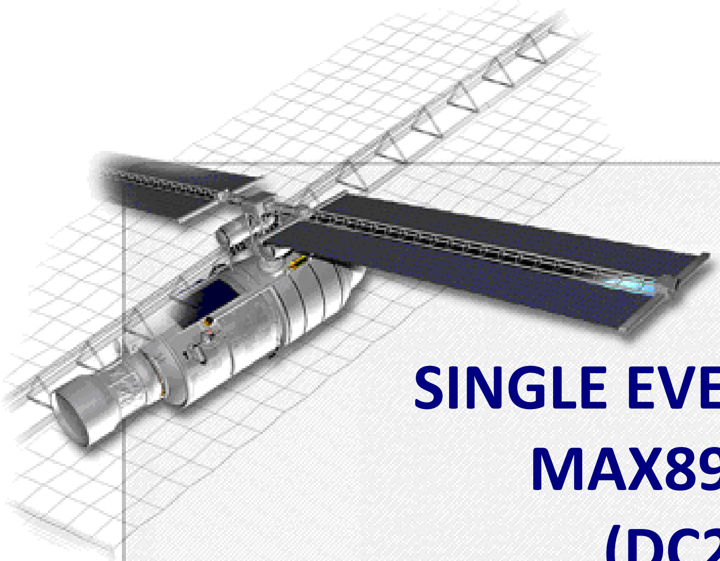
HEAVY ION and LASER TEST REPORT



SINGLE EVENT EFFECTS
MAX890LESA+
(DC2319)
1.2A, Current-Limited, High-Side P-Channel Switch with Thermal Shutdown
From
Maxim Integrated

TRAD/TI/MAX890LESA+/2319/ESA/JB/2308			Labège, July 23rd, 2024
			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
J. BULIN		**A. AL YOUSSEF**	**B. VANDEVELDE**
Revision: 0	First edition of the test report – 10/11/23		
Revision: 1	LASER testing added in Appendix B		
To:	**R. KARPOV**		Project/Program:
Company:	**European Space Agency**		

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)
SEL	Single Event Latch-up
SET	Single Event Transient

Abstract

The main objective of this test was to evaluate the sensitivity of the MAX890LESA+, a 1.2A, Current-Limited, High-Side P-Channel Switch with Thermal Shutdown versus SEL and SET.
The irradiation was performed at RADEF with a maximum LET of 56.8 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
No SEL was observed with a LET of 56.8 MeV.cm²/mg, Xenon heavy ion.
No destructive events were observed.

The SET test was performed under SET test conditions (see Table 7).

In SET test configuration
SET on OUT pin (SET OUT) were observed with a minimum LET of 13.3 MeV.cm²/mg, Iron heavy ion.
No lower LET tested during this test campaign.
N.B: each event occurring on OUT was coupled with an event on /FAULT (observed under heavy ions and LASER testing).

SET on /FAULT (SET /FAULT) pin were observed with a minimum LET of 38.8 MeV.cm²/mg, Silver heavy ion.
No SET on /FAULT pin was observed with a LET of 13.3 MeV.cm²/mg, Iron heavy ion.

1. Introduction

This report includes the test results of the heavy ion SEE test sequence carried out on the MAX890LESA+, a 1.2A, Current-Limited, High-Side P-Channel Switch with Thermal Shutdown from Maxim Integrated, susceptible to show SEL and SET 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, 2 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/MAX890LESA+/SOIC-8/SEE/210923 Rev0 dated 21/09/2023

2.2. Reference documents

[RD1] ESCC Basic specification No. 25100 Issue 2 of October 2014
[RD2] Datasheet: MAX890-MAX890L_datasheet 19-1146; Rev 4; dated April 2011
[RD3] S. Dubos et al., “Review of Alternatives to Heavy Ions Broad Beam for SEL Screening of COTS”, in RADECS 2023 proceedings

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 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 MAX890L smart, low-voltage, P-channel, MOSFET power switch is intended for high-side load-switching applications. This switch operates with inputs from +2.7V to +5.5V, making it ideal for both +3V and +5V systems. Internal current-limiting circuitry protects the input supply against overload. Thermal-overload protection limits power dissipation and junction temperatures.
The MAX890L's maximum current limit is 1.2A. The current limit through the switch is programmed with a resistor from SET to ground. The quiescent supply current is a low 10µA. When the switch is off, the supply current decreases to 0.1µA.

4.2. Identification

Part designation	MAX890LESA+
Manufacturer	Maxim Integrated
Part function	1.2A, Current-Limited, High-Side P-Channel Switch with Thermal Shutdown

Table 2: Part identification

4.3. Procurement information

Package	8 SO
Date code	2319
Lot code No.	0006948376
Number of tested parts	2 irradiated samples

Table 3: Part procurement information

4.4. Sample preparation

3 parts were delidded for heavy ion testing, no sample was damaged during this operation.
2 parts were thinned (back-side) for LASER testing, no sample was damaged during this operation.
A functional test was performed on delidded and thinned samples to check that devices were not degraded by these operations.
Among the 3 delidded samples available for the heavy ion test campaign, 2 were irradiated and 1 was not used.
Among the 2 thinned samples available for the LASER test campaign, all were irradiated.

4.5. Sample pictures

4.5.1. External view

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

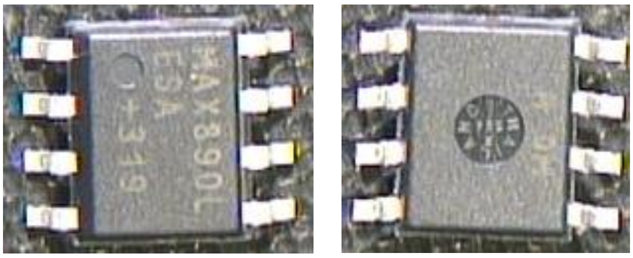


Figure 1: Pictures of the package

4.5.2. Internal view

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

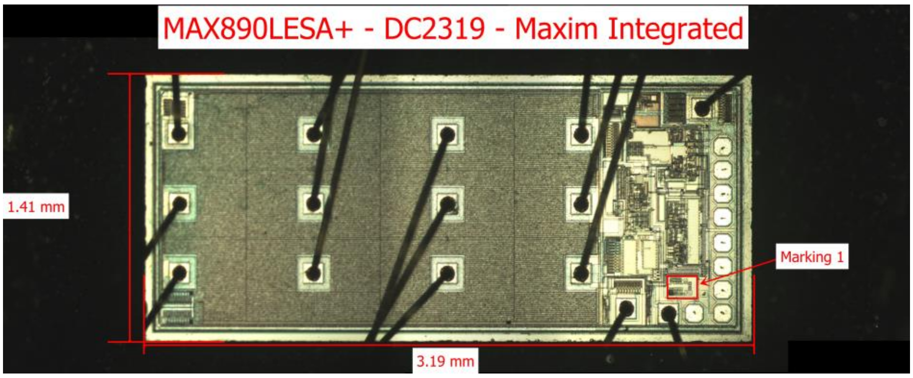


Figure 2: Picture of the internal overall view

Figure 3: Picture of the die markings

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.

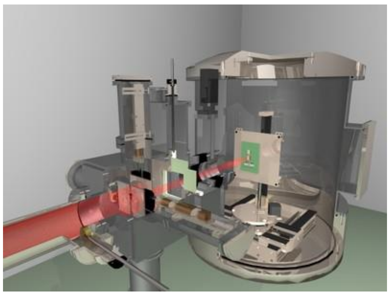


Figure 4: RADEF facility

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 **Erreur ! Source du renvoi introuvable.** where heavy ions used for this test campaign are highlighted.
The tests on MAX890LESA+ are performed in air, therefore the LET and range are calculated according to the Kapton degrader, if used, (for this test Kapton were used only with Xenon heavy ion (50 µm)), and the distance between collimator and the component.

ION	Energy (MeV)	Range (µm(Si))	LET (MeV.cm²/mg)
$^{126}Xe^{44+}$	1446.48	105.71	56.8
$^{107}Ag^{37+}$	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	1.5

Table 4: RADEF heavy ion list

6. Test procedure and setup

6.1. Test method

With respect to reference documents (see 2 Documents), runs were performed:

- Up to a fluence of 1E+7 cm^{-2} with only SEL monitoring.
- Up to 100 events or a fluence of 5E+6 cm^{-2} for SET runs.

6.2. Test principle

6.2.1. 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. 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 GeV system protection.

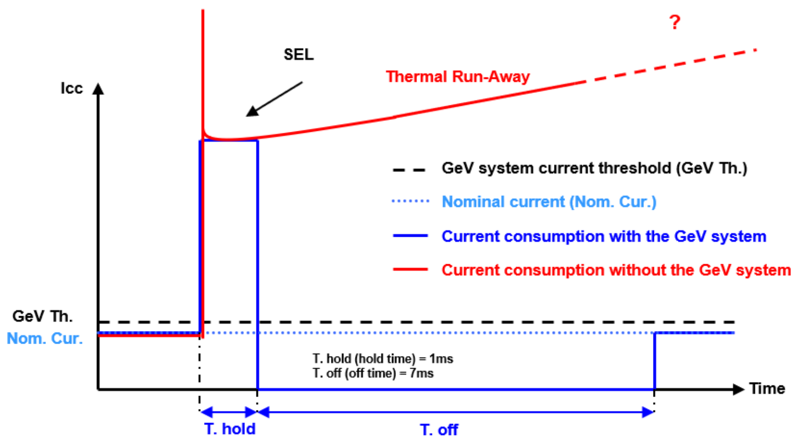


Figure 5: Common SEL characteristic

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.

6.2.2. SET test principle

A SET event is a temporary voltage excursion (voltage spike) at a node in a logic, or linear, integrated circuit, caused by a single energetic particle strike.

On static output signals, the SET can be a positive or negative amplitude variation. Two trigger thresholds (positive and negative) are used to detect the event when the monitored signal is out of the detection range (Figure 6). All SET are counted and their waveforms are recorded using an oscilloscope.

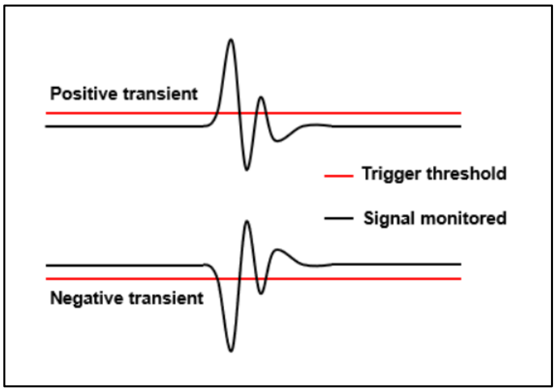


Figure 6: SET in static mode characteristic

6.2.3. SET OUT and SET /FAULT

During irradiation, SET observed on OUT pin have led to active the fault indicator on /FAULT pin (left part of Figure 7). SET observed on /FAULT pin were post-analysed to separate real SET (right part of Figure 7) and activation of the fault indicator due to event on OUT. On Figure 7, OUT is the red signal while /FAULT is the black one. These events are shown in Appendix A.

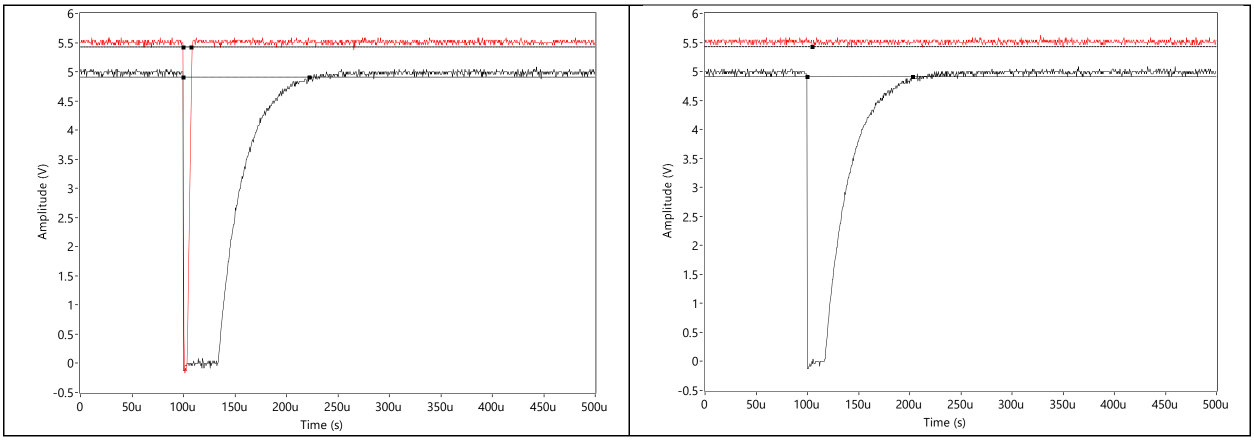


Figure 7: SET on OUT and /FAULT pins

6.3. Test bench description

6.3.1. Test bench overview

Figure 8 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 10).
- 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.

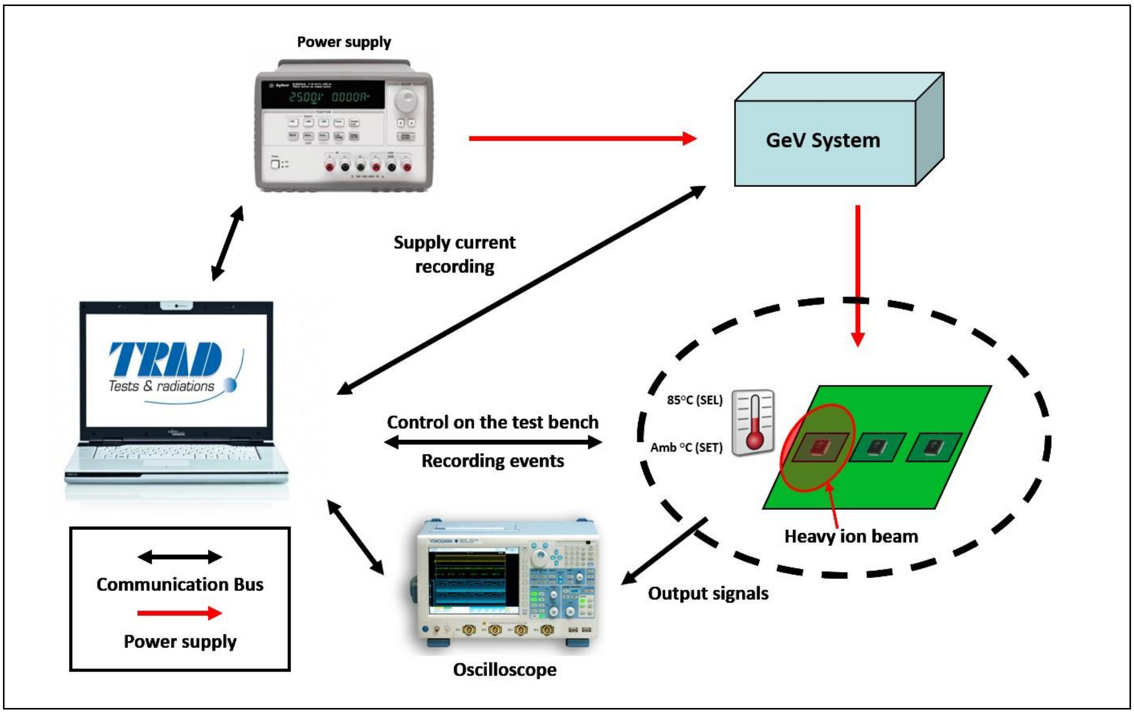


Figure 8: Test bench description

6.3.2. Heating system

TRAD has developed a specific heating system to heat and regulate the temperature of the DUT. Figure 9 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.

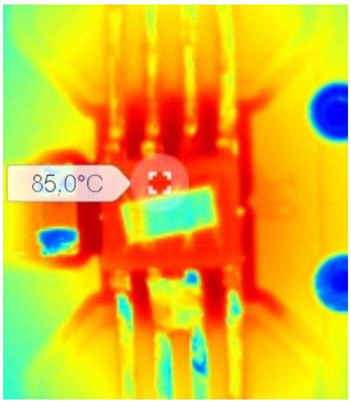


Figure 9: Thermal image of MAX890LESA+ heated to 85°C

6.3.3. Test equipment identification

TEST BOARD	TRAD/CT1/I/GeV_DEMI_POS/8-PIN_1.27mm/MG/2301
EQUIPMENT	SM-87, SM-96, GR-27, GeV-3
TEST PROGRAM	TRAD_TI_MAX890LESA_SEL-SET-GeV_V10.spf

Table 5: Equipment identification

6.3.4. Test board description

The TRAD test board schematic referenced "TRAD/CT1/I/GeV_DEMI_POS/8-PIN_1.27mm/MG/2301" is illustrated in Figure 10.

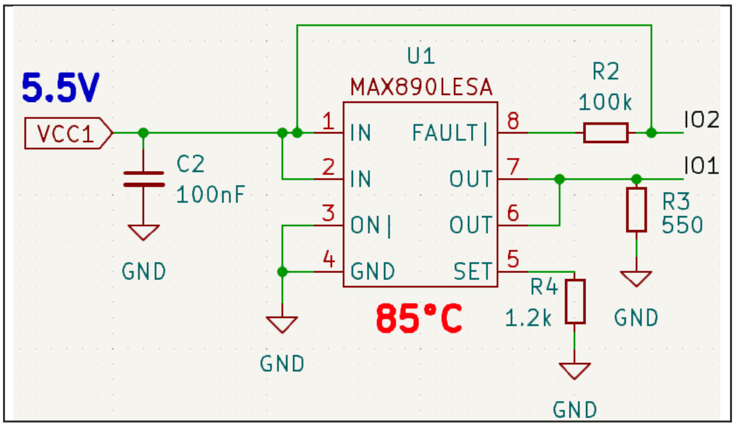


Figure 10: Test board schematic

6.3.5. Test conditions and event detection thresholds

SEL test

	VIN
Voltage	5.5 V
$I_{nominal}$	10 mA
$I_{threshold}$	20 mA
T_{hold}	1 ms
$T_{cut\ off}$	7 ms
Temperature	85°C

Table 6: SEL test conditions and detection thresholds

SET test

	VIN = 5.5 V	
	OUT	**/FAULT**
$V_{nominal}$	5.47 V	5 V
Negative trigger threshold	5.42 V	4.9 V
Temperature	Ambient	

Table 7: Static SET 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	Reference	Test conditions	Part	T° (°C)	Ion	Energy (MeV)	Tilt (°)	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)	SET OUT	SET OUT Cross Section (cm²)	SET FAULT/	SET FAULT/ Cross Section (cm²)
1	**MAX890LESA+**	**SEL**	**1**	**85**	**Ag**	1714	**0**	38.8	158.0	1.01E+04	**989**	**1.00E+07**	6.21	6.21	**0**	<1.00E-07	**-**	-	**-**	-
1	**MAX890LESA+**	**SEL**	**2**	**85**	**Ag**	1714	**0**	38.8	158.0	1.01E+04	**989**	**1.00E+07**	6.21	6.21	**0**	<1.00E-07	**-**	-	**-**	-
2	**MAX890LESA+**	**SEL**	**1**	**85**	**Xe**	1446.5	**0**	56.8	105.7	1.02E+04	**985**	**1.00E+07**	9.09	15.30	**0**	<1.00E-07	**-**	-	**-**	-
2	**MAX890LESA+**	**SEL**	**2**	**85**	**Xe**	1446.5	**0**	56.8	105.7	1.02E+04	**985**	**1.00E+07**	9.09	15.30	**0**	<1.00E-07	**-**	-	**-**	-
3	**MAX890LESA+**	**SET**	**1**	**amb**	**Fe**	941	**0**	13.3	214.0	6.83E+03	**732**	**5.00E+06**	1.06	16.36	**-**	-	**21**	4.20E-06	**0**	<2.00E-07
4	**MAX890LESA+**	**SET**	**1**	**amb**	**Xe**	1446.5	**0**	56.8	105.7	5.54E+03	**716**	**3.97E+06**	3.61	19.97	**-**	-	**56**	1.41E-05	**249**	6.27E-05
5	**MAX890LESA+**	**SET**	**1**	**amb**	**Ag**	1714	**0**	38.8	158.0	6.85E+03	**765**	**5.24E+06**	3.25	23.23	**-**	-	**47**	8.97E-06	**76**	1.45E-05

Table 8: MAX890LESA+ test run table

SEE detailed results are described in the following sections.

9.2. Cumulated dose table

Part No.	Cumulated Dose (krad)
1	23.23
2	15.3

Table 9: 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
No SEL was observed with a LET of 56.8 MeV.cm²/mg, Xenon heavy ion.

9.3.2. SEL cross sections

Hereafter are shown the SEL cross section values for each tested component.

In SEL test condition

	MAX890LESA+ SEL Cross Section (cm²) in SEL test configuration					
LET Eff (MeV.cm²/mg)	**Part No. 1**			**Part No. 2**		
	error (-)	cross section	error (+)	error (-)	cross section	error (+)
56.8	0.00E+00	<1.00E-07	3.69E-07	0.00E+00	<1.00E-07	3.69E-07
38.8	0.00E+00	<1.00E-07	3.69E-07	0.00E+00	<1.00E-07	3.69E-07

Table 10: MAX890LESA+ SEL cross section values in SEL test configuration

9.4. SET /FAULT test results

9.4.1. SET /FAULT LET threshold

The SET /FAULT test was performed under SET test conditions (see Table 7).

In SET test configuration
SET /FAULT were observed with a minimum LET of 38.8 MeV.cm²/mg, Silver heavy ion.
No SET /FAULT was observed with a LET of 13.3 MeV.cm²/mg, Iron heavy ion.

9.4.2. SET /FAULT cross sections

Hereafter are shown the SET /FAULT cross section values for each tested component on the /FAULT signal.

In SET test condition

	MAX890LESA+ SET FAULT/ Cross Section (cm²) in SET test configuration		
LET Eff (MeV.cm²/mg)	Part No. 1		
	error (-)	cross section	error (+)
56.8	7.55E-06	6.27E-05	8.29E-06
38.8	3.08E-06	1.45E-05	3.65E-06
13.3	0.00E+00	<2.00E-07	7.38E-07

Table 11: MAX890LESA+ SET /FAULT cross section values in SET test configuration

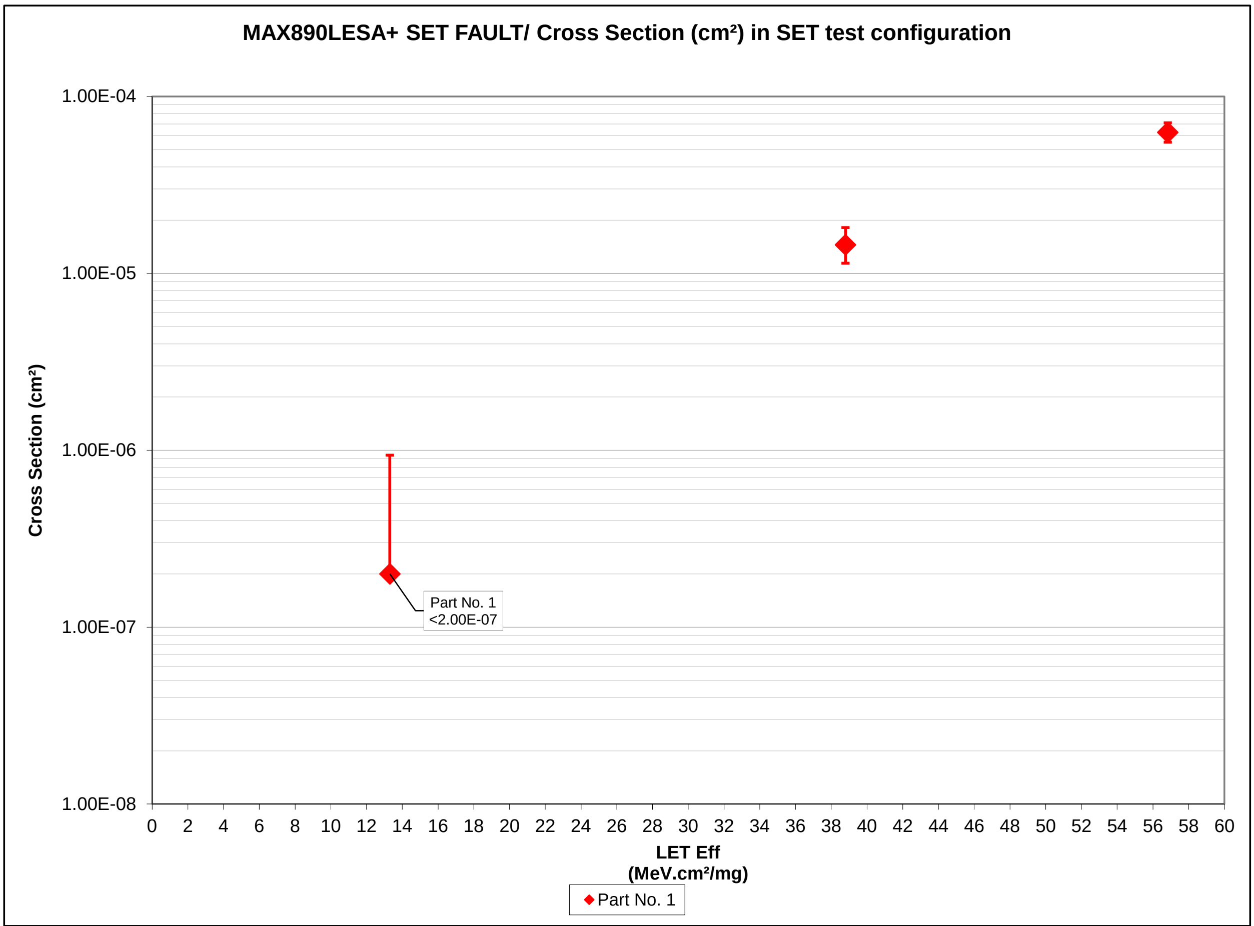


Figure 11: MAX890LESA+ SET /FAULT cross section curve in SET test configuration

9.4.3. SET /FAULT worst case

This section presents a selection of worst SET /FAULT observed during this test campaign.
Further analysis on observed events can be found in appendix A. The appendix contents cumulative and distribution charts.

In SET test configuration

The worst SET /FAULT duration event observed on /FAULT was occurred during run No. 4 on part No. 1.

Run No.	4
Part No.	1
Test Conditions	SET
Type event	Negative SET
Ion LET (MeV.cm²/mg)	56.8
Absolute amplitude	5.208 V
Relative amplitude	-0.12 V
Duration	125 µs

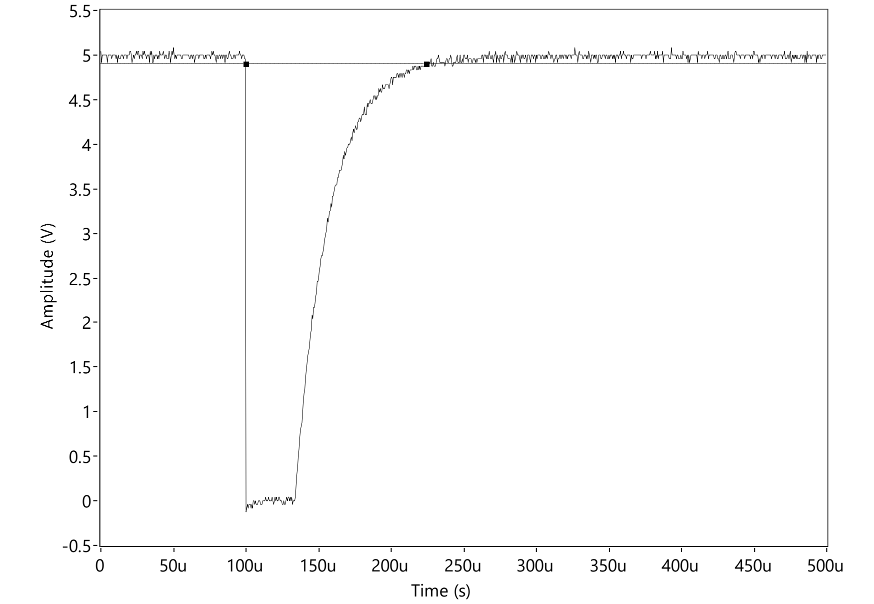


Figure 12: SET /FAULT worst case duration

9.5. SET OUT test results

9.5.1. SET OUT let threshold

The SET OUT test was performed under SET test conditions (see Table 7).

In SET test configuration
SET OUT were observed with a minimum LET of 13.3 MeV.cm²/mg, Iron heavy ion.
No lower LET tested during this test campaign.

9.5.2. SET OUT cross sections

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

In SET test condition

LET Eff (MeV.cm²/mg)	MAX890LESA+ SET OUT Cross Section (cm²) in SET test configuration — Part No. 1: error (-)	cross section	error (+)
56.8	3.45E-06	1.41E-05	4.21E-06
38.8	2.38E-06	8.97E-06	2.96E-06
13.3	1.60E-06	4.20E-06	2.22E-06

Table 12: MAX890LESA+ SET OUT cross section values in SET test configuration

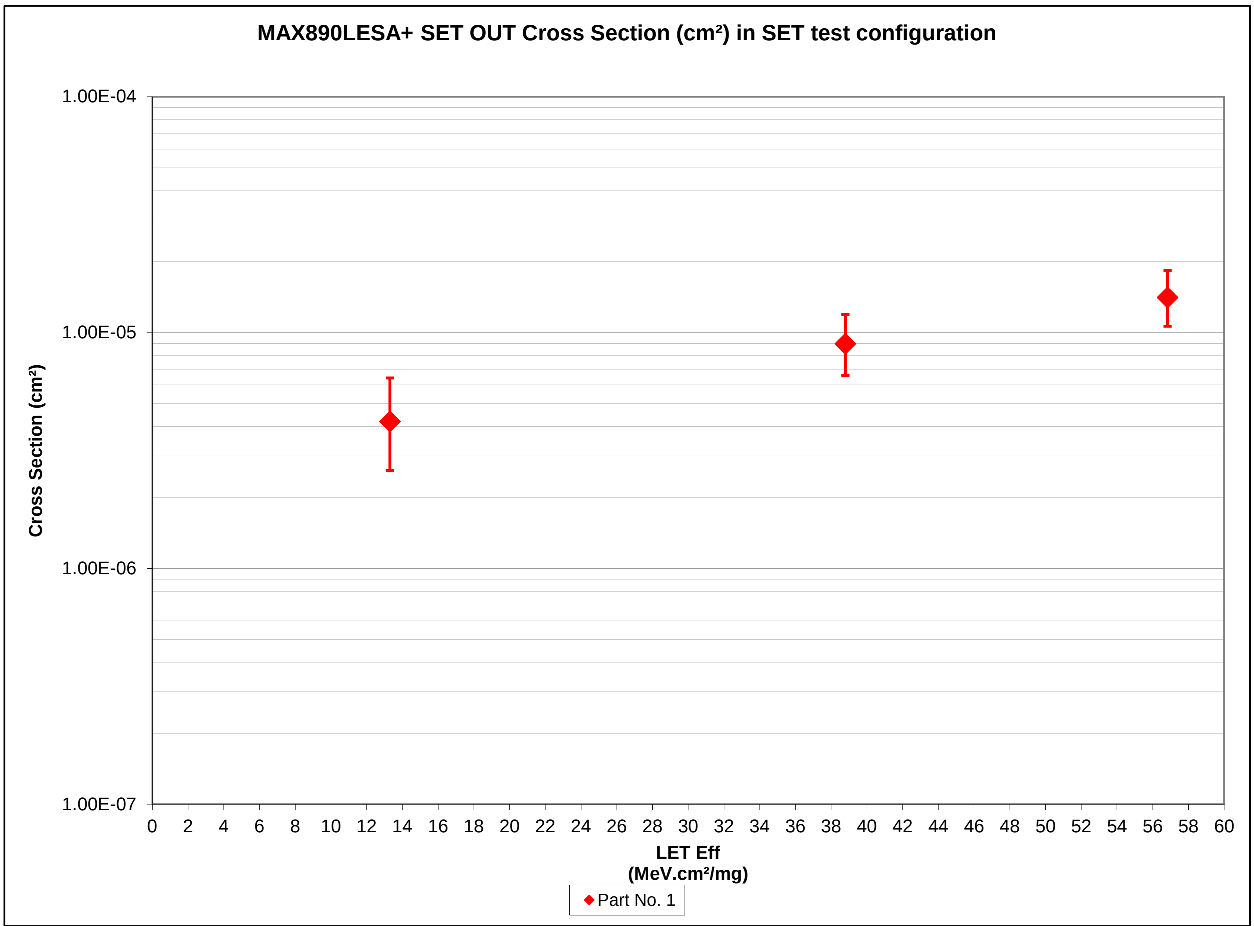


Figure 13: MAX890LESA+ SET OUT cross section curve in SET test configuration

9.5.3. SET OUT worst case

This section presents a selection of worst SET OUT observed during this test campaign.
Further analysis on observed events can be found in appendix A. The appendix contents cumulative and distribution charts.

In SET test configuration

The worst SET OUT duration event observed on OUT was occurred during run No. 4 on part No. 1.

Run No.	4
Part No.	1
Test Conditions	SET
Type event	Negative SET
Ion LET (MeV.cm²/mg)	56.8
Absolute Amplitude	5.75 V
Relative amplitude	-0.12 V
Duration	9 µs

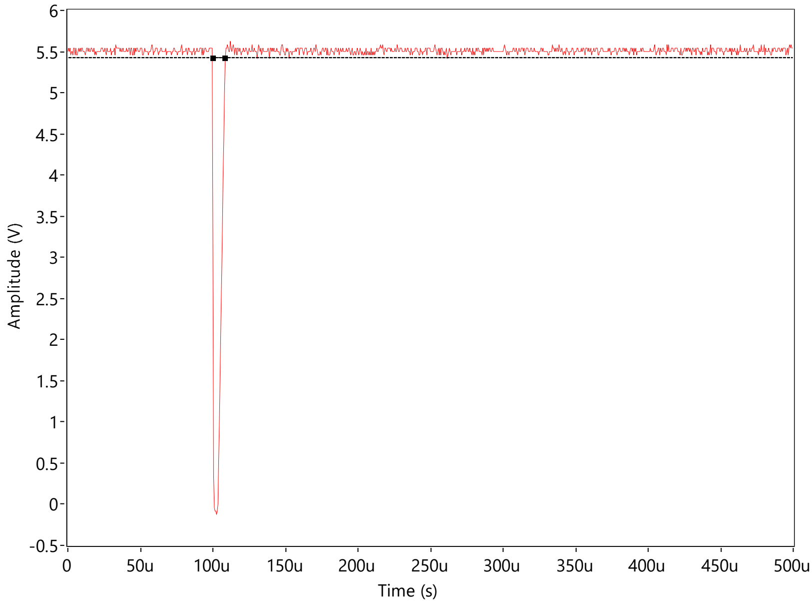


Figure 14: SET OUT worst case duration

10. Conclusion

The heavy ions test was performed on MAX890LESA+. The aim of the test was to evaluate the sensitivity of the device versus SEL and SET.

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

In SEL test configuration
No SEL was observed with a LET of 56.8 MeV.cm²/mg, Xenon heavy ion.

The SET test was performed under SET test conditions (see Table 7).

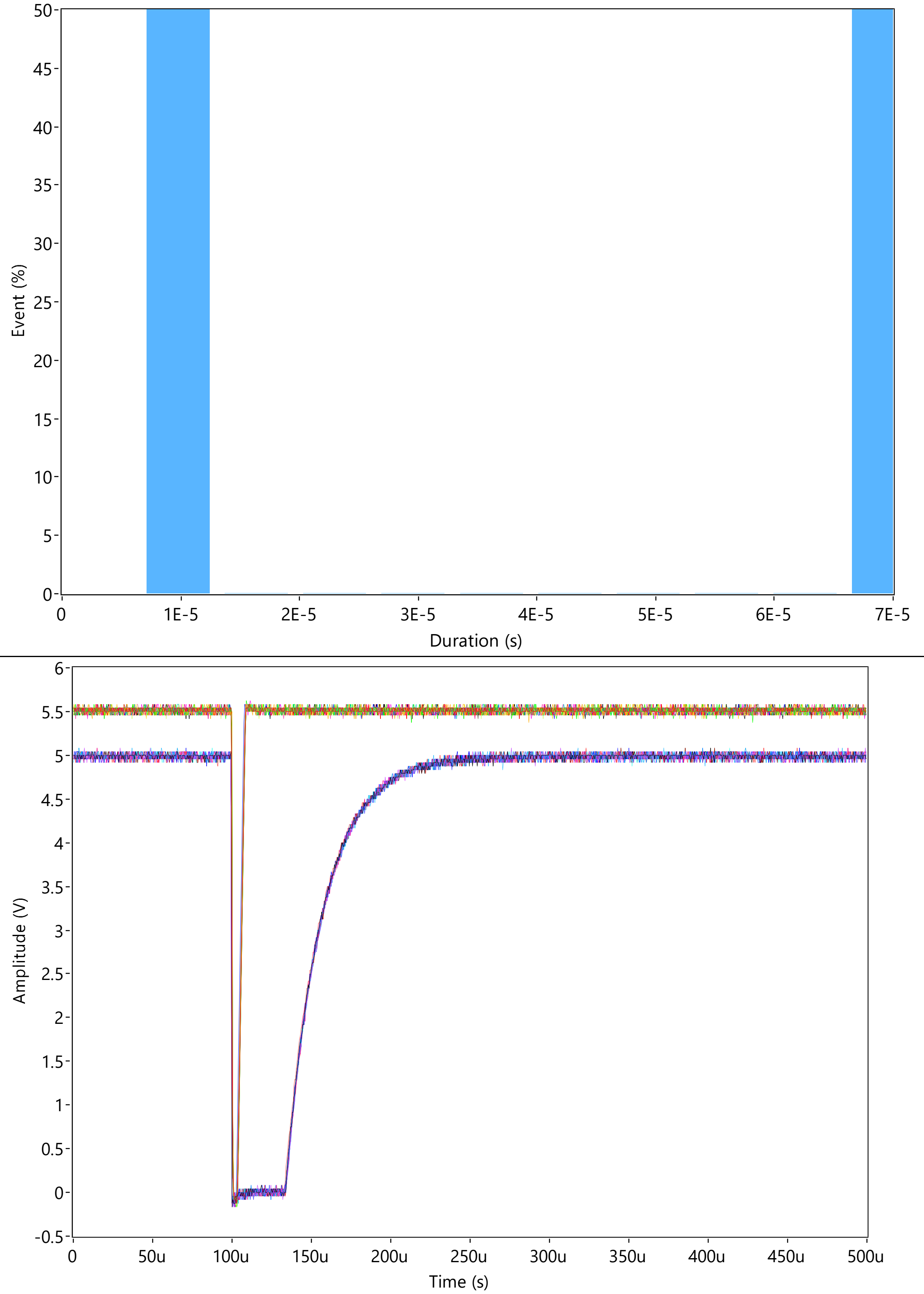
In SET test configuration
SET on OUT pin were observed with a minimum LET of 13.3 MeV.cm²/mg, Iron heavy ion.
No lower LET tested during this test campaign.
N.B: each event occurring on OUT was coupled with an event on /FAULT (observed under heavy ions and LASER testing).

SET on /FAULT pin were observed with a minimum LET of 38.8 MeV.cm²/mg, Silver heavy ion.
No SET on /FAULT pin was observed with a LET of 13.3 MeV.cm²/mg, Iron heavy ion.

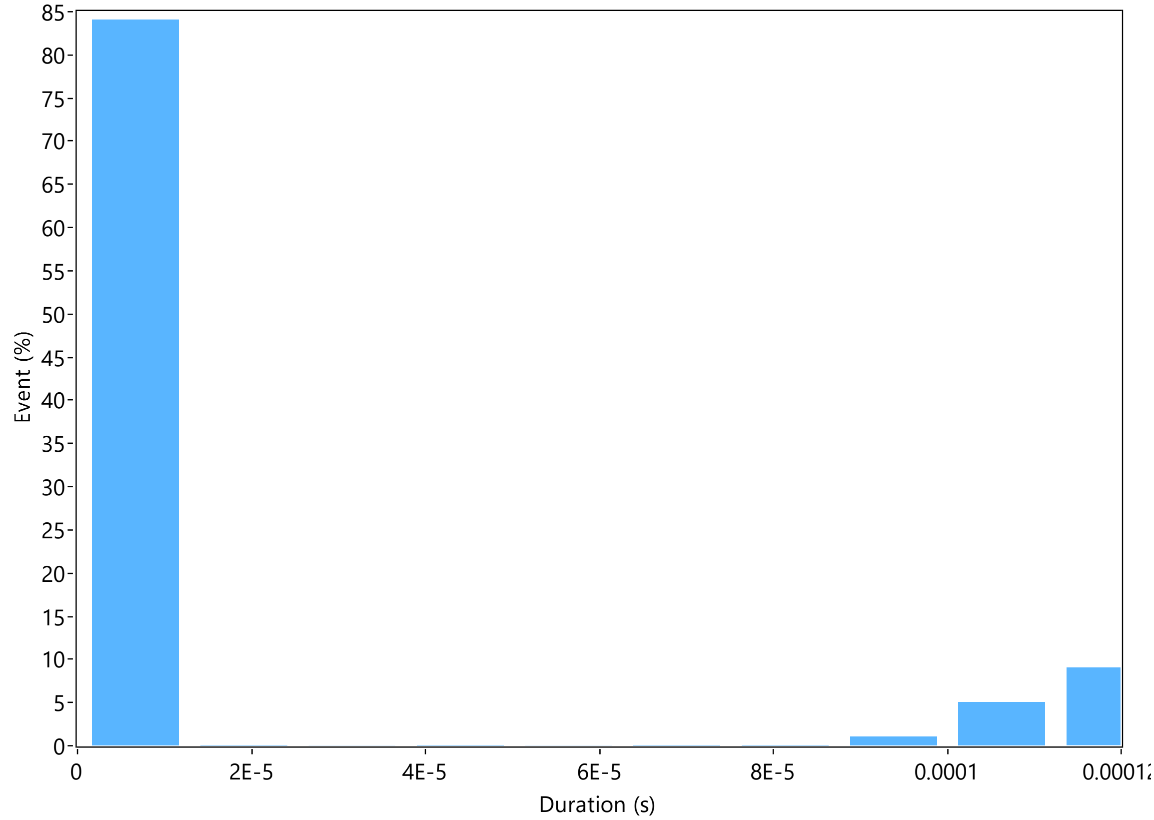
Further analysis on each run can be found in appendixes with:
- Cumulative charts representing on the same chart all the detected events,
- Distribution charts representing event amplitude versus events duration,
- Histograms representing the durations of all detected events,
- Histograms representing the amplitudes of all detected events.

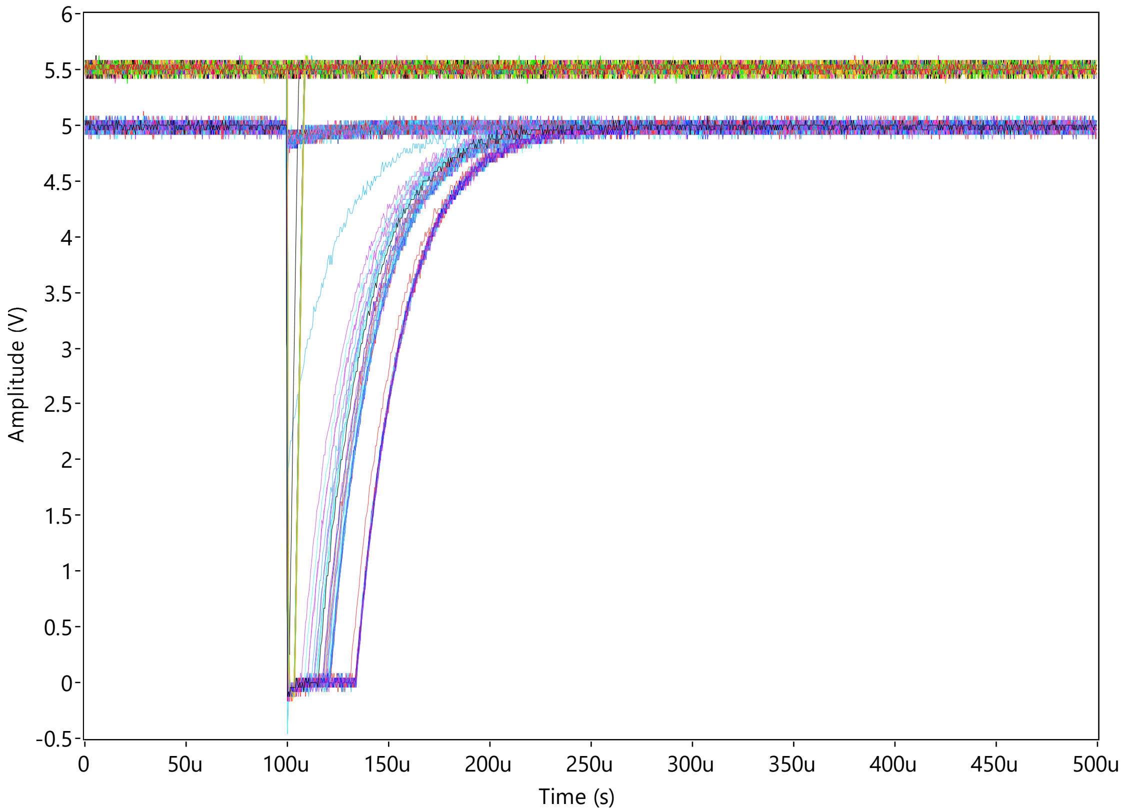
Appendix A. Static SET results analysis

Curves at 5.5 V represent the OUT signals
Curves at 5 V represent the /FAULT signals

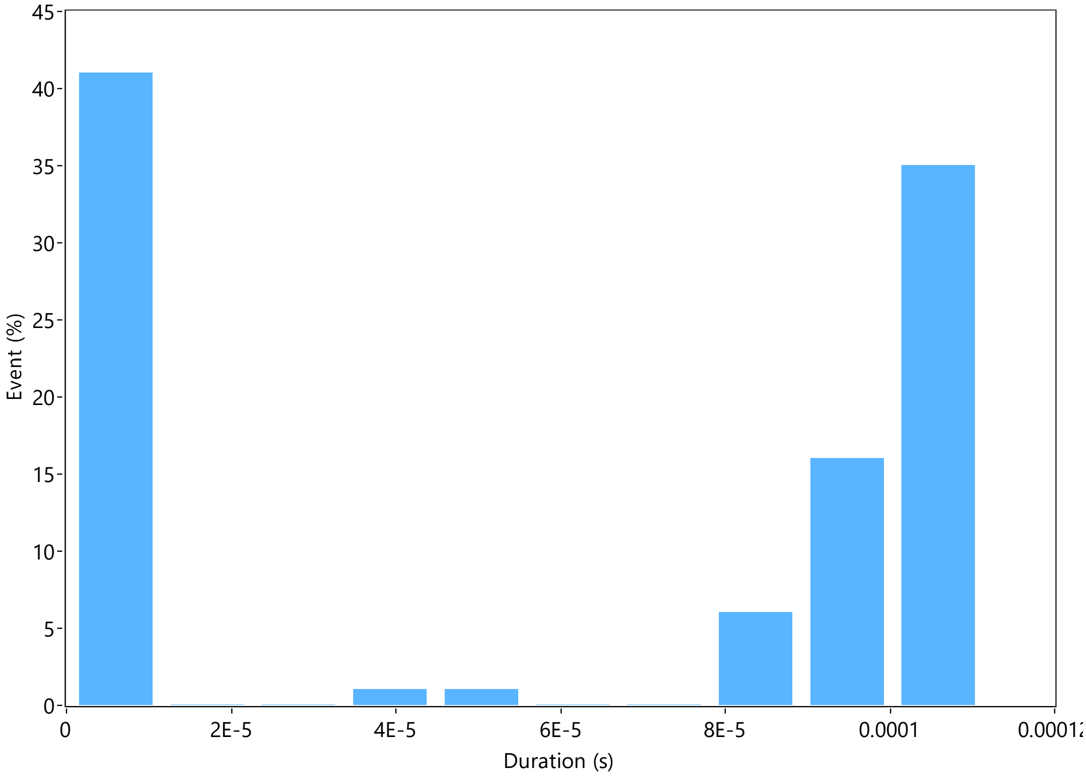


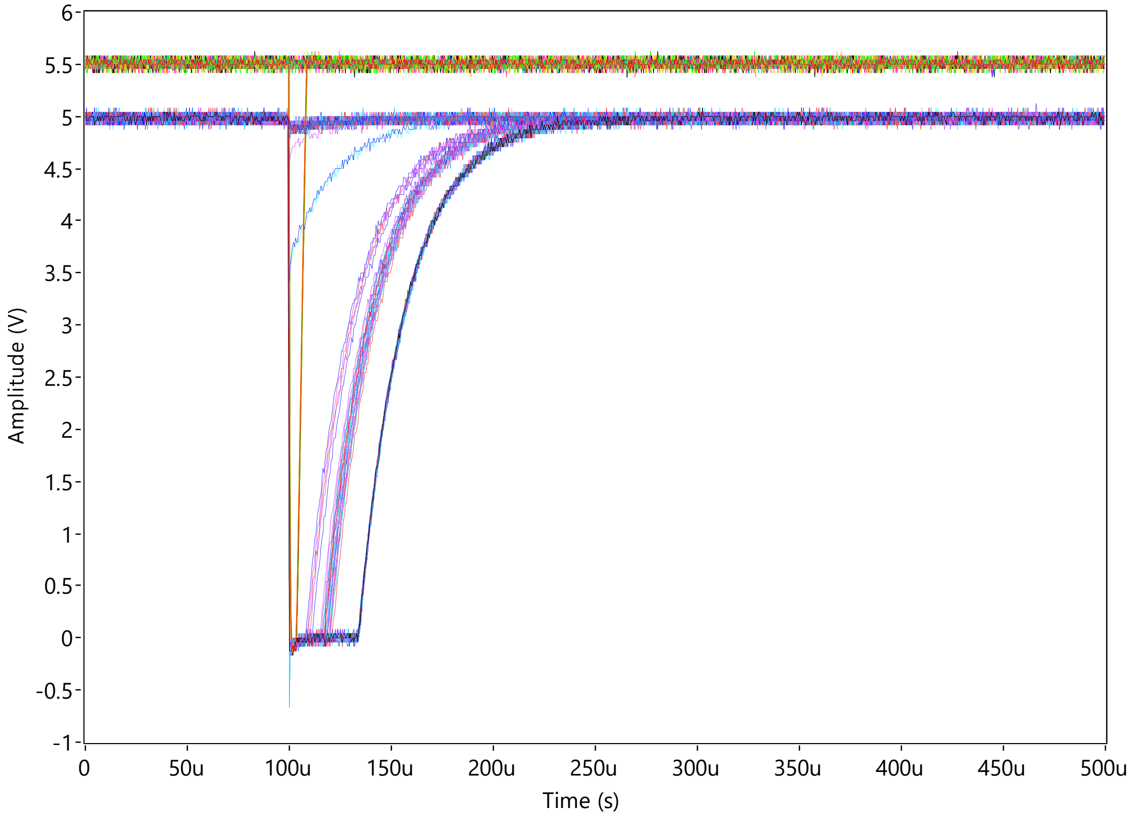
Run 3. Events recap





Run 4. Events recap





Run 5. Events recap

Appendix B. LASER testing

B.1. LASER parameters

The LASER test bench LISA developed at TRAD is dedicated to Single Event Effects testing. The LISA facility is based on a Nd:YAG pulsed LASER. Its overview and specifications are given in Table 13 and a schematic of the optical bench is given in Figure 15 below.

Reference	Coherent Helios 1064	
Wavelength	1064 µm	
Pulse duration	400 ps	
Pulse energy at output	50 µJ.pulse^{-1}	
Frequency	Single shot to 50kHz	
Shot to shot stability	± 5%	

Table 13: Overview of LISA and specifications of the Nd:YAG pulsed LASER from LISA

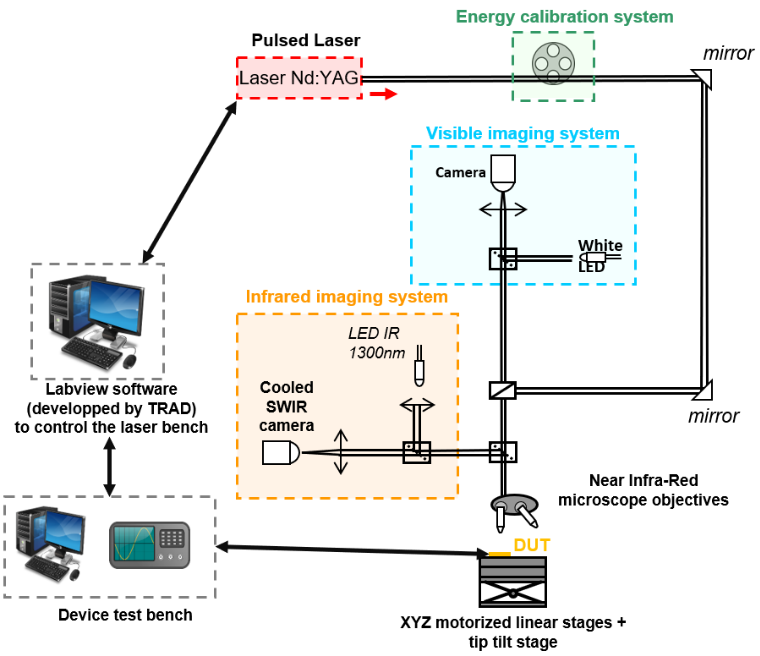


Figure 15: LISA laser test bench

The LASER spot is focused into the device active layer using apochromatic objective lens allowing to reach spot diameters of:

- 8 µm with the X10 objective
- 2.6 µm with the X50 objective

Motorized stages are used to move the LASER spot on the device under test with a great precision (minimal increment of ± 0,1 µm). The pulse energy can be modified in a continuous way using a motorized half-wave plate between two polarizers, and the energy range is comprised between ~0.3nJ/pulse and 150 nJ/pulse (depending on the objective used). Finally, an imaging system, including a visible and an infrared camera, is used to localize precisely the LASER spot focused on the device, and to monitor the "irradiation" of the part.

Several test modes are accessible with the dedicated LabVIEW software:

- Fast scan mode (S-scan): a pulse frequency, a step between two shots and an area are defined, and the moving stages proceed to scan the area at constant speed, calculated such that a pulse is shot for every step defined (ex: f=500Hz, dx=2µm, v=1000µm.s^{-1}). This mode is used prior to the others to localize the sensitive area(s) of the DUTs, before going further. It is however limited by the maximum speed of the moving stages, i.e. 2000µm. $s^{-1.}$
- Manual mode: the DUT is scanned manually, by moving the stages with the LabVIEW software, and shooting at low frequency (below 1kHz to avoid cumulative effects). This is usually used to determine precisely the location of the sensitive areas, once a fast scan has been performed.
- Step-by-step mode: the DUT is scanned with precision in a selected area. In this mode, an area is defined as well as a step between two pulses. The moving stages moves step by step on the selected area and a single shot is triggered for each position.

Correspondence between Laser pulse energy and heavy ion LET is not straightforward, because two very different processes and interactions are involved in charges creations in the semiconductor: the ionization process under heavy ions and the photoelectric effect under pulsed Laser.

However, an empirical correspondence has been established in the frame of a TRAD/CNES study on the LISA facility ([RD3]). Indeed, several devices with known sensitivity to SEL under heavy ions were also tested under Laser at TRAD, and a linear dependence was observed between their SEL LET threshold and SEL LASER Energy threshold. It was thus identified that the {0 – 2.5} nJ/pulse energy range (energy in sensitive volume) is representative of the {0 – 60} MeV.cm²/mg LET range. Note that this comparison is only valid with SEL effect and with the X50 objective.

The pulse energy used under Laser and given in the test result tables in this report is measured just before entering substrate, using a power meter. However, to provide comparative results between several devices, absorption by the silicon substrate, with various thicknesses, must be considered. Indeed, as the pulse propagate through the substrate to reach the active layer, a fraction of the pulse energy is lost and not used for triggering Single Event Effects. This estimation of remaining energy in the active layer is done using a Beer Lambert law, as described below:

$$Ef = Ei(1 - R)e^{-\alpha d} \quad \textbf{10.a}$$

With :

- R : the reflection of the beam at the Air/Si interface, which is ~31%
- d : the substrate thickness, indicated in each results' table for each reference
- α : the absorption coefficient in silicon (considered as undoped)

As a result, the classification given in Abstract of this document, is based on these pulse energies and on results obtained in [RD3], by recalculating the energy used during the tests (considering the substrate thicknesses). Note that this classification may be only valid for SEL effect.

During LASER testing, the whole die is scanned with the same test bench used during heavy ions testing with same test conditions for SEL and SET detections. The objective of this test campaign is to reproduce the set of events observed under heavy ion with LASER. LASER parameters used during this test campaign were:

- In SEL test configuration: Objective x50 and an energy of ≈ 2.5nJ/pulse in the sensitive volume.
- In SET test configuration: Objective x10 and an energy of 10nJ/pulse.

B.2. Test results

Run	Duration (s)	Part	T (°C)	Objective	Beam diameter (µm)	Pulse energy (nJ/pulse)	Pulse energy in active area (nJ/pulse)	Test mode	f (Hz)	dx (µm)	Scan speed (µm.s-1)	SEL	SET
1	1680	L1	85	X50	2.6	6.4	2	S-scan	650	3	1950	0	82
2	1680	L1	85	X50	2.6	9.04	2.8	S-scan	650	3	1950	0	172
6	2700	L2	Amb	X10	8	10.01	-	Scan	-	15	-	0	42
7	-	L2	Amb	X10	8	10.01	-	Manual	-	-	-	0	677
Conclusion: no SEL/DSEE observed in SEL test config. / sensitive areas identified in SET test config.													

Table 14: MAX890LESA+ LASER test results

B.3. Sensitive areas on die

Each sensitive area identified is numbered and worst cases are given for each area.

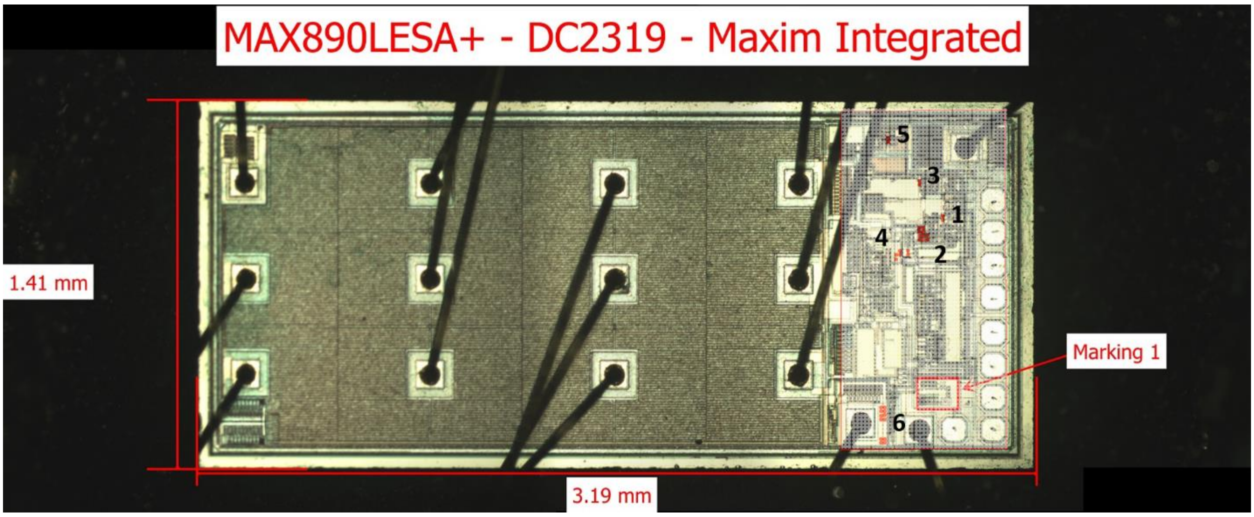


Figure 16: LISA laser test bench

B.4. Event worst cases for each area

SET /FAULT worst case on area 1

Area	1
Part No.	L2
Test Conditions	SET
Type event	Negative SET
nJ/pulse	56.8
Absolute amplitude	5.125 V
Relative amplitude	0 V
Duration	97.5 µs

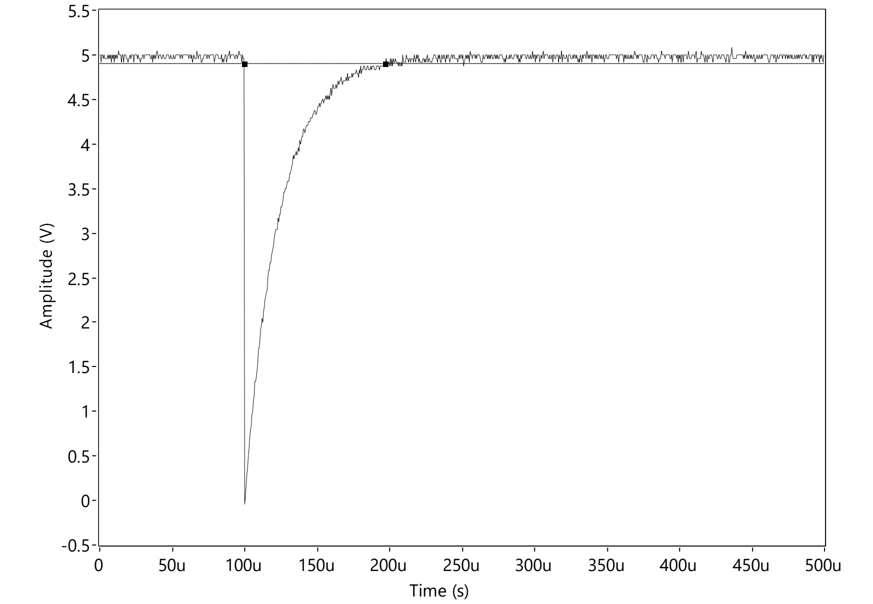


Figure 17: SET /FAULT worst case on area 1

SET /FAULT worst case on area 2

Area	2
Part No.	L2
Test Conditions	SET
Type event	Negative SET
nJ/pulse	56.8
Absolute amplitude	5.125 V
Relative amplitude	0 V
Duration	115 µs

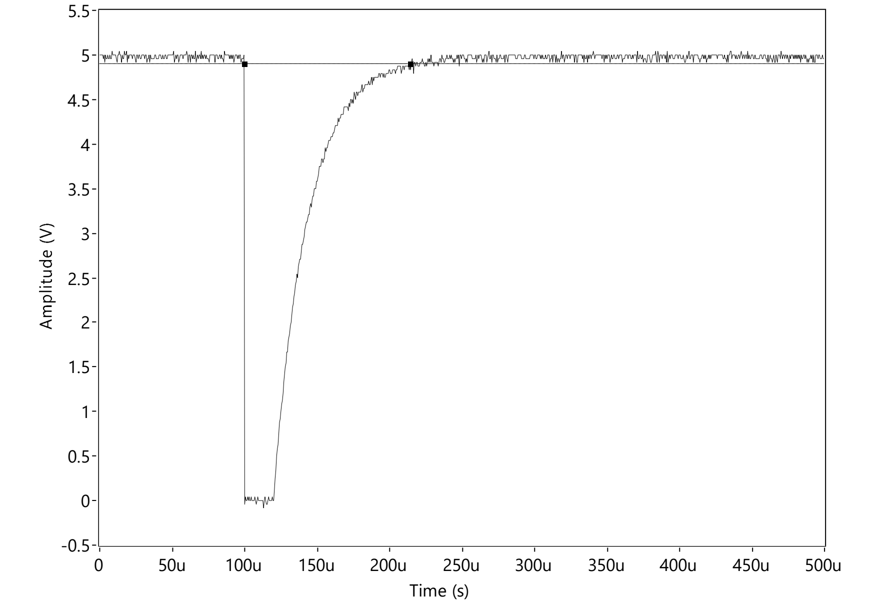


Figure 18: SET /FAULT worst on case area 2

SET /FAULT worst case on area 3

Area	3
Part No.	L2
Test Conditions	SET
Type event	Negative SET
nJ/pulse	56.8
Absolute amplitude	5.125 V
Relative amplitude	0 V
Duration	104.5 µs

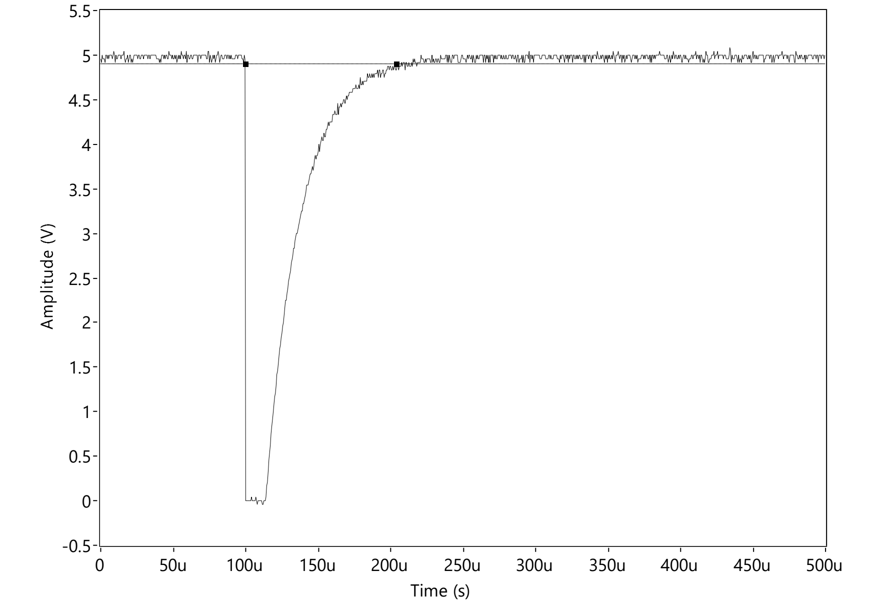


Figure 19: SET /FAULT worst case on area 3

SET /FAULT worst case on area 4

Area	4
Part No.	L2
Test Conditions	SET
Type event	Negative SET
nJ/pulse	56.8
Absolute Amplitude	5.08 V
Relative amplitude	0 V
Duration	96.5 µs

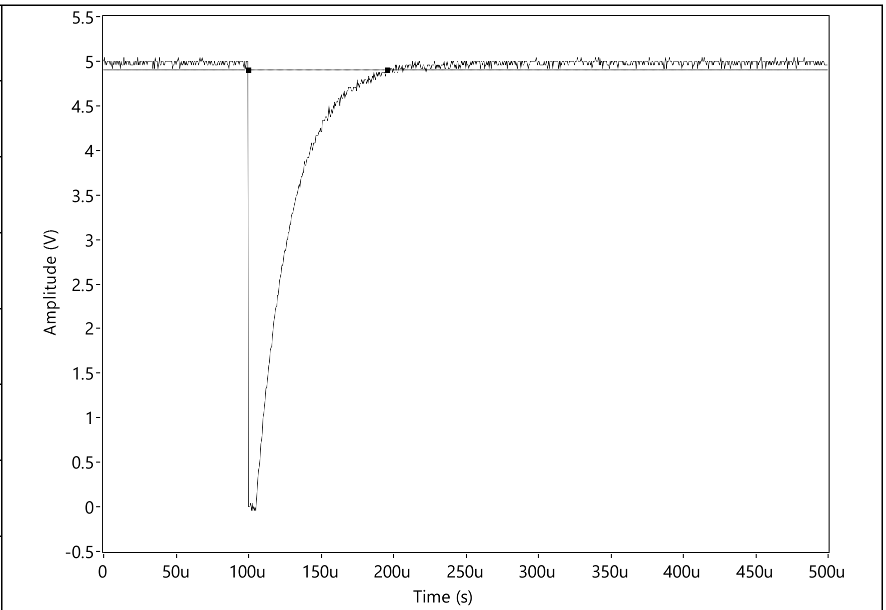


Figure 20: SET /FAULT worst case on area 4

SET /FAULT worst case on area 5

Area	5
Part No.	L2
Test Conditions	SET
Type event	Negative SET
nJ/pulse	56.8
Absolute amplitude	3.04 V
Relative amplitude	2 V
Duration	77.5 µs

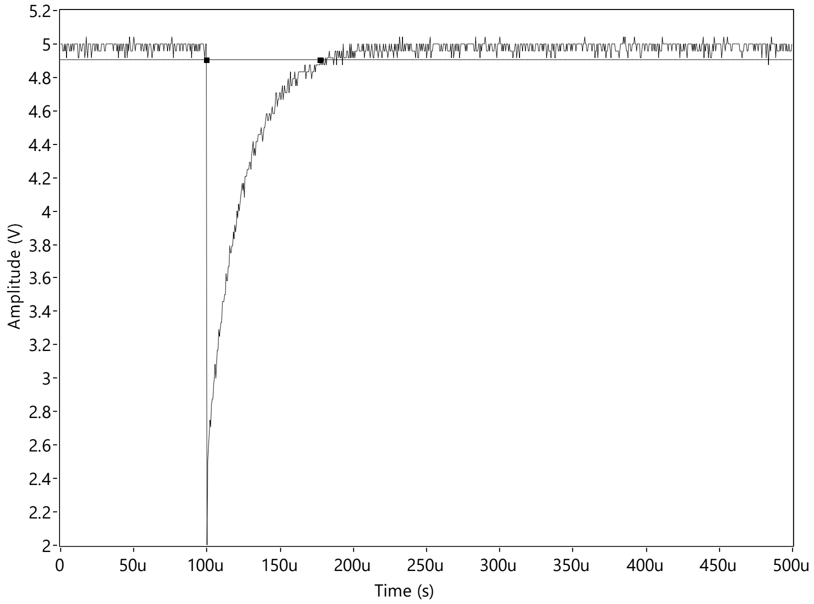


Figure 21: SET /FAULT worst case on area 5

SET /FAULT worst case on area 6

Area	4
Part No.	L2
Test Conditions	SET
Type event	Negative SET
nJ/pulse	56.8
Absolute Amplitude	5.5 V
Relative amplitude	0 V
Duration	127.5 µs

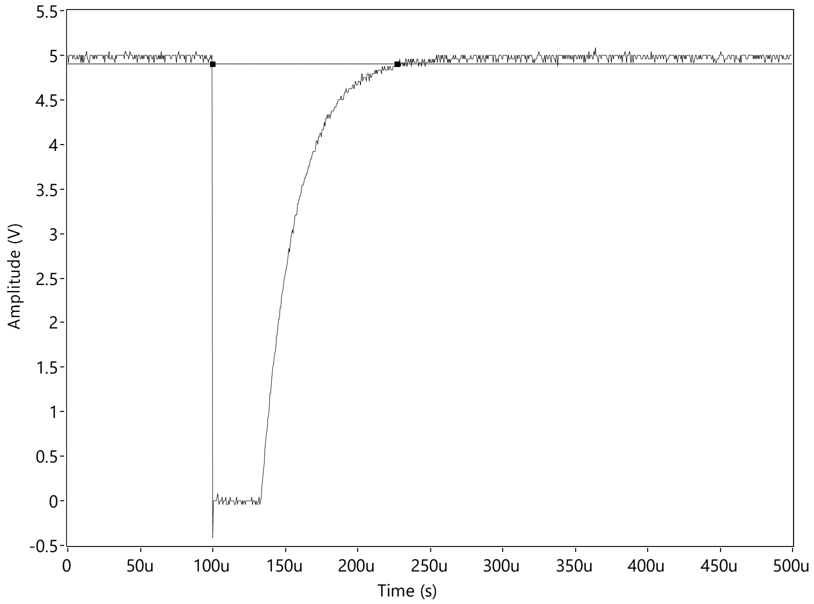


Figure 22: SET /FAULT worst case on area 6

SET OUT worst case on area 6

Area	6
Part No.	L2
Test Conditions	SET
Type event	Negative SET
nJ/pulse	56.8
Absolute Amplitude	5.58 V
Relative amplitude	0 V
Duration	8.5 µs

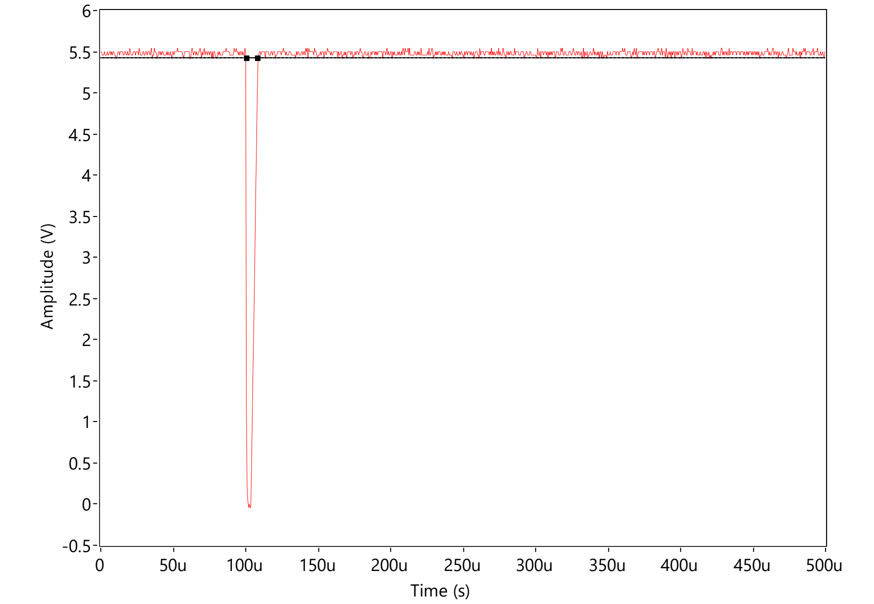


Figure 23: SET OUT worst case on area 6