Microsemi

Single Event Radiation Test Report

Microsemi LX7730

64 Analog Input RAD Tolerant Telemetry Controller

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1. Purpose and Scope

This test report presents the results of the LX7730 (64 Analog Input RAD Telemetry Controller) Single Event Effects radiation tests that were performed at the Berkeley LBNL Cyclotron on June 29th 2015 and May 2nd 2016.
Several Microsemi engineers participated in the test.

During these two tests we fully executed the tests described in the test plan **AD1**.
During the test campaign of June 29th we were able to demonstrate a strong initial radiation performance of the device:

- SEL immunity.
- SET immunities on voltages regulated by the device.

During the test campaign of May 2nd we were able to confirm the strong radiation performance of the device:

- Strong performance of the complete telemetry chain under the beam (DC and AC).
- Strong performance of the current sources.
- No SEFIs.

The test data we present below shows that the design is immune to SEL and SEFIs.

2. Applicable Document and Lot Identifiers

The following document forms a part of this test plan and shall be read in conjunction with it.

- Single Event Radiation Test Plan – Microsemi LX7730 64 Analog Input RAD Tolerant Telemetry Controller –– **AD1**

Lot IDs and product version for product tested is as follows:

Packaged parts with serial numbers 200 - 249 are v1r2 silicon revision and lots:
Lot # T59280
Lot # E26133

Packaged parts with serial numbers 1000 - 1060 are v1r4 silicon revision and lots:
Lot # T69493
Lot # E27915

3. TEST SETUP

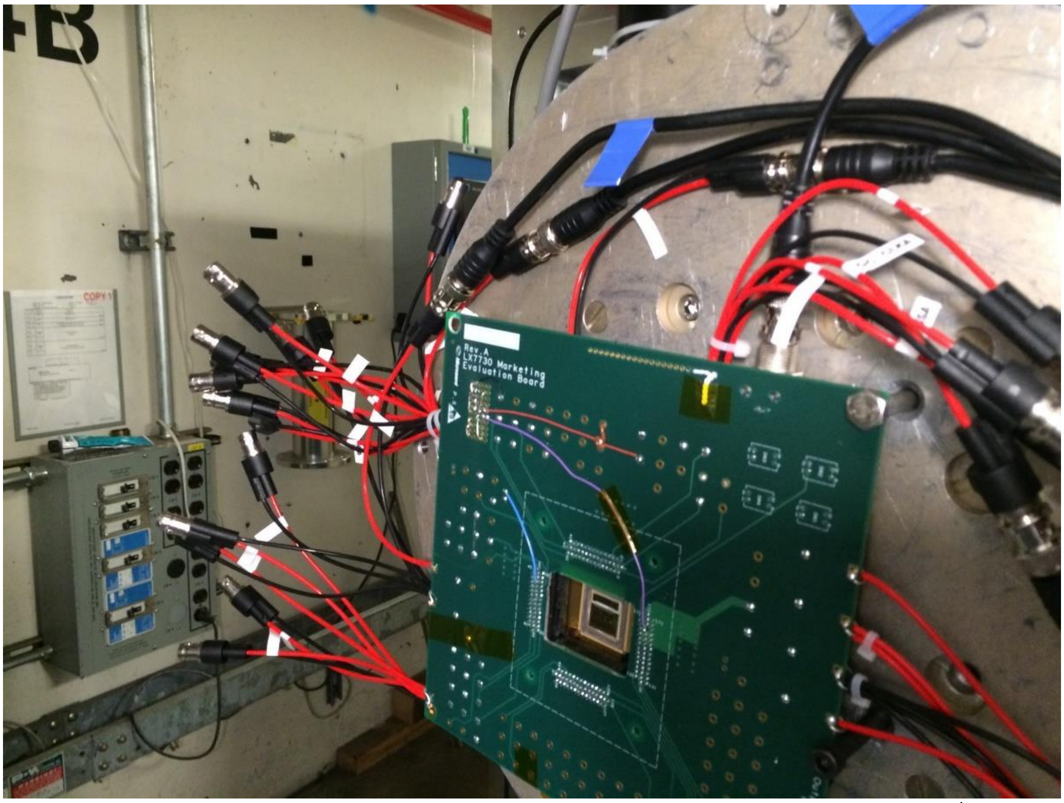
3.1. DUT TEST SETUP

On June 29th 2015, 4 different devices were used for the single event test (see run table in 4.9) :

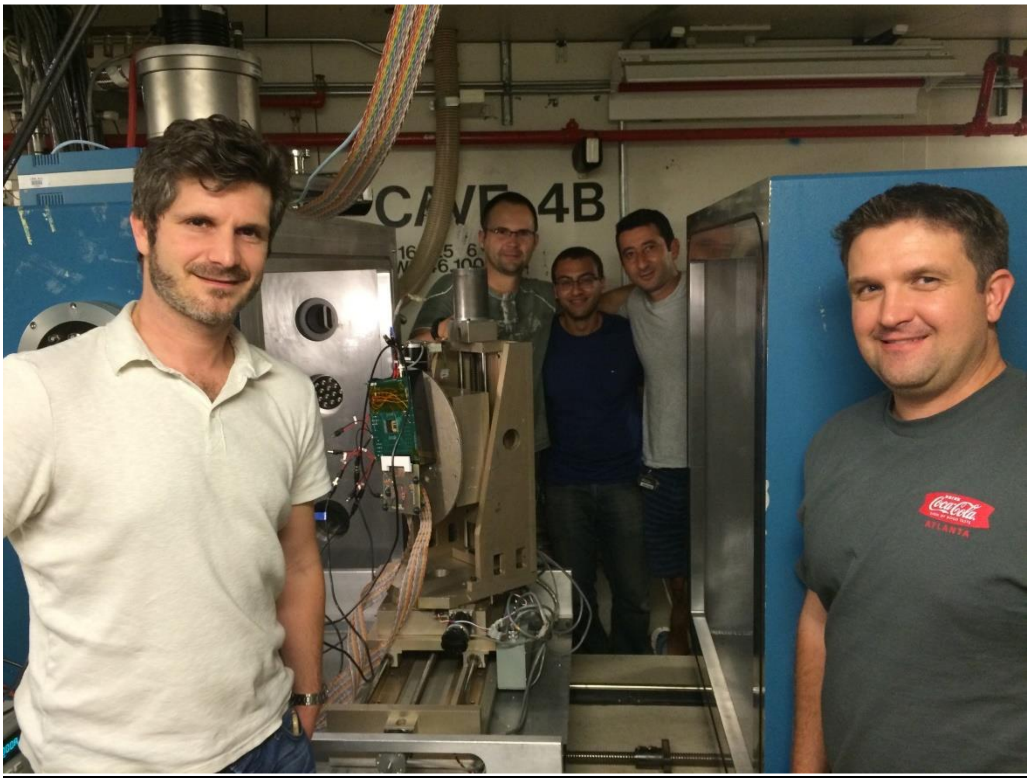
- SN 214 and SN 211: SEL tests at 125°C. An Omega thermal pad KHLV-0502/5 was used to heat the back of the ceramic: During the test, the DUT temperature was controlled real time by a thermocouple.
- SN 210: SEL tests at 125°C and SET tests at 25°C.
- SN 203: all other testst.

On May 2nd 2016, 3 additional devices were used for the single event test (see run table in 4.9) :

- SN 1011 for current source and SET test.
- SN 1004 for AC telemetry test.
- SN 1007 for DC telemetry test, scan chain test and for specific POR (Power On reset) tests.



Picture 1: DUT mounted on the vacuum chamber frame – test on June 29th.



Picture 2: Test crew around the test vacuum chamber.

3.2. BIASING, MONITORING AND BEAM SETUP.

- For SEL tests all voltages were forced to ensure the worst case test condition with maximum voltages and temperatures (+125°C):
  VCC=16V
  VDD=5.5V – forced for SEL tests only
  VEE=-16V – forced for SEL tests only

- For all other tests, VCC was set at its typical value and VEE/VDD were provided by the high voltage chip (the LX7730 is a dual die module using two different processes). Tests were performed at ambient temperature, case temperature was close to to 50°Cdue the DUT power dissipation inside the vacuum chamber

All the test equipment was placed inside the control room and the various DUT commands were sent using the SPI interface, either as low speed (through the laptop) or at high speed (using an FGPA application board). All SPI signals were sent through single BNC cables.

Picture 3: Test setup in the control room.

4. Test Results

All results detailed in this section were taken both on June 29th 2015 and May 2nd 2016.

For all the detailed test conditions of the following tests, refer to **AD1** and the detailed run table presented in §4.9 and §4.10.

In all error rate predictions using CRÈME 96 presented below, the following assumptions have been taken:

- Al shielding is 1g/cm2 or 3.705mm or 145.866 mils.
- Regarding the Solar Min/Max, we took the hypothesis of 2012 (close to solar max). As a reminder the max of Solar cycle 24 was in 2013.4 (previous min in 2009 and future min in 2020).

4.1. POR test

See below for detailed test conditions.

Previous testing showed a POR issue, which required a design fix. The new silicon with the design fix has been tested on May 2nd 2016. The results show that the POR issue has been fixed, two tests were conducted to verify the POR fix :

1. The current source test with POR shows no reset up to LET = 67.87 MeV.cm^2/mg (runs #4 to #17). In this test, the current source is turned-on and a value is loaded into the current source register. No Reset is observed meaning the register does not get reset.
2. The POR pin was monitored and no event is observed up to LET = 79.10 MeV.cm^2/mg and Fluence = 2.5e7 particles/cm^2.

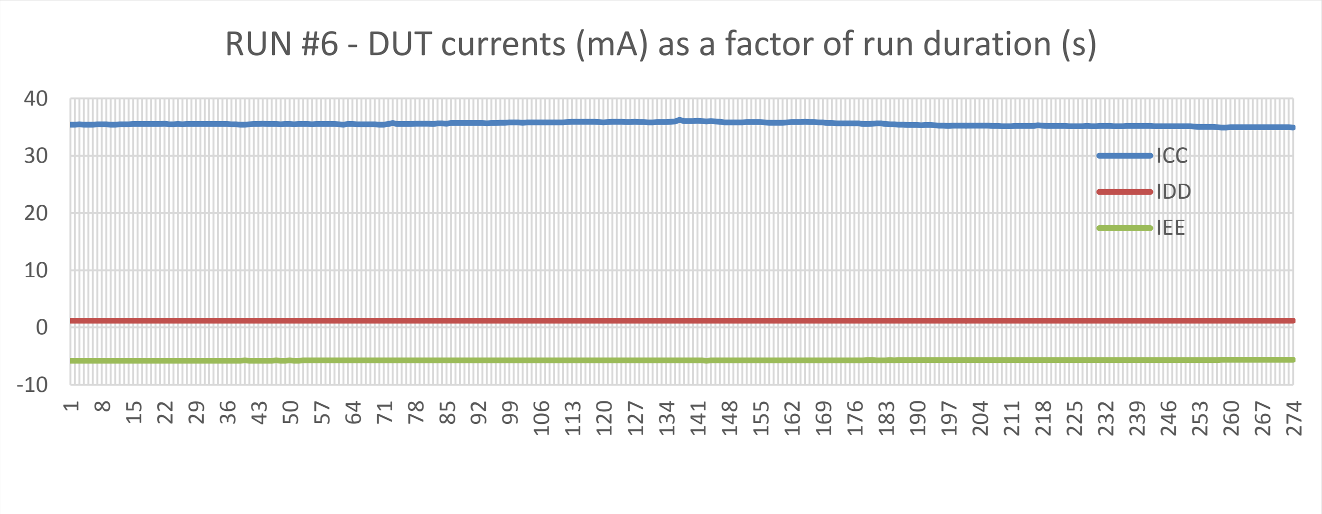
A filtering capacitor on the RESETB pin of 100nF is recommended at the application level.
All runs in this report were performed with a value of 1uF, The cap was reduced further down to 100pF and no RESET events were observed in either case.

4.2. SEL tests : results

See AD1 §4.1 for detailed test conditions.

Results from June 29th:
SEL tests were performed at 125°C during runs #1 to #7 and #16. A total of 3 different samples have been tested and no SEL events were observed.

This chart below presents ICC, IDD and IEE as a factor of run duration for run #6: Fluence = 2e7 particles/cm^2 and LET = 83.13 MeV.cm^2/mg.



Conclusion:

- 3 devices tested: SN214, SN211 and SN210.
- **Test up to 1e8 particles/cm² and 87.85 MeV.cm²/mg (run #16).**

⇨ **We conclude that the device is SEL immune.**

4.3. Regulator TEST: results

See AD1 §4.2 for detailed test conditions.

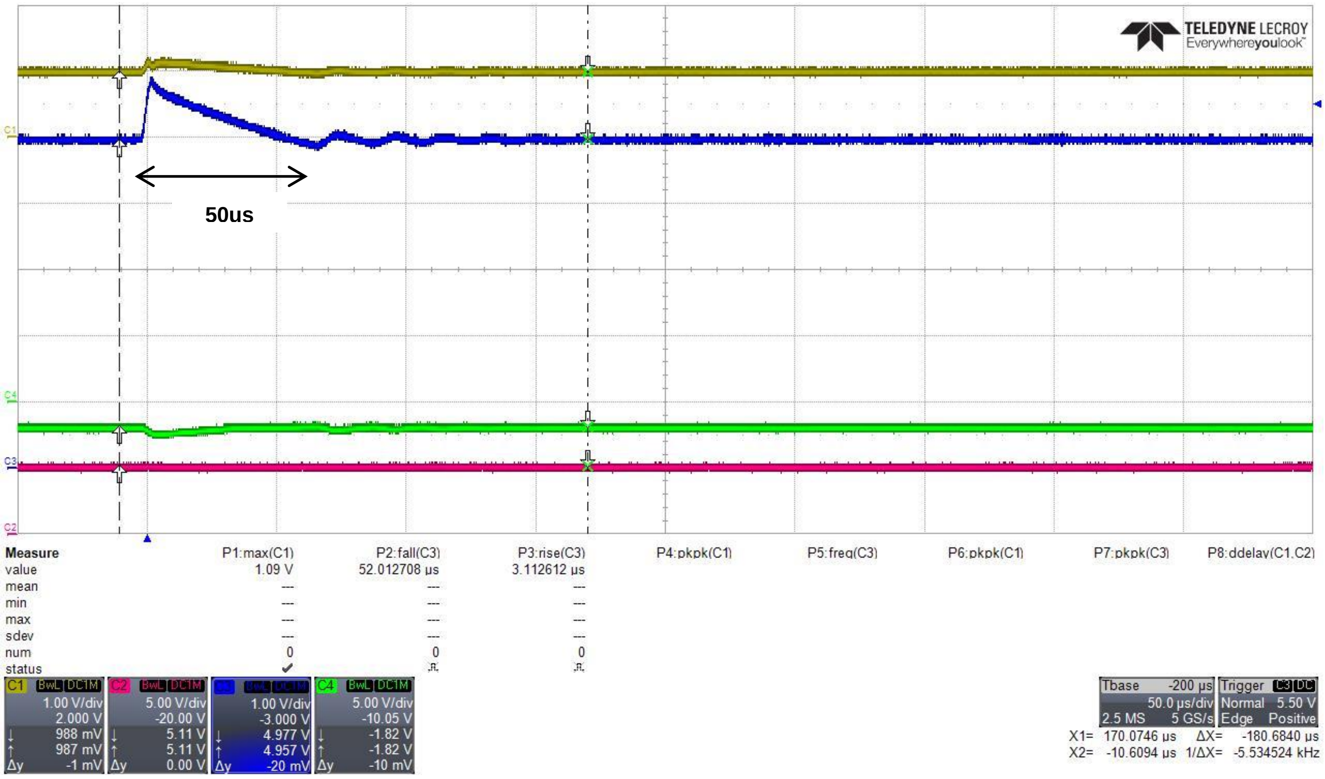
SET tests were performed at room temperature as the 3 power supplies were monitored during most of the runs.

Results from June 29th:

Run #	Ion	LET (MeV.cm²/mg)	Tilt	Effective LET (MeV.cm²/mg)	Flux (cm-2.s-1)	Effective Fluence (cm⁻²)	TID (krad)	SETs	# events	X-section	Test
8		59	0	58.78	1.00E+04	2.64E+06	2.5	0			SET test on +5V with threshold detection at +/-500mV.
9		59	0	58.78	6.00E+04	3.00E+06	2.84	1			SET test on +5V with threshold detection at -150mV.
10		59	0	58.78	6.43E+04	1.50E+07	14.2	0			SET test on +5V with threshold detection at +/-100mV.
11		59	45	83.13	6.00E+04	1.50E+07	14.2	0,0			SET test on +5V and +5V_ref with threshold detection at +/-100mV.
12		59	-45	83.13	8.70E+04	1.50E+07	20.1	0,0			SET test on +5V_ref and -2V with threshold detection at +/-100mV.
13		59	-45	83.13	9.07E+04	1.50E+07	20.1	0			SET test on VEE with threshold detection at +/-100mV.

Results from May 2nd:

The VREF test checks for upsets on the VREF regulator output. An event is triggered if the output rises above 5.5V.

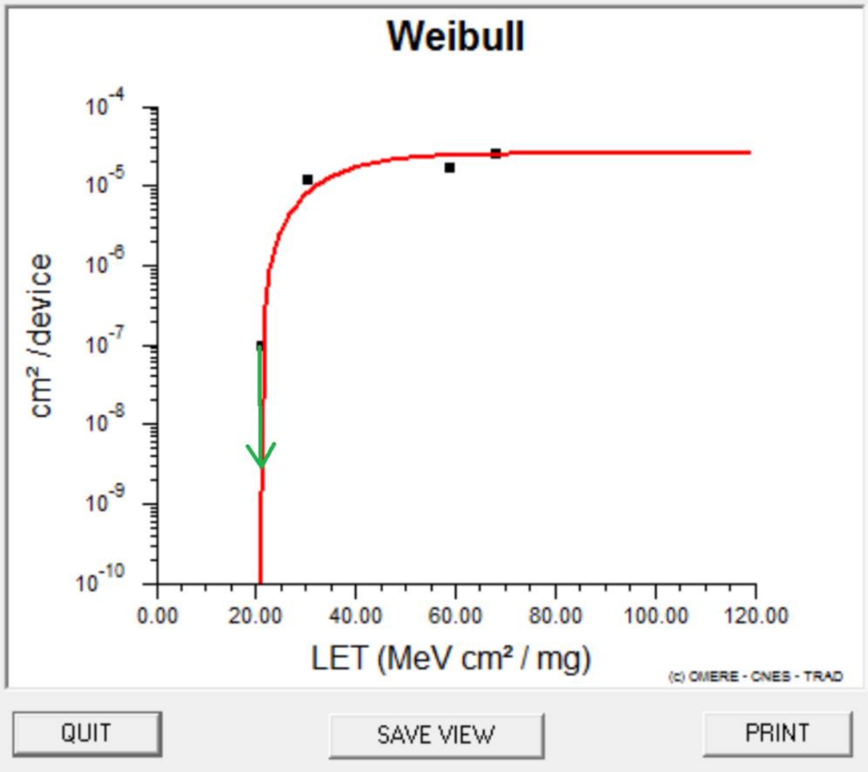


C3: VREF - Trigger on upsets above 5.5V
C1: CH12 - Curent Source on, 2mA - 500Ω load
C2: +5v
C4: MINUS2V

VREF bypass capacitor is 100nF vs the +5V bypass capacitor which is 1uF. This is one possible reason for no noticeable upsets on the +5V generated supply

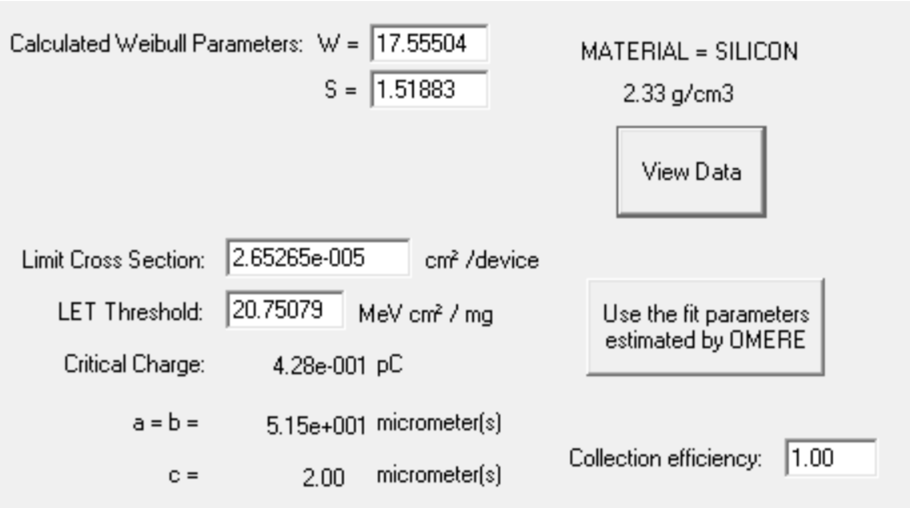
Summary of events:

Run #	Ion	LET (MeV.cm^2/mg)	Tilt	Effective LET (MeV.cm^2/mg)	Flux (cm-2.s-1)	Effective Fluence (cm^{-2})	TID (krad)	SETs	# events	X-section
29	Cu	21.17	0	**21.17**	1.10E+05	1.00E+07	3.41	X	1	**1.00E-07**
27	Kr	30.23	0	**30.23**	7.00E+04	5.02E+06	2.45	X	66	**1.31E-05**
26	Xe	58.78	0	**58.78**	9.00E+04	5.64E+06	5.35	X	100	**1.77E-05**
25	Xe	58.78	30	**67.87**	1.00E+05	1.00E+07	10.94	X	265	**2.65E-05**

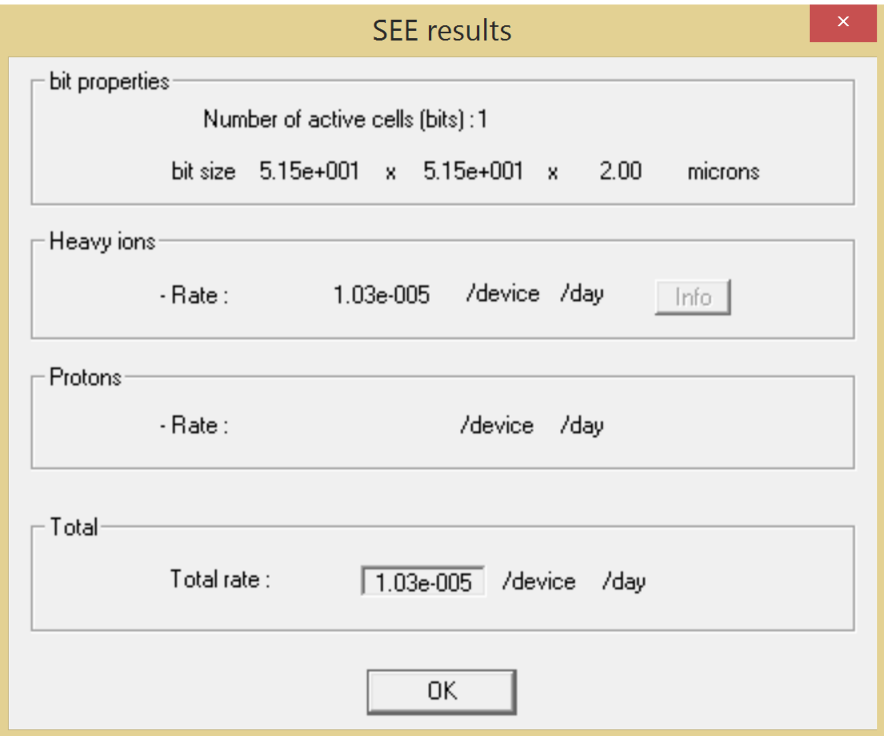


Run #26, 0 events seen, 1 set for Weibull FIT (green arrow).

Additional Weibull parameters:



Based on the new SEE test data collected on May 2nd 2016, in a Benchmark GEO orbit, this cross-section vs LET curve corresponds to:



⇨ **This corresponds to 1 SET (positive trigger) on the 5V reference every 265 years**

4.4. SCAN CHAIN TEST: RESULTS

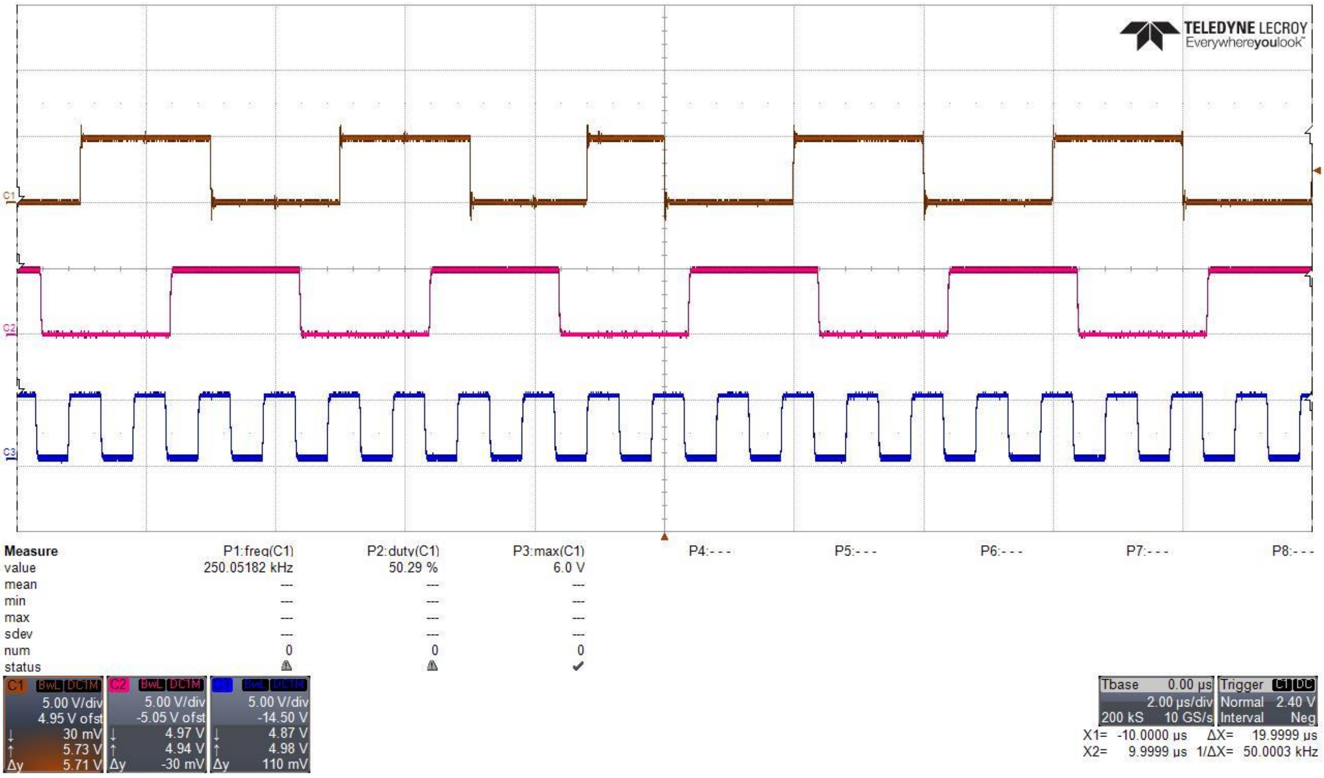
See AD1 §4.3 for detailed test conditions.

There are 269 FF in the scan chain.

Results from May 2nd:

A signal generator is used to input the scan clock and scan in. The scan clock is set at 1MHz and the scan in is set to 250KHz. The scan out is monitored for pulses outside of the 2µS window by +/- 500nS

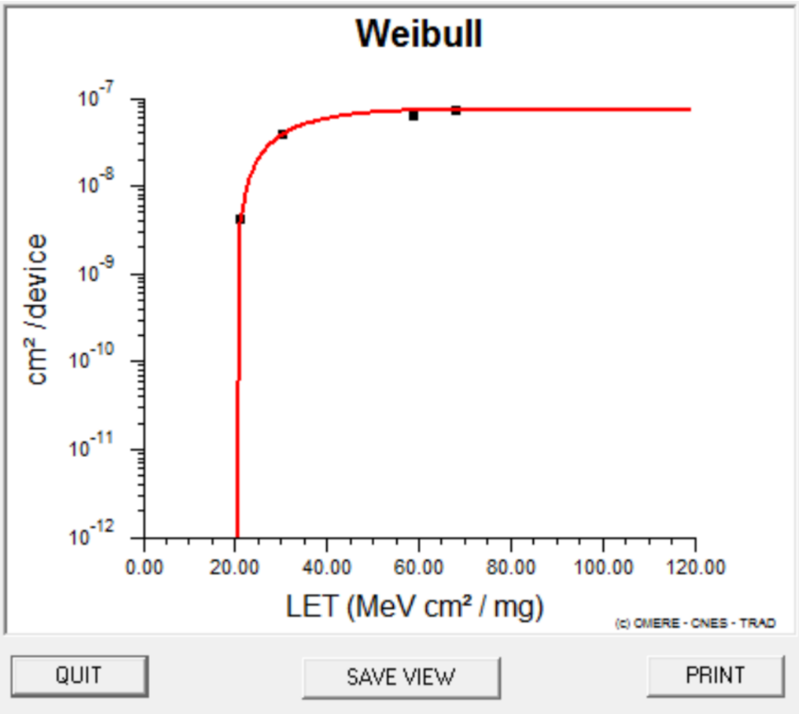
The scope print below shows the scan clk, scan in and scan out (1 event seen on scan OUT – mid print, brown trace).



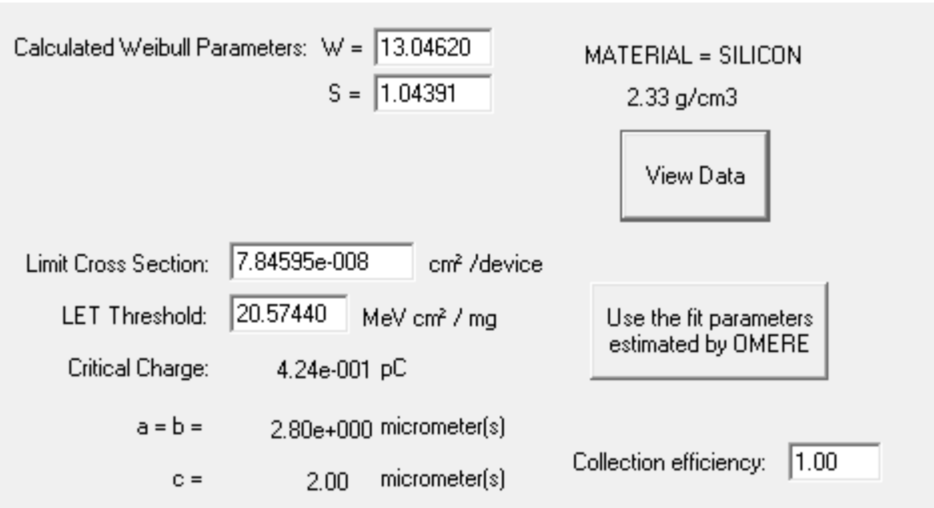
C1: Scan out
C2: Scan in
C3: Scan clock

Summary of events:

Run #	Ion	LET (MeV.cm²/mg)	Tilt	Effective LET (MeV.cm²/mg)	Flux (cm-2.s-1)	Effective Fluence (cm⁻²)	TID (krad)	SEUs	# events	X-section
42	Xe	58.78	30	67.87	6.40E+04	1.00E+07	10.94	X	211	7.84E-08
40	Xe	58.78	0	58.78	3.60E+04	1.00E+06	0.95	X	16	5.95E-08
41	Xe	58.78	0	58.78	3.60E+04	1.00E+07	9.48	X	193	7.17E-08
				58.78						6.56E-08
43	Kr	30.23	0	30.23	7.00E+04	1.00E+07	4.87	X	108	4.01E-08
44	Cu	21.17	0	21.17	7.00E+04	1.00E+07	3.41	X	12	4.46E-09

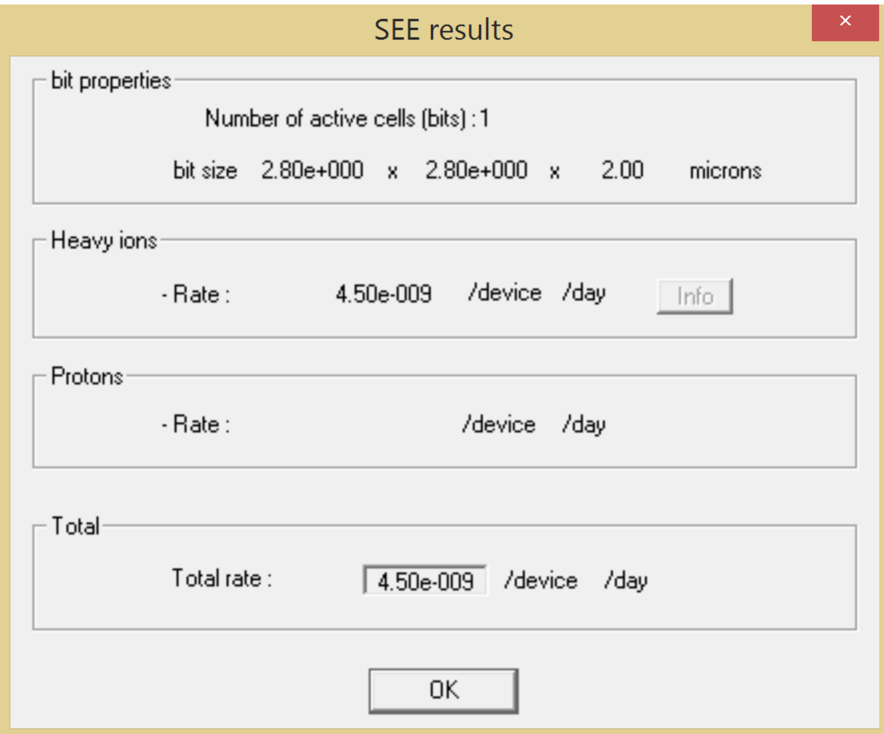


Additional Weibull parameters:



⇨ The Weibull fit is nicely shaped as well. The raw cross sections are divided by 269 (number of internal FFs).

Based on the SEE test data collected on May 2nd 2016, in a Benchmark GEO orbit, this cross-section vs LET curve corresponds to:



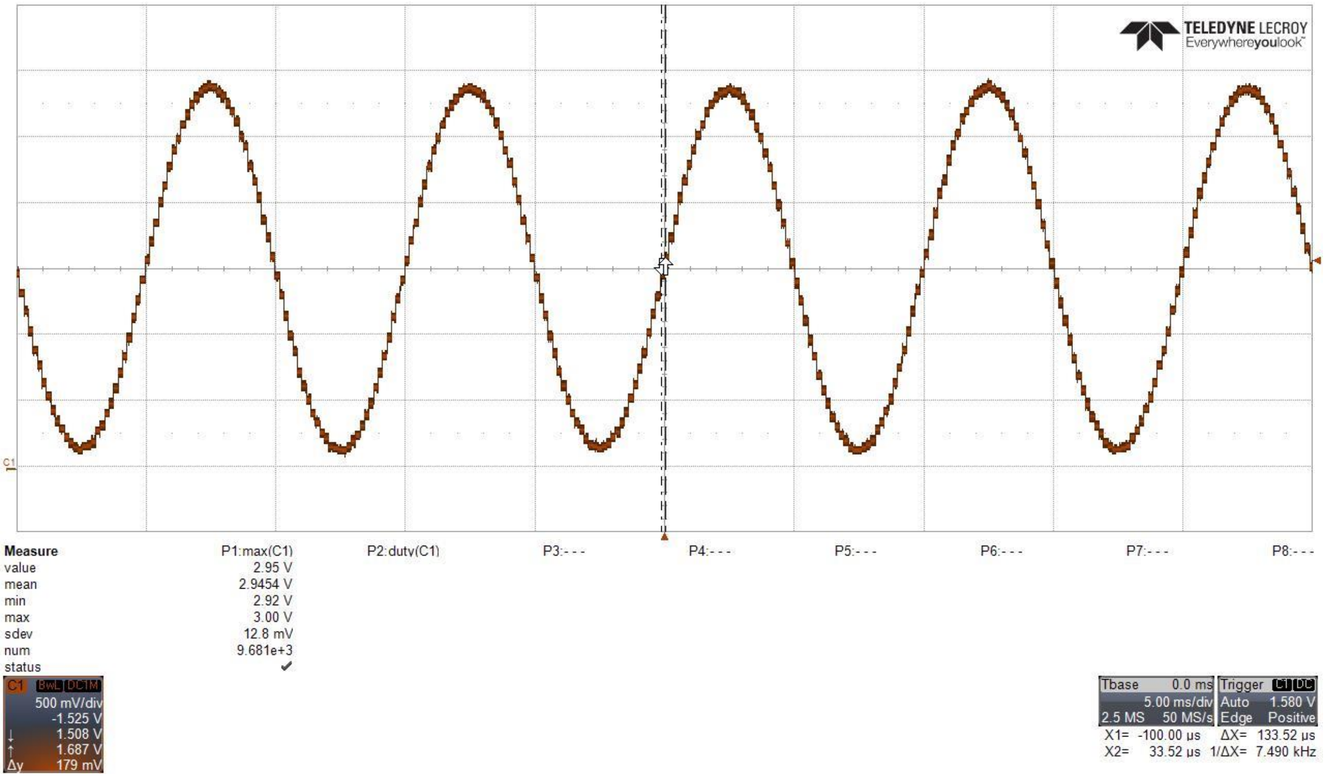
⇨ **Error rate is 4.5e-009 / bit / day.** This is very negligible.

4.5. AC TELEMETRY TESTS: RESULTS

See AD1 §4.5 for detailed test conditions.

Testing the LX7730 in this mode is actually testing most of the blocks at once and is very representative of an actual “in-flight” application.

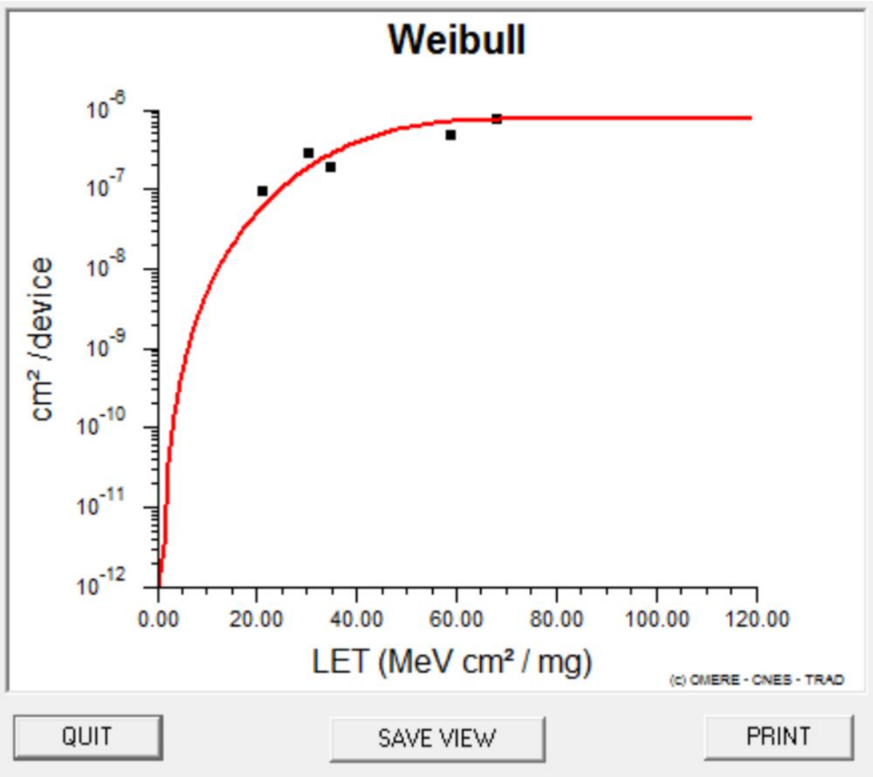
Results from May 2nd 2016:
A 100Hz 0V to 1V sin wave is input to CH9, CH10 is grounded. The Amplifier is set to a gain of 2. The ADC samples every 170uS. An FPGA reads the ADC through the SPI bus and outputs the value to a DAC to show the digital outputs on the oscilloscope. Upsets noted in this test are a break in SPI communication. The DAC ouput will stop updating because the FPGA is not receiving data from the LX7730. The most likely cause is an extra clock or data edge will unsynchronize the SPI and cause parity errors. In which case the part needs to be reset and SPI commands re-sent.



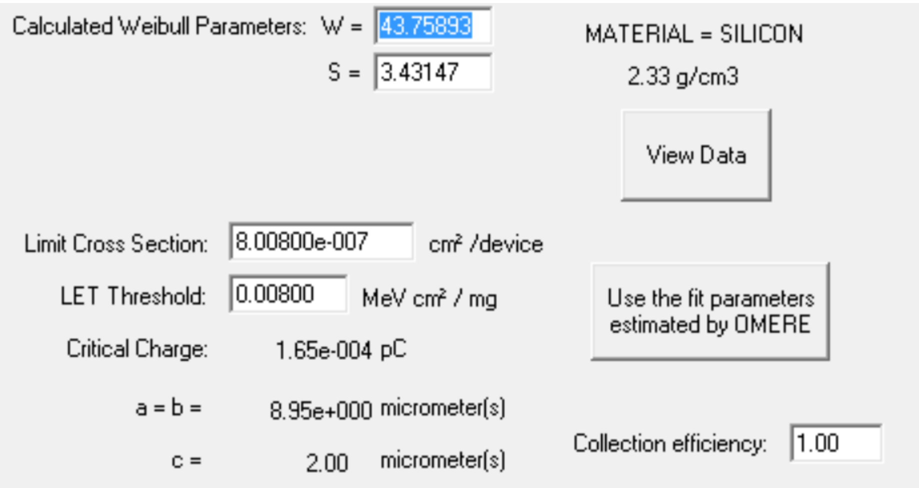
C1: FPGA DAC output

Summary of events:

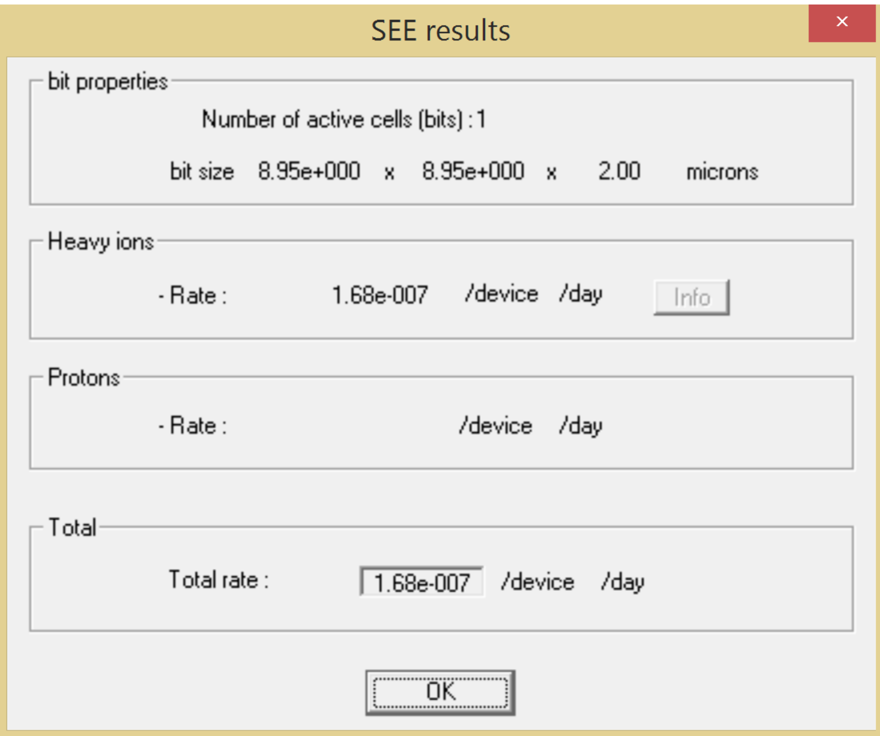
Run #	Ion	LET (MeV.cm^2/mg)	Tilt	Effective LET (MeV.cm^2/mg)	Flux (cm-2.s-1)	Effective Fluence (cm^{-2})	TID (krad)	SETs	# events	X-section
30	Cu	21.17	0	21.17	6.00E+04	1.00E+07	3.41	X	1	1.00E-07
31	Cu	21.17	0	21.17	6.00E+04	1.00E+07	3.41	X	1	1.00E-07
				21.17						**1.00E-07**
32	Cu	21.17	30	**24.45**	3.00E+04	1.00E+07	3.94	X	0	**0.00E+00**
33	Kr	30.23	0	**30.23**	4.00E+04	1.00E+07	4.87	X	3	**3.00E-07**
34	Kr	30.23	-30	**34.91**	4.00E+04	1.00E+07	5.63	X	2	**2.00E-07**
35	Xe	58.78	0	58.78	4.00E+04	1.00E+07	9.48	X	4	4.00E-07
36	Xe	58.78	0	58.78	4.00E+04	2.00E+07	18.96	X	13	6.50E-07
				58.78						**5.25E-07**
37	Xe	58.78	30	67.87	4.00E+04	2.00E+07	21.89	X	16	8.00E-07
38	Xe	58.78	-30	67.87	4.00E+04	1.00E+07	10.94	X	8	8.00E-07
				67.87						**8.00E-07**



Additional Weibull parameters:



Based on the SEE test data collected on May 2nd 2016, in a Benchmark GEO orbit, this cross-section vs LET curve corresponds to:



⇨ **1 AC SPI upset error every 16,300 years**

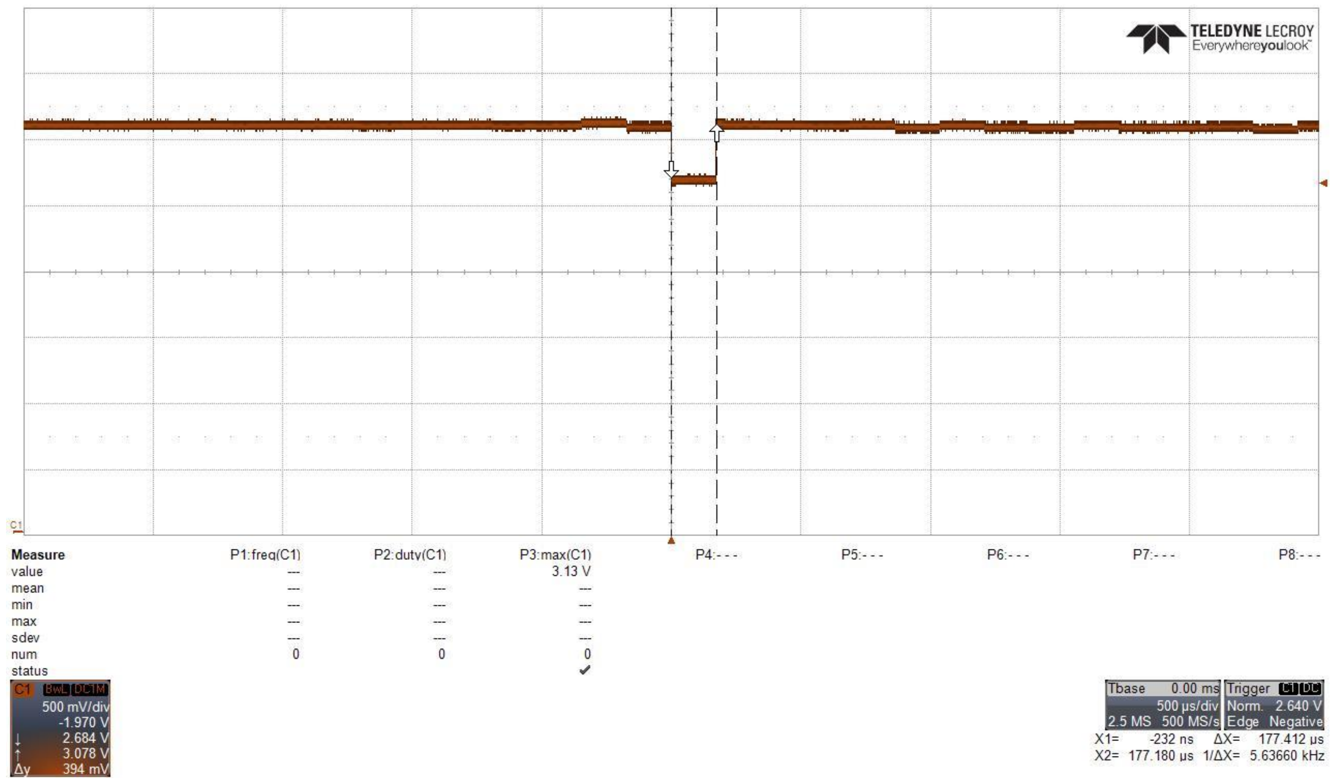
Note: We are lacking a measurement point at 10MeV, so the LET threshold is uncertain.

4.6. DC TELEMETRY TESTS: RESULTS

See AD1 §4.4 for detailed test conditions.

Results from May 2nd:

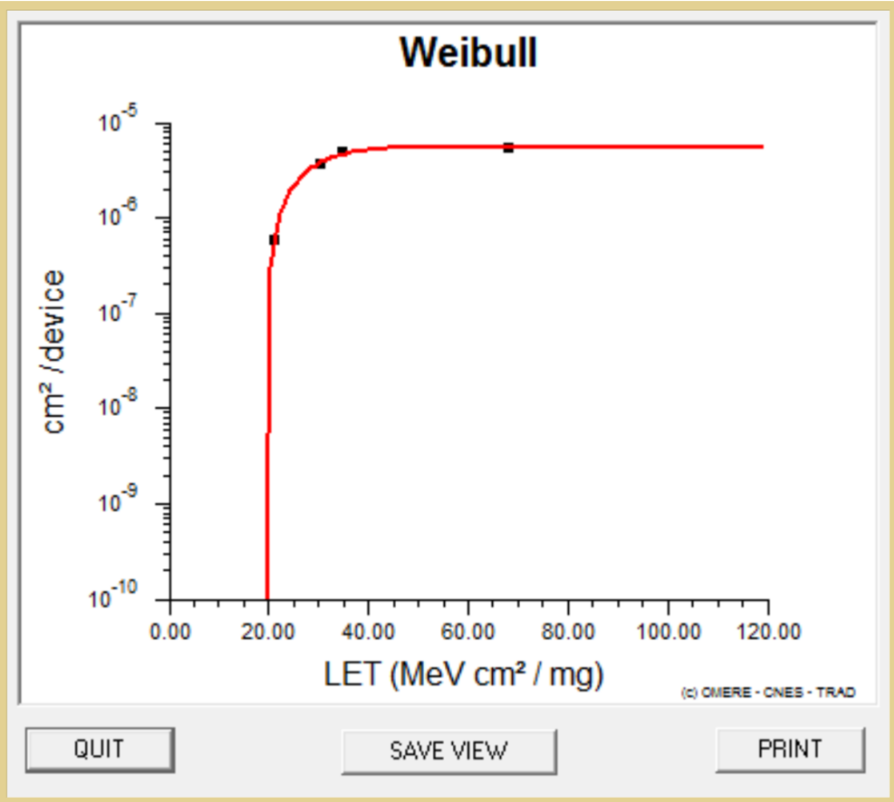
A DC voltage 1V is input to CH9, CH10 is grounded. The Amplifier is set to a gain of 2. The ADC samples every 170uS. An FPGA reads the ADC through the SPI bus and outputs the value to a DAC to show the digital outputs on the oscilloscope. Upsets noted in this test are triggered when the DAC output is 500mV below the typical output of 3.2V. Note: SPI communication upsets like the ones noted in the AC telemetry test are not counted in this test.



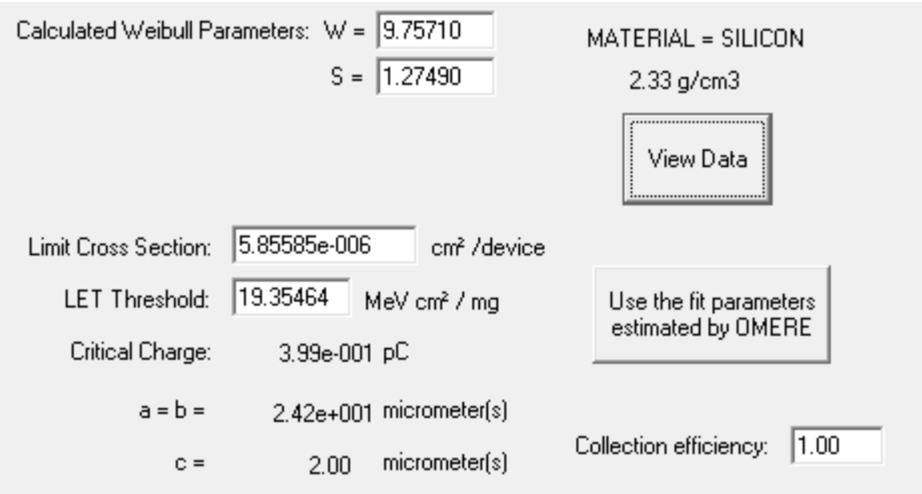
C1: FPGA DAC output

<u>Summary of events:</u>

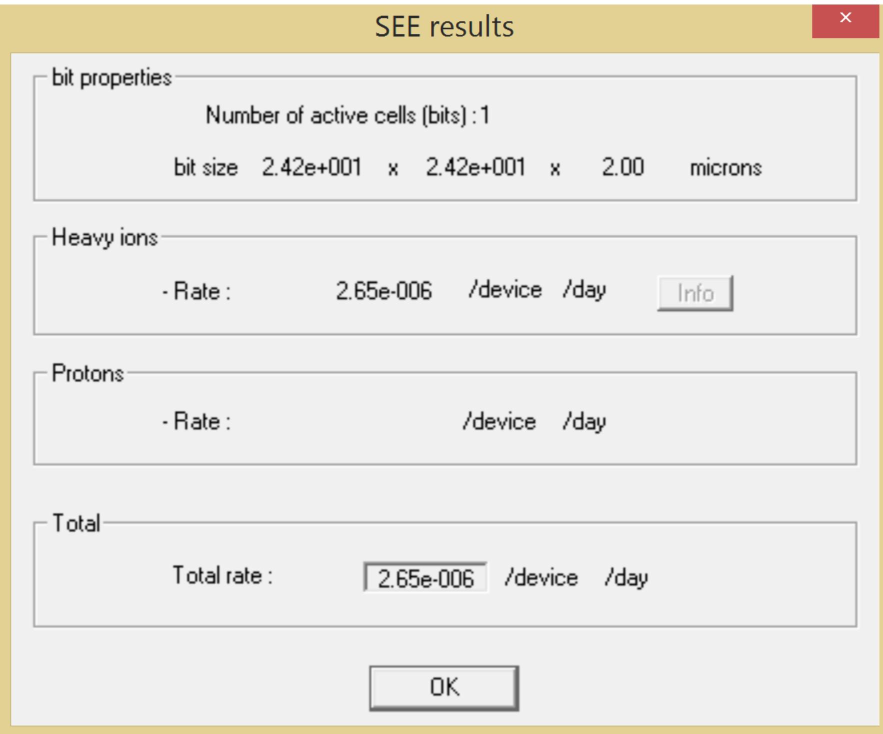
Run #	Ion	LET (MeV.cm²/mg)	Tilt	Effective LET (MeV.cm²/mg)	Flux (cm-2.s-1)	Effective Fluence (cm⁻²)	TID (krad)	SEUs	SETs	# events	X-section
58	Cu	21.17	0	21.17	1.20E+05	1.00E+07	3.41		X	19	1.90E-06
59	Cu	21.17	0	21.17	1.20E+05	1.00E+07	3.41		X	0	0.00E+00
60	Cu	21.17	0	21.17	1.20E+05	1.00E+07	3.41		X	0	0.00E+00
				21.17							**6.33E-07**
57	Kr	30.23	0	**30.23**	1.30E+05	4.17E+06	2.03		X	16	**3.84E-06**
56	Kr	30.23	30	**34.91**	1.30E+05	5.35E+06	3.01		X	28	**5.23E-06**
55	Xe	58.78	30	**67.87**	6.50E+04	3.59E+06	3.93		X	21	**5.85E-06**



Additional Weibull parameters:



Based on the SEE test data collected on May 2nd 2016, in a Benchmark GEO orbit, this cross-section vs LET curve corresponds to:

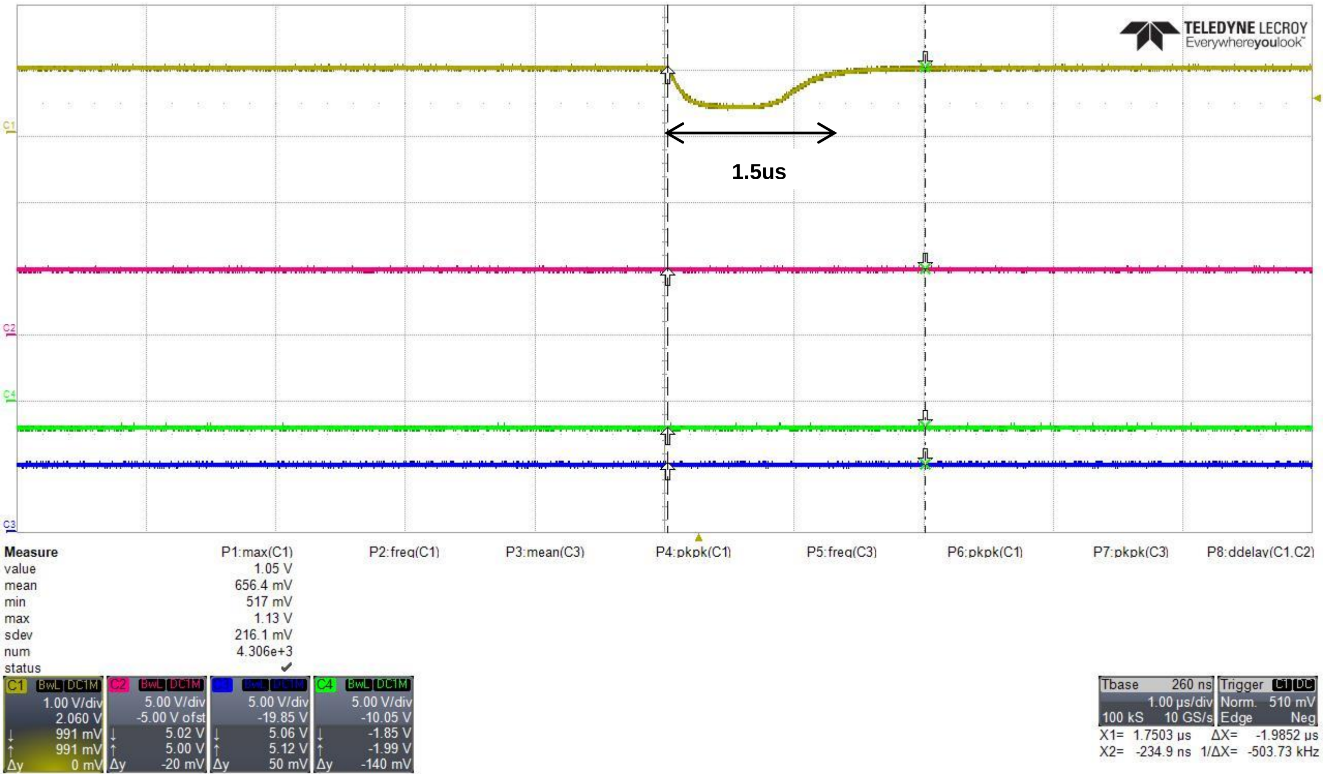


⇨ **This corresponds to DC telemetry error every 1,033 years**

4.7. CURRENT SOURCES TESTS: RESULTS

See AD1 §4.1 for detailed test conditions.

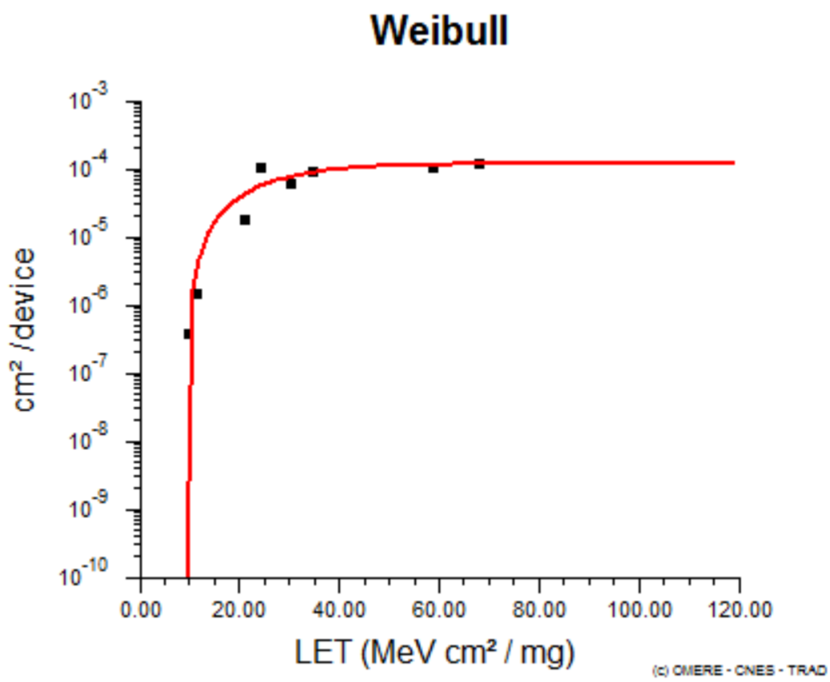
Results from May 2nd:
The current source test checks the 250uA to 4mA adjustable driver. The current source is set to 2mA and directed to output on CH12. CH12 has a 500Ω load. The voltage is measured on CH12 with a nominal output of 1V. An event is triggered if the output falls below 0.5V



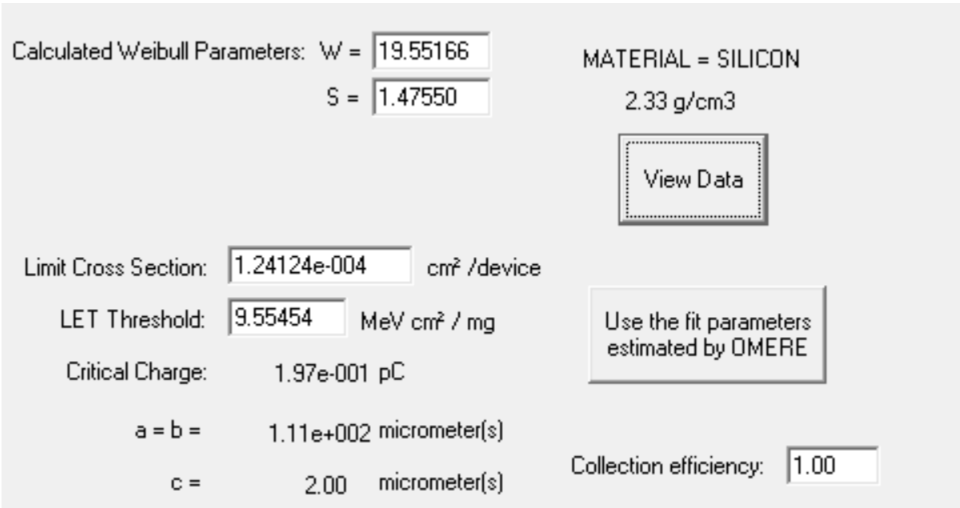
C1: CH12 - Current Source on, 2mA - 500Ω load - Trigger on upsets below 0.5V
C2: +5v
C3: VREF
C4: MINUS2V

Summary of events:

Run #	Ion	LET (MeV.cm²/mg)	Tilt	Effective LET (MeV.cm²/mg)	Flux (cm-2.s-1)	Effective Fluence (cm⁻²)	TID (krad)	SETs	# events	X-section
4	Xe	58.78	-30	**67.87**	**1.00E+05**	**2.00E+07**	**21.89**	**X**	**2473**	**1.24E-04**
5	Xe	58.78	0	58.78	1.00E+05	1.00E+07	9.48	X	1120	1.12E-04
7	Xe	58.78	0	58.78	1.00E+05	1.00E+07	9.48	X	1097	1.10E-04
				58.78						**1.11E-04**
11	Kr	30.23	30	34.91	7.00E+04	1.28E+06	0.72	X	151	1.18E-04
12	Kr	30.23	30	34.91	7.00E+04	1.86E+06	1.05	X	155	8.33E-05
14	Kr	30.23	30	34.91	4.00E+04	2.02E+06	1.14	X	186	9.21E-05
				34.91						**9.78E-05**
9	Kr	30.23	0	30.23	1.00E+05	2.06E+06	1.00	X	132	6.41E-05
10	Kr	30.23	0	30.23	1.00E+05	1.87E+06	0.91	X	113	6.04E-05
				30.23						**6.23E-05**
16	Cu	21.17	-30	**24.45**	6.00E+04	1.50E+06	0.59	X	168	**1.12E-04**
15	Cu	21.17	0	**21.17**	6.00E+04	3.22E+06	1.10	X	63	**1.96E-05**
17	Ar	9.74	-30	**11.25**	7.00E+04	3.88E+06	0.70	X	6	**1.55E-06**
18	Ar	9.74	0	**9.74**	7.00E+04	1.00E+07	1.57	X	4	**4.00E-07**



Additional Weibull parameters:

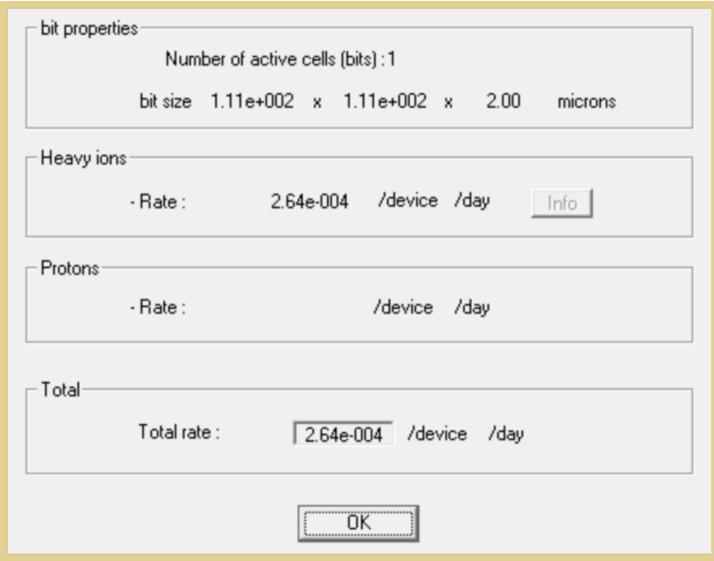


⇨ The Weibull fit is nicely shaped.

Based on the SEE test data collected on May 2nd 2016, in a Benchmark GEO orbit, this cross-section vs LET curve corresponds to:

<u>Current source test with an extra 6.8nF on the channel</u>

Run #	Ion	LET (MeV.cm²/mg)	Tilt	Effective LET (MeV.cm²/mg)	Flux (cm-2.s-1)	Effective Fluence (cm^{-2})	TID (krad)	SETs	# events	X-section
45	Cu	21.2	0	21.17	6.90E+04	1.00E+07	3.41	X	0	0.00E+00
46	Xe	58.8	0	58.78	1.10E+05	1.00E+07	9.48	X	0	0.00E+00
47	Xe	58.8	30	67.87	1.10E+05	1.00E+07	10.94	X	0	0.00E+00
48	Xe	58.8	30	67.87	1.10E+05	1.00E+07	10.94	X	0	0.00E+00



- ⇨ **1 error every 10.04 years** without any caps on the board.
- ⇨ We also verified that **with a 6.8 nF cap** on the current source (see run table below) **no errors were seen up to the LET of 67.87 MeV.cm²/mg with a fluence of 1e7particles/cm²**.

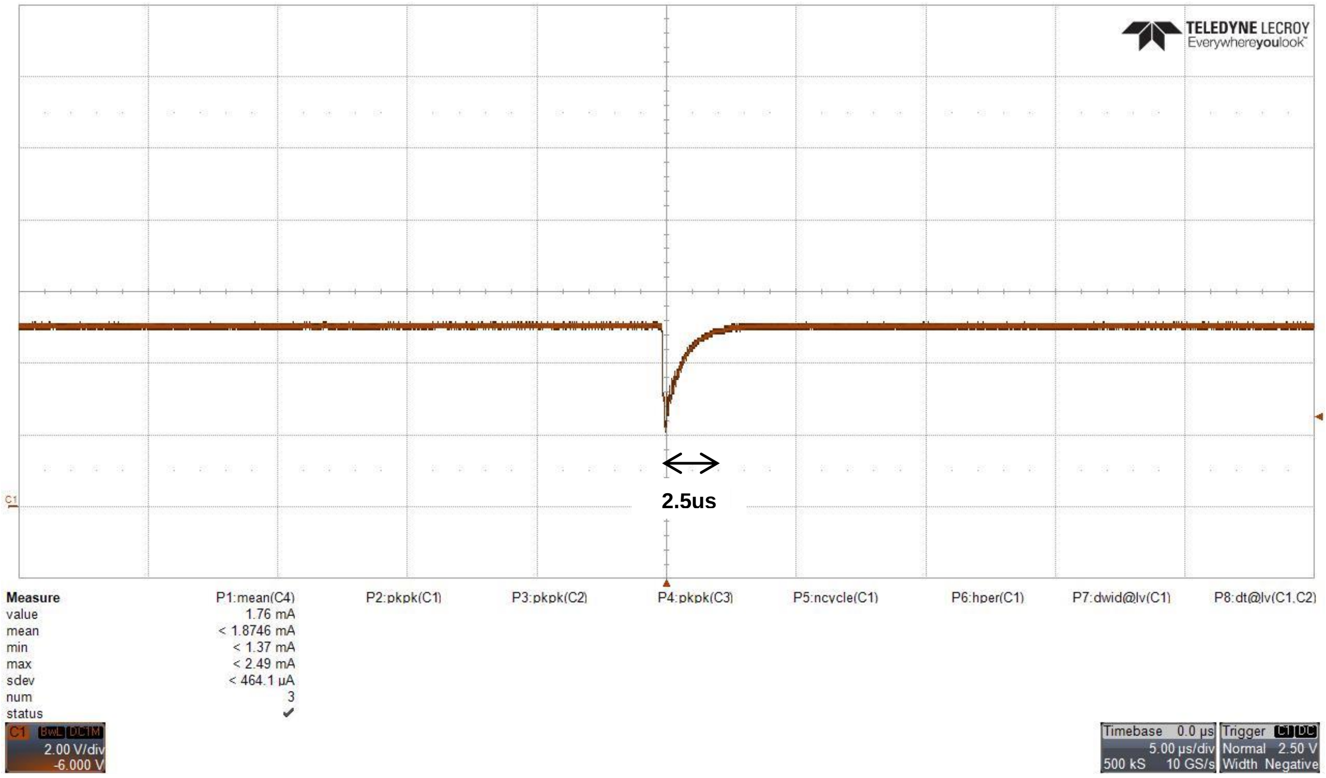
Run #	Ion	LET (MeV.cm²/mg)	Tilt	Effective LET (MeV.cm²/mg)	Flux (cm-2.s-1)	Effective Fluence (cm⁻²)	TID (krad)	SETs	# events	X-section
45	Cu	21.2	0	21.17	6.90E+04	1.00E+07	3.41	X	0	0.00E+00
46	Xe	58.8	0	58.78	1.10E+05	1.00E+07	9.48	X	0	0.00E+00
47	Xe	58.8	30	67.87	1.10E+05	1.00E+07	10.94	X	0	0.00E+00
48	Xe	58.8	30	67.87	1.10E+05	1.00E+07	10.94	X	0	0.00E+00

4.8. COLD SPARE TESTS: RESULTS

See below for detailed test conditions.

Results from June 29th:

Cold spare tests were performed during runs #20 (58.78 MeV.cm²/mg) and #21 (83.13 MeV.cm²/mg). CH11 is connected to a 1M resistor biased to 5V. Some current transients have been seen on the tested input. However, this transient is not latched. The input current does not change and return to normal after 2.5 us.



C1:CH11

⇨ **We can conclude that no cold spare functionality events have been witnessed up to an LET of 83 MeV.cm^2/mg.**

4.9. Detailed Run Table – test performed on June 29th 2015

The table hereafter contains all the run details. All runs results have been described in the previous chapters. All runs were performed with the 10AMeV Xe.

Run #	Part	T (°C)	LET (MeV.cm²/mg)	Tilt	Effective LET (MeV.cm²/mg)	Flux (cm-2.s-1)	time (sec)	Effective Fluence (cm-2)	Approximate TID krad(Si)	SEL	SEUs	SETs	SEFIs	Run setup	Pre run ICC/IDD	Post run ICC/IDD	Comments
1	214	70	59	0	58.78	4.00E+04		1.00E+06	0.95	0				VCC=16V VDD=5.5V VEE=-16V	ICC_pre=68.48mA IDD_pre=1.23mA ICC_pre=5.25mA	ICC_post=67.79mA IDD_post=1.22mA IEE_post=5.27mA	
2	214	70	59	0	58.78	4.00E+04		1.00E+07	9.48	0				VCC=16V VDD=5.5V VEE=-16V	ICC_pre=67.80mA IDD_pre=1.22mA IEE_pre=5.27mA	ICC_post=67.59mA IDD_post=1.22mA IEE_post=5.26mA	Scope trace ref see_1run3. We see small glitches on the current probe of VCC and potential SETs on -2V, +5 and +5ref
3	214	71	59	45	83.13	4.00E+04	379	1.00E+07	13.4	0				VCC=16V VDD=5.5V VEE=-16V	ICC_pre=67.57mA IDD_pre=1.22mA IEE_pre=5.26mA	ICC_post=67.16mA IDD_post=1.22mA IEE_post=5.24mA	Scope trace ref see_2run. Same as previous run.
4	214	126	59	45	83.13	7.00E+04	240	1.00E+07	13.4	0				VCC=16V VDD=5.5V VEE=-16V	ICC_pre=74.42mA IDD_pre=1.28mA IEE_pre=3.50mA	ICC_post=75.21mA IDD_post=1.27mA IEE_post=5.92mA	For this run all 3 currents are recorded: 1 sample / s. Scope trace ref see_4run. Same as previous on SETS.
5	214	128	59	45	83.13	1.30E+05	771	7.00E+07	93.8	0				VCC=16V VDD=5.5V VEE=-16V	ICC_pre=75.14mA IDD_pre=1.27mA IEE_pre=5.89mA	ICC_post=75.37mA IDD_post=1.24mA IEE_post=6.39mA	For this run all 3 currents are recorded: 1 sample / s. Files are saved in .txt format. Scope trace ref see_5run. Same as previous on SETS. Some functional tests were run on the part to verify post run functionality (registers are read, acquisition is performed on 4 voltage monitors).

Run #	Part	T (°C)	LET (MeV.cm²/mg)	Tilt	Effective LET (MeV.cm²/mg)	Flux (cm-2.s-1)	time (sec)	Effective Fluence (cm^{-2})	Approximate TID krad(Si)	SEL	SEUs	SETs	SEFIs	Run setup	Pre run ICC/IDD	Post run ICC/IDD	Comments
6	211	125	59	-45	83.13	1.16E+05	248	2.01E+07	26.9	0				VCC=16V VDD=5.5V VEE=-16V +5V=5.5V	ICC_pre=35.28mA IDD_pre=1.19mA IEE_pre=5.75mA I_+5V_pre=42.6mA	ICC_post=34.94mA IDD_post=1.19mA IEE_post=5.64mA I_+5V_post=42.52mA	On this run, we force +5V to +5.5V (bypass regulator).
7	211	127	59	-48	87.85	1.16E+05	1046	8.01E+07	113.5	0				VCC=16V VDD=5.5V VEE=-16V +5V=5.5V	ICC_pre=34.20mA IDD_pre=1.19mA IEE_pre=5.64mA I_+5V_pre=42.55mA	ICC_post=32.86mA IDD_post=mA IEE_post=mA I_+5V_pre=mA	On this run, we force +5V to +5.5V (bypass regulator).
8	210	48	59	0	58.78	1.00E+04	113	2.64E+06	2.5	0		0		VCC=15V VDD=5.5V	ICC_pre=73.95mA IDD_pre=1.00mA	ICC_post=74.55mA IDD_post=1.01mA	SET test on +5V with threshold detection at +/- 500mV.
9	210	48	59	0	58.78	6.00E+04	51	3.00E+06	2.84	0		1		VCC=15V VDD=5.5V	ICC_pre=74.55mA IDD_pre=1.01mA	ICC_post=74.67mA IDD_post=1.01mA	SET test on +5V with threshold detection at -150mV. Scope trace ref see_9run
10	210	48	59	0	58.78	6.43E+04	241	1.50E+07	14.2	0		0		VCC=15V VDD=5.5V	ICC_pre=74.67mA IDD_pre=1.01mA	ICC_post=74.58mA IDD_post=1.01mA	SET test on +5V with threshold detection at +/- 100mV.
11	210	48	59	45	83.13	6.00E+04	254	1.50E+07	14.2	0		0,0		VCC=15V VDD=5.5V	ICC_pre=74.58mA IDD_pre=1.01mA	ICC_post=74.06mA IDD_post=1.00mA	SET test on +5V and +5V_ref with threshold detection at +/- 100mV.
12	210	48	59	-45	83.13	8.70E+04	227	1.50E+07	20.1	0		0,0		VCC=15V VDD=3.3V	ICC_pre=73.00mA IDD_pre=1.01mA	ICC_post=72.68mA IDD_post=0.83mA	SET test on +5V_ref and -2V with threshold detection at +/- 100mV.
13	210	50	59	-45	83.13	9.07E+04	235	1.50E+07	20.1	0		0		VCC=15V VDD=3.3V	ICC_pre=72.65mA IDD_pre=0.84mA	ICC_post=72.57mA IDD_post=0.83mA	SET test on VEE with threshold detection at +/- 100mV.
14	210	50	59	0	58.78	8.21E+04	63	5.06E+06	4.8	0	N/A			VCC=15V VDD=3.3V	ICC_pre=72.55mA IDD_pre=1.1mA	ICC_post=72.90mA IDD_post=0.832mA	Full scale DAC test at speed. SPI command low then high. We look at DAC_P. Test difficult to

Run #	Part	T (°C)	LET (MeV.cm^2/mg)	Tilt	Effective LET (MeV.cm^2/mg)	Flux (cm-2.s-1)	time (sec)	Effective Fluence (cm^{-2})	Approximate TID krad(Si)	SEL	SEUs	SETs	SEFIs	Run setup	Pre run ICC/IDD	Post run ICC/IDD	Comments
																	conclude on.
15	210	50	59	0	58.78	1.41E+02	131	1.76E+04	0.02	0			No	VCC=15V VDD=3.3V	ICC_pre=76mA IDD_pre=1.00mA	ICC_post=76mA IDD_post=1.05mA	Full scale differential AC telemetry CH9/CH10. Input amplitude=800mV , F=10Hz. Scope trace ref see_15run. Noise related issue at the end of the run.
16	210	125	59	48	87.85	9.07E+04	1958	1.00E+08	141.7	0				VCC=16V VDD=5.5V	ICC_pre=82.44mA IDD_pre=1.02mA	ICC_post=88.32mA IDD_post=1.03mA	Last SEL test on sample #210. No SEL.
17	203	50	59	0	58.78	2.08E+04	46	1.00E+06	0.95	0		0		VCC=15V VDD=3.3V	ICC_pre=73.65mA IDD_pre=0.83mA	ICC_post=73.95mA IDD_post=0.83mA	Looking at POE and UVLO no upset
18	203	50	59	0	58.78	2.27E+04	45	1.02E+06	0.97	0		0		VCC=15V VDD=3.3V	ICC_pre=mA IDD_pre=mA	ICC_post=mA IDD_post=mA	Try run, no conclusive data.
19	203	50	59	0	58.78	6.82E+04	133	8.17E+06	7.74	0	N/A			VCC=15V VDD=3.3V	ICC_pre=mA IDD_pre=mA	ICC_post=mA IDD_post=mA	Scan chain test. Noise issues, scan chain not stable during test. Scope trace ref see_15run1 before beam #1. Scope trace ref see_15run2 before beam #2. Scope trace ref see_15run3 during beam #3. Scope trace ref see_15run4 during beam #4.

Run #	Part	T (°C)	LET (MeV.cm²/mg)	Tilt	Effective LET (MeV.cm²/mg)	Flux (cm-2.s-1)	time (sec)	Effective Fluence (cm^{-2})	Approximate TID krad(Si)	SEL	SEUs	SETs	SEFIs	Run setup	Pre run ICC/IDD	Post run ICC/IDD	Comments
20	203	50	59	0	58.78	6.29E+04	179	1.00E+07	9.48	0				VCC=open VDD=open	ICC_pre=mA IDD_pre=mA	ICC_post=mA IDD_post=mA	Cold Spare test with resistor network. Voltage is forced on I/O while device remains unpowered. Some glitches but no input latchup = 11 events (no real apparently). Scope trace ref see_15run6 during beam.
21	203	50	59	45	83.13	6.53E+04	205	1.00E+07	13.4	0				VCC=open VDD=open	ICC_pre=mA IDD_pre=mA	ICC_post=mA IDD_post=mA	Cold Spare test with resistor network. No events.

4.10. Detailed Run Table – Test performed on May 2nd 2016

Run #	Test	Part	T (°C)	Ion	Energy (MeV)	LET (MeV.cm²/mg)	Tilt	Effective LET (MeV.cm²/mg)	Flux (cm-2.s-1)	Effective Fluence (cm-2)	TID (krad)	SEUs	SETs	# events	X-section	Comments
4	Curent source / POR	1011	25	Xe	10AMeV	58.8	##	67.87	1.00E+05	2.00E+07	21.89		X	2473	1.24E-04	POR is OK Board is OK Many SETs but less - not making sense
5	Curent source / POR	1011	25	Xe	10AMeV	58.8	0	58.78	1.00E+05	1.00E+07	9.48		X	1120	1.12E-04	OK
7	Curent source / POR	1011	25	Xe	10AMeV	58.8	0	58.78	1.00E+05	1.00E+07	9.48		X	1097	1.10E-04	OK
9	Curent source / POR	1011	25	Kr	10AMeV	30.2	0	30.23	1.00E+05	2.06E+06	1.00		X	132	6.41E-05	
10	Curent source / POR	1011	25	Kr	10AMeV	30.2	0	30.23	1.00E+05	1.87E+06	0.91		X	113	6.04E-05	
11	Curent source / POR	1011	25	Kr	10AMeV	30.2	30	34.91	7.00E+04	1.28E+06	0.72		X	151	1.18E-04	
12	Curent source / POR	1011	25	Kr	10AMeV	30.2	30	34.91	7.00E+04	1.86E+06	1.05		X	155	8.33E-05	
14	Curent source / POR	1011	25	Kr	10AMeV	30.2	30	34.91	4.00E+04	2.02E+06	1.14		X	186	9.21E-05	
15	Curent source / POR	1011	25	Cu	10AMeV	21.2	0	21.17	6.00E+04	3.22E+06	1.10		X	63	1.96E-05	
16	Curent source / POR	1011	25	Cu	10AMeV	21.2	##	24.45	6.00E+04	1.50E+06	0.59		X	168	1.12E-04	More events but they are shorter and lower
17	Curent source / POR	1011	25	Ar	10AMeV	9.74	##	11.25	7.00E+04	3.88E+06	0.70		X	6	1.55E-06	
18	Curent source / POR	1011	25	Ar	10AMeV	9.74	0	9.74	7.00E+04	1.00E+07	1.57		X	4	4.00E-07	
19	SET on supplies / 4.2	1011	25	Xe	10AMeV	58.8	0	58.78	1.00E+05	1.00E+07	9.48		X	0	0.00E+00	+5.0V is monitored. Trigger negative on 4.5V.
20	SET on supplies / 4.2	1011	25	Xe	10AMeV	58.8	0	58.78	1.00E+05	1.00E+07	9.48		X	0	0.00E+00	+5.0V is monitored. Trigger positive on 5.5V.
21	SET on supplies / 4.2	1011	25	Xe	10AMeV	58.8	30	67.87	1.00E+05	1.00E+07	10.94		X	0	0.00E+00	Vref is monitored. Trigger negative on 4.5V.
25	SET on supplies / 4.2	1011	25	Xe	10AMeV	58.8	30	67.87	1.00E+05	1.00E+07	10.94		X	265	2.65E-05	Vref is monitored. Trigger positive on 5.5V.

Run #	Test	Part	T (°C)	Ion	Energy (MeV)	LET (MeV.cm²/mg)	Tilt	Effective LET (MeV.cm²/mg)	Flux (cm-2.s-1)	Effective Fluence (cm⁻²)	TID (krad)	SEUs	SETs	# events	X-section	Comments
26	SET on supplies / 4.2	1011	25	Xe	10AMeV	58.8	0	58.78	9.00E+04	5.64E+06	5.35		X	100	1.77E-05	Vref is monitored. Trigger positive on 5.5V.
27	SET on supplies / 4.2	1011	25	Kr	10AMeV	30.2	0	30.23	7.00E+04	5.02E+06	2.45		X	66	1.31E-05	Vref is monitored. Trigger positive on 5.5V.
28	SET on supplies / 4.2	1011	25	Ar	10AMeV	9.74	0	9.74	7.00E+04	1.00E+07	1.57		X	0	0.00E+00	Vref is monitored. Trigger positive on 5.5V.
29	SET on supplies / 4.2	1011	25	Cu	10AMeV	21.2	0	21.17	1.10E+05	1.00E+07	3.41		X	0	0.00E+00	Vref is monitored. Trigger positive on 5.5V.
30	AC Telemetry / 4.5	1004	25	Cu	10AMeV	21.2	0	21.17	6.00E+04	1.00E+07	3.41		X	1	1.00E-07	Visual trigger on scope
31	AC Telemetry / 4.5	1004	25	Cu	10AMeV	21.2	0	21.17	6.00E+04	1.00E+07	3.41		X	1	1.00E-07	Visual trigger on scope
32	AC Telemetry / 4.5	1004	25	Cu	10AMeV	21.2	30	24.45	3.00E+04	1.00E+07	3.94		X	0	0.00E+00	Visual trigger on scope
33	AC Telemetry / 4.5	1004	25	Kr	10AMeV	30.2	0	30.23	4.00E+04	1.00E+07	4.87		X	3	3.00E-07	
34	AC Telemetry / 4.5	1004	25	Kr	10AMeV	30.2	##	34.91	4.00E+04	1.00E+07	5.63		X	2	2.00E-07	
35	AC Telemetry / 4.5	1004	25	Xe	10AMeV	58.8	0	58.78	4.00E+04	1.00E+07	9.48		X	4	4.00E-07	
36	AC Telemetry / 4.5	1004	25	Xe	10AMeV	58.8	0	58.78	4.00E+04	2.00E+07	18.96		X	13	6.50E-07	
37	AC Telemetry / 4.5	1004	25	Xe	10AMeV	58.8	30	67.87	4.00E+04	2.00E+07	21.89		X	16	8.00E-07	
38	AC Telemetry / 4.5	1004	25	Xe	10AMeV	58.8	##	67.87	4.00E+04	1.00E+07	10.94		X	8	8.00E-07	
40	Scan Chain / 4.3	1007	25	Xe	10AMeV	58.8	0	58.78	3.60E+04	1.00E+06	0.95	X		16	1.60E-05	Trigger on negative pulses outside 4us +/-500ns
41	Scan Chain / 4.3	1007	25	Xe	10AMeV	58.8	0	58.78	3.60E+04	1.00E+07	9.48	X		193	1.93E-05	Trigger on negative pulses outside 4us +/-500ns
42	Scan Chain / 4.3	1007	25	Xe	10AMeV	58.8	30	67.87	6.40E+04	1.00E+07	10.94	X		211	2.11E-05	Trigger on negative pulses outside 4us +/-500ns
43	Scan Chain / 4.3	1007	25	Kr	10AMeV	30.2	0	30.23	7.00E+04	1.00E+07	4.87	X		108	1.08E-05	Trigger on negative pulses outside 4us +/-500ns
44	Scan Chain / 4.3	1007	25	Cu	10AMeV	21.2	0	21.17	7.00E+04	1.00E+07	3.41	X		12	1.20E-06	Trigger on negative pulses outside 4us +/-500ns
45	Curent source	1007	25	Cu	10AMeV	21.2	0	21.17	6.90E+04	1.00E+07	3.41		X	0	0.00E+00	Add a 6.8nF cap on the current source Trigger on negative edge of current source Similar to run 15 with the additional cap

Run #	Test	Part	T (°C)	Ion	Energy (MeV)	LET (MeV.cm²/mg)	Tilt	Effective LET (MeV.cm²/mg)	Flux (cm-2.s-1)	Effective Fluence (cm⁻²)	TID (krad)	SEUs	SETs	# events	X-section	Comments
46	Curent source	1007	25	Xe	10AMeV	58.8	0	58.78	1.10E+05	1.00E+07	9.48		X	0	0.00E+00	Add a 6.8nF cap on the current source Trigger on negative edge of current source Similar to run 15 with the additional cap
47	Curent source	1007	25	Xe	10AMeV	58.8	30	67.87	1.10E+05	1.00E+07	10.94		X	0	0.00E+00	Add a 6.8nF cap on the current source Trigger on negative edge of current source Similar to run 15 with the additional cap
48	Curent source	1007	25	Xe	10AMeV	58.8	30	67.87	1.10E+05	1.00E+07	10.94		X	0	0.00E+00	Add a 6.8nF cap on the current source Trigger on positive edge of current source
49	POR test only	1007	25	Xe	10AMeV	58.8	0	58.78	1.00E+05	1.00E+07	9.48		X	0	0.00E+00	100pF on POR instead of 1uF+100pF ,POR pin is monitored
50	POR test only	1007	25	Xe	10AMeV	58.8	42	79.10	1.00E+05	2.51E+07	32.01		X	0	0.00E+00	100pF on POR instead of 1uF+100pF POR pin is monitored
55	DC Telemetry / 4.4	1007	25	Xe	10AMeV	58.8	30	67.87	6.50E+04	3.59E+06	3.93		X	21	5.85E-06	100pF on POR instead of 1uF+100pF Look for SETs, trigger negative. Out of sync SPI commands are not counted.
56	DC Telemetry / 4.4	1007	25	Kr	10AMeV	30.2	30	34.91	1.30E+05	5.35E+06	3.01		X	28	5.23E-06	100pF on POR instead of 1uF+100pF Look for SETs, trigger negative. Out of sync SPI commands are not counted.
57	DC Telemetry / 4.4	1007	25	Kr	10AMeV	30.2	0	30.23	1.30E+05	4.17E+06	2.03		X	16	3.84E-06	100pF on POR instead of 1uF+100pF Look for SETs, trigger negative. Out of sync SPI commands are not counted.

Run #	Test	Part	T (°C)	Ion	Energy (MeV)	LET (MeV.cm²/mg)	Tilt	Effective LET (MeV.cm²/mg)	Flux (cm-2.s-1)	Effective Fluence (cm⁻²)	TID (krad)	SEUs	SETs	# events	X-section	Comments
58	DC Telemetry / 4.4	1007	25	Cu	10AMeV	21.2	0	21.17	1.20E+05	1.00E+07	3.41		X	19	1.90E-06	100pF on POR instead of 1uF+100pF Look for SETs, trigger negative. Out of sync SPI commands are not counted.
59	DC Telemetry / 4.4	1007	25	Cu	10AMeV	21.2	0	21.17	1.20E+05	1.00E+07	3.41		X	0	0.00E+00	100pF on POR instead of 1uF+100pF Look for SETs, trigger positive. Out of sync SPI commands are not counted.
60	DC Telemetry / 4.4	1007	25	Cu	10AMeV	21.2	0	21.17	1.20E+05	1.00E+07	3.41		X	0	0.00E+00	100pF on POR instead of 1uF+100pF Look for SETs, trigger positive at mid value. Out of sync SPI commands are not counted.
61	DC Telemetry / 4.4	1007	25	Cu	10AMeV	21.2	0	21.17	1.20E+05	1.00E+07	3.41		X	X	1.00E-07	100pF on POR instead of 1uF+100pF Look for SETs, trigger negative at 500mV. Out of sync SPI commands are not counted. The trigger is not working well, events are not counted

5. CONCLUSION

The single event testing of the LX7730 performed on June 29th 2015 and May 2nd 2016 allowed us to conclude that:

- The design is SEL immune up to 87 MeV.cm^2/mg and 125℃ (fluence of 1e8 particles/cm^2).
- Strong performance of the complete telemetry chain under the beam (DC and AC).
- Strong performance of the current sources.
- No SEFIs.
- The cold spare functionality is immune to input latchups up to 83 MeV.cm^2/mg.
- The design shows outstanding performance for all evaluated blocks up to 83 MeV.cm^2/mg.

The LX7730 demonstrates outstanding heavy ion performance and is suitable for any space application (LEO, MEO, GEO or interplanetary).