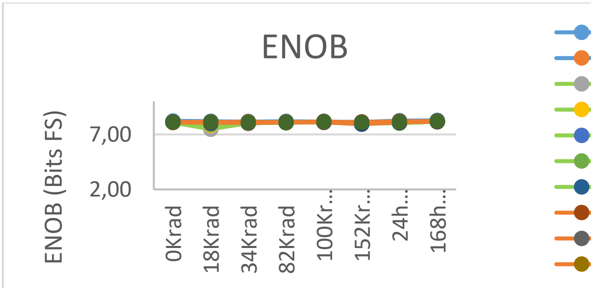


7.3.9 ENOB for core A, B, C & D @ Fin 1580MHz, -1dBFs

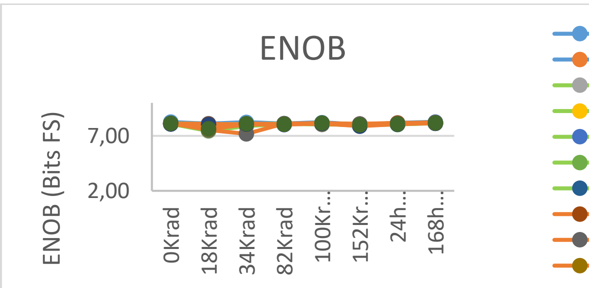
Core A



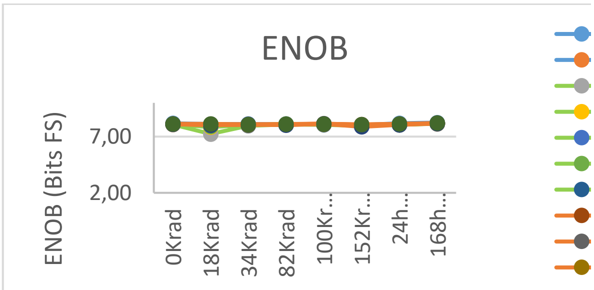
Core B



Core C



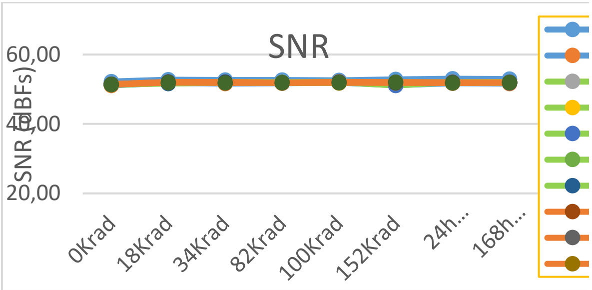
Core D



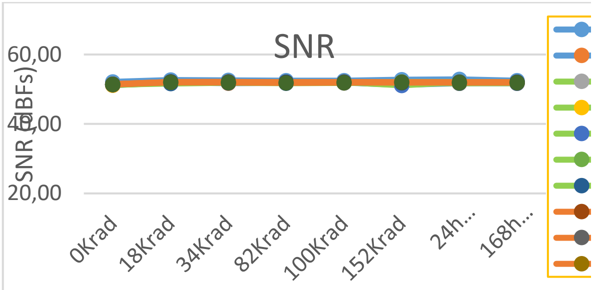
The variations in various Core, at step 18 & 34Krad are the consequence of an acquisition problem, which appears, on some reference devices too. The socket was cleaned and the problem disappears at the following steps.

7.3.10 SNR for core A, B, C & D @ Fin 1580MHz, -1dBFs

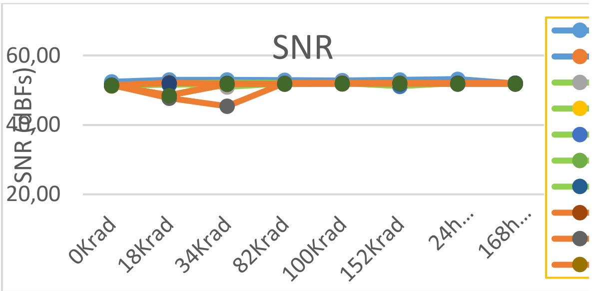
Core A



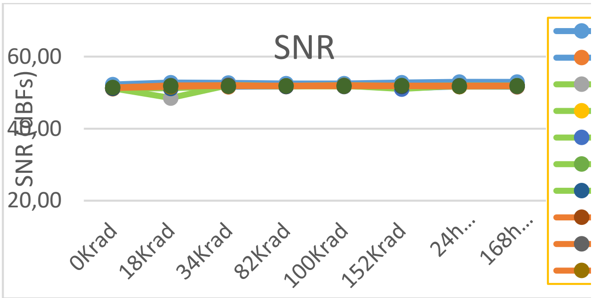
Core B



Core C



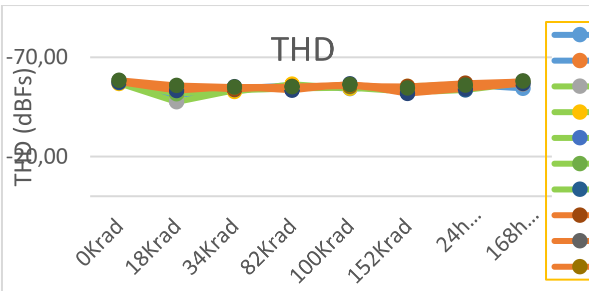
Core D



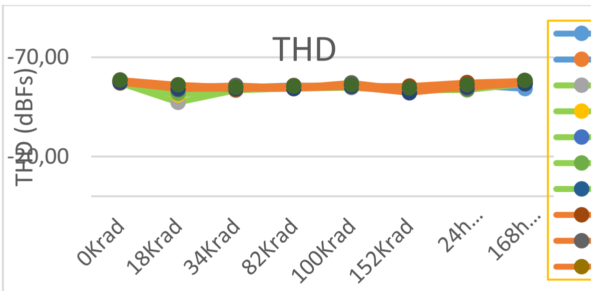
The variations in various Core, at step 18 & 34Krad are the consequence of an acquisition problem, which appears, on some reference devices too. The socket was cleaned and the problem disappears at the following steps.

7.3.11 THD for core A, B, C & D @ Fin 1580MHz, -1dBFs

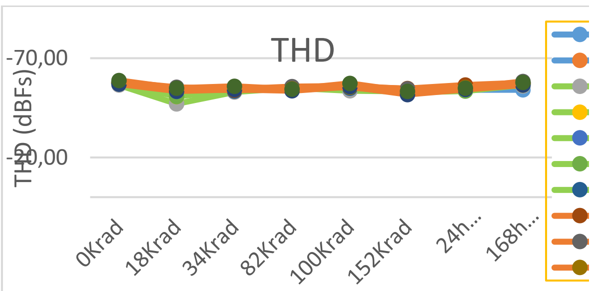
Core A



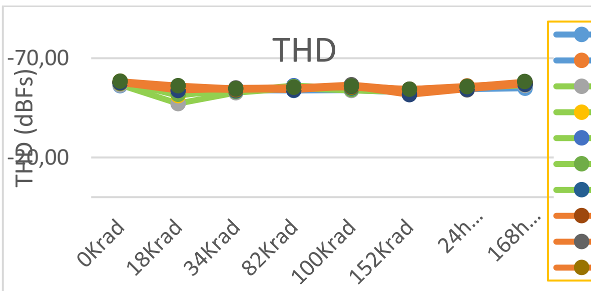
Core B



Core C



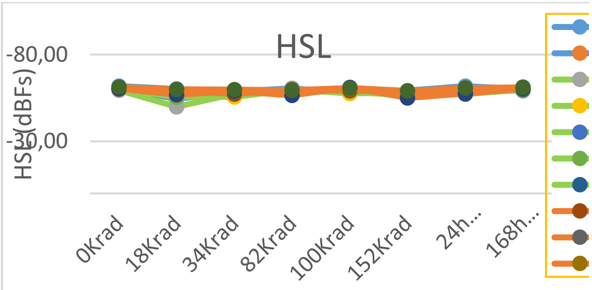
Core D



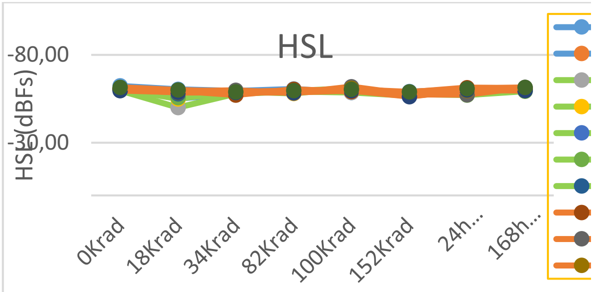
The variations in various Core, at step 18 & 34Krad are the consequence of an acquisition problem, which appears, on some reference devices too. The socket was cleaned and the problem disappears at the following steps.

7.3.12 HSL for core A, B, C & D @ Fin 1580MHz, -1dBFs

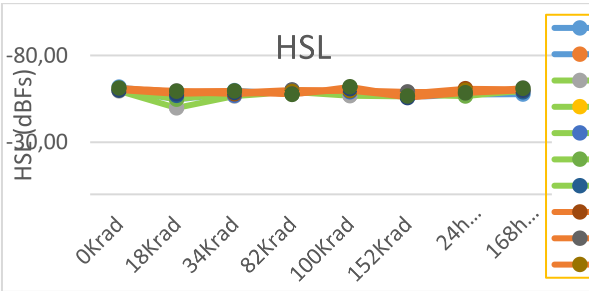
Core A



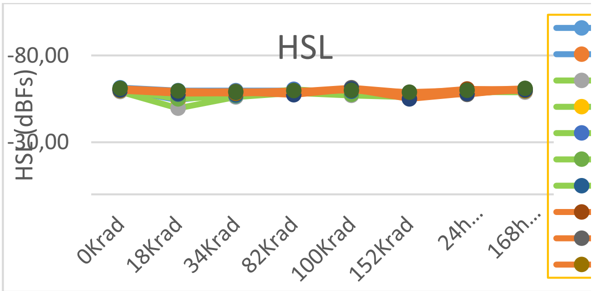
Core B



Core C



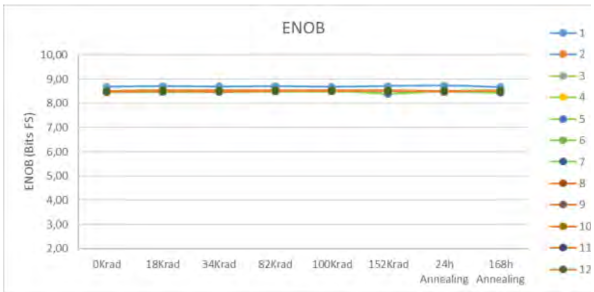
Core D



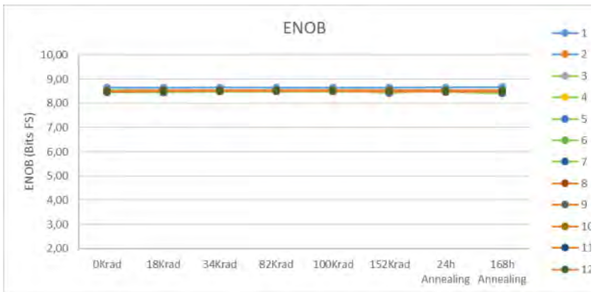
The variations in various Core, at step 18 & 34Krad are the consequence of an acquisition problem, which appears, on some reference devices too. The socket was cleaned and the problem disappears at the following steps.

7.3.13 ENOB for core A, B, C & D @ Fin 1580MHz, -12dBFs

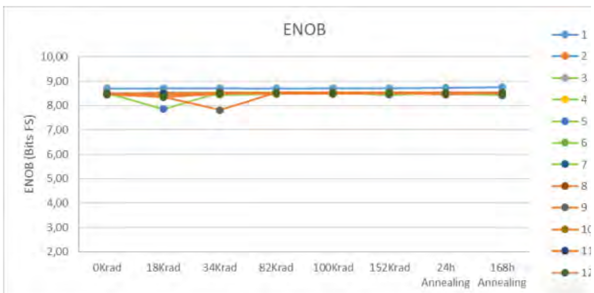
Core A



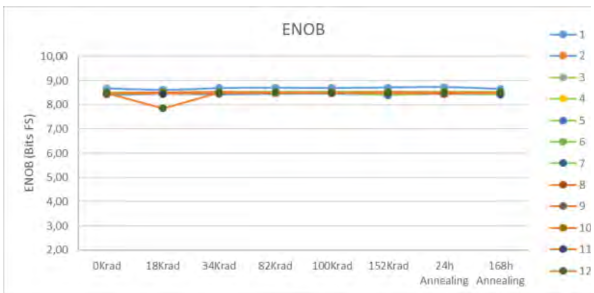
Core B



Core C



Core D



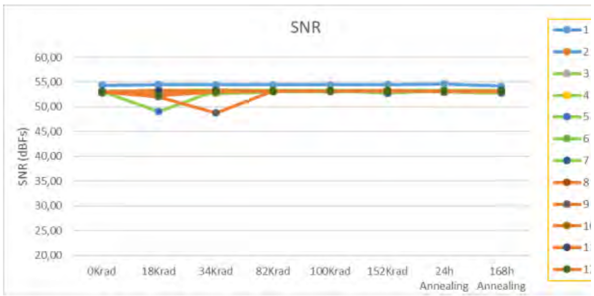
The variations in Core C&D, at step 18 & 34Krad are the consequence of an acquisition problem, which appears, on some reference devices too. The socket was cleaned and the problem disappears at the following steps.

7.3.14 SNR for core A, B, C & D @ Fin 1580MHz, -12dBFs

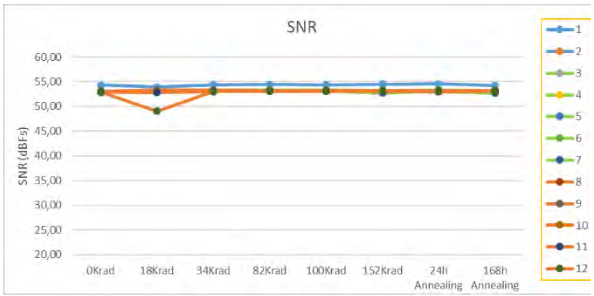
Core A

Core B

Core C



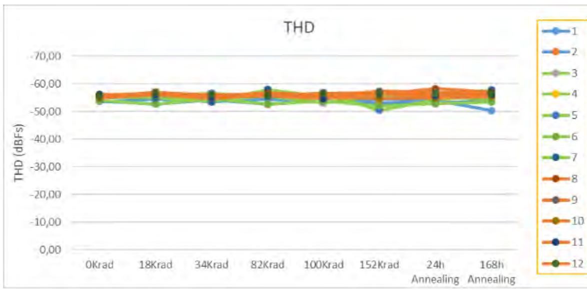
Core D



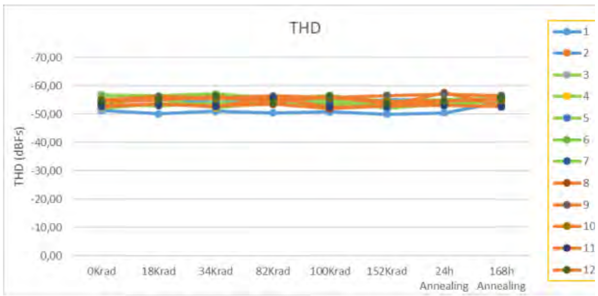
The variations in various Core, at step 18 & 34Krad are the consequence of an acquisition problem, which appears, on some reference devices too. The socket was cleaned and the problem disappears at the following steps.

7.3.15 THD for core A, B, C & D @ Fin 1580MHz, -12dBFs

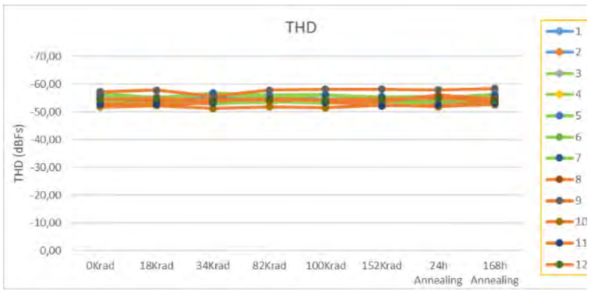
Core A



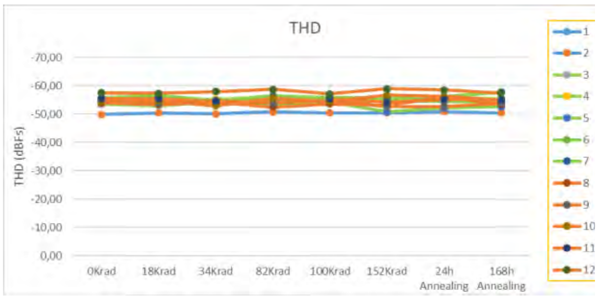
Core B



Core C

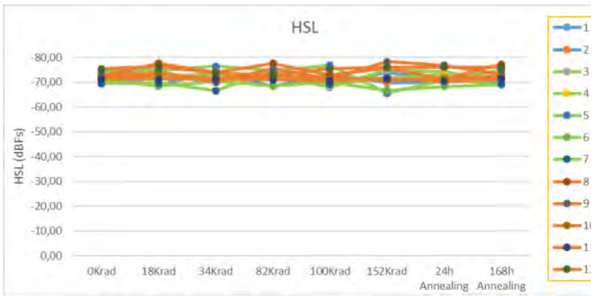


Core D

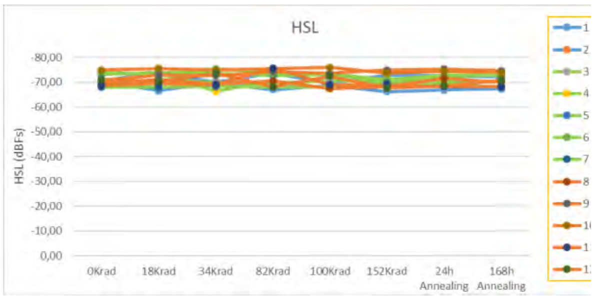


7.3.16 HSL for core A, B, C & D @ Fin 1580MHz, -12dBFs

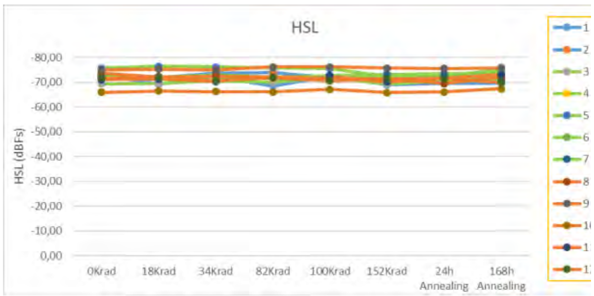
Core A



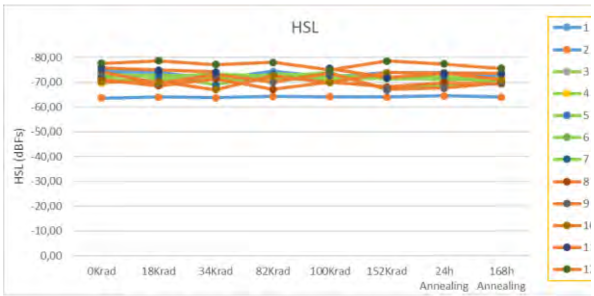
Core B



Core C

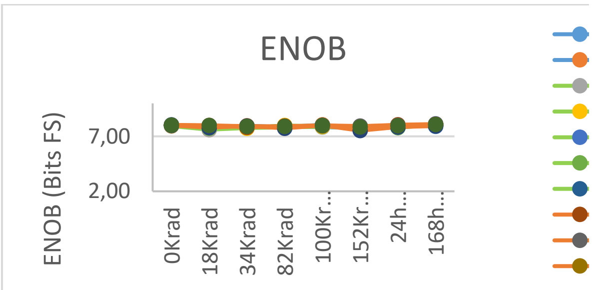


Core D

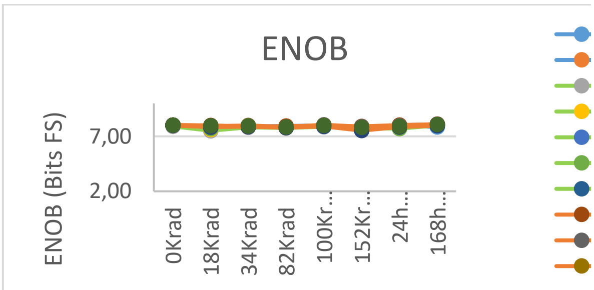


7.3.17 ENOB for core A, B, C & D @ Fin 2230MHz, -1dBFs

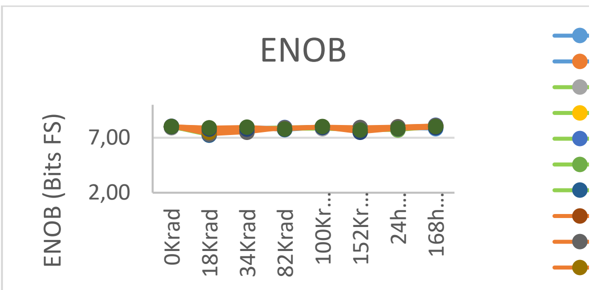
Core A



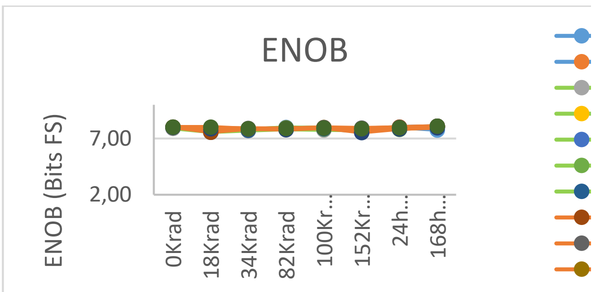
Core B



Core C

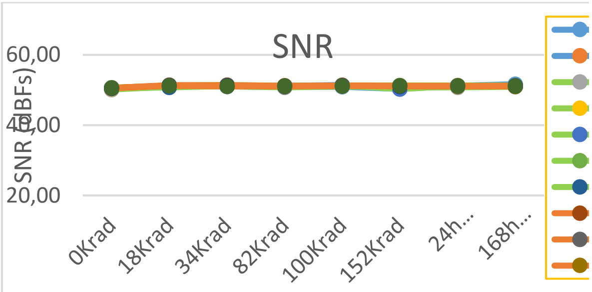


Core D

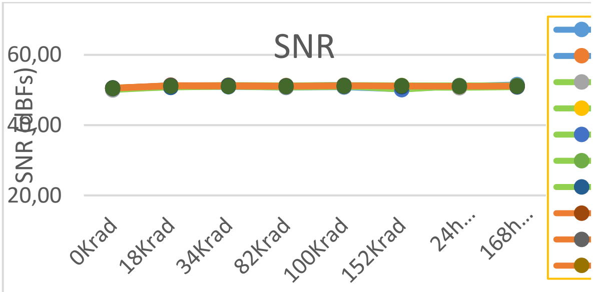


7.3.18 SNR for core A, B, C & D @ Fin 2230MHz, -1dBFs

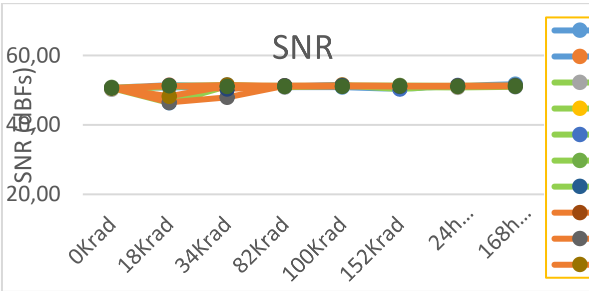
Core A



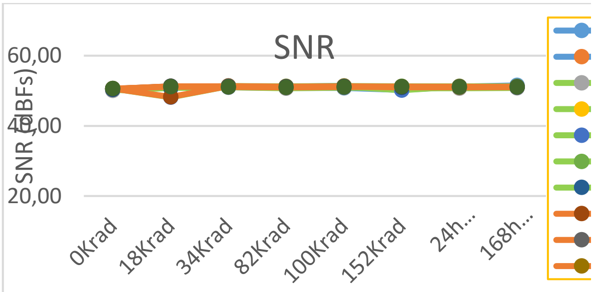
Core B



Core C



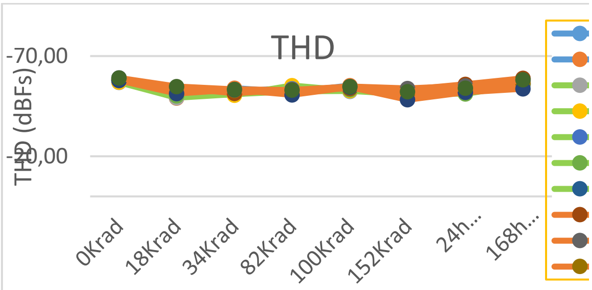
Core D



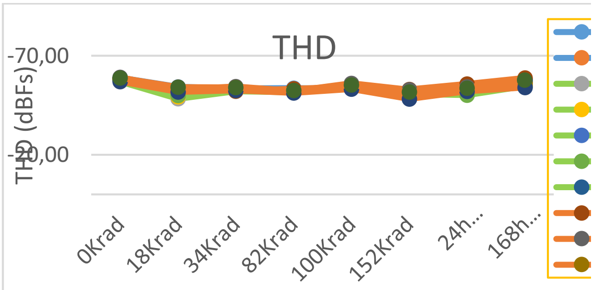
The variations in various Core, at step 18 & 34Krad are the consequence of an acquisition problem, which appears, on some reference devices too. The socket was cleaned and the problem disappears at the following steps.

7.3.19 THD for core A, B, C & D @ Fin 2230MHz, -1dBFs

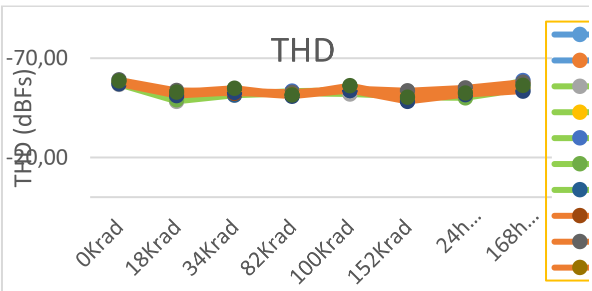
Core A



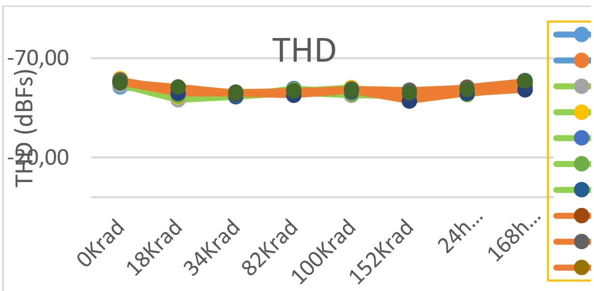
Core B



Core C



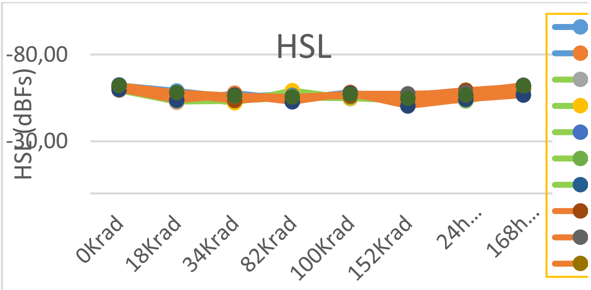
Core D



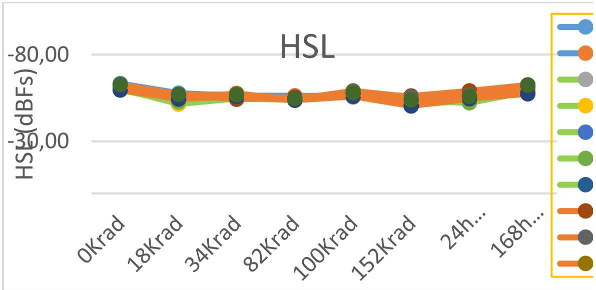
A problem of measurement occurs at 18Krad in those tests and remains in the following tests. All the devices (reference and irradiated parts) are impacted. However, none of these results shows a problem of TID.

7.3.20 HSL for core A, B, C & D @ Fin 2230MHz, -1dBFs

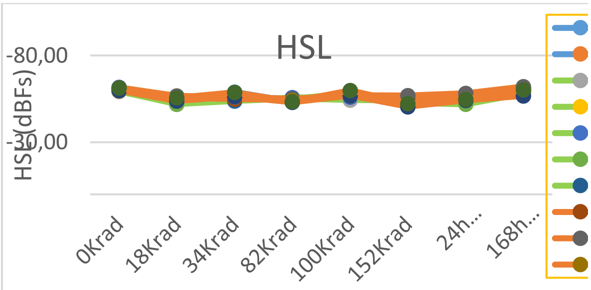
Core A



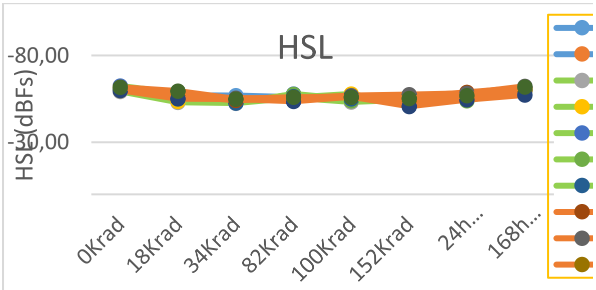
Core B



Core C



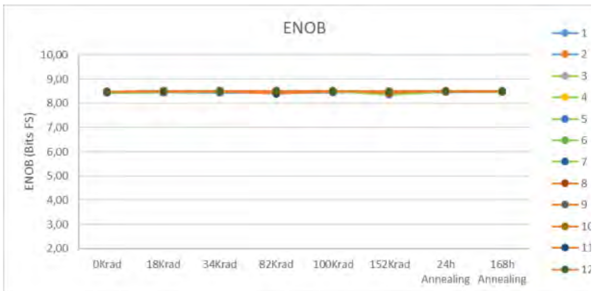
Core D



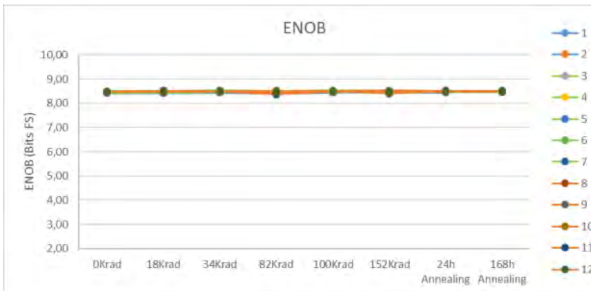
A problem of measurement occurs at 18Krad in those tests and remains in the following tests. All the devices (reference and irradiated parts) are impacted. However, none of these results shows a problem of TID.

7.3.21 ENOB for core A, B, C & D @ Fin 2230MHz, -12dBFs

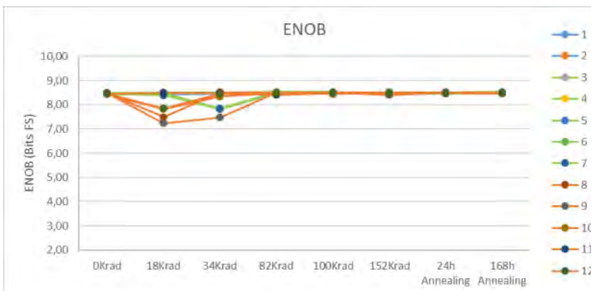
Core A



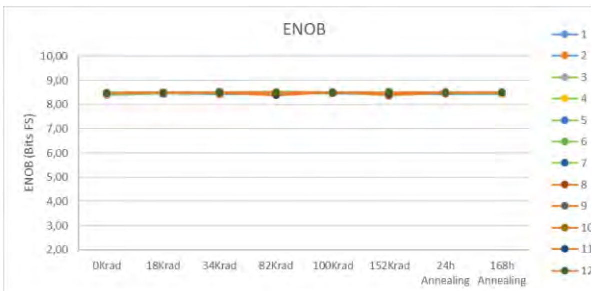
Core B



Core C



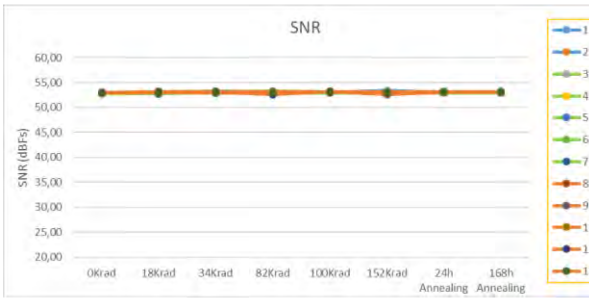
Core D



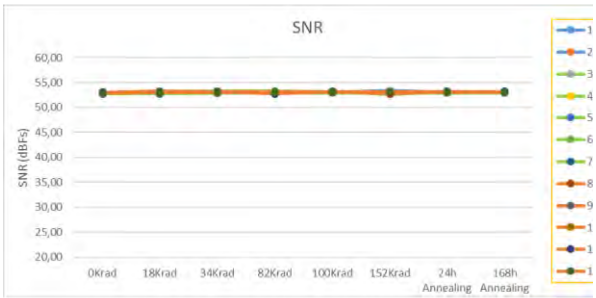
The variations in Core C, at step 18 & 34Krad are the consequence of an acquisition problem, which appears, on some reference devices too. The socket was cleaned and the problem disappears at the following steps.

7.3.22 SNR for core A, B, C & D @ Fin 2230MHz, -12dBFs

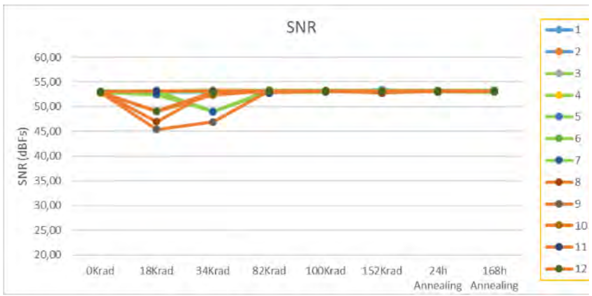
Core A



Core B



Core C



Core D

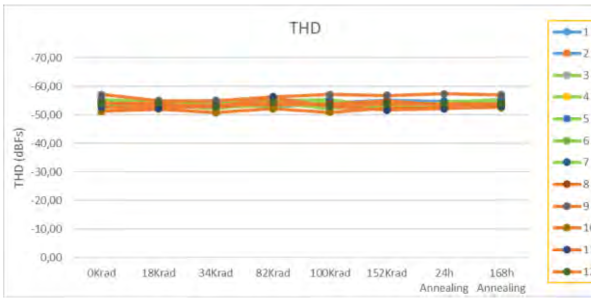
The variations in Core C, at step 18 & 34Krad are the consequence of an acquisition problem, which appears, on some reference devices too. The socket was cleaned and the problem disappears at the following steps.

7.3.23 THD for core A, B, C & D @ Fin 2230MHz, -12dBFs

Core A

Core B

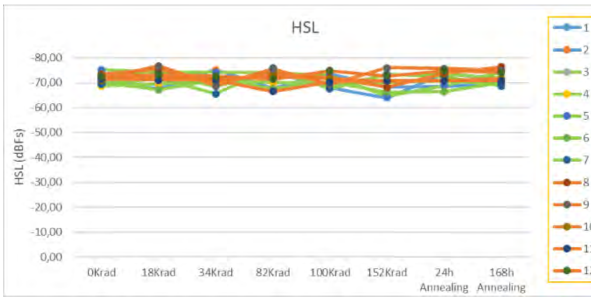
Core C



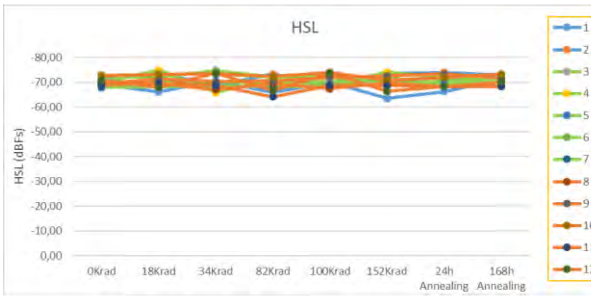
Core D

7.3.24 HSL for core A, B, C & D @ Fin 2230MHz, -12dBFs

Core A

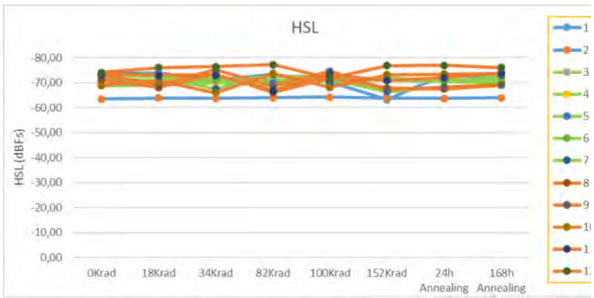


Core B



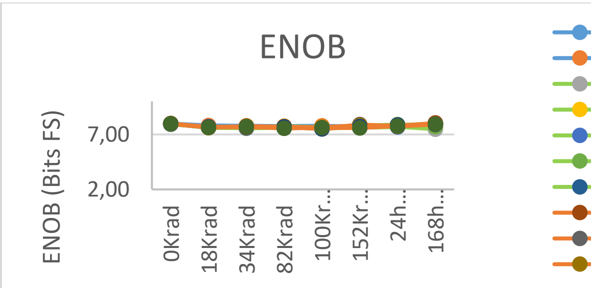
Core C

Core D

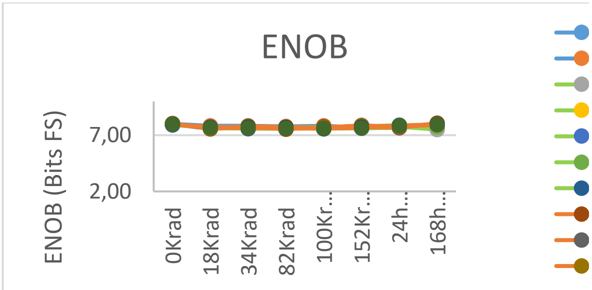


7.3.25 ENOB for core A, B, C & D @ Fin 5980MHz, -8dBFs

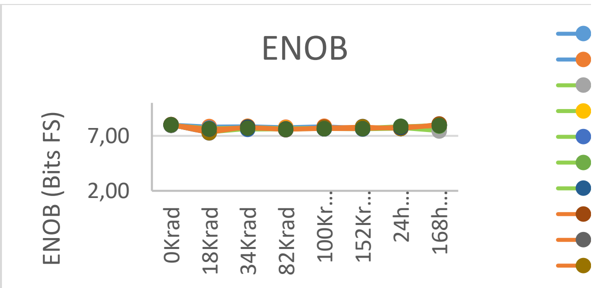
Core A



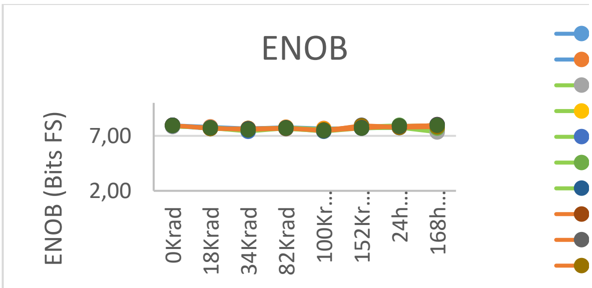
Core B



Core C

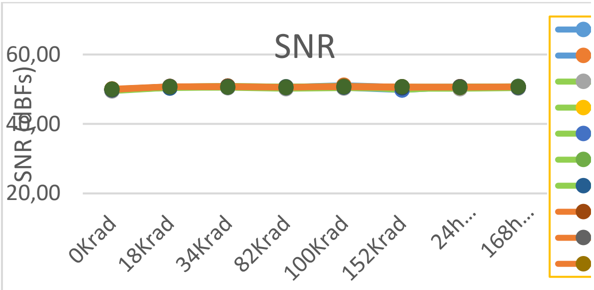


Core D

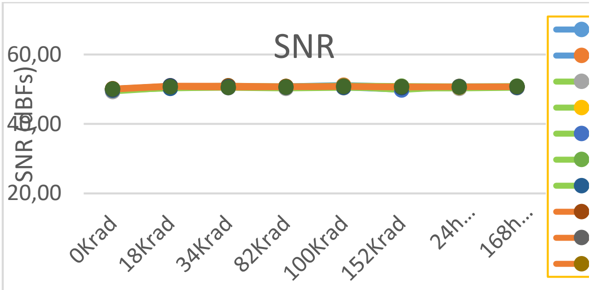


7.3.26 SNR for core A, B, C & D @ Fin 5980MHz, -8dBFs

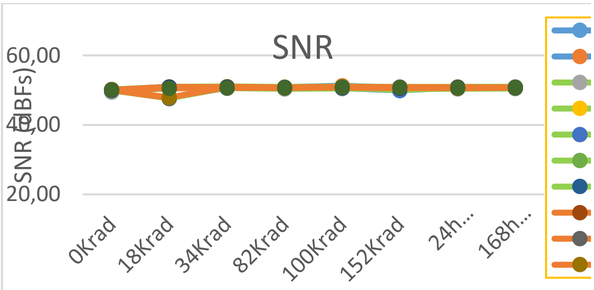
Core A



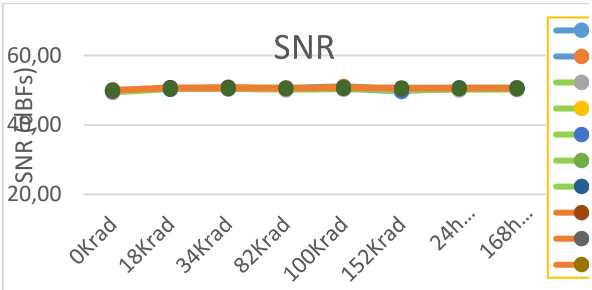
Core B



Core C

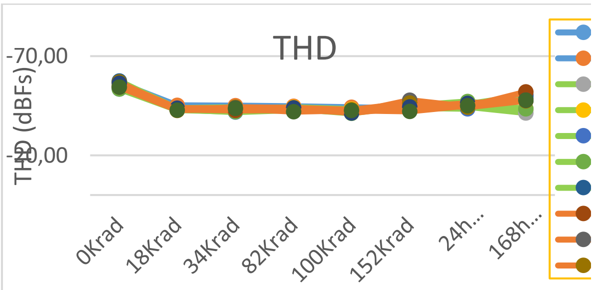


Core D

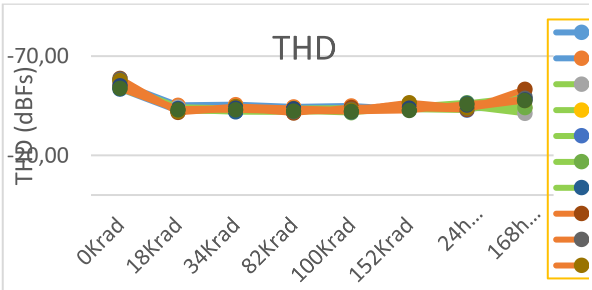


7.3.27 THD for core A, B, C & D @ Fin 5980MHz, -8dBFs

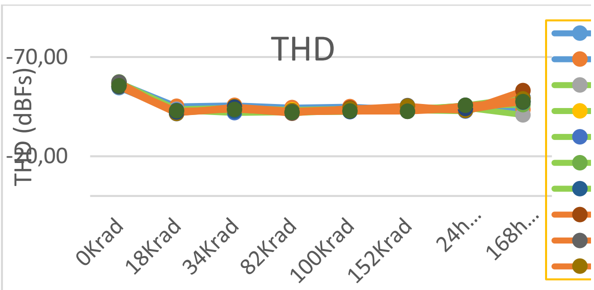
Core A



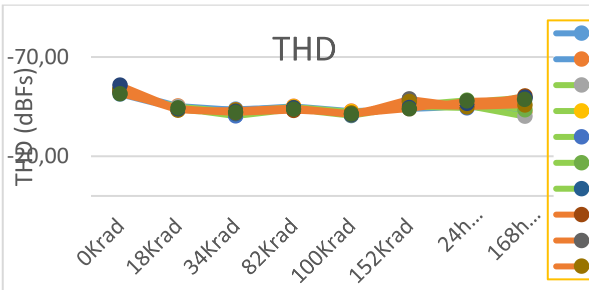
Core B



Core C



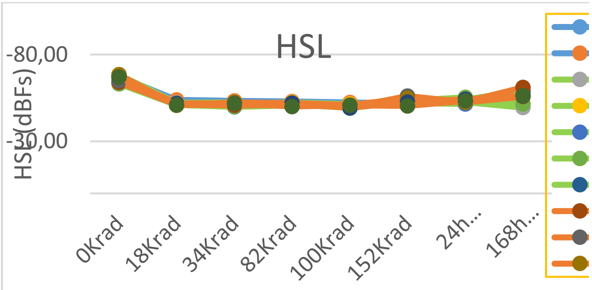
Core D



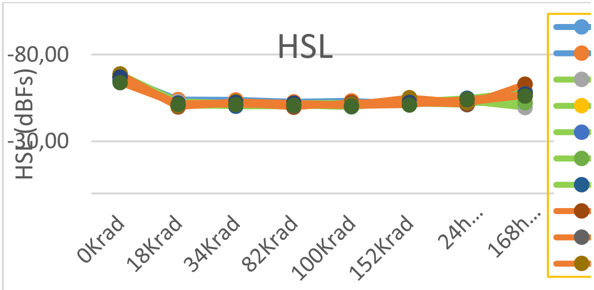
A problem of measurement occurs at 18Krad in those tests and remains in the following tests. All the devices (reference and irradiated parts) are impacted. However, none of these results shows a problem of TID.

7.3.28 HSL for core A, B, C & D @ Fin 5980MHz, -8dBFs

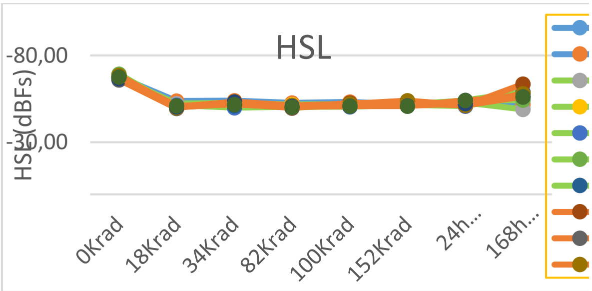
Core A



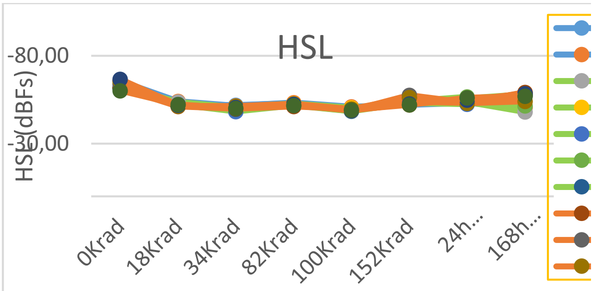
Core B



Core C



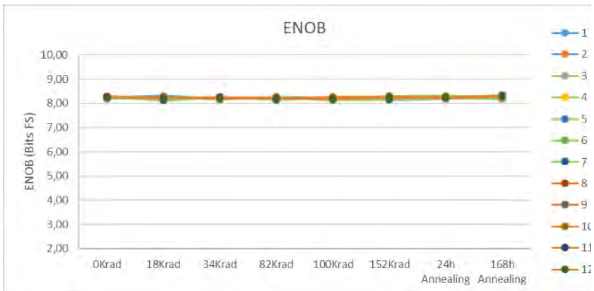
Core D



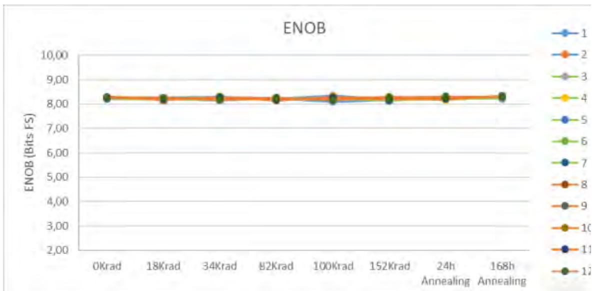
A problem of measurement occurs at 18Krad in those tests and remains in the following tests. All the devices (reference and irradiated parts) are impacted. However, none of these results shows a problem of TID.

7.3.29 ENOB for core A, B, C & D @ Fin 5980MHz, -12dBFs

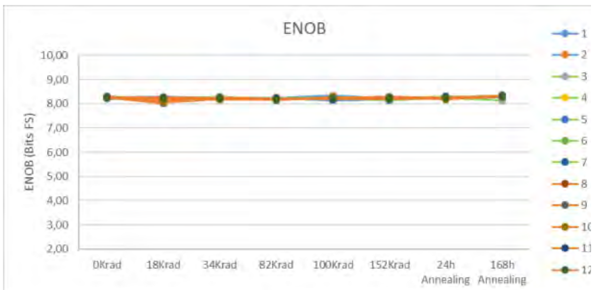
Core A



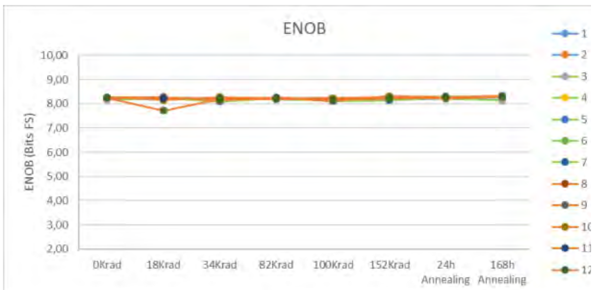
Core B



Core C



Core D

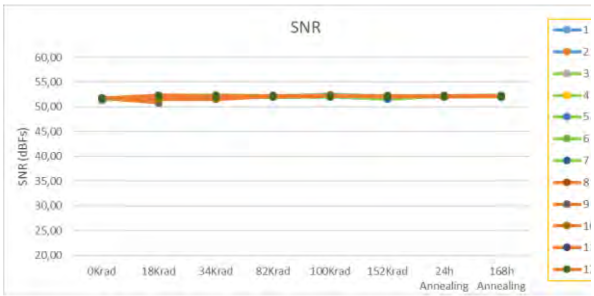


7.3.30 SNR for core A, B, C & D @ Fin 5980MHz, -12dBFs

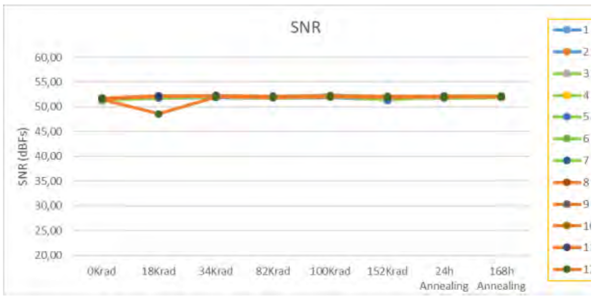
Core A

Core B

Core C



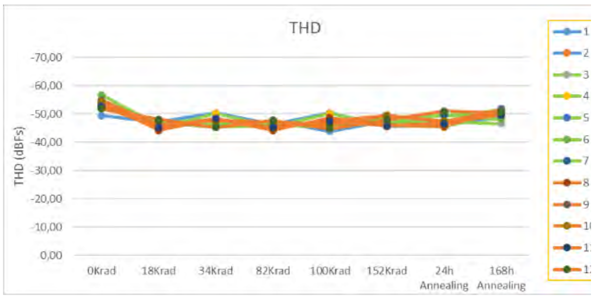
Core D



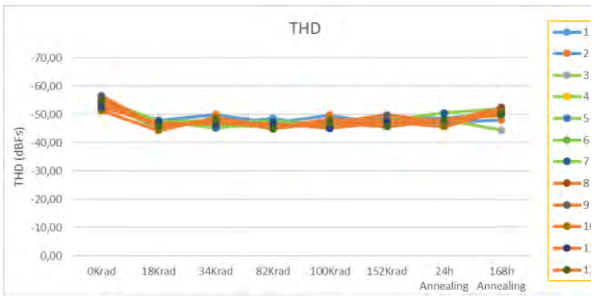
7.3.31 THD for core A, B, C & D @ Fin 5980MHz, -12dBFs

Core A

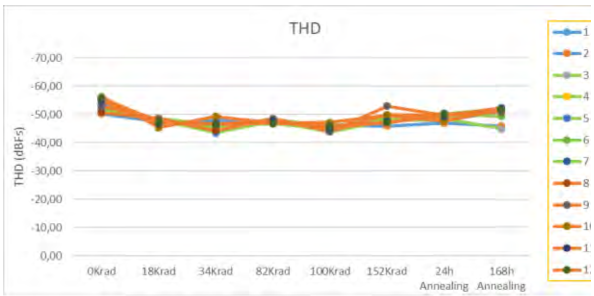
Core B



Core C



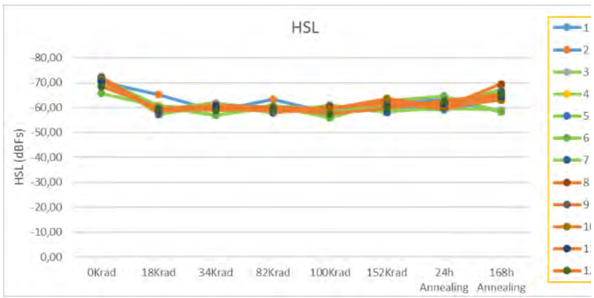
Core D



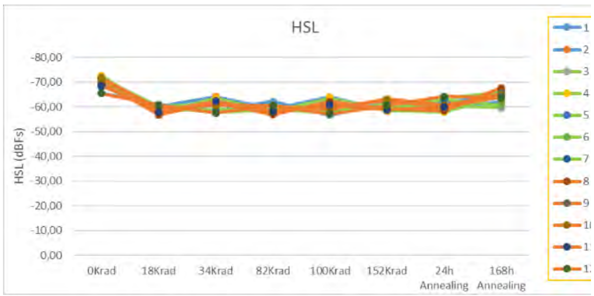
A problem of measurement occurs at 18Krad in those tests and remains in the following tests. All the devices (reference and irradiated parts) are impacted. However, none of these results shows a problem of TID.

7.3.32 HSL for core A, B, C & D @ Fin 5980MHz, -12dBFs

Core A

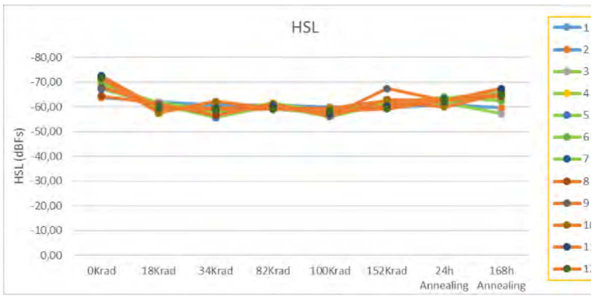


Core B



Core C

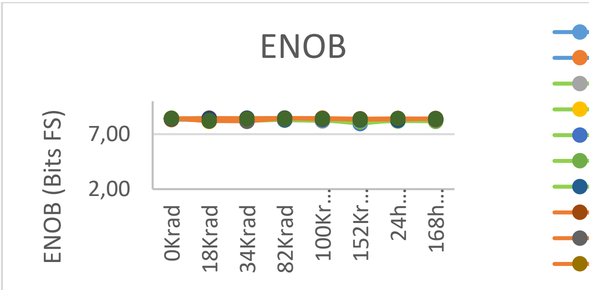
Core D



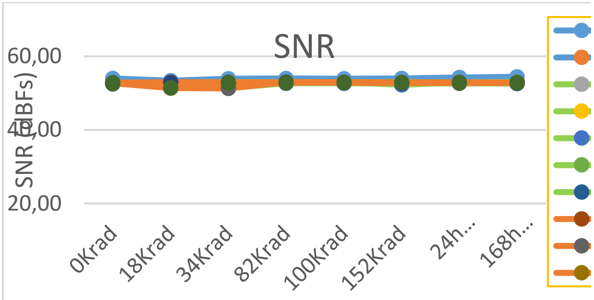
A problem of measurement occurs at 18Krad in those tests and remains in the following tests. All the devices (reference and irradiated parts) are impacted. However, none of these results shows a problem of TID.

7.3.33 1 Channel Mode @ Fin 100MHz, -1dBFs

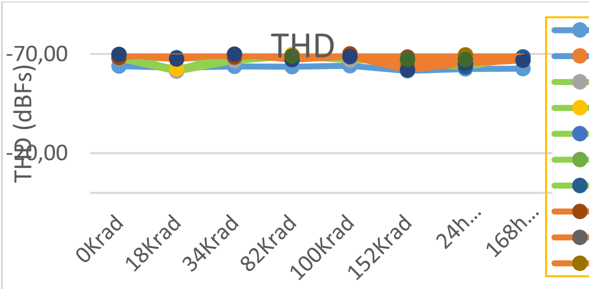
ENOB



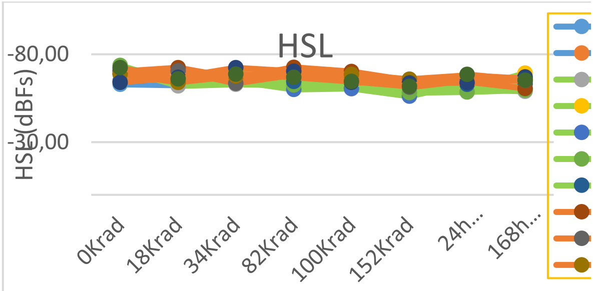
SNR



THD

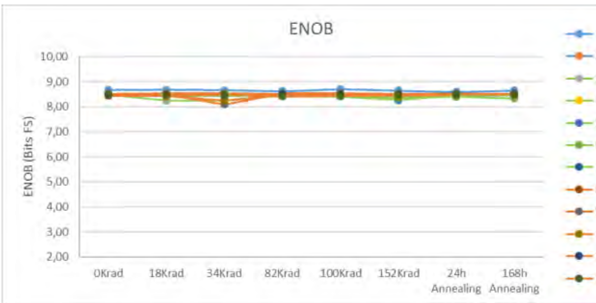


HSL

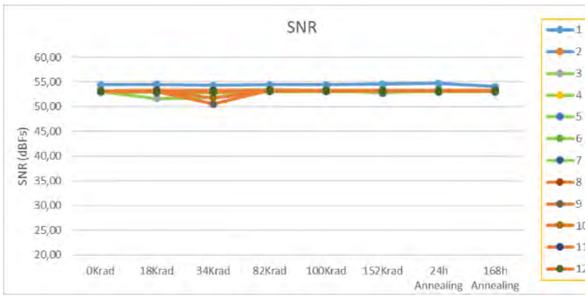


7.3.34 1 Channel Mode @ Fin 100MHz, -12dBFs

ENOB

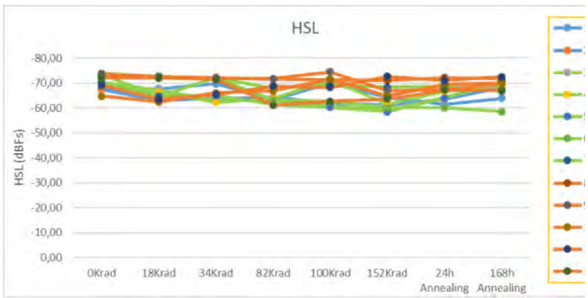


SNR



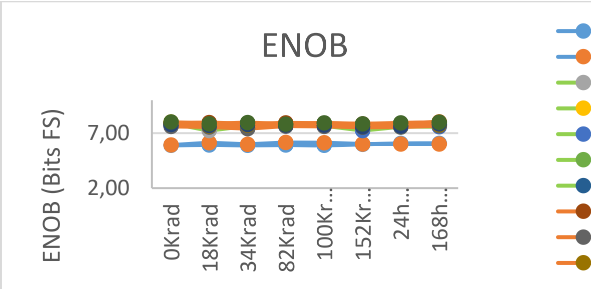
THD

HSL

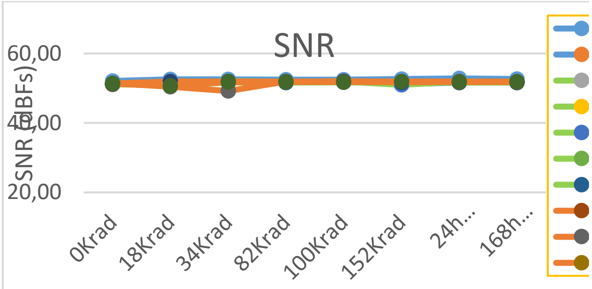


7.3.35 1 Channel Mode @ Fin 1580MHz, -1dBFs

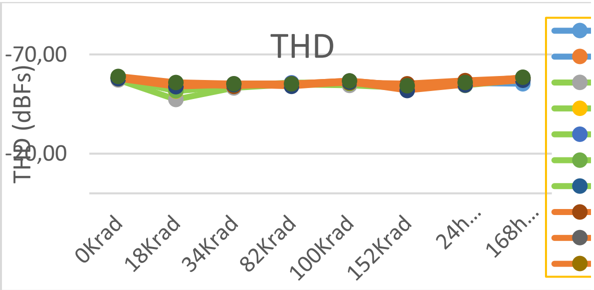
ENOB



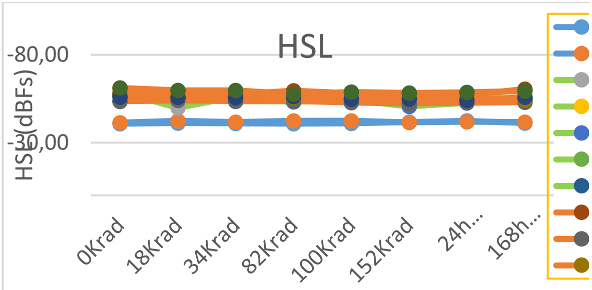
SNR



THD



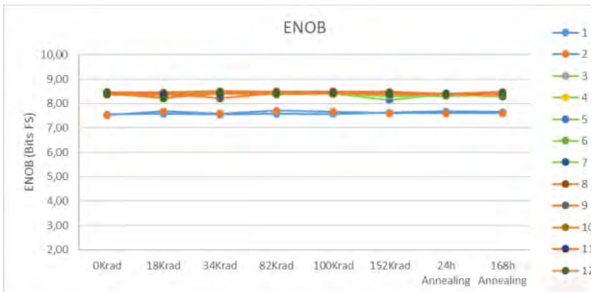
HSL



The performances of the two reference parts (1 & 2) are under the other because of the manual calibration witch have not been optimized.

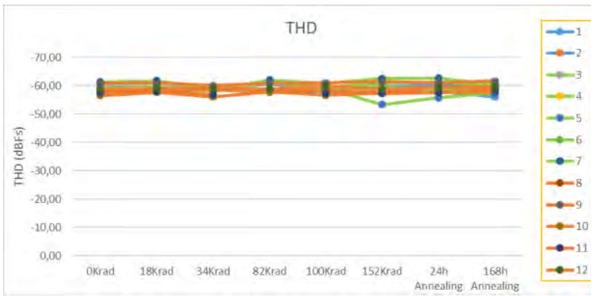
7.3.36 1 Channel Mode @ Fin 1580MHz, -12dBFs

ENOB

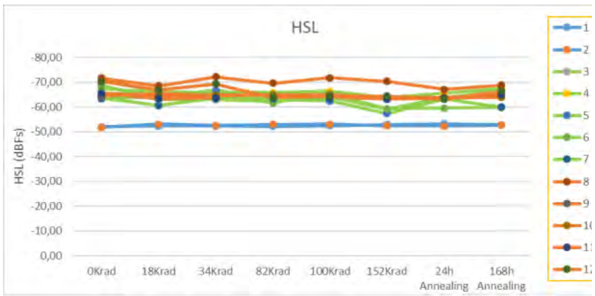


SNR

THD



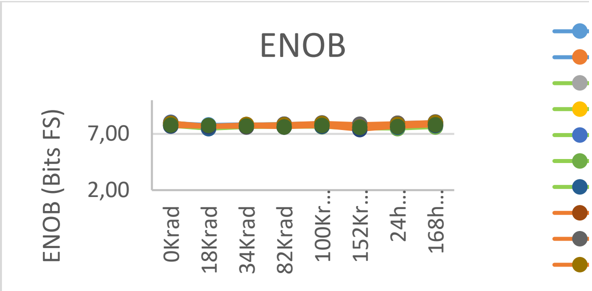
HSL



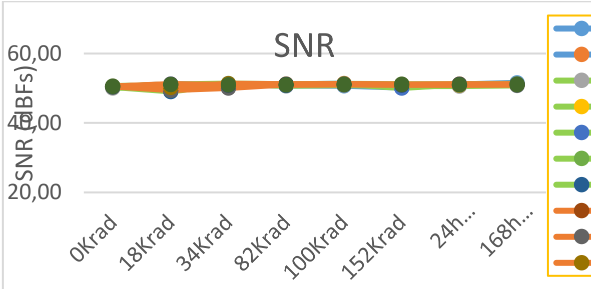
The performances of the two reference parts (1 & 2) are under the other because of the manual calibration witch have not been optimized.

7.3.37 1 Channel Mode @ Fin 2230MHz, -1dBFs

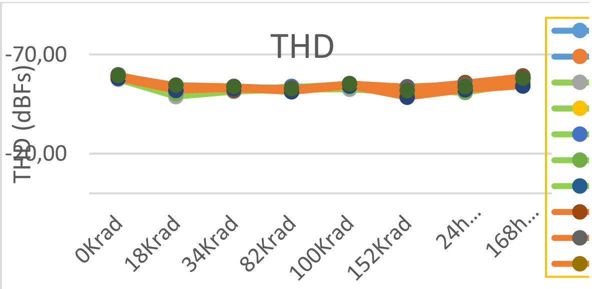
ENOB



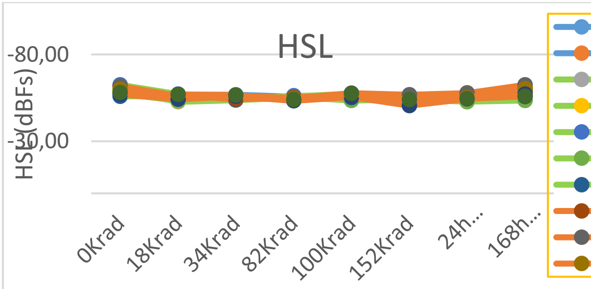
SNR



THD

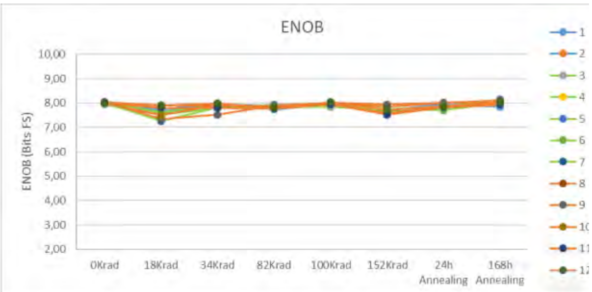


HSL

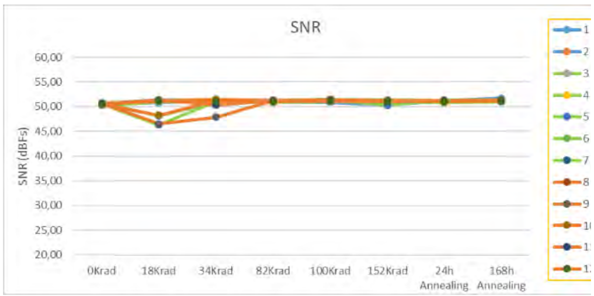


7.3.38 1 Channel Mode @ Fin 2230MHz, -12dBFs

ENOB

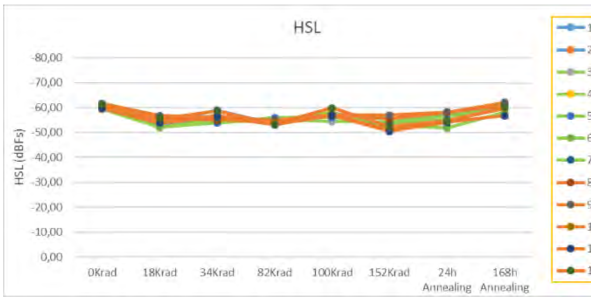


SNR



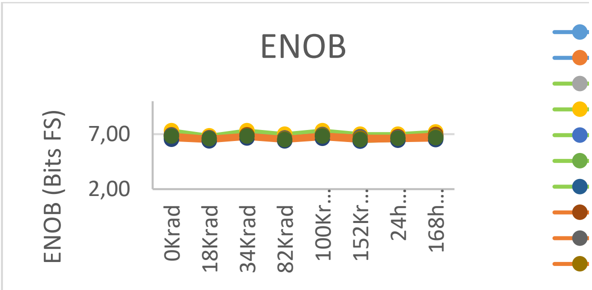
THD

HSL

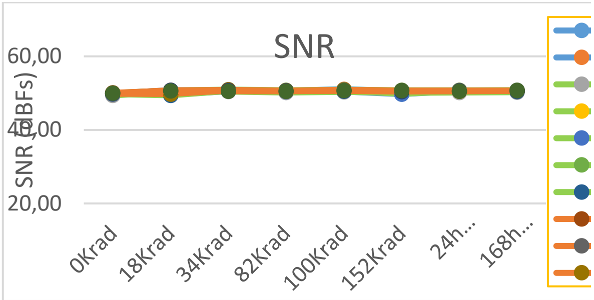


7.3.39 1 Channel Mode @ Fin 5980MHz, -8dBFs

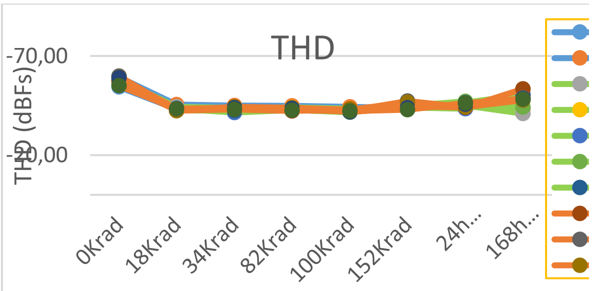
ENOB



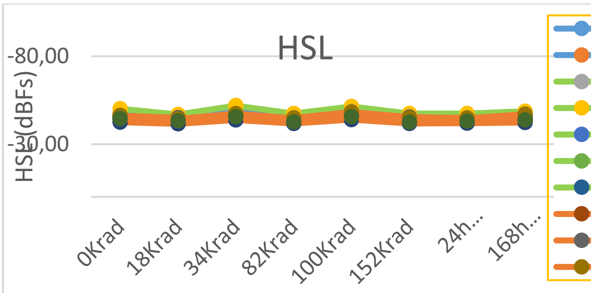
SNR



THD



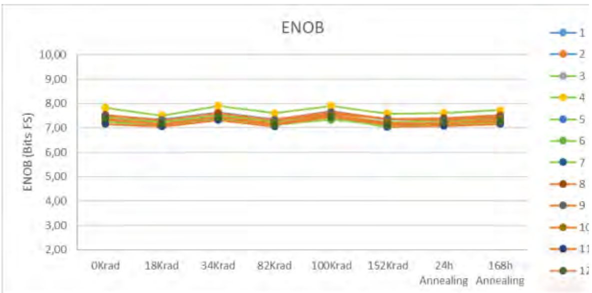
HSL



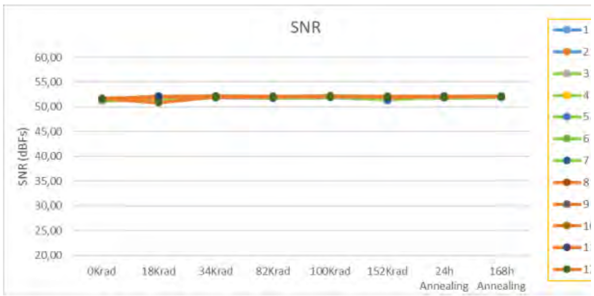
A problem of measurement occurs at 18Krad in those tests and remains in the following tests. All the devices (reference and irradiated parts) are impacted. However, none of these results shows a problem of TID.

7.3.40 1 Channel Mode @ Fin 5980MHz, -12dBFs

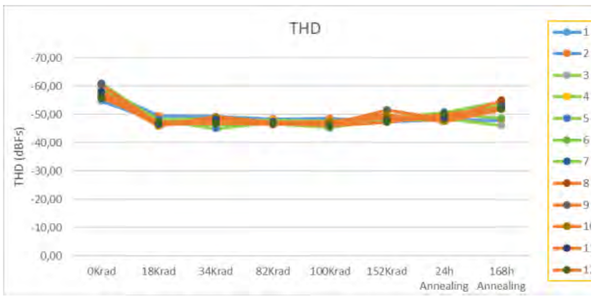
ENOB



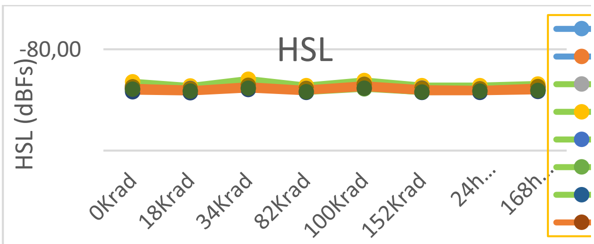
SNR



THD



HSL



A problem of measurement occurs at 18Krad in those tests and remains in the following tests. All the devices (reference and irradiated parts) are impacted. However, none of these results shows a problem of TID.

7.3.41 FFT conclusion

Despite some variations due to the measurement environment only, present on the reference parts too, the FFT performances are not impacted by the TID up to 150Krad(Si).

7.4 Automatic Test Equipment (ATE) : Post irradiation tests

No significant variation appeared during the post irradiation tests, just some minor I-V variation without any consequence on the device.

8. HEAVY IONS TEST

8.1 Organization of activities

The devices were procured by THALES ALENIA SPACE FRANCE to TRAD. The samples were thinning by THALES ALENIA SPACE FRANCE. The testing board and testing software were developed by TRAD. The heavy ion campaign was performed by TRAD. The next table summarizes the responsible entity for each activity of involved in this project:

1	Procurement of Test Samples	THALES ALENIA SPACE FRANCE
2	Preparation of Test Samples (thinning)	THALES ALENIA SPACE FRANCE
3	Preparation of Test Hardware and Test Program	TRAD
4	Samples Check out	TRAD
5	Accelerator Test	TRAD
6	Heavy Ion Test Report	TRAD

Table 1: Organization of activities

8.2 Parts information

8.2.1 Sample preparation

6 parts were thinned at 67µm (No. 1 and 4), at 70µm (No. 8), 73µm (No.2) and 76µm (No. 3 and 6) by THALES ALENIA SPACE FRANCE.

A functional test was performed on delidded samples by Teledyne e2v to check that devices were not degraded by the delidding operation.

Among the 6 delidded samples available for the test campaign, 3 were irradiated and 3 were not used.

8.2.2 Sample pictures

The Figure 1 shows an external view of the part.

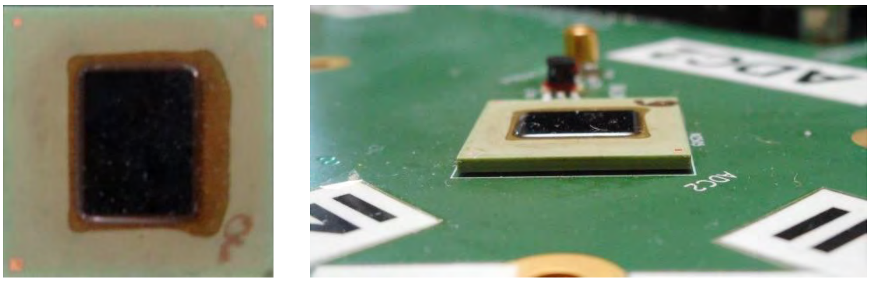
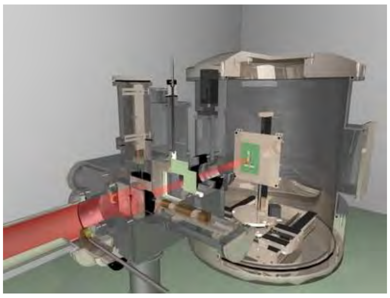


Figure 1: Pictures of the package

8.3 Dosimetry and irradiation facility

8.3.1 RADEF Heavy Ion Test Facility

The cyclotron used is a versatile, sector-focused accelerator for producing beams from hydrogen to xenon.



Heavy ion irradiations are performed in a vacuum chamber with an inside diameter of 75 cm and a height of 81 cm. The vacuum in the chamber is achieved after 5 minutes of pumping, and venting takes also only a few minutes. Irradiations can also be performed in air, therefore the LET and the range is calculated according the distance between the collimator and the component.

The components can be fixed on a 25x25cm^2 aluminium plate which will be mounted on the linear movement apparatus inside the chamber. The DUT can be moved in the X and Y directions and also tilting is possible.

A CCD camera with a magnifying telescope is located at the other end of the beam line to determine accurate positioning of the components. The coordinates are stored in the computer's memory allowing fast positioning of various targets during the test.

8.3.2 Dosimetry

To control and monitor the beam parameters, scintillation plastics connected to photomultiplier tubes are used as detectors. Four of such kinds of detectors are very close and placed around the edges of the beam. Detector can be moved to the front of the DUT and evaluate flux and homogeneity.

The spot size is 2 cm^2 and for special cases up to a diameter of 70 mm in vacuum. The Spot Homogeneity is ± 10 %

8.3.3 Beam characteristics

The beam flux is variable between a few particles s^{-1}cm^{-2} and 1.5E+4 s^{-1}cm^{-2} and is set depending on the device sensitivity. On special request, the users have the possibility to increase the flux up to 1E+6 s^{-1}cm^{-2}.

Characteristics of heavy ions available at RADEF during the test campaign are listed in Table 2 where heavy ions used for this test campaign are highlighted.

The tests on EV12AQ600 are performed in air, therefore the LET and range are calculated according Kapton degrader, if there is one, and the distance between collimator and the component.

Ion	Energy (MeV)	Range (µm(Si))	LET (MeV.cm²/mg)	LET calculated after 25 µm of Kapton,7 mm of air and 70µm of Silicon (MeV.cm²/mg)
$^{126}Xe^{44+}$	2059	157	48.5	67
$^{83}Kr^{29+}$	1358	185	24.5	33
$^{57}Fe^{20+}$	941	214	13.3	17
$^{40}Ar^{14+}$	657	264	7.2	9
$^{20}Ne^{7+}$	328	360	2.3	2.8
$^{17}O^{6+}$	284	481	1.52	1.52

Table 2: RADEF 16.3 MeV/u heavy ion list

8.4 Test procedure and setup

8.4.1 Test method

The test is divided in two parts, with respect to reference or applicable documents (see §4)

- Runs are performed up to a fluence of 1E+7 cm^{-2} with only SEL monitoring. This configuration allowed us to verify the latchup sensitivity of the device.
- Runs are performed up to a fluence of 1E+6 cm^{-2} for the SET, SEU and SEFI detection. A latchup monitoring is used during these tests in order to protect the component. This configuration allowed us to verify the SET, SEU and SEFI sensitivities of the device.

8.4.2 Test principle

8.4.2.1 *SEL test principle*

A SEL is a permanent event that results from the activation of a parasitic thyristor structure creating low impedance conduction path in the device. The consequent high current can potentially damage the device, possibly even leading to its destruction due to overcurrent. A power cycle is required to correct this situation.

GeV is a specific equipment developed by TRAD to protect the DUT and to perform SEL characterization. The power supply is applied to the DUT through GeV which protects the DUT against over consumption. Indeed, GeV continuously monitors and records the current consumption. A programmable threshold current is set above the nominal operating value of the supply current. During irradiations, if the current consumption exceeds the threshold during a defined “hold time”, a SEL is counted and the DUT is switched off during a defined “off time”. Once the event is defused, the power supply is switched ON again with the nominal current consumption expected.

Figure 2 shows a common SEL characteristic, with and without the GeV system protection.

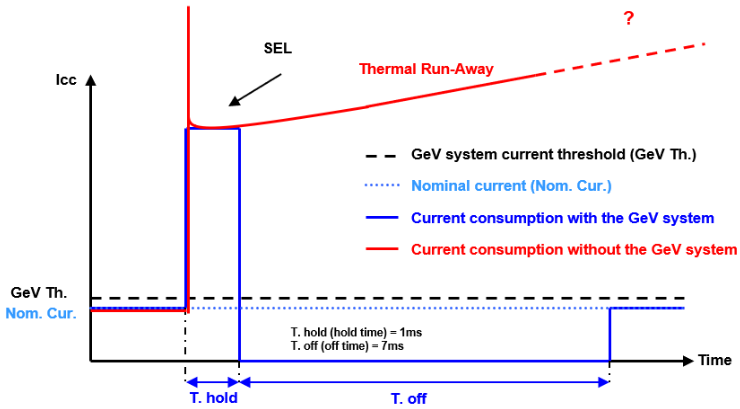


Figure 2: Common SEL characteristic

The SEL test is performed at maximum operating voltage and temperature.

TRAD uses a dedicated system to heat and regulate the DUT temperature. The temperature is visualized and regulated from outside of the vacuum chamber during the irradiation.

The DUT was tested in following modes:

Mode	Channel Mode	Clock Frequency	Analog Input Frequency
1	1	6.4 Gsps	3.19950264GHz
2	2		
3	4		

Table 3: SEL Configurations

8.4.2.2 *SET test principle*

The GeV system is always used to detect SEL and protect the DUT.

SET is an event described by a voltage amplitude and a timing parameter.

To detect these events, the output voltage component is monitored using an oscilloscope.

The following configurations were tested.

<u>**On SSO pin:**</u>

Pulse width modifications are detected with an oscilloscope. The trigger is activated if the pulse is either shorter than the specified time T1 or longer than specified time T2 (Figure 3). The positive or negative going pulse is measured at the specified voltage level.

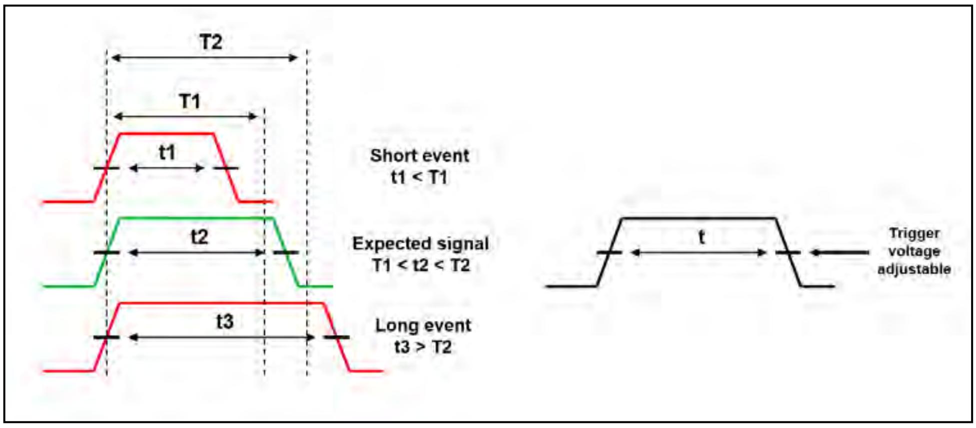


Figure 3: SET on SSO pin characteristic

<u>**On SYNCO pin:**</u>

The SET was a negative amplitude variation. One trigger threshold is used to detect SET. A SET is detected when the monitored signal is out of the detection range (Figure 4). All SET are counted and their waveforms are recorded using an oscilloscope.

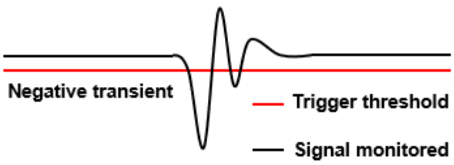


Figure 4: SET on SYNCO pin characteristic

8.4.2.3 *SEU/SEFI test principle*

A nominal operating voltage was applied on all supplies of the DUT.

The following registers were set to:

- EXTRA_SEE_PROTECT = 0b1
- CAL_SET_SEL = 0b000
- TIMER_CTRL = 0b 111

The DUT was tested in following modes:

Mode	Channel Mode	Clock Frequency	Analog Input Frequency	Tj°	Options
1	1	6.4 Gsps	3.19950264GHz	Ambient	
2	2			Ambient	
3	4			Ambient	
4	1			Ambient	Power Supply Maximum
5	1			Ambient	Power Supply Minimum
6	1			125 °C	
7	4			Ambient	EXT_BW_DISABLE = 0b1
8	1			Ambient	SYNCO_SSO_CLKOUT_FULL_SWING_EN = 0b11 AB_HSSL_FULL_SWING_EN = 0b1 CD_HSSL_FULL_SWING_EN = 0b1

Table 4: SEU/SEFI Configurations

The configuration registers were read at the beginning and the end of each run.

Test was performed at 6.4GHz, the input frequency was calculated in order to get 1 LSB change per clock cycle. It is obtained with following equation:

$$\frac{Fclk}{2^{12}\pi}$$

Where Fclk is the sampling frequency of each Core. In this case with the sampling frequency set at 1.6 GHz by ADC core, the input frequency was set at 3.19950264 GHz, for a beat frequency and output of 497.359 kHz.

Due to noisy environment, the tolerance to detect an upset was adjusted during irradiation.

Fclk and Fin RF generators were synchronized for coherence issue. The REF OUT of HFG was connected to Ext_Ref_In.

In case of event, the following data was saved:

- The last correct data before occurrence of an event
- The data corrupted by the upset

- The first correct data following an upset
- The clock counter index in order to be able to position the upset in the time domain

Two thousand successive corrupted data were saved after each event for each core.

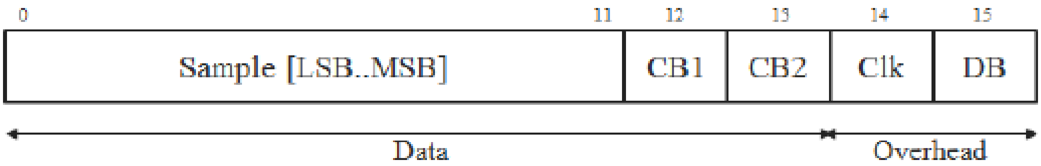
A SEFI was considered if eight hundred successive conversions were out the tolerance band, or if these successive conversions were identical.

Three steps were performed to restart the DUT in normal functional when a SEFI was detected:

- SEFI 1: The registers were read, next a new synchronization of ADC is performed. In this case the SEFI was counted like a SEFI on serial lanes (SEFI_COM).
- SEFI 2: If the SEFI was not defused, registers were read and a next reset was applied. Then, registers were written and a synchronization of the ADC was performed.
- SEFI 3: If the SEFI state was still observed, registers were read and a ON/OFF cycle on power supply was performed. A reset was then applied and registers were written with a synchronization of the ADC.

Each time a SEFI1 is detected, a shutter is activated. This shutter prevent the beam to access to the DUT and let the time to the system to identify if the SEFI is a SEFI1, SEFI2 or a SEFI3.

The ADC send a 16-bits word by EsiStream serial link. This word consists of 4 bits header and the convert data of 12-bits.



The 14 LSBs are encoded and the DB bit (parity bit) is used to decode the 14-bit data. If this bit is affected by a heavy ion, the data and the following data are not correctly decoded by the receiver.

The Clk, CB2 and CB1 bits were used to detect a SEU or SEFI on the DB bit. The Control Bit CB2 and CB1 were configured respectively to timestamp and parity bit trough the ADC registers.

If Clk or CB2 or CB1 were wrong, a SEU header was detected.

If 10 successive errors on these tree bits of header were observed, a SEFI header was detected and the process SEFI was applied.

8.4.3 Test bench description

8.4.3.1 *Test bench overview*

Figure 5 provides a global view of the test bench. It is composed by:

- A computer to control the test equipment and to record the SEE.
- A test board to bias and operate the DUT.
- A power supply for the DUT and auxiliary components.
- A GeV System to protect the DUT, detect and record SEL.
- An oscilloscope to detect and record SET.
- A HFG and splitter to applied sine signal on the input pins.

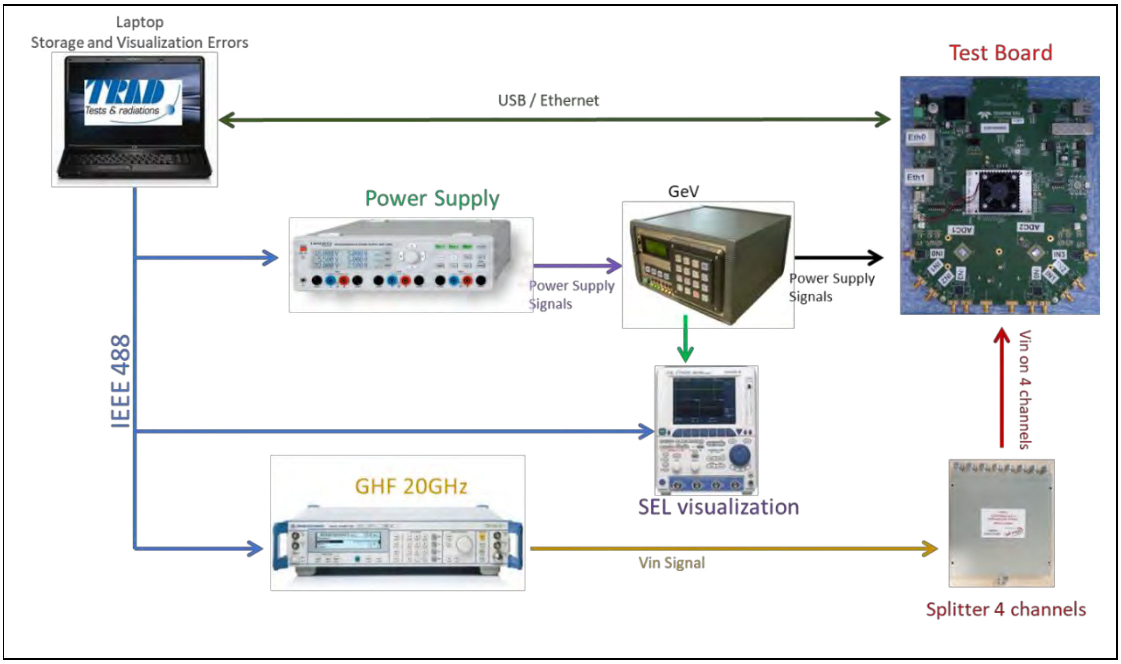


Figure 5: Test bench description

8.4.3.2 *Test equipment identification*

TEST BOARD	TRAD/TA2/I/EV12AQ600/XXX1/ELG/0619 TRAD/TA3/I/EV12AQ600/XXX1/ELG/0619 INTERSTELLAR ADC-DEMOBOARD SN: 010200004 INTERSTELLAR ADC-DEMOBOARD SN: 010200005 INTERSTELLAR ADC-DEMOBOARD SN: 020100002
EQUIPMENT	GeV 9; AR-94; SM-96; MI-85; SMR20; Splitter 8-Channel
TEST PROGRAM	TRAD_TI_EV12AQ600_XXX1_V10.spf TRAD_TI_EV12AQ600_XXX1_V10.bit

Table 5: Equipment identification

8.4.3.3 ***Test conditions and event detection thresholds***

SEL test

	EV12AQ600		
	VccA	**VccO**	**VccD**
Voltage	3.45 V	2.65 V	1.3 V
$I_{threshold}$	2 A	400 mA	250 mA
T_{hold}	1 ms		
$T_{cut\ off}$	7 ms		
MODE	1		
Temperature	125°C		

Table 6: SEL test conditions and detection threshold

SET test

	EV12AQ600 VccA = 3.3V, VccO = 2.5V, VccD = 1.2 V
	SYNCO
$V_{nominal}$	3.3 V
Trigger threshold	3.1 V
Temperature	~ 92°C

Table 7: SYNCO SET test conditions and detection threshold

	EV12AQ600 VccA = 3.3V, VccO = 2.5V, VccD = 1.2 V
	SSO
$T_{on\ nominal}$	2.4 ns
T_{on} max threshold	2 ns
T_{on} min threshold	2.8 ns
Temperature	~ 92°C

Table 8: SSO SET test conditions and detection threshold

SEU/SEFI test

	EV12AQ600 **VccA = 3.3V, VccO = 2.5V, VccD = 1.2 V**
Tolerance	± 120 LSB
Temperature	~ 92°C

Table 9: SEU/ SEFI test conditions and detection threshold

8.5 Test story

During the campaign, several forms of SEFI have been detected, however, it appears finally that only SEFI1 must be counted.

- From Run no. 1 to no. 16, the shutter was not implemented, so false SEFI2 were detected. They disappears as soon as the implementation of the shutter.
- In Run no. 22 two false SEFI3 were detected, but they were the consequence of a problem with the shutter

8.6 Non conformance

Test sequence, test and measurement conditions were nominal.

9. HEAVY IONS RESULTS

In this chapter are presented the SEE test results.

First, test runs summary tables provides details of the runs performed during this campaign, their parameters and results.

Then, for each event type are given their corresponding LET threshold, cross section and worst cases when it is applicable.

On the cross section curves are plotted their corresponding error bars.

The following formulas is used to calculate these error bars. It can be found in ESCC Basic specification No. 25100.

$$\delta\sigma \times F = \sqrt{(\delta Nevents)^2 + (\mathrm{Nevents} \times \frac{\delta \mathrm{F}}{F})^2}$$

where :

- F is the fluence
- $\sigma = N_{events} / F$
- δF/F is the uncertainty on the measured fluence (±10%).
- δN_{events} is the variance on the measured number of events.

Assuming that SEE events are random, the probability of events follows a Poisson distribution. The variance on the number of events is calculated from the chi-square distribution for a given confidence level. In this test report, we used a confidence level of 95%.

9.1 Test run summary

EV12AQ600														Single Event Effect	
Run	Test configuration	Part	T° (°C)	Ion	Energy (MeV)	Range (µm)	LET (MeV.cm²/mg)	Calculated LET* (MeV.cm²/mg)	Flux (φ) (cm-2.s-1)	Time (s)	Run Fluence (cm-2)	Run Dose (krad)	Cumulated Dose (krad)	SEL	SEL Cross Section (cm²)
1	MODE1	6	125	126 Xe 44+	2059	157	48.5	67.0	1.42E+04	705	1.00E+07	10.72	10.72	0	<1.00E-07
2	MODE2	6	125	126 Xe 44+	2059	157	48.5	67.0	2.18E+04	458	1.00E+07	10.72	21.44	0	<1.00E-07
3	MODE3	6	125	126 Xe 44+	2059	157	48.5	67.0	2.15E+04	466	1.00E+07	10.72	32.16	0	<1.00E-07
23	MODE1	2	125	126 Xe 44+	2059	157	48.5	67.0	1.25E+04	803	1.00E+07	11	10.72	0	<1.00E-07
33	MODE1	4	125	126 Xe 44+	2059	157	48.5	67.0	1.87E+04	536	1.00E+07	10.72	10.72	0	<1.00E-07

Table 10: EV12AQ600 SEL test run table

: Setting run not taken into account
* : LET calculated after 25 µm of Kapton,7 mm of air and 70µm of Silicon

EV12AQ600														Single Event Effect			
Run	Test configuration	Part	T° (°C)	Ion	Energy (MeV)	Range (µm)	LET (MeV.cm²/mg)	Calculated LET* (MeV.cm²/mg)	Flux (φ) (cm-2.s-1)	Time (s)	Run Fluence (cm-2)	Run Dose (krad)	Cumulated Dose (krad)	SET_SSO	SET_SSO Cross Section (cm²)	SET_SYNCO	SET_SYNCO Cross Section (cm²)
4	MODE1	6	93	126 Xe 44+	2059	157	48.5	67.0	1.11E+02	945	1.05E+05	0.11	32.27	-	-	-	-
5	MODE1	6	94	126 Xe 44+	2059	157	48.5	67.0	2.89E+02	1807	5.23E+05	0.56	32.83	10	1.91E-05	0	<1.91E-06
6	MODE2	6	94	126 Xe 44+	2059	157	48.5	67.0	3.33E+02	3005	1.00E+06	1.07	33.91	14	1.40E-05	1	1.00E-06
7	MODE3	6	93	126 Xe 44+	2059	157	48.5	67.0	3.17E+02	514	1.63E+05	0.17	34.08	-	-	-	-
8	MODE3	6	93	126 Xe 44+	2059	157	48.5	67.0	3.04E+02	3289	1.00E+06	1.07	35.15	12	1.20E-05	1	1.00E-06
9	MODE1	6	93	57 Fe 20+	941	214	13.3	17.0	5.69E+02	879	5.00E+05	0.14	35.29	3	6.00E-06	1	2.00E-06
10	MODE2	6	94	57 Fe 20+	941	214	13.3	17.0	5.27E+02	1897	1.00E+06	0.27	35.56	7	7.00E-06	1	1.00E-06
11	MODE3	6	94	57 Fe 20+	941	214	13.3	17.0	4.45E+02	2247	1.00E+06	0.27	35.83	4	4.00E-06	2	2.00E-06
12	MODE1	6	94	17 O 6+	284	481	1.52	1.52	2.01E+03	497	1.00E+06	0.02	35.86	1	1.00E-06	0	<1.00E-06
13	MODE2	6	94	17 O 6+	284	481	1.52	1.52	3.47E+03	288	1.00E+06	0.02	35.88	0	<1.00E-06	0	<1.00E-06
14	MODE3	6	94	17 O 6+	284	481	1.52	1.52	3.46E+03	289	1.00E+06	0.02	35.90	0	<1.00E-06	0	<1.00E-06
15	MODE1	6	94	40 Ar 14+	657	264	7.2	9.0	8.14E+02	1228	1.00E+06	0.14	36.05	1	1.00E-06	1	1.00E-06
16	MODE2	6	94	40 Ar 14+	657	264	7.2	9.0	9.67E+02	1034	1.00E+06	0.14	36.19	0	<1.00E-06	0	<1.00E-06
17	MODE3	6	93	40 Ar 14+	657	264	7.2	9.0	4.45E+02	176	7.84E+04	0.01	36.20	-	-	-	-
18	MODE3	6	93	40 Ar 14+	657	264	7.2	9.0	1.03E+03	969	1.00E+06	0.14	36.35	0	<1.00E-06	0	<1.00E-06
19	MODE1	6	94	83 Kr 29+	1358	185	24.5	33.0	3.48E+02	2876	1.00E+06	0.53	36.88	5	5.00E-06	1	1.00E-06
20	MODE2	6	93	83 Kr 29+	1358	185	24.5	33.0	4.24E+02	2361	1.00E+06	0.53	37.40	8	8.00E-06	0	<1.00E-06
21	MODE3	6	94	83 Kr 29+	1358	185	24.5	33.0	8.28E+02	1208	1.00E+06	0.53	37.93	9	9.00E-06	0	<1.00E-06
22	MODE1	6	93	126 Xe 44+	2059	157	48.5	67.0	6.04E+02	1656	1.00E+06	1.07	39.00	12	1.20E-05	1	1.00E-06
24	MODE1	2	94	126 Xe 44+	2059	157	48.5	67.0	4.06E+02	2465	1.00E+06	1.07	11.79	17	1.70E-05	2	2.00E-06
25	MODE1	2	93	83 Kr 29+	1358	185	24.5	33.0	6.75E+02	1482	1.00E+06	0.53	12.32	11	1.10E-05	0	<1.00E-06
26	MODE1	2	93	57 Fe 20+	941	214	13.3	17.0	1.08E+03	927	1.00E+06	0.27	12.59	2	2.00E-06	0	<1.00E-06
27	MODE1	2	93	40 Ar 14+	657	264	7.2	9.0	2.07E+03	484	1.00E+06	0.14	12.74	2	2.00E-06	0	<1.00E-06
28	MODE1	2	93	17 O 6+	284	481	1.52	1.52	4.76E+03	210	1.00E+06	0.02	12.76	0	<1.00E-06	0	<1.00E-06
29	MODE4	2	93	126 Xe 44+	2059	157	48.5	67.0	3.75E+02	1333	5.00E+05	0.54	13.30	9	1.80E-05	0	<2.00E-06
30	MODE5	2	90	126 Xe 44+	2059	157	48.5	67.0	5.85E+02	854	5.00E+05	0.54	13.83	5	1.00E-05	0	<2.00E-06
31	MODE7	2	93	126 Xe 44+	2059	157	48.5	67.0	5.48E+02	913	5.00E+05	0.54	14.37	3	6.00E-06	1	2.00E-06
32	MODE8	2	93	126 Xe 44+	2059	157	48.5	67.0	5.53E+02	904	5.00E+05	0.54	14.90	4	8.00E-06	1	2.00E-06
34	MODE6	4	125	126 Xe 44+	2059	157	48.5	67.0	2.59E+02	1933	5.00E+05	0.54	11.26	9	1.80E-05	2	4.00E-06

Table 11: EV12AQ600 SET test run table

▨ : Setting run not taken into account

* : LET calculated after 25 µm of Kapton,7 mm of air and 70µm of Silicon

EV12AQ600														Single Event Effect									
Run	Test configuration	Part	T° (°C)	Ion	Energy (MeV)	Range (µm)	LET (MeV.cm²/mg)	Calculated LET* (MeV.cm²/mg)	Flux (φ) (cm-2.s-1)	Time (s)	Run Fluence (cm-2)	Run Dose (krad)	Cumulated Dose (krad)	SEU_A	SEU_A Cross Section (cm²)	SEU_B	SEU_B Cross Section (cm²)	SEU_C	SEU_C Cross Section (cm²)	SEU_D	SEU_D Cross Section (cm²)	SEU_ABCD	SEU_ABCD Cross Section (cm²)
4	MODE1	6	93	126 Xe 44+	2059	157	48.5	67.0	1.11E+02	945	1.05E+05	0.11	32.27	-	-	-	-	-	-	-	-	-	-
5	MODE1	6	94	126 Xe 44+	2059	157	48.5	67.0	2.89E+02	1807	5.23E+05	0.56	32.83	69	1.32E-04	73	1.40E-04	68	1.30E-04	91	1.74E-04	25	4.78E-05
6	MODE2	6	94	126 Xe 44+	2059	157	48.5	67.0	3.33E+02	3005	1.00E+06	1.07	33.91	159	1.59E-04	152	1.52E-04	182	1.82E-04	160	1.60E-04	40	4.00E-05
7	MODE3	6	93	126 Xe 44+	2059	157	48.5	67.0	3.17E+02	514	1.63E+05	0.17	34.08	-	-	-	-	-	-	-	-	-	-
8	MODE3	6	93	126 Xe 44+	2059	157	48.5	67.0	3.04E+02	3289	1.00E+06	1.07	35.15	166	1.66E-04	162	1.62E-04	123	1.23E-04	145	1.45E-04	27	2.70E-05
9	MODE1	6	93	57 Fe 20+	941	214	13.3	17.0	5.69E+02	879	5.00E+05	0.14	35.29	26	5.20E-05	24	4.80E-05	44	8.80E-05	28	5.60E-05	3	6.00E-06
10	MODE2	6	94	57 Fe 20+	941	214	13.3	17.0	5.27E+02	1897	1.00E+06	0.27	35.56	73	7.30E-05	73	7.30E-05	75	7.50E-05	71	7.10E-05	8	8.00E-06
11	MODE3	6	94	57 Fe 20+	941	214	13.3	17.0	4.45E+02	2247	1.00E+06	0.27	35.83	59	5.90E-05	78	7.80E-05	91	9.10E-05	69	6.90E-05	7	7.00E-06
12	MODE1	6	94	17 O 6+	284	481	1.52	1.52	2.01E+03	497	1.00E+06	0.02	35.86	11	1.10E-05	9	9.00E-06	7	7.00E-06	7	7.00E-06	0	<1.00E-06
13	MODE2	6	94	17 O 6+	284	481	1.52	1.52	3.47E+03	288	1.00E+06	0.02	35.88	7	7.00E-06	10	1.00E-05	10	1.00E-05	10	1.00E-05	1	1.00E-06
14	MODE3	6	94	17 O 6+	284	481	1.52	1.52	3.46E+03	289	1.00E+06	0.02	35.90	5	5.00E-06	10	1.00E-05	8	8.00E-06	7	7.00E-06	0	<1.00E-06
15	MODE1	6	94	40 Ar 14+	657	264	7.2	9.0	8.14E+02	1228	1.00E+06	0.14	36.05	36	3.60E-05	33	3.30E-05	31	3.10E-05	40	4.00E-05	4	4.00E-06
16	MODE2	6	94	40 Ar 14+	657	264	7.2	9.0	9.67E+02	1034	1.00E+06	0.14	36.19	33	3.30E-05	50	5.00E-05	44	4.40E-05	42	4.20E-05	2	2.00E-06
17	MODE3	6	93	40 Ar 14+	657	264	7.2	9.0	4.45E+02	176	7.84E+04	0.01	36.20	-	-	-	-	-	-	-	-	-	-
18	MODE3	6	93	40 Ar 14+	657	264	7.2	9.0	1.03E+03	969	1.00E+06	0.14	36.35	51	5.10E-05	52	5.20E-05	54	5.40E-05	44	4.40E-05	8	8.00E-06
19	MODE1	6	94	83 Kr 29+	1358	185	24.5	33.0	3.48E+02	2876	1.00E+06	0.53	36.88	161	1.61E-04	151	1.51E-04	142	1.42E-04	142	1.42E-04	30	3.00E-05
20	MODE2	6	93	83 Kr 29+	1358	185	24.5	33.0	4.24E+02	2361	1.00E+06	0.53	37.40	157	1.57E-04	134	1.34E-04	142	1.42E-04	143	1.43E-04	24	2.40E-05
21	MODE3	6	94	83 Kr 29+	1358	185	24.5	33.0	8.28E+02	1208	1.00E+06	0.53	37.93	106	1.06E-04	142	1.42E-04	160	1.60E-04	146	1.46E-04	17	1.70E-05
22	MODE1	6	93	126 Xe 44+	2059	157	48.5	67.0	6.04E+02	1656	1.00E+06	1.07	39.00	205	2.05E-04	194	1.94E-04	230	2.30E-04	177	1.77E-04	70	7.00E-05
24	MODE1	2	94	126 Xe 44+	2059	157	48.5	67.0	4.06E+02	2465	1.00E+06	1.07	11.79	224	2.24E-04	190	1.90E-04	219	2.19E-04	216	2.16E-04	58	5.80E-05
25	MODE1	2	93	83 Kr 29+	1358	185	24.5	33.0	6.75E+02	1482	1.00E+06	0.53	12.32	147	1.47E-04	133	1.33E-04	130	1.30E-04	129	1.29E-04	20	2.00E-05
26	MODE1	2	93	57 Fe 20+	941	214	13.3	17.0	1.08E+03	927	1.00E+06	0.27	12.59	74	7.40E-05	67	6.70E-05	86	8.60E-05	95	9.50E-05	17	1.70E-05
27	MODE1	2	93	40 Ar 14+	657	264	7.2	9.0	2.07E+03	484	1.00E+06	0.14	12.74	49	4.90E-05	41	4.10E-05	51	5.10E-05	64	6.40E-05	9	9.00E-06
28	MODE1	2	93	17 O 6+	284	481	1.52	1.52	4.76E+03	210	1.00E+06	0.02	12.76	10	1.00E-05	7	7.00E-06	10	1.00E-05	7	7.00E-06	0	<1.00E-06
29	MODE4	2	93	126 Xe 44+	2059	157	48.5	67.0	3.75E+02	1333	5.00E+05	0.54	13.30	105	2.10E-04	100	2.00E-04	77	1.54E-04	97	1.94E-04	25	5.00E-05
30	MODE5	2	90	126 Xe 44+	2059	157	48.5	67.0	5.85E+02	854	5.00E+05	0.54	13.83	91	1.82E-04	74	1.48E-04	106	2.12E-04	98	1.96E-04	28	5.60E-05
31	MODE7	2	93	126 Xe 44+	2059	157	48.5	67.0	5.48E+02	913	5.00E+05	0.54	14.37	89	1.78E-04	97	1.94E-04	104	2.08E-04	90	1.80E-04	11	2.20E-05
32	MODE8	2	93	126 Xe 44+	2059	157	48.5	67.0	5.53E+02	904	5.00E+05	0.54	14.90	86	1.72E-04	100	2.00E-04	96	1.92E-04	102	2.04E-04	28	5.60E-05
34	MODE6	4	125	126 Xe 44+	2059	157	48.5	67.0	2.59E+02	1933	5.00E+05	0.54	11.26	114	2.28E-04	98	1.96E-04	110	2.20E-04	95	1.90E-04	28	5.60E-05

Table 12: EV12AQ600 SEU test run table 1/3

▭ : Setting run not taken into account

* : LET calculated after 25 µm of Kapton,7 mm of air and 70µm of Silicon

EV12AQ600													Single Event Effect											
Run	Test configuration	Part	T° (°C)	Ion	Energy (MeV)	Range (µm)	LET (MeV.cm²/mg)	Calculated LET* (MeV.cm²/mg)	Flux (φ) (cm-2.s-1)	Time (s)	Run Fluence (cm-2)	Run Dose (krad)	Cumulated Dose (krad)	SEU_AB	SEU_AB Cross Section (cm²)	SEU_CD	SEU_CD Cross Section (cm²)	SEU_AC	SEU_AC Cross Section (cm²)	SEU_AD	SEU_AD Cross Section (cm²)	SEU_BC	SEU_BC Cross Section (cm²)	SEU_BD	SEU_BD Cross Section (cm²)
4	MODE1	6	93	126 Xe 44+	2059	157	48.5	67.0	1.11E+02	945	1.05E+05	0.11	32.27	-	-	-	-	-	-	-	-	-	-	-	-
5	MODE1	6	94	126 Xe 44+	2059	157	48.5	67.0	2.89E+02	1807	5.23E+05	0.56	32.83	1	1.91E-06	2	3.82E-06	0	<1.91E-06	0	<1.91E-06	0	<1.91E-06	0	<1.91E-06
6	MODE2	6	94	126 Xe 44+	2059	157	48.5	67.0	3.33E+02	3005	1.00E+06	1.07	33.91	14	1.40E-05	9	9.00E-06	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06
7	MODE3	6	93	126 Xe 44+	2059	157	48.5	67.0	3.17E+02	514	1.63E+05	0.17	34.08	-	-	-	-	-	-	-	-	-	-	-	-
8	MODE3	6	93	126 Xe 44+	2059	157	48.5	67.0	3.04E+02	3289	1.00E+06	1.07	35.15	3	3.00E-06	3	3.00E-06	2	2.00E-06	0	<1.00E-06	0	<1.00E-06	1	1.00E-06
9	MODE1	6	93	57 Fe 20+	941	214	13.3	17.0	5.69E+02	879	5.00E+05	0.14	35.29	0	<2.00E-06	0	<2.00E-06	0	<2.00E-06	0	<2.00E-06	0	<2.00E-06	0	<2.00E-06
10	MODE2	6	94	57 Fe 20+	941	214	13.3	17.0	5.27E+02	1897	1.00E+06	0.27	35.56	3	3.00E-06	3	3.00E-06	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06
11	MODE3	6	94	57 Fe 20+	941	214	13.3	17.0	4.45E+02	2247	1.00E+06	0.27	35.83	1	1.00E-06	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06	1	1.00E-06	0	<1.00E-06
12	MODE1	6	94	17 O 6+	284	481	1.52	1.52	2.01E+03	497	1.00E+06	0.02	35.86	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06	1	1.00E-06
13	MODE2	6	94	17 O 6+	284	481	1.52	1.52	3.47E+03	288	1.00E+06	0.02	35.88	0	<1.00E-06	0	<1.00E-06	1	1.00E-06	0	<1.00E-06	0	<1.00E-06	1	1.00E-06
14	MODE3	6	94	17 O 6+	284	481	1.52	1.52	3.46E+03	289	1.00E+06	0.02	35.90	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06
15	MODE1	6	94	40 Ar 14+	657	264	7.2	9.0	8.14E+02	1228	1.00E+06	0.14	36.05	1	1.00E-06	0	<1.00E-06	1	1.00E-06	0	<1.00E-06	0	<1.00E-06	1	1.00E-06
16	MODE2	6	94	40 Ar 14+	657	264	7.2	9.0	9.67E+02	1034	1.00E+06	0.14	36.19	0	<1.00E-06	1	1.00E-06	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06
17	MODE3	6	93	40 Ar 14+	657	264	7.2	9.0	4.45E+02	176	7.84E+04	0.01	36.20	-	-	-	-	-	-	-	-	-	-	-	-
18	MODE3	6	93	40 Ar 14+	657	264	7.2	9.0	1.03E+03	969	1.00E+06	0.14	36.35	1	1.00E-06	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06	1	1.00E-06
19	MODE1	6	94	83 Kr 29+	1358	185	24.5	33.0	3.48E+02	2876	1.00E+06	0.53	36.88	0	<1.00E-06	1	1.00E-06	0	<1.00E-06	0	<1.00E-06	1	1.00E-06	2	2.00E-06
20	MODE2	6	93	83 Kr 29+	1358	185	24.5	33.0	4.24E+02	2361	1.00E+06	0.53	37.40	4	4.00E-06	1	1.00E-06	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06	1	1.00E-06
21	MODE3	6	94	83 Kr 29+	1358	185	24.5	33.0	8.28E+02	1208	1.00E+06	0.53	37.93	3	3.00E-06	2	2.00E-06	0	<1.00E-06	1	1.00E-06	1	1.00E-06	0	<1.00E-06
22	MODE1	6	93	126 Xe 44+	2059	157	48.5	67.0	6.04E+02	1656	1.00E+06	1.07	39.00	3	3.00E-06	0	<1.00E-06	1	1.00E-06	0	<1.00E-06	2	2.00E-06	0	<1.00E-06
24	MODE1	2	94	126 Xe 44+	2059	157	48.5	67.0	4.06E+02	2465	1.00E+06	1.07	11.79	1	1.00E-06	1	1.00E-06	1	1.00E-06	0	<1.00E-06	1	1.00E-06	1	1.00E-06
25	MODE1	2	93	83 Kr 29+	1358	185	24.5	33.0	6.75E+02	1482	1.00E+06	0.53	12.32	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06	2	2.00E-06
26	MODE1	2	93	57 Fe 20+	941	214	13.3	17.0	1.08E+03	927	1.00E+06	0.27	12.59	1	1.00E-06	1	1.00E-06	0	<1.00E-06	0	<1.00E-06	1	1.00E-06	2	2.00E-06
27	MODE1	2	93	40 Ar 14+	657	264	7.2	9.0	2.07E+03	484	1.00E+06	0.14	12.74	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06
28	MODE1	2	93	17 O 6+	284	481	1.52	1.52	4.76E+03	210	1.00E+06	0.02	12.76	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06
29	MODE4	2	93	126 Xe 44+	2059	157	48.5	67.0	3.75E+02	1333	5.00E+05	0.54	13.30	1	2.00E-06	0	<2.00E-06	0	<2.00E-06	0	<2.00E-06	0	<2.00E-06	0	<2.00E-06
30	MODE5	2	90	126 Xe 44+	2059	157	48.5	67.0	5.85E+02	854	5.00E+05	0.54	13.83	0	<2.00E-06	0	<2.00E-06	0	<2.00E-06	0	<2.00E-06	1	2.00E-06	0	<2.00E-06
31	MODE7	2	93	126 Xe 44+	2059	157	48.5	67.0	5.48E+02	913	5.00E+05	0.54	14.37	2	4.00E-06	3	6.00E-06	0	<2.00E-06	1	2.00E-06	0	<2.00E-06	0	<2.00E-06
32	MODE8	2	93	126 Xe 44+	2059	157	48.5	67.0	5.53E+02	904	5.00E+05	0.54	14.90	0	<2.00E-06	0	<2.00E-06	0	<2.00E-06	0	<2.00E-06	1	2.00E-06	0	<2.00E-06
34	MODE6	4	125	126 Xe 44+	2059	157	48.5	67.0	2.59E+02	1933	5.00E+05	0.54	11.26	0	<2.00E-06	0	<2.00E-06	2	4.00E-06	0	<2.00E-06	0	<2.00E-06	0	<2.00E-06

Table 13: EV12AQ600 SEU test run table 2/3

: Setting run not taken into account
* : LET calculated after 25 µm of Kapton,7 mm of air and 70µm of Silicon

EV12AQ600														Single Event Effect							
Run	Test configuration	Part	T° (°C)	Ion	Energy (MeV)	Range (µm)	LET (MeV.cm²/mg)	Calculated LET* (MeV.cm²/mg)	Flux (φ) (cm-2.s-1)	Time (s)	Run Fluence (cm-2)	Run Dose (krad)	Cumulated Dose (krad)	SEU_ABC	SEU_ABC Cross Section (cm²)	SEU_ABD	SEU_ABD Cross Section (cm²)	SEU_ACD	SEU_ACD Cross Section (cm²)	SEU_BCD	SEU_BCD Cross Section (cm²)
4	MODE1	6	93	126 Xe 44+	2059	157	48.5	67.0	1.11E+02	945	1.05E+05	0.11	32.27	-	-	-	-	-	-	-	-
5	MODE1	6	94	126 Xe 44+	2059	157	48.5	67.0	2.89E+02	1807	5.23E+05	0.56	32.83	0	<1.91E-06	0	<1.91E-06	0	<1.91E-06	0	<1.91E-06
6	MODE2	6	94	126 Xe 44+	2059	157	48.5	67.0	3.33E+02	3005	1.00E+06	1.07	33.91	1	1.00E-06	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06
7	MODE3	6	93	126 Xe 44+	2059	157	48.5	67.0	3.17E+02	514	1.63E+05	0.17	34.08	-	-	-	-	-	-	-	-
8	MODE3	6	93	126 Xe 44+	2059	157	48.5	67.0	3.04E+02	3289	1.00E+06	1.07	35.15	1	1.00E-06	0	<1.00E-06	1	1.00E-06	1	1.00E-06
9	MODE1	6	93	57 Fe 20+	941	214	13.3	17.0	5.69E+02	879	5.00E+05	0.14	35.29	0	<2.00E-06	0	<2.00E-06	0	<2.00E-06	0	<2.00E-06
10	MODE2	6	94	57 Fe 20+	941	214	13.3	17.0	5.27E+02	1897	1.00E+06	0.27	35.56	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06
11	MODE3	6	94	57 Fe 20+	941	214	13.3	17.0	4.45E+02	2247	1.00E+06	0.27	35.83	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06
12	MODE1	6	94	17 O 6+	284	481	1.52	1.52	2.01E+03	497	1.00E+06	0.02	35.86	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06
13	MODE2	6	94	17 O 6+	284	481	1.52	1.52	3.47E+03	288	1.00E+06	0.02	35.88	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06
14	MODE3	6	94	17 O 6+	284	481	1.52	1.52	3.46E+03	289	1.00E+06	0.02	35.90	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06
15	MODE1	6	94	40 Ar 14+	657	264	7.2	9.0	8.14E+02	1228	1.00E+06	0.14	36.05	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06
16	MODE2	6	94	40 Ar 14+	657	264	7.2	9.0	9.67E+02	1034	1.00E+06	0.14	36.19	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06
17	MODE3	6	93	40 Ar 14+	657	264	7.2	9.0	4.45E+02	176	7.84E+04	0.01	36.20	-	-	-	-	-	-	-	-
18	MODE3	6	93	40 Ar 14+	657	264	7.2	9.0	1.03E+03	969	1.00E+06	0.14	36.35	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06
19	MODE1	6	94	83 Kr 29+	1358	185	24.5	33.0	3.48E+02	2876	1.00E+06	0.53	36.88	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06
20	MODE2	6	93	83 Kr 29+	1358	185	24.5	33.0	4.24E+02	2361	1.00E+06	0.53	37.40	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06	1	1.00E-06
21	MODE3	6	94	83 Kr 29+	1358	185	24.5	33.0	8.28E+02	1208	1.00E+06	0.53	37.93	1	1.00E-06	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06
22	MODE1	6	93	126 Xe 44+	2059	157	48.5	67.0	6.04E+02	1656	1.00E+06	1.07	39.00	0	<1.00E-06	1	1.00E-06	0	<1.00E-06	0	<1.00E-06
24	MODE1	2	94	126 Xe 44+	2059	157	48.5	67.0	4.06E+02	2465	1.00E+06	1.07	11.79	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06
25	MODE1	2	93	83 Kr 29+	1358	185	24.5	33.0	6.75E+02	1482	1.00E+06	0.53	12.32	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06
26	MODE1	2	93	57 Fe 20+	941	214	13.3	17.0	1.08E+03	927	1.00E+06	0.27	12.59	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06
27	MODE1	2	93	40 Ar 14+	657	264	7.2	9.0	2.07E+03	484	1.00E+06	0.14	12.74	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06
28	MODE1	2	93	17 O 6+	284	481	1.52	1.52	4.76E+03	210	1.00E+06	0.02	12.76	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06
29	MODE4	2	93	126 Xe 44+	2059	157	48.5	67.0	3.75E+02	1333	5.00E+05	0.54	13.30	0	<2.00E-06	0	<2.00E-06	0	<2.00E-06	0	<2.00E-06
30	MODE5	2	90	126 Xe 44+	2059	157	48.5	67.0	5.85E+02	854	5.00E+05	0.54	13.83	0	<2.00E-06	0	<2.00E-06	0	<2.00E-06	0	<2.00E-06
31	MODE7	2	93	126 Xe 44+	2059	157	48.5	67.0	5.48E+02	913	5.00E+05	0.54	14.37	0	<2.00E-06	0	<2.00E-06	0	<2.00E-06	1	2.00E-06
32	MODE8	2	93	126 Xe 44+	2059	157	48.5	67.0	5.53E+02	904	5.00E+05	0.54	14.90	0	<2.00E-06	0	<2.00E-06	0	<2.00E-06	0	<2.00E-06
34	MODE6	4	125	126 Xe 44+	2059	157	48.5	67.0	2.59E+02	1933	5.00E+05	0.54	11.26	0	<2.00E-06	0	<2.00E-06	0	<2.00E-06	0	<2.00E-06

Table 14: EV12AQ600 SEU test run table 3/3

▭ : Setting run not taken into account

* : LET calculated after 25 µm of Kapton,7 mm of air and 70µm of Silicon

EV12AQ600													Single Event Effect									
Run	Test configuration	Part	T° (°C)	Ion	Energy (MeV)	Range (µm)	LET (MeV.cm²/mg)	Calculated LET* (MeV.cm²/mg)	Flux (φ) (cm-2.s-1)	Time (s)	Run Fluence (cm-2)	Run Dose (krad)	Cumulated Dose (krad)	SEU_SERIAL _COM_A	SEU_SERIAL _COM_A Cross Section (cm²)	SEU_SERIAL _COM_B	SEU_SERIAL _COM_B Cross Section (cm²)	SEU_SERIAL _COM_C	SEU_SERIAL _COM_C Cross Section (cm²)	SEU_SERIAL _COM_D	SEU_SERIAL _COM_D Cross Section (cm²)	SEU_SERIAL _COM_ABCD	SEU_SERIAL _COM_ABCD Cross Section (cm²)
4	MODE1	6	93	126 Xe 44+	2059	157	48.5	67.0	1.11E+02	945	1.05E+05	0.11	32.27	-	-	-	-	-	-	-	-	-	-
5	MODE1	6	94	126 Xe 44+	2059	157	48.5	67.0	2.89E+02	1807	5.23E+05	0.56	32.83	17	3.25E-05	10	1.91E-05	7	1.34E-05	16	3.06E-05	50	9.56E-05
6	MODE2	6	94	126 Xe 44+	2059	157	48.5	67.0	3.33E+02	3005	1.00E+06	1.07	33.91	13	1.30E-05	10	1.00E-05	8	8.00E-06	17	1.70E-05	48	4.80E-05
7	MODE3	6	93	126 Xe 44+	2059	157	48.5	67.0	3.17E+02	514	1.63E+05	0.17	34.08	-	-	-	-	-	-	-	-	-	-
8	MODE3	6	93	126 Xe 44+	2059	157	48.5	67.0	3.04E+02	3289	1.00E+06	1.07	35.15	13	1.30E-05	12	1.20E-05	11	1.10E-05	13	1.30E-05	49	4.90E-05
9	MODE1	6	93	57 Fe 20+	941	214	13.3	17.0	5.69E+02	879	5.00E+05	0.14	35.29	13	2.60E-05	4	8.00E-06	13	2.60E-05	15	3.00E-05	45	9.00E-05
10	MODE2	6	94	57 Fe 20+	941	214	13.3	17.0	5.27E+02	1897	1.00E+06	0.27	35.56	16	1.60E-05	13	1.30E-05	15	1.50E-05	15	1.50E-05	59	5.90E-05
11	MODE3	6	94	57 Fe 20+	941	214	13.3	17.0	4.45E+02	2247	1.00E+06	0.27	35.83	14	1.40E-05	15	1.50E-05	17	1.70E-05	14	1.40E-05	60	6.00E-05
12	MODE1	6	94	17 O 6+	284	481	1.52	1.52	2.01E+03	497	1.00E+06	0.02	35.86	5	5.00E-06	1	1.00E-06	7	7.00E-06	3	3.00E-06	16	1.60E-05
13	MODE2	6	94	17 O 6+	284	481	1.52	1.52	3.47E+03	288	1.00E+06	0.02	35.88	4	4.00E-06	6	6.00E-06	6	6.00E-06	5	5.00E-06	21	2.10E-05
14	MODE3	6	94	17 O 6+	284	481	1.52	1.52	3.46E+03	289	1.00E+06	0.02	35.90	3	3.00E-06	3	3.00E-06	3	3.00E-06	5	5.00E-06	14	1.40E-05
15	MODE1	6	94	40 Ar 14+	657	264	7.2	9.0	8.14E+02	1228	1.00E+06	0.14	36.05	4	4.00E-06	10	1.00E-05	7	7.00E-06	9	9.00E-06	30	3.00E-05
16	MODE2	6	94	40 Ar 14+	657	264	7.2	9.0	9.67E+02	1034	1.00E+06	0.14	36.19	8	8.00E-06	12	1.20E-05	6	6.00E-06	8	8.00E-06	34	3.40E-05
17	MODE3	6	93	40 Ar 14+	657	264	7.2	9.0	4.45E+02	176	7.84E+04	0.01	36.20	-	-	-	-	-	-	-	-	-	-
18	MODE3	6	93	40 Ar 14+	657	264	7.2	9.0	1.03E+03	969	1.00E+06	0.14	36.35	16	1.60E-05	13	1.30E-05	22	2.20E-05	7	7.00E-06	58	5.80E-05
19	MODE1	6	94	83 Kr 29+	1358	185	24.5	33.0	3.48E+02	2876	1.00E+06	0.53	36.88	13	1.30E-05	7	7.00E-06	11	1.10E-05	14	1.40E-05	45	4.50E-05
20	MODE2	6	93	83 Kr 29+	1358	185	24.5	33.0	4.24E+02	2361	1.00E+06	0.53	37.40	19	1.90E-05	20	2.00E-05	12	1.20E-05	14	1.40E-05	65	6.50E-05
21	MODE3	6	94	83 Kr 29+	1358	185	24.5	33.0	8.28E+02	1208	1.00E+06	0.53	37.93	9	9.00E-06	12	1.20E-05	18	1.80E-05	17	1.70E-05	56	5.60E-05
22	MODE1	6	93	126 Xe 44+	2059	157	48.5	67.0	6.04E+02	1656	1.00E+06	1.07	39.00	10	1.00E-05	11	1.10E-05	7	7.00E-06	10	1.00E-05	38	3.80E-05
24	MODE1	2	94	126 Xe 44+	2059	157	48.5	67.0	4.06E+02	2465	1.00E+06	1.07	11.79	6	6.00E-06	16	1.60E-05	10	1.00E-05	10	1.00E-05	42	4.20E-05
25	MODE1	2	93	83 Kr 29+	1358	185	24.5	33.0	6.75E+02	1482	1.00E+06	0.53	12.32	12	1.20E-05	13	1.30E-05	10	1.00E-05	14	1.40E-05	49	4.90E-05
26	MODE1	2	93	57 Fe 20+	941	214	13.3	17.0	1.08E+03	927	1.00E+06	0.27	12.59	20	2.00E-05	9	9.00E-06	4	4.00E-06	7	7.00E-06	40	4.00E-05
27	MODE1	2	93	40 Ar 14+	657	264	7.2	9.0	2.07E+03	484	1.00E+06	0.14	12.74	11	1.10E-05	11	1.10E-05	16	1.60E-05	15	1.50E-05	53	5.30E-05
28	MODE1	2	93	17 O 6+	284	481	1.52	1.52	4.76E+03	210	1.00E+06	0.02	12.76	3	3.00E-06	3	3.00E-06	8	8.00E-06	4	4.00E-06	18	1.80E-05
29	MODE4	2	93	126 Xe 44+	2059	157	48.5	67.0	3.75E+02	1333	5.00E+05	0.54	13.30	5	1.00E-05	14	2.80E-05	10	2.00E-05	15	3.00E-05	44	8.80E-05
30	MODE5	2	90	126 Xe 44+	2059	157	48.5	67.0	5.85E+02	854	5.00E+05	0.54	13.83	12	2.40E-05	9	1.80E-05	11	2.20E-05	8	1.60E-05	40	8.00E-05
31	MODE7	2	93	126 Xe 44+	2059	157	48.5	67.0	5.48E+02	913	5.00E+05	0.54	14.37	12	2.40E-05	7	1.40E-05	8	1.60E-05	8	1.60E-05	35	7.00E-05
32	MODE8	2	93	126 Xe 44+	2059	157	48.5	67.0	5.53E+02	904	5.00E+05	0.54	14.90	13	2.60E-05	8	1.60E-05	10	2.00E-05	15	3.00E-05	46	9.20E-05
34	MODE6	4	125	126 Xe 44+	2059	157	48.5	67.0	2.59E+02	1933	5.00E+05	0.54	11.26	15	3.00E-05	8	1.60E-05	10	2.00E-05	29	5.80E-05	62	1.24E-04

Table 15: EV12AQ600 SEU on serial lanes test run table

▭ : Setting run not taken into account

* : LET calculated after 25 µm of Kapton,7 mm of air and 70µm of Silicon

EV12AQ600													Single Event Effect									
Run	Test configuration	Part	T° (°C)	Ion	Energy (MeV)	Range (µm)	LET (MeV.cm²/mg)	Calculated LET* (MeV.cm²/mg)	Flux (φ) (cm-2.s-1)	Time (s)	Run Fluence (cm-2)	Run Dose (krad)	Cumulated Dose (krad)	SEFI_SERIAL_COM_A	SEFI_SERIAL_COM_A Cross Section (cm²)	SEFI_SERIAL_COM_B	SEFI_SERIAL_COM_B Cross Section (cm²)	SEFI_SERIAL_COM_C	SEFI_SERIAL_COM_C Cross Section (cm²)	SEFI_SERIAL_COM_D	SEFI_SERIAL_COM_D Cross Section (cm²)	SEFI_SERIAL_COM_ABCD	SEFI_SERIAL_COM_ABCD Cross Section (cm²)
4	MODE1	6	93	126 Xe 44+	2059	157	48.5	67.0	1.11E+02	945	1.05E+05	0.11	32.27	-	-	-	-	-	-	-	-	-	-
5	MODE1	6	94	126 Xe 44+	2059	157	48.5	67.0	2.89E+02	1807	5.23E+05	0.56	32.83	18	3.44E-05	19	3.63E-05	16	3.06E-05	21	4.02E-05	5	9.56E-06
6	MODE2	6	94	126 Xe 44+	2059	157	48.5	67.0	3.33E+02	3005	1.00E+06	1.07	33.91	23	2.30E-05	31	3.10E-05	38	3.80E-05	35	3.50E-05	5	5.00E-06
7	MODE3	6	93	126 Xe 44+	2059	157	48.5	67.0	3.17E+02	514	1.63E+05	0.17	34.08	-	-	-	-	-	-	-	-	-	-
8	MODE3	6	93	126 Xe 44+	2059	157	48.5	67.0	3.04E+02	3289	1.00E+06	1.07	35.15	28	2.80E-05	29	2.90E-05	37	3.70E-05	39	3.90E-05	14	1.40E-05
9	MODE1	6	93	57 Fe 20+	941	214	13.3	17.0	5.69E+02	879	5.00E+05	0.14	35.29	13	2.60E-05	8	1.60E-05	9	1.80E-05	5	1.00E-05	2	4.00E-06
10	MODE2	6	94	57 Fe 20+	941	214	13.3	17.0	5.27E+02	1897	1.00E+06	0.27	35.56	12	1.20E-05	10	1.00E-05	23	2.30E-05	11	1.10E-05	0	<1.00E-06
11	MODE3	6	94	57 Fe 20+	941	214	13.3	17.0	4.45E+02	2247	1.00E+06	0.27	35.83	18	1.80E-05	9	9.00E-06	15	1.50E-05	20	2.00E-05	2	2.00E-06
12	MODE1	6	94	17 O 6+	284	481	1.52	1.52	2.01E+03	497	1.00E+06	0.02	35.86	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06	1	1.00E-06	0	<1.00E-06
13	MODE2	6	94	17 O 6+	284	481	1.52	1.52	3.47E+03	288	1.00E+06	0.02	35.88	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06	0	<1.00E-06
14	MODE3	6	94	17 O 6+	284	481	1.52	1.52	3.46E+03	289	1.00E+06	0.02	35.90	1	1.00E-06	0	<1.00E-06	2	2.00E-06	0	<1.00E-06	0	<1.00E-06
15	MODE1	6	94	40 Ar 14+	657	264	7.2	9.0	8.14E+02	1228	1.00E+06	0.14	36.05	19	1.90E-05	7	7.00E-06	6	6.00E-06	6	6.00E-06	1	1.00E-06
16	MODE2	6	94	40 Ar 14+	657	264	7.2	9.0	9.67E+02	1034	1.00E+06	0.14	36.19	9	9.00E-06	10	1.00E-05	8	8.00E-06	8	8.00E-06	1	1.00E-06
17	MODE3	6	93	40 Ar 14+	657	264	7.2	9.0	4.45E+02	176	7.84E+04	0.01	36.20	-	-	-	-	-	-	-	-	-	-
18	MODE3	6	93	40 Ar 14+	657	264	7.2	9.0	1.03E+03	969	1.00E+06	0.14	36.35	8	8.00E-06	10	1.00E-05	15	1.50E-05	12	1.20E-05	1	1.00E-06
19	MODE1	6	94	83 Kr 29+	1358	185	24.5	33.0	3.48E+02	2876	1.00E+06	0.53	36.88	33	3.30E-05	29	2.90E-05	34	3.40E-05	30	3.00E-05	1	1.00E-06
20	MODE2	6	93	83 Kr 29+	1358	185	24.5	33.0	4.24E+02	2361	1.00E+06	0.53	37.40	28	2.80E-05	31	3.10E-05	25	2.50E-05	29	2.90E-05	6	6.00E-06
21	MODE3	6	94	83 Kr 29+	1358	185	24.5	33.0	8.28E+02	1208	1.00E+06	0.53	37.93	27	2.70E-05	28	2.80E-05	29	2.90E-05	34	3.40E-05	8	8.00E-06
22	MODE1	6	93	126 Xe 44+	2059	157	48.5	67.0	6.04E+02	1656	1.00E+06	1.07	39.00	64	6.40E-05	57	5.70E-05	49	4.90E-05	41	4.10E-05	12	1.20E-05
24	MODE1	2	94	126 Xe 44+	2059	157	48.5	67.0	4.06E+02	2465	1.00E+06	1.07	11.79	46	4.60E-05	43	4.30E-05	48	4.80E-05	40	4.00E-05	8	8.00E-06
25	MODE1	2	93	83 Kr 29+	1358	185	24.5	33.0	6.75E+02	1482	1.00E+06	0.53	12.32	23	2.30E-05	26	2.60E-05	26	2.60E-05	26	2.60E-05	4	4.00E-06
26	MODE1	2	93	57 Fe 20+	941	214	13.3	17.0	1.08E+03	927	1.00E+06	0.27	12.59	21	2.10E-05	19	1.90E-05	23	2.30E-05	16	1.60E-05	3	3.00E-06
27	MODE1	2	93	40 Ar 14+	657	264	7.2	9.0	2.07E+03	484	1.00E+06	0.14	12.74	8	8.00E-06	18	1.80E-05	10	1.00E-05	13	1.30E-05	0	<1.00E-06
28	MODE1	2	93	17 O 6+	284	481	1.52	1.52	4.76E+03	210	1.00E+06	0.02	12.76	1	1.00E-06	0	<1.00E-06	1	1.00E-06	1	1.00E-06	0	<1.00E-06
29	MODE4	2	93	126 Xe 44+	2059	157	48.5	67.0	3.75E+02	1333	5.00E+05	0.54	13.30	29	5.80E-05	16	3.20E-05	23	4.60E-05	17	3.40E-05	4	8.00E-06
30	MODE5	2	90	126 Xe 44+	2059	157	48.5	67.0	5.85E+02	854	5.00E+05	0.54	13.83	26	5.20E-05	20	4.00E-05	24	4.80E-05	21	4.20E-05	9	1.80E-05
31	MODE7	2	93	126 Xe 44+	2059	157	48.5	67.0	5.48E+02	913	5.00E+05	0.54	14.37	19	3.80E-05	20	4.00E-05	21	4.20E-05	21	4.20E-05	8	1.60E-05
32	MODE8	2	93	126 Xe 44+	2059	157	48.5	67.0	5.53E+02	904	5.00E+05	0.54	14.90	12	2.40E-05	24	4.80E-05	24	4.80E-05	24	4.80E-05	5	1.00E-05
34	MODE6	4	125	126 Xe 44+	2059	157	48.5	67.0	2.59E+02	1933	5.00E+05	0.54	11.26	20	4.00E-05	20	4.00E-05	15	3.00E-05	18	3.60E-05	5	1.00E-05

Table 16: EV12AQ600 SEFI on serial lanes test run table

: Setting run not taken into account
* : LET calculated after 25 µm of Kapton,7 mm of air and 70µm of Silicon

SEE detailed results are described in the following section.

9.2 SET on SSO test results

9.2.1 SET on SSO LET threshold

The SET on SSO test is performed at 92°C ±2°C.

In MODE1 test configuration

SET on SSO were observed with a minimum LET of 1.5 MeV.cm²/mg, Oxygen heavy ion.

No LET threshold was found with available heavy ions during this test campaign.

9.2.2 SET on SSO cross sections

Hereafter are shown the SET on SSO cross section values for each tested component.

In MODE1 test configuration

	EV12AQ600 SET on SSO Cross Section (cm²) in MODE1 test configuration					
LET Eff (MeV.cm²/mg)	Part No. 6			Part No. 2		
	error (-)	cross section	error (+)	error (-)	cross section	error (+)
67.0	5.80E-06	1.20E-05	8.96E-06	7.10E-06	1.70E-05	1.02E-05
33.0	3.38E-06	5.00E-06	6.67E-06	5.51E-06	1.10E-05	8.68E-06
17.0	4.76E-06	6.00E-06	1.15E-05	1.76E-06	2.00E-06	5.22E-06
9.0	9.75E-07	1.00E-06	4.57E-06	1.76E-06	2.00E-06	5.22E-06
1.5	9.75E-07	1.00E-06	4.57E-06	0.00E+00	<1.00E-06	3.69E-06

Table 17: EV12AQ600 SET on SSO cross section values in MODE1 test configuration

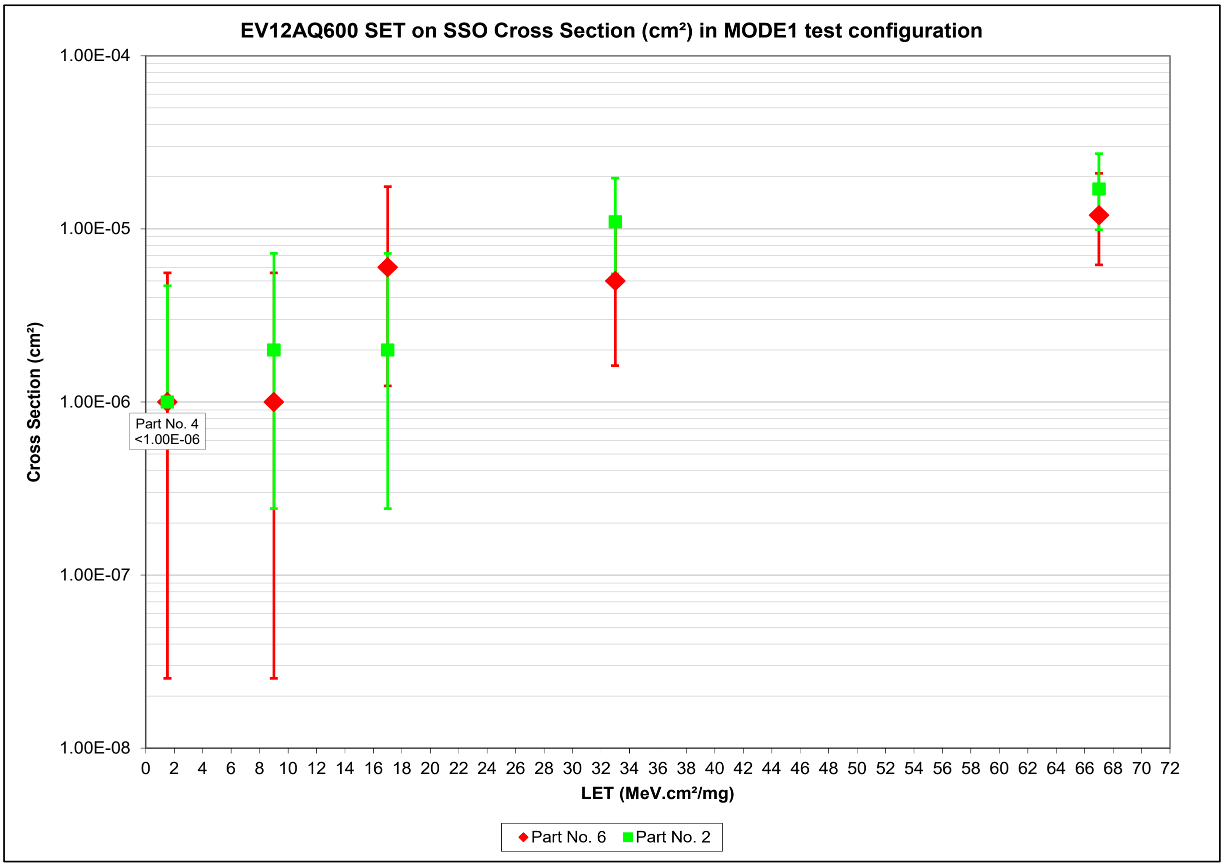


Figure 6: EV12AQ600 SET on SSO cross section curve in MODE1 test configuration

9.2.3 SET on SSO worst case

This section presents a selection of worst SET observed on SSO during the test of the EV12AQ600.

In SET test configuration

The worst SET observed on SSO occurred during run No. 24 on part No. 2.

Run No.	24
Part No.	2
Type event	SET
Ion LET (MeV.cm²/mg)	67.0
Duration	14 ns

Figure 7: SET on SSO worst case

9.3 SET on SYNCO test results

9.3.1 SET on SYNCO LET threshold

The SET on SYNCO test is performed at 92°C ±2°C.

In MODE1 test configuration

SET on SYNCO were observed with a minimum LET of 9.0 MeV.cm²/mg, Argon heavy ion.

No SET on SYNCO was observed with a LET of 1.5 MeV.cm²/mg, Oxygen heavy ion.

9.3.2 SET on SYNCO cross sections

Hereafter are shown the SET on SYNCO cross section values for each tested component.

In MODE1 test configuration

	EV12AQ600 SET on SYNCO Cross Section (cm²) in MODE1 test configuration					
LET Eff (MeV.cm²/mg)	Part No. 6			Part No. 2		
	error (-)	cross section	error (+)	error (-)	cross section	error (+)
67.0	9.75E-07	1.00E-06	4.57E-06	1.76E-06	2.00E-06	5.22E-06
33.0	9.75E-07	1.00E-06	4.57E-06	0.00E+00	<1.00E-06	3.69E-06
17.0	1.95E-06	2.00E-06	9.14E-06	0.00E+00	<1.00E-06	3.69E-06
9.0	9.75E-07	1.00E-06	4.57E-06	0.00E+00	<1.00E-06	3.69E-06
1.5	0.00E+00	<1.00E-06	3.69E-06	0.00E+00	<1.00E-06	3.69E-06

Table 18: EV12AQ600 SET on SYNCO cross section values in MODE1 test configuration

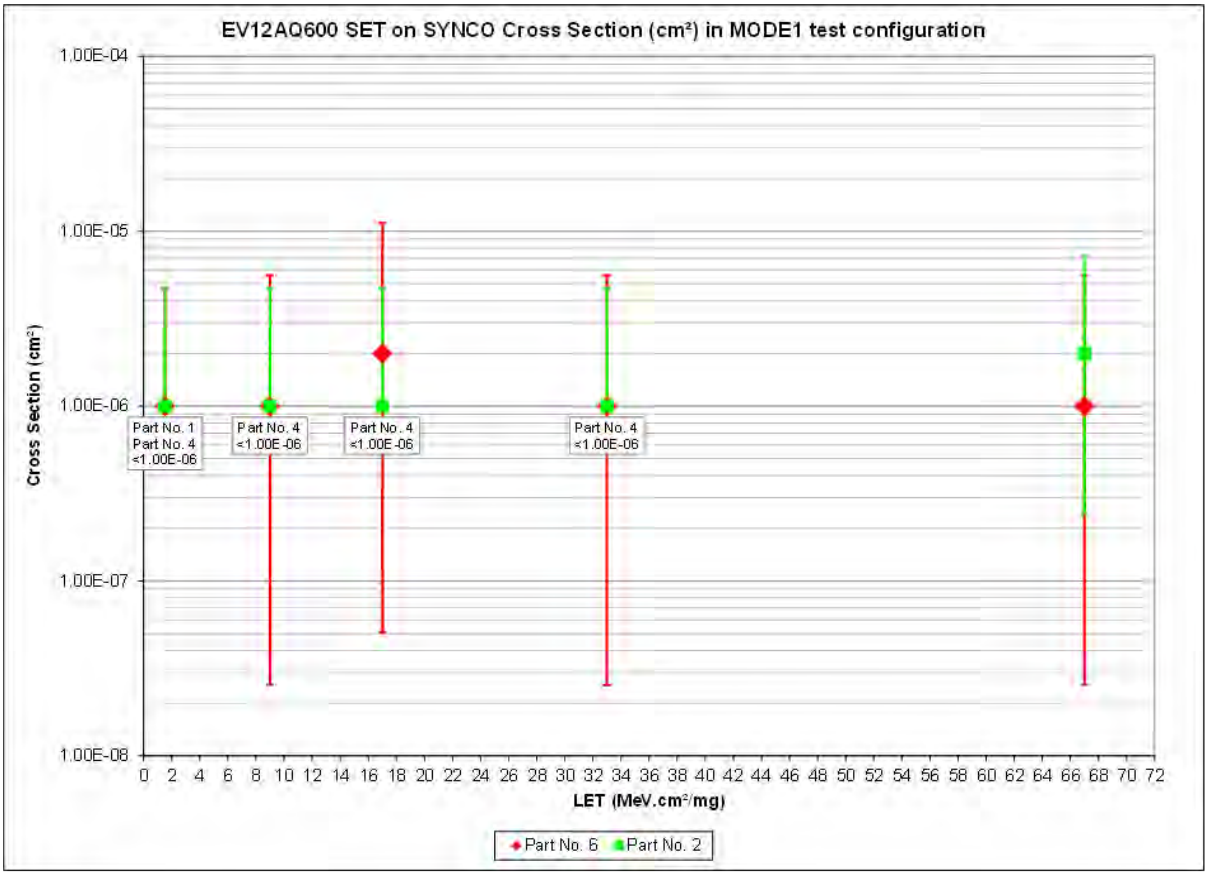


Figure 8: EV12AQ600 SET on SYNCO cross section curve in MODE1 test configuration

9.3.3 SET on SYNCO worst case

This section presents a selection of worst SET observed on SYNCO during the test of the EV12AQ600.

In SET test configuration

The worst SET observed on SYNCO occurred during run No. 22 on part No. 6.

Run No.	22
Part No.	6
Type event	SET
Ion LET (MeV.cm²/mg)	67.0
Absolute amplitude	1.29 V
Relative amplitude	2.01 V
Duration	2 ns

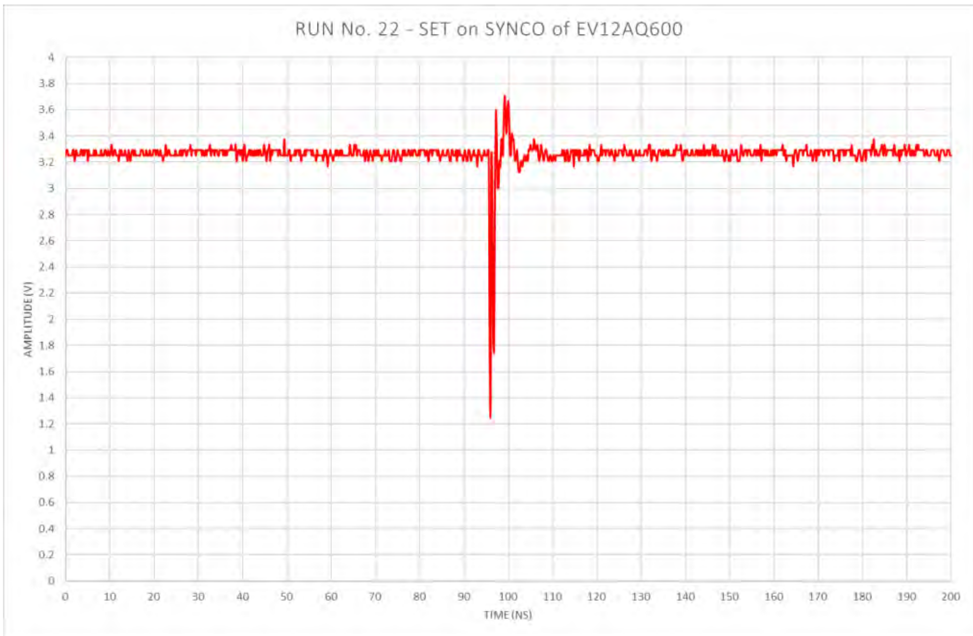


Figure 9: SET on SYNCO worst case

9.4 SEU test results

9.4.1 SEU LET threshold

The SEU on core A, B, C and D test is performed at 92°C ±2°C.

In MODE1 test configuration

SEU on core A, B, C and D were observed with a minimum LET of 1.5 MeV.cm²/mg, Oxygen heavy ion.

No LET threshold was found with available heavy ions during this test campaign.

9.4.2 SEU on core A cross sections

Hereafter are shown the SEU on core A cross section values for each tested component.

In MODE1 test configuration

	EV12AQ600 SEU on core A Cross Section (cm²) in MODE1 test configuration					
LET Eff (MeV.cm²/mg)	Part No. 6			Part No. 2		
	error (-)	cross section	error (+)	error (-)	cross section	error (+)
67.0	2.71E-05	2.05E-04	3.01E-05	2.84E-05	2.24E-04	3.13E-05
33.0	2.39E-05	1.61E-04	2.69E-05	2.28E-05	1.47E-04	2.58E-05
17.0	1.80E-05	5.20E-05	2.42E-05	1.59E-05	7.40E-05	1.89E-05
9.0	1.08E-05	3.60E-05	1.38E-05	1.27E-05	4.90E-05	1.58E-05
1.5	5.51E-06	1.10E-05	8.68E-06	5.20E-06	1.00E-05	8.39E-06

Table 19: EV12AQ600 SEU on core A cross section values in MODE1 test configuration

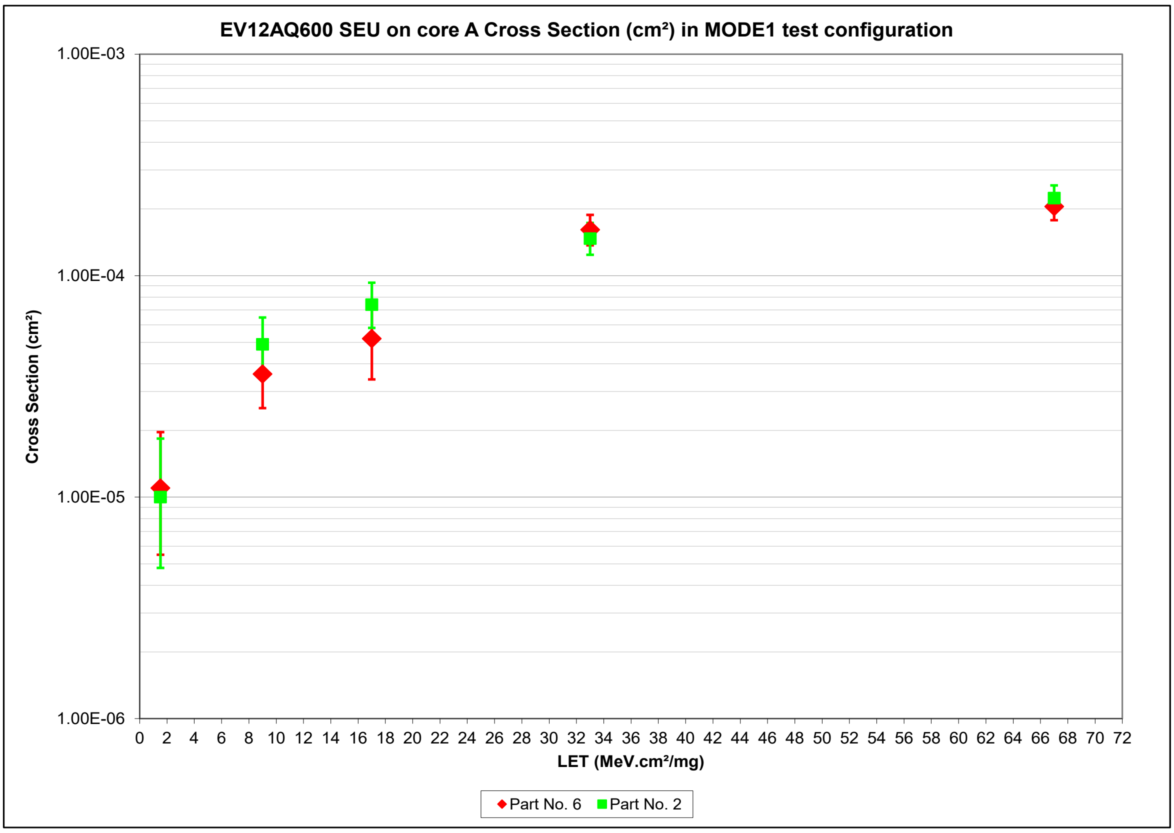


Figure 10: EV12AQ600 SEU on core A cross section curve in MODE1 test configuration

9.4.3 SEU on core A, B, C and D cross sections

Hereafter are shown the SEU on core A, B, C and D cross section values for each tested component.

<u>In MODE1 test configuration</u>

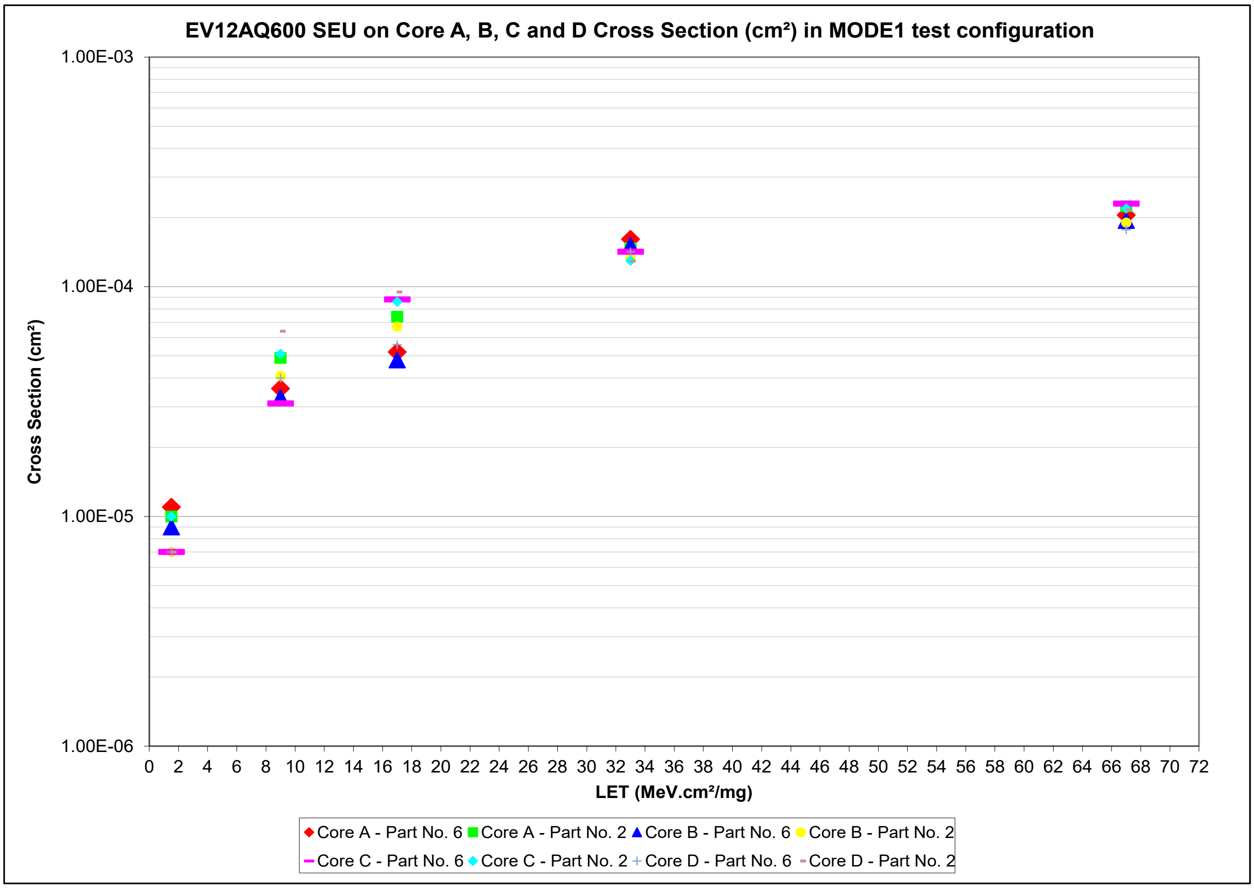


Figure 11: EV12AQ600 SEU on core A, B, C and D cross section curve in MODE1 test configuration

9.4.4 SEU cases

This section presents a selection of SEU cases observed on the A, B, C or D core during the test in MODE 1 of the EV12AQ600

Figure 12: EV12AQ600 SEU case n°1 on B core in MODE1 test configuration

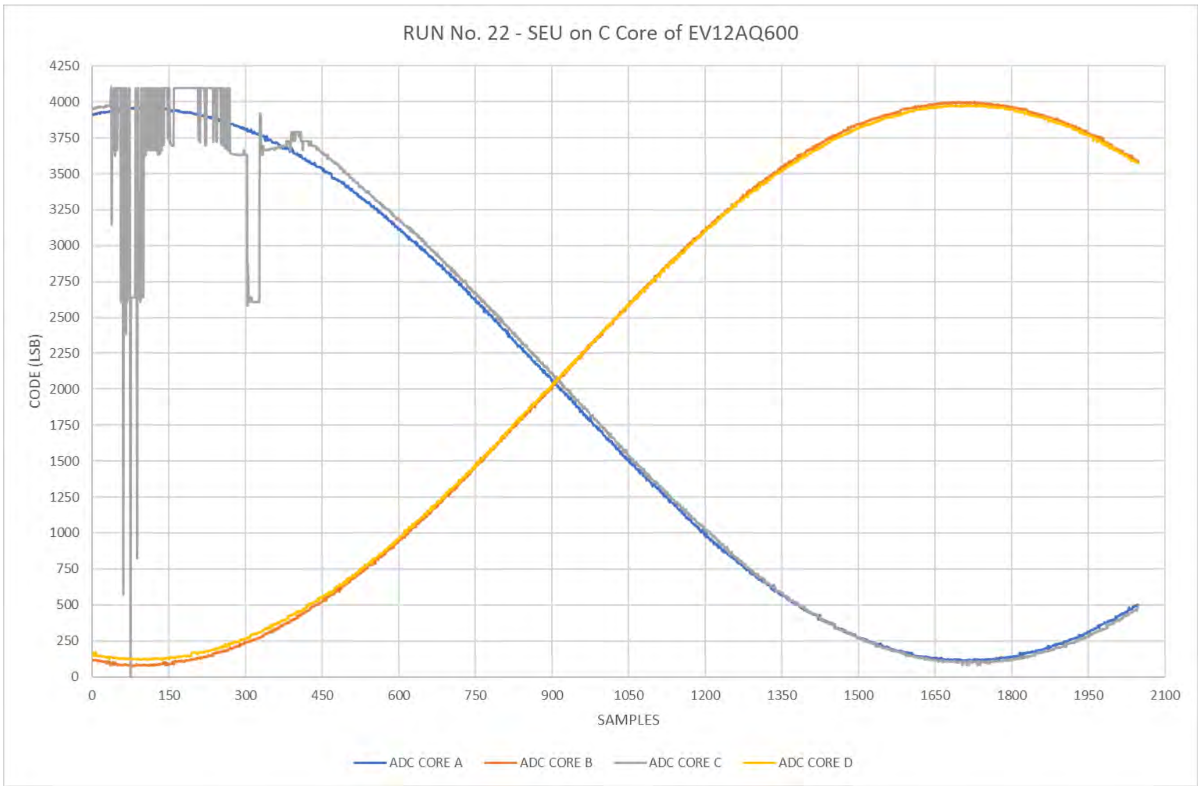


Figure 13: EV12AQ600 SEU case n°2 on C core in MODE1 test configuration

9.4.5 SEU case on A, B, C and D cores

This section presents a selection of SEU case observed in same time on the A, B, C and D cores during the test in MODE 1 of the EV12AQ600

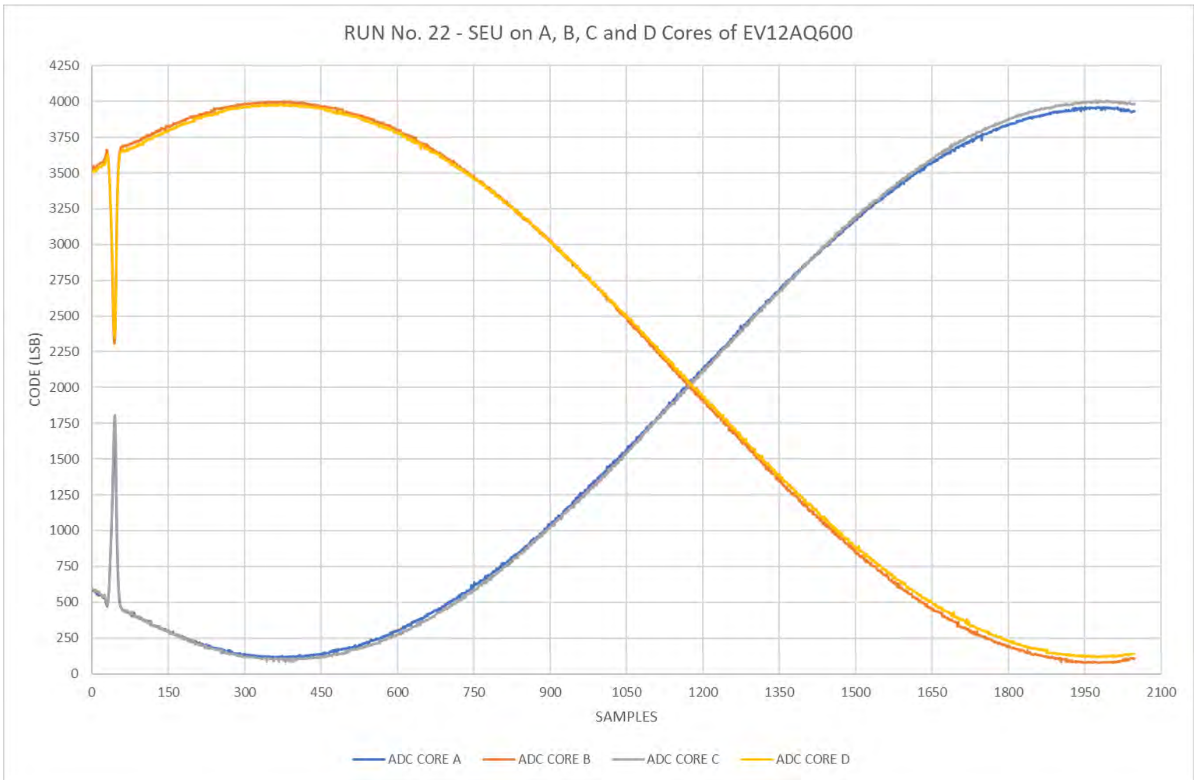


Figure 14: EV12AQ600 SEU case n°1 on A, B, C and D cores in MODE1 test configuration

Figure 15: EV12AQ600 SEU case n°2 on A, B, C and D cores in MODE1 test configuration

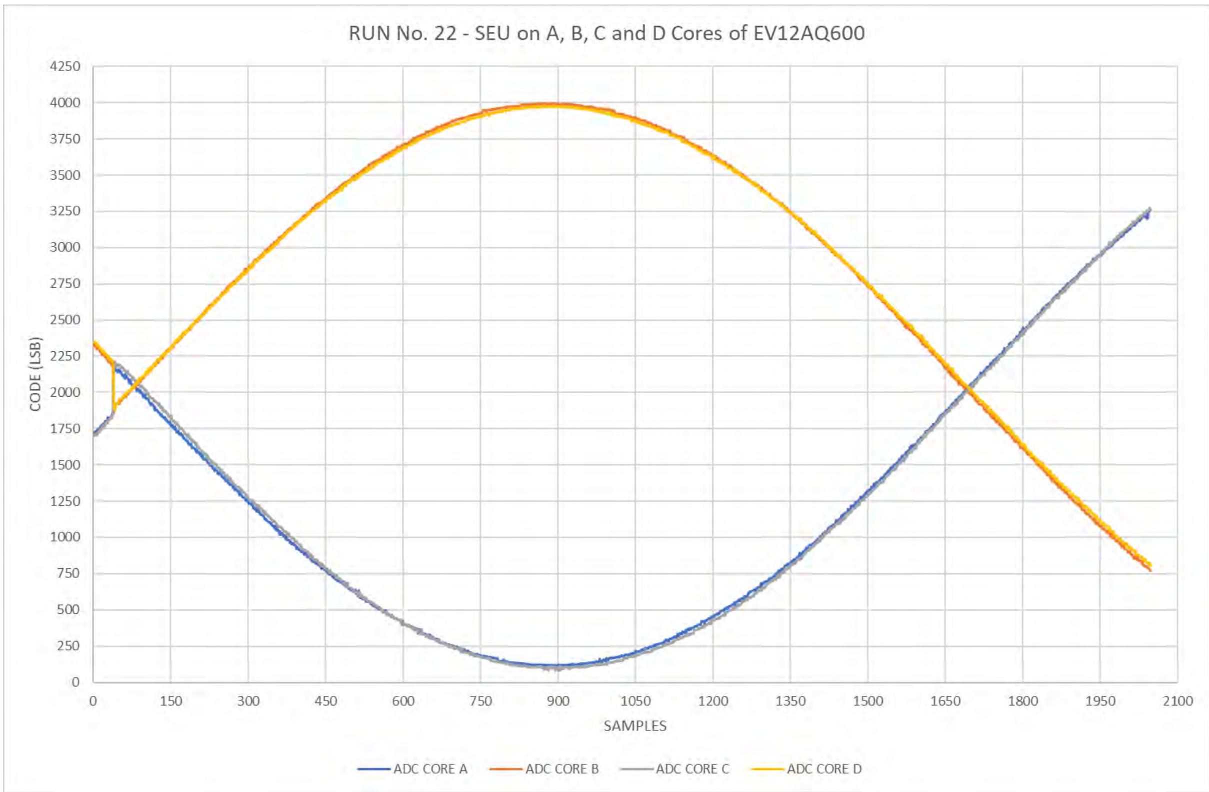


Figure 16: EV12AQ600 SEU case n°3 on A, B, C and D cores in MODE1 test configuration

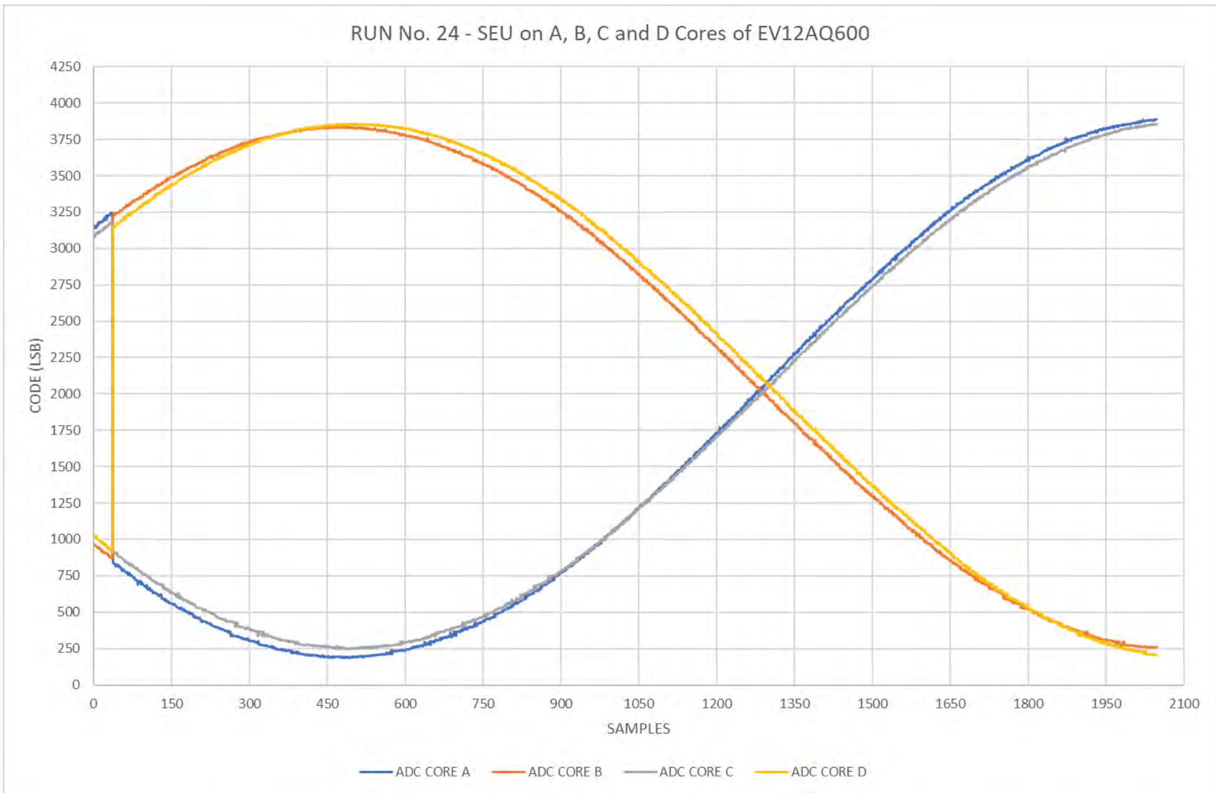


Figure 17: EV12AQ600 SEU case n°4 on A, B, C and D cores in MODE1 test configuration

9.5 SEU on serial lanes test results

9.5.1 SEU on serial lanes LET threshold

The SEU on serial lanes test is performed at 92°C ±2°C.

In MODE1 test configuration

SEU on serial lanes were observed with a minimum LET of 1.5 MeV.cm²/mg, Oxygen heavy ion.

No LET threshold was found with available heavy ions during this test campaign.

9.5.2 SEU on serial lanes of core A cross sections

Hereafter are shown the SEU on serial lanes of core A cross section values for each tested component.

In MODE1 test configuration

	EV12AQ600 SEU on serial communication of core A Cross Section (cm²) in MODE1 test configuration					
LET Eff (MeV.cm²/mg)	Part No. 6			Part No. 2		
	error (-)	cross section	error (+)	error (-)	cross section	error (+)
67.0	5.20E-06	1.00E-05	8.39E-06	3.80E-06	6.00E-06	7.06E-06
33.0	6.08E-06	1.30E-05	9.23E-06	5.80E-06	1.20E-05	8.96E-06
17.0	1.22E-05	2.60E-05	1.85E-05	7.78E-06	2.00E-05	1.09E-05
9.0	2.91E-06	4.00E-06	6.24E-06	5.51E-06	1.10E-05	8.68E-06
1.5	3.38E-06	5.00E-06	6.67E-06	2.38E-06	3.00E-06	5.77E-06

Table 20: EV12AQ600 SEU on serial lanes of core A cross section values in MODE1 test configuration

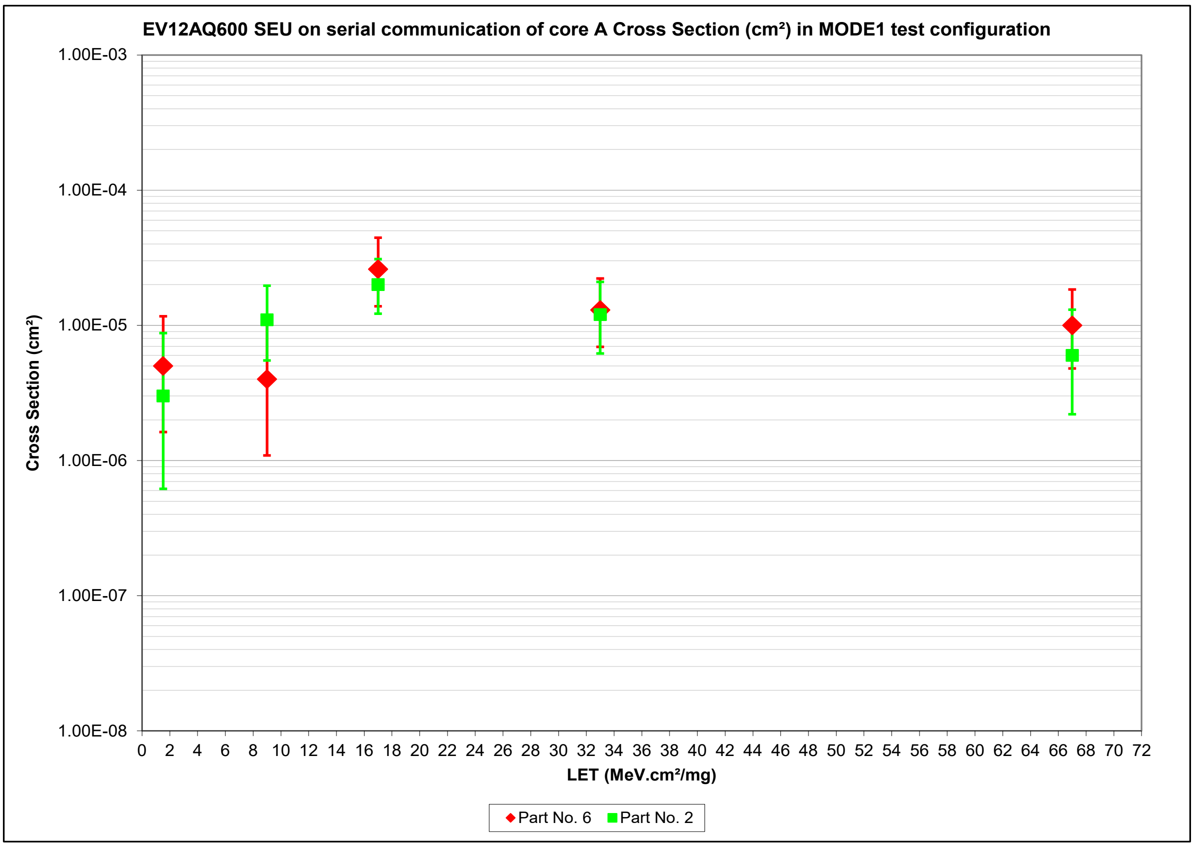


Figure 18: EV12AQ600 SEU on serial lanes of core A cross section curve in MODE1 test configuration

9.5.3 SEU on serial lanes of core A, B, C and D cross sections

Hereafter are shown the SEU on serial lanes of core A, B, C and D cross section values for each tested component.

In MODE1 test configuration

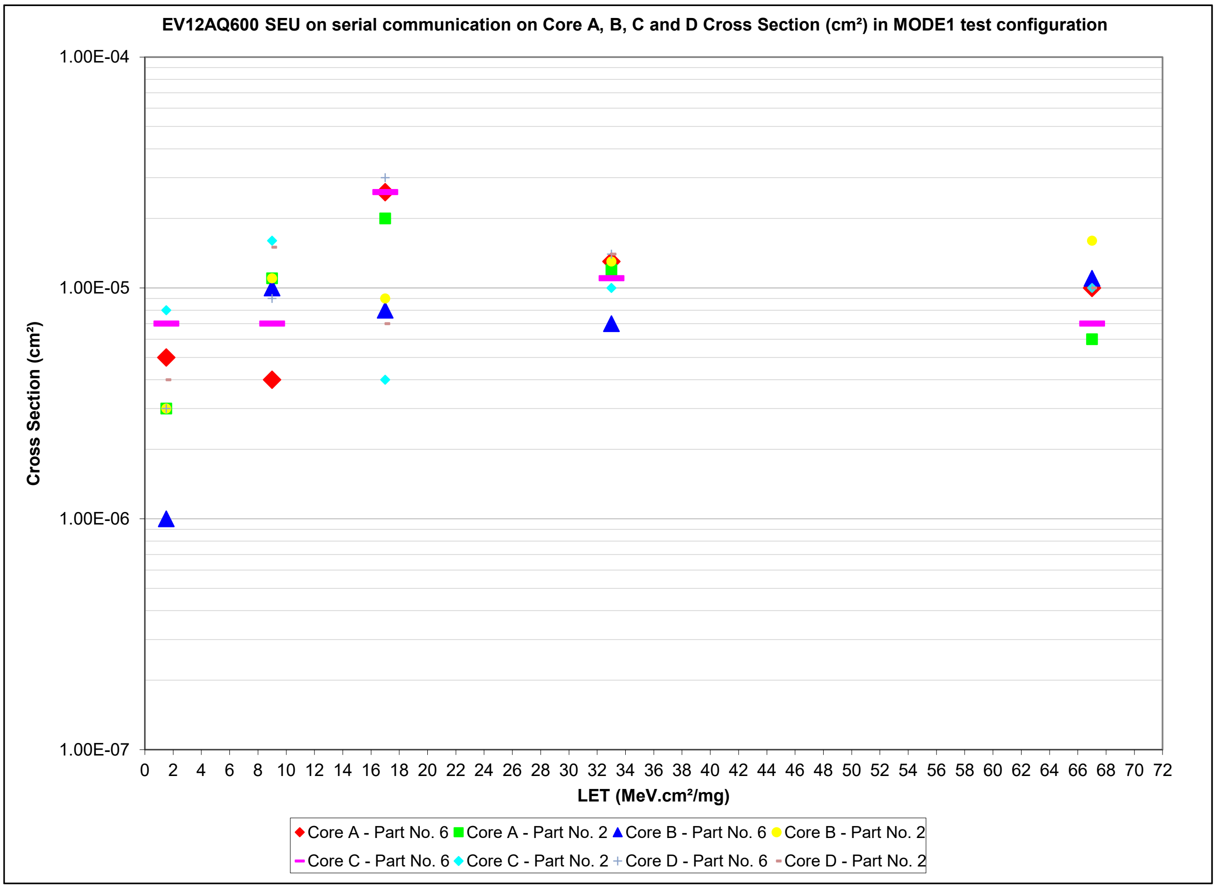


Figure 19: EV12AQ600 SEU on serial lanes of core A, B, C and D cross section curve in MODE1 test configuration

9.6 SEFI on serial lanes test results

9.6.1 SEFI detection and management

The SEFI1 were considered if:

- Eight hundred successive conversions of the analog output were out of the tolerance or if these successive conversions were identical

or

- 10 successive errors were observed on CLK, CB2 (timestamp) and CB1 (parity bit).

Each time a SEFI1 was detected, a shutter was activated. This shutter prevents the beam to access to the DUT and let the time to the system to identify if the SEFI is a SEFI1, SEFI2 or a SEFI3.

Due to a technical problem, the shutter was not effective on run 1 to 16. The results have been cleaned to take this event into account.

After a SEFI1 detection, a SYNC was systematically applied. After this simple SYNC the circuit has fully recovered in 100% of cases.

As the SYNC has particularly an impact on the serial link, we can affirm that the only origin of SEFI is located into the output serial link.

A post-treatment has proved that in every SEFI, either the parity bit of the concern serial link was set to ‘1’, either the CLK, CB2 and CB1 were erroneous during at least 10 clock cycles.

As all the SEFI1 were solved by the SYNC command, no SEFI2 and SEFI3 were detected.

In EV12AQ600, 100% of the SEFI were detected by the check of the CLK, CB2 (timestamp) and CB1 (parity bit), and all the SEFI were solved by a simple SYNC.

9.6.2 SEFI on serial lanes LET threshold

The SEFI on serial lanes of core A, B, C and D test is performed at 92°C ±2°C.

In MODE1 test configuration

SEFI on serial lanes of core A, B, C and D were observed with a minimum LET of 1.5 MeV.cm²/mg, Oxygen heavy ion.

No LET threshold was found with available heavy ions during this test campaign.

9.6.3 SEFI on serial lanes of core A cross sections

Hereafter are shown the SEFI on serial lanes of core A cross section values for each tested component.

In MODE1 test configuration

	EV12AQ600 SEFI on serial communication of core A Cross Section (cm²) in MODE1 test configuration					
LET Eff (MeV.cm²/mg)	Part No. 6			Part No. 2		
	error (-)	cross section	error (+)	error (-)	cross section	error (+)
67.0	1.47E-05	6.40E-05	1.77E-05	1.23E-05	4.60E-05	1.54E-05
33.0	1.03E-05	3.30E-05	1.33E-05	8.42E-06	2.30E-05	1.15E-05
17.0	1.22E-05	2.60E-05	1.85E-05	8.00E-06	2.10E-05	1.11E-05
9.0	7.56E-06	1.90E-05	1.07E-05	4.55E-06	8.00E-06	7.76E-06
1.5	0.00E+00	<1.00E-06	3.69E-06	9.75E-07	1.00E-06	4.57E-06

Table 21: EV12AQ600 SEFI on serial lanes of core A cross section values in MODE1 test configuration

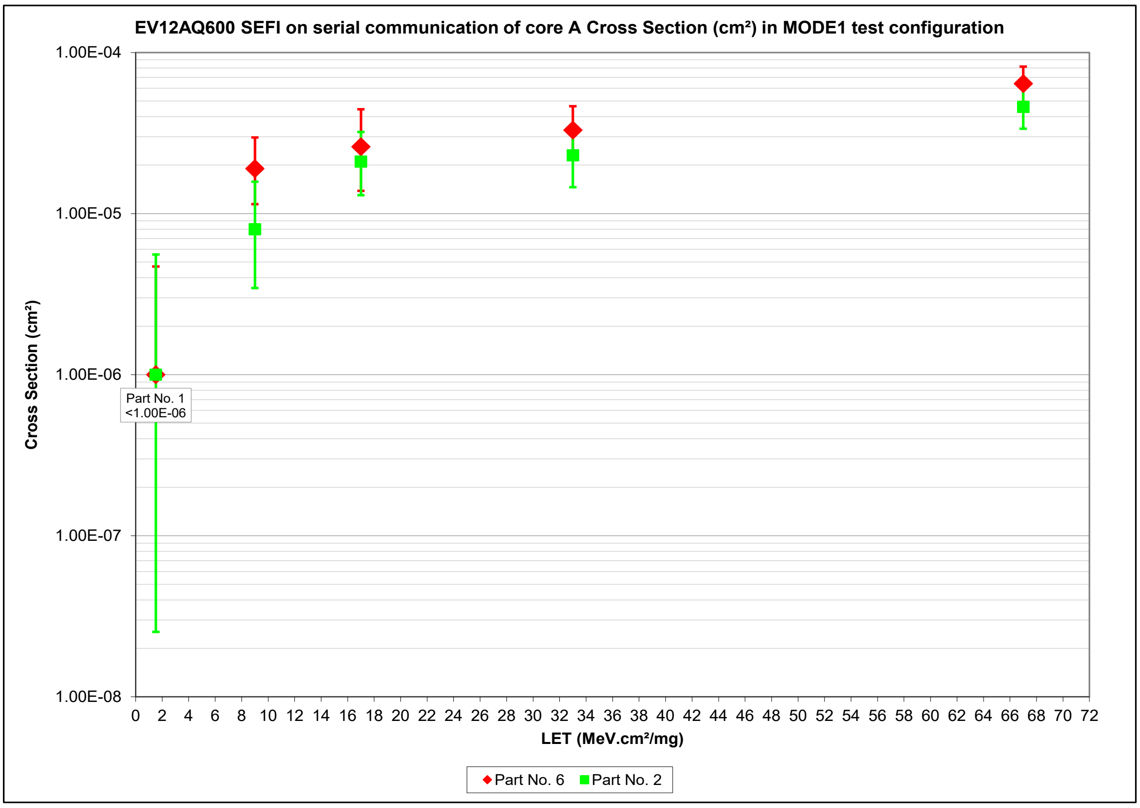


Figure 20: EV12AQ600 SEFI on serial lanes of core A cross section curve in MODE1 test configuration

9.6.4 SEFI on serial lanes of core A, B, C and D cross sections

Hereafter are shown the SEFI on serial lanes of core A, B, C and D cross section values for each tested component.

<u>In MODE1 test configuration</u>

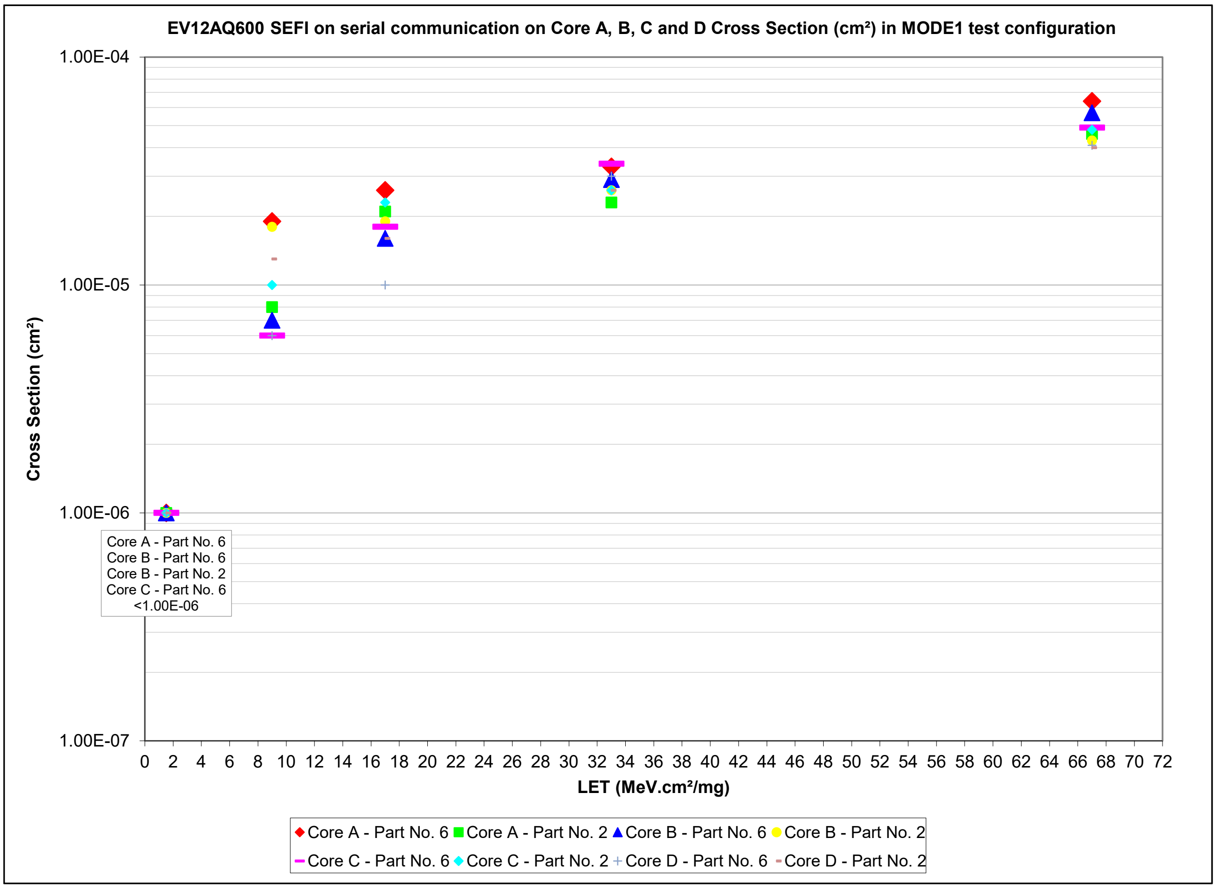


Figure 21: EV12AQ600 SEFI on serial lanes of core A, B, C and D cross section curve in MODE1 test configuration

9.6.5 SEFI on serial lanes case

This section presents a selection of SEFI case observed on serial lanes of A, B, C and D core during the test in MODE 1 of the EV12AQ600

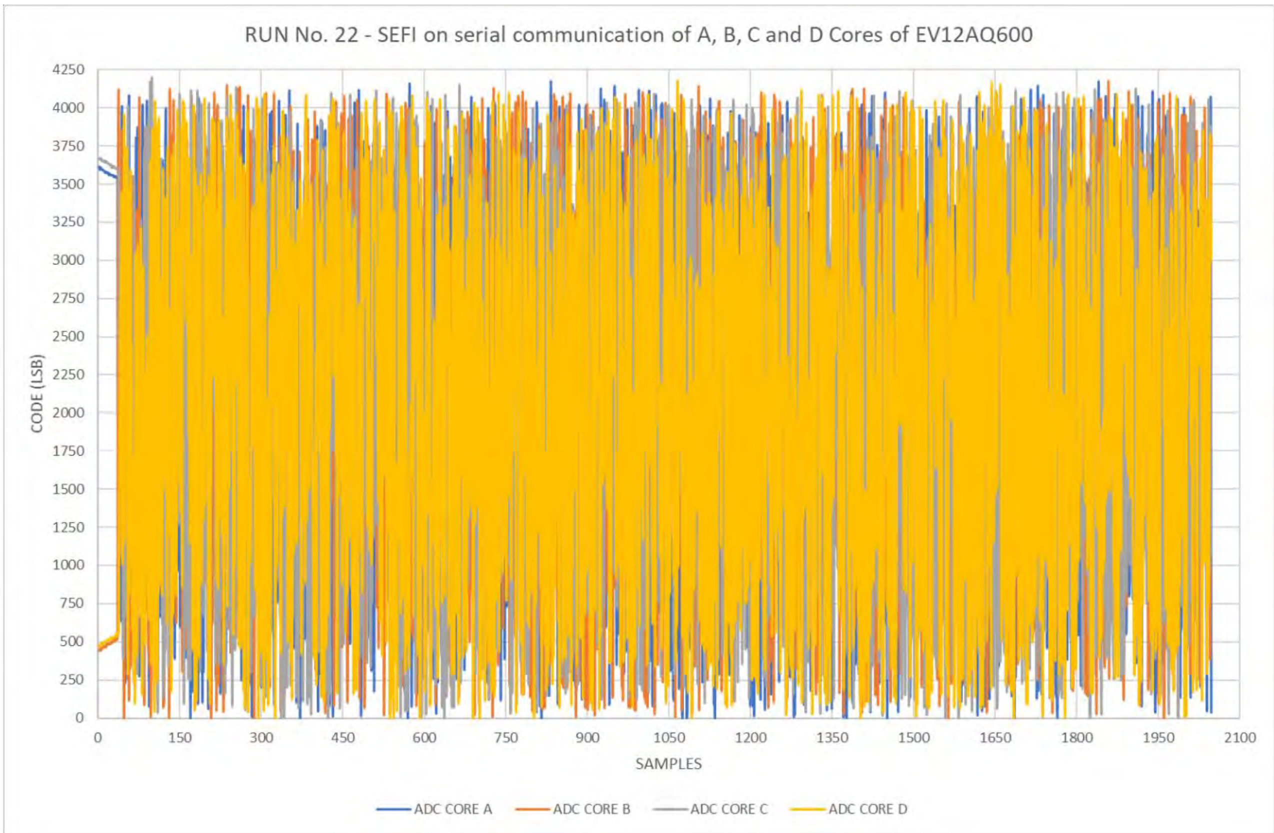


Figure 22: EV12AQ600 SEFI on serial lanes case n°1 in MODE1 test configuration

10. CONCLUSION

TID:
Ten devices, five ON, five OFF, were tested, with a dose rate of 36rad/h and up to a total dose of 150Krad(Si).
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 device under test (P/N EVP12AQ600SH) had neither functional failure nor parameter drift up to 150 Krad (Si) with a dose rate of 36rad/h (10mrad/s).

SEE:
The main objective of this test was to evaluate the sensitivity of the EVP12AQ600SH, an Analog to Digital Converter, to Single Event Latch up (SEL) and Single Event Effects (SEU, SEFI, SET).
This test was performed by TRAD for THALES ALENIA SPACE FRANCE at RADEF with a maximum LET at 67 MeV.cm²/mg. Irradiations were performed from November 6th, 2020 to November 7th, 2020. During this test campaign, 3 samples were irradiated.

The behavior of the fours cores is identical.

The SEL test was performed at 125°C ±1°C.
- No SEL was detected with a LET of 67 MeV.cm²/mg.

The SET on SSO test is performed at 92°C:
- SET on SSO were observed with a minimum LET of 1.5 MeV.cm²/mg
- No LET threshold was found with available heavy ions during this test campaign

The SET on SYNCO test was performed at 92°C:
- SET on SYNCO were observed with a minimum LET of 9.0 MeV.cm²/mg.
- No SET on SYNCO was observed with a LET of 1.5 MeV.cm²/mg.

The SEU on core A, B, C and D test was performed at 92°C:
- SEU on core A, B, C and D were observed with a minimum LET of 1.5 MeV.cm²/mg.
- No LET threshold was found with available heavy ions during this test campaign.

The SEU on serial lanes of core A, B, C and D test is performed at 92°C:
- SEU on the serial lanes of core A, B, C and D were observed with a minimum LET of 1.5MeV.cm²/mg.
- No LET threshold was found with available heavy ions during this test campaign.

The SEFI on serial lanes of core A, B, C and D test is performed at 92°C:
- SEFI on serial lanes of core A, B, C and D were observed with a minimum LET of 1.5MeV.cm²/mg.
- No LET threshold was found with available heavy ions during this test campaign.

In the EV12AQ600, 100% of the SEFI were detected by the check of the CLK, CB2 (timestamp) and CB1 (parity bit), and all the SEFI were solved by a simple SYNC.

The EV12AQ600 Quad channel 12 bits 1.6GSps ADC has successfully pass this heavy ions test. The latch-up immunity, the perfect similarity of the four cores, the SEFI easy to manage and the very good performances of both, SSO and SYNCO signals must be particularly noted.

Those results, TID and SEE, prove that this device is usable for most of the space applications like long-term missions or GEO satellites.

ANNEX 1 : CO60 IRRADIATION CERTIFICATE

TRAD Tests & radiations

cofrac ESSAIS
ACCREDITATION
N° 1-6110
Gamma irradiation, dose deposit
Scope on the Cofrac website
www.cofrac.fr

Co^{60} IRRADIATION CERTIFICATE

Customer: ASI Case followed up by: MF
FAO: Ronan MAREC

Source: Coblat-60 (Co60)	
Certificate	N° 36708 of 08/10/2015
Activity	14.8 TBq of 04/09/2015

Reference : PV/ATR/AQ600/XXX1/ASI/MF/1904 Rev: II
Device irradiated : AQ600
Irradiation certificate applied only to the device subjected to the irradiation
In agreement with the quality procedure according ESCC 22900 (Pro.016 Rev. 5)

Irradiation environment

	Units	Min	Max	Time-weighted average
Temperature	°C	18.4	23.4	20.2
Relative humidity	%	35.1	68.9	55.5

Dose rate measurement

The instruments used for dose rate measurement is a PTW ionization chamber(TM30013) and universal dosemeter UNIDOS E which is controlled annually.

UNIDOS E	Serial number: 82253	Certificate number: 18D256	Date: 09/11/2018
TM30013	Serial number: 9314	Certificate number: 18D256	Date: 09/11/2018

The measurement unit of the international system for the dose rate is Gy/s. We commonly use rad/h (1 Gy/h = 100 rad/h).
The dose rate is measured at the center of the device.

TRAD position	Date	Dose rate [rad/h] (Kerma in the air)
36-43	18/04/2019	38.25
	07/08/2019	38.05
36-44	18/04/2019	38.05
	07/08/2019	38.16
36-51	18/04/2019	38.12
	07/08/2019	37.86
36-52	18/04/2019	37.94
	07/08/2019	38.22
36-53	18/04/2019	38.24
	07/08/2019	38.21
36-54	18/04/2019	37.69
	07/08/2019	37.81

[illegible]

Dosimetry

Each exit and input of Cobalt-60 source is logged in a digital file. We compute the dose at each step taking into account the source decay, the dose rate measured by the gamma probe and the downtime irradiation.

TRAD position	Date	Total ionizing dose [krad] (Kerma in the air)	Lot No. (if applicable)
36-43	17/05/2019	0	Board 3
	07/06/2019	18.20	
	27/06/2019	35.49	
	30/08/2019	91.45	
	13/09/2019	103.73	
	14/11/2019	158.26	
36-44	17/05/2019	0	Board 4
	07/06/2019	18.11	
	27/06/2019	35.30	
	30/08/2019	91.13	
	13/09/2019	103.45	
	14/11/2019	158.14	
36-51	17/05/2019	0	Board 5
	07/06/2019	18.14	
	27/06/2019	35.37	
	30/08/2019	91.30	
	13/09/2019	103.32	
	14/11/2019	157.58	
36-52	17/05/2019	0	Board 2
	07/06/2019	18.05	
	27/06/2019	35.20	
	30/08/2019	90.96	
	13/09/2019	103.30	
	14/11/2019	158.07	
36-53	17/05/2019	0	Board 1
	07/06/2019	18.20	
	27/06/2019	35.48	
	30/08/2019	91.51	
	13/09/2019	103.85	
	14/11/2019	158.61	
36-54	17/05/2019	0	Board 6
	07/06/2019	17.53	
	27/06/2019	34.97	
	30/08/2019	90.28	
	13/09/2019	102.48	
	14/11/2019	156.67	

Measurement uncertainty : 1.0% *The measurement uncertainty is expressed at two standard uncertainties (k=2).*

ESCC 22900: The dose at the device under test shall be measured to a resolution of better than 10%. The test devices shall be exposed to within 10% of the specified radiation dose level(s).

The gamma-ray dose rate of a Cobalt 60 source shall be calibrated in accordance with the requirements of ESCC Basic Specification No. 21500 to 5% or better. Dosimetry shall be traceable to national standards.

Written by	Quality control and Approved by
25/11/2019 M. FULLALOVE	26/11/2019 Y. PADIE

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