Single Event Effects Radiation Test Report

Microsemi LX7720

Power Driver with Rotation and Position Sensing

TABLE OF CONTENT

1. PURPOSE AND SCOPE

This test report presents the results of the LX7720 (Power Driver with Rotation and Position Sensing) Single Event Effects radiation tests that were performed at the Texas A&M Cyclotron using a 15MeV/n cocktail beam on October 30th 2018.
Several Microsemi engineers participated in the test. This testing is complementing the test ran on July 26th, 2018.

During this test we fully executed the tests described in the test plan.

The test data we present below shows that the design is immune to SEL/SEB/SEGR up to 60MeV.cm2/mg and 125°C (fluence of 1e7 particles/cm2) with some sensitivities observed at 80.2MeV.cm2/mg. No SEFIs were observed. Characterization for transients on all blocks of the design are presented.

2. APPLICABLE DOCUMENT

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

- Single Event Radiation Test Plan – Microsemi LX7720 Power Driver with Rotation and Position Sensing

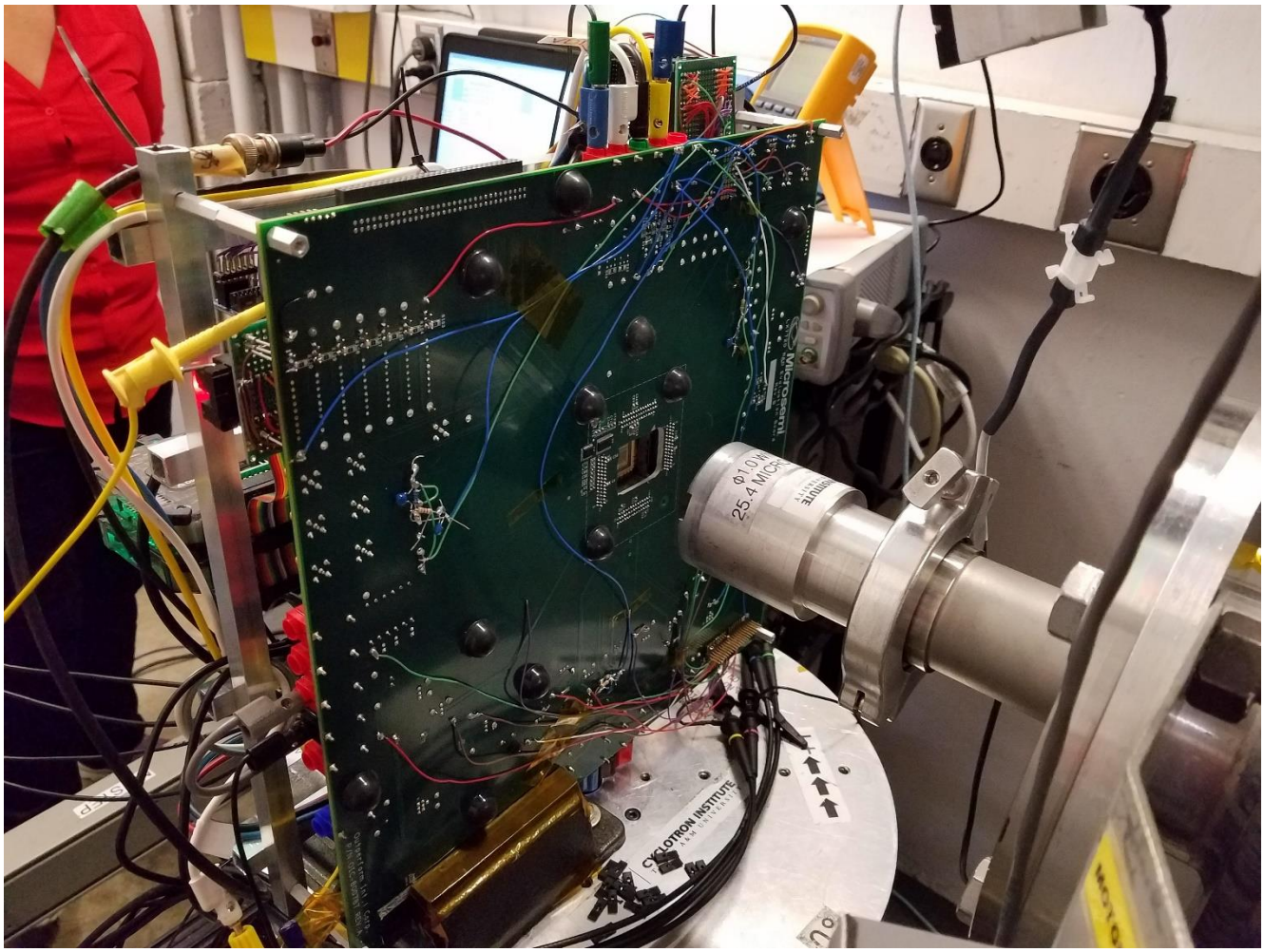
3. TEST SETUP

3.1. DUT TEST SETUP

5 devices were used for the SEL/SEB/SEGR tests (see run table in 4.13) :
- Lot numbers: HV Die: E42448, LV Die: T93847
- Serial numbers: 200_SEE, 201_SEE, 203_SEE, 204_SEE and 206_SEE

3 devices were used for the SET tests (see run table in 4.14) :
- Lot numbers: HV Die: E42448, LV Die: T93847
- Serial numbers: 207_SEE and 204_SEE
- Lot numbers: HV Die: E42657, LV Die: U00011
- Serial number: 300

2 devices were used for the SEU tests (see run table in 4.15) :
- Lot numbers: HV Die: E42657, LV Die: U00011
- Serial numbers: FIB1 and FIB2



Picture 1: DUT mounted on the plate.

3.2. BIASING

For SEL/SEB/SEGR tests all voltages were forced to ensure the worst case test condition with maximum voltages and temperature (+125°C):

- Supplies: VGS=18V, VEE=-18V External, DMOD_PS=18V, VCC=VDD=5.5V, VMPS=36-120V
- Clocks: MOD_CLK=24MHz, CP_CLK=200kHz
- All UD_IN#, LD_IN# and DMOD_IN# can be remotely independently set high or low
- One channel will be set with UD_IN#=high and LD_IN#=low
- Other channels will be set with UD_IN#=low and LD_IN#=high
- DMOD_IN_N=Low, DMOD_IN_P=High
- BL_TH=2.5V, BLI5=2.2V, BLI6=2.8V, BLI1-4=0V
- SM_EN=Low
- SCP=High
- ADC1_N=ADC1_P=VREF
- ADC2_N=VREF-0.4V, ADC2_P=VREF+0.4V
- ADC3_N=ADC3_P=VREF
- RTN_B= 0V, CSPS_B=VGS, CS_B= +200mV
- RTN_C=CS_A=VMPS (30-50V), CSPS_A=VBOOST
-
- RTN_D=CS_D= 0V, CSPS_D=VGS

For SET tests all voltages were forced to nominal conditions and room temperature:

- Supplies: VGS=15V, VEE=-15V External, DMOD_PS=15V, VCC=5.0V, VDD=3.3V, VMPS=50V
- Clocks: MOD_CLK=24MHz, CP_CLK=200kHz
- UD_IN_A=Low and LD_IN_B=High
- UD_IN_B=Low and LD_IN_B=High
- UD_IN_C=Low and LD_IN_C=High
- UD_IN_D=High and LD_IN_A=Low
- DMOD_IN_N=Low, DMOD_IN_P=High
- BL_TH=2.5V, BLI5=2.2V, BLI6=2.8V, BLI1-4=0V at rest and used to set test mode
- Testmode1= 0V except for POR test using test mode (remotely controllable)
- SM_EN=Low
- SCP=High
- ADC1_N=ADC1_P=VREF
- ADC2_N=VREF-0.4V, ADC2_P=VREF+0.4V
- ADC3_N=ADC3_P=VREF
- RTN_A=CS_C= 0V, CSPS_C=VGS
- RTN_B= 0V, CSPS_B=VGS, CS_B= +200mV
- RTN_C=CS_A=VMPS (30-50V), CSPS_A=VBOOST
- RTN_D=CS_D= 0V, CSPS_D=VGS

For SEU tests all voltages were forced to nominal conditions and room temperature:

- Supplies: VGS=15V, VEE=-15V External, DMOD_PS=15V, VCC=5.0V, VDD=3.3V, VMPS=50V
- Clocks: MOD_CLK=24MHz, CP_CLK=200kHz
- Parts were fibbed to force scan chain mode

4. TEST RESULTS

All results detailed in this section were taken on October 30th and October 31st 2018.

For all the detailed test conditions of the following tests, refer to the test plan and the detailed run table presented in §4.13-16.

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), 18 years mission. As a reminder the max of Solar cycle 24 was in 2013.4 (previous min in 2009 and future min in 2020).

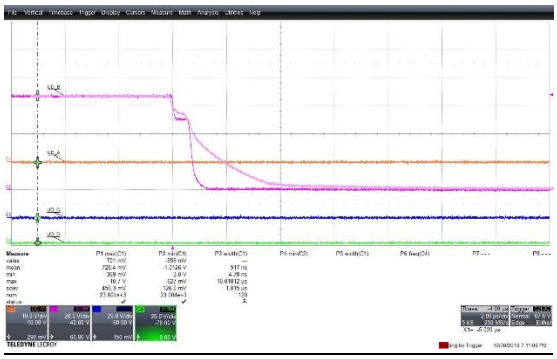
4.1. SEL/SEB/SEGR AND SEFI TEST: RESULTS

Results at 60MeV.cm^2/mg

SEL/SEB/SEGR tests were performed at 125°C and 60MeV.cm^2/mg during runs #14 and #20 to #22. 2 different samples have been tested and no SEL/SEB/SEGR events were observed with total fluence of 1e7 particles/cm^2 for each sample.

Results at 80.2MeV.cm^2/mg

SEL/SEB/SEGR tests were performed at 125°C at 80.2MeV.cm^2/mg during runs 12-13, 15-19 and 23-27.
Some sensitivity was observed when testing the MOSFET drivers in static mode (UD high state). The Rdson of the low side driver of UD was seen increasing, impacting the turn-off time of UD- see below. This effect was not observed when the MOSFET driver was driven with a dynamic signal.



Conclusion:

- ⇨ **We conclude that the device is SEL/SEB/SEGR immune at 60MeV.cm^2/mg.**
- ⇨ Some sensitivities at 80.2MeV.cm2/mg were observed in the gate drivers but no SEL/SEB/SEGR.
- ⇨ No SEFIs were observed.

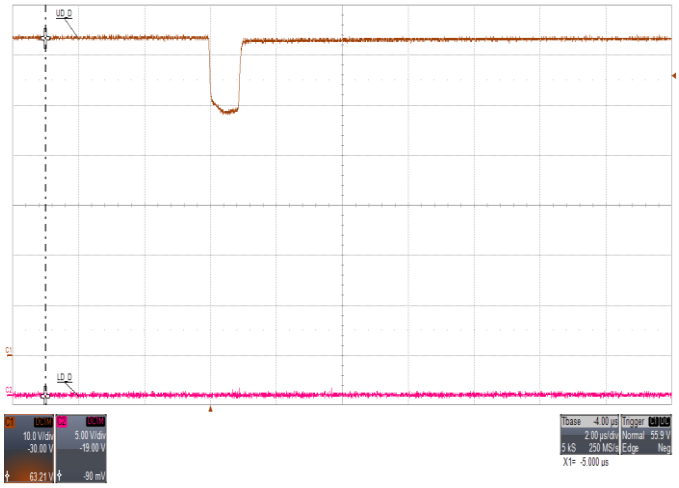
4.2. MOSFET DRIVERS TEST: RESULTS

SET tests were performed at room temperature for both UD and LD drivers connected to a MOSFET half-bridge in both on and off conditions.

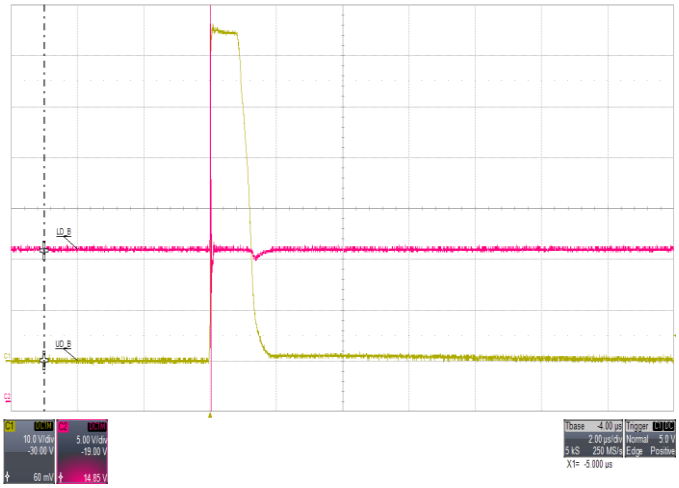
Run #	Part #	Ion	Air (mm)	Initial LET (MeVcm^2/mg)	Tilt Angle (Deg)	Flux (cm^{-2}.s^{-1})	Effective Fluence (cm^{-2})	Effective LET (MeVcm^2/mg)	UD Off, Pos SET	UD On, Neg SET	LD Off, Pos SET	LD On, Neg SET	UD Off, Pos Events cm^2/dev	UD On, Neg Events cm^2/dev	LD Off, Pos Events cm^2/dev	LD On Neg Events cm^2/dev
29	207_SEE	Pr	50	60.0	0.0	1.0E+04	8.29E+05	60.00	628	294			7.58E-4	3.55E-4		
30	207_SEE	Pr	50	60.0	0.0	1.0E+04	8.01E+05	60.00			285	534			3.56E-4	6.67E-4
31	207_SEE	Pr	50	60.0	0.0	9.7E+03	7.79E+05	60.00			246	569			3.16E-4	7.30E-4
32	207_SEE	Pr	50	60.0	0.0	9.4E+03	7.48E+05	60.00			264	505			3.53E-4	6.75E-4
60	207_SEE	Cu	50	20.3	0.0	2.4E+04	2.37E+05	20.30	84	20			3.54E-4	8.44E-5		
61	207_SEE	Cu	50	20.3	0.0	2.4E+04	2.17E+06	20.30			262	543			1.21E-4	2.50E-4
69	207_SEE	Ar	50	8.6	0.0	7.2E+04	5.77E+06	8.60	474	213			8.21E-5	3.69E-5		
70	207_SEE	Ar	50	8.6	0.0	5.8E+04	1.66E+06	8.60			61	133			3.68E-5	8.03E-5
71	207_SEE	Ar	50	8.6	0.0	6.0E+04	4.75E+06	8.60			180	367			3.79E-5	7.73E-5
94	204_SEE	Ne	90	2.9	-51.0	6.5E+04	3.47E+06	4.61	5	3			1.44E-6	8.65E-7		
95	204_SEE	Ne	90	2.9	-51.0	6.5E+04	3.49E+06	4.61			5	5			1.43E-6	1.43E-6
99	204_SEE	Ne	90	2.9	-15.0	1.0E+05	7.98E+06	3.00	6	6			7.52E-7	7.52E-7		
100	204_SEE	Ne	90	2.9	-15.0	9.9E+04	8.16E+06	3.00			4	5			4.90E-7	6.13E-7

SET waveforms

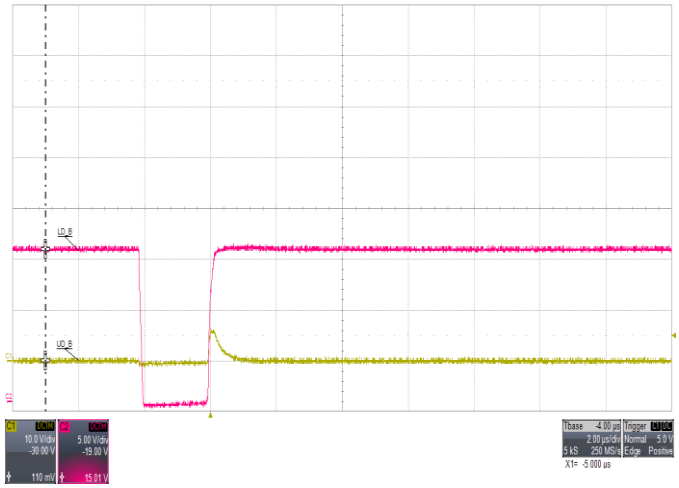
UD On, transient off: duration <1us



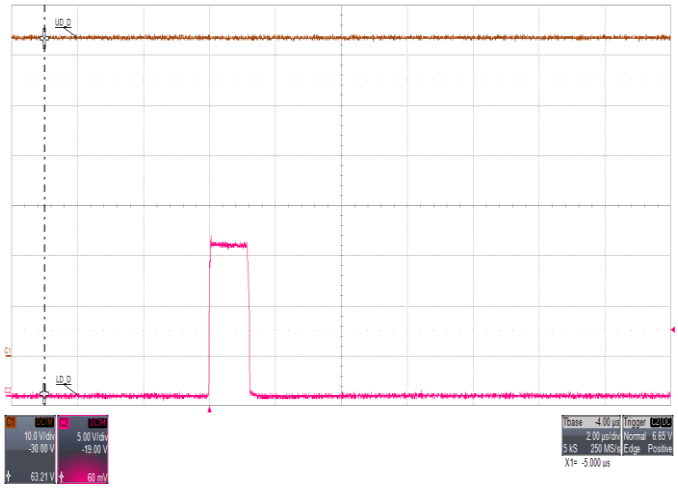
UD Off, transient on: duration <1.5us



LD On, transient off: duration <2.2us

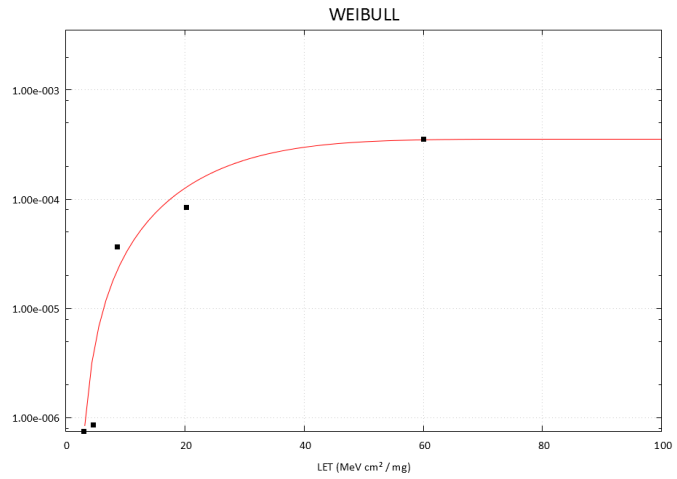


LD Off, transient on: duration <1.5us



Weibull charts and parameters

UD On, transient off



Calculated Weibull W = 27.64542 S = 1.91666

MATERIAL = SILICON 2.33 g/cm3

View Data | Export data

Limit Cross 3.55355e-004 cm² /device

LET 2.0135 MeV cm² /

Critical 0.04152 pC

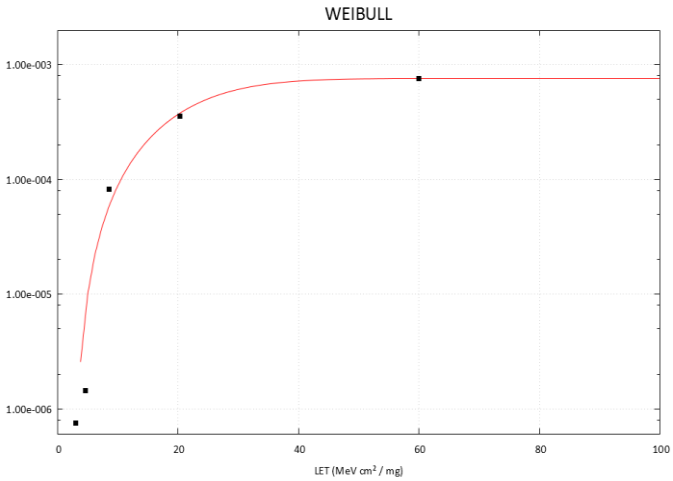
Use the fit parameters estimated by OMERE

a = b 1.89e+002 micrometer(s)

c = 2.00 micrometer(s)

Collection 1.00

UD Off, transient on



Calculated Weibull W = 21.33001 S = 1.96106

MATERIAL = SILICON 2.33 g/cm3

View Data | Export data

Limit Cross 7.58758e-004 cm² /device

LET 2.67657 MeV cm² /

Critical 5.52e-002 pC

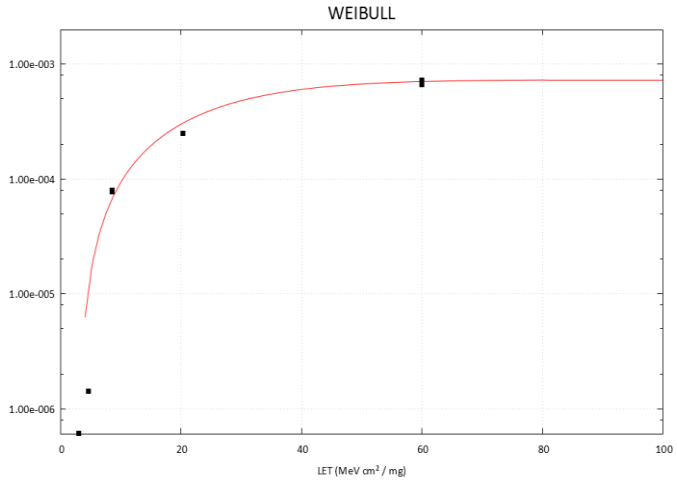
Use the fit parameters estimated by OMERE

a = b 2.75e+002 micrometer(s)

c = 2.00 micrometer(s)

Collection 1.00

LD On, transient off



Calculated Weibull W = 25.89342 S = 1.53565

MATERIAL = SILICON 2.33 g/cm3

View Data | Export data

Limit Cross 7.30701e-004 cm² /device

LET 2.92260 MeV cm² /

Critical 6.03e-002 pC

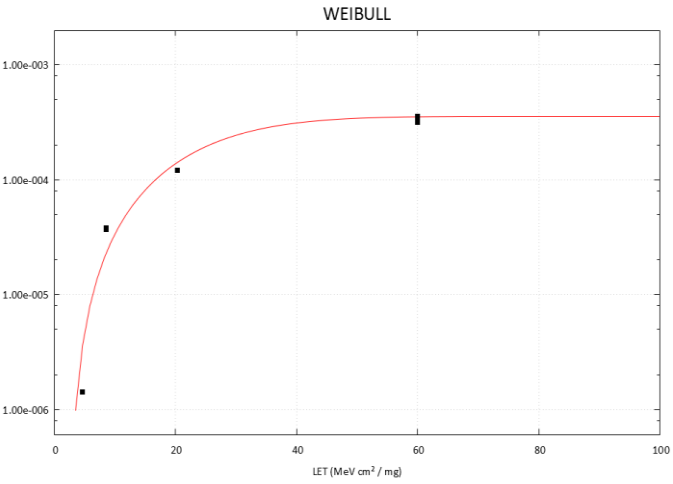
Use the fit parameters estimated by OMERE

a = b 2.70e+002 micrometer(s)

c = 2.00 micrometer(s)

Collection 1.00

LD Off, transient on



Calculated Weibull W = 25.70481 S = 1.91270

MATERIAL = SILICON 2.33 g/cm3

View Data | Export data

Limit Cross 3.56356e-004 cm² /device

LET 2.34581 MeV cm² /

Critical 4.84e-002 pC

Use the fit parameters estimated by OMERE

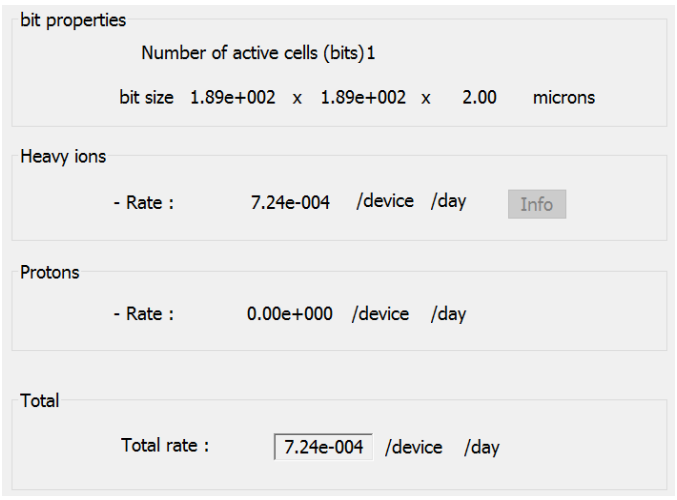
a = b 1.89e+002 micrometer(s)

c = 2.00 micrometer(s)

Collection 1.00

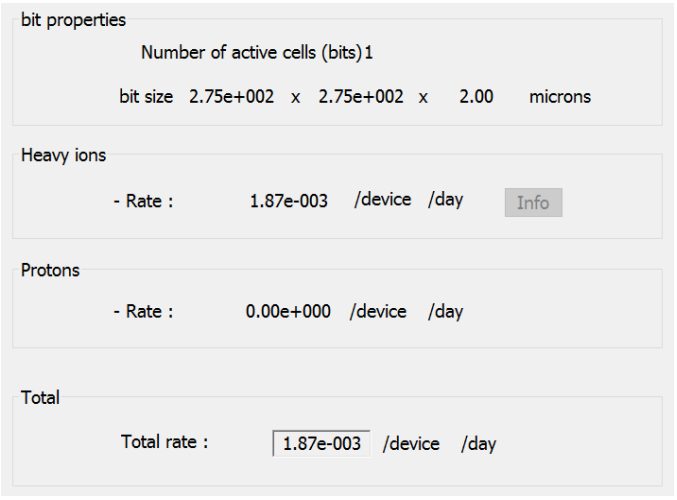
SET rates

UD On, transient off



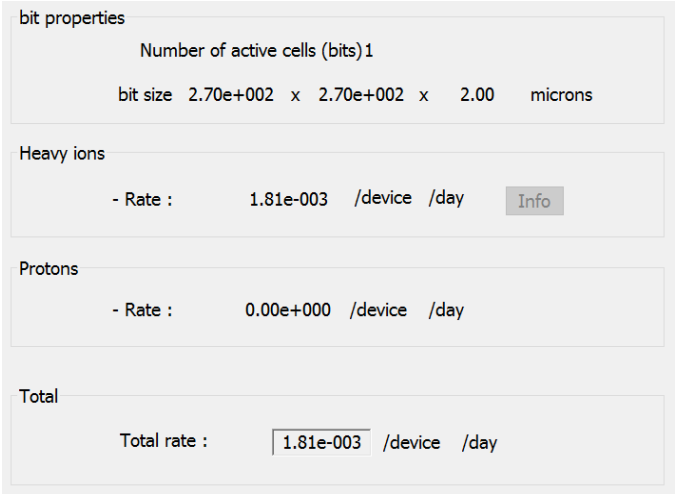
→ 1 upset every 3.78 years/driver

UD Off, transient on



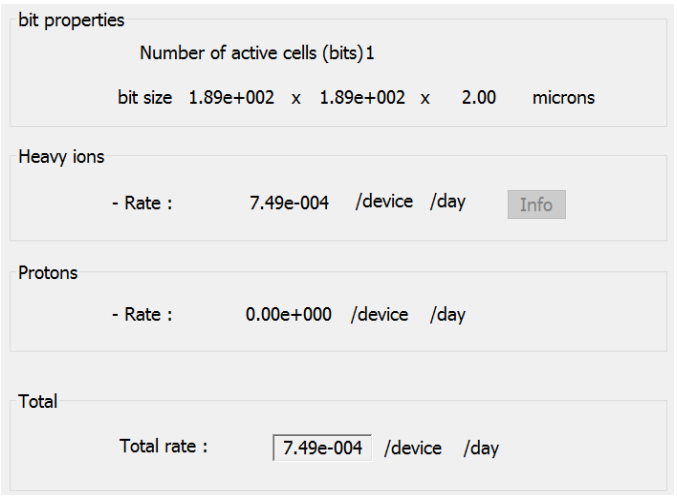
→ 1 upset every 1.47 years/driver

LD On, transient off



→ 1 upset every 1.51 years/driver

LD Off, transient on



→ 1 upset every 3.66 years/driver

The occurrence for these MOSFET driver transients is low and the duration for an on trainsient is short, around 1.5us. In a typical application with an external full H-Bridge, the 1.5us on-transients may only result in some transient shoot-through current.

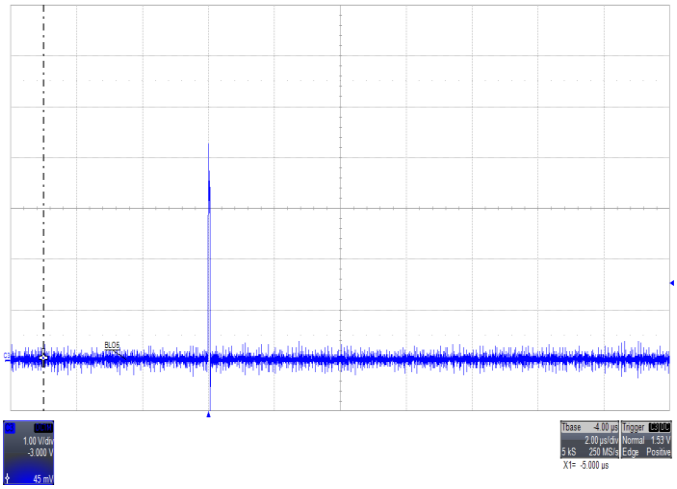
4.3. BI-LEVEL I/O TEST: RESULTS

SET tests were performed at room temperature for bi-level input 300mV below and above the threshold.

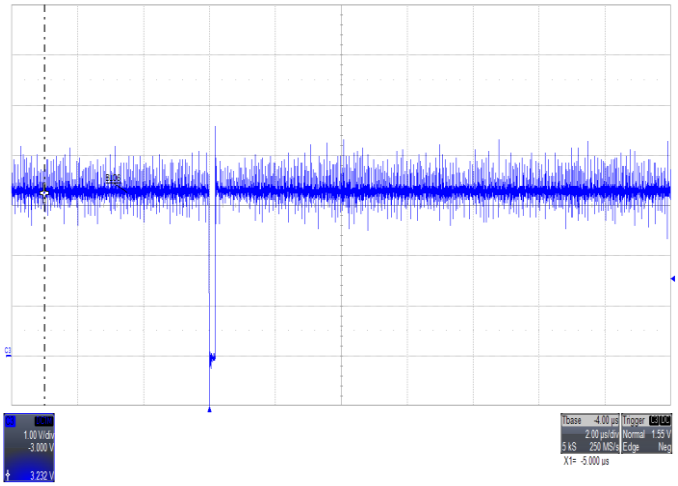
Run #	Part #	Ion	Air (mm)	Initial LET ($MeVcm^2/mg$)	Tilt Angle (Deg)	Flux ($cm^{-2}.s^{-1}$)	Effective Fluence (cm^{-2})	Effective LET ($MeVcm^2/mg$)	BLO Low, Pos SET	BLO High, Neg SET	BLO Low, Pos Events cm^2/dev	BLO High, Neg Events cm^2/dev
35	207_SEE	Pr	50	60.00	0.0	9.3E+05	7.72E+05	60.00	9	39	1.17E-5	5.05E-5
63	207_SEE	Cu	50	20.30	0.0	2.6E+04	2.10E+06	20.30	12	79	5.71E-6	3.76E-5
73	207_SEE	Ar	50	8.60	0.0	6.9E+04	5.53E+06	8.60	27	106	4.88E-6	1.92E-5
97	204_SEE	Ne	90	2.90	-51.0	6.7E+04	3.64E+06	4.61	2	16	5.49E-7	4.40E-6
102	204_SEE	Ne	90	2.90	-15.0	9.7E+04	7.93E+06	3.00	2	7	2.52E-7	8.83E-7

SET waveforms

Transient BLO low to high: duration <0.2us

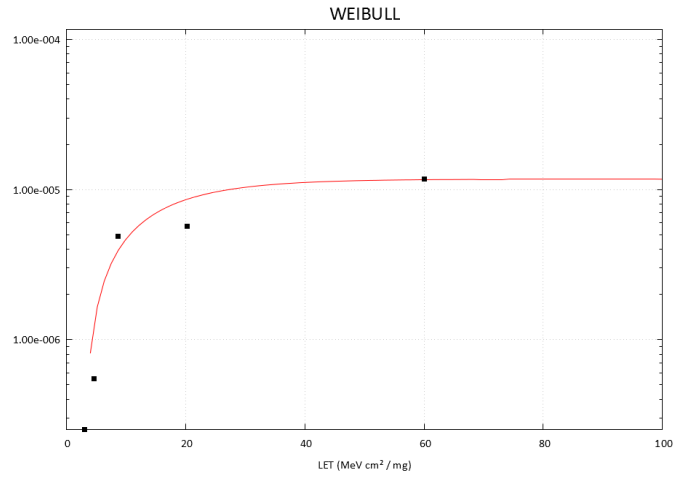


Transient BLO high to low: duration <0.4us



Weibull charts and parameters

Transient BLO low to high: duration <0.2us



Calculated Weibull W = 13.39925 S = 1.08162 MATERIAL = SILICON 2.33 g/cm3 View Data Export data

Limit Cross 1.17114e-005 cm² /device

LET 2.82779 MeV cm² /

Critical 5.83e-002 pC

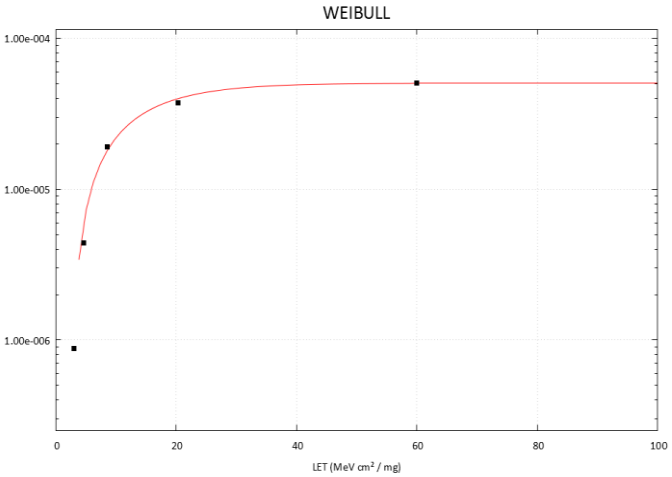
a = b 3.42e+001 micrometer(s)

c = 2.00 micrometer(s)

Use the fit parameters estimated by OMERE

Collection 1.00

Transient BLO high to low: duration <0.4us



Calculated Weibull W = 11.95365 S = 1.14651 MATERIAL = SILICON 2.33 g/cm3 View Data Export data

Limit Cross 5.05504e-005 cm² /device

LET 2.70615 MeV cm² /

Critical 5.58e-002 pC

a = b 7.11e+001 micrometer(s)

c = 2.00 micrometer(s)

Use the fit parameters estimated by OMERE

Collection 1.00

SET Rates

Transient BLO low to high: duration <0.2us

bit properties

Number of active cells (bits) 1

bit size 3.42e+001 x 3.42e+001 x 2.00 microns

Heavy ions

- Rate : 7.53e-005 /device /day Info

Protons

- Rate : 0.00e+000 /device /day

Total

Total rate : 7.53e-005 /device /day

→ 1 upset every 36.4 years

Transient BLO high to low: duration <0.4us

bit properties

Number of active cells (bits) 1

bit size 7.11e+001 x 7.11e+001 x 2.00 microns

Heavy ions

- Rate : 3.74e-004 /device /day Info

Protons

- Rate : 0.00e+000 /device /day

Total

Total rate : 3.74e-004 /device /day

→ 1 upset every 7.3 years

Transients observed on the bilevel telemetry function are of low occurrence and short duration <0.4us, could be easily filtered externally/in the FPGA if required.

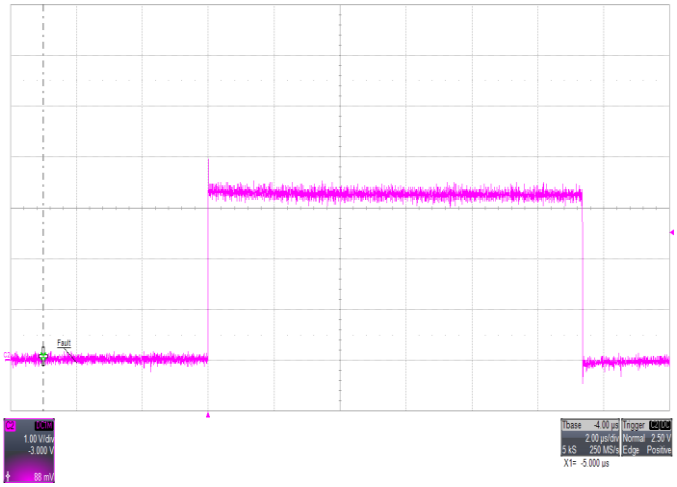
4.4. OTW AND PR_FAULT TEST: RESULTS

SET tests were performed at room temperature for the over temperature warning (OTW) and power supply faults PR_FAULT) outputs.

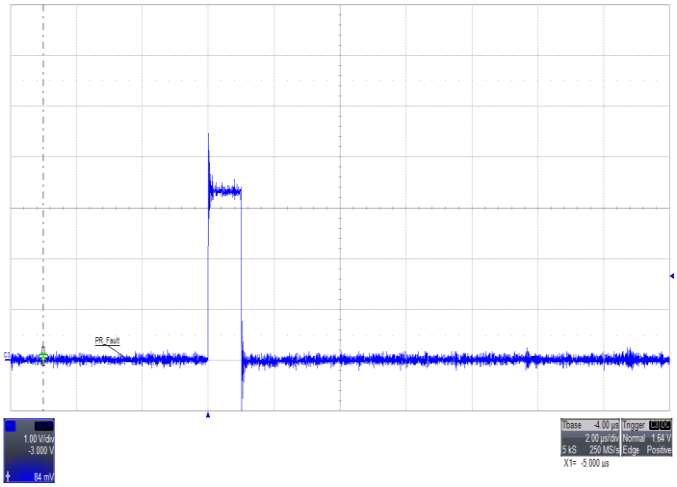
Run #	Part #	Ion	Air (mm)	Initial LET (MeVcm^2/mg)	Tilt Angle (Deg)	Flux (cm^{-2}.s^{-1})	Effective Fluence (cm^{-2})	Effective LET (MeVcm^2/mg)	UD Off, Pos SET	UD On, Neg SET	LD Off, Pos Events cm^2/dev	LD On Neg Events cm^2/dev
33	207_SEE	Pr	50	60.00	0.0	9.4E+03	7.77E+05	60.00	824		1.06E-3	
35	207_SEE	Pr	50	60.00	0.0	9.3E+05	7.72E+05	60.00		780		1.01E-3
62	207_SEE	Cu	50	20.30	0.0	2.4E+04	2.15E+06	20.30	347		1.61E-4	0.00E+0
63	207_SEE	Cu	50	20.30	0.0	2.6E+04	2.10E+06	20.30		504		2.40E-4
66	207_SEE	Cu	50	20.30	0.0	2.6E+04	1.38E+06	20.30	223		1.62E-4	
67	207_SEE	Cu	50	20.30	0.0	2.7E+04	7.08E+05	20.30	113		1.60E-4	
68	207_SEE	Cu	90	21.90	-48.0	2.6E+04	1.13E+06	32.73	294		2.60E-4	
72	207_SEE	Ar	50	8.60	0.0	6.7E+04	5.40E+06	8.60	335		6.20E-5	
73	207_SEE	Ar	50	8.60	0.0	6.9E+04	5.53E+06	8.60		63		1.14E-5
84	204_SEE	Ar	50	8.60	0.0	4.7E+04	3.89E+06	8.60	234		6.02E-5	
96	204_SEE	Ne	90	2.90	-51.0	6.6E+04	3.55E+06	4.61	21		5.92E-6	
97	204_SEE	Ne	90	2.90	-51.0	6.7E+04	3.64E+06	4.61		12		3.30E-6
101	204_SEE	Ne	90	2.90	-15.0	1.0E+05	8.14E+06	3.00	31		3.81E-6	0.00E+0
102	204_SEE	Ne	90	2.90	-15.0	9.7E+04	7.93E+06	3.00		5		6.31E-7
105	204_SEE	Kr	90	30.80	-16.0	4.0E+04	3.22E+06	32.04	821		2.55E-4	
106	204_SEE	Kr	90	30.80	-51.0	4.0E+04	2.16E+06	48.94	1549		7.17E-4	

SET waveforms

Transient OTW low to high: duration <12us

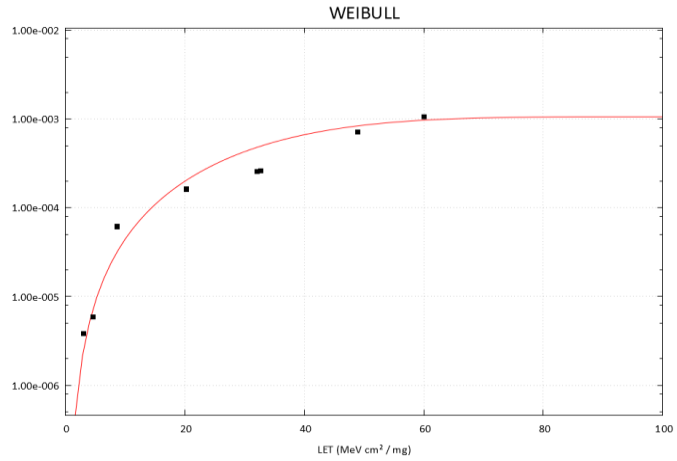


Transient PR_FAULT low to high: duration <1us



Weibull charts and parameters

Transient OTW low to high



Calculated Weibull W = 39.87779 S = 2.20796 MATERIAL = SILICON 2.33 g/cm3 View Data Export data

Limit Cross 1.06105e-003 cm² /device

LET 0.46108 MeV cm² /

Critical 9.51e-003 pC

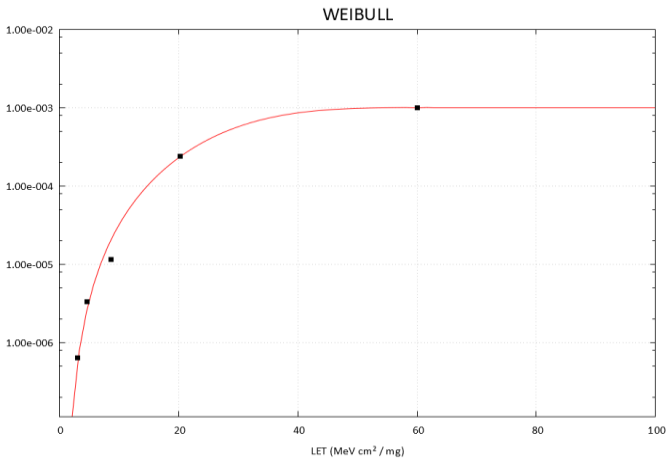
Use the fit parameters estimated by OMERE

a = b 3.26e+002 micrometer(s)

c = 2.00 micrometer(s)

Collection 1.00

Transient PR_FAULT low to high



Calculated Weibull W = 30.98606 S = 2.79360 MATERIAL = SILICON 2.33 g/cm3 View Data Export data

Limit Cross 1.01101e-003 cm² /device

LET 0.94204 MeV cm² /

Critical 1.94e-002 pC

Use the fit parameters estimated by OMERE

a = b 3.18e+002 micrometer(s)

c = 2.00 micrometer(s)

Collection 1.00

SET Rates

Transient OTW low to high

bit properties

Number of active cells (bits) 1

bit size 3.26e+002 x 3.26e+002 x 2.00 microns

Heavy ions

- Rate : 1.40e-003 /device /day Info

Protons

- Rate : 0.00e+000 /device /day

Total

Total rate : 1.40e-003 /device /day

→ 1 upset every 1.96 years

Transient PR_FAULT low to high

bit properties

Number of active cells (bits) 1

bit size 3.18e+002 x 3.18e+002 x 2.00 microns

Heavy ions

- Rate : 1.27e-003 /device /day Info

Protons

- Rate : 0.00e+000 /device /day

Total

Total rate : 1.27e-003 /device /day

→ 1 upset every 2.16 years

Transients observed on the fault detect functions for the power rails and the over temperature warning are of low occurrence and short duration around 10us, could be easily filtered externally/in the FPGA if required.

4.5. DEMOD DRIVER TEST: RESULTS

SET tests were performed at room temperature for the DEMOD driver in both high and low condition. No SET were observed.

Run #	Part #	Ion	Air (mm)	Initial LET (MeVcm^2/mg)	Tilt Angle (Deg)	Flux (cm^{-2}.s^{-1})	Effective Fluence (cm^{-2})	Effective LET (MeVcm^2/mg)	DMOD_P High, Neg SET	DMOD_N Low, Pos SET	DMOD_P High, Neg Events cm^2/dev	DMOD_N Low, Pos Events cm^2/dev
66	207_SEE	Cu	50	20.30	0.0	2.6E+04	1.38E+06	20.30	0	0	0.00E+0	0.00E+0
67	207_SEE	Cu	50	20.30	0.0	2.7E+04	7.08E+05	20.30	0	0	0.00E+0	0.00E+0
68	207_SEE	Cu	90	21.90	-48.0	2.6E+04	1.13E+06	32.73	0	0	0.00E+0	0.00E+0
72	207_SEE	Ar	50	8.60	0.00	6.7E+04	5.40E+06	8.60	0	0	0.00E+0	0.00E+0
84	204_SEE	Ar	50	8.60	0.00	4.7E+04	3.89E+06	8.60	0	0	0.00E+0	0.00E+0
96	204_SEE	Ne	90	2.90	-51.0	6.6E+04	3.55E+06	4.61	0	0	0.00E+0	0.00E+0
101	204_SEE	Ne	90	2.90	-15.0	1.0E+05	8.14E+06	3.00	0	0	0.00E+0	0.00E+0
105	204_SEE	Kr	90	30.80	-16.0	4.0E+04	3.22E+06	32.04	0	0	0.00E+0	0.00E+0
106	204_SEE	Kr	90	30.80	-51.0	4.0E+04	2.16E+06	48.94	0	0	0.00E+0	0.00E+0

No upsets were observed on any of the tests performed for the demod driver, in both on and off-states.

4.6. VREF TEST: RESULTS

SET tests were performed at room temperature for the VREF. No SET were observed.

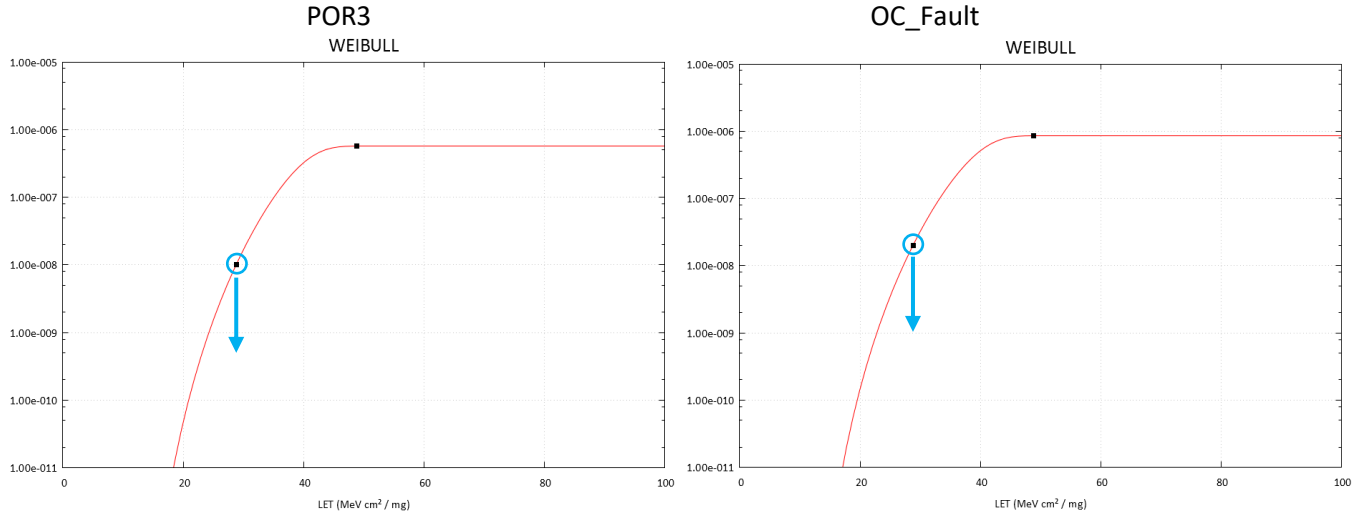
Run #	Part #	Ion	Air (mm)	Initial LET (MeVcm^2/mg)	Tilt Angle (Deg)	Flux (cm^{-2}.s^{-1})	Effective Fluence (cm^{-2})	Effective LET (MeVcm^2/mg)	VREF Pos SET	VREF Neg SET	VREF Pos Events cm^2/dev	VREF Neg Events cm^2/dev
29	207_SEE	Pr	50	60.00	0.00	1.0E+04	8.29E+05	60.00	0		0.00E+0	
30	207_SEE	Pr	50	60.00	0.00	1.0E+04	8.01E+05	60.00		0		0.00E+0
31	207_SEE	Pr	50	60.00	0.00	9.7E+03	7.79E+05	60.00		0		0.00E+0
32	207_SEE	Pr	50	60.00	0.00	9.4E+03	7.48E+05	60.00		0		0.00E+0
61	207_SEE	Cu	50	20.30	0.00	2.4E+04	2.17E+06	20.30	0		0.00E+0	
62	207_SEE	Cu	50	20.30	0.00	2.4E+04	2.15E+06	20.30		0		0.00E+0
69	207_SEE	Ar	50	8.60	0.00	7.2E+04	5.77E+06	8.60	0		0.00E+0	
70	207_SEE	Ar	50	8.60	0.00	5.8E+04	1.66E+06	8.60		0		0.00E+0
71	207_SEE	Ar	50	8.60	0.00	6.0E+04	4.75E+06	8.60		0		0.00E+0
94	204_SEE	Ne	90	2.90	-51.0	6.5E+04	3.47E+06	4.61	0		0.00E+0	
95	204_SEE	Ne	90	2.90	-51.0	6.5E+04	3.49E+06	4.61		0		0.00E+0
99	204_SEE	Ne	90	2.90	-15.0	1.0E+05	7.98E+06	3.00	0		0.00E+0	
100	204_SEE	Ne	90	2.90	-15.0	9.9E+04	8.16E+06	3.00		0		0.00E+0

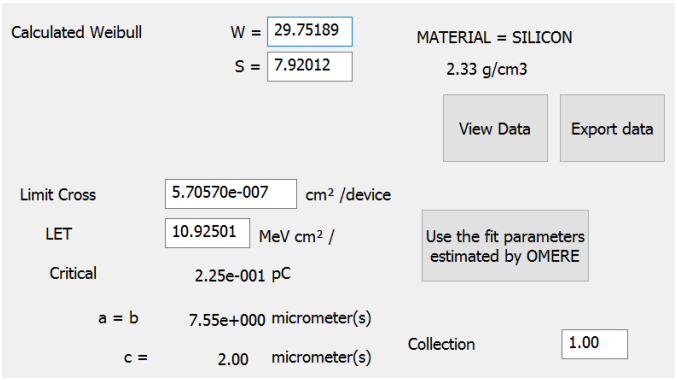
No upsets were observed on any of the tests for the VREF reference.

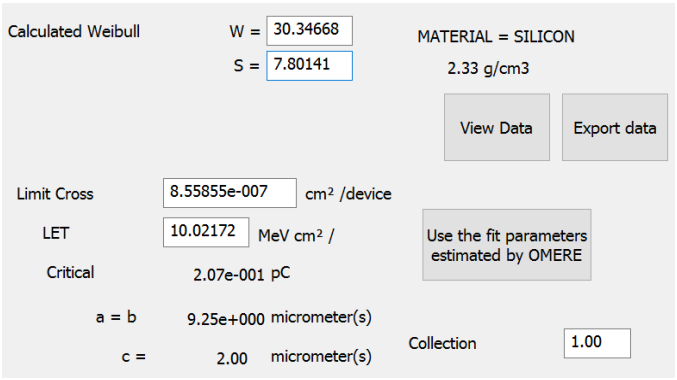
4.7. POR AND OC_FAULT TEST: RESULTS

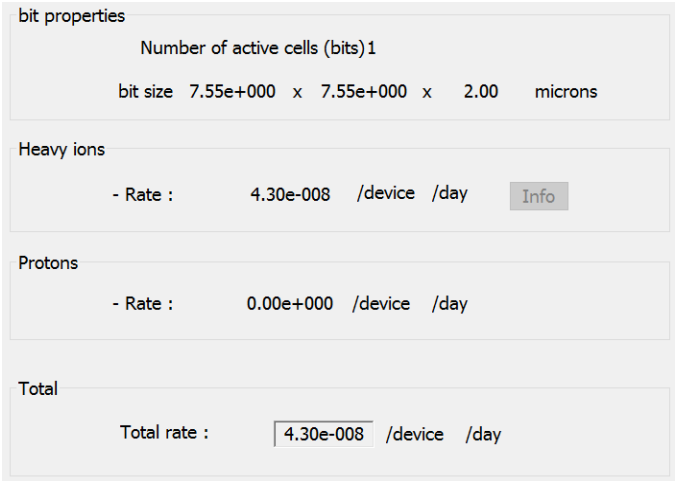
SET tests were performed at room temperature for the internal signals POR2 and POR3 as well as the overcurrent fault output (OC_FAULT).
At 28.8MeVcm²/mg, no SET were observed on all 3 signals.

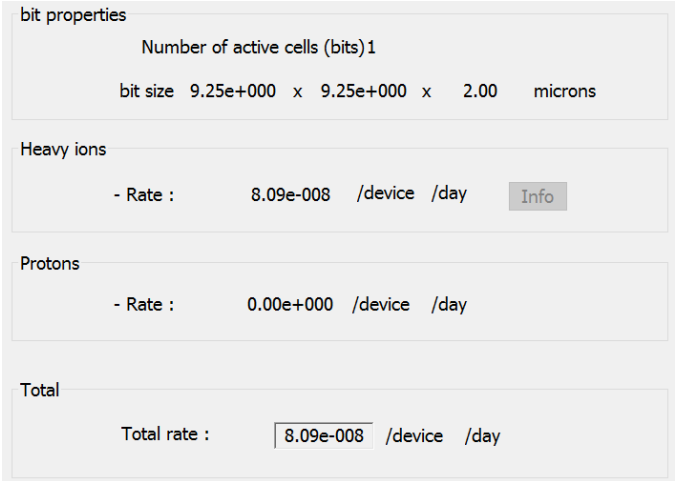
Run #	Part #	Ion	Air (mm)	Initial LET (MeVcm²/mg)	Tilt Angle (Deg)	Flux (cm⁻².s⁻¹)	Effective Fluence (cm⁻²)	Effective LET (MeVcm²/mg)	POR2 Pos SET	POR3 Pos SET	OC_Fault Pos SET	POR2 Pos Events cm²/dev	POR3 Pos Events cm²/dev	OC_Fault Pos Events cm²/dev
111	300	Kr	50	28.80	0.0	4.4E+04	3.30E+06	28.80	0	0	0	0.00E+0	0.00E+0	0.00E+0
112	300	Kr	90	30.80	-51.0	4.7E+04	3.51E+06	48.94	0	2	3	0.00E+0	5.70E-7	8.55E-7











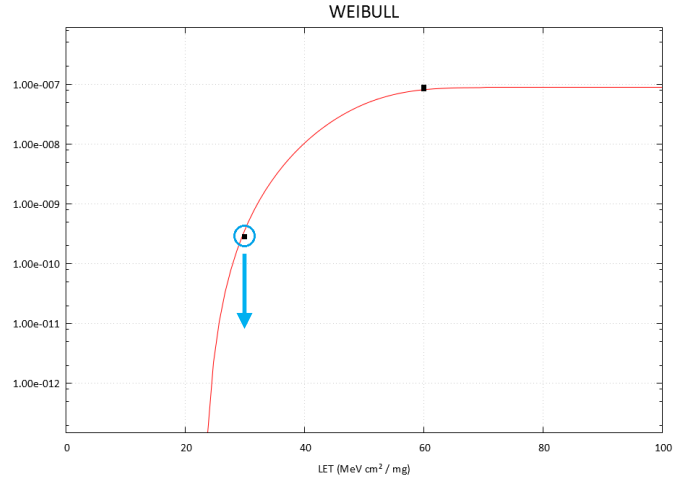
→ 1 upset every 63715 years/device

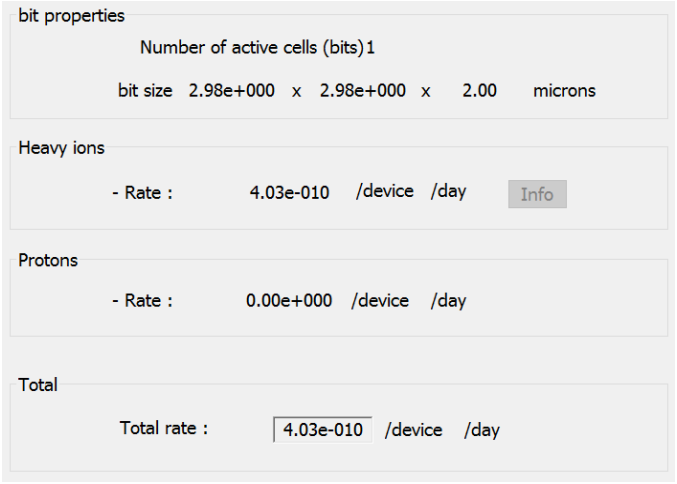
→ 1 upset every 33866 years/device

Very low upset rates of the POR and Overcurrent fault circuitry were observed.

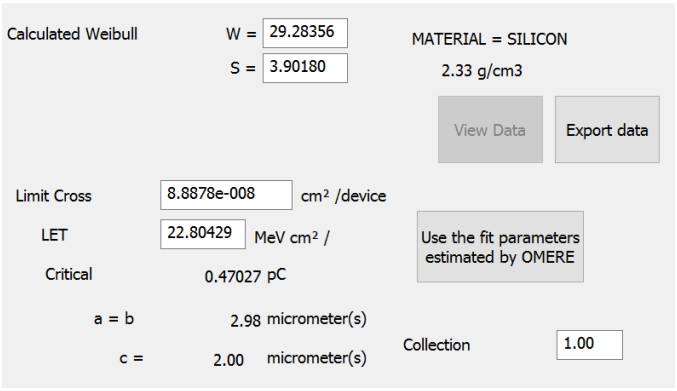
4.8. SCAN CHAIN FF SEU - STATIC: RESULTS

Run #	Part #	Ion	Air (mm)	Initial LET (MeVcm²/mg)	Tilt Angle (Deg)	Flux (cm⁻².s⁻¹)	Effective Fluence (cm⁻²)	Effective LET (MeVcm²/mg)	Bits Upsets	Upsets cm²/bit
38	FIB1	Pr	50	60.00	0.0	2.0E+04	2.04E+05	60.00	0	0.00E+00
39	FIB1	Pr	50	60.00	0.0	4.0E+04	1.08E+06	60.00	15	8.32E-08
40	FIB1	Pr	50	60.00	0.0	4.3E+04	1.50E+06	60.00	22	8.78E-08
48	FIB1	Cu	90	21.90	-50.0	2.9E+04	1.00E+06	34.07	0	0.00E+00
49	FIB1	Cu	90	21.90	-50.0	6.3E+04	2.16E+06	34.07	0	0.00E+00
50	FIB1	Cu	90	21.90	-43.0	6.2E+04	2.46E+06	29.94	0	0.00E+00
51	FIB1	Cu	90	21.90	-43.0	6.3E+04	2.51E+06	29.94	0	0.00E+00
52	FIB1	Cu	90	21.90	-43.0	6.7E+04	2.62E+06	29.94	0	0.00E+00
57	FIB1	Cu	90	21.90	0.0	6.6E+04	5.98E+06	21.90	0	0.00E+00
77	FIB1	Ar	90	9.10	-50.0	6.7E+04	4.12E+06	14.16	0	0.00E+00
80	FIB2	Ar	90	9.10	-50.0	4.7E+04	2.87E+06	14.16	0	0.00E+00





→ 1 upset every 6.8e6 years/bit



4.9. SCAN CHAIN FF SEU - DYNAMIC: RESULTS

- All 156 flip-flops. A 1 MHz clock and 250kHz input pattern are used to test the flip-flop chain.
- Flip-flops in the registers and digital busses are included in the scan chain.

All Runs

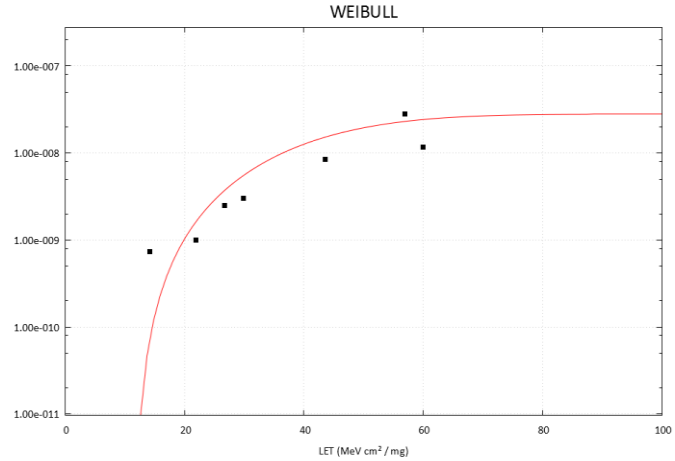
Run #	Part #	Ion	Air (mm)	Initial LET (MeVcm²/mg)	Tilt Angle (Deg)	Flux (cm⁻².s⁻¹)	Effective Fluence (cm⁻²)	Effective LET (MeVcm²/mg)	Bits Upsets	Bits Upstes cm²/bit
41	FIB1	Pr	50	60.00	0.0	4.3E+04	1.58E+06	60.00	5	1.9E-08
42	FIB1	Pr	50	60.00	0.0	4.3E+04	1.53E+06	60.00	1	3.9E-09
43	FIB1	Cu	90	21.90	-50.0	4.6E+04	1.62E+06	34.07	0	0
44	FIB1	Cu	90	21.90	-50.0	4.0E+04	1.34E+06	34.07	0	0
46	FIB1	Cu	90	21.90	-50.0	3.0E+04	9.70E+05	34.07	0	0
47	FIB1	Cu	90	21.90	-50.0	3.0E+04	1.90E+06	34.07	0	0
53	FIB1	Cu	90	21.90	-43.0	6.5E+04	4.88E+06	29.94	0	0
54	FIB1	Cu	90	21.90	-35.0	6.6E+04	4.77E+06	26.73	2	2.5E-09
55	FIB1	Cu	90	21.90	0.0	6.3E+04	6.00E+06	21.90	0	0
56	FIB1	Cu	90	21.90	0.0	6.1E+04	5.97E+06	21.90	2	2E-09
75	FIB1	Ar	90	9.10	-50.0	7.1E+04	4.36E+06	14.16	0	0
76	FIB1	Ar	90	9.10	-50.0	6.8E+04	4.20E+06	14.16	0	0
78	FIB2	Ar	90	9.10	-50.0	7.5E+04	4.62E+06	14.16	0	0
79	FIB2	Ar	90	9.10	-50.0	4.9E+04	3.06E+06	14.16	2	3.9E-09
82	FIB2	Ar	90	8.60	0.0	4.9E+04	4.68E+06	8.60	0	0
83	FIB2	Ar	90	8.60	0.0	4.8E+04	4.63E+06	8.60	0	0

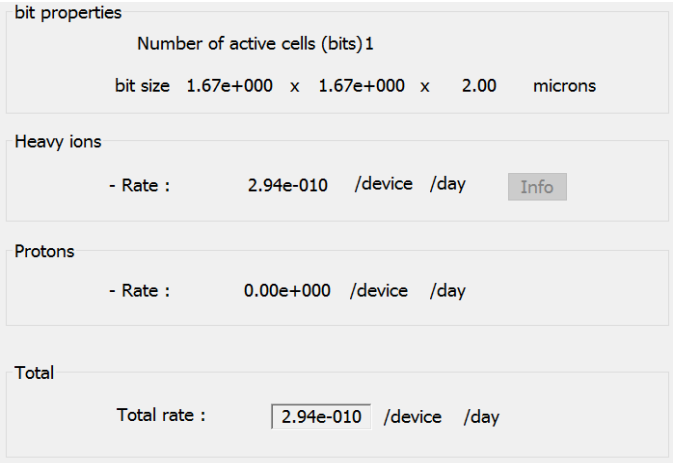
Same LET runs combined

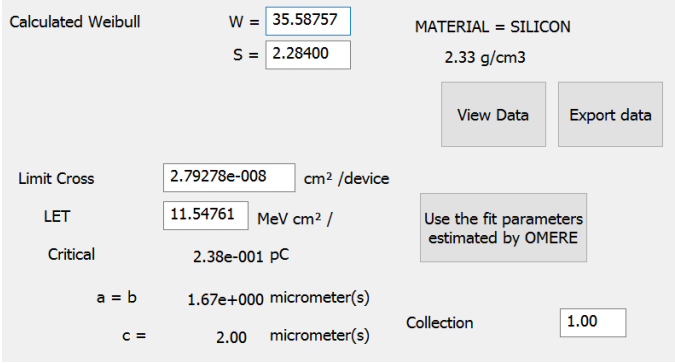
Effective Fluence (cm⁻²)	Effective LET (MeVcm²/mg)	Bits Upsets	Bits Upstes cm²/bit
3.11E+06	60.0	6	1.16E-08
5.83E+06	34.1	0	0.00E+00
4.88E+06	29.9	0	0.00E+00
4.77E+06	26.7	2	2.51E-09
1.20E+07	21.9	2	1.00E-09
1.62E+07	14.2	2	7.37E-10
9.31E+06	8.6	0	0.00E+00

Results from previous test performed in August 2018 (Same LET runs combined)

Effective Fluence (cm⁻²)	Effective LET (MeVcm²/mg)	Bits Upsets	Bits Upsets cm²/bit
5.16E+06	56.9	24	2.79E-08
7.12E+06	43.6	10	8.41E-09
4.00E+06	29.9	2	2.99E-09







→ 1 upset every 9.3e6 years/bit

We are observing very good results on the scan chain/Flip-Flops performance with very low upset rates of 4.03e-10/bit/day in static and 2.94e-10/bit/day.

Note: The LX7720 is essentially an analog power solution, where the FFs have minimal functional use:

- 90 of these FF are used for internal setting prior to zener programming -> no impact on the function of the device.
- 35 are for fault filter setting -> minimal functional impact, fault signals may show a transient but will recover.
- 27 FFs are for enable signals for the demodulator and the ADCs-> will only cause transients in enable for demodulator and ADC data. No Latched-behavior.
- 4 FFs are used to set the charge pump clock-> an upset could create a temporary frequency change on the VBOOST and VEE signals with no or nominal functional impact.

4.10. Other Digital Upsets: results

Two other digital upset types were observed during the scan chain SEU testing. The first type is a clock shift of the whole scan chain most probably caused by a SET on the clock buffer. The second is characterized as miscellaneous because the cause of these upsets cannot be exactly determined.
The upset rates for these are very low.

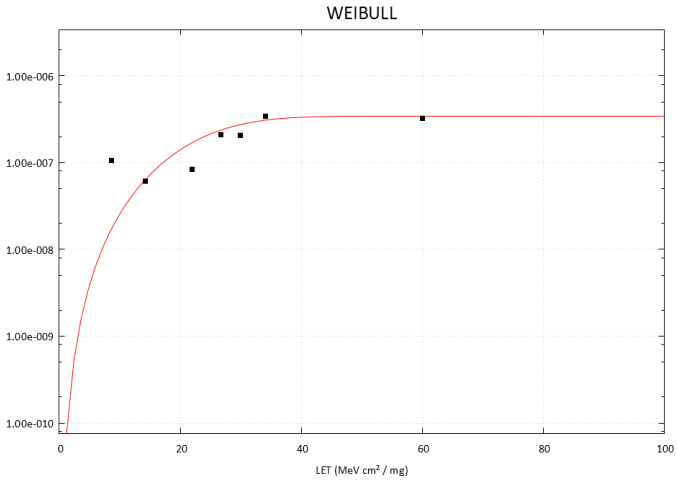
All Runs

Run #	Part #	Ion	Air (mm)	Initial LET (MeVcm^2/mg)	Tilt Angle (Deg)	Flux (cm^{-2}.s^{-1})	Effective Fluence (cm^{-2})	Effective LET (MeVcm^2/mg)	CLK shifts	Misc	CLK shifts cm^2/device	Misc cm^2/device
41	FIB1	Pr	50	60.00	0.0	4.3E+04	1.58E+06	60.0	0	4	0.00E+00	2.53E-06
42	FIB1	Pr	50	60.00	0.0	4.3E+04	1.53E+06	60.0	1	3	6.54E-07	1.96E-06
43	FIB1	Cu	90	21.90	-50.0	4.6E+04	1.62E+06	34.1	1	1	6.17E-07	6.17E-07
44	FIB1	Cu	90	21.90	-50.0	4.0E+04	1.34E+06	34.1	0	0	0.00E+00	0.00E+00
46	FIB1	Cu	90	21.90	-50.0	3.0E+04	9.70E+05	34.1	0	0	0.00E+00	0.00E+00
47	FIB1	Cu	90	21.90	-50.0	3.0E+04	1.90E+06	34.1	1	0	5.26E-07	0.00E+00
53	FIB1	Cu	90	21.90	-43.0	6.5E+04	4.88E+06	29.9	1	4	2.05E-07	8.20E-07
54	FIB1	Cu	90	21.90	-35.0	6.6E+04	4.77E+06	26.7	1	1	2.10E-07	2.10E-07
55	FIB1	Cu	90	21.90	0.0	6.3E+04	6.00E+06	21.9	1	0	1.67E-07	0.00E+00
56	FIB1	Cu	90	21.90	0.0	6.1E+04	5.97E+06	21.9	0	2	0.00E+00	3.35E-07
75	FIB1	Ar	90	9.10	-50.0	7.1E+04	4.36E+06	14.2	0	N/A	0.00E+00	N/A
76	FIB1	Ar	90	9.10	-50.0	6.8E+04	4.20E+06	14.2	1	N/A	2.38E-07	N/A
78	FIB2	Ar	90	9.10	-50.0	7.5E+04	4.62E+06	14.2	0	0	0.00E+00	0.00E+00
79	FIB2	Ar	90	9.10	-50.0	4.9E+04	3.06E+06	14.2	0	0	0.00E+00	0.00E+00
82	FIB2	Ar	90	8.60	0.0	4.9E+04	4.68E+06	8.6	1	0	2.14E-07	0.00E+00
83	FIB2	Ar	90	8.60	0.0	4.8E+04	4.63E+06	8.6	0	0	0.00E+00	0.00E+00

Same LET runs combined

Effective Fluence (cm^{-2})	Effective LET (MeVcm^2/mg)	CLK shifts	Misc	CLK shifts cm^2/device	Misc cm^2/device
1.58E+06	60.0	1	5	3.22E-07	2.25E-06
1.90E+06	34.1	2	1	3.43E-07	1.72E-07
4.88E+06	29.9	1	4	2.05E-07	8.20E-07
4.77E+06	26.7	1	1	2.10E-07	2.10E-07
6.00E+06	21.9	1	2	8.35E-08	1.67E-07
3.06E+06	14.2	1	0	6.16E-08	0.00E+00
4.63E+06	8.6	1	0	1.07E-07	0.00E+00

Clock Shift



Calculated Weibull W = 25.19832 S = 2.76882 MATERIAL = SILICON 2.33 g/cm3 View Data Export data

Limit Cross 3.43343e-007 cm² /device

LET 0.00100 MeV cm² /

Critical 2.06e-005 pC

Use the fit parameters estimated by OMERE

a = b 5.86e+000 micrometer(s)

c = 2.00 micrometer(s)

Collection 1.00

bit properties

Number of active cells (bits) 1

bit size 5.86e+000 x 5.86e+000 x 2.00 microns

Heavy ions

- Rate : 3.18e-007 /device /day Info

Protons

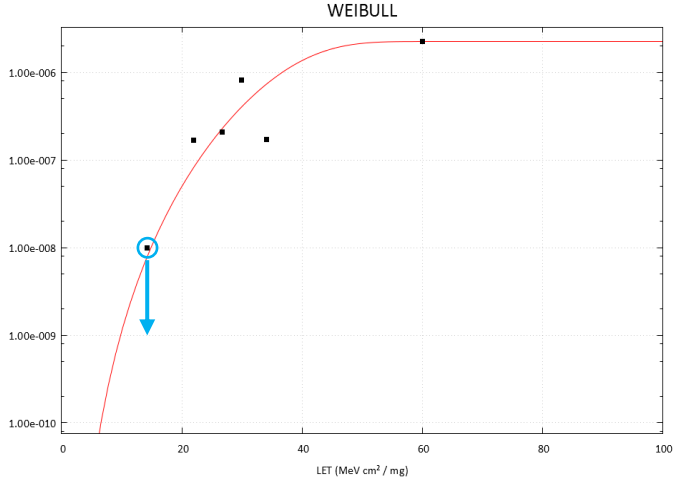
- Rate : 0.00e+000 /device /day

Total

Total rate : 3.18e-007 /device /day

→ 1 upset every 8615 years/device

Miscellaneous



Calculated Weibull W = 39.95725 S = 5.26134 MATERIAL = SILICON 2.33 g/cm3 View Data Export data

Limit Cross 2.25225e-006 cm² /device

LET 0.60027 MeV cm² /

Critical 1.24e-002 pC

Use the fit parameters estimated by OMERE

a = b 1.50e+001 micrometer(s)

c = 2.00 micrometer(s)

Collection 1.00

bit properties

Number of active cells (bits) 1

bit size 1.50e+001 x 1.50e+001 x 2.00 microns

Heavy ions

- Rate : 4.25e-007 /device /day Info

Protons

- Rate : 0.00e+000 /device /day

Total

Total rate : 4.25e-007 /device /day

→ 1 upset every 6446 years/device

4.11. ADC TEST: RESULTS

The ADC was tested in two conditions:

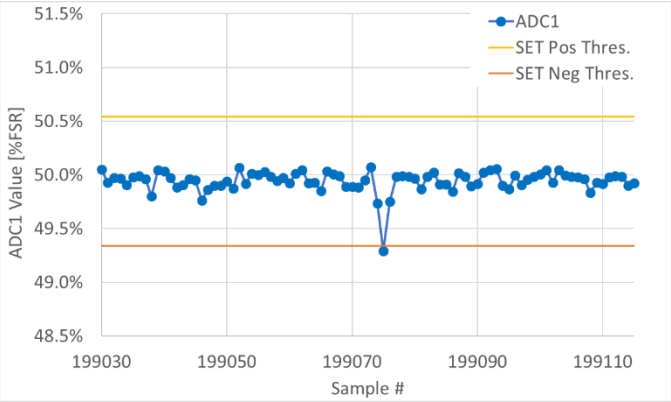
1. ADC1 with Zero input: ADC_P and ADC_N shorted together and tied to VREF (2.5V)
2. ADC2 with max linear range DC signal: ADC_P=VREF+0.4V and ADC_N=VREF-0.4V using resistors divider

The ADC clock was 24MHz and the data was processed using a sync3 filter with OSR=256 .

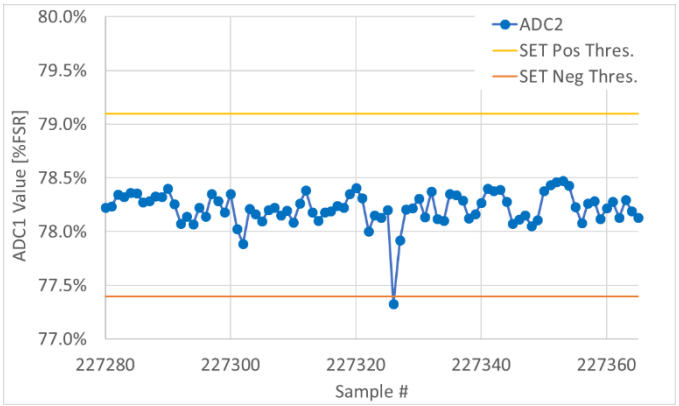
The use of a resistors divider for ADC2 resulted in higher system/setup injected noise than ADC1. In order to not count noise as SET, the SET amplitude thresholds need to be set at the noise 6 sigma or more. Therefore the SET are defined as transients with amplitude that exceed ±0.85%FSR for ADC2 and ±0.60%FSR for ADC1

Example of a transients

ADC1



ADC2



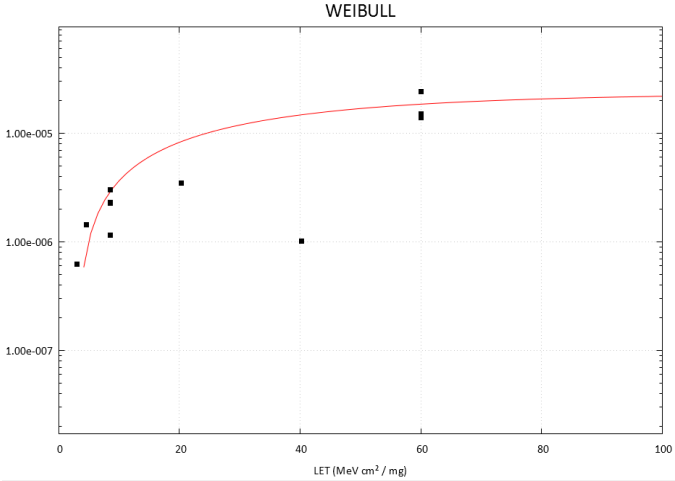
ADC1 – Zero Input

Run #	Part #	Ion	Air (mm)	Initial LET (MeVcm²/mg)	Tilt Angle (Deg)	Flux (cm⁻².s⁻¹)	Effective Fluence (cm⁻²)	Effective LET (MeVcm²/mg)	ADC1 SET	SET cm²/device
29	207_SEE	Pr	50	60.0	0.0	1.0E+04	8.29E+05	60.0	3	1.38E-05
30	207_SEE	Pr	50	60.0	0.0	1.0E+04	8.01E+05	60.0	20	2.41E-05
59	207_SEE	Cu	50	20.3	0.0	5.2E+04	4.89E+06	60.0	12	1.50E-05
69	207_SEE	Ar	50	8.6	0.0	7.2E+04	5.77E+06	20.3	17	3.48E-06
70	207_SEE	Ar	50	8.6	0.0	5.8E+04	1.66E+06	8.6	13	2.25E-06
71	207_SEE	Ar	50	8.6	0.0	6.0E+04	4.75E+06	8.6	5	3.02E-06
85	204_SEE	Ar	50	8.6	0.0	5.2E+04	4.30E+06	8.6	11	2.32E-06
94	204_SEE	Ne	90	2.9	-51.0	6.5E+04	3.47E+06	8.6	5	1.16E-06
99	204_SEE	Ne	90	2.9	-15.0	1.0E+05	7.98E+06	4.6	5	1.44E-06
113	300	Kr	90	30.8	-40.0	4.6E+04	2.97E+06	3.0	5	6.27E-07

ADC2 – Max linear range DC signal

Run #	Part #	Ion	Air (mm)	Initial LET (MeVcm²/mg)	Tilt Angle (Deg)	Flux (cm⁻².s⁻¹)	Effective Fluence (cm⁻²)	Effective LET (MeVcm²/mg)	ADC2 SET	SET cm²/device
32	207_SEE	Pr	50	60.0	0.0	9.4E+03	7.48E+05	60.0	34	4.55E-05
61	207_SEE	Cu	50	20.3	0.0	2.4E+04	2.17E+06	20.3	30	1.38E-05
95	204_SEE	Ne	90	2.9	-51.0	6.5E+04	3.49E+06	4.6	9	2.58E-06
100	204_SEE	Ne	90	2.9	-15.0	9.9E+04	8.16E+06	3.0	3	3.68E-07
114	300	Kr	90	30.8	-40.0	4.6E+04	3.03E+06	40.21	5	1.65E-06

ADC1 – Zero Input



Calculated Weibull W = 37.17940 S = 1.06314 MATERIAL = SILICON 2.33 g/cm3 View Data Export data

Limit Cross 2.33056e-005 cm² /device

LET 2.98756 MeV cm² /

Critical 6.16e-002 pC

Use the fit parameters estimated by OMERE

a = b 4.83e+001 micrometer(s)

c = 2.00 micrometer(s)

Collection 1.00

bit properties

Number of active cells (bits) 1

bit size 4.83e+001 x 4.83e+001 x 2.00 microns

Heavy ions

- Rate : 6.24e-005 /device /day Info

Protons

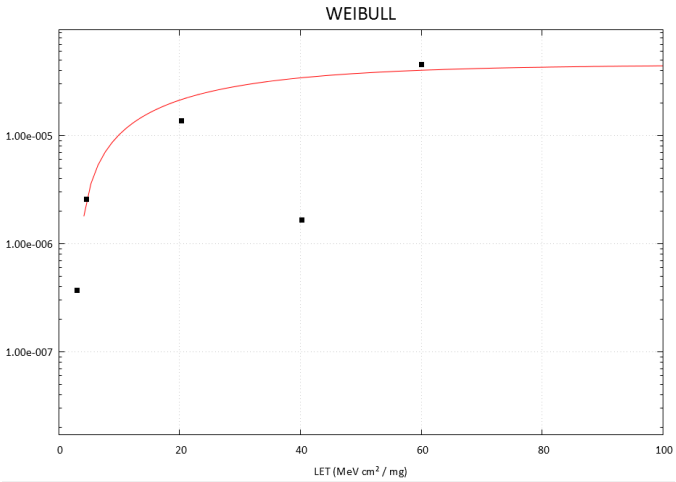
- Rate : 0.00e+000 /device /day

Total

Total rate : 6.24e-005 /device /day

→ 1 upset every 44 years/ADC

ADC2 – Max linear range DC signal



Calculated Weibull W = 26.38047 S = 1.02883 MATERIAL = SILICON 2.33 g/cm3 View Data Export data

Limit Cross 4.51013e-005 cm² /device

LET 2.98756 MeV cm² /

Critical 6.16e-002 pC

Use the fit parameters estimated by OMERE

a = b 6.72e+001 micrometer(s)

c = 2.00 micrometer(s)

Collection 1.00

bit properties

Number of active cells (bits) 1

bit size 6.72e+001 x 6.72e+001 x 2.00 microns

Heavy ions

- Rate : 1.76e-004 /device /day Info

Protons

- Rate : 0.00e+000 /device /day

Total

Total rate : 1.76e-004 /device /day

→ 1 upset every 15.6 years/ADC

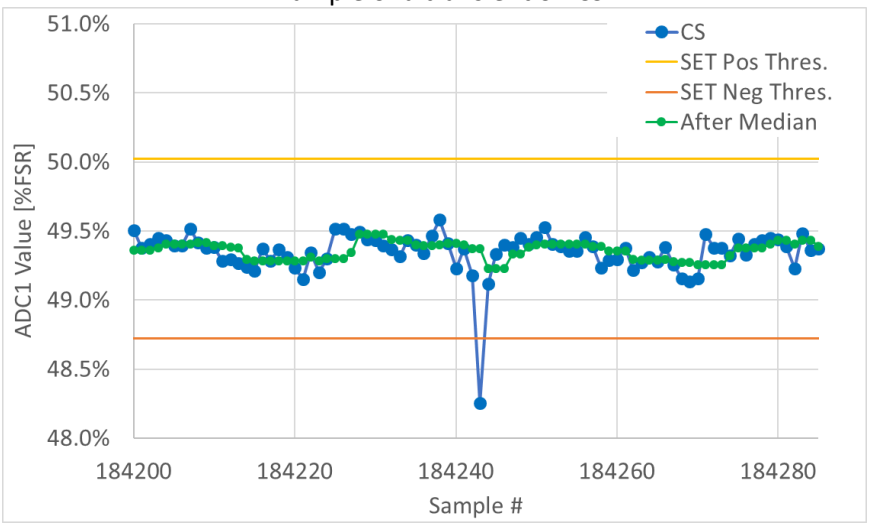
4.12. CURRENT SENSE TEST: RESULTS

The Current Sense was tested with CS and RTN connected to MGND

The CS ADC clock was 24MHz and the data was processed using a two stage filter. The first stage is a sinc3 filter with an OSR=256 and the second stage is a median filter that takes into account 7 samples of the sinc3 filter. First stage results are shown in the "CS_A SET" column, second stage results are shown in the "CS_A SET After Median Filter" column.

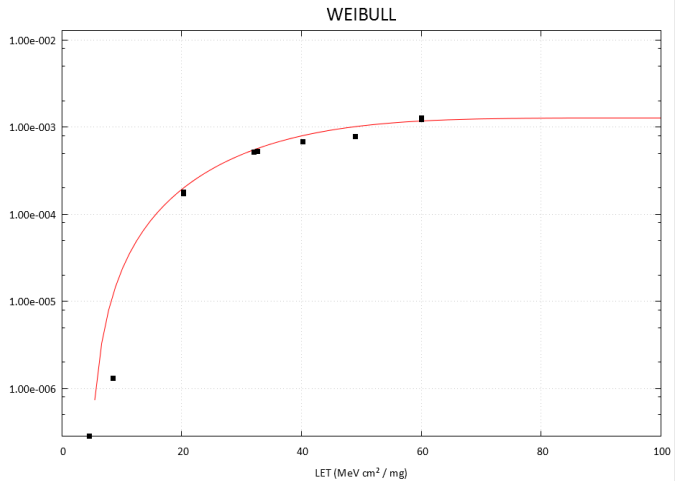
In order to not count noise as SET, the SET amplitude thresholds need to be set at the noise 6 sigma or more. In this case, SET are defined as transients with amplitude that exceed ±0.65%FSR. The use of the recommended median filter completely eliminate all observed transients.

Example of a transient on CS



Run #	Part #	Ion	Air (mm)	Initial LET (MeVcm²/mg)	Tilt Angle (Deg)	Flux (cm⁻².s⁻¹)	Effective Fluence (cm⁻²)	Effective LET (MeVcm²/mg)	CS_A SET	SET cm²/device	CS_A SET After Median Filter
31	207_SEE	Pr	50	60.00	0.0	9.7E+03	7.79E+05	60.0	993	1.27E-03	0
33	207_SEE	Pr	50	60.00	0.0	9.4E+03	7.77E+05	60.0	953	1.23E-03	0
62	207_SEE	Cu	50	20.30	0.0	2.4E+04	2.15E+06	20.3	372	1.73E-04	0
66	207_SEE	Cu	50	20.30	0.0	2.6E+04	1.38E+06	20.3	247	1.79E-04	0
68	207_SEE	Cu	90	21.90	-48.0	2.6E+04	1.13E+06	32.7	589	5.21E-04	0
72	207_SEE	Ar	50	8.60	0.0	6.7E+04	5.40E+06	8.6	7	1.30E-06	0
84	204_SEE	Ar	50	8.60	0.0	4.7E+04	3.89E+06	8.6	0	0.00E+00	0
96	204_SEE	Ne	90	2.90	-51.0	6.6E+04	3.55E+06	4.6	1	2.82E-07	0
101	204_SEE	Ne	90	2.90	-15.0	1.0E+05	8.14E+06	3.0	0	0.00E+00	0
105	204_SEE	Kr	90	30.80	-16.0	4.0E+04	3.22E+06	32.0	1646	5.11E-04	0
106	204_SEE	Kr	90	30.80	-51.0	4.0E+04	2.16E+06	48.9	1686	7.81E-04	0
115	300	Kr	90	30.80	-40.0	4.6E+04	3.04E+06	40.2	2066	6.80E-04	0

CS



Calculated Weibull W = 36.09900 S = 2.16665

MATERIAL = SILICON
2.33 g/cm3

View Data | Export data

Limit Cross 1.27127e-003 cm² /device

LET 4.34135 MeV cm² /

Critical 8.95e-002 pC

Use the fit parameters estimated by OMERE

a = b 3.57e+002 micrometer(s)

c = 2.00 micrometer(s)

Collection 1.00

bit properties

Number of active cells (bits) 1

bit size 3.57e+002 x 3.57e+002 x 2.00 microns

Heavy ions

- Rate : 1.07e-003 /device /day Info

Protons

- Rate : 0.00e+000 /device /day

Total

Total rate : 1.07e-003 /device /day

→ 1 upset every 2.6 years/CS without median filter, no upsets with median filter

4.13. DETAILED RUN TABLES FOR SEL/SEB

Runs Parameters									Supplies currents (mA)											Events		
Run #	Part #	Ion	Air (mm)	Initial LET ($MeVcm^2/mg$)	Tilt Angle (Deg)	Flux ($cm^{-2}.s^{-1}$)	Effective Fluence (cm^{-2})	Effective LET ($MeVcm^2/mg$)	VGS Pre	VMPS Pre	VDD Pre	VCC Pre	VEE Pre	VGS Post	VMPS Post	VDD Post	VCC Post	VEE Post	VMPS Voltage	SEL SEB SEGR	Other Stress	Temp.
1	200_SEE	Pr	50	60.00	0.00	4.5E+04	2.14E+05	60.0	36.7	3.0	45.5	195.4	4.8	36.7	3.0	45.5	195.4	4.8	40V			125C
2	200_SEE	Pr	50	60.00	0.00	4.9E+04	1.00E+06	60.0	36.7	3.0	45.5	195.4	4.8	36.7	3.0	45.5	195.4	4.8	40V			125C
3	200_SEE	Pr	50	60.00	0.00	5.0E+05	1.00E+07	60.0	36.7	3.0	45.5	195.4	4.8	37.0	3.0	45.5	195.4	4.9	40V			125C
4	200_SEE	Pr	50	60.00	0.00	4.8E+04	1.31E+06	60.0	37.0	3.0	45.5	195.4	4.9	37.0	3.0	45.5	195.4	4.9	40V			125C
5	200_SEE	Pr	50	60.00	0.00	4.9E+04	1.00E+07	60.0	36.8	3.8	45.0	186.9	4.9	36.9	3.8	44.9	186.8	4.9	50V			125C
6	200_SEE	Pr	50	60.00	0.00	4.8E+04	1.00E+07	60.0	37.2	4.6	44.9	187.0	4.9	37.2	4.6	44.8	187.1	4.9	60V[3]			125C
7	200_SEE	Pr	50	60.00	0.00	4.6E+04	5.47E+05	60.0	37.2	10.7	44.8	187.2	4.9	37.2	CL	44.8	187.1	4.9	120V[3]		X[1]	125C
8	201_SEE	Pr	90	63.20	-38.00	4.9E+04	1.00E+07	80.2	37.5	2.9	44.7	194.0	5.0	37.5	3.0	44.5	196.5	5.0	40V			125C
9	201_SEE	Pr	90	63.20	-38.00	4.9E+04	1.00E+07	80.2	37.4	3.7	44.5	193.9	5.0	37.9	3.8	43.9	188.5	5.2	50V			125C
10	201_SEE	Pr	90	63.20	-38.00	4.6E+04	1.00E+07	80.2	37.7	4.5	44.0	188.1	5.2	38.0	4.6	43.8	188.8	5.2	60V[3]			125C
11	201_SEE	Pr	90	63.20	-38.00	4.6E+04	1.22E+06	80.2	37.8	5.5	44.0	188.6	5.2	37.2	0.0	43.8	188.8	5.2	70V[3]		X[1]	125C
12	201_SEE	Pr	90	63.20	-38.00	4.7E+04	1.00E+07	80.2	39.9	3.8	44.0	188.5	4.6	40.3	3.8	43.8	189.3	4.5	50V			125C
13	201_SEE	Pr	90	63.20	-38.00	4.6E+04	1.00E+07	80.2	40.1	4.7	44.0	188.9	4.5	40.6	4.6	43.8	189.7	4.9	60V[3]			125C
14	203_SEE	Pr	50	60.00	0.00	4.9E+04	1.00E+07	60.0	36.9	4.5	45.0	196.5	4.9	36.8	4.5	44.8	194.0	4.9	60V[3]			125C
15	203_SEE	Pr	50	63.20	-38.00	4.9E+04	1.00E+07	80.2	36.7	3.7	44.8	194.0	4.9	36.7	3.7	44.0	188.2	5.2	50V		X[2]	125C
16	203_SEE	Pr	50	63.20	-38.00	4.5E+04	1.00E+07	80.2	36.3	3.0	44.2	187.6	4.3	36.5	3.0	44.2	187.8	4.3	40V		X[2]	125C
17	203_SEE	Pr	50	63.20	-38.00	4.5E+04	1.00E+07	80.2	36.1	2.4	44.2	187.7	3.8	35.8	2.4	44.4	187.6	3.8	36V		X[2]	125C
18	206_SEE	Pr	50	63.20	-38.00	3.8E+04	9.60E+06	80.2	35.8	2.5	45.2	184.2	4.8	36.5	2.4	44.6	184.8	4.9	36V		X[2]	125C
19	206_SEE	Pr	50	63.20	-38.00	3.8E+04	2.00E+06	80.2	35.9	2.9	44.5	184.3	4.2	35.9	2.9	44.5	184.3	4.2	40V		X[2]	125C
20	204_SEE	Pr	50	60.00	0.00	4.5E+04	2.02E+06	60.0	36.5	4.5	45.7	185.7	4.8	36.9	4.4	45.8	194.5	4.8	60V[3]			125C
21	204_SEE	Pr	50	60.00	0.00	4.1E+04	4.00E+06	60.0	36.9	4.4	45.8	194.5	4.8	37.4	4.5	44.5	193.0	4.9	60V[3]			125C
22	204_SEE	Pr	50	60.00	0.00	3.7E+04	4.00E+06	60.0	37.4	4.5	44.5	193.0	4.9	37.7	4.5	44.5	194.5	5.1	60V[3]			125C
23	204_SEE	Pr	50	63.20	-38.00	3.6E+04	1.29E+06	80.2	37.4	2.5	45.1	186.4	5.0	37.5	2.5	44.9	186.2	4.8	36V			125C
24	204_SEE	Pr	50	63.20	-38.00	3.6E+04	5.00E+06	80.2	37.5	2.5	44.9	186.2	4.8	37.5	2.5	44.9	186.2	4.8	36V			125C
25	204_SEE	Pr	50	63.20	-38.00	3.5E+04	3.80E+06	80.2	37.5	2.5	44.9	186.2	4.8	37.3	2.5	44.9	185.9	4.7	36V			125C
26	204_SEE	Pr	50	63.20	-38.00	3.3E+04	5.00E+06	80.2	36.6	Switch	44.5	185.7	4.8	36.6	Switch	44.5	185.7	4.8	50V			125C
27	204_SEE	Pr	50	63.20	-38.00	3.3E+04	5.00E+06	80.2	37.2	4.6	44.9	186.2	4.8	37.2	4.6	44.5	186.0	4.8	60V[3]			125C

Note 1: We are observing a damage in the upper driver, not directly attributed to SEL/SEB/SEGR.
Note 2: We are observing an increase in the fall time of the upper driver, not attributed to SEL/SEB/SEGR.
Note 3: For information only. Test performed at VMPS supply voltage higher than the datasheet max operating condition of the device.

4.14. DETAILED RUN TABLES FOR SET

Runs Parameters									Events																			
									Run Type A				Run Type B				Run Type C				Run Type D				Run Type E			
Run #	Part #	Ion	Air (mm)	Initial LET ($MeVcm^2/mg$)	Tilt Angle (Deg)	Flux ($cm^{-2}.s^{-1}$)	Effective Fluence (cm^{-2})	Effective LET ($MeVcm^2/mg$)	UD Pos SET	UD Neg SET	VRef Pos SET	ADC 4a	LD Pos SET	LD Neg SET	VRef Neg SET	ADC 4b	Mod Pos SET	Mod Neg SET	OTW Pos SET	CS 5a	BLIO Pos SET	BLIO Neg SET	PR_FLT Pos SET	CS 5b	POR2 SET	POR3 SET	OC_FLT Pos SET	Temperature
28	207_SEE	Pr	50	60.00	0.00	1.0E+04	2.17E+05	60.0	Bad run																			Room
29	207_SEE	Pr	50	60.00	0.00	1.0E+04	8.29E+05	60.0	628	294	0	sav																Room
30	207_SEE	Pr	50	60.00	0.00	1.0E+04	8.01E+05	60.0				sav	285	534	0													Room
31	207_SEE	Pr	50	60.00	0.00	9.7E+03	7.79E+05	60.0					246	569	0					sav								Room
32	207_SEE	Pr	50	60.00	0.00	9.4E+03	7.48E+05	60.0					264	505	0	sav												Room
33	207_SEE	Pr	50	60.00	0.00	9.4E+03	7.77E+05	60.0									X	0	824	sav								Room
34	207_SEE	Pr	50	60.00	0.00	9.4E+03	6.46E+05	60.0									Just for jpg											Room
35	207_SEE	Pr	50	60.00	0.00	9.3E+05	7.72E+05	60.0													9	39	780	sav				Room
36	207_SEE	Pr	50	60.00	0.00	2.2E+04	9.98E+05	60.0																				Room
37	207_SEE	Pr	50	60.00	0.00	2.2E+04	1.80E+06	60.0																	X	X	X	Room
58	207_SEE	Cu	50	20.30	0.00	4.7E+04	2.55E+05	20.3	x	x	x	x	x															Room
59	207_SEE	Cu	50	20.30	0.00	5.2E+04	4.89E+06	20.3	too	too	0	sav																Room
60	207_SEE	Cu	50	20.30	0.00	2.4E+04	2.37E+05	20.3	84	20	0	x																Room
61	207_SEE	Cu	50	20.30	0.00	2.4E+04	2.17E+06	20.3					262	543	0	sav												Room
62	207_SEE	Cu	50	20.30	0.00	2.4E+04	2.15E+06	20.3									X	0	347	sav								Room
63	207_SEE	Cu	50	20.30	0.00	2.6E+04	2.10E+06	20.3													12	79	504	sav				Room
64	207_SEE	Cu	50	20.30	0.00	2.4E+04	1.39E+06	20.3																	X	X	X	Room
65	207_SEE	Cu	50	20.30	0.00	2.4E+04	1.88E+06	20.3																	X	X	X	Room
66	207_SEE	Cu	50	20.30	0.00	2.6E+04	1.38E+06	20.3									0	0	223	sav								Room
67	207_SEE	Cu	50	20.30	0.00	2.7E+04	7.08E+05	20.3									0	0	113									Room
68	207_SEE	Cu	90	21.90	-48.00	2.6E+04	1.13E+06	32.7									0	0	294	sav								Room
69	207_SEE	Ar	50	8.60	0.00	7.2E+04	5.77E+06	8.6	474	213	0	sav																Room
70	207_SEE	Ar	50	8.60	0.00	5.8E+04	1.66E+06	8.6					61	133	0	sav												Room
71	207_SEE	Ar	50	8.60	0.00	6.0E+04	4.75E+06	8.6					180	367	0	sav												Room
72	207_SEE	Ar	50	8.60	0.00	6.7E+04	5.40E+06	8.6									0	0	335	sav								Room
73	207_SEE	Ar	50	8.60	0.00	6.9E+04	5.53E+06	8.6													27	106	63	sav				Room
74	207_SEE	Ar	50	8.60	0.00	6.4E+04	5.21E+06	8.6																	X	X	X	Room
84	204_SEE	Ar	50	8.60	0.00	4.7E+04	3.89E+06	8.6									0	0	234	sav								Room
85	204_SEE	Ar	50	8.60	0.00	5.2E+04	4.30E+06	8.6				sav																Room
86	204_SEE	Ar	50	8.60	0.00	5.0E+04	3.84E+06	8.6																				Room
87	204_SEE	Ar	50	8.60	0.00	4.7E+04	1.23E+06	8.6																				Room
88	204_SEE	Ar	50	8.60	0.00	4.7E+04	2.95E+06	8.6																				Room
89	204_SEE	Ne	90	2.90	-50.00	5.3E+04	2.80E+06	4.5																				Room
90	204_SEE	Ne	90	2.90	-50.00	5.4E+04	3.24E+06	4.5																				Room
91	204_SEE	Ne	90	2.90	-50.00	5.5E+04	5.00E+06	4.5																				Room
92	204_SEE	Ne	90	2.90	-50.00	6.0E+04	2.56E+06	4.5																				Room
93	204_SEE	Ne	90	2.90	-50.00	6.0E+04	4.40E+06	4.5																	X	X	X	Room
94	204_SEE	Ne	90	2.90	-51.00	6.5E+04	3.47E+06	4.6	5	3	0	sav																Room
95	204_SEE	Ne	90	2.90	-51.00	6.5E+04	3.49E+06	4.6					5	5	0	sav												Room
96	204_SEE	Ne	90	2.90	-51.00	6.6E+04	3.55E+06	4.6									0	0	21	sav								Room

97	204_SEE	Ne	90	2.90	-51.00	6.7E+04	3.64E+06	4.6												2	16	12	sav				Room
98	204_SEE	Ne	90	2.90	-51.00	6.6E+04	4.62E+06	4.6																X	X	X	Room
99	204_SEE	Ne	90	2.90	-15.00	1.0E+05	7.98E+06	3.0	6	6	0	sav															Room
100	204_SEE	Ne	90	2.90	-15.00	9.9E+04	8.16E+06	3.0					4	5	0	sav											Room
101	204_SEE	Ne	90	2.90	-15.00	1.0E+05	8.14E+06	3.0									0	0	31	sav							Room
102	204_SEE	Ne	90	2.90	-15.00	9.7E+04	7.93E+06	3.0													2	7	5	sav			Room
103	204_SEE	Ne	90	2.90	-15.00	1.0E+05	6.60E+06	3.0																	X	X	X	Room
104	204_SEE	Ne	90	2.90	-15.00	1.0E+05	9.93E+06	3.0																	X	X	X	Room
105	204_SEE	Kr	90	30.80	-16.00	4.0E+04	3.22E+06	32.0									0	0	821	sav							Room
106	204_SEE	Kr	90	30.80	-51.00	4.0E+04	2.16E+06	48.9									0	0	1549	sav							Room
107	204_SEE	Kr	50	28.80	0.00	4.3E+04	0.75E+06	28.8																	Bad run		Room
108	300	Kr	50	28.80	0.00	3.9E+04	0.91E+06	28.8																	Bad run		Room
109	300	Kr	50	28.80	0.00	4.0E+04	2.29E+06	28.8																	Bad run		Room
110	300	Kr	50	28.80	0.00	4.2E+04	2.37E+06	28.8																	Bad run		Room
111	300	Kr	50	28.80	0.00	4.4E+04	3.30E+06	28.8																	0	0	0	Room
112	300	Kr	90	30.80	-51.00	4.7E+04	3.51E+06	48.9																	0	2	3	Room
113	300	Kr	90	30.80	-40.00	4.6E+04	2.97E+06	40.2				sav															Room
114	300	Kr	90	30.80	-40.00	4.6E+04	3.03E+06	40.2								sav											Room
115	300	Kr	90	30.80	-40.00	4.6E+04	3.04E+06	40.2												sav							Room
116	300	Kr	90	30.80	-40.00	4.5E+04	3.01E+06	40.2																sav				Room

4.15. DETAILED RUN TABLES FOR SEU

Runs Parameters									Events Count				
Run #	Part #	Ion	Air (mm)	Initial LET (MeVcm²/mg)	Tilt Angle (Deg)	Flux ($cm^{-2}.s^{-1}$)	Effective Fluence (cm^{-2})	Effective LET (MeVcm²/mg)	Bits upsets dynamic	Bits upsets static	CLK Shifts	Misc	Temperature
38	FIB1	Pr	50	60.00	0.00	2.0E+04	2.04E+05	60.0		0			Room
39	FIB1	Pr	50	60.00	0.00	4.0E+04	1.08E+06	60.0		15			Room
40	FIB1	Pr	50	60.00	0.00	4.3E+04	1.50E+06	60.0		22			Room
41	FIB1	Pr	50	60.00	0.00	4.3E+04	1.58E+06	60.0	5		0	4	Room
42	FIB1	Pr	50	60.00	0.00	4.3E+04	1.53E+06	60.0	1		1	3	Room
43	FIB1	Cu	90	21.90	-50.00	4.6E+04	1.62E+06	34.1	0		1	1	Room
44	FIB1	Cu	90	21.90	-50.00	4.0E+04	1.34E+06	34.1	0		0	0	Room
45	FIB1	Cu	90	21.90	-50.00	3.1E+04	1.00E+06	34.1	Bad Run				Room
46	FIB1	Cu	90	21.90	-50.00	3.0E+04	9.70E+05	34.1	0		0	0	Room
47	FIB1	Cu	90	21.90	-50.00	3.0E+04	1.90E+06	34.1	0		1	0	Room
48	FIB1	Cu	90	21.90	-50.00	2.9E+04	1.00E+06	34.1		0			Room
49	FIB1	Cu	90	21.90	-50.00	6.3E+04	2.16E+06	34.1		0			Room
50	FIB1	Cu	90	21.90	-43.00	6.2E+04	2.46E+06	29.9		0			Room
51	FIB1	Cu	90	21.90	-43.00	6.3E+04	2.51E+06	29.9		0			Room
52	FIB1	Cu	90	21.90	-43.00	6.7E+04	2.62E+06	29.9		0			Room
53	FIB1	Cu	90	21.90	-43.00	6.5E+04	4.88E+06	29.9	0		1	4	Room
54	FIB1	Cu	90	21.90	-35.00	6.6E+04	4.77E+06	26.7	2		1	1	Room
55	FIB1	Cu	90	21.90	0.00	6.3E+04	6.00E+06	21.9	0		1	0	Room
56	FIB1	Cu	90	21.90	0.00	6.1E+04	5.97E+06	21.9	2		0	2	Room
57	FIB1	Cu	90	21.90	0.00	6.6E+04	5.98E+06	21.9		0			Room
75	FIB1	Ar	90	9.10	-50.00	7.1E+04	4.36E+06	14.2	0		0	N/A	Room
76	FIB1	Ar	90	9.10	-50.00	6.8E+04	4.20E+06	14.2	0		1	N/A	Room
77	FIB1	Ar	90	9.10	-50.00	6.7E+04	4.12E+06	14.2		0			Room
78	FIB2	Ar	90	9.10	-50.00	7.5E+04	4.62E+06	14.2	0		0	0	Room
79	FIB2	Ar	90	9.10	-50.00	4.9E+04	3.06E+06	14.2	2		0	0	Room
80	FIB2	Ar	90	9.10	-50.00	4.7E+04	2.87E+06	14.2		0			Room
81	FIB2	Ar	90	9.10	-50.00	4.2E+04	1.81E+05	14.2	Bad Run				Room
82	FIB2	Ar	90	8.60	0.00	4.9E+04	4.68E+06	8.6	0		1	0	Room
83	FIB2	Ar	90	8.60	0.00	4.8E+04	4.63E+06	8.6	0		0	0	Room

4.16. DETAILED RUN TABLES FOR TEST PERFORMED ON JULY 26TH

Runs Parameters									Supplies currents (mA)											Events				
Run #	Part #	Ion	Air (mm)	Initial LET ($MeVcm^2/mg$)	Tilt Angle (Deg)	Flux ($cm^{-2}.s^{-1}$)	Effective Fluence (cm^{-2})	Effective LET ($MeVcm^2/mg$)	VGS Pre	VMPS Pre	VDD Pre	VCC Pre	VEE Pre	VGS Post	VMPS Post	VDD Post	VCC Post	VEE Post	VMPS Voltage	SEL SEB SEGR	Other Stress	SET Events	Scan Chain SEU	Temp.
1	1_SEE	Au	50	87.10	0.0	5.8E+04	0.99E+06	87.1	39.7	0.0	32.0	141.5	6.0	42.8		31.5	150.5	6.0	150V[2]		X[1]			125C
2	1_SEE	Au	50	87.10	0.0	5.7E+04	1.00E+07	87.1	42.8		31.5	150.5	6.0	42.4		31.4	150.5	6.0	150V[2]		X[1]			125C
3	1_SEE	Au	50	87.10	30.0	5.9E+04	1.00E+07	100.6	42.4		31.4	150.5	6.0	41.8	8.7	31.2	151.0	6.0	150V[2]		X[1]			125C
4	2_SEE	Au	50	87.10	0.0	7.1E+04	1.04E+06	87.1	38.3	0.0	33.4	137.2	5.9	38.3	0.0	33.4	137.2	5.9	36V					125C
5	2_SEE	Au	50	87.10	0.0	7.1E+04	2.97E+06	87.1	38.3	0.0	33.4	137.2	5.9	38.5	0.0	33.5	137.3	6.0	36V					125C
6	2_SEE	Au	50	87.10	0.0	7.2E+04	2.97E+06	87.1	38.5	0.0	33.5	137.3	6.0	38.5	0.0	33.5	137.1	6.0	36V					125C
7	2_SEE	Au	50	87.10	0.0	7.6E+04	3.00E+06	87.1	38.5	0.0	33.5	137.1	6.0	38.5	0.0	33.5	137.1	6.0	36V					125C
8	2_SEE	Au	50	87.10	0.0	7.9E+04	3.04E+06	87.1	38.6	0.0	33.0	131.4	6.1	33.7	0.0	33.0	131.2	6.0	70V[2]		X[1]			125C
9	3_SEE	Au	90	89.00	0.0	6.6E+04	1.44E+06	89.0	41.0	0.0	32.5	141.0	6.3	41.5	0.0	32.5	141.6	6.4	50V					125C
10	3_SEE	Au	50	87.10	0.0	8.0E+04	1.00E+07	87.1	41.5	0.0	32.5	141.6	6.4	41.7	0.0	32.4	141.8	6.5	50V		X[1]			125C
11	3CC_SEE	Ag	50	43.60	0.0	8.0E+04	2.32E+06	43.6	41.7	0.0	23.6	134.3	6.5	23.7	0.0	3.1	23.7	6.9	50V				5	Room
12	3CC_SEE	Ag	50	43.60	0.0	8.4E+04	2.40E+06	43.6	23.7	0.0	3.1	23.7	6.9	23.7	0.0	3.1	23.7	6.9	50V				4	Room
13	3CC_SEE	Ag	50	43.60	0.0	8.4E+04	2.40E+06	43.6	23.7	0.0	3.1	23.7	6.9	23.7	0.0	3.1	23.7	6.9	50V				1	Room
14	3CC_SEE	Ag	50	43.60	40.0	7.8E+04	1.72E+06	56.9	23.7	0.0	3.1	23.7	6.9	23.7	0.0	3.1	23.7	6.9	50V				4	Room
15	3CC_SEE	Ag	50	43.60	40.0	7.9E+04	1.72E+06	56.9	23.7	0.0	3.1	23.7	6.9	23.7	0.0	3.1	23.7	6.9	50V				8	Room
16	3CC_SEE	Ag	50	43.60	40.0	7.9E+04	1.72E+06	56.9	23.7	0.0	3.1	23.7	6.9	23.7	0.0	3.1	23.7	6.9	50V				12	Room
17	3CC_SEE	Ag	50	43.60	0.0	7.4E+04	1.99E+06	43.6											50V					Room
18	3CC_SEE	Ag	50	43.60	0.0	7.5E+04	3.05E+06	43.6											50V					Room
19	3CC_SEE	Ag	50	43.60	0.0	7.5E+04	5.02E+06	43.6											50V					Room
20	3CC_SEE	Ag	50	43.60	0.0	7.6E+04	7.18E+06	43.6											50V					Room
21	3CC_SEE	Ag	50	43.60	0.0	7.2E+04	0.69E+06	43.6											50V					Room
22	3CC_SEE	Ag	50	43.60	0.0	7.8E+04	5.03E+06	43.6											50V					Room
23	3CC_SEE	Ag	50	43.60	0.0	7.8E+04	1.44E+06	43.6											50V			180		Room
24	3CC_SEE	Ag	50	43.60	0.0	7.5E+04	0.86E+06	43.6											50V			84		Room
25	3CC_SEE	Ag	50	43.60	0.0	7.7E+04	1.01E+06	43.6											50V			89		Room
26	3CC_SEE	Kr	50	28.80	0.0	7.5E+04	2.18E+06	28.8											50V			0		Room
27	3CC_SEE	Kr	50	28.80	0.0	7.0E+04	0.68E+06	28.8											50V			100		Room
28	3CC_SEE	Kr	50	28.80	0.0	7.0E+04	0.93E+06	28.8											50V			112		Room
29	3CC_SEE	Kr	50	28.80	0.0	6.7E+04	0.47E+06	28.8											50V			71		Room
30	3CC_SEE	Kr	50	28.80	0.0	6.7E+04	1.96E+06	28.8											50V				1	Room
31	3CC_SEE	Kr	50	28.80	0.0	7.1E+04	2.04E+06	28.8											50V				1	Room

Note 1: We are observing a damage in the upper driver, not directly attributed to SEL/SEB/SEGR.

Note 2: For information only. Test performed at VMPS supply voltage higher than the datasheet max operating condition of the device.

5. CONCLUSION

The single event testing of the LX7720 performed at the Texas A&M Cyclotron on October 30th 2018 allowed us to conclude that:

- The design is immune to SEL/SEB/SEGR up to 60MeV.cm2/mg and 125°C (fluence of 1e7 particles/cm2) with some sensitivities observed at 80.2MeV.cm2/mg.
- No SEFIs observed.
- Very low upset rates for the scan chain/flip-flop in both static and dynamic modes, 4.03e-10/bit/day and 2.94e-10/bit/day respectively.
- Strong performance of all blocks with respect to transients, MOSFET drivers, power rails and temperature fault detection blocks, bilevel telemetry blocks, internally generated reference blocks, demodulator block, ADC and Current Sense.