RADIATION TEST REPORT

Heavy Ion and Proton Testing

of

UC1707J

Dual Channel Power Driver

from Unitrode

ESA Purchase Order No 181635 dated 13/08/98

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I. INTRODUCTION

This report presents the results of a heavy ion Single Event Effects (SEEs) test program carried out for the XMM project on Unitrode UC1707 Dual Channel Power driver.

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

For proton test, these tests took place at the European Proton Irradiation Facility (PIF), Paul Scherrer Institute in Villingen, Switzerland.

The main aims of these tests were to assess the UC1707 susceptibility to Single Event Upsets (SEUs) using :

(a) a test configuration equivalent to BA ACU design used on XMM,

(b) a test configuration equivalent to LASCO design used on XMM.

Both test configurations are described in paragraph IV.3.

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 Purchase Order No 181635 dated 13/08/98.

II. APPLICABLE DOCUMENTS

The following documents are applicable:

- XMM SOW QCA/RHS-98XMM01.DOC July 98, Issue 0 (e-mail dated June 25, 98), Radiation SEE Testing of RH1078M, LM139, UC1842 and UC1707 for XMM.
- Proposal for SEE Testing of RH1078M, LM139, UC1842, UC1707 for XMM - Hirex Doc No HRX/98.3568 Issue 1, dated July 2, 1998 -

II.1 REFERENCE DOCUMENTS

- Unitrode, UC1707 data sheet.
- Single Event Effects Test method and Guidelines ESA/SCC basic specification No 25100
- The Heavy Ion Irradiation Facility at CYCLONE, UCL document, Centre de Recherches du Cyclotron (IEEE NSREC'96, Workshop Record, Indian Wells, California, 1996)
- Paul Scherrer Institut Users Guide

III. DEVICE INFORMATION

III.1 DEVICE DESCRIPTION

Dual Channel Power Driver

III.2 PROCUREMENT OF TEST SAMPLES

5 hirel samples have been procured by ESA.
(Serial Numbers : #061, #062, #063, #064, #065)

III.3 PREPARATION OF SAMPLES

3 devices with the following numbers #061, #062, #063 have been delidded by Hirex lab.
No sample has been mechanically damaged during this operation.

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

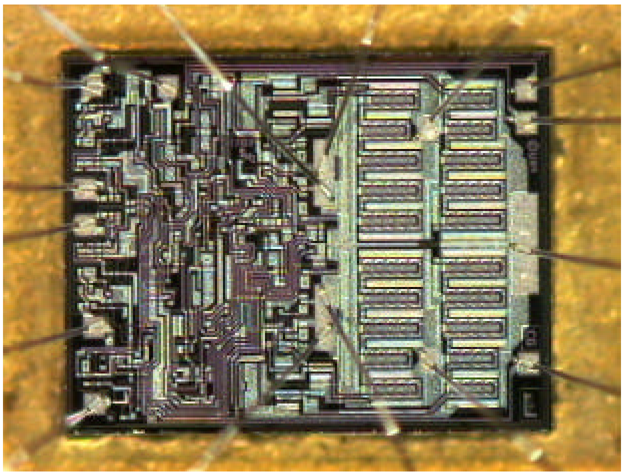
Description of the devices is as follows:

Part type :	UC1707
Manufacturer :	Unitrode
Package :	Cerdip DIL-8
Quality Level :	Hirel
Date Code :	9145
Serial Number :	#061, #062, #063, #064, #065
Die Technology :	Bipolar
Top Marking:	SIC01-01002B
Die Size :	2.65 mm x 2.1 mm approximately
Die Marking :	U 84 1707 SMG
Heavy ion test samples (delidded) :	2 (#061, #062)
Proton test samples :	2 (#064, #065)

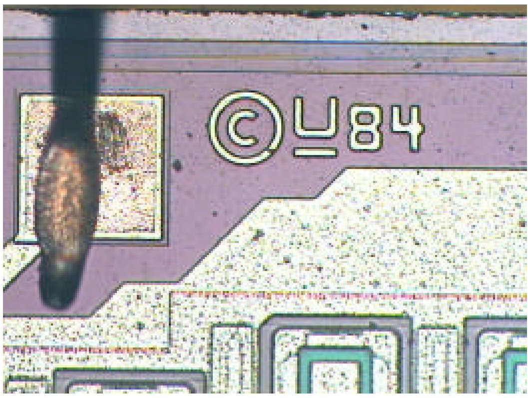
External and Internal Photos are shown in Figure 1.

Figure 1 – UC1707, External and Internal Photos

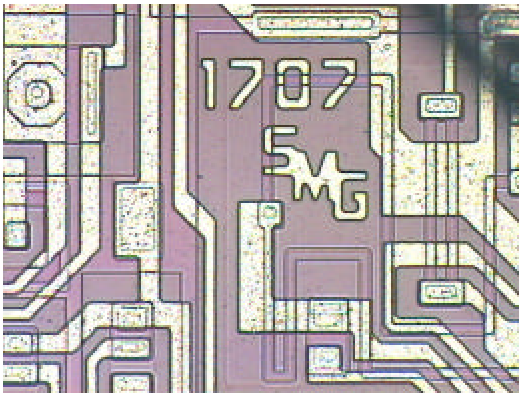
Top view



Die full view



Die marking, detail



Die marking, detail

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 an application specific test board.

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

The complete test equipment is constituted of:

- 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

Generic device test set-up is presented in Figure 2.

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.

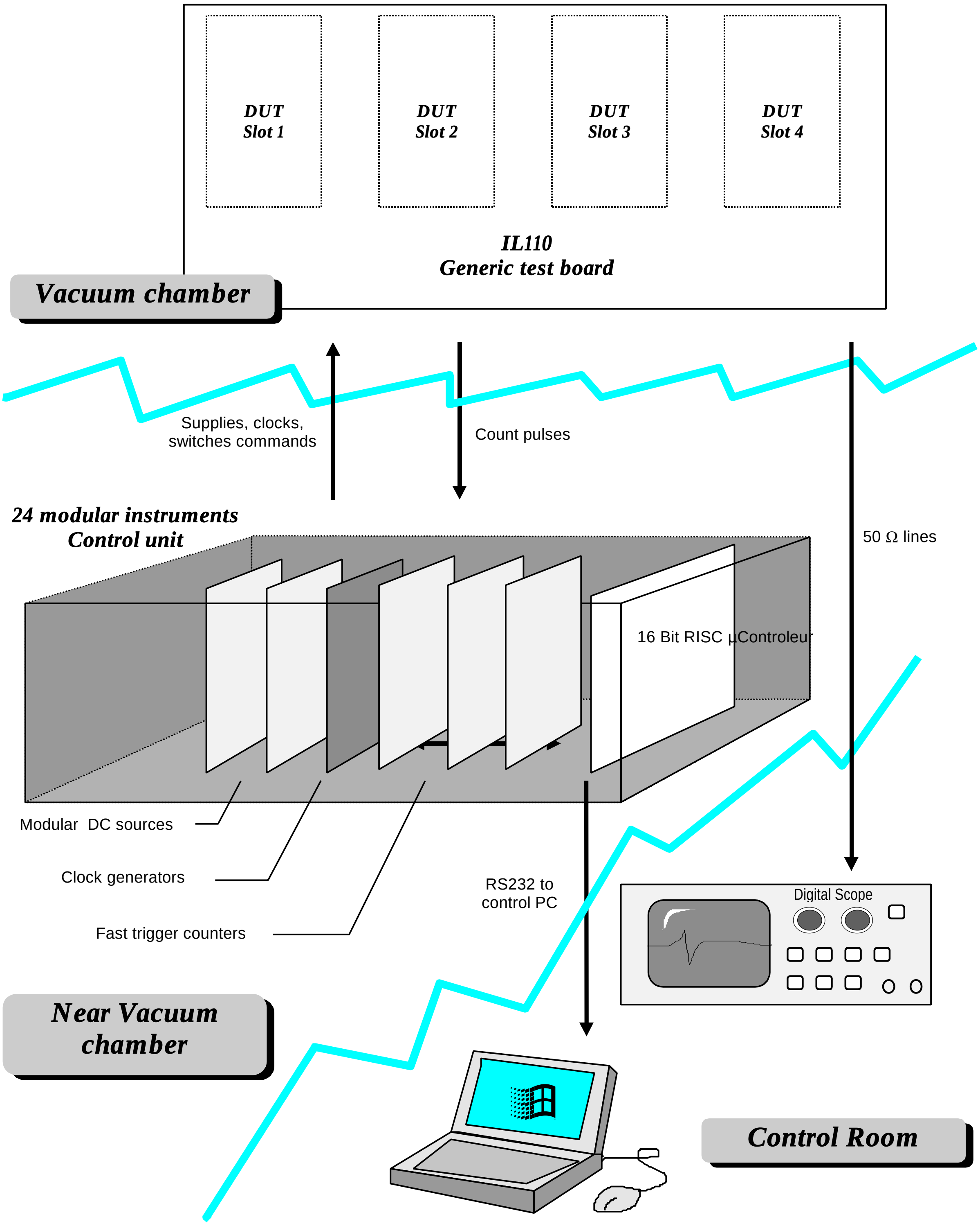


Figure 2 - Generic Device Test Set-up

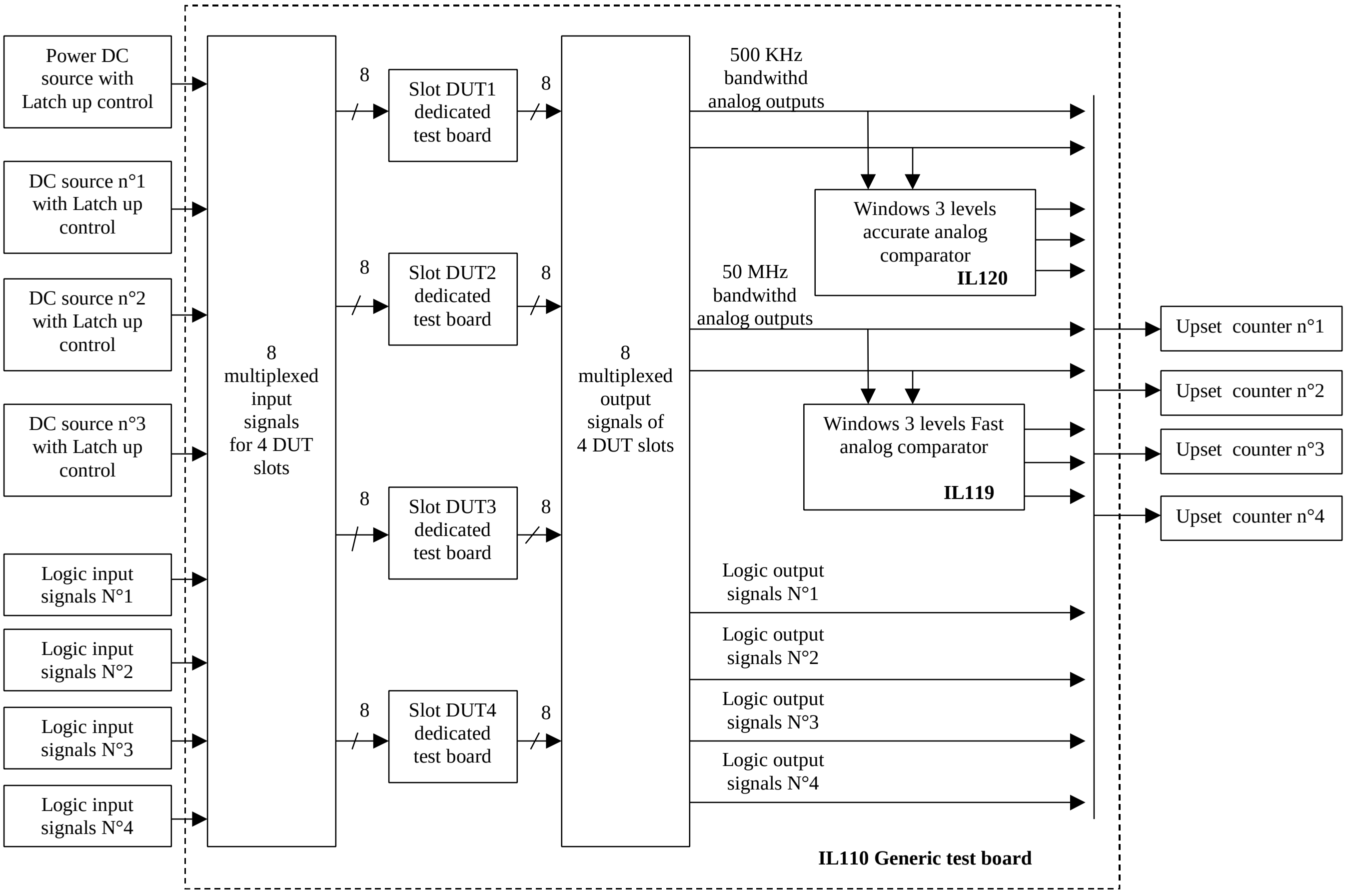


Figure 3 - Mother board synoptic

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

Device function is to drive power MOSFETs in a DC-DC switch converter.
Internal Latch is a RS type flip flop with precedence of SET input over RESET.
When SET is activated, output signal of this flip-flop inhibits the external power MOSFETs.
SET input is normally activated by the comparator, the nominal function of which is to observe the power current, to protect the MOSFETS in case of over-current.
When RESET input is held at 1 (or N.C.), the latch is transparent.
When RESET input is held at 0, the only way to re-initialize the latch once the comparator output has triggered the SET signal, is to power off the DUT.

Two test configurations have been used which are representative of two different designs used on XMM :

IV.3.1 BA ACU Design

Test principle :

The latch is connected with RESET=0 (latch is enabled). Comparator is used to detect a supply over-voltage.

Test will be done with DC input signals (no clocked inputs).
Output circuit load will not be simulated (transformer + power stage).
As input logic gates will be held "on", any change at the latch output will be detected by the DUT output voltage transition to low state.

A time delay circuit is added for automatic reset of the latch, after a wait state of 1ms in order to observe transient upsets and permanent upsets.

Pin 7 will also be monitored to check if short transients may be detected at the output of the comparator that would not trigger the latch.

External DC sources will be used at the input of the comparator to get known accurate differential voltage.

The working point will be set at 6.2V with equivalent source impedance (resistor + capacitor), to be representative of the application.

Types of events detected :

The following events will be counted separately :

- comparator output change,
- Latch state change,
- Transient detected at the driver output.

Functional Check :

A 5µs @ 1Hz signal changing the 6.2 v reference threshold allows for the counting activation.

Design change to improve upset tolerance :

A decoupling capacitor will be added at Pin7 : transients at the comparator output would then be filtered. If the comparator is more sensitive than the latch itself, this can improve the overall tolerance.
Electrically, this change seems acceptable; however, with this change, hysteresis effect is no more given by resistor R436=100k.

Different test set-up conditions :

Two different set-up conditions have been used and corresponding bias figures are given in the here below table :

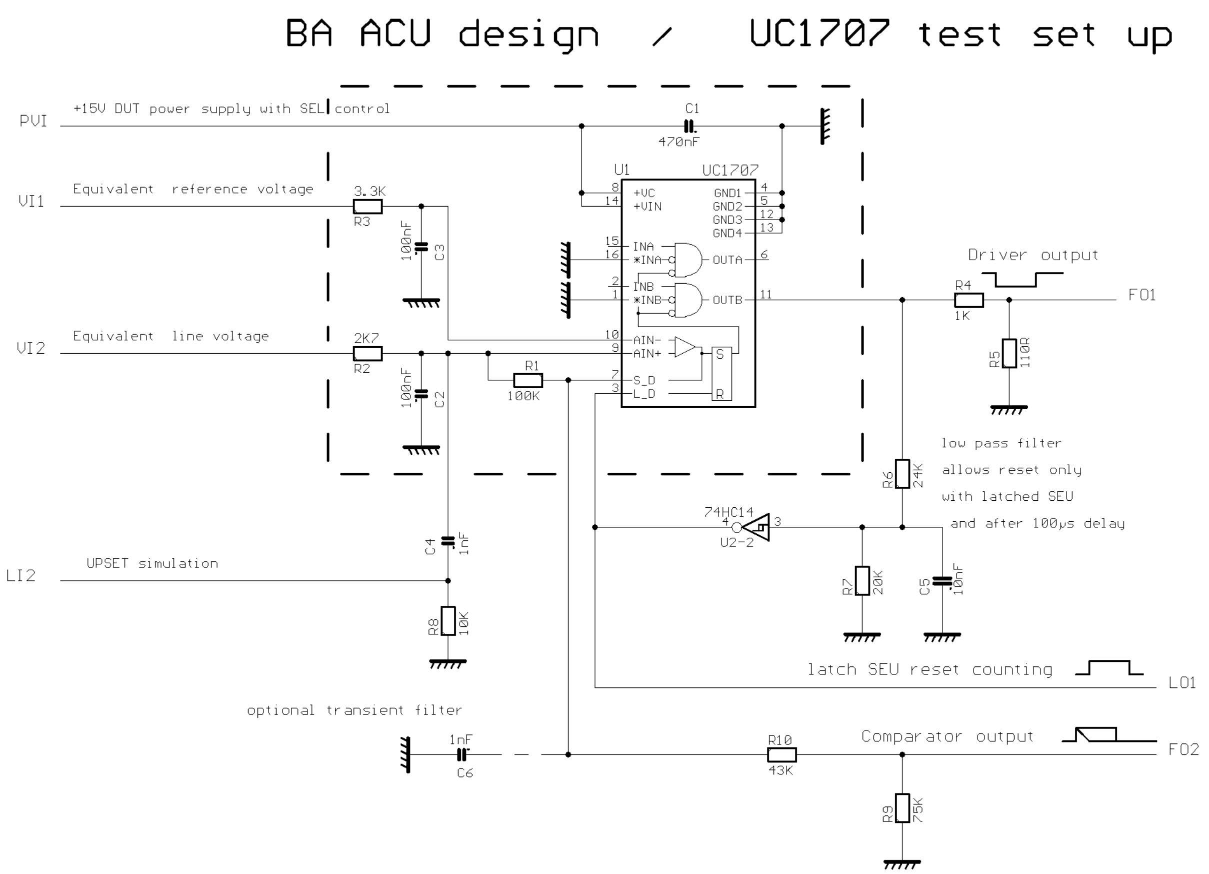
Test board		Signal definition	Signal state	Set up 1	Set up 2
				CLOSE TO TRIG.	FAR FROM TRIG. = 500mV
DC source	PVI	DUT supply	15V 20.8mA	30mA limit threshold	
DC source	VI1	Reference voltage input	trig. level	6.2V	
DC source	VI2	Line voltage input	trig. level	6.5V	6V
Scope chan 1	FO1	Driver output	14V to 0V	10V / Div	
Scope chan 2	FO2	Comparator output	0V to 3V	200mV / Div	
Counter 1	FO1	Driver output	14V to 0V	Trig @ 10V **$**	
Counter 2	FO2	Comparator output	0V to 3V	Trig @ 800mV **#**	
Counter 3	LO1	Latched SEU	Logic level	Trig @2.5V **#**	

Note : actual differential input level is calculated as follow:

(Reference) – (line) – (130mV UC1707 internal offset) – (200mV external hysteresis effect with R1 resistor)

Table 1 – UC1707, BA ACU Design Test Conditions

Figure 4 – UC1707 BA ACU Design Test Synoptic



IV.3.2 LASCO Design configuration

Test principle :

The latch is connected with RESET=1 (latch is disabled). Comparator input is used as an on/off signal.

Test will be done with DC input signals (no clocked inputs).
Output circuit load will not be simulated (transformer + power stage).
As input logic gates will be held "on", any change at the latch output will be detected by the driver output voltage transition to low state.
Direct observation of comparator output, pin 7.
Observation of one driver output to detect any transient generated in the latch (transparent) area, the driver area or the logic input area.

External DC sources will be used at the input of the comparator to get known accurate differential voltage.

The working point will be set at 6.2V with equivalent source impedance (resistor only), to be representative of the application.

Types of events detected :

The following events will be counted separately :

- Transient limited to the comparator output,
- Transient detected at the driver output,

Functional Check :

A 5µs @ 1Hz signal changing the 6V2 reference threshold allows for the counting activation.

<u>Different test set-up conditions :</u>

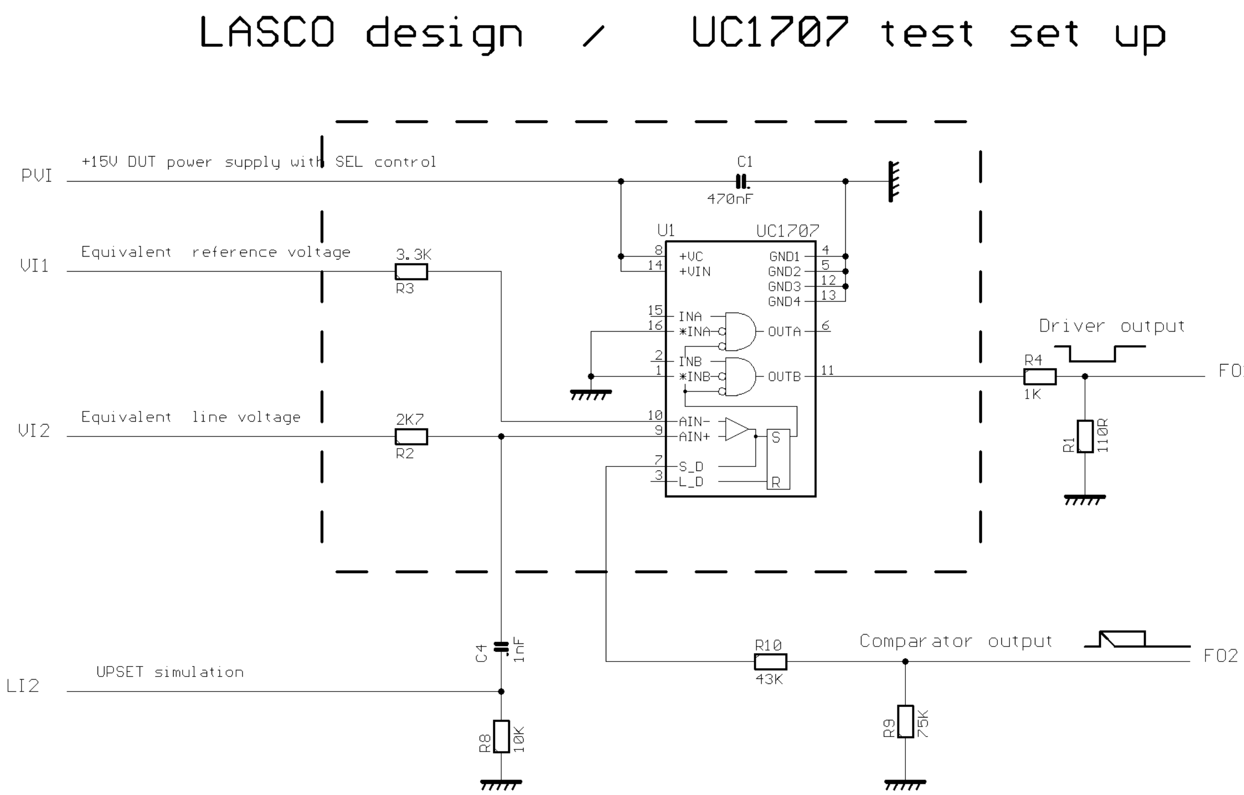
Two different set-up conditions have been used and corresponding bias figures are given in the here below table :

Test board		Signal definition	Signal state	Set up 1	Set up 2
				FAR FROM TRIG. = 3V.	**Closed to trig.**
DC source	PVI	DUT supply	15V 20.8mA	30mA limit threshold	
DC source	VI1	Reference voltage input	trig. level	6V	6.2V
DC source	VI2	Line voltage input	trig. level	3V	6.1V
Scope chan 1	FO1	Driver output	14V to 0V	10V / Div	
Scope chan 2	FO2	Comparator output	0V to 3V	200mV / Div	
Counter 1	FO1	Driver output	14V to 0V	Trig @ 10V $	
Counter 2	FO2	Comparator output	0V to 3V	Trig @ 800mV #	

Note : actual differential input level is calculated as follow:
(Reference) – (line) – (130mV UC1707 internal offset)

Table 2 – UC1707, LASCO Design Test Conditions

Figure 5 – UC1707 LASCO Design Test 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.1.

V.1.2.2 Flux Range

Particle flux could be varied from few hundred ions/cm²/sec up to a ten thousand ions/cm²/sec under normal operations (tilt 0°).

V.1.2.3 Particle Fluence Levels

Fluence level was comprised between 3 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.1.

V.1.2.6 Test Temperature Range

All the tests performed were conducted at ambient temperature.

V.2 PROTONS

Test at the cyclotron accelerator was performed at Paul Scherrer Institut (Switzerland) under HIREX Engineering responsibility.

V.2.1 Beam Source

In collaboration with the European Space Agency (ESA), the needed equipment for single events studies using protons has been built and installed on the PIF beam line in the NA hall of PSI cyclotron.

Irradiation is carried out in air.

V.2.2 Beam Set-up

V.2.2.1 Proton Beam Selection

The PSI (Paul Scherrer Institut) cyclotron has a primary beam of 590 MeV which can be degraded to lower energies by Al-absorbers. At the ESTEC coordinated Proton Irradiation Facility (PIF) beam line which is dedicated to SEU work, degraded calibrated beams from 300 to 30 MeVs can be delivered.

Alu Degrader (mm)	Energy (MeV)	LET(Si) (MeV/cm)	LET(Si) (MeV/mg/cm²)
2	300,3	6,66	2,86 E-03
121	200,2	8,461	3,63 E-03
207	99,6	13,664	5,86 E-03
224	69,8	17,814	7,64 E-03
233	49,2	23,32	1,00 E-02
237	37,5	28,844	1,24 E-02

For each run, information is provided on the beam characteristics in the detailed results tables provided in paragraph VI.2.

V.2.2.2 Flux Range

Particle flux could be varied from 1xE107 protons/cm²/sec up to 5xE8 protons/cm²/sec under normal operations (tilt 0°).

V.2.2.3 Particle Fluence Levels

Fluence level was comprised between 1 x10E10 and 5 x10E10 protons/cm².

V.2.2.4 Dosimetry

The current PIF dosimetry system and procedures were used.

V.2.2.5 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.2.

V.2.2.6 Test Temperature Range

All the tests performed were conducted at ambient temperature.

VI. RESULTS

VI.1 HEAVY IONS RESULTS

BA ACU Design

As mentioned in paragraph IV.3.1, the effect of Single Event Upset was monitored and counted at three different locations of the test circuit :

Comparator error : At the output of the comparator, see F02 line in Figure 4.

Driver error : At the output of the driver, see F01line in Figure 4.

Latched SEU error : If the latch state has changed, see L01 line in Figure 4

Results are presented in Table 3, Table 4, Table 5 and Table 6.

The first two tables give the results with the two different working operating conditions which are described in Table 1.

A main outcome is that comparator output cannot be observed at PIN7 as signal observed at this pin follows the latch state. This is not in line with UC1707 schematic provided in Unitrode datasheet. With condition 1, i.e. closed to the comparator trigger level, the number of latched SEU errors is much higher than with condition 2. This result shows the sensitivity of the comparator area.

The last two tables give the results with the filter capacitor added.

It can be seen that the use of 1nF capacitor (run36 to run 40) decreases significantly the number of latched SEU errors. With a 10 nF capacitor (run065 and higher), no more latched SEU error are counted

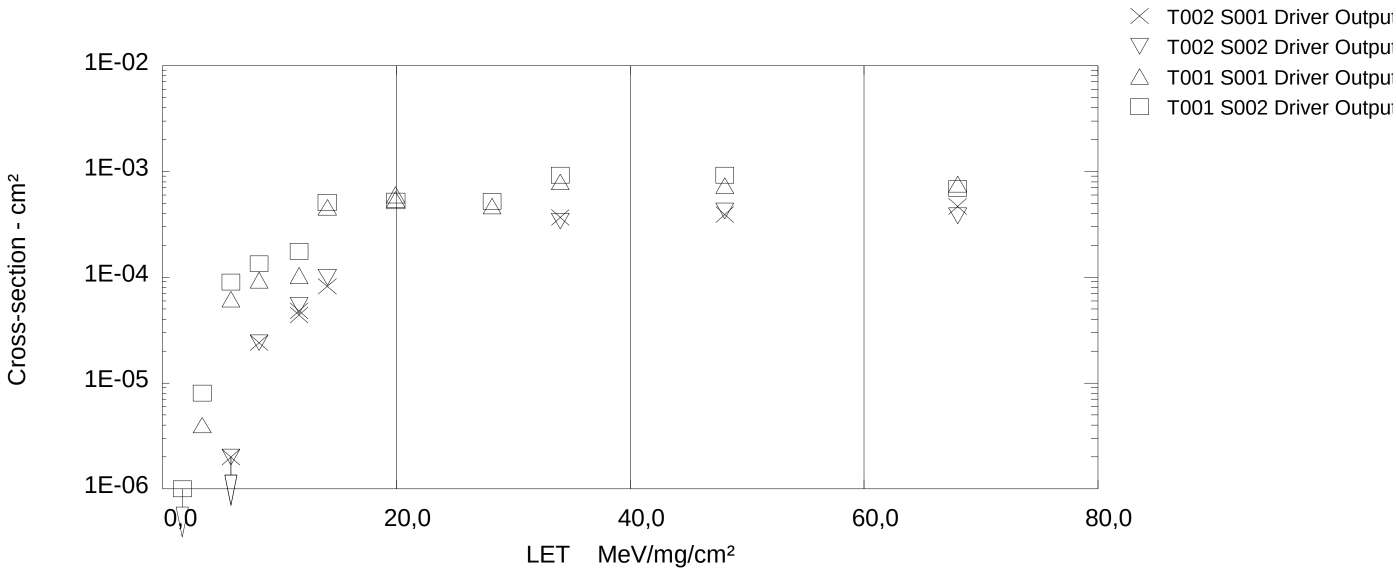
Corresponding SEU error cross-sections per device versus LET, are plotted in Figure 6, Figure 7, and Figure 8 for the two different working operating conditions.

LASCO Design

Results are presented in Table 7 and Table 8. These tables give the results with the two different working operating conditions which are described in Table 2.

It must be noted that with Lasco configuration, the amplitude of comparator events are too small to be counted by the counter inside the tester.
However, thanks to a digital scope, it was possible to illustrate typical upsets occurrence (see Figure 10 and Figure 11).

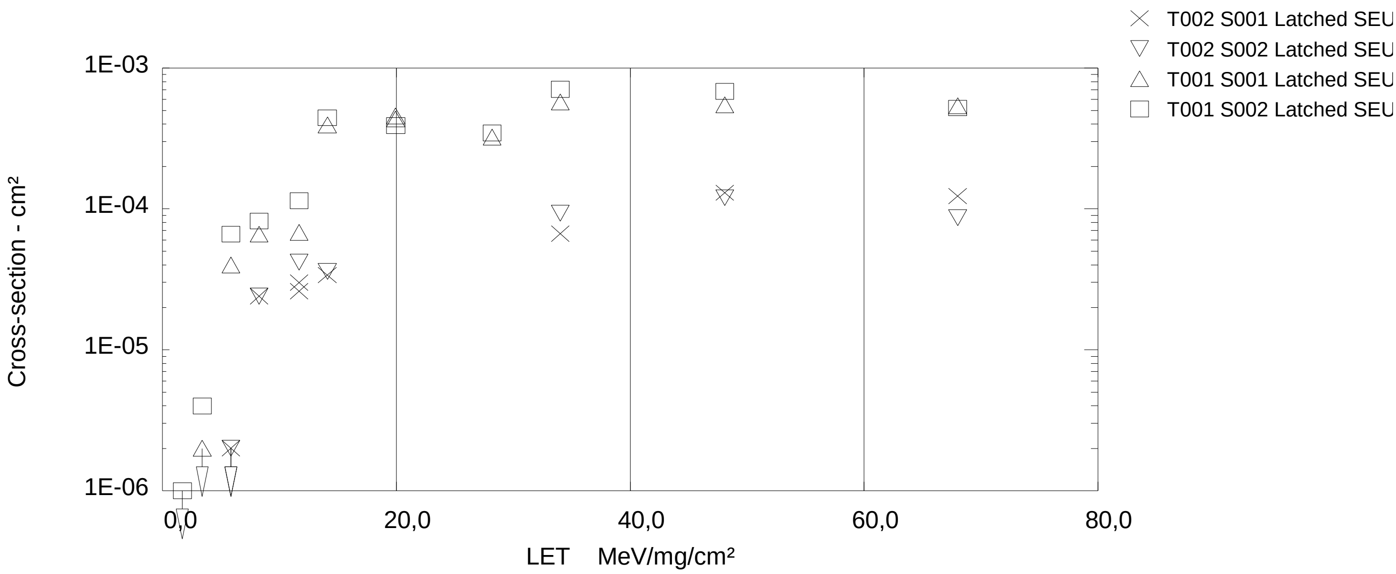
Corresponding SEU error cross-sections per device versus LET, are plotted in Figure 9 for the two different working operating conditions.



Run ID	Test	Sample	Error Type	Fluence p/cm²	LET Mev/mg/cm²	Nb Errors cm²	Sigma
R00039	T002	S001	Driver Output	5,01 E+05	14,1	41	8,191 E-05
R00146	T002	S001	Driver Output	5,00 E+05	5,8	0	2,000 E-06 *
R00147	T002	S001	Driver Output	5,00 E+05	11,7	22	4,400 E-05
R00148	T002	S001	Driver Output	5,00 E+05	8,3	12	2,400 E-05
R00149	T002	S001	Driver Output	5,00 E+05	11,7	24	4,800 E-05
R00204	T002	S001	Driver Output	3,00 E+05	68,0	140	4,667 E-04
R00205	T002	S001	Driver Output	3,00 E+05	48,1	117	3,900 E-04
R00206	T002	S001	Driver Output	3,00 E+05	34,0	110	3,667 E-04
R00054	T002	S002	Driver Output	5,00 E+05	14,1	50	1,000 E-04
R00156	T002	S002	Driver Output	5,00 E+05	5,8	0	2,000 E-06 *
R00157	T002	S002	Driver Output	5,00 E+05	8,3	12	2,400 E-05
R00158	T002	S002	Driver Output	5,00 E+05	11,7	27	5,400 E-05
R00207	T002	S002	Driver Output	3,00 E+05	34,0	102	3,400 E-04
R00208	T002	S002	Driver Output	3,00 E+05	48,1	127	4,233 E-04
R00209	T002	S002	Driver Output	3,00 E+05	68,0	114	3,800 E-04
R00033	T001	S001	Driver Output	5,04 E+05	14,1	230	4,566 E-04
R00034	T001	S001	Driver Output	5,02 E+05	19,9	301	5,999 E-04
R00035	T001	S001	Driver Output	5,01 E+05	28,2	235	4,687 E-04
R00066	T001	S001	Driver Output	1,00 E+06	19,9	544	5,440 E-04
R00143	T001	S001	Driver Output	5,00 E+05	11,7	52	1,040 E-04
R00144	T001	S001	Driver Output	5,00 E+05	8,3	47	9,400 E-05
R00145	T001	S001	Driver Output	5,00 E+05	5,8	31	6,200 E-05
R00193	T001	S001	Driver Output	3,00 E+05	34,0	239	7,967 E-04
R00194	T001	S001	Driver Output	3,00 E+05	48,1	220	7,333 E-04
R00195	T001	S001	Driver Output	3,00 E+05	68,0	228	7,600 E-04
R00304	T001	S001	Driver Output	5,00 E+05	3,4	2	4,000 E-06
R00051	T001	S002	Driver Output	5,00 E+05	14,1	256	5,120 E-04
R00052	T001	S002	Driver Output	5,00 E+05	19,9	264	5,280 E-04
R00053	T001	S002	Driver Output	5,00 E+05	28,2	260	5,200 E-04
R00153	T001	S002	Driver Output	5,00 E+05	11,7	88	1,760 E-04
R00154	T001	S002	Driver Output	5,00 E+05	8,3	67	1,340 E-04
R00155	T001	S002	Driver Output	5,00 E+05	5,8	45	9,000 E-05
R00196	T001	S002	Driver Output	3,00 E+05	68,0	207	6,900 E-04
R00199	T001	S002	Driver Output	3,00 E+05	48,1	277	9,233 E-04
R00200	T001	S002	Driver Output	3,00 E+05	34,0	277	9,233 E-04
R00305	T001	S002	Driver Output	1,00 E+06	3,4	8	8,000 E-06
R00306	T001	S002	Driver Output	1,00 E+06	1,7	0	1,000 E-06 *

T001=condition1 T002=condition2

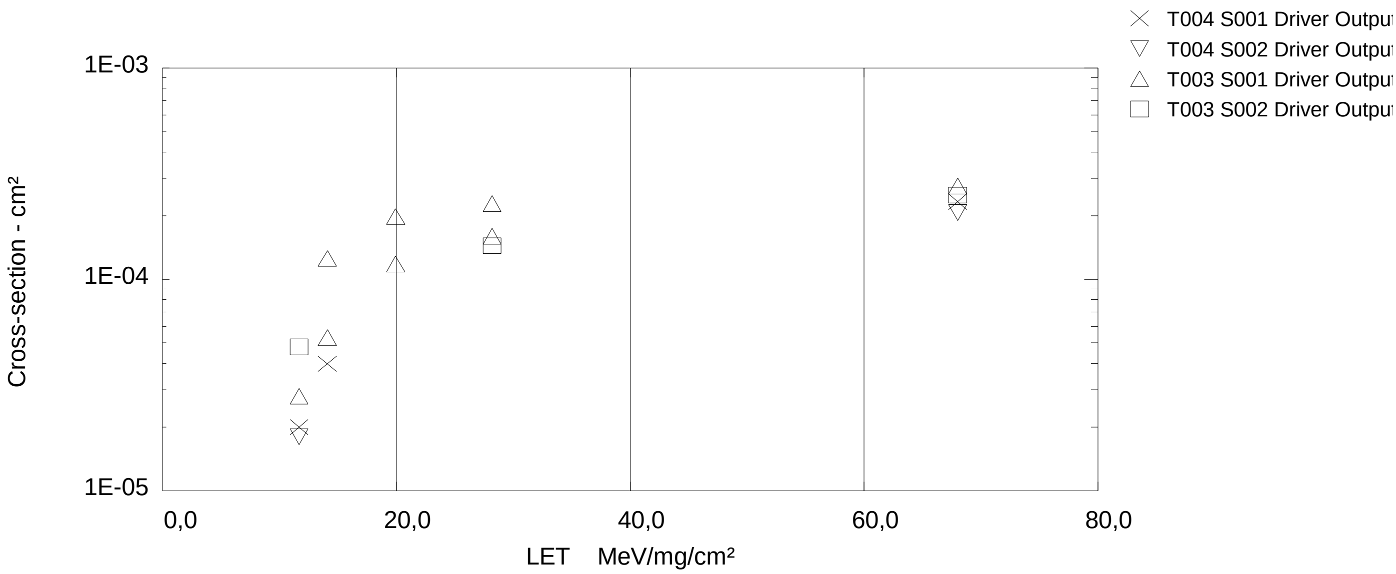
Figure 6 – UC1707, Heavy ion test, BA ACU design, driver output errors, SEU Cross-section versus LET



Run ID	Test	Sample	Error Type	Fluence p/cm²	LET Mev/mg/cm²	Nb Errors cm²	Sigma
R00039	T002	S001	Latched SEU	5,01 E+05	14,1	17	3,396 E-05
R00146	T002	S001	Latched SEU	5,00 E+05	5,8	0	2,000 E-06 *
R00147	T002	S001	Latched SEU	5,00 E+05	11,7	15	3,000 E-05
R00148	T002	S001	Latched SEU	5,00 E+05	8,3	12	2,400 E-05
R00149	T002	S001	Latched SEU	5,00 E+05	11,7	13	2,600 E-05
R00204	T002	S001	Latched SEU	3,00 E+05	68,0	37	1,233 E-04
R00205	T002	S001	Latched SEU	3,00 E+05	48,1	39	1,300 E-04
R00206	T002	S001	Latched SEU	3,00 E+05	34,0	20	6,667 E-05
R00054	T002	S002	Latched SEU	5,00 E+05	14,1	18	3,600 E-05
R00156	T002	S002	Latched SEU	5,00 E+05	5,8	0	2,000 E-06 *
R00157	T002	S002	Latched SEU	5,00 E+05	8,3	12	2,400 E-05
R00158	T002	S002	Latched SEU	5,00 E+05	11,7	21	4,200 E-05
R00207	T002	S002	Latched SEU	3,00 E+05	34,0	28	9,333 E-05
R00208	T002	S002	Latched SEU	3,00 E+05	48,1	36	1,200 E-04
R00209	T002	S002	Latched SEU	3,00 E+05	68,0	26	8,667 E-05
R00033	T001	S001	Latched SEU	5,04 E+05	14,1	198	3,930 E-04
R00034	T001	S001	Latched SEU	5,02 E+05	19,9	229	4,564 E-04
R00035	T001	S001	Latched SEU	5,01 E+05	28,2	162	3,231 E-04
R00066	T001	S001	Latched SEU	1,00 E+06	19,9	433	4,330 E-04
R00143	T001	S001	Latched SEU	5,00 E+05	11,7	34	6,800 E-05
R00144	T001	S001	Latched SEU	5,00 E+05	8,3	33	6,600 E-05
R00145	T001	S001	Latched SEU	5,00 E+05	5,8	20	4,000 E-05
R00193	T001	S001	Latched SEU	3,00 E+05	34,0	172	5,733 E-04
R00194	T001	S001	Latched SEU	3,00 E+05	48,1	164	5,467 E-04
R00195	T001	S001	Latched SEU	3,00 E+05	68,0	162	5,400 E-04
R00304	T001	S001	Latched SEU	5,00 E+05	3,4	0	2,000 E-06 *
R00051	T001	S002	Latched SEU	5,00 E+05	14,1	221	4,420 E-04
R00052	T001	S002	Latched SEU	5,00 E+05	19,9	195	3,900 E-04
R00053	T001	S002	Latched SEU	5,00 E+05	28,2	173	3,460 E-04
R00153	T001	S002	Latched SEU	5,00 E+05	11,7	57	1,140 E-04
R00154	T001	S002	Latched SEU	5,00 E+05	8,3	41	8,200 E-05
R00155	T001	S002	Latched SEU	5,00 E+05	5,8	33	6,600 E-05
R00196	T001	S002	Latched SEU	3,00 E+05	68,0	156	5,200 E-04
R00199	T001	S002	Latched SEU	3,00 E+05	48,1	205	6,833 E-04
R00200	T001	S002	Latched SEU	3,00 E+05	34,0	212	7,067 E-04
R00305	T001	S002	Latched SEU	1,00 E+06	3,4	4	4,000 E-06
R00306	T001	S002	Latched SEU	1,00 E+06	1,7	0	1,000 E-06 *

T001=condition1 T002=condition2

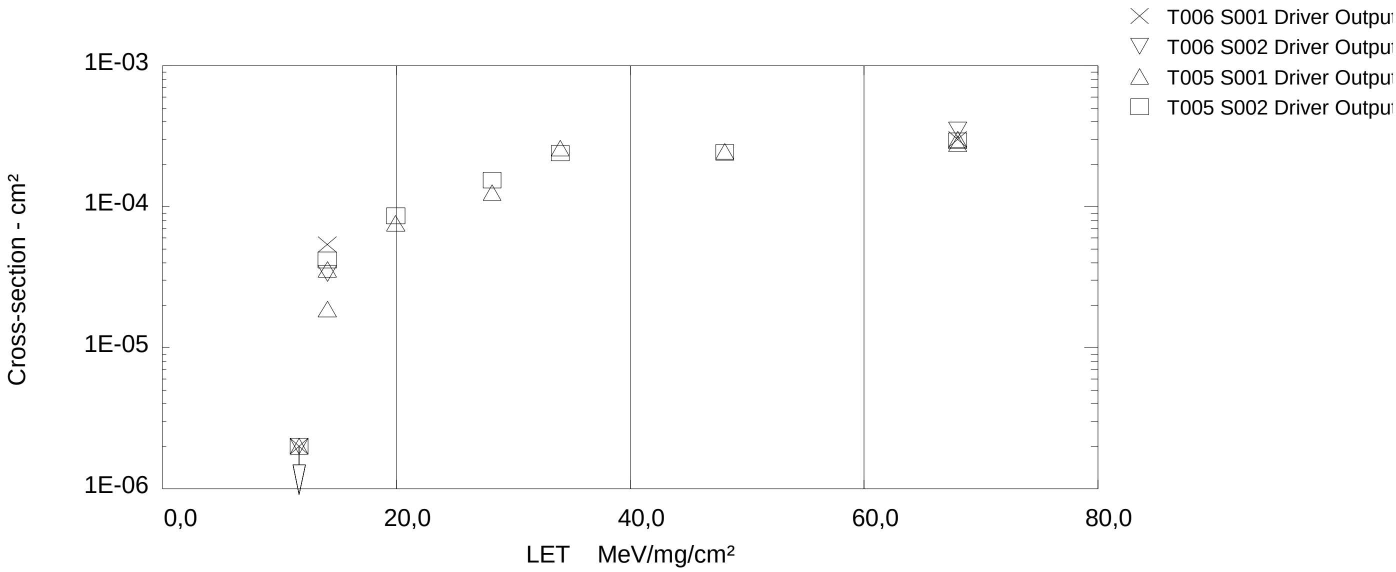
Figure 7 – UC1707, Heavy ion test, BA ACU design, Latched SEU errors, SEU Cross-section versus LET



Run ID	Test	Sample	Error Type	Fluence p/cm²	LET Mev/mg/cm²	Nb Errors cm²	Sigma
R00040	T004	S001	Driver Output	5,02 E+05	14,1	20	3,984 E-05
R00150	T004	S001	Driver Output	5,00 E+05	11,7	10	2,000 E-05
R00203	T004	S001	Driver Output	3,00 E+05	68,0	70	2,333 E-04
R00159	T004	S002	Driver Output	5,00 E+05	11,7	9	1,800 E-05
R00210	T004	S002	Driver Output	3,00 E+05	68,0	62	2,067 E-04
R00036	T003	S001	Driver Output	5,03 E+05	14,1	63	1,254 E-04
R00037	T003	S001	Driver Output	5,00 E+05	19,9	99	1,980 E-04
R00038	T003	S001	Driver Output	5,00 E+05	28,2	114	2,279 E-04
R00065	T003	S001	Driver Output	1,00 E+06	14,1	53	5,300 E-05
R00067	T003	S001	Driver Output	1,00 E+06	19,9	118	1,180 E-04
R00068	T003	S001	Driver Output	1,00 E+06	28,2	160	1,600 E-04
R00151	T003	S001	Driver Output	5,00 E+05	11,7	14	2,800 E-05
R00202	T003	S001	Driver Output	3,00 E+05	68,0	83	2,767 E-04
R00069	T003	S002	Driver Output	1,00 E+06	28,2	144	1,440 E-04
R00152	T003	S002	Driver Output	5,00 E+05	11,7	24	4,800 E-05
R00201	T003	S002	Driver Output	3,00 E+05	68,0	75	2,500 E-04

T003=condition1 T004=condition2

Figure 8 – UC1707, Heavy ion test, BA ACU design, driver output errors, filter capacitor added, SEU Cross-section versus LET



Run ID	Test	Sample	Error Type	Fluence p/cm²	LET Mev/mg/cm²	Nb Errors cm²	Sigma
R00045	T006	S001	Driver Output	5,00 E+05	14,1	27	5,400 E-05
R00162	T006	S001	Driver Output	5,00 E+05	11,7	0	2,000 E-06 *
R00219	T006	S001	Driver Output	3,00 E+05	68,0	90	3,000 E-04
R00050	T006	S002	Driver Output	5,05 E+05	14,1	17	3,367 E-05
R00161	T006	S002	Driver Output	5,00 E+05	11,7	1	2,000 E-06
R00220	T006	S002	Driver Output	3,00 E+05	68,0	105	3,500 E-04
R00041	T005	S001	Driver Output	2,13 E+05	14,1	4	1,878 E-05
R00042	T005	S001	Driver Output	5,02 E+05	14,1	18	3,587 E-05
R00043	T005	S001	Driver Output	5,00 E+05	19,9	38	7,600 E-05
R00046	T005	S001	Driver Output	5,01 E+05	28,2	63	1,259 E-04
R00163	T005	S001	Driver Output	5,00 E+05	11,7	0	2,000 E-06 *
R00214	T005	S001	Driver Output	3,00 E+05	34,0	78	2,600 E-04
R00215	T005	S001	Driver Output	3,00 E+05	48,1	74	2,467 E-04
R00217	T005	S001	Driver Output	3,00 E+05	68,0	90	3,000 E-04
R00218	T005	S001	Driver Output	3,00 E+05	68,0	84	2,800 E-04
R00047	T005	S002	Driver Output	5,00 E+05	14,1	21	4,200 E-05
R00048	T005	S002	Driver Output	5,00 E+05	19,9	43	8,600 E-05
R00049	T005	S002	Driver Output	5,00 E+05	28,2	77	1,540 E-04
R00160	T005	S002	Driver Output	5,00 E+05	11,7	0	2,000 E-06 *
R00211	T005	S002	Driver Output	3,00 E+05	68,0	88	2,933 E-04
R00212	T005	S002	Driver Output	3,00 E+05	48,1	73	2,433 E-04
R00213	T005	S002	Driver Output	3,00 E+05	34,0	72	2,400 E-04

T005 = Condition1 T006 = Condition 2

Figure 9 – UC1707, Heavy ion test, LASCO design, driver output errors, SEU Cross-section versus LET

Table 3 – Heavy ion test results on Unitrode UC1707, Test T001 BA ACU Condition 1

Run	Sample	Ion	Angle	Eff. LET	Run Time	Flux	TID per Sample	Fluence	Errors		
ID No	ID No	ID No	°	Mev/mg/cm²	sec	P/cm²/sec	Rads (Si)	P/cm²	Comp.	Driver	Latched SEU
R00031	S001	I004	0	14,1	262	3,82 E+03	2,26 E+02	1,00 E+06	445	449	373
R00032	S001	I004	45	19,94	89	2,89 E+03	3,08 E+02	2,57 E+05	114	124	95
R00033	S001	I004	0	14,1	135	3,73 E+03	4,21 E+02	5,04 E+05	197	230	198
R00034	S001	I004	45	19,94	194	2,59 E+03	5,81 E+02	5,02 E+05	229	301	229
R00035	S001	I004	60	28,2	324	1,55 E+03	8,08 E+02	5,01 E+05	161	235	162
R00051	S002	I004	0	14,1	67	7,46 E+03	7,25 E+02	5,00 E+05	220	256	221
R00052	S002	I004	45	19,94	107	4,67 E+03	8,84 E+02	5,00 E+05	196	264	195
R00053	S002	I004	60	28,2	161	3,11 E+03	1,11 E+03	5,00 E+05	174	260	173
R00066	S001	I004	45	19,94	197	5,08 E+03	2,85 E+03	1,00 E+06	427	544	433
R00143	S001	I005	60	11,7	80	6,25 E+03	3,71 E+03	5,00 E+05	34	52	34
R00144	S001	I005	45	8,27	57	8,77 E+03	3,78 E+03	5,00 E+05	33	47	33
R00145	S001	I005	0	5,85	40	1,25 E+04	3,83 E+03	5,00 E+05	19	31	20
R00153	S002	I005	60	11,7	70	7,14 E+03	1,86 E+03	5,00 E+05	56	88	57
R00154	S002	I005	45	8,27	123	4,07 E+03	1,93 E+03	5,00 E+05	42	67	41
R00155	S002	I005	0	5,85	125	4,00 E+03	1,97 E+03	5,00 E+05	33	45	33
R00193	S001	I003	0	34	34	8,82 E+03	4,66 E+03	3,00 E+05	171	239	172
R00194	S001	I003	45	48,08	69	4,35 E+03	4,89 E+03	3,00 E+05	161	220	164
R00195	S001	I003	60	68	96	3,13 E+03	5,22 E+03	3,00 E+05	162	228	162
R00196	S002	I003	60	68	96	3,13 E+03	2,79 E+03	3,00 E+05	157	207	156
R00199	S002	I003	45	48,08	64	4,69 E+03	3,48 E+03	3,00 E+05	206	277	205
R00200	S002	I003	0	34	38	7,89 E+03	3,64 E+03	3,00 E+05	210	277	212
R00304	S001	I007	60	3,4	68	7,35 E+03	8,32 E+03	5,00 E+05	0	2	0
R00305	S002	I007	60	3,4	130	7,69 E+03	6,12 E+03	1,00 E+06	4	8	4
R00306	S002	I007	0	1,7	67	1,49 E+04	6,14 E+03	1,00 E+06	0	0	0

Ion ID	Specy	Energy	LET	Range
		MeV	Mev/mg/cm²	µm
I004	40-Ar	150	14,1	42
I005	20-Ne	78	5,85	45
I003	84-Kr	316	34	43
I007	10-B	41	1,7	80

Sample ID	SN	Part Type	Date Code	Comments
S001	#061	UC1707	9145	Unitrode
S002	#062	Uc1707	9145	Unitrode

Note Condition 1 : Ref=6.18V, Line=6.48V

Table 4 – Heavy ion test results on Unitrode UC1707, Test T002 BA ACU Condition 2

Run ID No	Sample ID No	Ion ID No	Angle °	Eff. LET Mev/mg/cm²	Run Time sec	Flux P/cm²/sec	TID per Sample Rads (Si)	Fluence P/cm²	Errors Comp.	Errors Driver	Errors Latched SEU
R00039	S001	I004	0	14,1	189	2,65 E+03	1,42 E+03	5,01 E+05	17	41	17
R00054	S002	I004	0	14,1	75	6,67 E+03	1,22 E+03	5,00 E+05	18	50	18
R00146	S001	I005	0	5,85	40	1,25 E+04	3,87 E+03	5,00 E+05	0	0	0
R00147	S001	I005	60	11,7	78	6,41 E+03	3,97 E+03	5,00 E+05	15	22	15
R00148	S001	I005	45	8,27	48	1,04 E+04	4,03 E+03	5,00 E+05	12	12	12
R00149	S001	I005	60	11,7	77	6,49 E+03	4,13 E+03	5,00 E+05	13	24	13
R00156	S002	I005	0	5,85	90	5,56 E+03	2,02 E+03	5,00 E+05	0	0	0
R00157	S002	I005	45	8,27	121	4,13 E+03	2,09 E+03	5,00 E+05	12	12	12
R00158	S002	I005	60	11,7	180	2,78 E+03	2,18 E+03	5,00 E+05	21	27	21
R00204	S001	I003	60	68	84	3,57 E+03	6,20 E+03	3,00 E+05	37	140	37
R00205	S001	I003	45	48,08	61	4,92 E+03	6,43 E+03	3,00 E+05	39	117	39
R00206	S001	I003	0	34	36	8,33 E+03	6,59 E+03	3,00 E+05	20	110	20
R00207	S002	I003	0	34	43	6,98 E+03	4,13 E+03	3,00 E+05	28	102	28
R00208	S002	I003	45	48,08	56	5,36 E+03	4,36 E+03	3,00 E+05	36	127	36
R00209	S002	I003	60	68	86	3,49 E+03	4,69 E+03	3,00 E+05	26	114	26

Ion ID	Specy	Energy MeV	LET Mev/mg/cm²	Range µm
I004	40-Ar	150	14,1	42
I005	20-Ne	78	5,85	45
I003	84-Kr	316	34	43
I007	10-B	41	1,7	80

Sample ID	SN	Part Type	Date Code	Comments
S001	#061	UC1707	9145	Unitrode
S002	#062	Uc1707	9145	Unitrode

Note Condition 2 : Ref=6.18V, Line=6.00V

Table 5 – Heavy ion test results on Unitrode UC1707,
Test T003 BA ACU Condition 1 + filter capacitor

Run ID No	**Sample** ID No	**Ion** ID No	**Angle** °	**Eff. LET** Mev/mg/cm²	**Run Time** sec	**Flux** P/cm²/sec	**TID per Sample** Rads (Si)	**Fluence** P/cm²	**Errors** Comp.	Driver	Latched SEU
R00036	S001	I004	0	14,1	165	3,05 E+03	9,21 E+02	5,03 E+05	16	63	16
R00037	S001	I004	45	19,94	38	1,32 E+04	1,08 E+03	5,00 E+05	23	99	23
R00038	S001	I004	60	28,2	360	1,39 E+03	1,31 E+03	5,00 E+05	23	114	23
R00065	S001	I004	0	14,1	112	8,93 E+03	2,53 E+03	1,00 E+06	0	53	0
R00067	S001	I004	45	19,94	210	4,76 E+03	3,17 E+03	1,00 E+06	0	118	0
R00068	S001	I004	60	28,2	286	3,50 E+03	3,62 E+03	1,00 E+06	0	160	0
R00069	S002	I004	60	28,2	325	3,08 E+03	1,67 E+03	1,00 E+06	0	144	0
R00151	S001	I005	60	11,7	63	7,94 E+03	4,31 E+03	5,00 E+05	0	14	0
R00152	S002	I005	60	11,7	74	6,76 E+03	1,77 E+03	5,00 E+05	0	24	0
R00201	S002	I003	60	68	82	3,66 E+03	3,97 E+03	3,00 E+05	0	75	0
R00202	S001	I003	60	68	77	3,90 E+03	5,55 E+03	3,00 E+05	0	83	0

Ion ID	Specy	Energy MeV	LET Mev/mg/cm²	Range µm
I004	40-Ar	150	14,1	42
I005	20-Ne	78	5,85	45
I003	84-Kr	316	34	43
I007	10-B	41	1,7	80

Sample ID	SN	Part Type	Date Code	Comments
S001	#061	UC1707	9145	Unitrode
S002	#062	Uc1707	9145	Unitrode

Note Condition 1 : Ref=6.18V, Line=6.48V

Table 6 – Heavy ion test results on Unitrode UC1707,
Test T004 BA ACU Condition 2 + filter capacitor

Run ID No	**Sample** ID No	**Ion** ID No	**Angle** °	**Eff. LET** Mev/mg/cm²	**Run Time** sec	**Flux** P/cm²/sec	**TID per Sample** Rads (Si)	**Fluence** P/cm²	**Errors** Comp.	Driver	Latched SEU
R00040	S001	I004	0	14,1	203	2,47 E+03	1,53 E+03	5,02 E+05	0	20	0
R00150	S001	I005	60	11,7	48	1,04 E+04	4,22 E+03	5,00 E+05	0	10	0
R00159	S002	I005	60	11,7	194	2,58 E+03	2,27 E+03	5,00 E+05	0	9	0
R00203	S001	I003	60	68	77	3,90 E+03	5,87 E+03	3,00 E+05	0	70	0
R00210	S002	I003	60	68	88	3,41 E+03	5,02 E+03	3,00 E+05	0	62	0

Ion ID	Specy	Energy MeV	LET Mev/mg/cm²	Range µm
I004	40-Ar	150	14,1	42
I005	20-Ne	78	5,85	45
I003	84-Kr	316	34	43
I007	10-B	41	1,7	80

Sample ID	SN	Part Type	Date Code	Comments
S001	#061	UC1707	9145	Unitrode
S002	#062	Uc1707	9145	Unitrode

Note Condition 2 : Ref=6.18V, Line=6.00V

Table 7 – Heavy ion test results on Unitrode UC1707, Test T005 LASCO Condition 1

Run ID No	Sample ID No	Ion ID No	Angle °	Eff. LET Mev/mg/cm²	Run Time sec	Flux P/cm²/sec	TID per Sample Rads (Si)	Fluence P/cm²	Errors Comp.	 Driver
R00041	S001	I004	0	14,1	87	2,45 E+03	1,58 E+03	2,13 E+05	0	4
R00042	S001	I004	0	14,1	152	3,30 E+03	1,69 E+03	5,02 E+05	0	18
R00043	S001	I004	45	19,94	152	3,29 E+03	1,85 E+03	5,00 E+05	0	38
R00046	S001	I004	60	28,2	256	1,96 E+03	2,30 E+03	5,01 E+05	0	63
R00047	S002	I004	0	14,1	56	8,93 E+03	1,13 E+02	5,00 E+05	0	21
R00048	S002	I004	45	19,94	70	7,14 E+03	2,72 E+02	5,00 E+05	0	43
R00049	S002	I004	60	28,2	89	5,62 E+03	4,98 E+02	5,00 E+05	0	77
R00160	S002	I005	60	11,7	130	3,85 E+03	2,37 E+03	5,00 E+05	0	0
R00163	S001	I005	60	11,7	231	2,16 E+03	4,50 E+03	5,00 E+05	0	0
R00211	S002	I003	60	68	84	3,57 E+03	5,34 E+03	3,00 E+05	0	88
R00212	S002	I003	45	48,08	67	4,48 E+03	5,57 E+03	3,00 E+05	0	73
R00213	S002	I003	0	34	46	6,52 E+03	5,74 E+03	3,00 E+05	0	72
R00214	S001	I003	0	34	54	5,56 E+03	6,76 E+03	3,00 E+05	0	78
R00215	S001	I003	45	48,08	79	3,80 E+03	6,99 E+03	3,00 E+05	0	74
R00217	S001	I003	60	68	100	3,00 E+03	7,64 E+03	3,00 E+05	1	90
R00218	S001	I003	60	68	108	2,78 E+03	7,97 E+03	3,00 E+05	0	84

Ion ID	Specy	Energy MeV	LET Mev/mg/cm²	Range µm
I004	40-Ar	150	14,1	42
I005	20-Ne	78	5,85	45
I003	84-Kr	316	34	43
I007	10-B	41	1,7	80

Sample ID	SN	Part Type	Date Code	Comments
S001	#061	UC1707	9145	Unitrode
S002	#062	Uc1707	9145	Unitrode

Note Condition 1 : Ref=6.01V, Line=3.00V

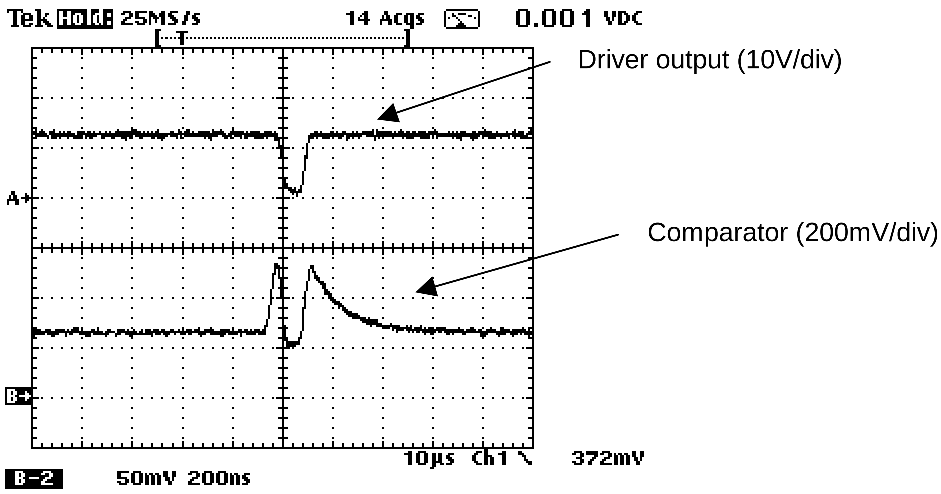
Table 8 – Heavy ion test results on Unitrode UC1707, Test T006 LASCO Condition 2

Run ID No	**Sample** ID No	**Ion** ID No	**Angle** °	**Eff. LET** Mev/mg/cm²	**Run Time** sec	**Flux** P/cm²/sec	**TID per Sample** Rads (Si)	**Fluence** P/cm²	**Errors** Comp.	Driver
R00045	S001	I004	0	14,1	114	4,39 E+03	2,08 E+03	5,00 E+05	0	27
R00050	S002	I004	0	14,1	43	1,17 E+04	6,12 E+02	5,05 E+05	0	17
R00161	S002	I005	60	11,7	213	2,35 E+03	2,46 E+03	5,00 E+05	0	1
R00162	S001	I005	60	11,7	225	2,22 E+03	4,41 E+03	5,00 E+05	0	0
R00219	S001	I003	60	68	103	2,91 E+03	8,29 E+03	3,00 E+05	0	90
R00220	S002	I003	60	68	104	2,88 E+03	6,06 E+03	3,00 E+05	0	105

Ion ID	Specy	Energy MeV	LET Mev/mg/cm²	Range µm
I004	40-Ar	150	14,1	42
I005	20-Ne	78	5,85	45
I003	84-Kr	316	34	43
I007	10-B	41	1,7	80

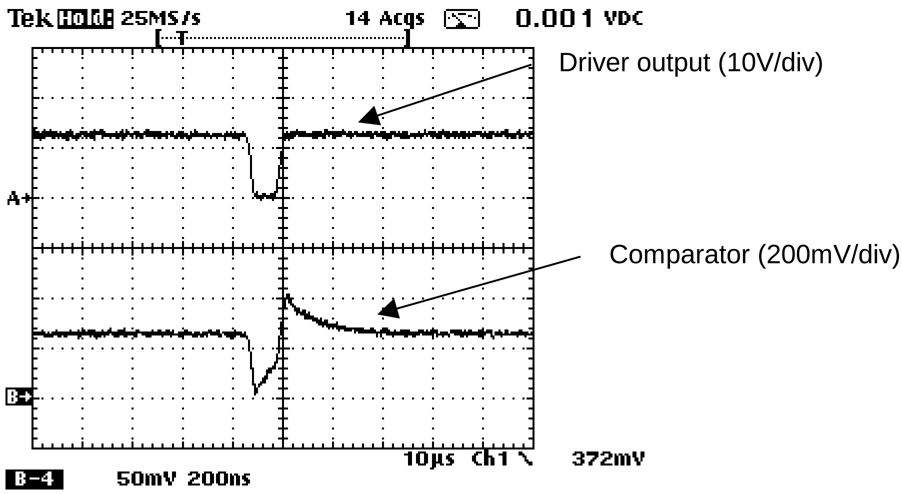
Sample ID	SN	Part Type	Date Code	Comments
S001	#061	UC1707	9145	Unitrode
S002	#062	Uc1707	9145	Unitrode

Note Condition 2 : Ref=6.19V, Line=6.06V



SEU on comparator induce a transient on driver output.
Please note the reaction of the latch transient on the comparator

Figure 10 – UC1707, Heavy ion test, LASCO design, Scope record



SEU on driver output.
Please note the reaction of the latch transient on the comparator

Figure 11 - UC1707, Heavy ion test, LASCO design, Scope record

VI.2 PROTONS RESULTS

Only BA ACU test configuration has been tested as it was the one found to be the more sensitive to heavy ion test.
The sensitivity to 300 MeV protons is quite low. Results are presented in Table 9 and Table 10 for two different operating conditions.

Table 9 – Proton test results on Unitrode UC1707, T001 test configuration, BA ACU Condition 1

Run ID No	Sample ID No	Proton ID No	Angle °	Eff. LET Mev/mg/cm²	Run Time sec	Flux P/cm²/sec	TID per Sample Rads (Si)	Fluence P/cm²	Comp.	Driver	Latched SEU
R00060	S033	P004	0	2,86 E-03	158	3,16 E+08	2,29 E+03	5,00 E+10	0	0	0
R00061	S032	P004	0	2,86 E-03	152	3,29 E+08	2,29 E+03	5,00 E+10	2	2	2
R00062	S032	P004	0	2,86 E-03	150	3,33 E+08	4,58 E+03	5,00 E+10	1	1	1
R00063	S033	P004	0	2,86 E-03	150	3,33 E+08	4,58 E+03	5,00 E+10	1	1	1

Proton ID	Energy MeV	LET Mev/mg/cm²	Range µm
P004	300,3	2,86 E-03	-

Sample ID	SN	Part Type	Date Code	Comments
S033	#65	UC1707	9145	Unitrode
S032	#64	UC1707	9145	Unitrode

Note :	Condition 1 : Ref=6.18V, Line=6.48V

Table 10 - Proton test results on Unitrode UC1707, T002 test configuration, BA ACU Condition 2

Run ID No	Sample ID No	Proton ID No	Angle °	Eff. LET Mev/mg/cm²	Run Time sec	Flux P/cm²/sec	TID per Sample Rads (Si)	Fluence P/cm²	Comp	Driver	Latched SEU
R00064	S033	P004	0	2,86 E-03	148	3,38 E+08	6,87 E+03	5,00 E+10	0	0	0
R00065	S033	P004	0	2,86 E-03	150	3,33 E+08	9,16 E+03	5,00 E+10	0	0	0
R00066	S032	P004	0	2,86 E-03	149	3,36 E+08	6,87 E+03	5,00 E+10	0	0	0
R00067	S032	P004	0	2,86 E-03	149	3,36 E+08	9,16 E+03	5,00 E+10	0	0	0

Proton ID	Energy MeV	LET Mev/mg/cm²	Range µm
P004	300,3	2,86 E-03	-

Sample ID	SN	Part Type	Date Code	Comments
S033	#65	UC1707	9145	Unitrode
S032	#64	UC1707	9145	Unitrode

Note :	Condition 2 : Ref=6.18V, Line=6.00V

VII. CONCLUSION

SEU test have been conducted on UC1707 Dual Channel Power Driver from Unitrode, using both the heavy ions available at the University of Louvain facility and the protons available at Paul Scherrer Institut facility.

Heavy ion SEU susceptibility was obtained through the error cross section versus LET curve for two different test configurations.

The effect of a capacitor filter applied in the BA ACU equivalent configuration has been assessed and drastic improvement has been obtained.

Proton SEU susceptibility was found quite low and only BA ACU equivalent configuration has been tested to 300 MeV protons.

With these results, upset predictions on XMM orbit, can be performed for each error type and the associated risk can be assessed.