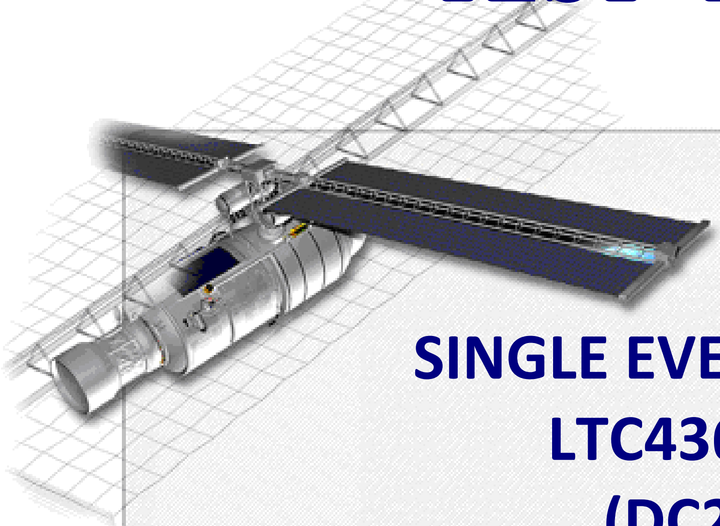
HEAVY ION and LASER TEST REPORT



SINGLE EVENT EFFECTS
LTC4361CTS8
(DC2316)
Overvoltage/Overcurrent Protection Controller
From
Analog Devices Inc.

TRAD/TI/LTC4361CTS8/2316/ESA/JB/2308	Labège, August 21th, 2024
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Revision: 0	First edition of the test report. – 12/12/23	
Revision: 1	LASER testing added in Appendix B	
To:	**R. KARPOV**	Project/Program:
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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
SEFI	Single Event Functional Interrupt

Abstract

The main objective of this test was to evaluate the sensitivity of the LTC4361CTS8, an Overvoltage/Overcurrent Protection Controller versus SEL, SET and SEFI.
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 LET of 56.8 MeV.cm²/mg, Xenon heavy ion.
No destructive events were observed.

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

In SEE test configuration
SET GATE were observed with a minimum LET of 13.3 MeV.cm²/mg, Iron heavy ion.
SET PGOOD were observed with a minimum LET of 13.3 MeV.cm²/mg, Iron heavy ion.
No lower LET was tested during this test campaign.
Same type of long event was observed between Heavy Ion and LASER testing.

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

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

1. Introduction

This report includes the test results of the heavy ion SEE test sequence carried out on the LTC4361CTS8, an Overvoltage/Overcurrent Protection Controller from Analog Devices Inc., susceptible to show SEL, SET and SEFI 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/LTC4361CTS8/SOT-23-8/SEE/210923/Rev0

2.2. Reference documents

[RD1] ESCC Basic specification No. 25100 Issue 2 of October 2014
[RD2] Datasheet: LTC4361-1-4361-2 D17016-0-6/18(c) Rev C
[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 and 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 LTC®4361 overvoltage/overcurrent protection controller safeguards 2.5V to 5.5V systems from input supply overvoltage. It is designed for portable devices with multiple power supply options including wall adaptors, car battery adaptors and USB ports.
The LTC4361 controls an external N-channel MOSFET in series with the input power supply. During overvoltage transients, the LTC4361 turns off the MOSFET within 1µs, isolating downstream components from the input supply. Inductive cable transients are absorbed by the MOSFET and load capacitance. In most applications, the LTC4361 provides protection from transients up to 80V without requiring transient voltage suppressors or other external components.
The LTC4361 has a delayed start-up and adjustable dV/ dt ramp-up for inrush current limiting. A PWRGD pin provides power good monitoring for VIN. The LTC4361 features a soft shutdown controlled by the ON pin and drives an optional external P-channel MOSFET for negative voltage protection. Following an overvoltage condition, the LTC4361 automatically restarts with a start-up delay. After an overcurrent fault, the LTC4361-1 remains off while the LTC4361-2 automatically restarts after a 130ms start-up delay.

4.2. Identification

Part designation	LTC4361CTS8
Manufacturer	Analog Devices Inc.
Part function	Overvoltage/Overcurrent Protection Controller

Table 2: Part identification

4.3. Procurement information

Package	8-Lead Plastic TSOT-23
Date code	2316
Lot code No.	AY64318.13
Number of tested parts	2 irradiated samples

Table 3: Part procurement information

4.4. Sample preparation

4 parts were delidded, 1 sample has been damaged during this operation.
8 parts were thinned (back-side) for LASER testing, 6 samples were 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 3 delidded samples available for the test campaign, 2 were irradiated and 1 was not used.
Among the 2 thinned samples available for the LASER test campaign, 1 sample was 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 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 red rectangles on Figure 2).

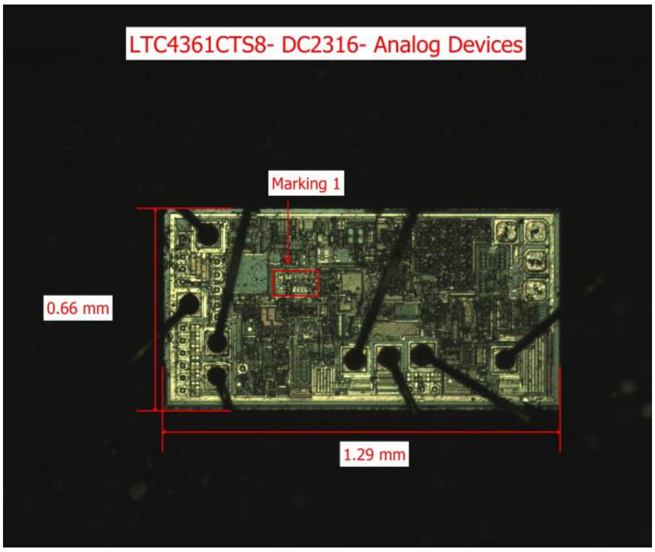


Figure 2: Picture of the internal overall view

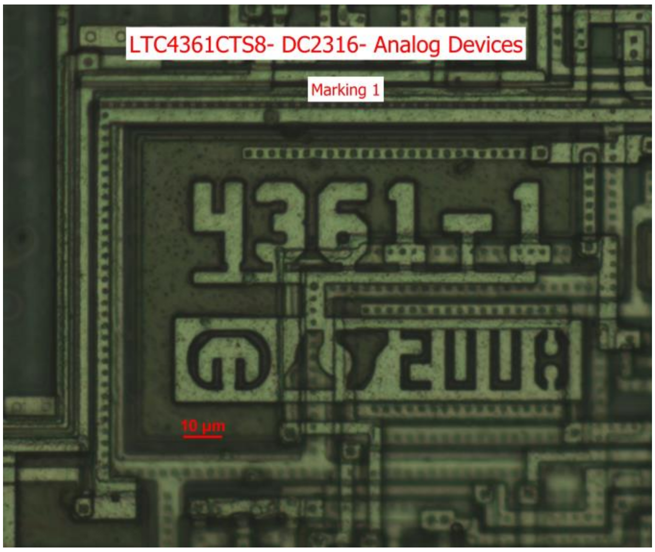


Figure 3: Picture of the die markings

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.

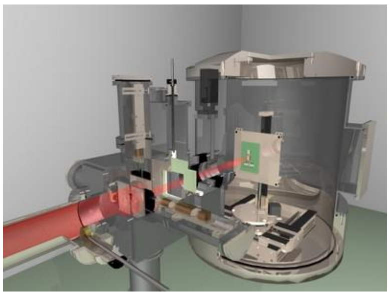


Figure 4: RADEF facility

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 Table 4 where heavy ions used for this test campaign are highlighted.
The tests on LTC4361CTS8 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.
- The fluence is adapted to accumulate a meaningful, i.e. statistically significant number of events (close to 100 events) 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.

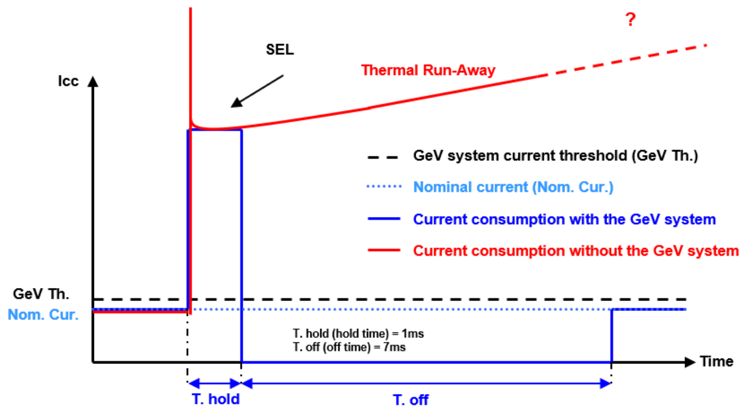


Figure 5: Common SEL characteristic

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.

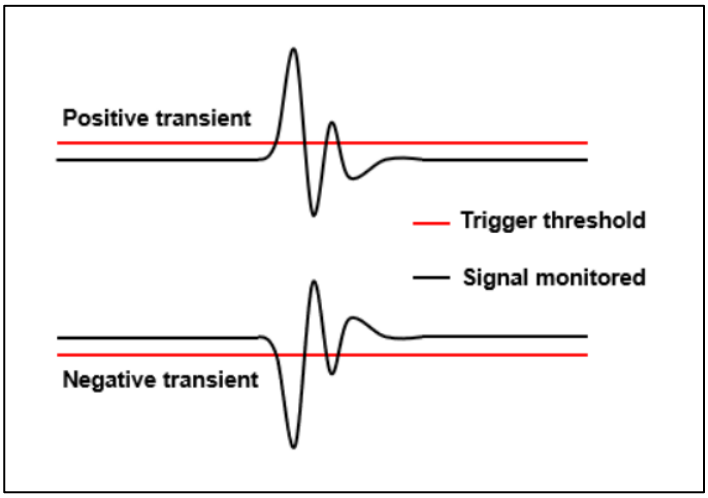


Figure 6: SET in static mode characteristic

Rajouter définition pour chaque signal

6.2.3. SEFI test principle

During this test campaign, a SEFI was considered if the GATE signal was monitored as low state for 4s. That duration was set because of some self-recovering was observed during irradiation. In case of SEFI occurrence, a power cycle was performed to recover the device's functionality.

6.3. Test bench description

6.3.1. Test bench overview

Figure 7 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 protect the DUT, detect and record SEL.
- An oscilloscope to detect and record SET.

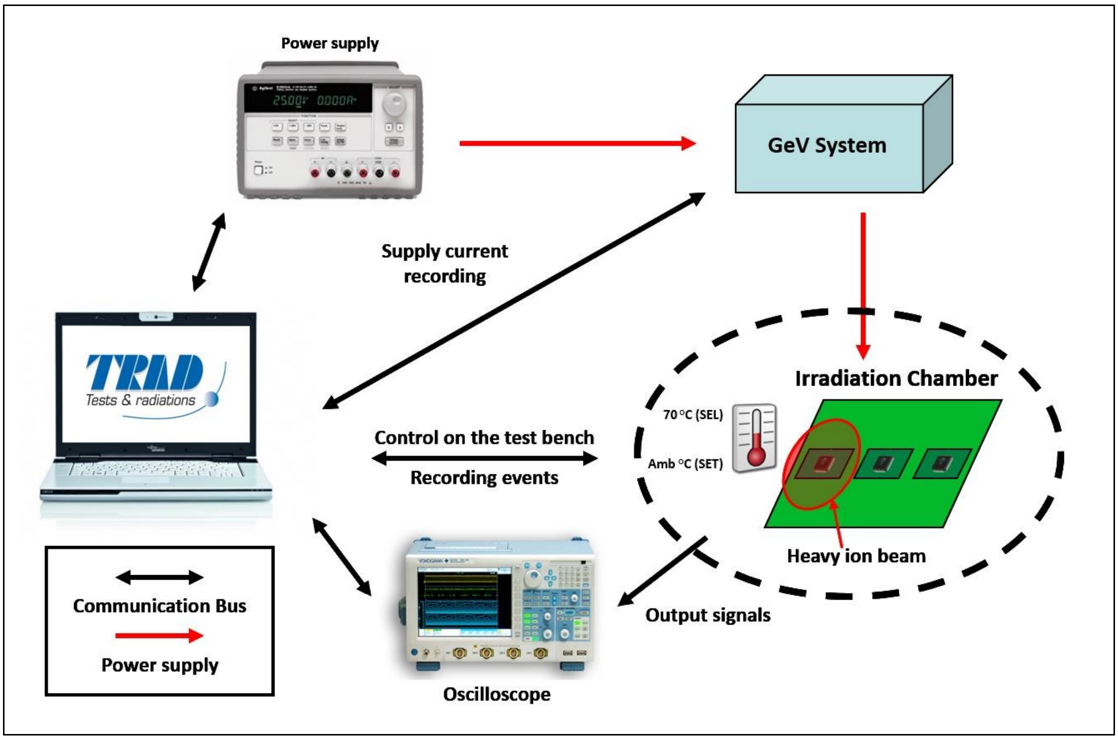


Figure 7: Test bench description

6.3.2. Heating system

TRAD has developed a specific heating system to heat and regulate the temperature of the DUT. Figure 8 shows a thermal image taken during the heating calibration of the DUT, the temperature of the die was set to 70°C as shown on the picture.

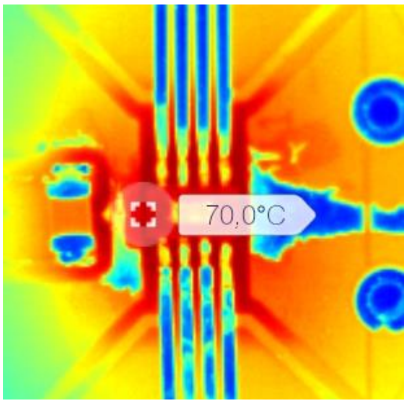


Figure 8: Thermal image of LTC4361CTS8 heated to 70°C

6.3.3. Test equipment identification

TEST BOARD	TRAD/CT1/I/GeV_DEMI_POS/8-PIN_0.65mm/MG/2301
EQUIPMENT	SM-87; SM-96; GR-27; GeV-3
TEST PROGRAM	TRAD_TI_LTC4361CT_SEL-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_0.65mm/MG/2301" is illustrated in Figure 9.

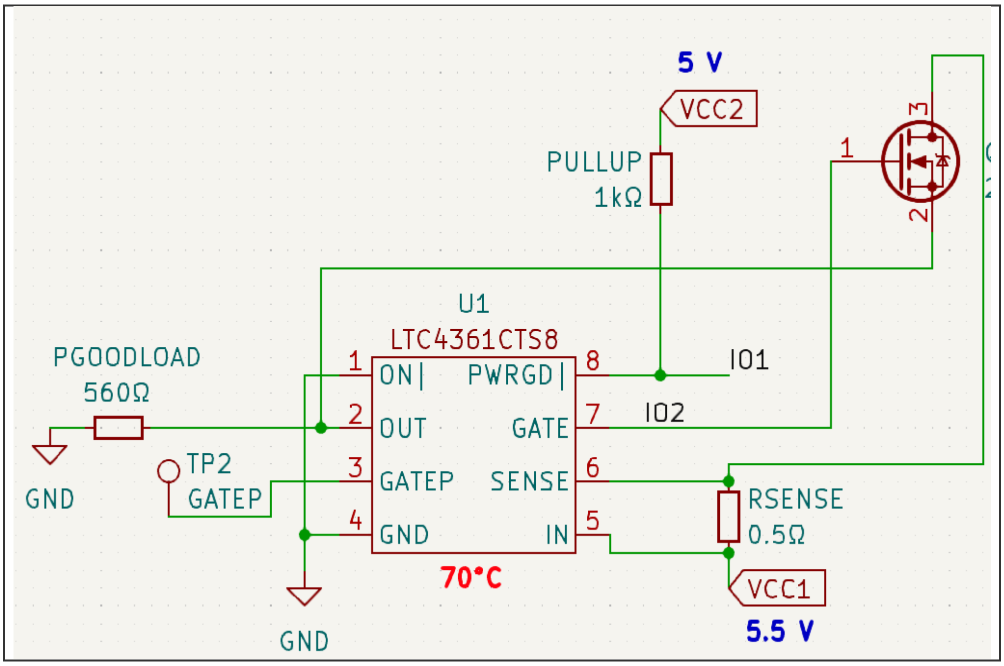


Figure 9: Test board schematic

6.3.5. Test conditions and event detection thresholds

SEL test

	VIN	PWRGD (pull-up)
Voltage	5.5 V	5 V
$I_{nominal}$	10 mA	5 mA
$I_{threshold}$	15 mA	10 mA
T_{hold}	1 ms	1 ms
$T_{cut\ off}$	7 ms	7 ms
Temperature	70°C	

Table 6: SEL test conditions and detection thresholds

SEE test

	VIN = 5.5V, PWRGD (Pull-up) = 5V	
	GATE	**PWRGD**
$V_{nominal}$	9.6 V	0 V
Trigger threshold	8 V	1 V
Temperature	Ambient	

Table 7: Static SET test conditions and detection thresholds

In SEE test runs, when the current dropped to 0mA, a manual "power cycle" was executed to restore the component to its normal operation.

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
- $\sigma = N_{events} / F$
- $\delta F/F$ 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)	SET PGOOD	SET PGOOD Cross Section (cm²)	SET GATE	SET GATE Cross Section (cm²)	SEFI	SEFI Cross Section (cm²)
1	SEL	1	70	Ag	1714	38.8	158.0	9.43E+03	1060	1.00E+07	6.21	6.21	0	<1.00E-07	-	-	-	-	-	-
1	SEL	2	70	Ag	1714	38.8	158.0	9.43E+03	1060	1.00E+07	6.21	6.21	0	<1.00E-07	-	-	-	-	-	-
2	SEL	1	70	Xe	1446.5	56.8	105.7	9.23E+03	1083	1.00E+07	9.09	15.30	0	<1.00E-07	-	-	-	-	-	-
2	SEL	2	70	Xe	1446.5	56.8	105.7	9.23E+03	1083	1.00E+07	9.09	15.30	0	<1.00E-07	-	-	-	-	-	-
3	SET	1	amb	Fe	941	13.3	214.0	1.33E+03	613	8.17E+05	0.17	15.47	-	-	0	<1.22E-06	99	1.21E-04	7	8.57E-06
4	SEFI	1	amb	Fe	941	13.3	214.0	8.69E+03	762	6.62E+06	1.41	16.88	-	-	-	-	-	-	30	4.53E-06
5	SET	1	amb	Xe	1446.5	56.8	105.7	5.77E+02	586	3.38E+05	0.31	17.19	-	-	1	2.96E-06	104	3.08E-04	9	2.66E-05
6	SEFI	1	amb	Xe	1446.5	56.8	105.7	2.05E+03	620	1.27E+06	1.15	18.35	-	-	-	-	-	-	43	3.39E-05
7	SEE	1	amb	Ag	1714	38.8	158.0	9.39E+02	799	7.50E+05	0.47	18.81								

Table 8: LTC4361CTS8 test run table

SEE detailed results are described in the following sections.

9.2. Cumulated dose table

Part No.	Cumulated Dose (krad)
1	18.81
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

	LTC4361CTS8 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: LTC4361CTS8 SEL cross section values in SEL test configuration

9.4. SET PGOOD test results

9.4.1. SET PGOOD LET threshold

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

In SEE test configuration

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

9.4.2. SET PGOOD cross sections

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

In SET test condition

LET Eff (MeV.cm²/mg)	LTC4361CTS8 SET PGOOD Cross Section (cm²) in SEE test configuration — Part No. 1 error (-)	cross section	error (+)
56.8	2.88E-06	2.96E-06	1.35E-05
13.3	0.00E+00	<1.22E-06	4.52E-06

Table 11: LTC4361CTS8 SET PGOOD cross section values in SET test configuration

Figure 10: LTC4361CTS8 SET PGOOD cross section curve in SET test configuration

9.5. SET GATE test results

9.5.1. SET GATE LET threshold

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

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

9.5.2. SET GATE cross sections

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

In SET test condition

LET Eff (MeV.cm²/mg)	LTC4361CTS8 SET GATE Cross Section (cm²) in SEE test configuration — Part No. 1 error (-)	cross section	error (+)
56.8	5.63E-05	3.08E-04	6.51E-05
13.3	2.27E-05	1.21E-04	2.64E-05

Table 12: LTC4361CTS8 SET GATE cross section values in SET test configuration

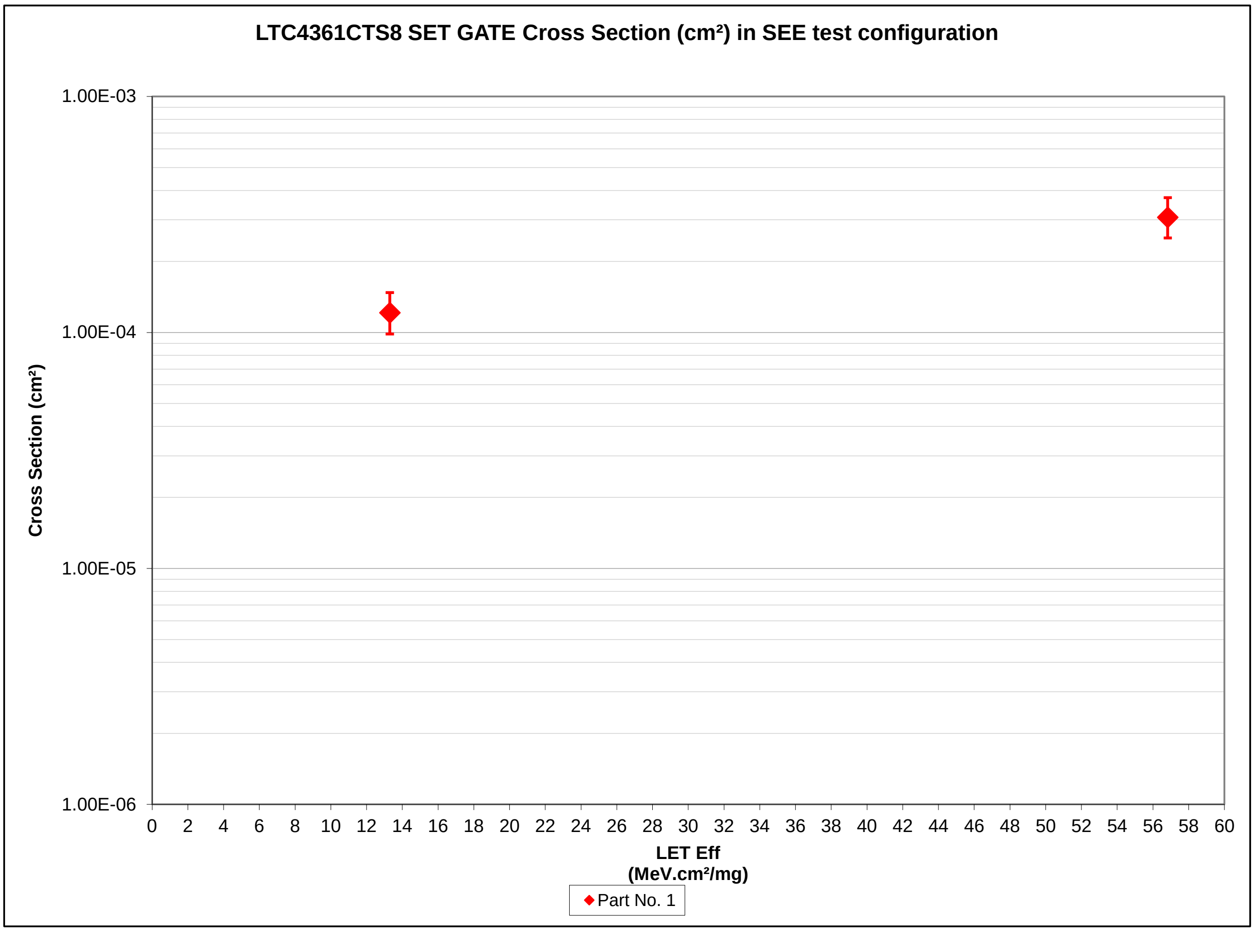


Figure 11: LTC4361CTS8 SET GATE cross section curve in SET test configuration

9.6. SEFI test results

9.6.1. SEFI LET threshold

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

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

9.6.2. SEFI cross sections

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

In SEFI test condition

LET Eff (MeV.cm²/mg)	LTC4361CTS8 SEFI Cross Section (cm²) in SEFI test configuration		
	Part No. 1		
	error (-)	cross section	error (+)
56.8	9.35E-06	3.39E-05	1.17E-05
13.3	1.47E-06	4.53E-06	1.94E-06

Table 13: LTC4361CTS8 SEFI cross section values in SEFI test configuration

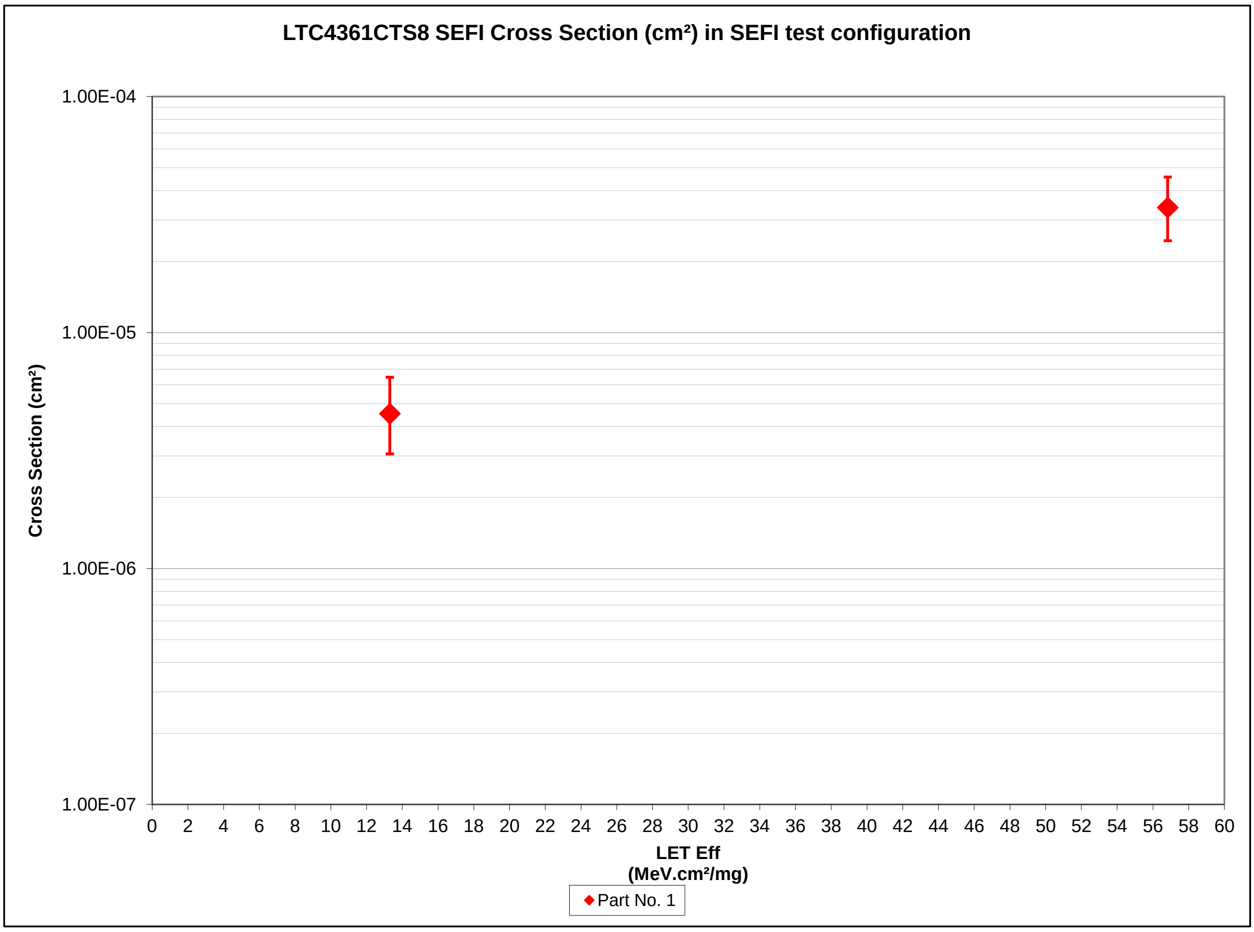


Figure 12: LTC4361CTS8 SEFI cross section curve in SEFI test configuration

9.7. SEE test results

During run No. 7 the test condition have been modified. The time base was shorter to determinate if events observed were triggered by GATE or by PGOOD. Due to the time base change the run No. 7, it is excluded from the SEE's cross sections.
The analyse showed that SEE were only triggered by heavy ions

9.8. SET GATE short amplitude

Due to the 8V threshold trigger (falling edge), events with an amplitude above were not triggered. Some captures of events triggered show events with lower amplitude (only observed with a LET = 56.8 Mev.cm²/mg). Because these events with low amplitude were not triggering the oscilloscope, their captures are random with large amplitude events and no conclusion can be done regarding their statistics. Nevertheless, it should be noticed that these events with a minimum amplitude above 8V are existing.

Figure 13 shows one of these recording for which the event with low amplitude occurs approximately 700ms after the event with large amplitude. These events can be also observed in Appendix A.

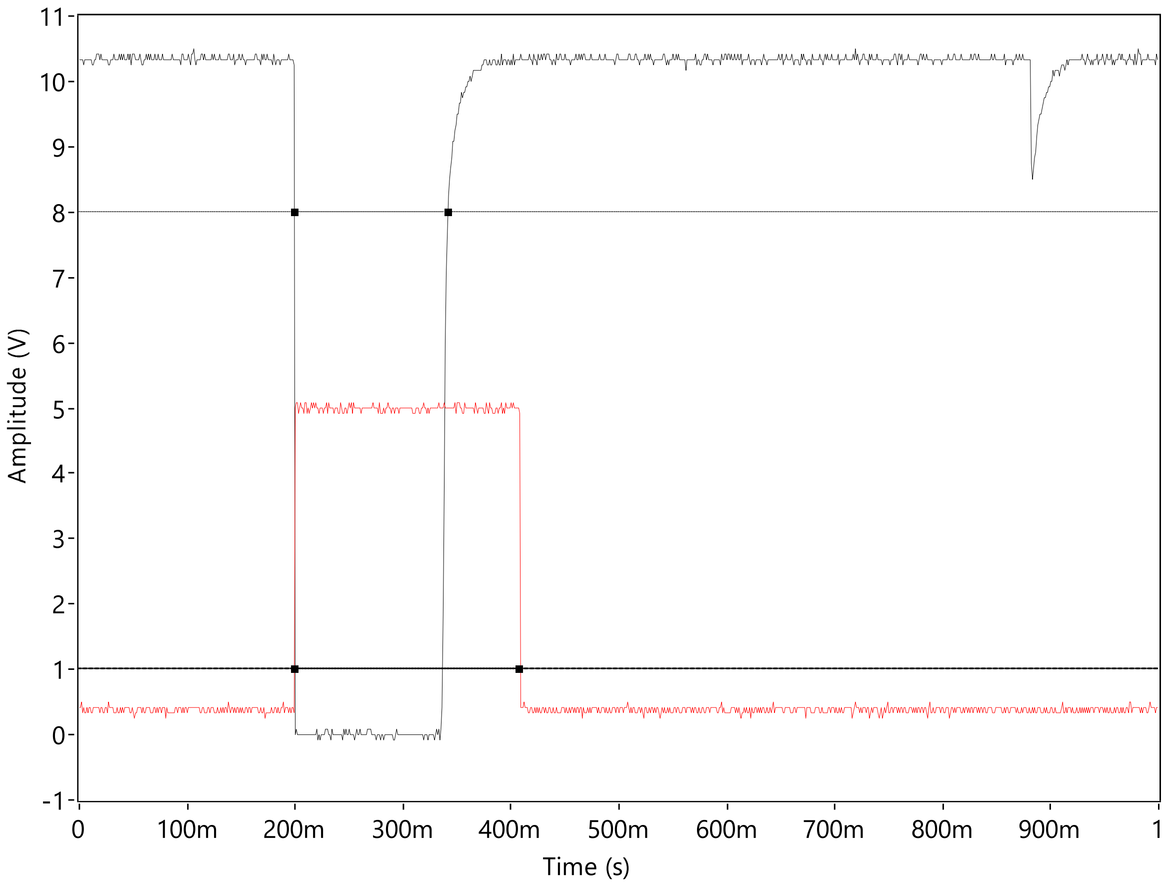


Figure 13: Event with low amplitude

10. Conclusion

The heavy ions test was performed on LTC4361CTS8. The aim of the test was to evaluate the sensitivity of the device versus SEL, SET and SEFI.

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

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

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

In SEE test configuration
SET GATE were observed with a minimum LET of 13.3 MeV.cm²/mg, Iron heavy ion.
SET PGOOD were observed with a minimum LET of 13.3 MeV.cm²/mg, Iron heavy ion.
No lower LET was tested during this test campaign.
Same type of long event was observed between Heavy Ion and LASER testing.

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

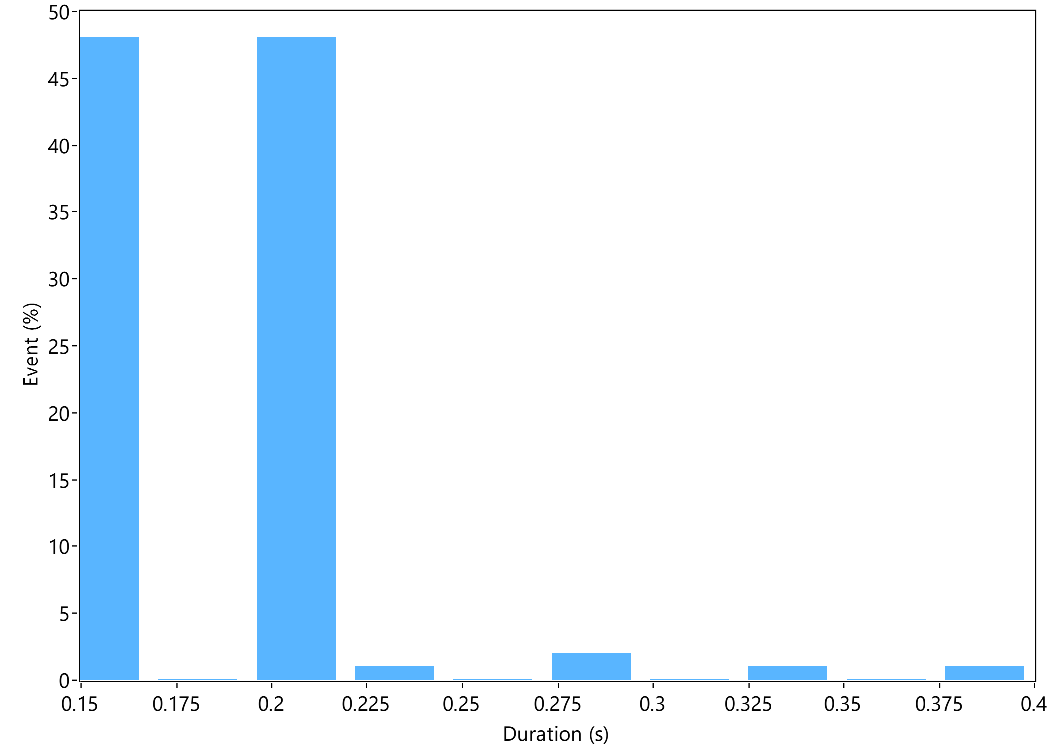
In SEE test configuration
SEFI were observed with a minimum LET of 13.3 MeV.cm²/mg, Iron heavy ion.
No lower LET was tested during this test campaign.

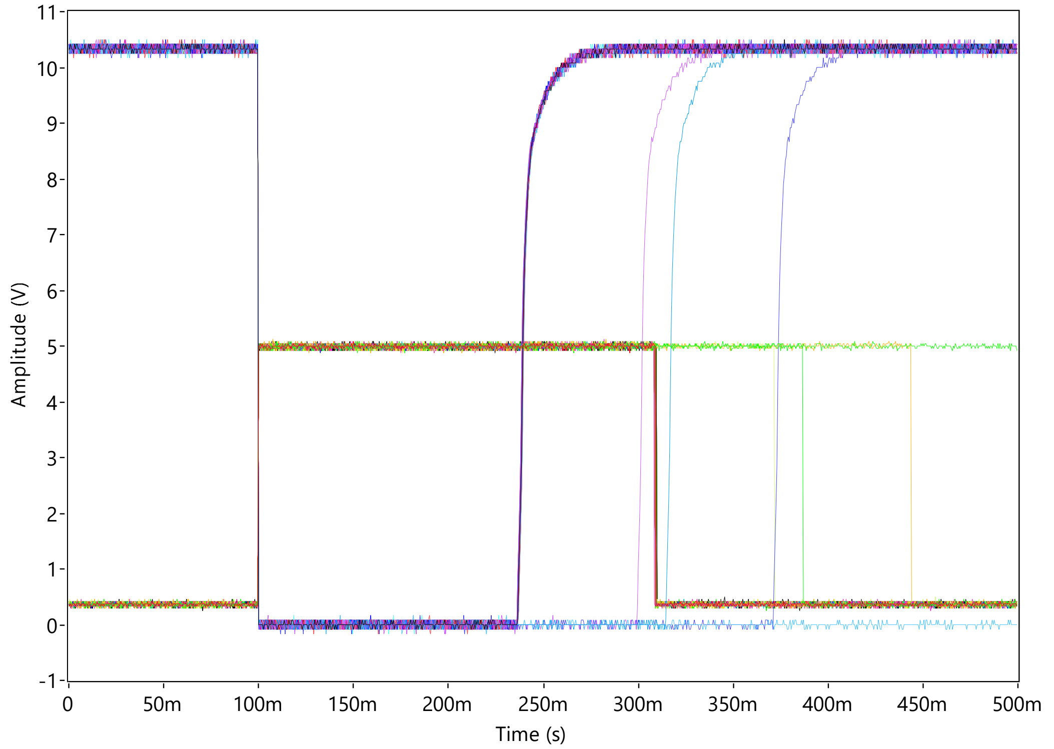
Further analysis on each run can be found in appendixes with:

- 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 10 V ± 0.5 V represent the GATE signals
Curves at 0 V represent the PGOOD signals





Run 3. Event recap

In SET test configuration

The worst complete positive SET PGOOD observed on PGOOD occurred during run No. 3 on part No. 1 event No. 4.

Run No.	3
Part No.	1
Test condition	**SET**
Type event	Positive SET
Ion LET (MeV.cm²/mg)	13.3
Absolute amplitude	5 V
Relative amplitude	4.6 V
Duration	386 ms

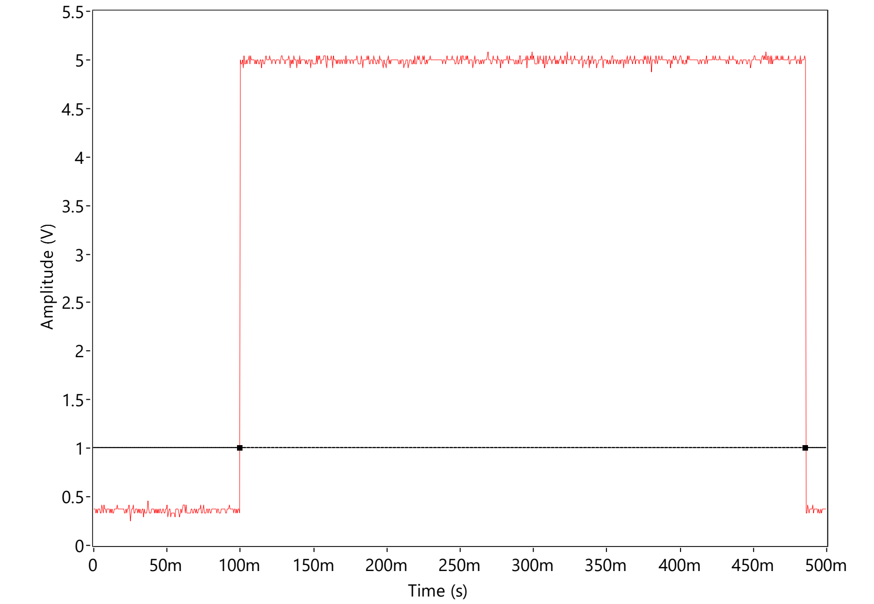


Figure 14: SET PGOOD worst case

In SET test configuration

The worst complete negative SET GATE observed on GATE occurred during run No. 3 on part No.1 event No. 23.

Run No.	3
Part No.	1
Test condition	**SET**
Type event	Negative SET
Ion LET (MeV.cm²/mg)	13.3
Absolute amplitude	10.35 V
Relative amplitude	10.35 V
Duration	277 ms

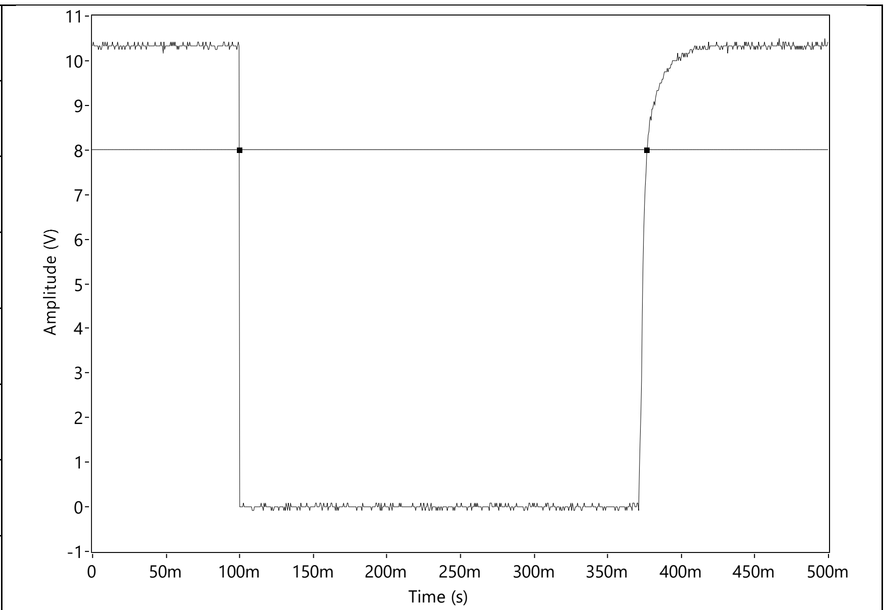
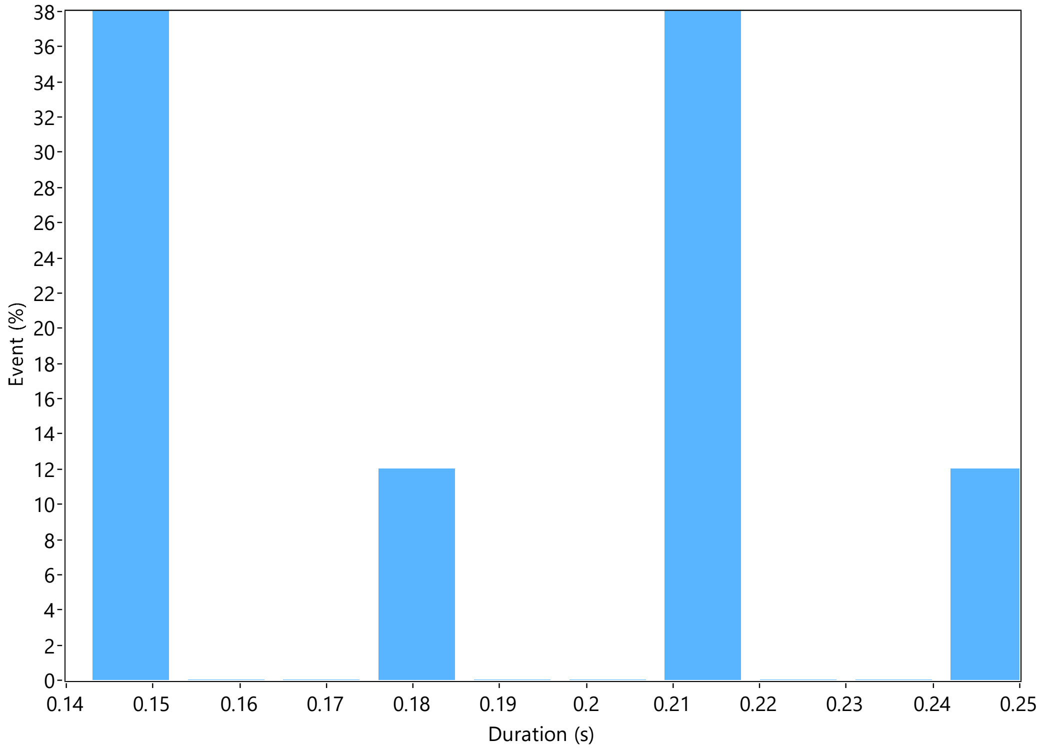
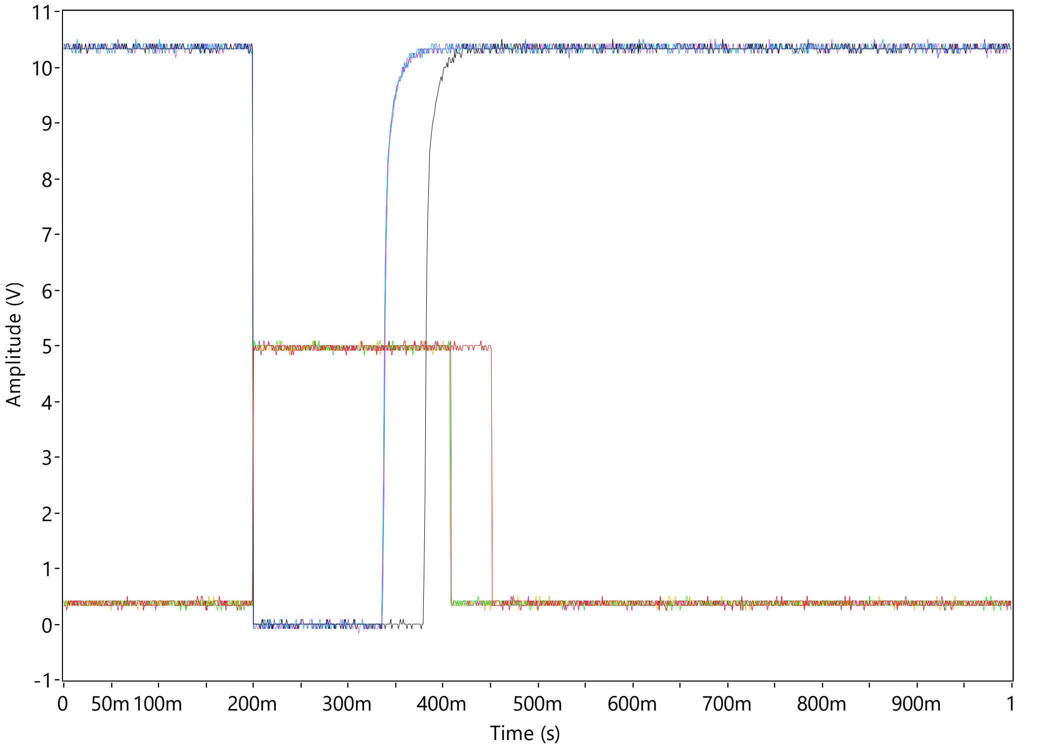
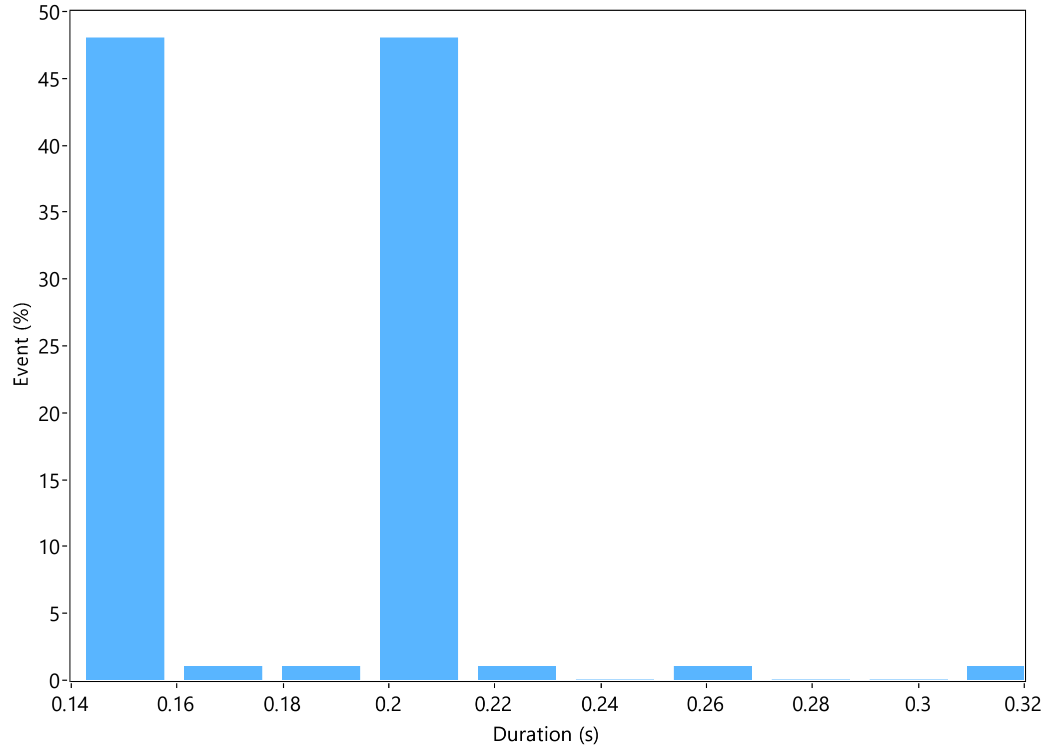


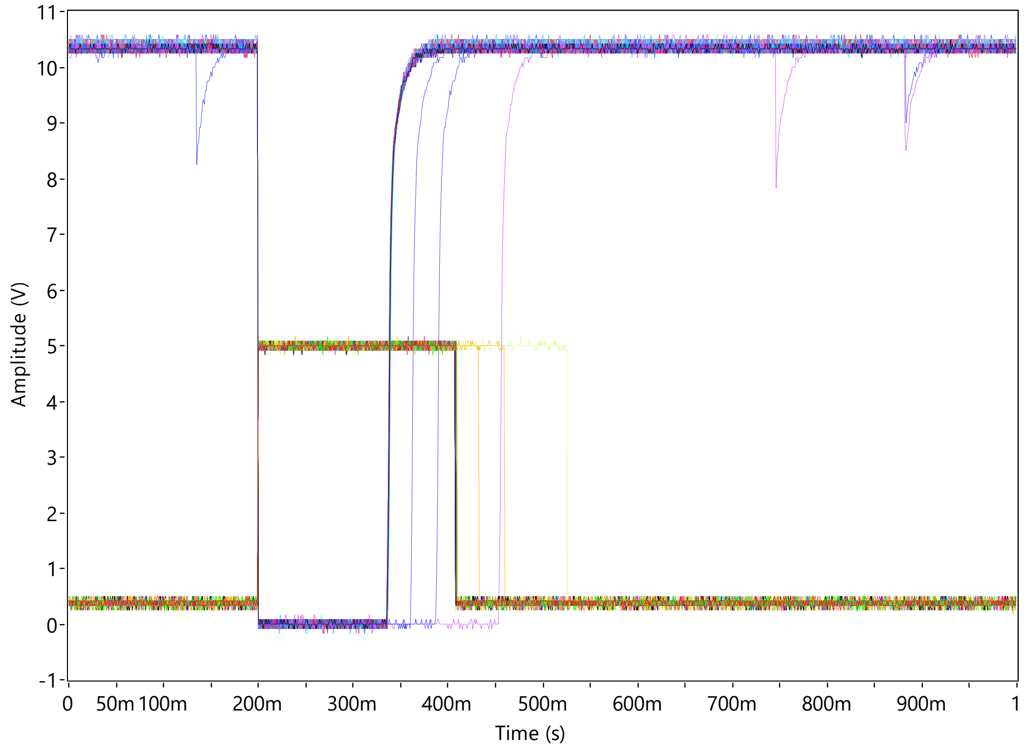
Figure 15: SET GATE worst case



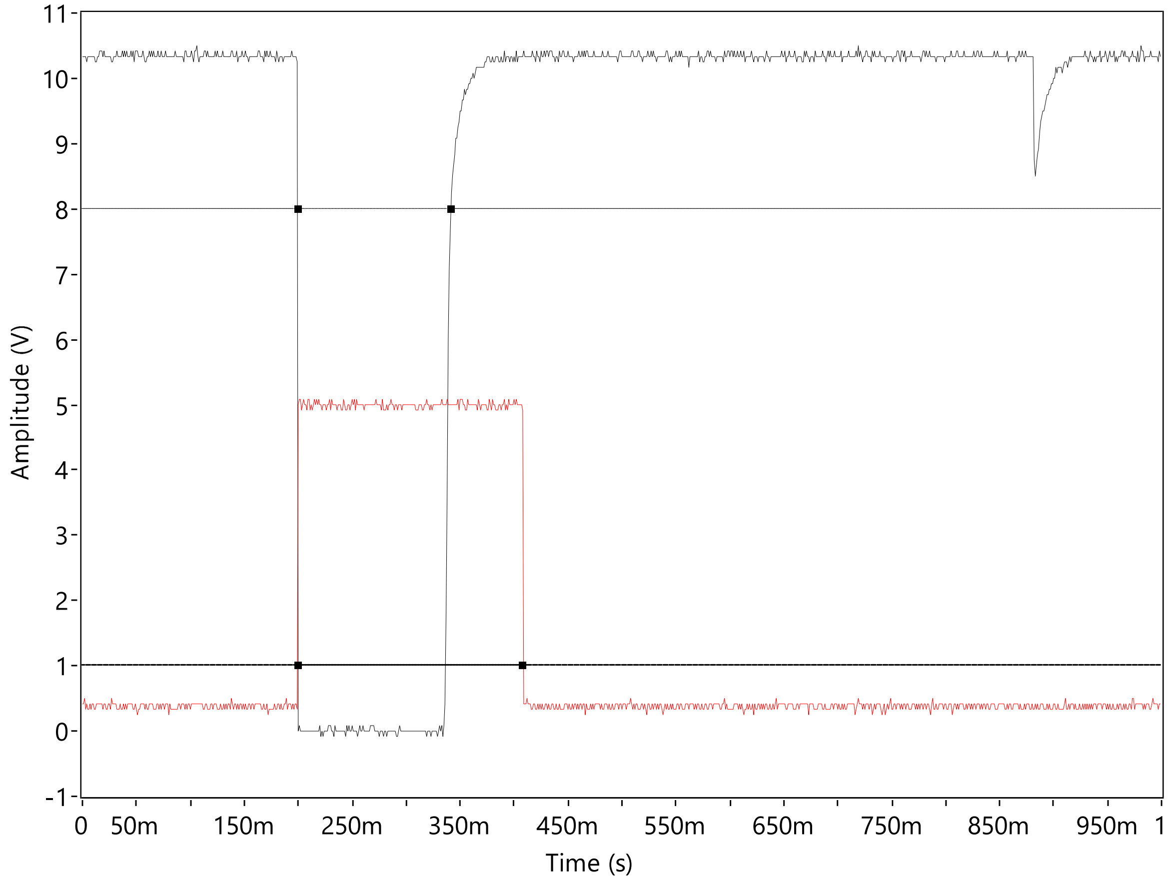


Run 4. Event recap

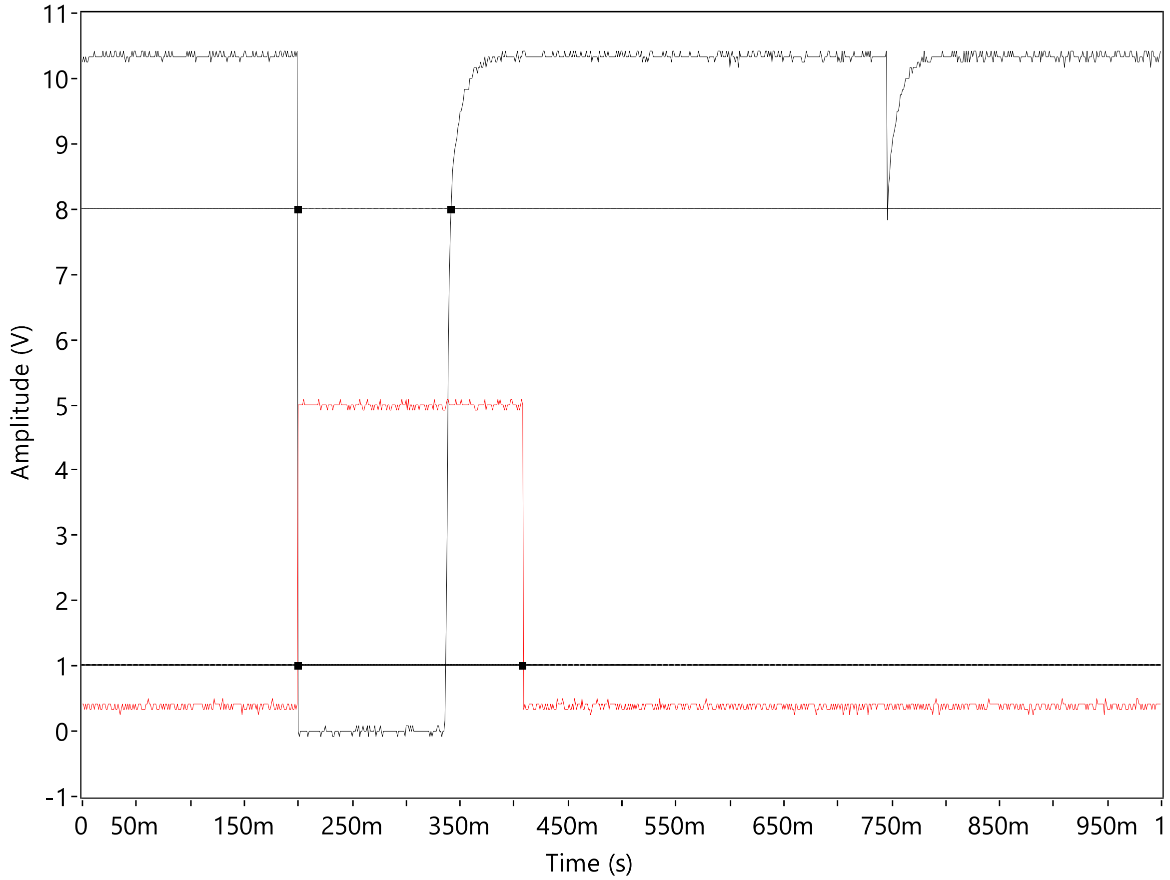




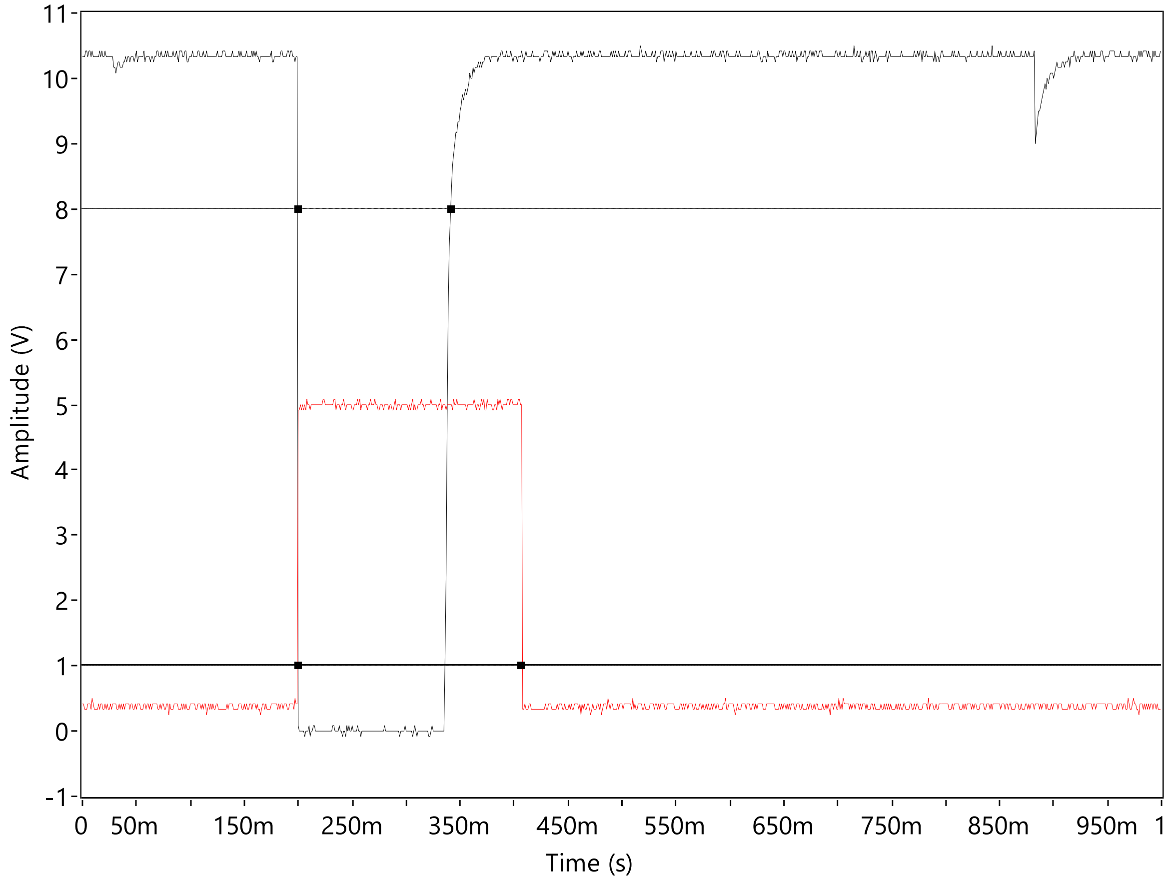
Run 5. Event recap



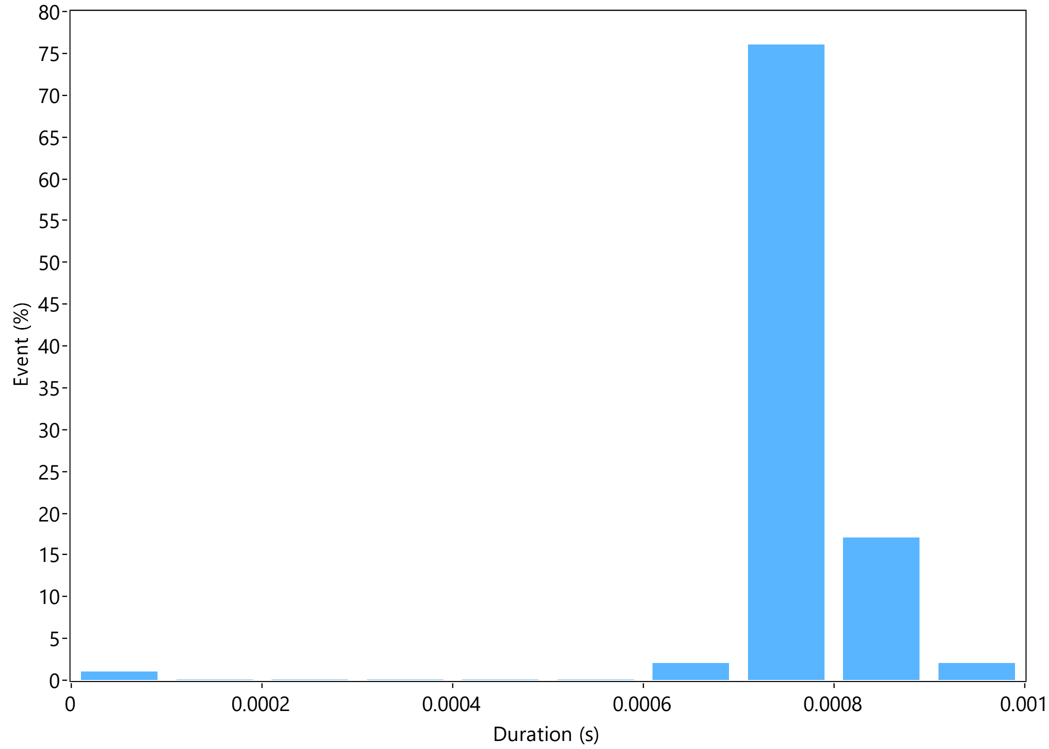
Run 5. Example of short event amplitude 1

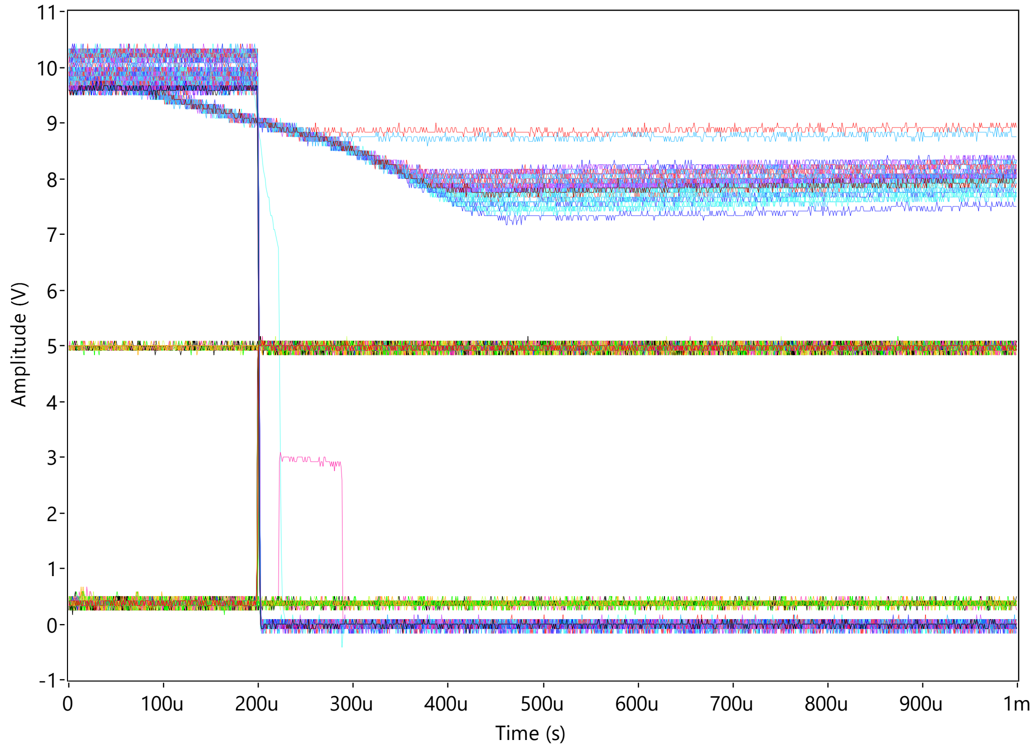


Run 5. Example of short event amplitude 2

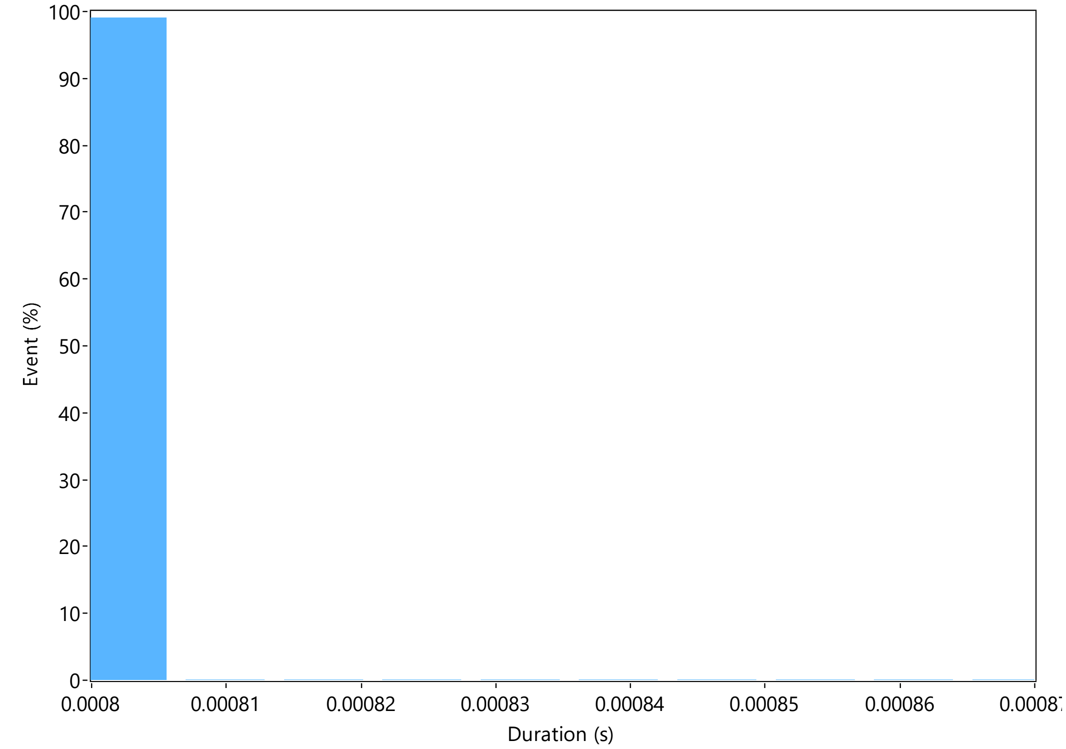


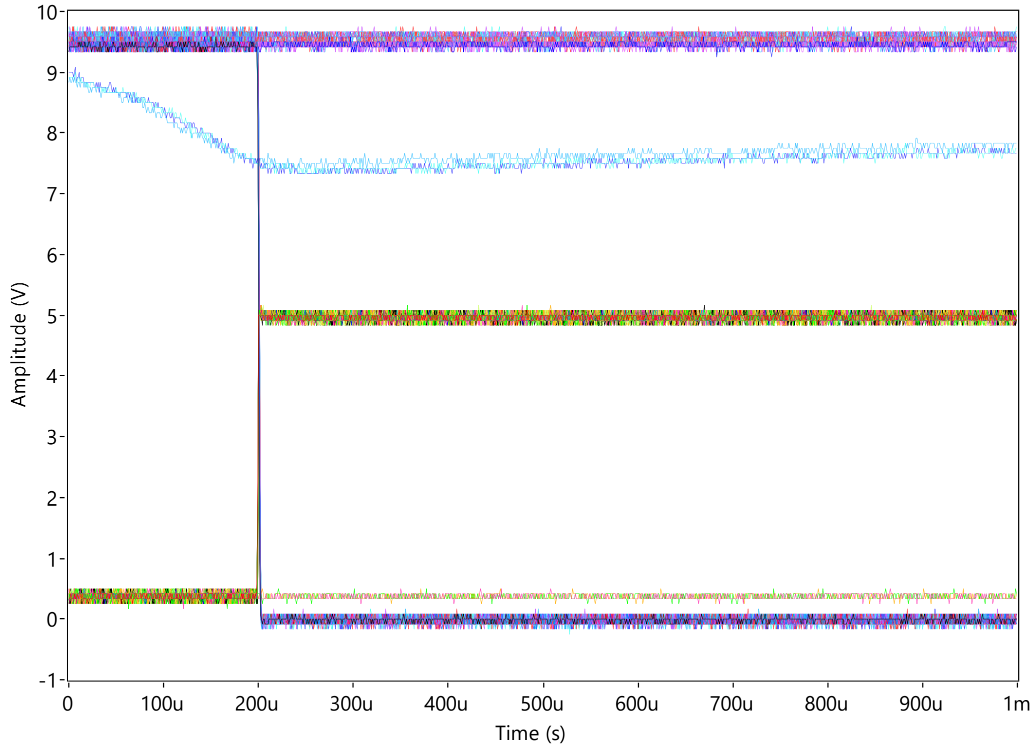
Run 5. Example of short event amplitude 3





Run 6. Event recap





Run 7. Event 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 14 and a schematic of the optical bench is given in Figure 16 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 14: Overview of LISA and specifications of the Nd:YAG pulsed LASER from LISA

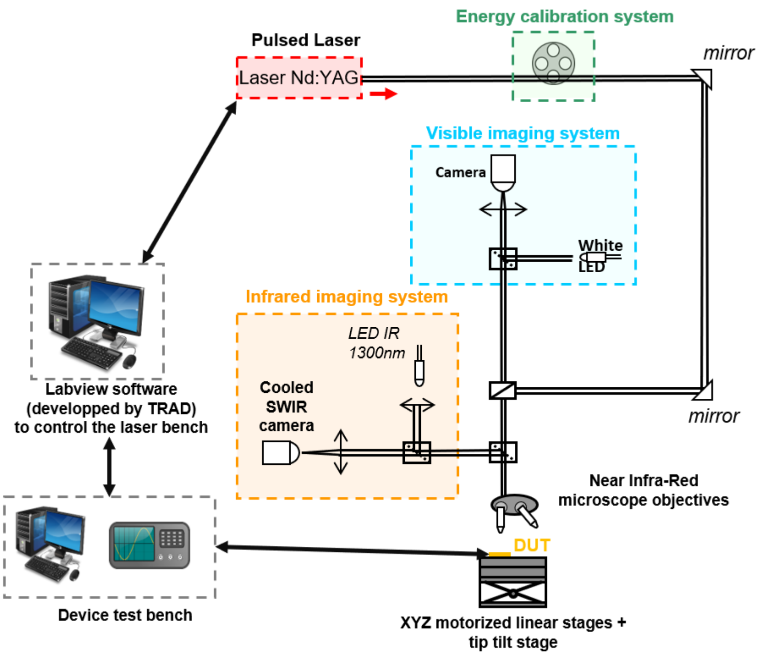


Figure 16: LISA laser test bench

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:

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

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)	SET PGOOD	SET GATE	SEFI	SEL
1	300	1	70	X10	8	6.05	-	S-scan	100	10	1000	0	22	5	0
2	1200	1	Amb	X10	8	6.05	-	Scan	-	10					
3	3600	3	Amb	X10	8	5.04	-	Scan	-	10	-	10	483	64	0
4	300	3	Amb	X50	2.6	6.01	2.51	S-scan	1000	2	2000	-	-	-	0
Conclusion: no SEL/DSEE observed in SEL test config. / Sensitive areas to SET/SEFI identified in SET test config.															

Table 15: LTC4361CTS8 LASER test results

B.3. Sensitive areas on die

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

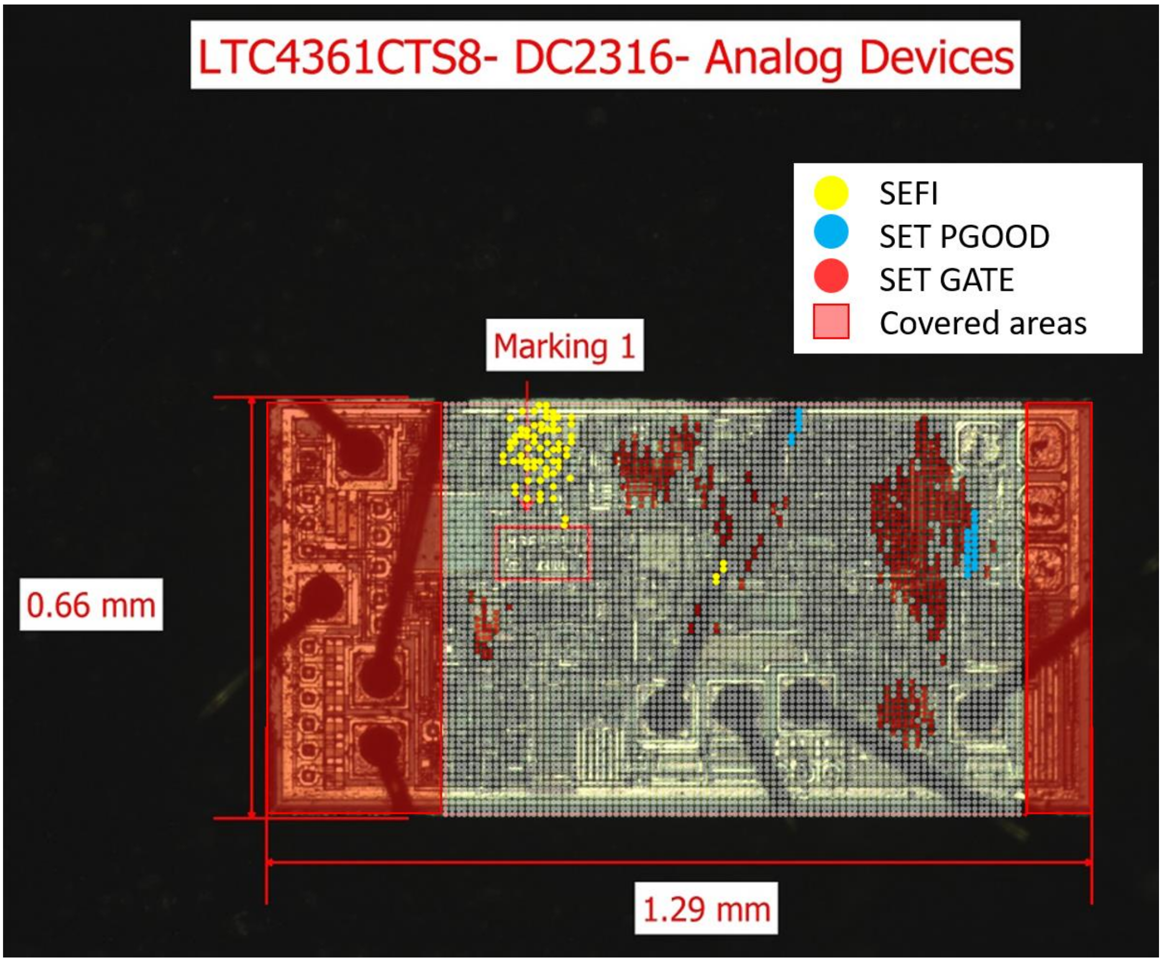


Figure 17: LISA LASER test bench

B.4. Event worst cases

SET PGOOD worst case

Part No.	3
Test Conditions	SET
Type event	Negative SET
nJ/pulse	5.04
Absolute amplitude	5 V
Duration	200.5 ms

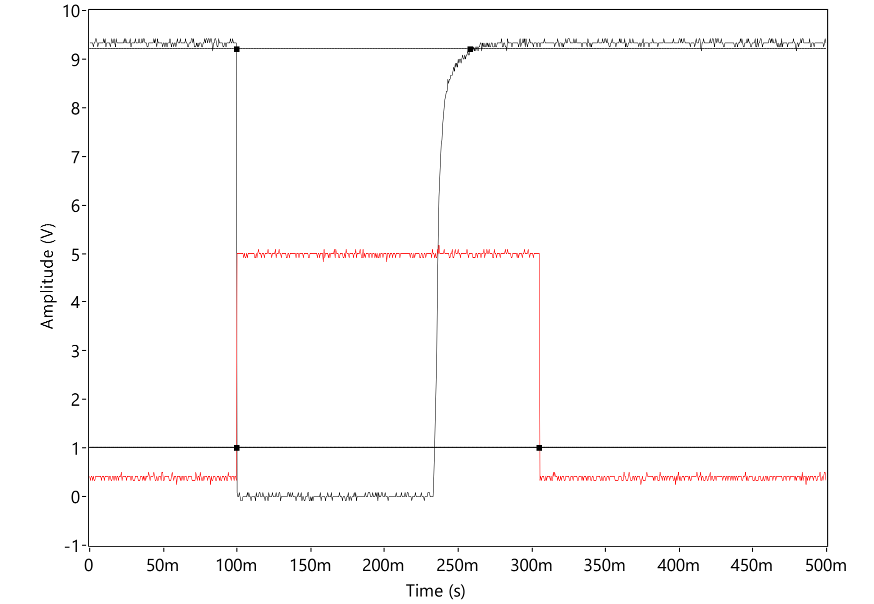


Figure 18: SET PGOOD worst case amplitude

Part No.	3
Test Conditions	SET
Type event	Negative SET
nJ/pulse	6.01
Absolute amplitude	5 V
Duration	396.5 ms

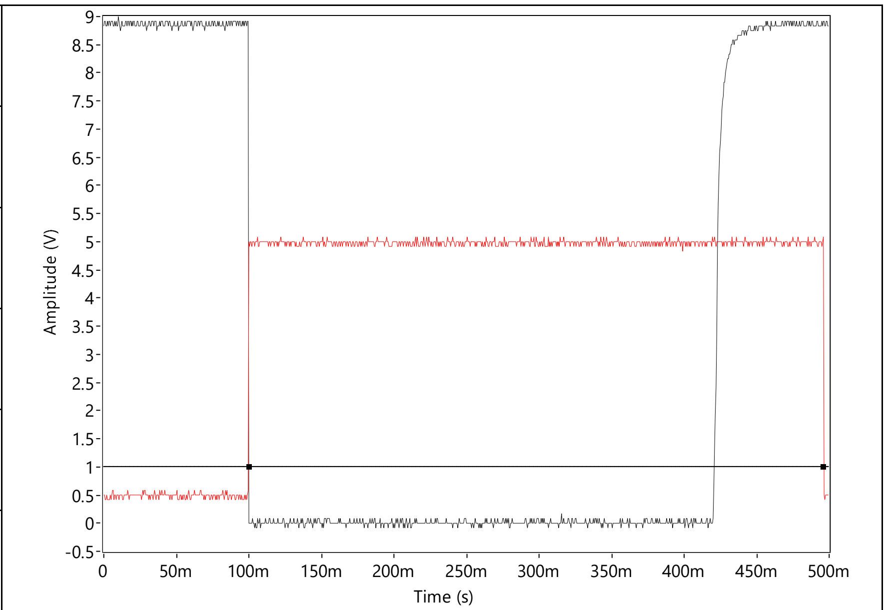


Figure 19: SET PGOOD worst case duration

SET GATE worst case

Part No.	3
Test Conditions	SET
Type event	Negative SET
nJ/pulse	5.04
Absolute amplitude	9.4 V
Duration	164.5 ms

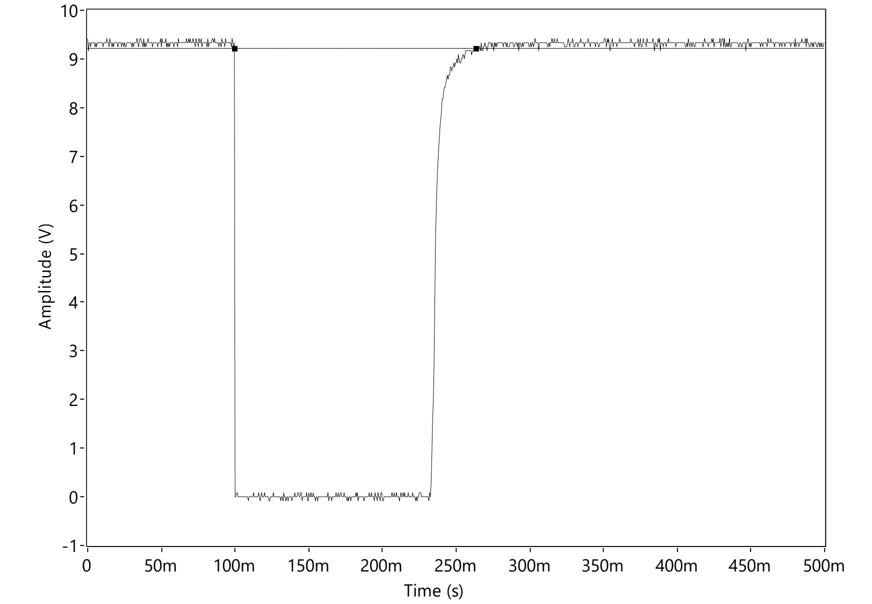


Figure 20: SET GATE worst on amplitude

Part No.	3
Test Conditions	SET
Type event	Negative SET
nJ/pulse	6.01
Absolute amplitude	9 V
Duration	364 ms

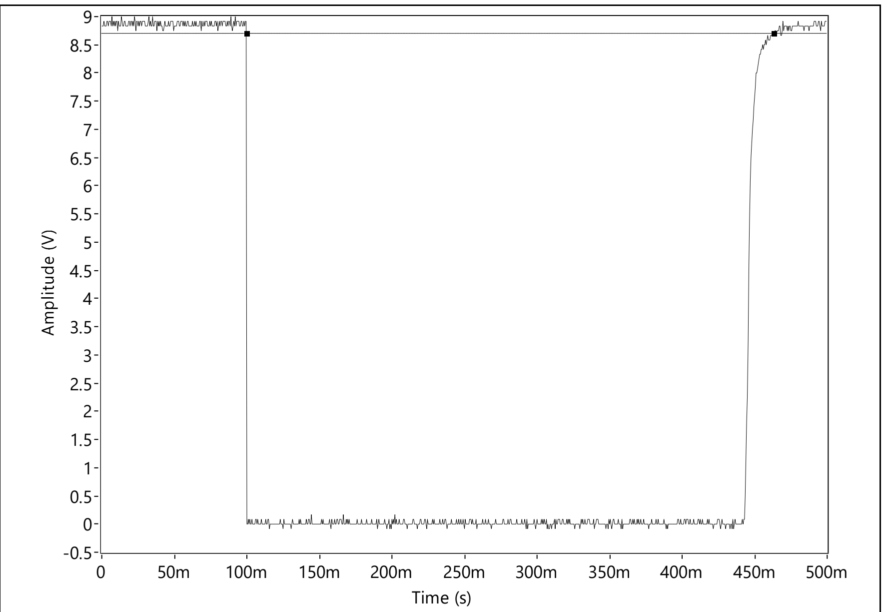


Figure 21: SET GATE worst on duration