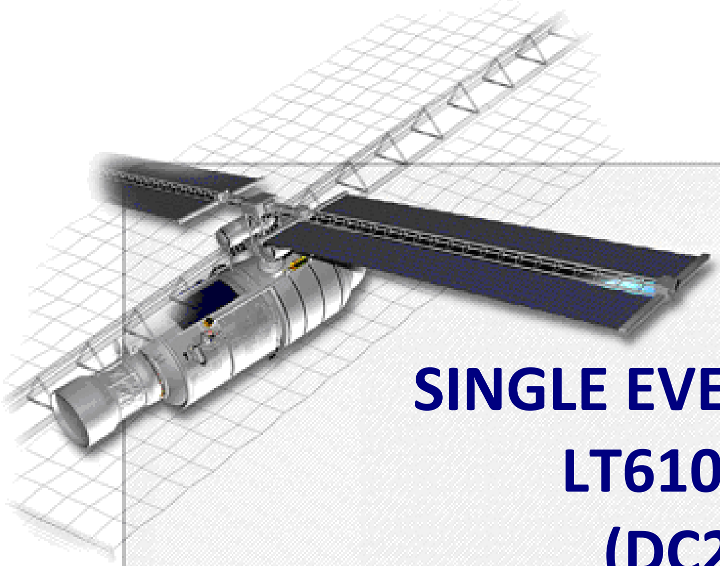
HEAVY ION TEST REPORT



SINGLE EVENT EFFECTS
LT6108IMS8
(DC2319)
High Side Current Sense Amplifier with Reference and Comparator
From
Linear Technology

TRAD/TI/LT6108IMS8/2319/ESA/TA/2308	Labège, December 15th, 2023
TRAD Tests & radiations a HEICO company / afaq ISO 9001 Qualité AFNOR CERTIFICATION	TRAD 907 voie l'occitane - 31670 Labège FRANCE Tel: +33 5 61 00 95 60 Email: trad@trad.fr Web site: www.trad.fr SIRET 397 862 038 00056 - TVA FR59397862038

Written by	Quality control by	Approved by
M. GUICHANE	**A. AL YOUSSEF**	**L. GOUYET**

Revision: 0	First edition of the test report.	
To:	**R. KARPOV**	Project/Program:
Company:	**European Space Agency**	

T

DISCLAIMER

The information contained herein is presented for informational purposes only. ESA does not make, and disclaims, any representation or warranty, express or implied, of the correctness and completeness of this information, and its fitness for a particular purpose. This information does not constitute or imply an ESA endorsement or approval for the use of any tested part in ESA activities or third-party activities. In particular, but without limitation, this is due to traceability which cannot be guaranteed on commercial components but is an important pre-requisite for the reusability of TID, TNID and SEE radiation test results. The information herein can therefore not be reused without further justifications which may vary depending on the type of space activity concerned.

Reproduction of parts of the test summary is authorised on the condition that clear reference is made to the test report number and this disclaimer.

ESA reserves the right to alter, revise, or rescind this document due to subsequent developments or additional test results. ESA intends, but cannot guarantee, that the ESARAD database always contains latest versions of the test reports.

CONTENTS

FIGURES

TABLES

Abbreviations and acronyms

DUT	Device Under Test
ESA	European Space Agency
LET	Linear Energy Transfer
RADEF	RADiation Effects Facility (Jyväskylä, Finland)
SEE	Single Event Effect
SEL	Single Event Latch-up
VASCO	VAcuum System for Californium Operation

Abstract

The main objective of this test was to evaluate the sensitivity of the LT6108IMS8, a High Side Current Sense Amplifier with Reference and Comparator versus SEL.

The irradiation was performed for ESA at RADEF with a maximum LET of 38.8 MeV.cm²/mg.
The main conclusions are the following.

The SEL test was performed under SEL test conditions (see Table 6).

In SEL test configuration
Destructive event was observed with a LET of 38.8 MeV.cm²/mg, Silver heavy ion.
No SEL was observed with a LET of 13.3 MeV.cm²/mg, Iron heavy ion.

N.B: SET were observed during irradiation but not recorded.

1. Introduction

This report includes the test results of the heavy ion SEE test sequence carried out on the LT6108IMS8, a High Side Current Sense Amplifier with Reference and Comparator from Linear Technology, susceptible to show SEL induced by heavy ions.

This test was performed for ESA at RADEF. Irradiations were performed from October 27th, 2023 to October 28th, 2023. During this test campaign, 3 samples were irradiated.

2. Documents

2.1. Applicable documents

[AD1] Technical proposal: TRAD/P/ESA/AO17950/AR/131222 Rev 0 dated 13/11/2022
[AD2] Irradiation test plan: ITP/TRA/TI/LT6108IMS8/MSOP8/AD/140923 Rev 0 dated 14/09/2023

2.2. Reference documents

[RD1] ESCC Basic specification No. 25100 Issue 2 of October 2014
[RD2] Datasheet: LT6108-1/LT6108-2: High Side Current Sense Amplifier with Reference and Comparator (Rev. A) dated 12/2012

3. Organization of activities

The devices were procured by TRAD. The samples were delidded by TRAD. The testing board and testing software were developed by TRAD. Before the campaign the samples were checked-out and the test bench was validated with californium test at TRAD. The test campaign was performed by TRAD under ESA supervision. The next table summarizes the responsible entity for each activity involved in this project:

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 out	TRAD
5	Accelerator Test	TRAD/ESA
6	Test Report	TRAD

Table 1: Organization of activities

4. Parts information

4.1. Device description

The LT®6108 is a complete high side current sense device that incorporates a precision current sense amplifier, an integrated voltage reference and a comparator. Two versions of the LT6108 are available. The LT6108-1 has a latching comparator and the LT6108-2 has a non-latching comparator. In addition, the current sense amplifier and comparator inputs and outputs are directly accessible. The amplifier gain and comparator trip point are configured by external resistors. The open-drain comparator output allows for easy interface to other system components.
The overall propagation delay of the LT6108 is typically only 1.4µs, allowing for quick reaction to overcurrent conditions. The 1MHz bandwidth allows the LT6108 to be used for error detection in critical applications such as motor control. The high threshold accuracy of the comparator, combined with the ability to latch the comparator, ensures the LT6108 can capture high speed events.
The LT6108 is fully specified for operation from –40°C to 125°C, making it suitable for industrial and automotive applications. The LT6108 is available in the small 8-lead MSOP and 8-lead DFN packages.

4.2. Identification

Part designation	LT6108IMS8
Manufacturer	Linear Technology
Part function	High Side Current Sense Amplifier with Reference and Comparator

Table 2: Part identification

4.3. Procurement information

Package	8-MSOP
Date code	2139
Lot code No.	AY66970.6
Number of tested parts	3 irradiated samples

Table 3: Part procurement information

4.4. Sample preparation

4 parts were delidded, no sample has been damaged during this operation.
A functional test was performed on delidded samples to check that devices were not degraded by the delidding operation.
Among the 4 delidded samples available for the test campaign, 3 were irradiated and 1 was not used.

4.5. Sample pictures

4.5.1. External view

The Figure 1 shows an external view of the parts. Left and right components on the picture are respectively the top and the bottom views of the package.

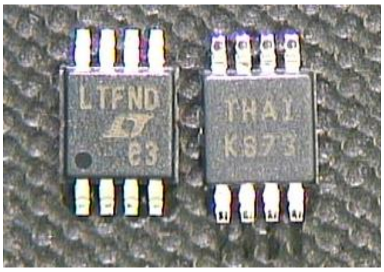


Figure 1: Picture of the package

4.5.2. Internal view

Figure 2 gives an overview of the die. Figure 3 presents a view of the internal marking observed on the die (indicated by a red rectangle on Figure 2).

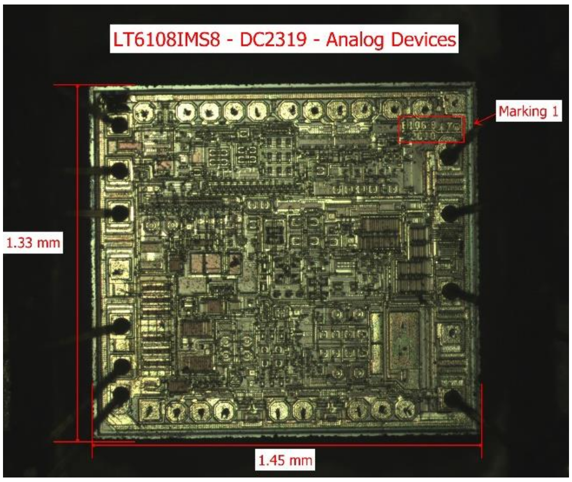


Figure 2: Picture of the internal overall view

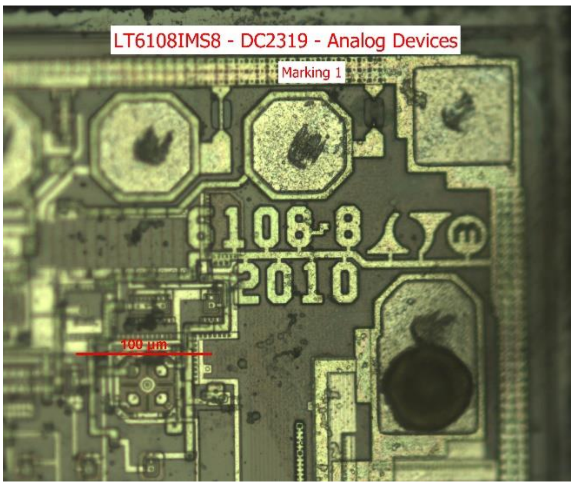


Figure 3: Picture of the die marking

5. Dosimetry and irradiation facility

5.1. 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.

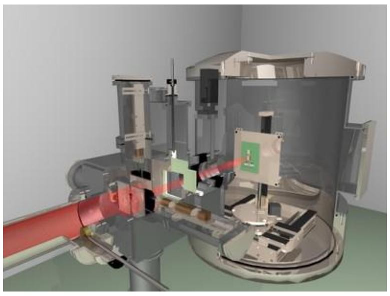


Figure 4: RADEF facility

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.

5.2. 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 %

5.3. 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 4 where heavy ions used for this test campaign are highlighted.

ION	Energy (MeV)	Range (µm(Si))	LET (MeV.cm²/mg)
$^{126}Xe^{44+}$	1446.48	105.71	56.83
$^{107}Ag^{37+}$	1714	158	38.8
$^{83}Kr^{29+}$	1358	185	24.5
$^{57}Fe^{20+}$	941	214	13.3
$^{40}Ar^{14+}$	657	264	7.2
$^{20}Ne^{7+}$	328	360	2.3
$^{17}O^{6+}$	284	481	1.52

Table 4: RADEF heavy ion list

6. Test procedure and setup

6.1. Test method

With respect to reference documents (see 2.1), runs were performed:

- Up to a fluence of 1E+7 cm^{-2} with only SEL monitoring.

6.2. 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.

GUARD 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 GUARD which protects the DUT against over consumption. Indeed, GUARD continuously monitors and records the current. 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 5 shows a common SEL characteristic, with and without the GUARD system protection

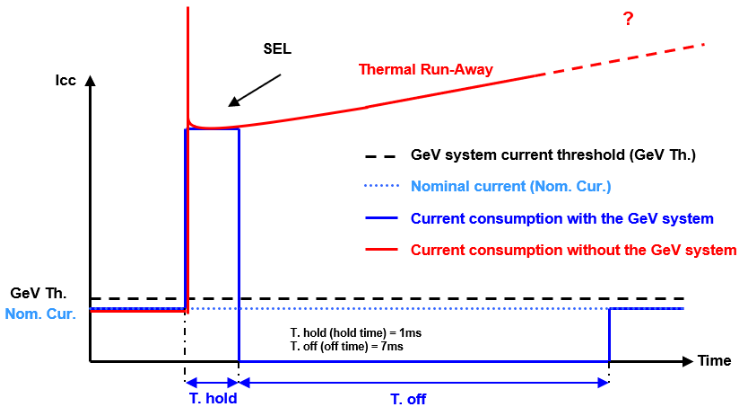


Figure 5: Common SEL characteristic

The SEL test was performed under SEL test conditions (see Table 6).
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.

6.3. Test bench description

6.3.1. Test bench overview

Figure 6 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 (schematic is shown in Figure 9).
- A power supply for the DUT and auxiliary components.
- A GeV System to heat the DUT.
- A GUARD System and an oscilloscope to protect the DUT, detect and record SEL.

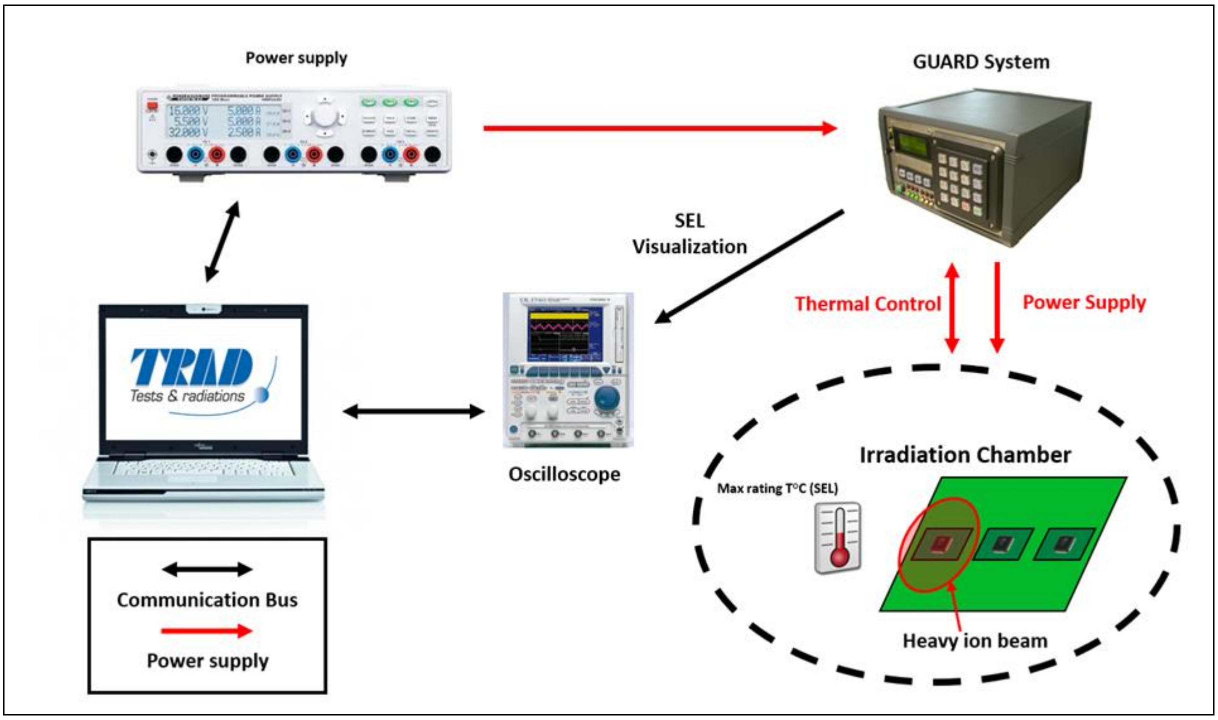


Figure 6: Test bench description

6.3.2. Validation of test hardware and program

Before performing the heavy ion test, the whole system (delidded sample, test board and software) was assembled and tested by TRAD in VASCO.

The VASCO is a vacuum chamber developed by TRAD in order to test the complete setup in vacuum with all cables length and electrical feedthroughs as used on the irradiation site.
The VASCO main characteristics are:
Chamber dimensions: 400x400x400mm, pressure 5.10^{-2} mbar.
Electrical feedthroughs available:
16 isolated BNC, 16 isolated SMA, 16 isolated SMB, 4 DB25, 3 HE10-40.
Other possibility on request

Validation runs are performed using Californium-252 source.
Californium-252 is a fissionable, transuranic radionuclide which decays by alpha particle emission with a half-life of 2.72 years.
The source emits alpha particles, fission fragments and fast neutrons. The fission fragments are used for SEE testing and these have a mean LET of 43 MeV.cm²/mg (Si) with 95% of the particles having LETs between 41 and 45 MeV.cm²/mg (Si). The mean range of the fission particles in silicon is 14.2µm.

Figure 7: VASCO picture

6.3.3. Heating system

TRAD has developed a specific heating system to heat and regulate the temperature of the DUT. Figure 8 shows a thermal image taken during the heating calibration of the DUT, the temperature of the die was set to 85°C as shown on the picture.

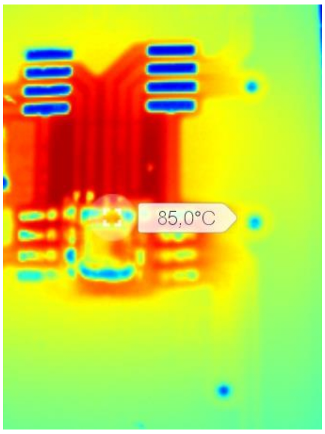


Figure 8: Thermal image of LT6108IMS8 heated to 85°C

6.3.4. Test equipment identification

TEST BOARD	TRAD/TA1/I/LT6108IMS8/MSOP8/AA/2309
EQUIPMENT	SM-87; ME-70; ME-54; GeV-3
TEST PROGRAM	LT6108IMS8_I_2319_B-MTP_V1_SEL

Table 5: Equipment identification

6.3.5. Test board description

The TRAD test board schematic referenced "TRAD/TA1/I/LT6108IMS8/MSOP8/AA/2309" is illustrated in Figure 9.

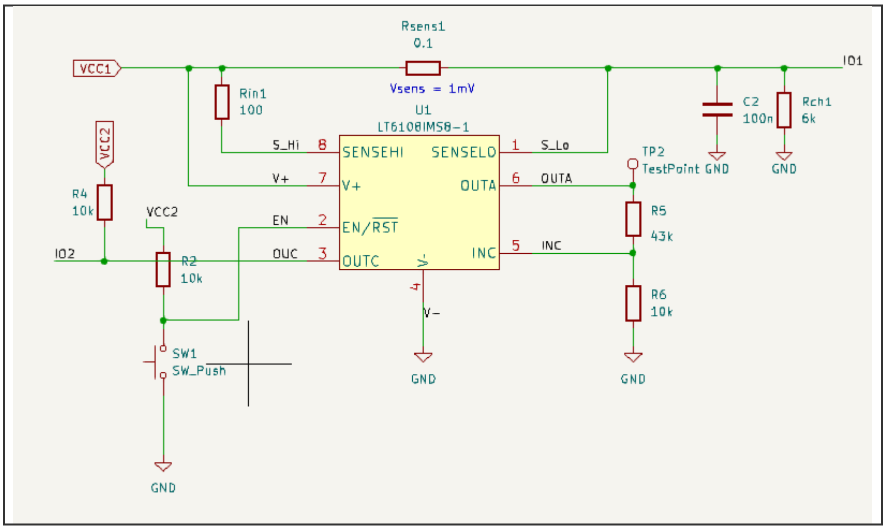


Figure 9: Test board schematic

6.3.6. Test conditions and event detection thresholds

SEL test

	VCC1	**VCC2**
Voltage	60 V	5.5 V
$I_{nominal}$	8 mA	77 µA
$I_{threshold}$	16 mA	1000 mA
T_{hold}	1 ms	1 ms
$T_{cut\ off}$	7 ms	7 ms
Temperature	85°C	

Table 6: SEL test conditions and detection thresholds

7. Test story

No atypical behaviour during the test to report.

8. Non conformance

Test sequence, test and measurement conditions were nominal.

9. 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

Run	Test configuration	Part	T° (°C)	Ion	Energy (MeV)	Eff. LET (MeV.cm²/mg)	Eff. Range (µm Si)	Flux (φ) ($cm^{-2}.s^{-1}$)	Time (s)	Run Fluence (cm^{-2})	Run Dose (krad)	Cumulated Dose (krad)	SEL	SEL Cross Section (cm²)	Destructive event	Destructive event Cross Section (cm²)
1	SEL	2	85	Ag	1714	38.8	158.0	1.12E+03	445	5.00E+05	0.31	0.31				
2	SEL	3	85	Ag	1714	38.8	158.0	4.63E+03	32	1.48E+05	0.09	0.09	1	6.76E-06	1	6.76E-06
2	SEL	2	85	Ag	1714	38.8	158.0	4.63E+03	32	1.48E+05	0.09	0.40	1	6.76E-06	0	<6.76E-06
3	SEL	2	85	Fe	941	13.3	214.0	1.41E+03	104	1.47E+05	0.03	0.43	0	<6.80E-06	0	<6.80E-06
3	SEL	4	85	Fe	941	13.3	214.0	1.41E+03	104	1.47E+05	0.03	0.03				
4	SEL	2	85	Fe	941	13.3	214.0	8.73E+03	1145	1.00E+07	2.13	2.56	0	<1.00E-07	0	<1.00E-07
4	SEL	4	85	Fe	941	13.3	214.0	8.73E+03	1145	1.00E+07	2.13	2.16	0	<1.00E-07	0	<1.00E-07

Table 7: LT6108IMS8 test run table

Setting run not considered.

SEE detailed results are described in the following sections.

9.2. Cumulated dose table

Part No.	Cumulated Dose (krad)
2	2.56
3	0.09
4	2.16

Table 8: Cumulated dose table

9.3. SEL test results

9.3.1. SEL LET threshold

The SEL test was performed under SEL test conditions (see Table 6).

In SEL test configuration

Destructive event was observed with a LET of 38.8 MeV.cm²/mg, Silver heavy ion.
No SEL was observed with a minimum LET of 13.3 MeV.cm²/mg, Iron heavy ion.

10. Conclusion

The heavy ion test was performed on LT6108IMS8. The aim of the test was to evaluate the sensitivity of the device versus SEL.

The SEL test was performed under SEL test configuration (see Table 6).

In SEL test configuration
Destructive event was observed with a LET of 38.8 MeV.cm²/mg, Silver heavy ion.
No SEL was observed with a LET of 13.3 MeV.cm²/mg, Iron heavy ion.

N.B: SET were observed during irradiation but not recorded.