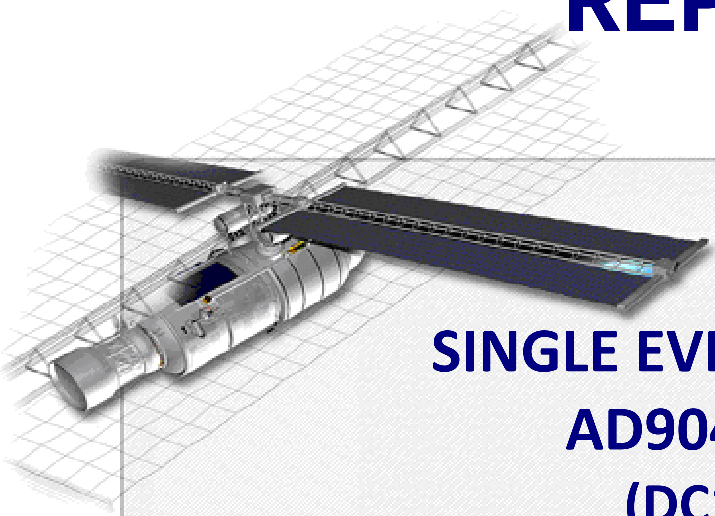
HEAVY IONS TEST REPORT



SINGLE EVENT EFFECTS
AD9042ASTZ
(DC1314)
12-Bit, 41 MSPS Monolithic A/D Converter
From
Analog Devices

TRAD/TI/AD9042ASTZ/1314/ESA/LG/1409		Labège, 09 September, 2015
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Revision: 1		
To: **ESA** **Marc POIZAT**		Project/Program: TID influence on the SEE sensitivity of active EEE components Ref: ESTEC Contract No.4000111336/14/NL/SW

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TABLES

1. Introduction

This report includes the test results of the heavy ions Single Event Effects (SEEs) test sequence carried out on the **AD9042ASTZ**, a **12-Bit, 41 MSPS Monolithic A/D Converter** from **Analog Devices**.

This test was performed for **ESA** at U.C.L (Université Catholique de Louvain, Louvain la Neuve, Belgium) on October 27th and 28th, 2014. Two samples were irradiated.

This test was performed for **ESA** on the **AD9042ASTZ** susceptible to show Single Event Latchups (SELs), Single Event Upsets (SEUs), Single Event Transients (SETs) and Single Event Functional Interrupt (SEFIs) induced by heavy ions. This test was performed as part of a global study to evaluate the potential synergetic effects of TID on SEE sensitivity. As a result, the development strategy for this test was not the characterization of the AD9042ATZ itself, but the evolution of its SEE sensitivity after submission to TID. The results presented in this report were obtained before TID irradiation (0 krad).

2. Documents

2.1. Applicable documents

Financial and technical proposal: TRAD/P/ESA/AO7751/AV/130214 Rev.0
Irradiation test plan: ITP/TRA/TI/AD9042/LQFP44/AD/200814 issue 2 of 15/10/2014

2.2. Reference documents

Data-sheet: AD9042 Datasheet from Analog Devices rev B of 10/2009

3. Organization of Activities

The relevant company has performed the following tasks during this evaluation:

1	Procurement of Test Samples	TRAD
2	Preparation of Test Samples (delidding)	TRAD
3	Preparation of Test Hardware and Test Program	TRAD
4	Samples Check	TRAD
5	Accelerator Test	TRAD
6	Heavy Ion Test Report	TRAD

Table 1: Organization of activities

4. Parts information

4.1. Device description

The AD9042 is a high speed, high performance, low power, monolithic 12-bit analog-to-digital converter (ADC). All necessary functions, including track-and-hold (T/H) and reference are included on chip to provide a complete conversion solution. The AD9042 operates from a single 5 V supply and provides CMOS-compatible digital outputs at 41 MSPS.

4.2. Identification

Type:	AD9042ASTZ
Manufacturer:	Analog Devices
Function:	12-Bit, 41 MSPS Monolithic A/D Converter

4.3. Procurement information

Package	QFP-44
Date code	1314
Sample size:	10 parts procured by TRAD

4.4. Sample Preparation

All parts were delidded by TRAD.
No sample was damaged during this operation.
A functional test sequence was performed on delidded samples to check that devices were not degraded by the delidding operation.
Among the 10 delidded samples available for the test campaign, 2 were irradiated and 8 were not used.

4.5. Sample pictures

4.5.1. External view

No marking was observed at the bottom of the package.

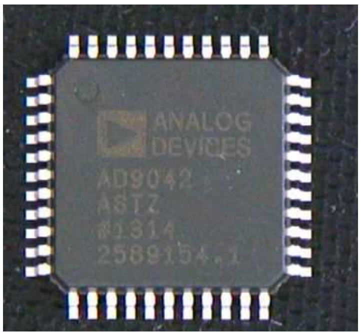


Figure 1: Package marking

4.5.2. Internal view

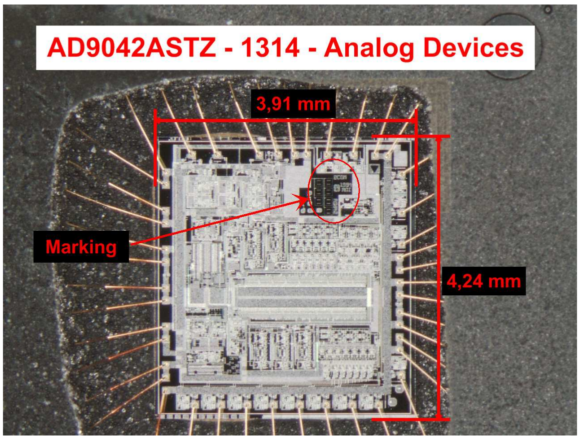


Figure 2: Internal overall view

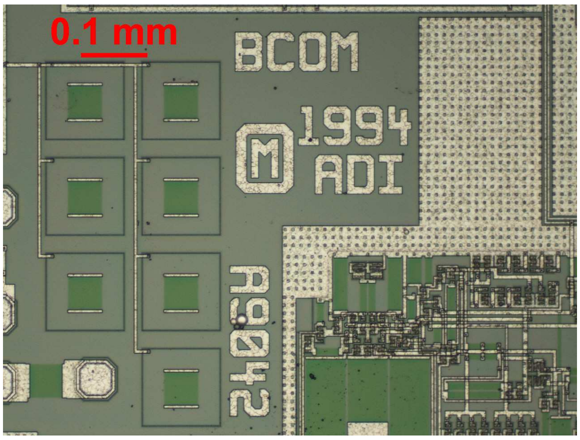


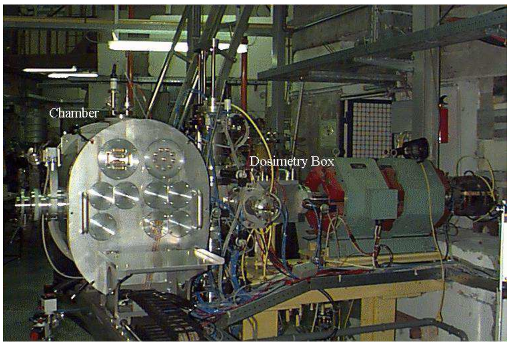
Figure 3: Die marking

5. Dosimetry and Irradiation Facilities

The test was performed at U.C.L (Université Catholique de Louvain) on October 27th and 28th, 2014. Two delidded samples were irradiated.

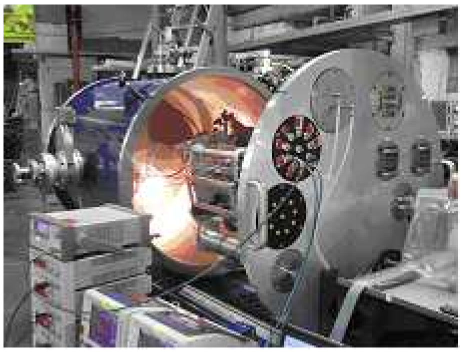
5.1. UCL Heavy Ion Test Facility (Université Catholique de Louvain - Belgique)

The CYClotron of LOuvain la NEuve (CYCLONE) is a multi-particle, variable energy, cyclotron capable of accelerating protons (up to 85 MeV), alpha particles and heavy ions.
For the heavy ions, the covered LET range is between 1.2 MeV.cm².mg^{-1} and 67.7 MeV.cm².mg^{-1}. Heavy ions available are separated in two "Ion Cocktails" named M/Q=5 and M/Q=3.3.



One of the main advantages of the UCL Heavy Ion Test Facility is the fast changing of ion species. Within the same cocktail, it takes only a few minutes to change from one ion to another.

The chamber has the shape of a barrel stretched vertically; its internal dimensions are 71 cm in height, 54 cm in width and 76 cm in depth. One side flange is used to support the board frame (25 X 25 cm) and user connectors.
The chamber is equipped with a vacuum system.



5.2. Dosimetry

To control and monitor the beam parameters, a dosimetry box is placed in front of the chamber. It contains a faraday cup, 2 Parallel Plate Avalanche Counters (PPAC).
Two additional surface barrier detectors are placed in the test chamber.
The faraday cup is used during beam preparation at high intensity.
A beam uniformity measurement is performed with a collimated surface barrier detector. This detector is placed on a X and Y movement. The final profile is drawn and the ± 10 % width is calculated. The Homogeneity is ± 10 % on a 25 mm diameter.
During the irradiation, the flux is integrated in order to give the delivered total fluence (particule.cm^{-2}) on the device.

5.3. Beam characteristics

The beam flux is variable between a few particles $s^{-1}cm^{-2}$ and $1.8 \cdot 10^4 s^{-1}cm^{-2}$ depending on the device sensitivity.

Available heavy ion characteristics are listed in the following tables (heavy ions used during the experiment are highlighted in yellow):

Ion	Energy (MeV)	Range (µm(Si))	LET (MeV.cm².mg^{-1})
$^{15}N^{3+}$	60	59	3.3
$^{20}Ne^{4+}$	78	45	6.4
$^{40}Ar^{8+}$	151	40	15.9
$^{84}Kr^{17+}$	305	39	40.4
$^{124}Xe^{25+}$	420	37	67.7

Table 2: UCL cocktail M/Q=5

Ion	Energy (MeV)	Range (µm(Si))	LET (MeV.cm².mg^{-1})
$^{13}C^{4+}$	131	292	1.1
$^{22}Ne^{7+}$	235	216	3
$^{40}Ar^{12+}$	372	117	10.2
$^{58}Ni^{18+}$	567	100	20.4
$^{83}Kr^{25+}$	756	92	32.6

Table 3: UCL cocktail M/Q=3.3

6. Test Procedure and Setup

6.1. Test procedure

6.1.1. Description of the test method

The test was divided in two parts, with respect to reference or applicable documents:

- Runs were performed up to a fluence of 1.10^{7} cm^{-2} with only SEL monitoring. This configuration allowed to verify the latchup sensitivity of the device.
- Runs were performed up to a fluence of 1.10^{6} cm^{-2} for the SEU, SET, and SEFI detection. A latchup monitoring was used during these tests in order to protect the component. This configuration allowed to verify the SEU, SET and SEFI sensitivity of the device.

The test was terminated when the maximum fluence was reached or when about a hundred events were recorded.

6.1.2. SEL Test Principle

The test was performed at nominal operating voltage and ambient temperature.
TRAD has developed a fully integrated test bench to perform Single Event Latchup tests (SEL). The GUARD system (Graphical Universal Autorange Delatcher) allows the user to easily protect his device under test and perform SEL characterization.
The power supply is applied to the device under test through the GUARD system.
The threshold current of the GUARD system is set according to the nominal current. If the nominal current exceeds the threshold current, the GUARD system is triggered and the event is counted as an SEL. Then, the GUARD system sends a trigger command to the oscilloscope, maintains the power supply during a defined 'Time hold' and cuts it off during a defined 'Time cut'. Then, the power supply is restarted with the nominal current expected consumption.
At the end of each run, the test program reads the oscilloscope's "Local Scope Counter" which represents the total event count and downloads the recorded current waveforms to store them.

Figure 4 shows an example of the SEL detection.

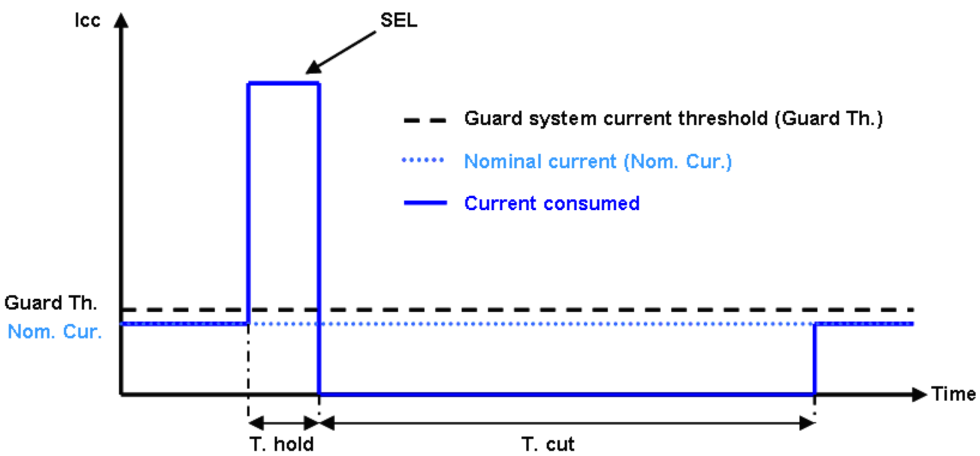


Figure 4: Common SEL characteristic.

6.1.3. SEU, SET and SEFI Test Principle

During test, the DUT is operated in continuous conversions at 5MHz frequency with a constant input signal. The digital output conversion is monitored to detect SEE events.

Before each run, 10000 consecutive conversions are initiated to define limits between which the conversions are considered valid (to these limits, we appreciatively add a ±2,5mV band to prevent the noisy environment). Out of these limits we consider that the conversion is in error. For a single error followed by a correct conversion a SEU is counted. For several consecutive conversion errors (<200 errors) a SET is counted. For 200 consecutive false conversions a SEFI type 1 is counted and for a conversion value which stays exactly the same during 200 conversions a SEFI type 2 is counted.

A set of 3 analog inputs (quarter, half and three-quarter of the input range) is firstly used to evaluate the least sensitive configuration. These configurations are respectively noted as SEE_1, SEE_2 and SEE_3. The least sensitive configuration is maintained for the remaining of the test proceedings.

6.2. Test bench description

6.2.1. Preparation of test hardware and program

TRAD has developed a specific test program and a specific motherboard to feed power supply to components.
The output of the DUT is processed using an FPGA development kit to check conversions and store errors.
The test system is driven by a personal computer through a standard IEEE488 communication interface. All signals are delivered and monitored by this equipment and SEE curves and data are saved in its memory.
At the end of each test run, data is transferred to the hard disk for storage. An overall description of the test system is given in Figure 5.
Before performing the heavy ion test, the whole system (delidded sample, test board and software) was assembled and tested by TRAD in V.A.S.C.O (Vacuum System for Californium Operation).

6.2.2. Test equipment identification

The tests were carried out with test boards developed by TRAD.

COMPUTER	PO-TE-097
REF. TEST BOARD	TRAD/CT1/I/AD9042/ZIP28/LS/1407
EQUIPMENT	ME-79, MI-52, MI-60, SM-92
TEST PROGRAM	AD9042_TI_ESA_V10.llb AD9042_TI_ESA_V10.xise

6.2.3. Test Bench description

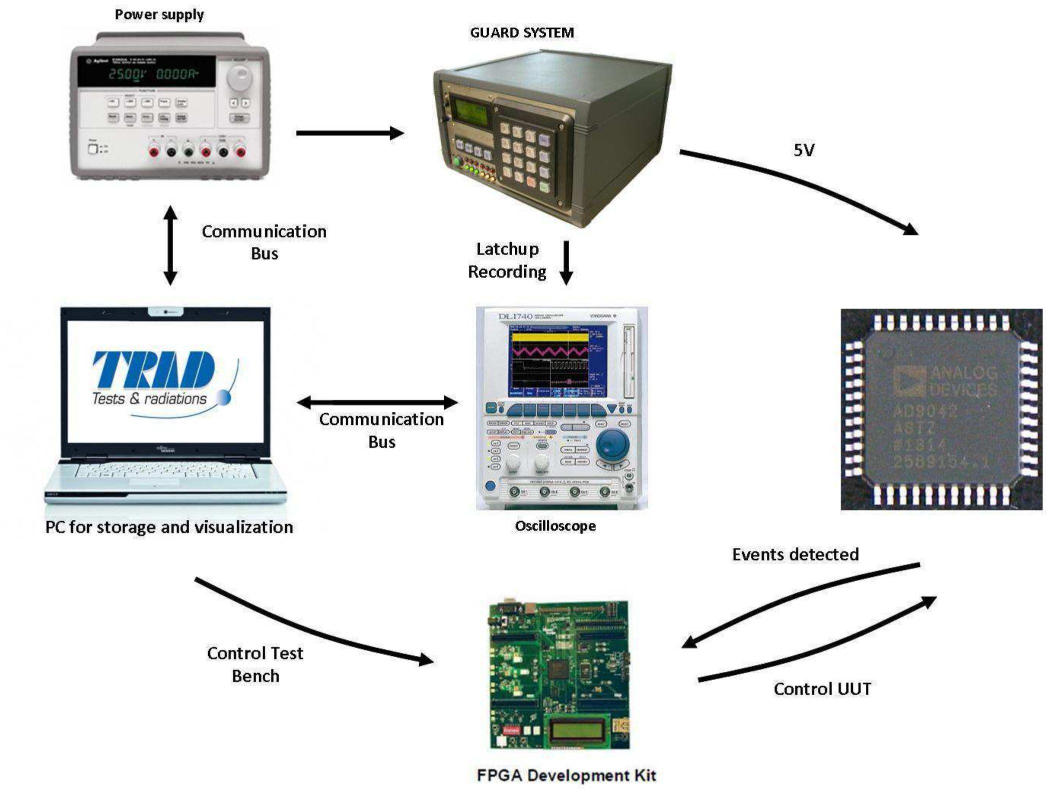


Figure 5: Test system description

6.2.4. Device setup and Test conditions

Input values for SET test are defined in the following table:

Vcc	5V		
Configuration	SEE_1	SEE_2	SEE_3
V_{in}	2.15V	2.4V	2.65

Table 4: SEE inputs configurations

Trigger threshold for SEL test is defined in the following table:

Power Supply	Avcc	Dvcc
Voltage Value	5V	5V
$I_{nominal}$	110mA	15mA
$I_{threshold}$	150mA	25mA
T_{hold}	1ms	
T_{cut}	7ms	
Temperature	25°C	

Table 5: SEL detection threshold

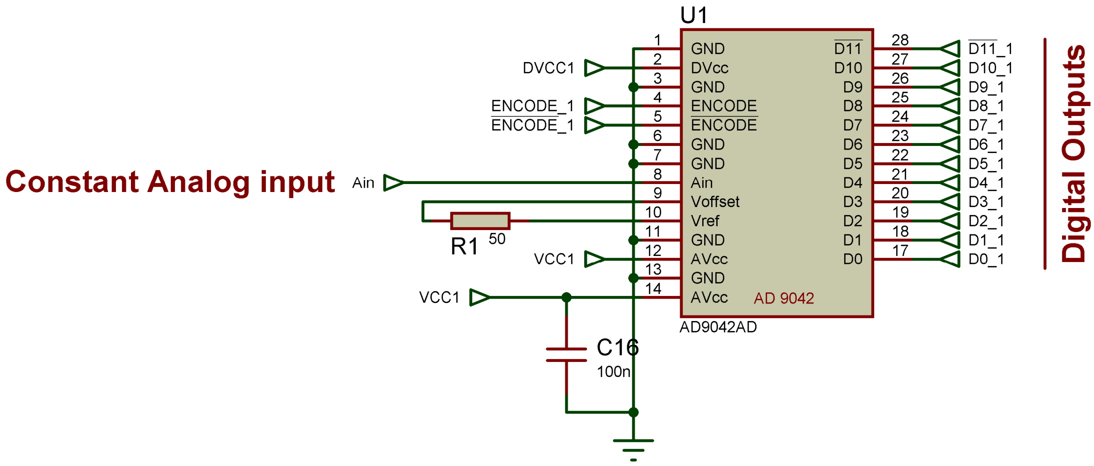


Figure 6: Test board schematic

7. Test Story

Test sequence, test and measurement conditions were nominal.

8. RESULTS

8.1. Summary of runs.

Runs performed during this campaign are summarized in the following table. Tests results are described in the following chapter.

AD9042ASTZ AVcc =5V DVcc = 5V T = 25°C												LATCHUP				SEE					
Run	**Part**	**Config**	**Ion**	**Energy (MeV)**	**Range (µm)**	**LET (MeV.cm²/mg)**	**Flux (φ) ($cm^{-2}.s^{-1}$)**	**Time (s)**	**Run Fluence (Φ) (cm^{-2})**	**Run Dose (krad)**	**Cumulated Dose (krad)**	**Avcc**	**Cross Section**	**Dvcc**	**Cross Section**	**SEU**	**Cross Section**	**SET**	**Cross Section**	**SEFI**	**Cross Section**
High LET M/Q=5																					
1	1	SEL	124Xe 26+	420	37	67.7	8.14E+03	1228	1.00E+07	10.832	10.832	0	<1.00E-07	0	<1.00E-07	-	-	-	-	-	-
2	2	SEL	124Xe 26+	420	37	67.7	1.01E+04	987	1.00E+07	10.832	10.832	0	<1.00E-07	0	<1.00E-07	-	-	-	-	-	-
3	2	SEE_2	124Xe 26+	420	37	67.7	2.03E+03	495	1.00E+06	1.087	11.919	0	<1.00E-06	0	<1.00E-06	518	5.16E-04	50	4.98E-05	0	<1.00E-06
4	2	SEE_1	124Xe 26+	420	37	67.7	3.02E+03	333	1.01E+06	1.089	13.008	0	<1.00E-06	0	<1.00E-06	530	5.27E-04	56	5.57E-05	0	<1.00E-06
5	2	SEE_3	124Xe 26+	420	37	67.7	3.00E+03	335	1.00E+06	1.088	14.095	0	<1.00E-06	0	<1.00E-06	546	5.44E-04	57	5.68E-05	0	<1.00E-06
6	1	SEE_2	124Xe 26+	420	37	67.7	2.97E+03	338	1.00E+06	1.088	11.920	0	<1.00E-06	0	<1.00E-06	503	5.01E-04	46	4.58E-05	0	<1.00E-06
7	1	SEE_2	84 Kr 17+	305	39	40.4	2.89E+03	348	1.00E+06	0.649	12.569	0	<1.00E-06	0	<1.00E-06	353	3.52E-04	43	4.28E-05	0	<1.00E-06
8	2	SEE_2	84 Kr 17+	305	39	40.4	3.12E+03	322	1.00E+06	0.650	14.745	0	<1.00E-06	0	<1.00E-06	400	3.98E-04	52	5.17E-05	0	<1.00E-06
High Range M/Q=3.3																					
9	1	SEE_2	83 Kr 25+	756	92	32.6	4.48E+03	225	1.01E+06	0.526	13.094	0	<1.00E-06	0	<1.00E-06	290	2.88E-04	38	3.77E-05	0	<1.00E-06
10	2	SEE_2	83 Kr 25+	756	92	32.6	5.14E+03	196	1.01E+06	0.526	15.271	0	<1.00E-06	0	<1.00E-06	327	3.24E-04	34	3.37E-05	0	<1.00E-06
11	2	SEE_2	40 Ar 12+	372	117	10.2	4.89E+03	206	1.01E+06	0.164	15.435	0	<1.00E-06	0	<1.00E-06	140	1.39E-04	7	6.95E-06	0	<1.00E-06
12	1	SEE_2	40 Ar 12+	372	117	10.2	5.06E+03	199	1.01E+06	0.164	13.259	0	<1.00E-06	0	<1.00E-06	146	1.45E-04	9	8.93E-06	0	<1.00E-06
13	1	SEE_2	13 C 4+	131	292	1.1	5.03E+03	200	1.01E+06	0.018	13.276	0	<1.00E-06	0	<1.00E-06	19	1.89E-05	0	<9.94E-07	0	<1.00E-06
14	2	SEE_2	13 C 4+	131	292	1.1	5.06E+03	199	1.01E+06	0.018	15.453	0	<1.00E-06	0	<1.00E-06	27	2.68E-05	0	<9.94E-07	0	<1.00E-06
15	2	SEE_2	22 Ne 7+	235	216	3	5.00E+03	201	1.01E+06	0.048	15.501	0	<1.00E-06	0	<1.00E-06	100	9.94E-05	0	<9.94E-07	0	<1.00E-06
16	1	SEE_2	22 Ne 7+	235	216	3	5.17E+03	195	1.01E+06	0.048	13.325	0	<1.00E-06	0	<1.00E-06	92	9.12E-05	0	<9.91E-07	0	<1.00E-06

Table 6: AD9042ASTZ test results

No SEL or SEFI were detected during this test.
SEU and SET events were detected during this test.

8.2. SEL test results.

The SEL test was performed at 25°C.
No SEL was observed during this test under Xenon irradiation with a total fluence equal to 1E+7 cm^{-2} with a particle angle of 0° (LET = 67.7 MeV.cm²/mg and range = 37µm).

8.2.1. SEL Cross sections

LET ($MeV.cm^2.mg^{-1}$)	AD9042ASTZ SEL Cross Section (cm^2)	
	N°1	N°2
67.7	<1.00E-07	<1.00E-07

Table 7: AD9042ASTZ SEL cross section results

8.3. SEE tests results

The SEE test was performed at 25°C.

The three tested configurations did not present a difference of sensitivity at Xenon Heavy Ion, LET = 67.7 MeV.cm²/mg. Configuration SEE_2 was selected to perform SEE tests.

SEUs were observed during the irradiation at Carbon Heavy Ion (LET = 1.1 MeV.cm²/mg).
SETs were observed during the irradiation down to Argon Heavy Ion (LET = 10.2 MeV.cm²/mg).
No SEFI was observed during this test under Xenon irradiation with a total fluence equal to 1E+6 cm^{-2} with a particle angle of 0° (LET = 67.7 MeV.cm²/mg and range = 37µm).

8.3.1. SEU Cross sections

AD9042ASTZ SEE_2 Config SEU Cross Section (cm^2)		
LET Eff ($MeV.cm^2.mg^{-1}$)	**SEU**	
	N° 1	N° 2
67.7	5.01E-04	5.16E-04
40.4	3.52E-04	3.98E-04
32.6	2.88E-04	3.24E-04
10.2	1.45E-04	1.39E-04
3	9.12E-05	9.94E-05
1.1	1.89E-05	2.68E-05

Table 8: AD9042ASTZ SEE_2 configuration SEU cross section results

The following figure presents the cross section of the SEU event on the digital outputs of the AD9042ASTZ part on SEE_2 configuration.
Error bars are calculated as described in the ESCC25100, using 95% confidence level and 10% fluence uncertainty.

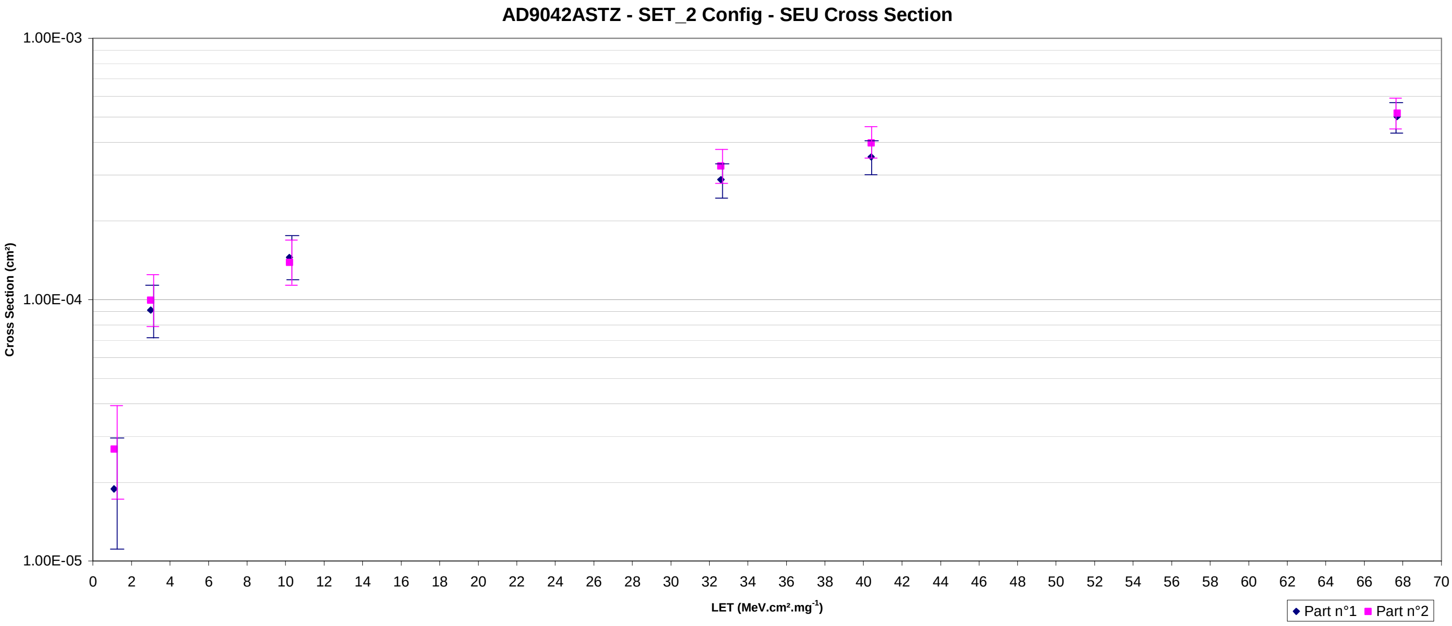


Figure 7: SEE_2 configuration SEU cross section curve for AD9042ASTZ

8.3.2. SET Cross sections

AD9042ASTZ SEE_2 Config SET Cross Section (cm2)		
LET Eff (MeV.cm².mg^{-1})	**SET**	
	N° 1	N° 2
67.7	4.58E-05	4.98E-05
40.4	4.28E-05	5.17E-05
32.6	3.77E-05	3.37E-05
10.2	8.93E-06	6.95E-06
3	<1.00E-06	<1.00E-06
1.1	<1.00E-06	<1.00E-06

Table 9: AD9042ASTZ, SEE_2 configuration, SET cross section results

The following figure presents the cross section of the SET event on the digital outputs of the A9042ASTZ part on SEE_2 configuration. Points represented by an arrow pointing down indicate that no events were observed at the corresponding LET. The evaluated cross section is then lower than 1.00 $10^{-6}cm^{-2}$, value corresponding to one event at maximum fluence.
Error bars are calculated as described in the ESCC25100, using 95% confidence level and 10% fluence uncertainty.

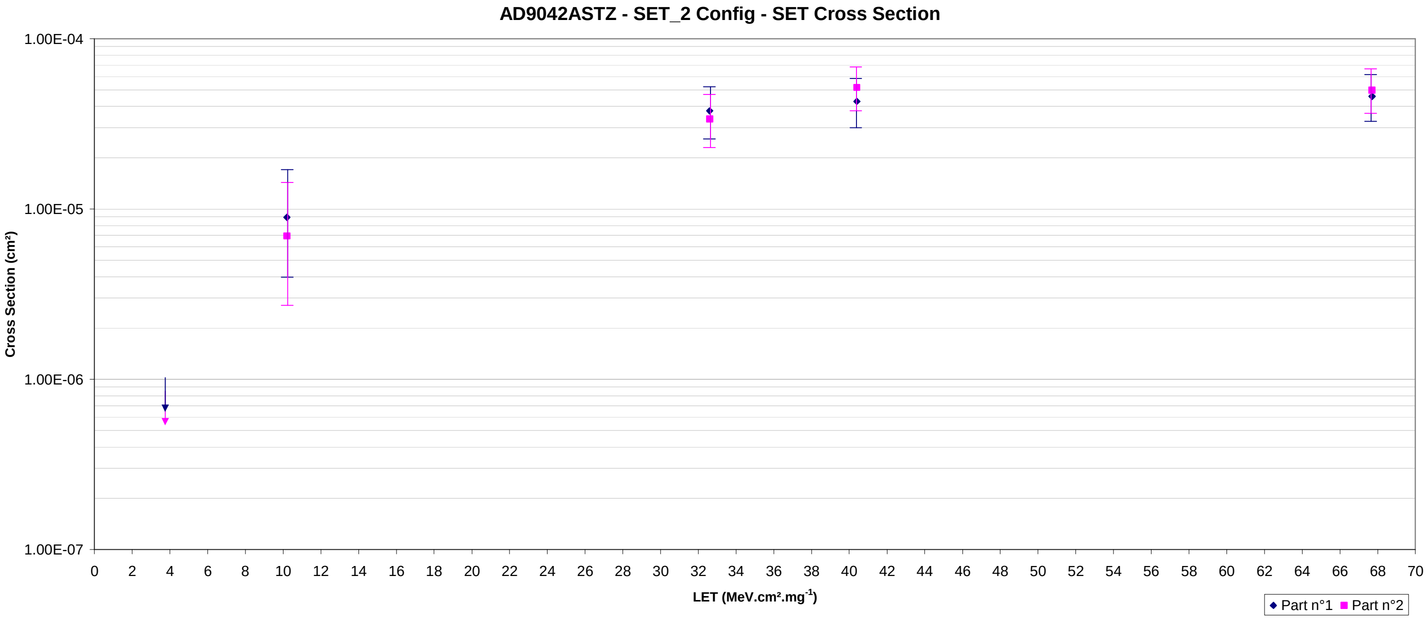


Figure 8: SEE_2 configuration SET cross section curve for AD9042ASTZ

8.3.3. SEFI Cross sections

LET ($MeV.cm^2.mg^{-1}$)	SEFI Cross Section (cm^2)	
	N°1	N°2
67.7	<1.00E-06	<1.00E-06

Table 10: AD9042ASTZ SEFI cross section results

9. Conclusion

Heavy ion tests were performed on AD9042ASTZ to evaluate the sensitivity of the device versus SEL, SEU, SET and SEFI. This test was performed as part of a global study to evaluate the potential synergetic effects of TID on SEE sensitivity. As a result, the development strategy for this test was not the characterization of the AD9042ATZ itself, but the evolution of its SEE sensitivity after submission to TID. The results presented in this report were obtained before TID irradiation (0 krad).

No SELs were observed with the LET value of 67.7MeV.cm²/mg (Xenon heavy ions).

No SEFIs were observed with the LET value of 67.7MeV.cm²/mg (Xenon heavy ions).

SETs were observed on the AD9042ASTZ with a minimum LET of 10.2 MeV.cm²/mg (Argon heavy ions). No SET was detected with a LET of 3 MeV.cm²/mg (Neon heavy ions).

SEUs were observed on the AD9042ASTZ with a minimum LET of 1.1 MeV.cm²/mg (Carbon heavy ions).

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