Single Event Transient Test Report

TL431BIDMR2G

Date Code: 1240
Programmable Shunt Regulator with 2.5V Bandgap Voltage Reference
ON Semiconductor

Prepared by	**Florian Krimmel**
Reference	**ESA-TECQEC-TR-2022-000879**
Issue/Revision	**1.0**
Date of Issue	**03/01/2022**
Status	**published/authorized**

APPROVAL

Title Single Event Transient Test Report TL431BIDMR2G	
Issue Number 0	**Revision Number** 0
Author Florian Krimmel	**Date** 03/01/2021
Approved By	**Date of Approval**

CHANGE LOG

Reason for change	Issue Nr.	Revision Number	Date

CHANGE RECORD

Issue Number 0	**Revision Number 0**		
Reason for change	**Date**	**Pages**	**Paragraph(s)**

DISTRIBUTION

Name/Organisational Unit

Table of contents:

1 APPLICABLE/REFERENCE DOCUMENTS

1. ESCC25100 section 6: Single Event Effects Test Methods and Guidelines
2. Datasheet of TL431BIDMR2G: https://www.onsemi.com/pdf/datasheet/tl431-d.pdf

2 TEST OBJECTIVES AND REQUIREMENTS TO BE VERIFIED

2.1 Test Objectives

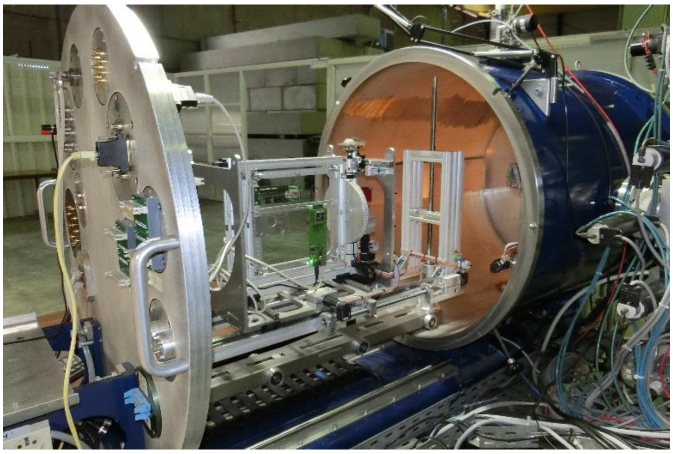
Test objective is to assess the heavy-ion SET sensitivity of this part.
This test report will be uploaded in the ESA Radiation Database (https://esarad.esa.int) and this data should also contribute to the development of safe design margins for COTS components.

The test campaign was performed on the 10th November at UCL.

2.2 Test facility

UCL Louvain Heavy Ion Facility

https://uclouvain.be/en/research-institutes/irmp/crc/heavy-ion-facility-hif.html



-Irradiation area: Ø25 mm
-Flux from a few ions/(s.cm2) up to 1,5E4 ions/(s.cm2)

Ion	Energy on device	Range on device	LET on device
	[MeV]	[µm]	[MeV/(mg/cm²)]
$^{13}C^{4+}$	131	269,3	1,3
$^{22}Ne^{7+}$	238	202	3,3
$^{27}Al^{8+}$	250	131,2	5,7
$^{36}Ar^{11+}$	353	114,0	9,9
$^{53}Cr^{16+}$	505	105,5	16,1
$^{58}Ni^{18+}$	582	100,5	20,4
$^{84}Kr^{25+}$	769	94,2	32,4
$^{103}Rh^{31+}$	957	87,3	46,1
$^{124}Xe^{35+}$	995	73,1	62,5

The ions used are highlighted.
Fluence was adapted in order to have enough statistical events.
All test were performed without tilting the components.

3 DUT & TEST CONFIGURATION/CONDITIONS

3.1 Description of the DUT

The TL431A, B integrated circuits are three−terminal programmable shunt regulator diodes. These monolithic IC voltage references operate as a low temperature coefficient zener which is programmable from V ref to 36 V with two external resistors.

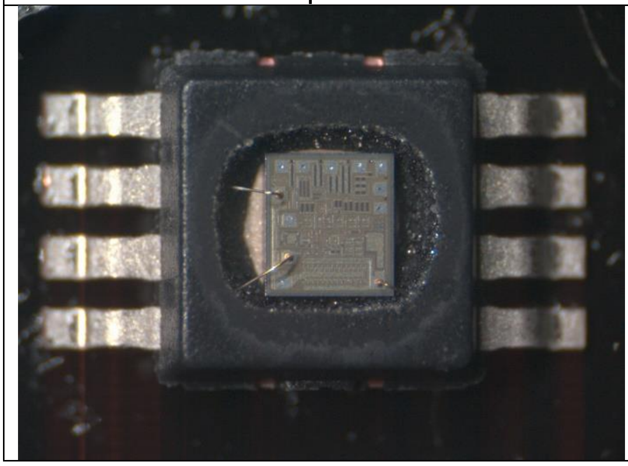
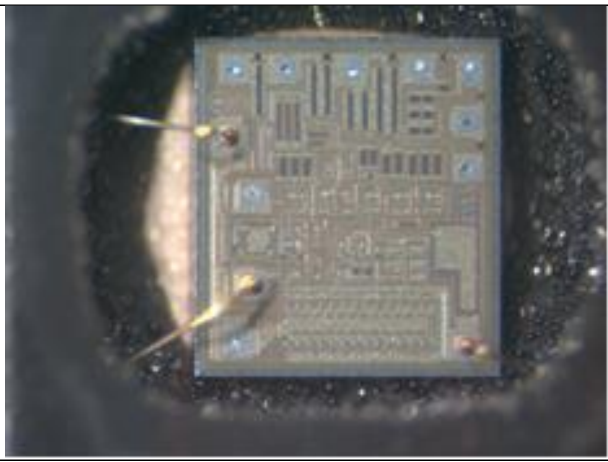
The table below shows the key parameters of the selected DUTs.

Component Family Name	Component Name	Manu-facturer	Automotive, AEC-Q100	Distributor	Component Laser Marking	Date-code YYWW	Lot-code from distributor
TL431	TL431BIDMR2G	ON Semi	no	Mouser	TBI RXN..	1240	-

Vz	Initial Tolerance	IZ_min	IZ_typ	IZ_max	Long term stab.	Hysteresis (thermal) -40 to 125 degC	Package
2.495 V	0.4 %	1mA	10mA	100mA	-	-	Micro8

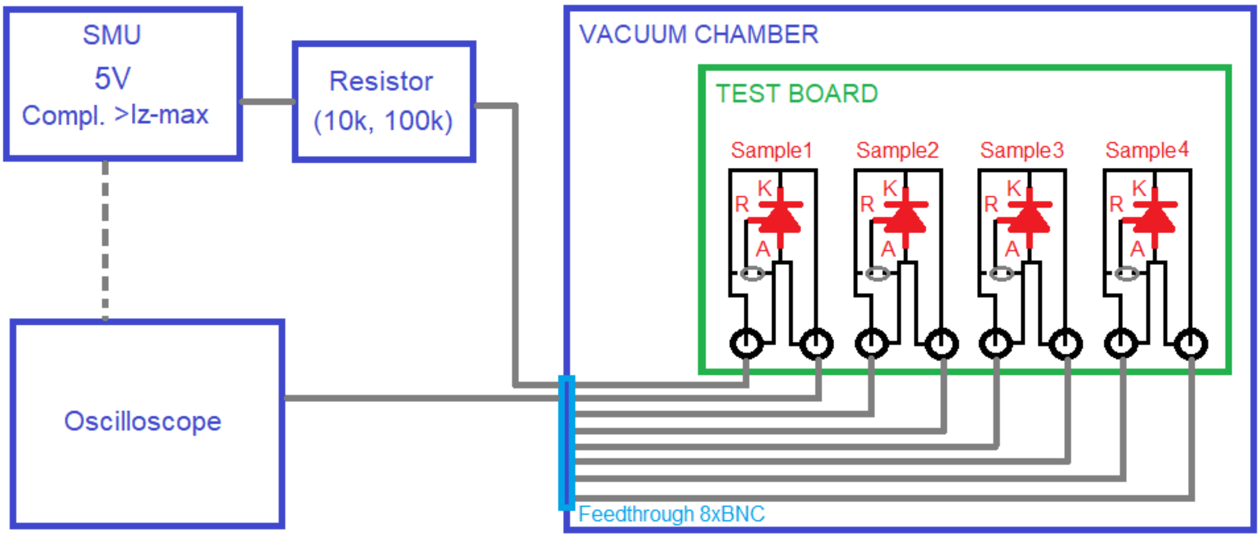
3.2 DUT Preparation

Two sets of the samples have been decapsulated by using Nitric Acid on the top side as shown in the pictures below:

Component	Die
	

3.3 Test set-up description and preparation

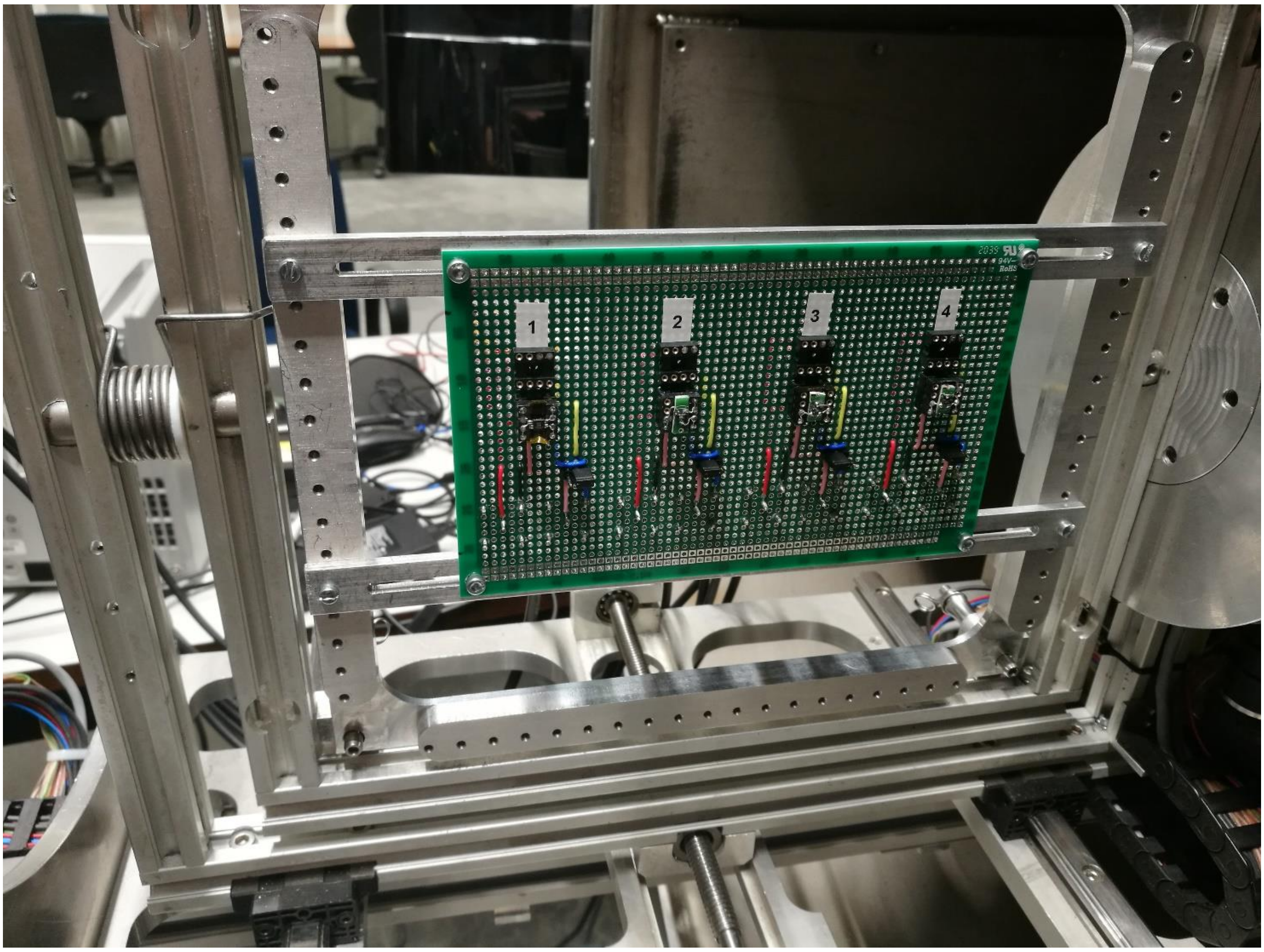
Schematic:



Measurement equipment:

Oscilloscope Agilent Technologies infiniium MSO9404A: 4Ghz	
SMU source measure unit KEITHLEY 2410	

Test Board mounted on the frame inside the vacuum chamber:



3.4 Test Parameters

Voltage Source:

- Provides a constant voltage of 5V
- Resistor adjusted accordingly to reach the min, typ and max Iz current (Value according to run log table)
- No capacitor on the input of the component

Load:

- Output of the references unloaded and without capacitor

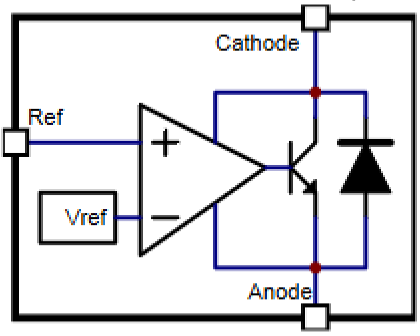
Environmental condition:

- All test performed under vacuum
- All test performed at room temperature

Oscilloscope:

- Trigger Mode: Window trigger (min and max)
- Trigger level: as small as possible depending on the background noise (+- 150mV)

Connection of the reference pin:



The reference pin can be connected via a jumper on the test board to the Anode or the Cathode.

4 TEST RESULTS

4.1 Run Log

The Log table below shows all successful runs related to the component TL431BIDMR2G:

PRE-RUN INPUTS

Run	DUT	Input Voltage (V)	Input resistor (Ohm)	Iz (MIN, TYP, MAX)	Ref pin configuration (A - anode or K -	Title (°)	Vacuum (Y/N)?	Particle	Energy (MeV)	LET Normal in Si (90°) [For P see "SRIM"]	LET Effective (in Si)	Range (um)	Flux target (/cm²/s)	Fluence target (/cm²)	Duration Target (sec)	Beam Homogenity (%)	Scope - Trig_high (V)	Scope - Trig_low (V)	Scope - Hold off time (us)
3	TL431_ON_S1	5	2400	MIN	K	0	Yes	Xe	995	62.5	62.5	73.1	2.00E+02	1.00E+09	5000000	10	2.65	2.35	20
4	TL431_ON_S1	5	240	TYP	K	0	Yes	Xe	995	62.5	62.5	73.1	2.00E+02	1.00E+09	5000000	10	2.65	2.35	20
5	TL431_ON_S1	5	240	TYP	K	0	Yes	Xe	995	62.5	62.5	73.1	2.00E+02	1.00E+09	5000000	10	2.65	2.35	20
6	TL431_ON_S1	5	240	TYP	K	0	Yes	Xe	995	62.5	62.5	73.1	2.00E+02	1.00E+09	5000000	10	2.65	2.35	20
7	TL431_ON_S1	5	27	MAX	K	0	Yes	Xe	995	62.5	62.5	73.1	2.00E+02	1.00E+09	5000000	10	2.65	2.35	20
25	TL431_ON_S1	5	240	TYP	K	0	Yes	Kr	769	32.4	32.4	94.2	1.00E+03	1.00E+09	1000000	10	2.65	2.35	20
26	TL431_ON_S1	5	240	TYP	K	0	Yes	Cr	505	16.1	16.1	105.5	1.00E+03	1.00E+09	1000000	10	2.65	2.35	20
30	TL431_ON_S1	20	240	TYP	A	0	Yes	Cr	505	16.1	16.1	105.5	5.00E+03	1.00E+09	200000	10	20.2	19.8	20

POST-RUN INPUTS & RESULTS

Run	DUT	Start time	Duration actual (sec)	Fluence actual (/cm²)	Cumulative Fluence (/cm²)	Flux actual (/cm²/s)	Run dose (krad)	Total dose (krad)	Test OK/ NOK	Vout average (V)	Iz measured (mA)	# SET (scope triggers)	SET XS (cm²)	Vmax for this run (V)	Vmin for this run (V)	Observations
3	TL431_ON_S1	17:18	435	8.89E+04	3.50E+05	204.367816	8.89E-02	8.89E-02	OK	2.46	1.045	214	2.41E-03	3.057	1.348	Output file set to "tsv" mode now. Time resolution to 20 us (based on previous runs). In "tsv" mode, we seem to be at a good flux (highest level) as it takes longer to record the events (almost the box "in progress" is appearing).
4	TL431_ON_S1	17:30	100	2.15E+04	3.71E+05	215	2.15E-02	1.10E-01	NOK	-	10.42	67	3.12E-03	>3.5	-	We saw some positive events above 3.5V (saturated due to scope settings). We stopped earlier and improved the settings to read up to 4V.
5	TL431_ON_S1	17:35	458	9.68E+04	4.68E+05	211.353712	9.68E-02	2.07E-01	OK - o	2.47	10.42	255	2.63E-03	>4	1.403	Positive SET going above 4V (max scope level), only a few though. Many SET fully captured.
6	TL431_ON_S1	17:47	435	9.24E+04	5.61E+05	212.413793	9.24E-02	3.00E-01	OK	2.47	10.42	280	3.03E-03	4.831	-	Clean run. However the Vmin was not recorded in time but did not go below the 1V visualisation, so all data recorded is good.
7	TL431_ON_S1	18:01	553	1.15E+05	6.76E+05	207.9566	1.15E-01	4.15E-01	OK - o	2.48	90.58	296	2.57E-03	>8	1.438	There were a few - not many - SET with amplitude higher than 8V (scope limit). There were also some SET very small (below 1 us and just above the trig voltage) that we did not seem in TYP or MIN condition.
25	TL431_ON_S1	21:47	150	1.43E+05	1.43E+05	953.333333	7.41E-02	4.89E-01	OK	2.47	10.42	244	1.71E-03	4.506	1.479	Settings are ok, run good.
26	TL431_ON_S1	22:11	343	3.44E+05	4.87E+05	1002.91545	8.86E-02	5.77E-01	OK	2.47	10.42	203	5.90E-04	4.125	1.045	Settings are ok, run good.
30	TL431_ON_S1	22:46	327	1.68E+06	1.68E+06	5137.61468	4.33E-01	1.01E+00	OK	-	0.024	0	0.00E+00	-	-	Config in Anode. NO events at all in these conditions.

The component has been tested with three different ions (Xe, Kr, Cr). Under Xe, three tests runs at different Iz currents have been done in order to spot the worst case conditions.

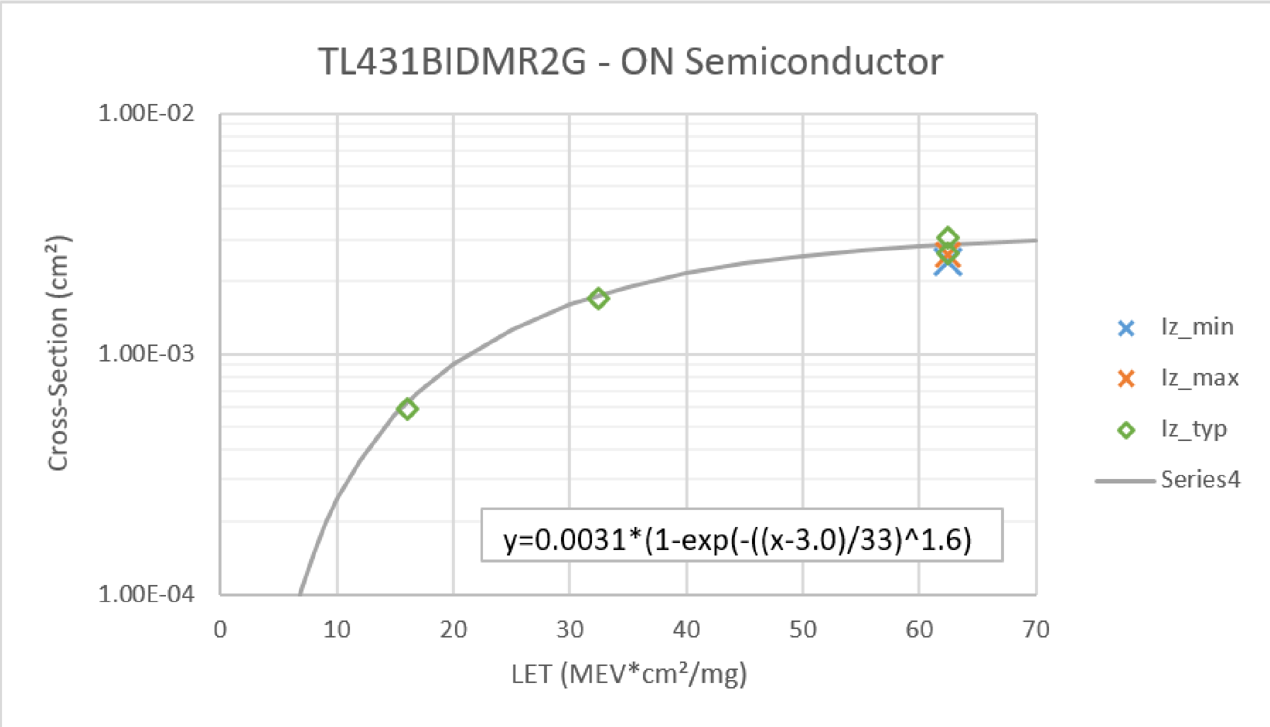
Only the typical Iz values was used to test under Kr and Cr.

The last run was done with a different reference pin configuration (Ref->Anode). Therefore, the component could be tested in the off mode of the output transistor. In this configuration no SET where seen.

The component received a total cumulative TID of 1.01 krad.

4.2 Cross Section

The cross section of all runs was calculated and is shown in the plot for different LETs.



Weibull parameters	
W	33
S	1.6
Limit	0.0031
LET threshold	3.0

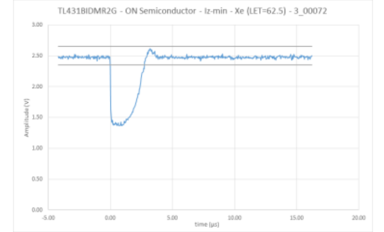
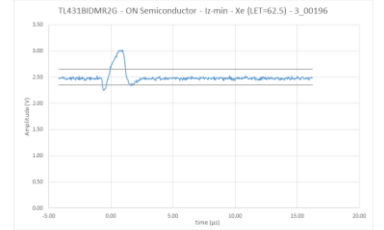
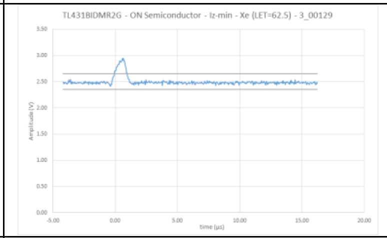
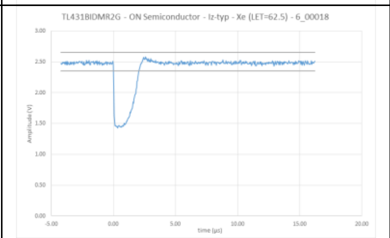
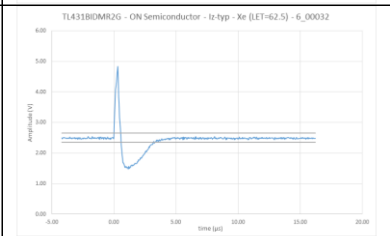
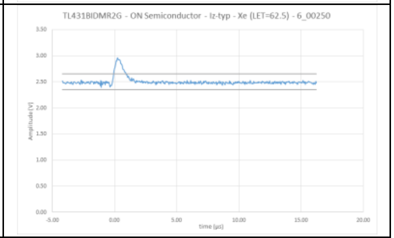
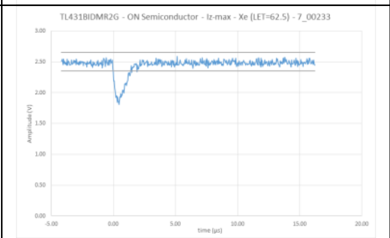
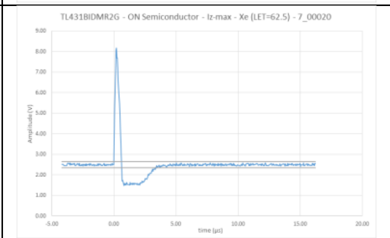
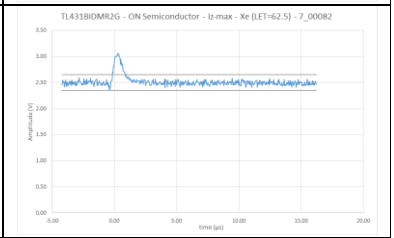
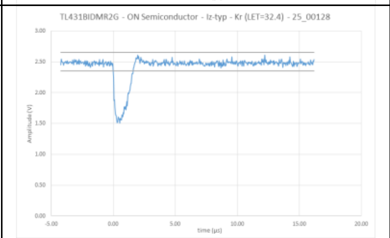
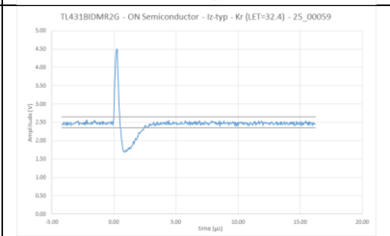
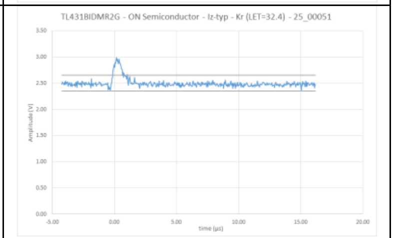
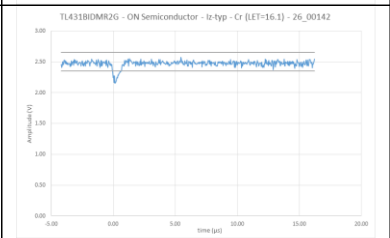
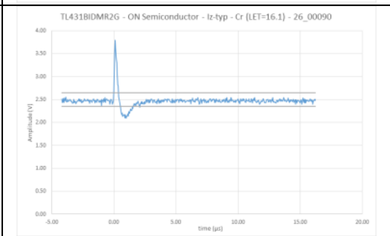
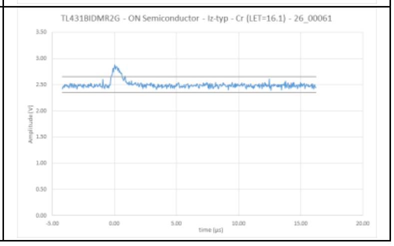
All different tested Iz condition show a similar behaviour in the same order of magnitude.

Due to the fact that around 300 events were measured, the very small error bars were not displayed.

The LET threshold is estimated only with 3 points interpolation with high inaccuracy. For a more accurate Weibull curve, more measurement points are required, including some close to the LET threshold.

4.3 Transients

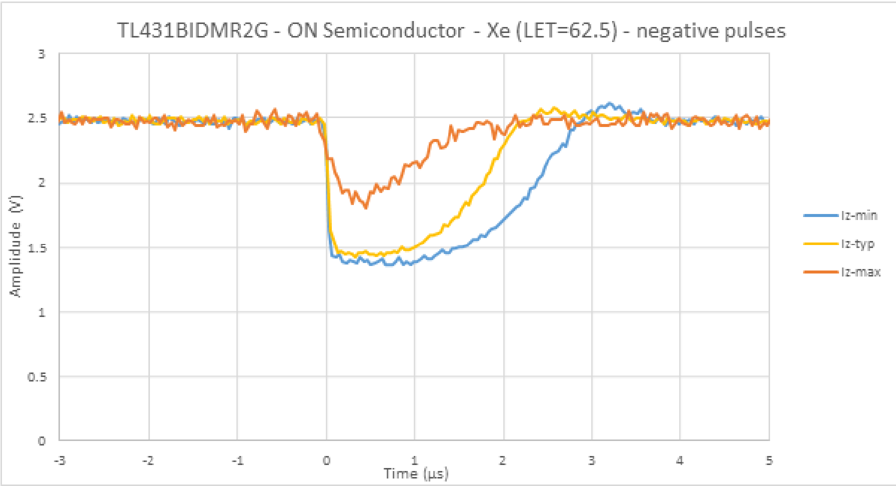
The following table shows examples of typical and worst case transients observed on the DUT. The trigger levels are shown by the grey lines.

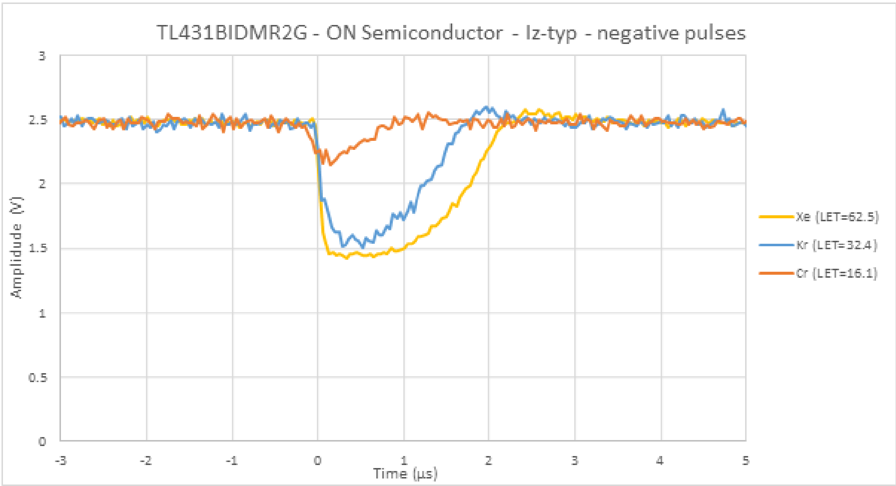
Run No.	only negative pulses	bipolar pulses	only positive pulses
3 Iz-min LET= 62.5			
6 Iz-typ LET= 62.5			
7 Iz-max LET= 62.5			
25 Iz-typ LET= 32.4			
26 Iz-typ LET= 16.1			

4.4 Transients Compared

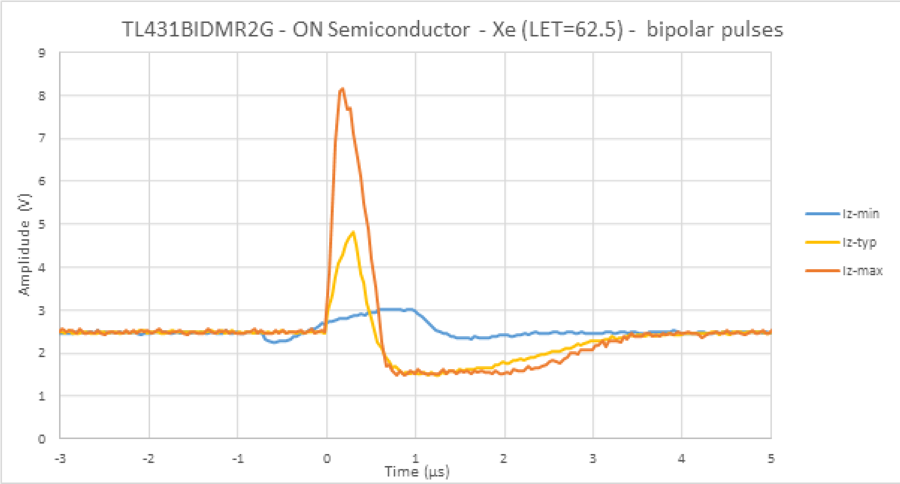
The following plots show the different shape of the worst-case transients for negative, positive and bipolar pulses regarding the LET and different Iz values.

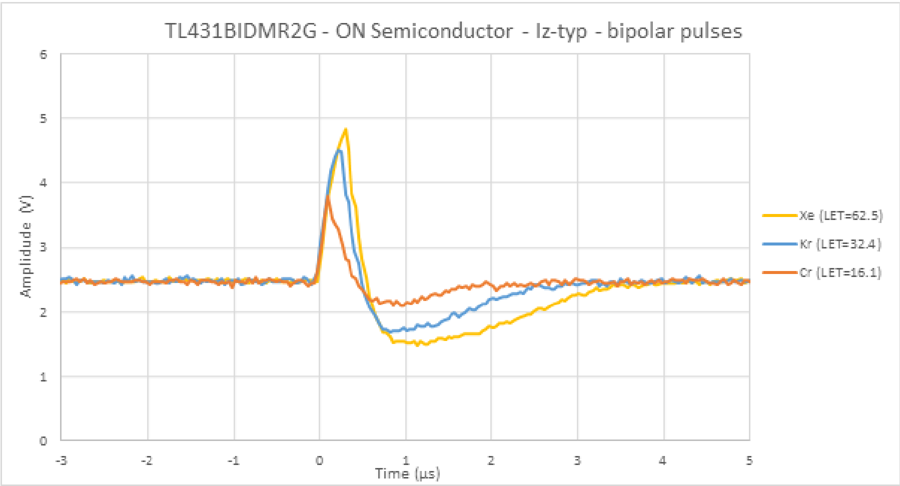
Negative pulses are those that have only exceeded the lower trigger level and the same for the positive pulses with the higher trigger level. Bipolar pulses are those events, which exceeded both the higher and the lower trigger level.



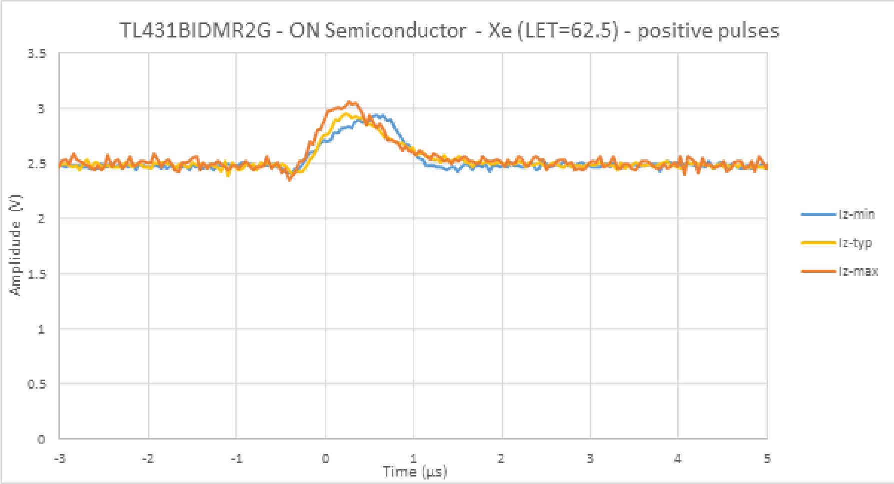


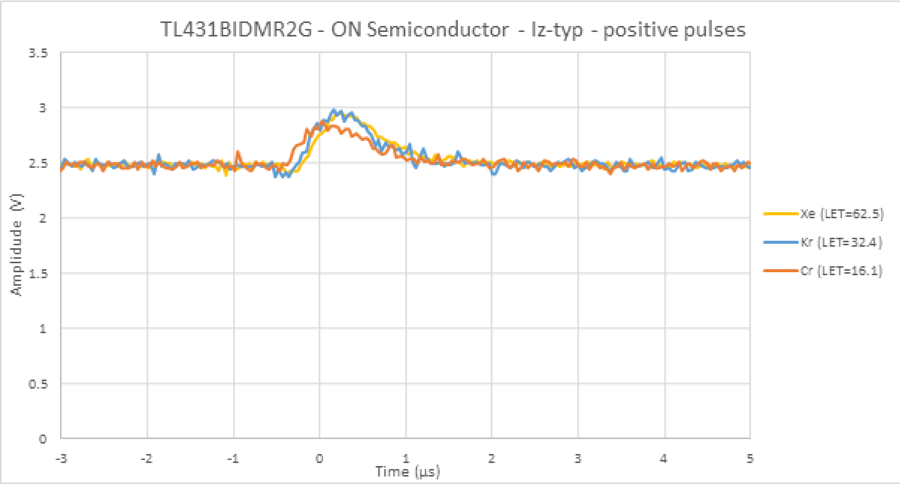
The worst-case negative transients seem to be dependent of the LET as well of the Iz condition in terms of their pulse width and there amplitude.





The worst-case bipolar transients seem to be dependent of the LET as well of the Iz condition in terms of their pulse width and there amplitude.

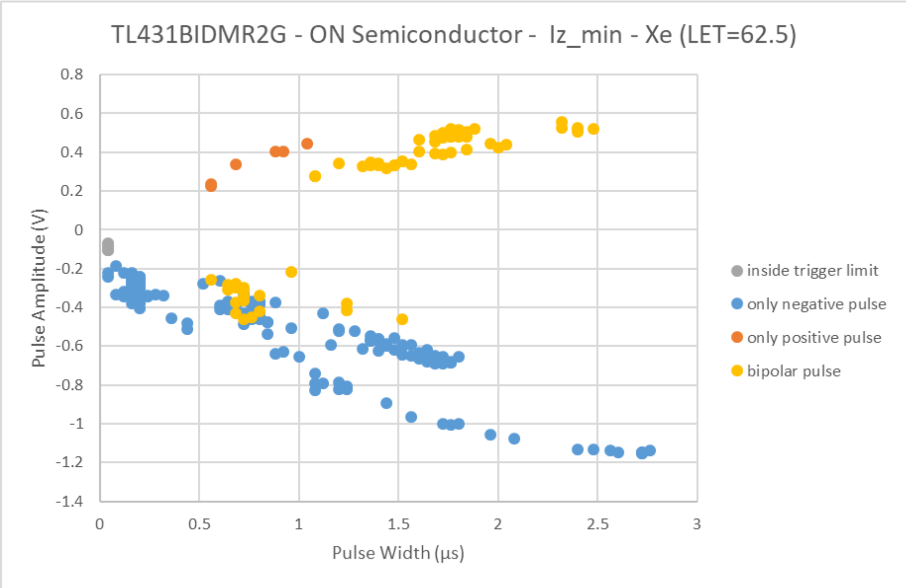


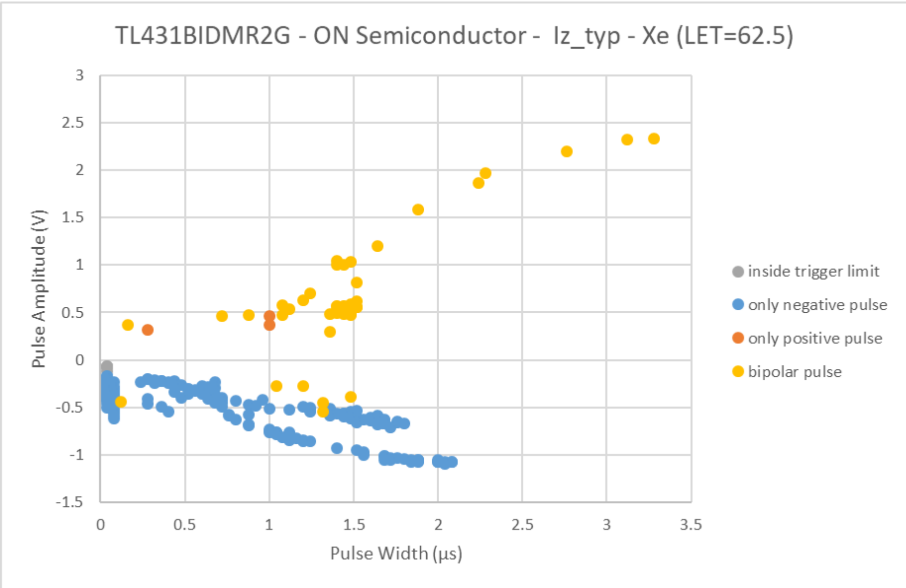


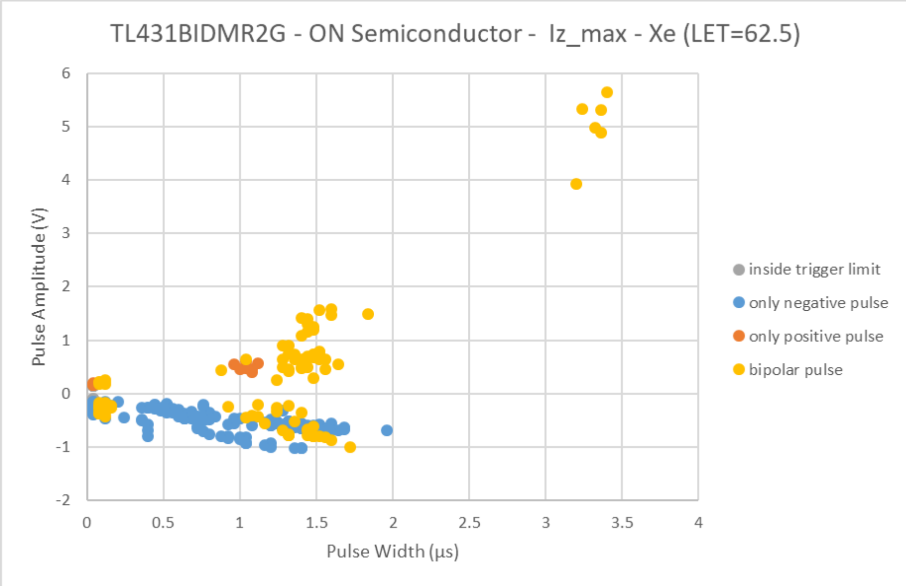
The worst-case positive transients seem to be mainly independent of the LET and Iz condition in terms of their pulse width and there amplitude.

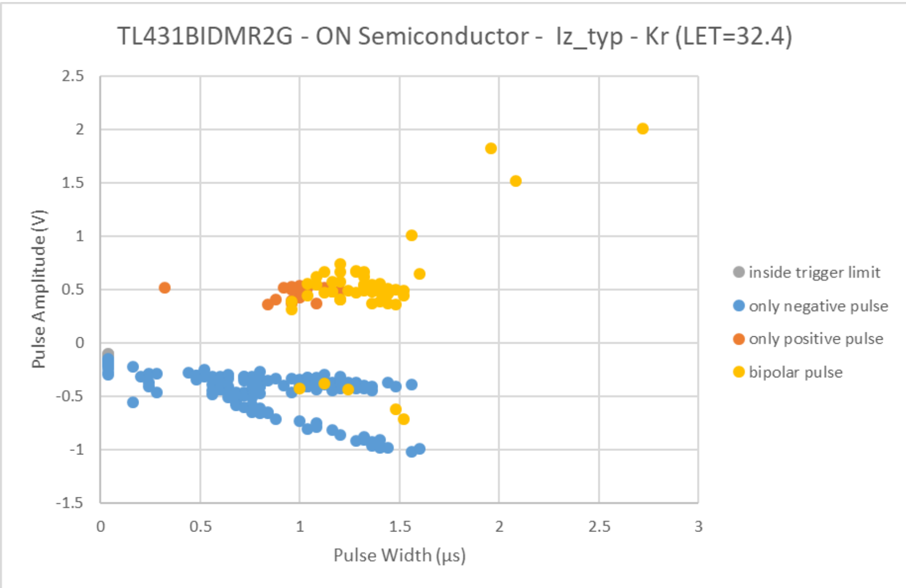
4.5 Pulse width and amplitude

The following plots show all transients for each run on a plot regarding their maximum amplitude and the pulse width. The colour of the groups indicates if the pulse was only negative, positive or bipolar.
The pulses in grey are events, which triggered the scope but do not show any measurement pion outside the trigger levels due to the limited sampling rate.
The Amplitude level is plotted relative to the average output voltage without events.

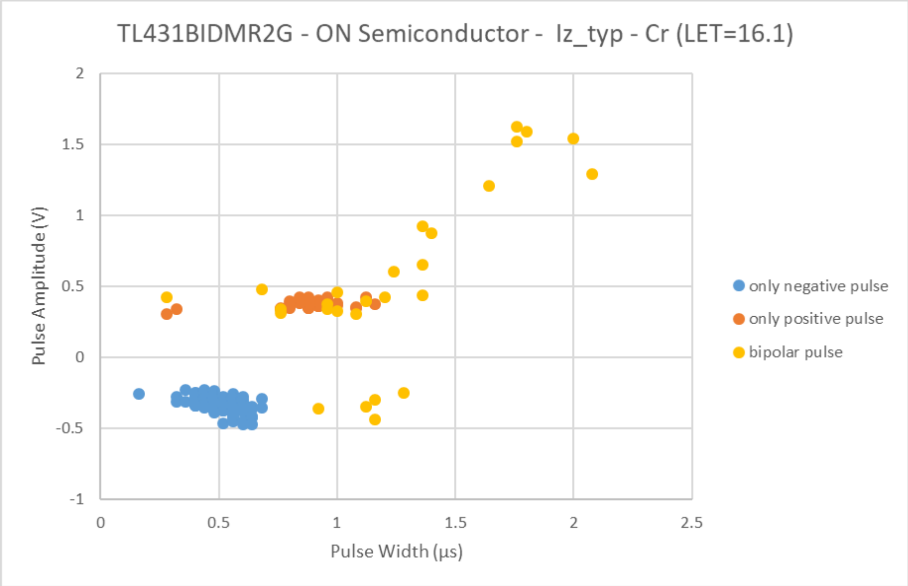






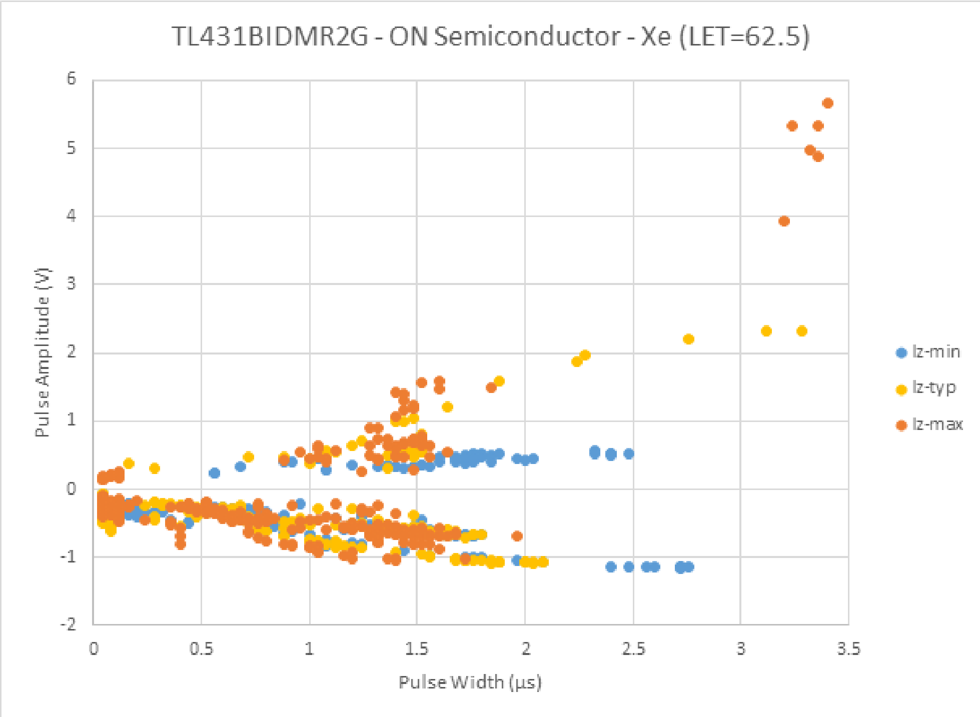


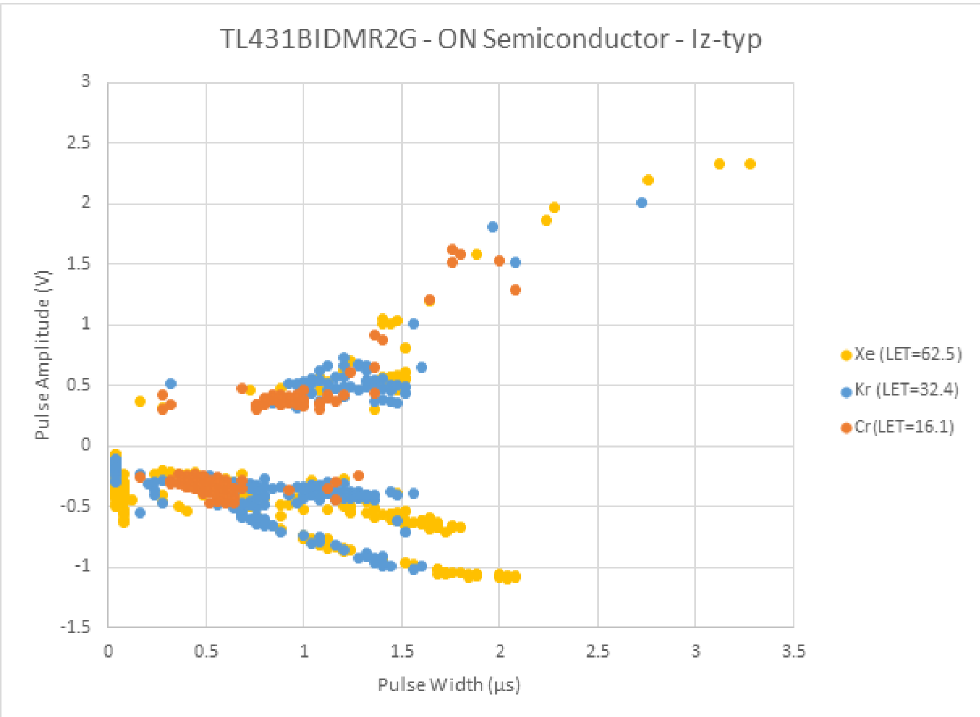
European Space Agency
Agence spatiale européenne


TL431BIDMR2G - ON Semiconductor - Iz_typ - Cr (LET=16.1)
Pulse Amplitude (V)
2
1.5
1
0.5
0
-0.5
-1
0
0.5
1
1.5
2
2.5
Pulse Width (µs)
only negative pulse
only positive pulse
bipolar pulse

4.6 Pulse width compared

The following plots show a comparison of pulse amplitude and pulse width vs. Iz current values and the LET.





5 CONCLUSION

No destructive events were observed up to an LET of 62.5 MeV*cm²/mg. All transients were analysed and their amplitudes were plotted against their width.

It seems that at these LET above 16, the Iz has more impact on the SET profile than the LET.

If SETs up to 3.5 µs pulse width and amplitudes of 6V can be filtered by using hardware filter devices next to the component, then there is no SET impact from this device.

Most of the pulses are bipolar or only negative. Especially for the max current measurement, a high positive voltage pulse could be observed. This could come from inductance loops in the test setup and could possibly be mitigated by using a capacitance on the input of the reference.

The cross section of the component could be calculated with the measurements to around 3.1E-03 cm² at a LET of 62.5 MeV*cm²/mg.

One run was done with a different reference pin configuration (Ref->Anode). Therefore, the component could be tested in the off mode of the output transistor. In this configuration no SET where seen.

Finding the LET threshold for these SET events was not the scope of this campaign.