RADIATION TEST REPORT

Heavy Ion Testing of RH119 Dual Voltage Comparator from Linear Technology

Using three different XMM design configurations

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European Space Agency Contract Report

The work described in this report was done under ESA contract.
Responsibility for the contents resides in the author or organization that prepared it

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TABLE OF CHANGES

Issue 1 May 17th, 1999

Original issue

Issue 2 June 21st, 1999
Addition of FDE/Sun tests results with 4.7 kohms pull-up resistors (R1,R22 in Figure 6)

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FIGURES

TABLES

I. INTRODUCTION

This report presents the results of a heavy ion Single Event Effects (SEEs) test program carried out for the XMM project on Linear Technology RH119 High Performance Dual Comparator.

XMM Hi-rel devices were tested at the European Heavy Ion Irradiation Facility (HIF) at Cyclone, Université Catholique de Louvain, Belgium.

The main aims of these tests were to assess the RH119 susceptibility to Single Event Upsets (SEUs) using three different designs configurations used on XMM :

(a) a test configuration equivalent to WDE design (see Figure 4).

(b) a test configuration equivalent to FDE Temp design (see Figure 5).

(c) a test configuration equivalent to FDE Sun design (see Figure 6).

Tests were performed in such a way that computation of the SEU rates in XMM orbit could be achieved on the test results data basis.

This work was performed for ESA/ESTEC under ESA Contract No 13413/98/NL/MV CCN No 01 dated 11/05/99

II. DOCUMENTS

II.1 APPLICABLE DOCUMENTS

AD1. Memorandum ref. XMM-998XMM01.doc dated 14 April, 1999

II.2 REFERENCE DOCUMENTS

RD1. Linear Technology, RH119 data sheet.
RD2. Single Event Effects Test method and Guidelines ESA/SCC basic specification No 25100
RD3. The Heavy Ion Irradiation Facility at CYCLONE, UCL document, Centre de Recherches du Cyclotron (IEEE NSREC'96, Workshop Record, Indian Wells, California, 1996)

III. DEVICE INFORMATION

III.1 DEVICE DESCRIPTION

High Performance Dual Comparator.

III.2 PROCUREMENT OF TEST SAMPLES

5 hirel samples (LAT2) have been delivered to Hirex by ESA.
Following Serial Numbers have been given : #001, #002, #003, #004, #005

III.3 PREPARATION OF SAMPLES

The 5 devices have been delidded by Hirex Lab.

III.4 SAMPLES CHECK OUT

A functional test sequence has been performed on delidded samples to check that devices have not been degraded by the delidding operation.

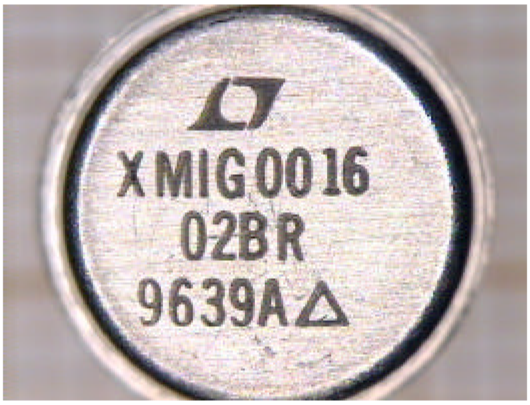
III.5 DEVICE DESCRIPTION

Description of the devices is as follows:

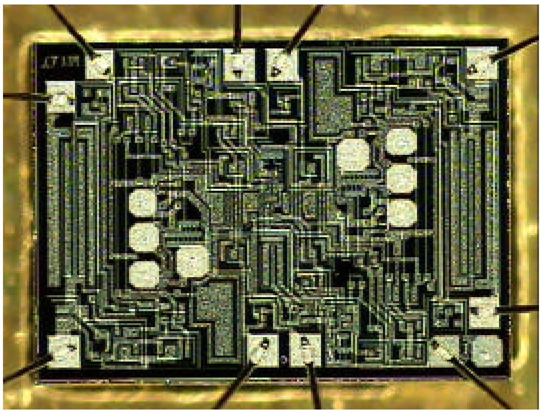
Part type :	RH119
Manufacturer :	Linear Technology
Package :	10-Lead TO-5 Metal Can
Quality Level :	Hirel
Date Code :	9639A
Serial Number :	#001, #002, #003, #004, #005
Die Technology :	Bipolar
Top Marking:	XMIG0016 02BR
Die Size :	2.0 mm x 1.4 mm approximately
Die Marking :	119
Heavy ion test samples (delidded) :	5 #001, #002, #003, #004, #005

External and Internal Photos are shown in Figure 1.

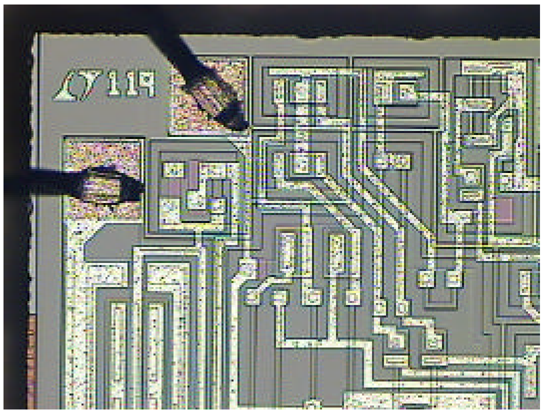
Figure 1 – RH119 External and Internal Photos



Top view



Die, Full view



Die, Marking

IV. DEVICE TEST PATTERN DEFINITION

IV.1 PREPARATION OF TEST HARDWARE AND PROGRAM

Overall device emulation, SEU and Latch-up detection, data storage and processing were implemented using an in-house test hardware and application specific test boards.

The generic in-house test equipment is driven by a PC computer through a RS232 line. All power supplies and input signals are delivered and monitored by the in-house equipment which also stores in its memory the output data from the device throughout the specific test board.

The application specific test board allowed to interface the standard test hardware with the device under test, in order to correctly emulate the relevant part, to record all the different type of errors during the irradiation and to set output signal for processing and storage by the standard test equipment.

At the end of each test run, data are transferred to the PC computer through the RS232 link for storage on hard disk or floppies.

IV.2 GENERIC TEST SET-UP

Generic device test set-up is presented in Figure 2.
This set-up is constituted of the following equipments:

- A PC computer (to configure and interface with the test system and store the data),
- An electronic rack with the instrumentation functions provided by a set of electronic modules,
- A mother board under vacuum which allows for the sequential test of up to 4 devices
- A digital oscilloscope to store analog upset waveform

IV.2.1 Mother board description (ref. IL110)

The motherboard acts as a standard interface between each DUT test board and the control unit :
For each DUT board slot, the following signals can be considered:

- 8 inputs signals
  - 4 programmable power supplies
  - 4 programmable clocks
- 8 output signals
  - 4 logic counting signals
  - 2 fast analog signals
  - 2 accurate analog signals

- Each device needs a dedicated plug-in test board compatible with IL110 mother board.
- IL110 board has been designed to comply with both PSI and Louvain test facilities .
- The number of slots is limited to four

Operation is multiplexed and only one slot is powered at one time.

Mother board synoptic is shown in Figure 3.

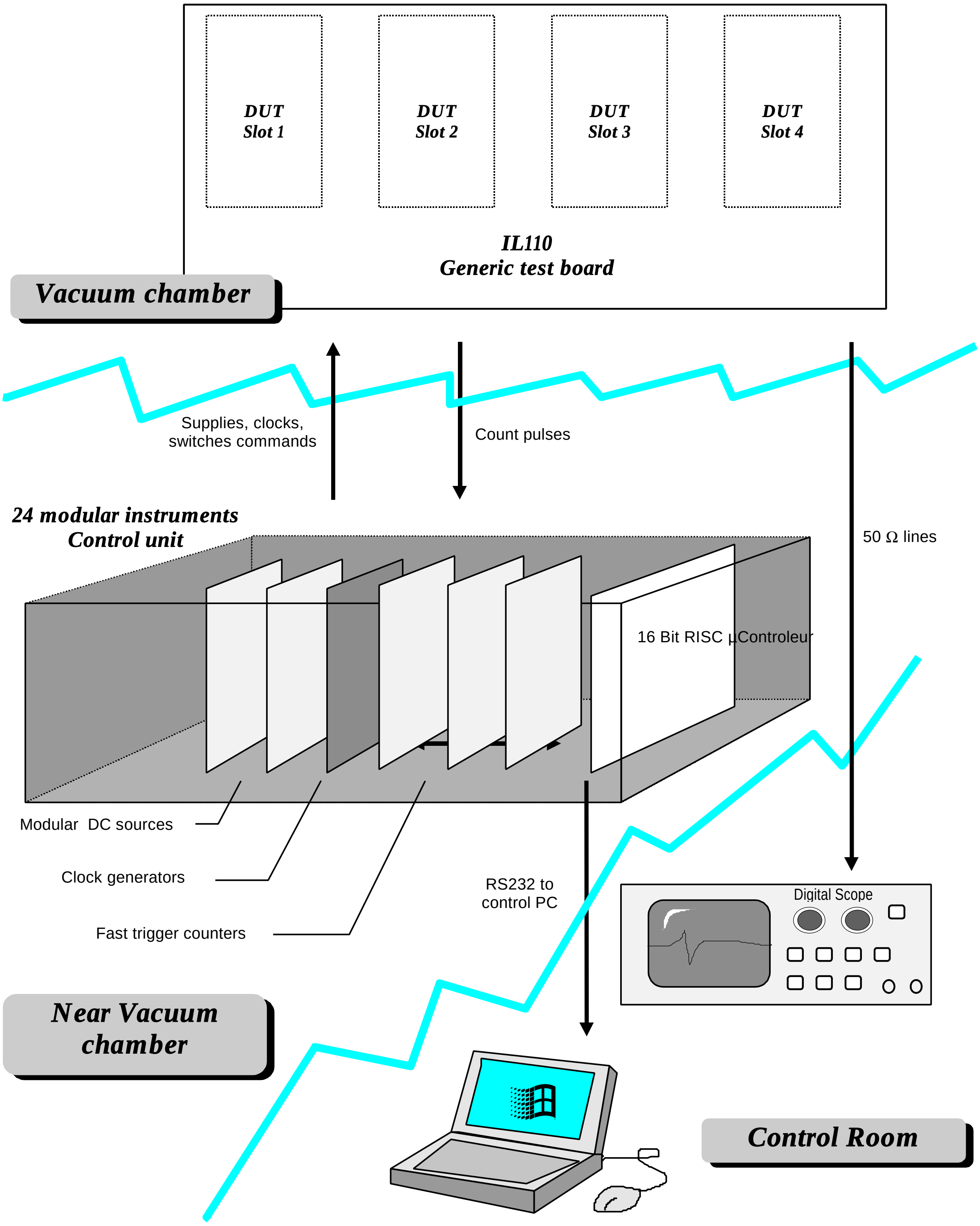


Figure 2 - Generic Device Test Set-up

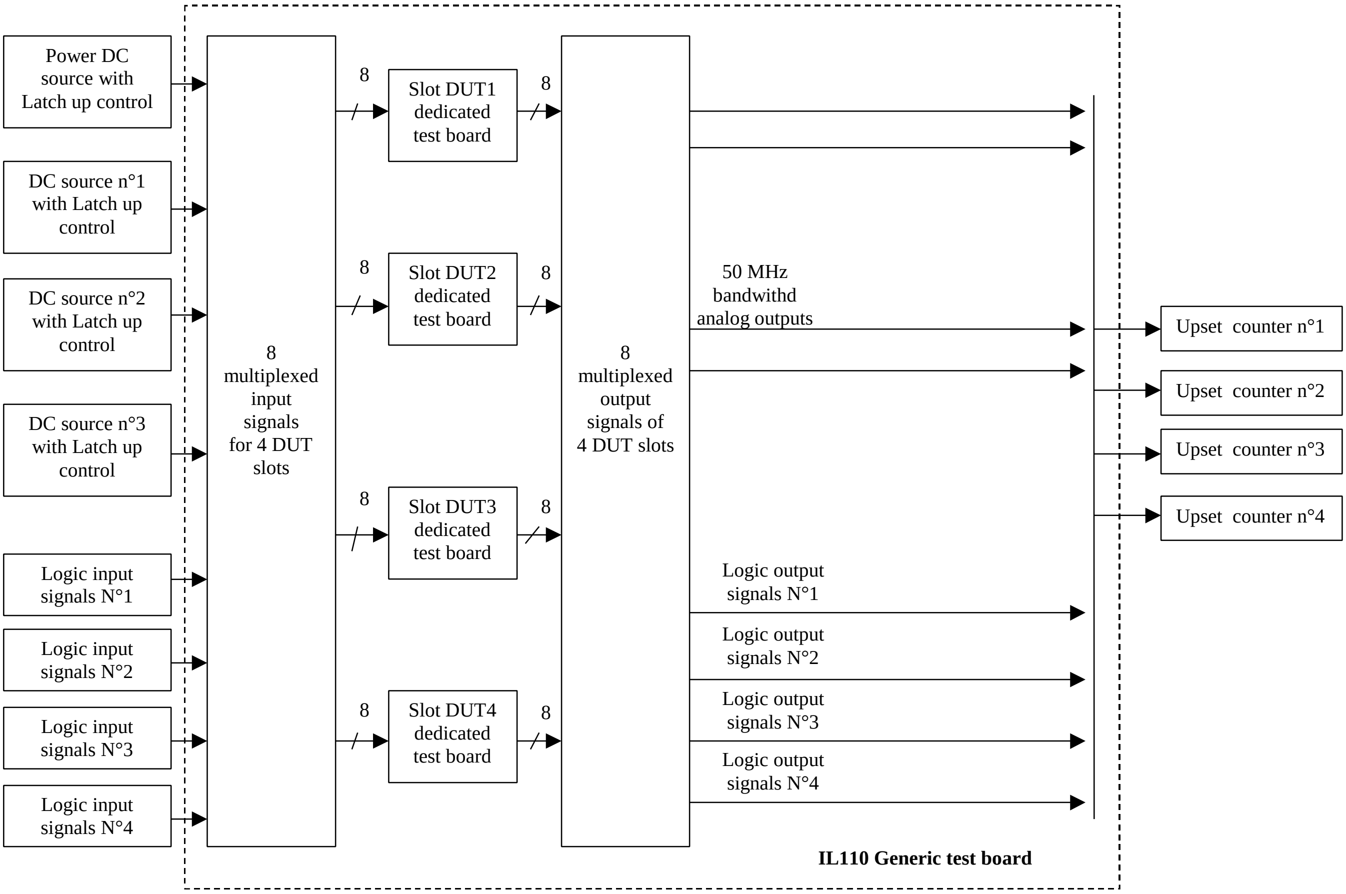


Figure 3 - Mother board synoptic

IV.2.2 DUT Test board description

The device under test is mounted on a specific board support which is plugged onto the motherboard.
Mechanical outlines : 141 mm x 50 mm, wrapping or printed circuit board with two 20 pins connectors.
According to test set up and device operating conditions, the test board can accept the mounting of :

- The DUT package with beam positioning constraints (unique for Louvain facilities)
- The golden chip
- The pattern generator
- any interface circuit such as buffer, latches ...
- a standalone micro controller if necessary...

Note : Beam focus diameter is limited to maximum 25 mm, to prevent the exposure of others devices which might be sensitive.

IV.3 TEST CONFIGURATIONS

Three test configurations equivalent to three different design implemented on XMM, have been used and the following names have been used in the present report:

- WDE
- FDE/Temp
- FDE/Sun

IV.3.1 WDE Design

See Design 1, Figure 4.

WDE Application :

- This application is intended for monitoring a shunt current with respect to ground level.
- Actual voltage level range at the shunt input is from 0 to –1V which corresponds to the trigger level.
- At the DUT comparator input, this voltage range corresponds to respectively 830mV to 0 V (trigger level)
- Minimum shunt voltage value of –300 mV was requested which corresponds to a comparator input of 580mV.
- The open collector output is connected to the reset pin of a 74HC74 D-latch which is active when low. This configuration gives a relatively high bandwidth.
- A 10kohms between the two devices combined with the input capacitance of the 74HC latch provides the effect of a low pass filter.

Test principle :

- The open collector comparator output is loaded by a resistor divider which provides a high level voltage closed to 5V (compliant with 74HC logical levels).
- A time delay circuit is added for automatic reset of the latch, after a wait state of 10µs.

Types of events detected :

- Transient upset limited to the comparator.
- 74HC74 output latch upset.

Functional Check :

A 50 ns @ 1Hz signal modifying minus input and allowing activation of counting function.

Design change to improve upset tolerance :

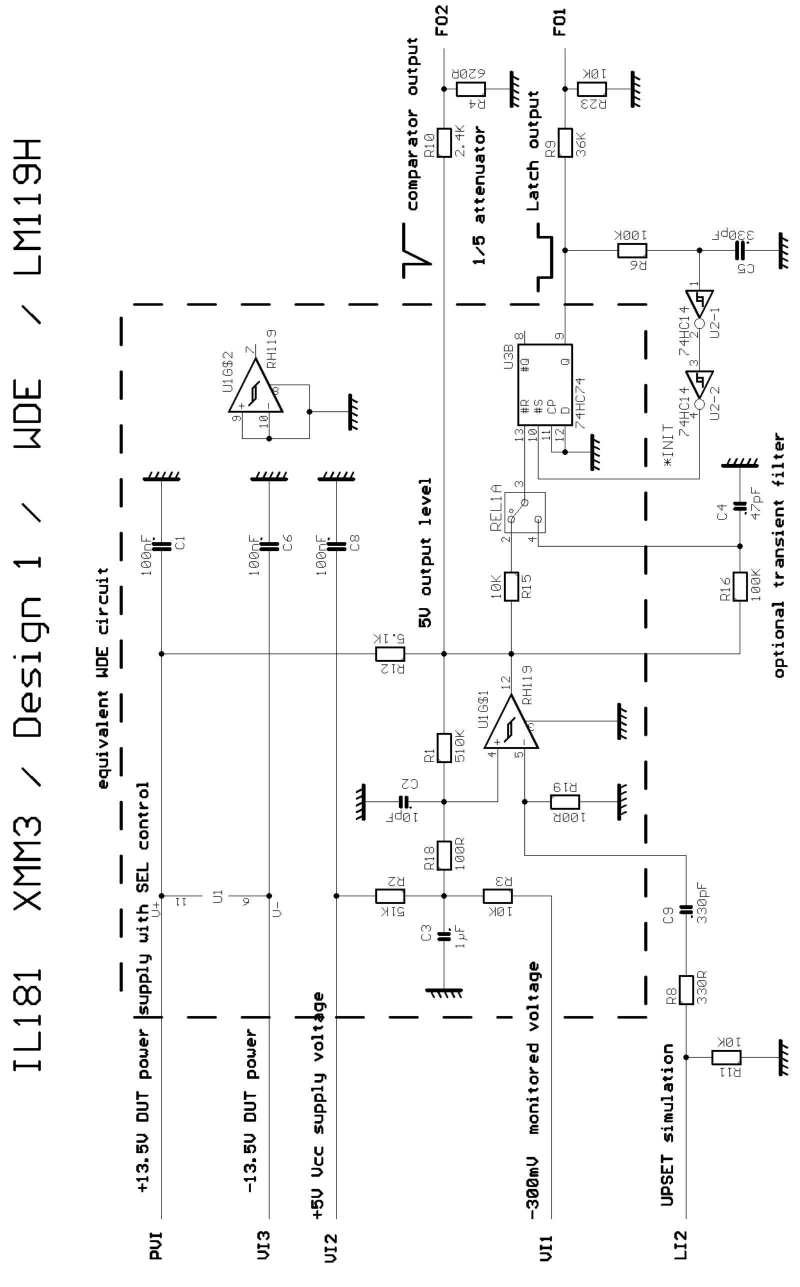
Increasing the value of either the filter resistor or the filter capacitance can be done to improve filtering.

Test set-up conditions :

Three different set-up conditions have been used:

Shunt current level (VI1)	Comparator Input	LI2
-650mV	+ 300 mV	0V
-300mV	+ 580 mV	0V
0 V	+ 830 mV	0V

Figure 4 – RH119 WDE Design Synoptic



IV.3.2 FDE/Temp Design

See Design 2, Figure 5.

FDE/Temp Application :

- This application is intended for monitoring two temperature sensors (thermistors).
- These thermistors are replaced by fixed resistors values corresponding to the following temperatures: 63°C for RTH1 and 45°C for RTH2.
- The two DUT open collector outputs are connected to the input of a chain of NOR gate (74HC02) which are then active when high. This configuration gives a relatively low bandwidth.
- For each comparator, a 10kohms pull up resistor (R1, R2) combined with the input capacitance of the 74HC02 provides the effect of a low pass filter.

Test principle :

- A time delay circuit is added for automatic reset of the RS latch, after a wait state of 100µs.
- It must be noted that only one DUT comparator is monitored for counting and visualisation via the scope while RS latch SEUs are counted for both DUT comparators strikes.

  The monitored DUT comparator is the one which is closer to the trigger level (0.65V between the two comparator inputs)

Types of events detected :

- Transient upset limited to the comparator.
- output latch upset of 74HC02 wired as an RS latch.

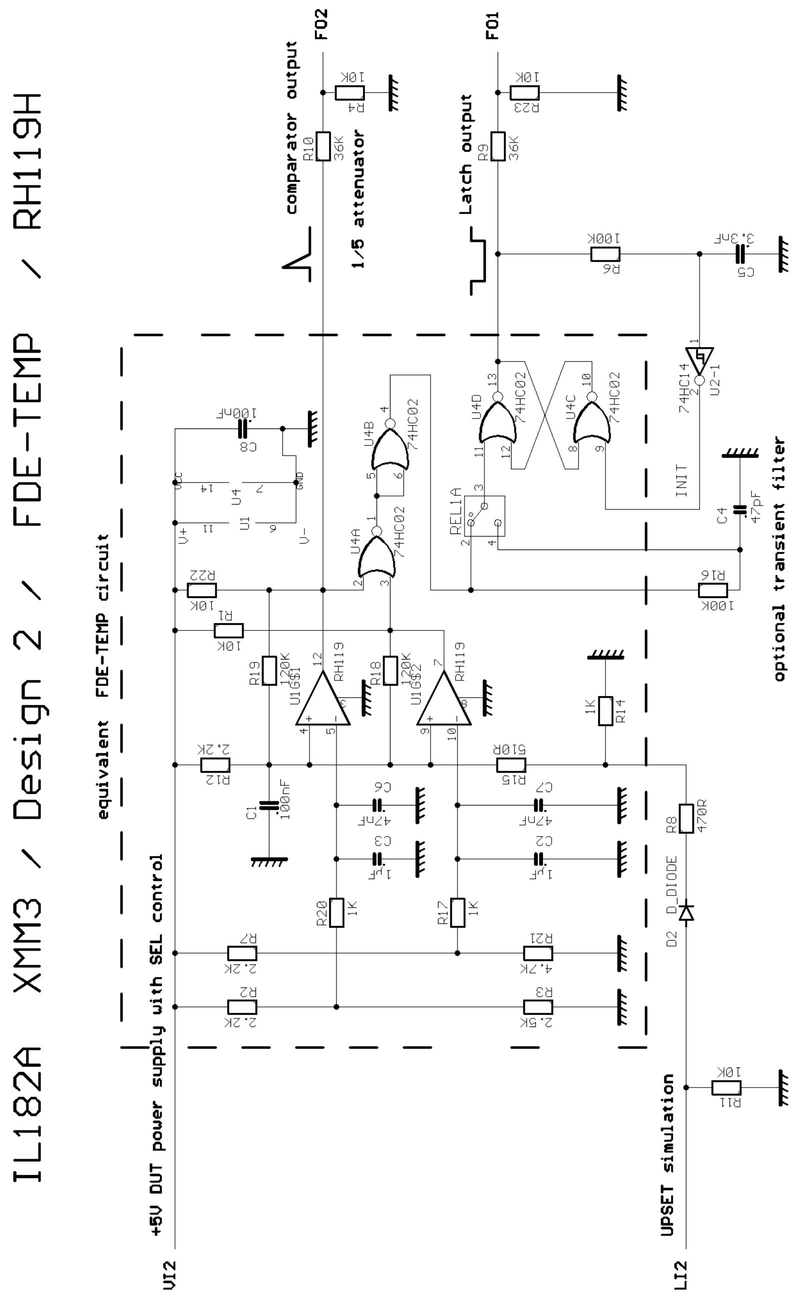
Functional Check :

A 50 ns @ 1Hz signal modifying plus input and allowing activation of counting function.

Design change to improve upset tolerance :

Increasing the value of either the filter resistor or the filter capacitance can be done to improve filtering.

Figure 5 – RH119 FDE/Temp Design Synoptic



IV.3.3 FDE/Sun Design

See design 3, Figure 6

FDE/Sun Application :

- This application is intended for sun control. Two analog voltages are monitored by the DUT with both trigger levels fixed at 2.5V.
- Fixed resistors values are used to obtain the following nominal input voltages of respectively 4.7V and 3.75V.
- The two DUT open collector outputs are connected to the input of a chain of NOR gate (74HC02) which are then active when high. This configuration gives a relatively low bandwidth.
- For each comparator, a 10kohms pull up resistor (R1, R22) has been used instead of the 4.7kohms identified into the actual design. This resistor combined with the input capacitance of the 74HC02 provides the effect of a low pass filter.

Tests results for this design configuration with 4.7 kohms pull-up resistors are presented in Appendix 1.

Test principle :

- A time delay circuit is added for automatic reset of the RS latch, after a wait state of 100µs.
- It must be noted that only one DUT comparator is monitored for counting and visualisation via the scope while RS latch SEUs are counted for both DUT comparators strikes.

  The monitored DUT comparator is the one which is closer to the trigger level (i.e. 3.75V)

Types of events detected :

- Transient upset limited to the comparator.
- output latch upset of 74HC02 wired as an RS latch.

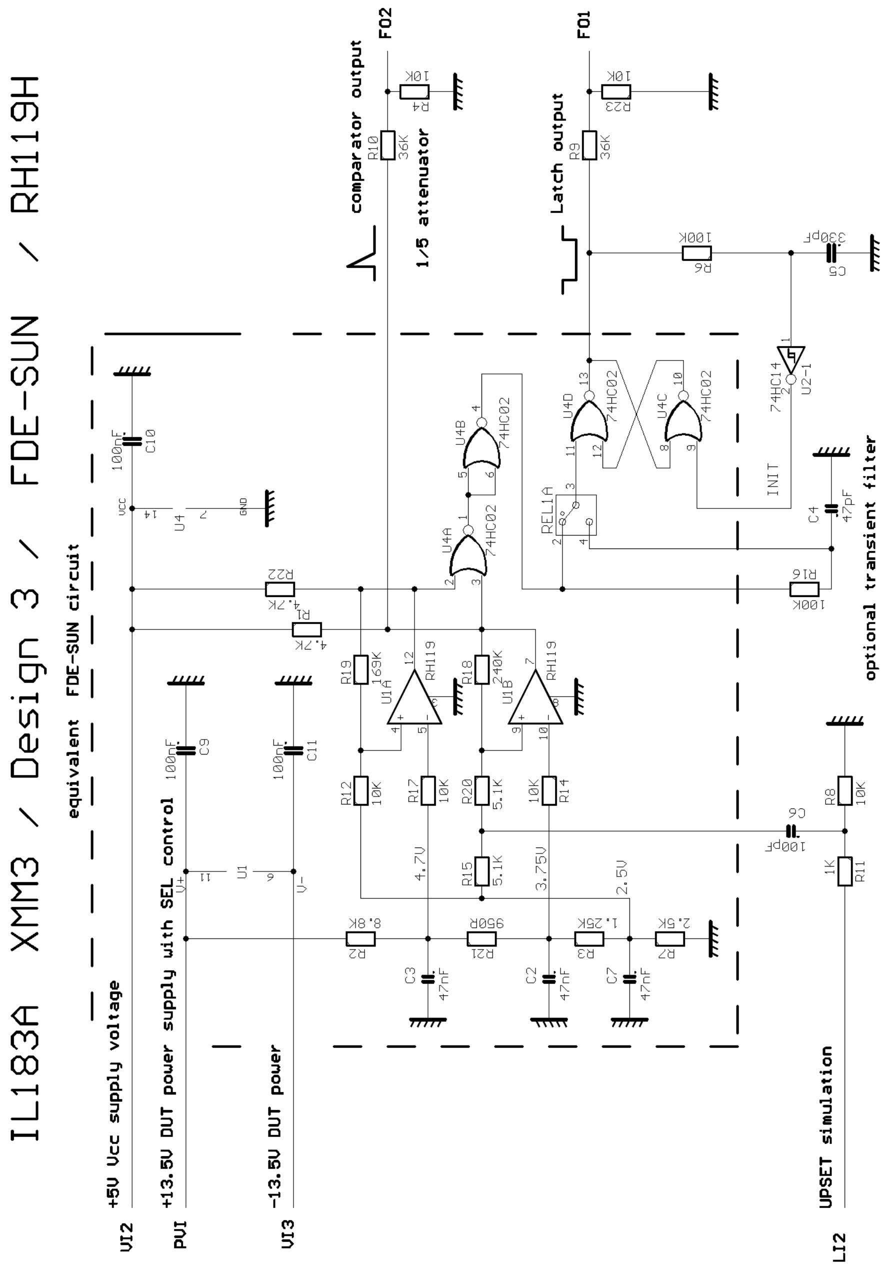
Functional Check :

A 50 ns @ 1Hz signal modifying plus input and allowing activation of counting function.

Design change to improve upset tolerance :

Increasing the value of either the filter resistor or the filter capacitance can be done to improve filtering.

Figure 6 – RH119 FDE/Sun Design Synoptic



V. TEST FACILITIES

V.1 HEAVY IONS

Test at the cyclotron accelerator was performed at Université de Louvain (UCL) in Louvain la neuve (Belgium) under HIREX Engineering responsibility.

V.1.1 Beam Source

In collaboration with the European Space Agency (ESA), the needed equipment for single events studies using heavy ions has been built and installed on the HIF beam line in the experimental hall of Louvain-la-Neuve cyclotron.
CYCLONE is a multi particle, variable energy, cyclotron capable of accelerating protons (up to 75 MeV), alpha particles and heavy ions. For the heavy ions, the covered energy range is between 0.6 MeV/AMU and 27.5 MeV/AMU. For these ions, the maximal energy can be determined by the formula :

$$110\ Q^2/M$$

where Q is the ion charge state, and M is the mass in Atomic Mass Units.

The heavy ions are produced in a double stage Electron Cyclotron Resonance (ECR) source. Such a source allows to produce highly charged ions and ion "cocktails". These are composed of ions with the same or very close M/Q ratios. The cocktail ions are injected in the cyclotron, accelerated at the same time and extracted separately by a fine tuning of the magnetic field or a slight changing of the RF frequency. This method is very convenient for a quick change of ion (in a few minutes) which is equivalent to a LET variation.

V.1.2 Beam Set-up

V.1.2.1 Ion Beam Selection

The LET range was obtained by changing the ion species and incident energy and changing the angle of incidence between the beam and the chip.
For each run, information is provided on the beam characteristics in the detailed results tables provided in paragraph VI.

V.1.2.2 Flux Range

For each run, the averaged flux value is provided in the detailed results tables of paragraph VI.

V.1.2.3 Particle Fluence Levels

Fluence level was comprised between 5 x10E5 and 1 x10E6 ions/cm²

V.1.2.4 Dosimetry

The current UCL Cyclotron dosimetry system and procedures were used.

V.1.2.5 Accumulated Total Dose

For each run, the computed equivalent cumulated doses received by the DUT sample, are provided in the detailed results tables of paragraph VI.

V.1.2.6 Test Temperature Range

All the tests performed were conducted at ambient temperature.

VI. HEAVY IONS RESULTS

VI.1 WDE DESIGN

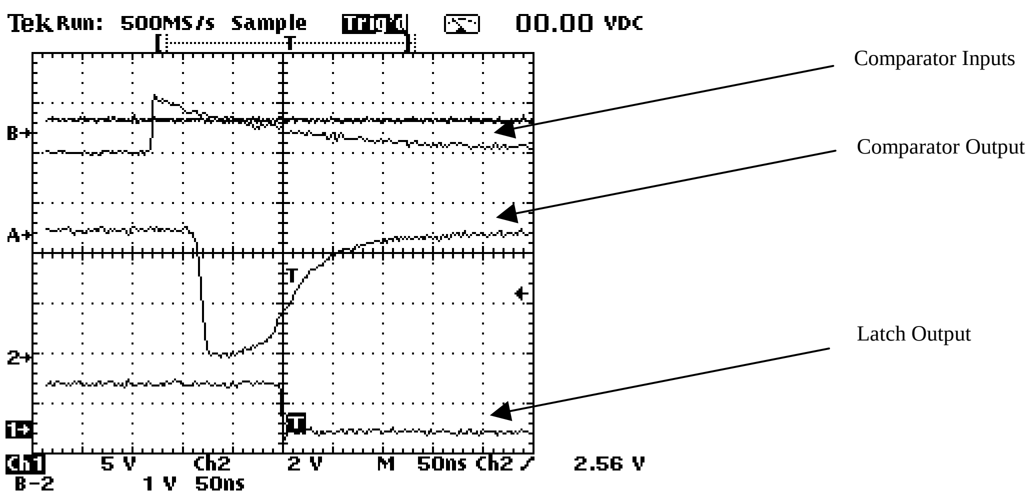
Table 1, Table 2, Table 3 give the results for the different runs performed at different LETs values for DUT comparator input respectively set at 580mV, 300mV and 830mV.
Results obtained with the optional filter (R16/C4) on are provided in Table 4.

Figure 10 provides the **comparator** output SEU error cross sections versus LET for the three comparator inputs conditions and for two different samples.
Figure 11 provides the **latch** output SEU error cross sections versus LET for the three comparator inputs conditions and for two different samples.
In these figures, it can be seen, when optional filter (R16=100kohms/C4=47pF) is on, that the number of comparator errors is still the same for a given LET value (as awaited) and that no more latch errors are detected (see also Table 4)

For run 63, the 10 kohms serial output resistor (R15) has been removed, thus providing a worst case for the latch error.

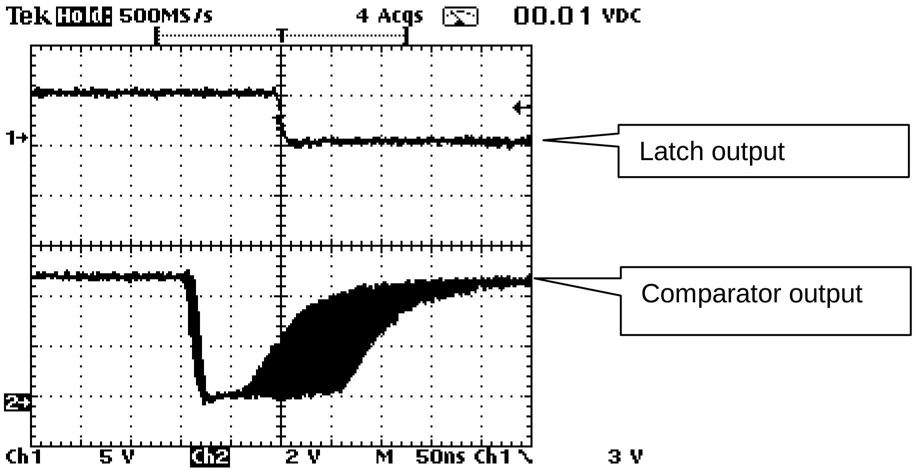
For runs 64 and 65, the high level voltage at the reset input of the 74HC latch has been increased from 5V (as per 74HC specification) to 6.5V which seems to be the level applied in the actual design.. This means that the internal clamp diode of this reset input is on most of the time.
(This 6.5V level is the clamp voltage which comes from the 11V generated by 1N5309 current source device biased with 13.5volts and loaded with a 22 kohms pull down resistor).
Fortunately, this condition increases the delay requested to trig the latch and no upset has been observed.

Figure 7 here below provides what can be observed with the scope when the upset simulation is activated (see Figure 4, 5V pulses on LI2), in absence of beam.
Figure 8 and Figure 9 give the envelop (minimum and maximum) of comparator output pulses which induce a latch error (latch signal is used to trigger the scope) for two conditions (with and without R15 serial resistor).
In the latter case (without the serial resistor), it can be seen that the minimum comparator output pulse needed to get a latch error is much smaller.



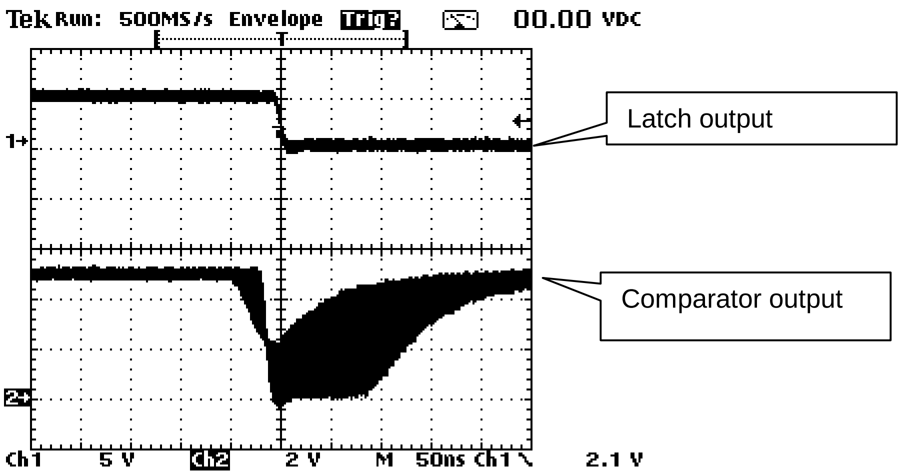
This scope record shows the internal time responses characteristics of the DUT

Figure 7 - Electrical Upset Simulation (No beam)



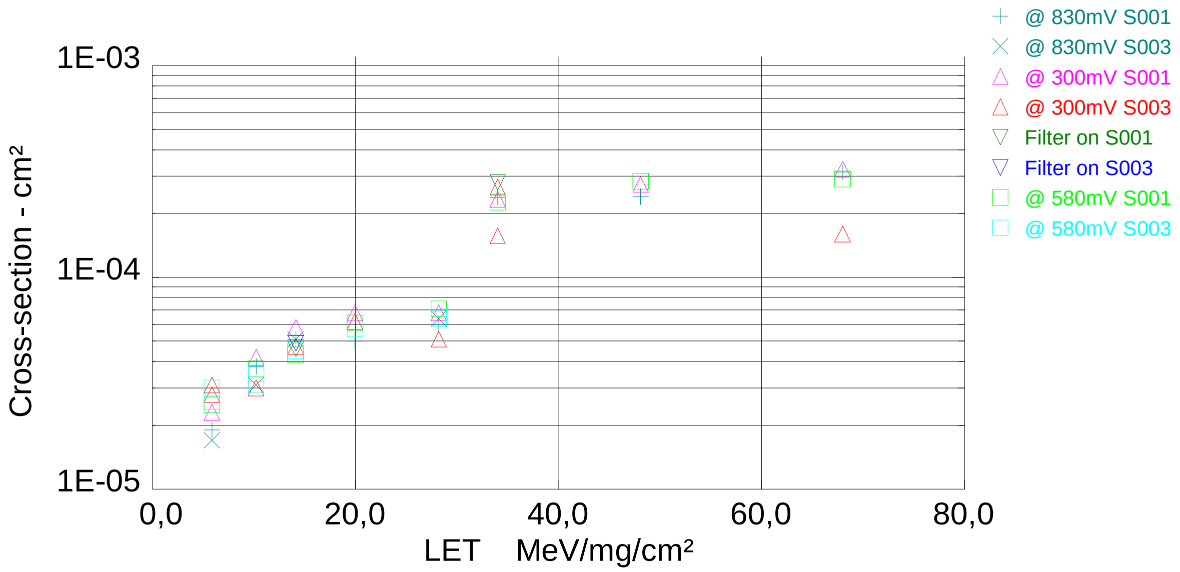
Run 47 comp input @ 600 mV and with the 10 kohms serial output resistor

Figure 8 – Minimum and maximum widths of Upset pulses which induce a latch error (with the 10kohms output serial resistance R15)



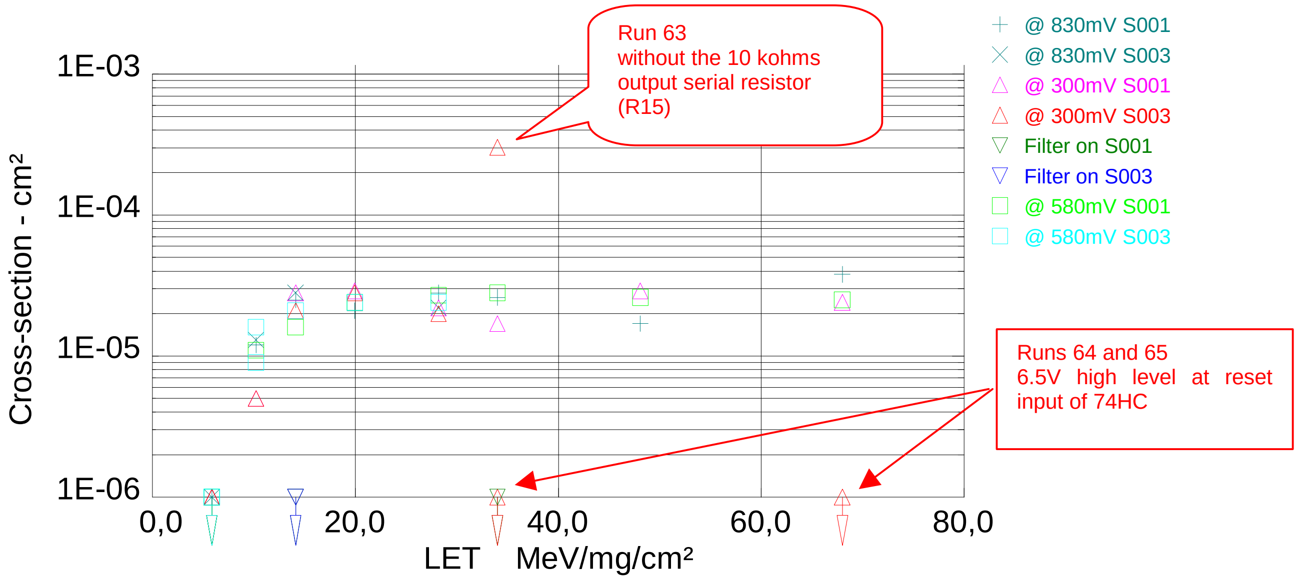
Run 63 comp input @ 300 mV and **without** the 10 kohms serial output resistor

Figure 9 – Minimum and maximum widths of Upset pulses which induce a latch error (without the 10kohms output serial resistance R15)



Run ID	Sample	Fluence (p/cm²)	LET (Mev/mg/cm²)	Nb Errors	Sigma (cm²)	
@ 830mV S001						
R00042	S001	1,00 E+06	5,8	19	1,900 E-05	
R00043	S001	1,00 E+06	10,2	38	3,800 E-05	
R00008	S001	1,00 E+06	14,1	51	5,100 E-05	
R00009	S001	1,00 E+06	19,9	50	5,000 E-05	
R00010	S001	1,00 E+06	28,2	60	6,000 E-05	
R00050	S001	1,00 E+06	34,0	239	2,390 E-04	
R00051	S001	1,00 E+06	48,1	241	2,410 E-04	
R00052	S001	1,00 E+06	68,0	314	3,140 E-04	
@ 830mV S003						
R00035	S003	1,00 E+06	5,8	17	1,700 E-05	
R00036	S003	1,00 E+06	10,2	31	3,100 E-05	
R00019	S003	1,00 E+06	14,1	51	5,100 E-05	
R00020	S003	1,00 E+06	28,2	64	6,400 E-05	
@ 300mV S001						
R00038	S001	1,00 E+06	5,8	23	2,300 E-05	
R00039	S001	1,00 E+06	10,2	42	4,200 E-05	
R00005	S001	1,00 E+06	14,1	58	5,800 E-05	
R00006	S001	1,00 E+06	19,9	68	6,800 E-05	
R00007	S001	1,00 E+06	28,2	68	6,800 E-05	
R00044	S001	1,00 E+06	34,0	234	2,340 E-04	
R00045	S001	1,00 E+06	48,1	275	2,750 E-04	
R00046	S001	1,00 E+06	68,0	324	3,240 E-04	
@ 300mV S003						
R00026	S003	1,00 E+06	5,8	31	3,100 E-05	
R00027	S003	1,00 E+06	5,8	28	2,800 E-05	
R00028	S003	1,00 E+06	10,2	30	3,000 E-05	
R00014	S003	1,00 E+06	14,1	47	4,700 E-05	
R00015	S003	1,00 E+06	19,9	62	6,200 E-05	
R00016	S003	1,00 E+06	28,2	51	5,100 E-05	
R00063	S003	1,00 E+06	34,0	267	2,670 E-04	* Without Serial Resistor (R15)
R00064	S003	1,00 E+06	34,0	157	1,570 E-04	* 6.5 V at 74HC Reset input
R00065	S003	1,00 E+06	68,0	160	1,600 E-04	* 6.5 V at 74HC Reset input
Filter on S001						
R00004	S001	1,00 E+06	14,1	46	4,600 E-05	
R00053	S001	1,00 E+06	34,0	281	2,810 E-04	
Filter on S003						
R00021	S003	1,00 E+06	14,1	49	4,900 E-05	
@ 580mV S001						
R00041	S001	1,00 E+06	5,8	25	2,500 E-05	
R00040	S001	1,00 E+06	10,2	37	3,700 E-05	
R00001	S001	1,00 E+06	14,1	43	4,300 E-05	
R00002	S001	1,00 E+06	19,9	61	6,100 E-05	
R00003	S001	1,00 E+06	28,2	71	7,100 E-05	
R00049	S001	1,00 E+06	34,0	227	2,270 E-04	
R00048	S001	1,00 E+06	48,1	284	2,840 E-04	
R00047	S001	1,00 E+06	68,0	292	2,920 E-04	
@ 580mV S003						
R00030	S003	1,00 E+06	5,8	30	3,000 E-05	
R00031	S003	1,00 E+06	5,8	26	2,600 E-05	
R00029	S003	1,00 E+06	10,2	31	3,100 E-05	
R00034	S003	1,00 E+06	10,2	35	3,500 E-05	
R00018	S003	1,00 E+06	14,1	45	4,500 E-05	
R00033	S003	1,00 E+06	19,9	57	5,700 E-05	
R00017	S003	1,00 E+06	28,2	64	6,400 E-05	

Figure 10 – WDE Comp,
SEU Error Cross section versus LET



Run ID	Sample	Fluence (p/cm²)	LET (Mev/mg/cm²)	Nb Errors	Sigma (cm²)
@ 830mV S001					
R00042	S001	1,00 E+06	5,8	0	1,000 E-06 *
R00043	S001	1,00 E+06	10,2	12	1,200 E-05
R00008	S001	1,00 E+06	14,1	25	2,500 E-05
R00009	S001	1,00 E+06	19,9	21	2,100 E-05
R00010	S001	1,00 E+06	28,2	28	2,800 E-05
R00050	S001	1,00 E+06	34,0	26	2,600 E-05
R00051	S001	1,00 E+06	48,1	17	1,700 E-05
R00052	S001	1,00 E+06	68,0	38	3,800 E-05
@ 830mV S003					
R00035	S003	1,00 E+06	5,8	0	1,000 E-06 *
R00036	S003	1,00 E+06	10,2	13	1,300 E-05
R00019	S003	1,00 E+06	14,1	28	2,800 E-05
R00020	S003	1,00 E+06	28,2	22	2,200 E-05
@ 300mV S001					
R00038	S001	1,00 E+06	5,8	0	1,000 E-06 *
R00039	S001	1,00 E+06	10,2	5	5,000 E-06
R00005	S001	1,00 E+06	14,1	28	2,800 E-05
R00006	S001	1,00 E+06	19,9	29	2,900 E-05
R00007	S001	1,00 E+06	28,2	22	2,200 E-05
R00044	S001	1,00 E+06	34,0	17	1,700 E-05
R00045	S001	1,00 E+06	48,1	29	2,900 E-05
R00046	S001	1,00 E+06	68,0	24	2,400 E-05
@ 300mV S003					
R00026	S003	1,00 E+06	5,8	0	1,000 E-06 *
R00027	S003	1,00 E+06	5,8	0	1,000 E-06 *
R00028	S003	1,00 E+06	10,2	5	5,000 E-06
R00014	S003	1,00 E+06	14,1	21	2,100 E-05
R00015	S003	1,00 E+06	19,9	28	2,800 E-05
R00016	S003	1,00 E+06	28,2	20	2,000 E-05
R00063	S003	1,00 E+06	34,0	302	3,020 E-04
R00064	S003	1,00 E+06	34,0	0	1,000 E-06 *
R00065	S003	1,00 E+06	68,0	0	1,000 E-06 *
Filter on S001					
R00004	S001	1,00 E+06	14,1	0	1,000 E-06 *
R00053	S001	1,00 E+06	34,0	0	1,000 E-06 *
Filter on S003					
R00021	S003	1,00 E+06	14,1	0	1,000 E-06 *
@ 580mV S001					
R00041	S001	1,00 E+06	5,8	0	1,000 E-06 *
R00040	S001	1,00 E+06	10,2	11	1,100 E-05
R00001	S001	1,00 E+06	14,1	16	1,600 E-05
R00002	S001	1,00 E+06	19,9	24	2,400 E-05
R00003	S001	1,00 E+06	28,2	27	2,700 E-05
R00049	S001	1,00 E+06	34,0	28	2,800 E-05
R00048	S001	1,00 E+06	48,1	26	2,600 E-05
R00047	S001	1,00 E+06	68,0	25	2,500 E-05
@ 580mV S003					
R00030	S003	1,00 E+06	5,8	0	1,000 E-06 *
R00031	S003	1,00 E+06	5,8	0	1,000 E-06 *
R00029	S003	1,00 E+06	10,2	9	9,000 E-06
R00034	S003	1,00 E+06	10,2	16	1,600 E-05
R00018	S003	1,00 E+06	14,1	21	2,100 E-05
R00033	S003	1,00 E+06	19,9	24	2,400 E-05
R00017	S003	1,00 E+06	28,2	24	2,400 E-05

* Without Serial Resistor (R15)
* 6.5 V at 74HC Reset input
6* .5 V at 74HC Reset input

Figure 11 – WDE Latched,
SEU Error Cross section versus LET

Table 1 – Heavy Ion Test results on Linear Technology RH1119: WDE, Comparator Input @ 580mV

Run	Sample	Ion	Angle	Eff. LET	Run Time	Flux	TID per Sample	Fluence	Latched	Comp
ID No	ID No	ID No	°	Mev/mg/cm²	sec	P/cm²/sec	Rads (Si)	P/cm²		
R00001	S001	I004	0	14,1	280	3,57 E+03	2,26 E+02	1,00 E+06	16	43
R00002	S001	I004	45	19,94	321	3,12 E+03	5,45 E+02	1,00 E+06	24	61
R00003	S001	I004	60	28,2	466	2,15 E+03	9,97 E+02	1,00 E+06	27	71
R00017	S003	I004	60	28,2	407	2,46 E+03	4,52 E+02	1,00 E+06	24	64
R00018	S003	I004	0	14,1	192	5,21 E+03	6,78 E+02	1,00 E+06	21	45
R00029	S003	I005	55	10,199	120	8,33 E+03	8,41 E+02	1,00 E+06	9	31
R00030	S003	I005	0	5,85	86	1,16 E+04	9,35 E+02	1,00 E+06	0	30
R00031	S003	I005	0	5,85	81	1,23 E+04	1,03 E+03	1,00 E+06	0	26
R00033	S003	I004	45	19,94	217	4,61 E+03	1,51 E+03	1,00 E+06	24	57
R00034	S003	I005	55	10,199	547	1,83 E+03	1,67 E+03	1,00 E+06	16	35
R00040	S001	I005	55	10,199	182	5,49 E+03	1,16 E+03	1,00 E+06	11	37
R00041	S001	I005	0	5,85	103	9,71 E+03	1,25 E+03	1,00 E+06	0	25
R00047	S001	I003	60	68,0	310	3,23 E+03	2,34 E+03	1,00 E+06	25	292
R00048	S001	I003	45	48,083	194	5,15 E+03	3,11 E+03	1,00 E+06	26	284
R00049	S001	I003	0	34,0	148	6,76 E+03	3,66 E+03	1,00 E+06	28	227

Ion ID	Specy	Energy	LET	Range
		MeV	Mev/mg/cm²	µm
I003	84-Kr	316	34	43
I004	40-Ar	150	14,1	42
I005	20-Ne	78	5,85	45

Sample ID	SN	Part Type	Date Code	Comments
S001	03	RH119H	9639A	XM-IS-IGG-0016
S003	05	RH119H	9639A	XM-IS-IGG-0016

Note

Table 2 – Heavy Ion Test results on Linear Technology RH119 : WDE, Comparator Input @ 300mV

Run	Sample	Ion	Angle	Eff. LET	Run Time	Flux	TID per Sample	Fluence	Latched	Comp
ID No	ID No	ID No	°	Mev/mg/cm²	sec	P/cm²/sec	Rads (Si)	P/cm²		
R00005	S001	I004	0	14,1	213	4,69 E+03	4,66 E+03	1,00 E+06	28	58
R00006	S001	I004	45	19,94	292	3,42 E+03	4,98 E+03	1,00 E+06	29	68
R00007	S001	I004	60	28,2	457	2,19 E+03	5,43 E+03	1,00 E+06	22	68
R00014	S003	I004	0	14,1	168	5,95 E+03	2,13 E+03	1,00 E+06	21	47
R00015	S003	I004	45	19,94	179	5,59 E+03	2,45 E+03	1,00 E+06	28	62
R00016	S003	I004	60	28,2	341	2,93 E+03	2,90 E+03	1,00 E+06	20	51
R00026	S003	I005	0	5,85	103	9,71 E+03	2,99 E+03	1,00 E+06	0	31
R00027	S003	I005	0	5,85	100	1,00 E+04	3,09 E+03	1,00 E+06	0	28
R00028	S003	I005	55	10,199	124	8,06 E+03	3,25 E+03	1,00 E+06	5	30
R00038	S001	I005	0	5,85	266	3,76 E+03	5,52 E+03	1,00 E+06	0	23
R00039	S001	I005	55	10,199	227	4,41 E+03	5,68 E+03	1,00 E+06	5	42
R00044	S001	I003	0	34,0	130	7,69 E+03	6,23 E+03	1,00 E+06	17	234
R00045	S001	I003	45	48,083	162	6,17 E+03	7,00 E+03	1,00 E+06	29	275
R00046	S001	I003	60	68,0	269	3,72 E+03	8,09 E+03	1,00 E+06	24	324
R00063	S003	I003	0	34,0	110	9,09 E+03	3,79 E+03	1,00 E+06	302	267
R00064	S003	I003	0	34,0	312	3,21 E+03	4,34 E+03	1,00 E+06	0	157
R00065	S003	I003	60	68,0	672	1,49 E+03	5,43 E+03	1,00 E+06	0	160

Ion ID	Specy	Energy	LET	Range
		MeV	Mev/mg/cm²	µm
I003	84-Kr	316	34	43
I004	40-Ar	150	14,1	42
I005	20-Ne	78	5,85	45

Sample ID	SN	Part Type	Date Code	Comments
S001	03	RH119H	9639A	XM-IS-IGG-0016
S003	05	RH119H	9639A	XM-IS-IGG-0016

Note

Table 3 – Heavy Ion Test results on Linear Technology RH119 : WDE, Comparator Input @ 830mV

Run	Sample	Ion	Angle	Eff. LET	Run Time	Flux	TID per Sample	Fluence	Latched	Comp
ID No	ID No	ID No	°	Mev/mg/cm²	sec	P/cm²/sec	Rads (Si)	P/cm²		
R00008	S001	I004	0	14,1	221	4,52 E+03	8,31 E+03	1,00 E+06	25	51
R00009	S001	I004	45	19,94	386	2,59 E+03	8,63 E+03	1,00 E+06	21	50
R00010	S001	I004	60	28,2	326	3,07 E+03	9,09 E+03	1,00 E+06	28	60
R00019	S003	I004	0	14,1	145	6,90 E+03	5,65 E+03	1,00 E+06	28	51
R00020	S003	I004	60	28,2	394	2,54 E+03	6,11 E+03	1,00 E+06	22	64
R00035	S003	I005	0	5,85	323	3,10 E+03	6,20 E+03	1,00 E+06	0	17
R00036	S003	I005	55	10,199	270	3,70 E+03	6,36 E+03	1,00 E+06	13	31
R00042	S001	I005	0	5,85	98	1,02 E+04	9,18 E+03	1,00 E+06	0	19
R00043	S001	I005	55	10,199	130	7,69 E+03	9,34 E+03	1,00 E+06	12	38
R00050	S001	I003	0	34,0	155	6,45 E+03	9,89 E+03	1,00 E+06	26	239
R00051	S001	I003	45	48,083	223	4,48 E+03	1,07 E+04	1,00 E+06	17	241
R00052	S001	I003	60	68,0	293	3,41 E+03	1,17 E+04	1,00 E+06	38	314

Ion ID	Specy	Energy MeV	LET Mev/mg/cm²	Range µm
I003	84-Kr	316	34	43
I004	40-Ar	150	14,1	42
I005	20-Ne	78	5,85	45

Sample ID	SN	Part Type	Date Code	Comments
S001	03	RH119H	9639A	XM-IS-IGG-0016
S003	05	RH119H	9639A	XM-IS-IGG-0016

Note

Table 4 – Heavy Ion Test results on Linear Technology RH119 : WDE plus additional filter

Run	Sample	Ion	Angle	Eff. LET	Run Time	Flux	TID per Sample	Fluence	Latched	Comp	Comment
ID No	ID No	ID No	°	Mev/mg/cm²	sec	P/cm²/sec	Rads (Si)	P/cm²			
R00004	S001	I004	0	14,1	300	3,33 E+03	3,88 E+03	1,00 E+06	0	46	Comp Input @580mV
R00021	S003	I004	0	14,1	201	4,98 E+03	1,90 E+03	1,00 E+06	0	49	Comp Input @300mV
R00053	S001	I003	0	34,0	218	4,59 E+03	4,43 E+03	1,00 E+06	0	281	Comp Input @300mV

Ion ID	Specy	Energy	LET	Range
		MeV	Mev/mg/cm²	µm
I003	84-Kr	316	34	43
I004	40-Ar	150	14,1	42
I005	20-Ne	78	5,85	45

Sample ID	SN	Part Type	Date Code	Comments
S001	03	RH119H	9639A	XM-IS-IGG-0016
S003	05	RH119H	9639A	XM-IS-IGG-0016

Note

VI.2 FDE/TEMP DESIGN

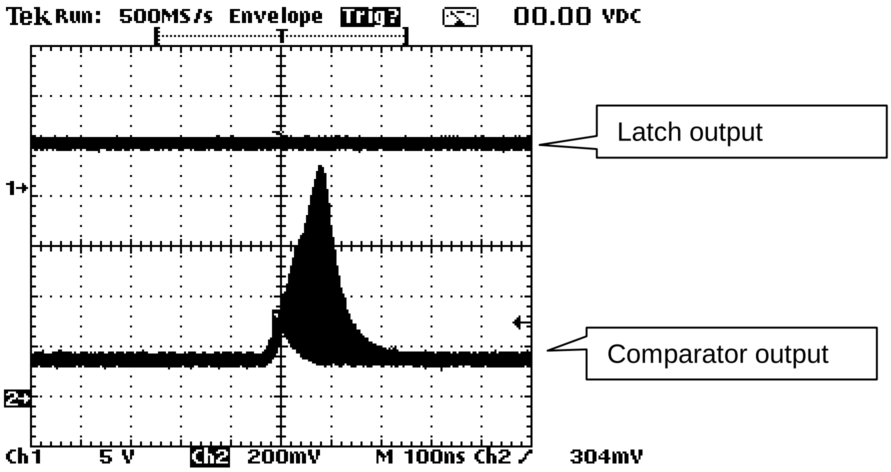
In this configuration, only one comparator output, out of the two DUT comparators, is monitored. However, an observed latch error, if any, can be triggered indifferently by a pulse generated in one of the two DUT comparators.

Table 5 give the results for the different runs.

Figure 13 provides the comparator output and the latch output SEU error cross sections versus LET.

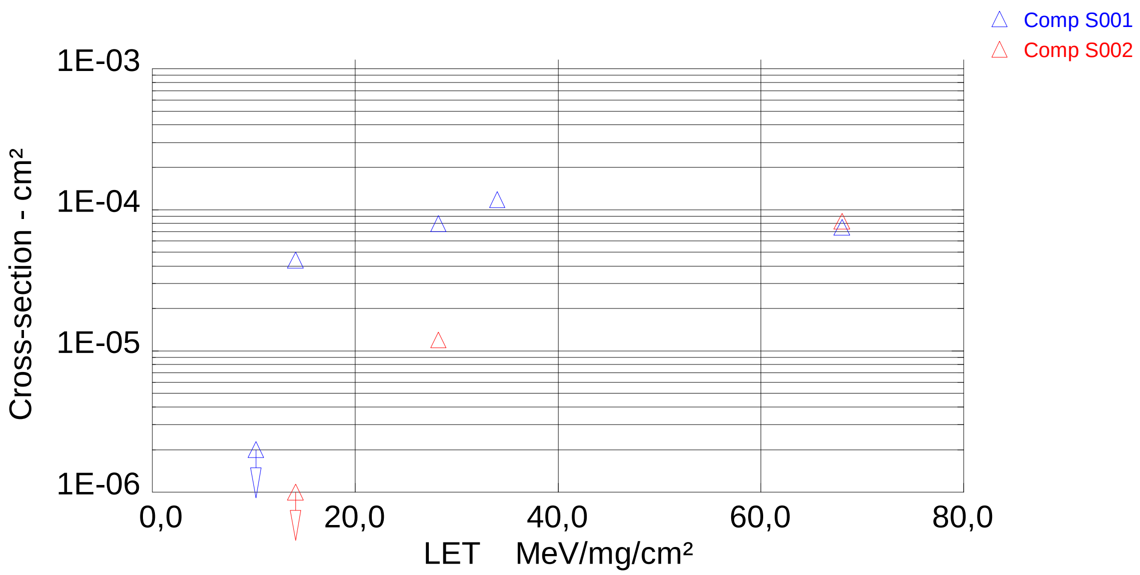
No latch error has been observed.

As an example, Figure 12 gives the envelop of comparator output transients observed during run 22 (LET =14.1 MeV/mg/cm²)



Run 22

Figure 12 – Comparator output transient envelop



Run ID	Sample	Fluence (p/cm²)	LET (Mev/mg/cm²)	Nb Errors	Sigma (cm²)
Comp S001					
R00037	S001	5,00 E+05	10,2	0	2,000 E-06 *
R00022	S001	1,00 E+06	14,1	44	4,400 E-05
R00023	S001	1,00 E+06	28,2	80	8,000 E-05
R00062	S001	1,00 E+06	34,0	118	1,180 E-04
R00061	S001	1,00 E+06	68,0	75	7,500 E-05
Comp S002					
R00011	S002	1,00 E+06	14,1	0	1,000 E-06 *
R00012	S002	1,00 E+06	28,2	12	1,200 E-05
R00055	S002	1,00 E+06	68,0	83	8,300 E-05

Figure 13 – FDE Temp
SEU Error Cross section versus LET

Table 5 – Heavy Ion Test Results on Linear Technology RH119 : FDE Temp

Run	Sample	Ion	Angle	Eff. LET	Run Time	Flux	TID per Sample	Fluence	Latched	Comp
ID No	ID No	ID No	°	Mev/mg/cm²	sec	P/cm²/sec	Rads (Si)	P/cm²		
R00011	S002	I004	0	14,1	179	5,59 E+03	2,26 E+02	1,00 E+06	0	0
R00012	S002	I004	60	28,2	307	3,26 E+03	6,78 E+02	1,00 E+06	0	12
R00022	S001	I004	0	14,1	249	4,02 E+03	1,20 E+04	1,00 E+06	0	44
R00023	S001	I004	60	28,2	363	2,75 E+03	1,24 E+04	1,00 E+06	0	80
R00037	S001	I005	55	10,199	160	3,13 E+03	1,25 E+04	5,00 E+05	0	0
R00055	S002	I003	60	68,0	248	4,03 E+03	2,31 E+03	1,00 E+06	0	83
R00061	S001	I003	60	68,0	192	5,21 E+03	1,36 E+04	1,00 E+06	0	75
R00062	S001	I003	0	34,0	113	8,85 E+03	1,41 E+04	1,00 E+06	0	118

Ion ID	Specy	Energy	LET	Range
		MeV	Mev/mg/cm²	µm
I003	84-Kr	316	34	43
I004	40-Ar	150	14,1	42
I005	20-Ne	78	5,85	45

Sample ID	SN	Part Type	Date Code	Comments
S001	03	RH119H	9639A	XM-IS-IGG-0016
S002	04	RH119H	9639A	XM-IS-IGG-0016

Note

VI.3 FDE/SUN DESIGN

In this configuration, only one comparator output, out of the two DUT comparators, is monitored. However, an observed latch error, if any, can be triggered indifferently by a pulse generated in one of the two DUT comparators.

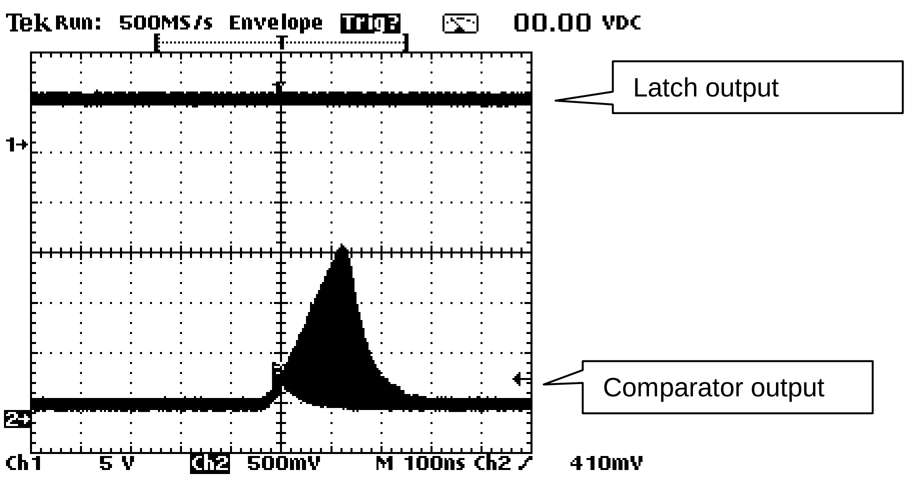
Table 6 give the results for the different runs.

As an example, Figure 14 gives the envelop of comparator output transients observed during run 25 (LET =28.2 MeV/mg/cm²)

Figure 15 provides the comparator output and the latch output SEU error cross sections versus LET.

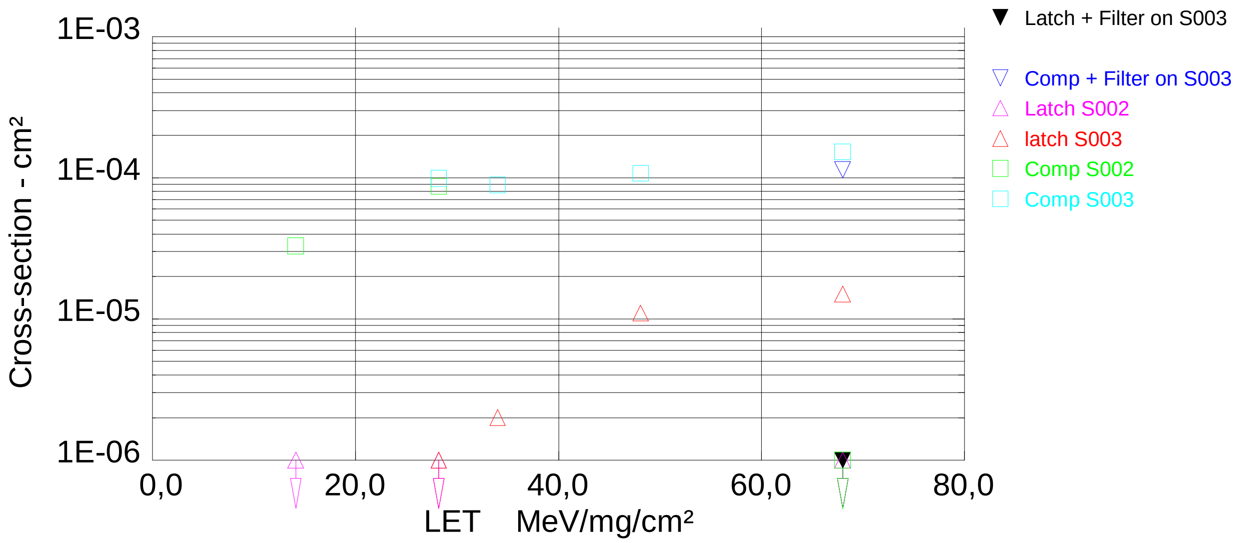
Few latch upsets have been observed with high LETs.
In this figure, it can be seen that, when optional filter (R16=100kohms/C4=47pF) is on, the number of comparator errors is still the same for a given LET value (as awaited) and that no more latch errors are detected.

For run 60, the change of the pull-up resistor from 10 kohms to 33 kohms has filtered all SEU transients and no more comparators upsets have been observed (pulse height is below the counter thresholdvalue of 1.12V used with the comparator output). No latch error is observed.



Run 25

Figure 14 – Typical example of comparator output SEU transient



Run ID	Sample	Fluence (p/cm²)	LET (Mev/mg/cm²)	Nb Errors	Sigma (cm²)	
Latch + Filter on S003						
R00059	S003	1,00 E+06	68,0	0	1,000 E-06 *	
Comp + Filter on S003						
R00059	S003	1,00 E+06	68,0	114	1,140 E-04	
Latch S002						
R00024	S002	1,00 E+06	14,1	0	1,000 E-06 *	
R00025	S002	1,00 E+06	28,2	0	1,000 E-06 *	
R00060	S002	1,00 E+06	68,0	0	1,000 E-06 *	* Pull-up resistor = 33kohms
latch S003						
R00013	S003	1,00 E+06	28,2	0	1,000 E-06 *	
R00058	S003	1,00 E+06	34,0	2	2,000 E-06	
R00057	S003	1,00 E+06	48,1	11	1,100 E-05	
R00056	S003	1,00 E+06	68,0	15	1,500 E-05	
Comp S002						
R00024	S002	1,00 E+06	14,1	33	3,300 E-05	
R00025	S002	1,00 E+06	28,2	87	8,700 E-05	
R00060	S002	1,00 E+06	68,0	0	1,000 E-06 *	* Pull-up resistor = 33kohms
Comp S003						
R00013	S003	1,00 E+06	28,2	99	9,900 E-05	
R00058	S003	1,00 E+06	34,0	89	8,900 E-05	
R00057	S003	1,00 E+06	48,1	108	1,080 E-04	
R00056	S003	1,00 E+06	68,0	153	1,530 E-04	

Figure 15 – FDE Sun
SEU Error Cross section versus LET

Table 6 – Heavy Ion Test Results on Linear Technology RH119 : FDE Sun

Run	Sample	Ion	Angle	Eff. LET	Run Time	Flux	TID per Sample	Fluence	Latched	Comp
ID No	ID No	ID No	°	Mev/mg/cm²	sec	P/cm²/sec	Rads (Si)	P/cm²		
R00013	S003	I004	60	28,2	332	3,01 E+03	6,81 E+03	1,00 E+06	0	99
R00024	S002	I004	0	14,1	250	4,00 E+03	2,54 E+03	1,00 E+06	0	33
R00025	S002	I004	60	28,2	384	2,60 E+03	2,99 E+03	1,00 E+06	0	87
R00056	S003	I003	60	68,0	256	3,91 E+03	7,90 E+03	1,00 E+06	15	153
R00057	S003	I003	45	48,083	184	5,43 E+03	8,67 E+03	1,00 E+06	11	108
R00058	S003	I003	0	34,0	404	2,48 E+03	9,22 E+03	1,00 E+06	2	89
R00060	S002	I003	60	68,0	199	5,03 E+03	4,08 E+03	1,00 E+06	0	0

Filter on

Run	Sample	Ion	Angle	Eff. LET	Run Time	Flux	TID per Sample	Fluence	Latched	Comp
ID No	ID No	ID No	°	Mev/mg/cm²	sec	P/cm²/sec	Rads (Si)	P/cm²		
R00059	S003	I003	60	68,0	404	2,48 E+03	1,03 E+04	1,00 E+06	0	114

Ion ID	Specy	Energy	LET	Range
		MeV	Mev/mg/cm²	µm
I003	84-Kr	316	34	43
I004	40-Ar	150	14,1	42
I005	20-Ne	78	5,85	45

Sample ID	SN	Part Type	Date Code	Comments
S002	04	RH119H	9639A	XM-IS-IGG-0016
S003	05	RH119H	9639A	XM-IS-IGG-0016

Note

VII. CONCLUSION

SEU test have been conducted on RH119 High performance Dual Comparator from Linear Technology, using the heavy ions available at the University of Louvain.
Heavy ion SEU susceptibility was obtained through the error cross section versus LET curve for three different test configurations.

WDE design:

Error Type	Test Conditions	Asymptotic Cross section (cm^2)	LET Threshold (MeV/mg/cm^2)
Comparator	Comp Input @ 300mV	~2.5E-4	< 5.8
	Comp Input @ 580mV	~2.9E-4	< 5.8
	Comp Input @ 830mV	~3.1E-4	< 5.8
Latch	Comp Input @ 300mV	~2.4E-5	5.8
	Comp Input @ 580mV	~2.8E-5	5.8
	Comp Input @ 830mV	~3.8E-5	5.8
	Comp Input @ 300mV and without output Serial resistor	~3E-4 @ LET of 34MeV/mg/cm^2	
	Comp Input @ 300mV and with 6.5V at 74HC Reset Input	< 1E-6	

FDE/Temp design

Error Type	Test Conditions	Asymptotic Cross section (cm^2)	LET Threshold (MeV/mg/cm^2)
Comparator		~1E-4	5.8
Latch		< 1E-6	

FDE/Sun design

Error Type	Test Conditions	Asymptotic Cross section (cm^2)	LET Threshold (MeV/mg/cm^2)
Comparator	Pull-up resistors=10kohms	~1.5E-4	< 14.1
	Pull-up resistors=33kohms (*)	< 1E-6	
Latch	Pull-up resistors=10kohms	~1.7E-4	28.2

(*) transients heights are below the comparator counter threshold value of 1.12V.

In Appendix 1, results obtained with pull-up resistors values of 4.7 kohms (similar to the ones used in the actual design) are presented and show a significant increase of latch errors.
FDE/Sun design with 4.7 kohms pull-up resistors

Error Type	Test Conditions	Asymptotic Cross section (cm^2)	LET Threshold (MeV/mg/cm^2)
Comparator	Pull-up resistors=4.7kohms	~1.7E-4	<5.8
Latch	Pull-up resistors=4.7kohms	~2.3E-4	5.8

Only one comparator is monitored while latch error can be triggered by a transient generated indifferently in one of the two DUT comparators.

With these results, upset predictions on XMM orbit, can be performed for each error type and the associated risk can be assessed.
More generally and based on these few experiments, it is thought that, characterization of the time response of the DUT alone to the worst case ion strike, could be used as an input to designers which then will check if the generated transient can be filtered.
For new designs, it is thought that, with the use of higher bandwidth (higher speed performance) devices, induced SEU pulses would be shorter and then could be filtered down to the requested design bandwidth.

Appendix 1 – Additional test on FDE/Sun configuration with 4.7 kohms pull-up resistors

An additional set of runs have been performed during a subsequent test campaign at Louvain on June 99, to check the FDE/Sun design sensitivity with pull-up resistors values equivalent to the ones used in the actual design (4.7 koms)

Table 7 here below gives the results per run and Figure 16 shows that there is no sgnificant difference on FDE/Sun comparator errors when tested with 10 kohms or 4.7 kohms pull-up resistors.
However it can be seen in Figure 17, that the use of 4.7 kohms pull-up resistors increases greatly the sensitivity to latch error.

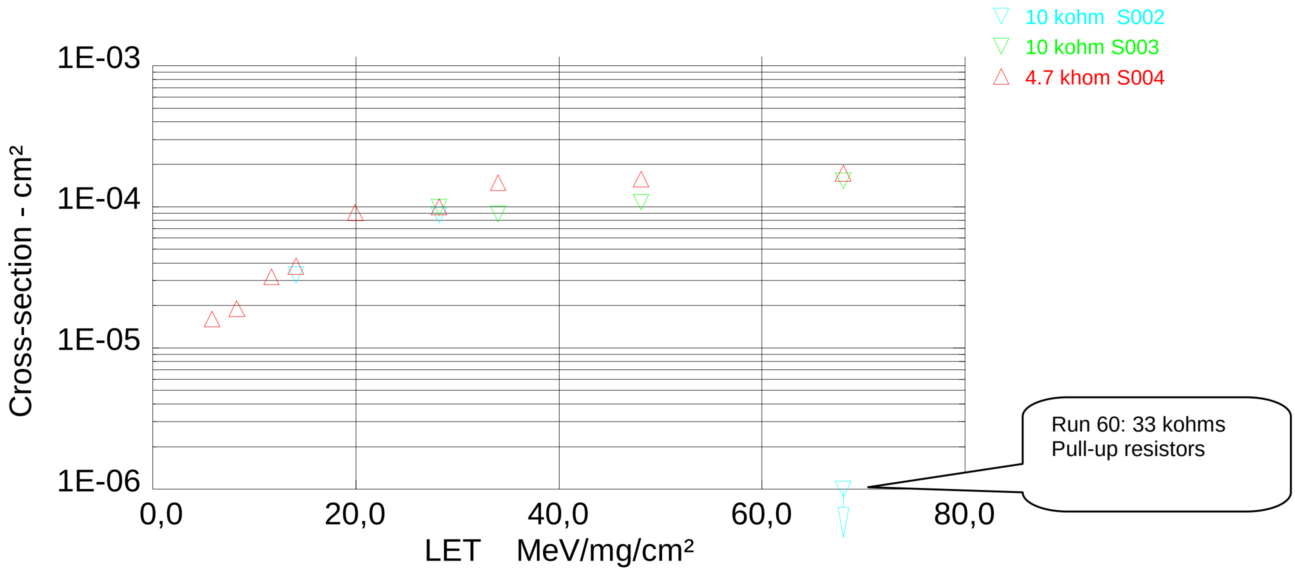
Table 7 – Heavy Ion Test Results on Linear Technology RH119 : FDE Sun with 4.7 kohms pull-up resistors

Run	Sample	Ion	Angle	Eff. LET	Run Time	Flux	TID per Sample	Fluence	Latched	Comp
ID No	ID No	ID No	°	Mev/mg/cm²	sec	P/cm²/sec	Rads (Si)	P/cm²		
R00067	S004	I003	0	34,0	226	4,42 E+03	1,09 E+03	1,00 E+06	167	148
R00068	S004	I003	45	48,083	250	4,00 E+03	1,86 E+03	1,00 E+06	191	157
R00069	S004	I003	60	68,0	298	3,36 E+03	2,95 E+03	1,00 E+06	236	173
R00070	S004	I004	0	14,1	112	8,93 E+03	3,18 E+03	1,00 E+06	52	38
R00071	S004	I004	45	19,94	165	6,06 E+03	3,49 E+03	1,00 E+06	122	91
R00072	S004	I004	60	28,2	232	4,31 E+03	3,95 E+03	1,00 E+06	114	100
R00075	S004	I005	0	5,85	96	1,04 E+04	4,27 E+03	1,00 E+06	14	16
R00076	S004	I005	45	8,273	125	8,00 E+03	4,40 E+03	1,00 E+06	26	19
R00077	S004	I005	60	11,7	197	5,08 E+03	4,59 E+03	1,00 E+06	45	32

Ion ID	Specy	Energy	LET	Range
		MeV	Mev/mg/cm²	µm
I003	84-Kr	316	34	43
I004	40-Ar	150	14,1	42
I005	20-Ne	78	5,85	45

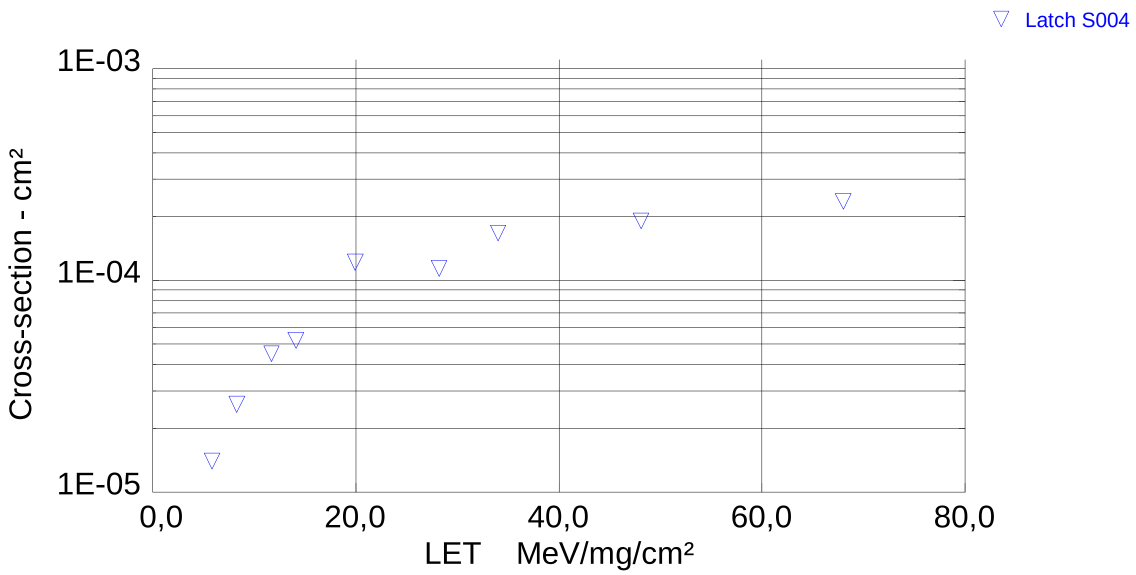
Sample ID	SN	Part Type	Date Code	Comments
S004	04	RH119H	9639A	XM-IS-IGG-0016

Note



Run ID	Sample	Fluence (p/cm²)	LET (Mev/mg/cm²)	Nb Errors	Sigma (cm²)	
10 kohm S002						
R00024	S002	1,00 E+06	14,1	33	3,300 E-05	
R00025	S002	1,00 E+06	28,2	87	8,700 E-05	
R00060	S002	1,00 E+06	68,0	0	1,000 E-06 *	33 khoms Pull-up resistor
10 kohm S003						
R00013	S003	1,00 E+06	28,2	99	9,900 E-05	
R00058	S003	1,00 E+06	34,0	89	8,900 E-05	
R00057	S003	1,00 E+06	48,1	108	1,080 E-04	
R00056	S003	1,00 E+06	68,0	153	1,530 E-04	
4.7 khom S004						
R00075	S004	1,00 E+06	5,8	16	1,600 E-05	
R00076	S004	1,00 E+06	8,3	19	1,900 E-05	
R00077	S004	1,00 E+06	11,7	32	3,200 E-05	
R00070	S004	1,00 E+06	14,1	38	3,800 E-05	
R00071	S004	1,00 E+06	19,9	91	9,100 E-05	
R00072	S004	1,00 E+06	28,2	100	1,000 E-04	
R00067	S004	1,00 E+06	34,0	148	1,480 E-04	
R00068	S004	1,00 E+06	48,1	157	1,570 E-04	
R00069	S004	1,00 E+06	68,0	173	1,730 E-04	

Figure 16 – FDE/Sun Comparator errors cross-section for different pull-up resistor values



Run ID	Sample	Fluence (p/cm²)	LET (Mev/mg/cm²)	Nb Errors	Sigma (cm²)
Latch S004					
R00075	S004	1,00 E+06	5,8	14	1,400 E-05
R00076	S004	1,00 E+06	8,3	26	2,600 E-05
R00077	S004	1,00 E+06	11,7	45	4,500 E-05
R00070	S004	1,00 E+06	14,1	52	5,200 E-05
R00071	S004	1,00 E+06	19,9	122	1,220 E-04
R00072	S004	1,00 E+06	28,2	114	1,140 E-04
R00067	S004	1,00 E+06	34,0	167	1,670 E-04
R00068	S004	1,00 E+06	48,1	191	1,910 E-04
R00069	S004	1,00 E+06	68,0	236	2,360 E-04

Figure 17 – FDE/Sun latch errors cross-section with 4.7 kohms pull-up resistors