HEAVY ION SINGLE EVENT EFFECTS RADIATION TEST REPORT

Part Type :

UC1823 PWM Controller

Manufacturer :

Unitrode

Programme :

Rosetta

Report Reference : ESA_QCA0203S_C

Issue : 01

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ESA Contract No 13528/99/NL/MV COO-11 dated 21/05/01

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

ESTEC Technical Officer: R. Harboe Sorensen

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Prepared by :	Hirex		Date :	May 27, 2004
Checked by :	F.X GUERRE	[signature]	Date :	May 27, 2004
Approved by :	J. F. MOUNES	[signature]	Date :	May 27, 2004

Heavy ion SEE characterization of Unitrode UC1823 PWM Controller for Rosetta programme

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1 Abstract

Under ESA Contract No 13528/99/NL/MV COO-11 dated 21/05/01 covering "Radiation Evaluation of COTS Semiconductor Components: "Radiation SEE Testing for ROSETTA ", four different linear device types were radiation assessed. Results from these assessments, primarily focusing on the sensitivity of these devices to Single Event Effects (SEE), are reported in four different reports. The below summary table lists for each report, manufacturer and evaluated types, along with some device features.

ESA Report Reference	Device	Function	Manufacturer	Case	Datecode
ESA_QCA0203S_C	UC1823	PWM Controller	Unitrode	16-Lead Cerdip	9640
ESA_QCA0204S_C	UC1844A	PWM Controller	Unitrode	8-Lead Cerdip	9917
ESA_QCA0205S_C	UC1901	Isolated Feed-back Generator	Unitrode	14-Lead Cerdip	9849A
ESA_QCA0206S_C	RH1011	Comparator	Linear Technology	8-Lead Cerdip	

2 INTRODUCTION

This report presents the results of a Single Event Effects (SEE) test program carried out on UC1823 PWM Controller from Unitrode.

The main objective of this evaluation was to evaluate the sensitivity of this device using a test configuration representative of actual Rosetta design.

Test was conducted on hi-rel samples delivered by ESA.

These devices were used for heavy ion test at the European Heavy Ion Irradiation Facility (HIF) at Cyclone, Université Catholique de Louvain, Belgium.

This work was performed for ESA/ESTEC under ESA Contract No 13528/99/NL/MV COO-11 dated 21/05/01.

3 REFERENCE DOCUMENTS

RD-1. Saab Ericsson Space Fax 22/10/01 ref. RO-SES-2170/01 "Rosetta, Test setup for UC1901 and UC1823".
RD-2. The Heavy Ion Irradiation Facility at CYCLONE, UCL document, Centre de Recherches du Cyclotron (IEEE NSREC'96, Workshop Record, Indian Wells, California, 1996).
RD-3. Single Event Effects Test method and Guidelines ESA/SCC basic specification No 25100.
RD-4. UC1823 Unitrode datasheet

4 DEVICE INFORMATION

Relevant device identification information is presented here after.

Part type:	UC1823
Manufacturer:	Unitrode
Package:	16-Lead Cerdip
Quality Level:	Hirel
Date Code:	9640
Die Technology:	Bipolar
Top Marking:	RA 0807 002 11 B Δ 201 U 6B 9640
Die Marking	UICC M 90
S/Ns	194, 195, 201

4.1 Samples preparation

Samples were mechanically opened by Hirex Engineering and photos of both the prepared sample and the die identification are presented in Figure 1.

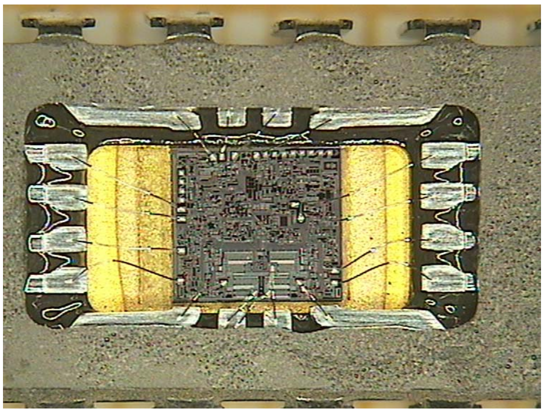


Photo # 1 :

Prepared Sample

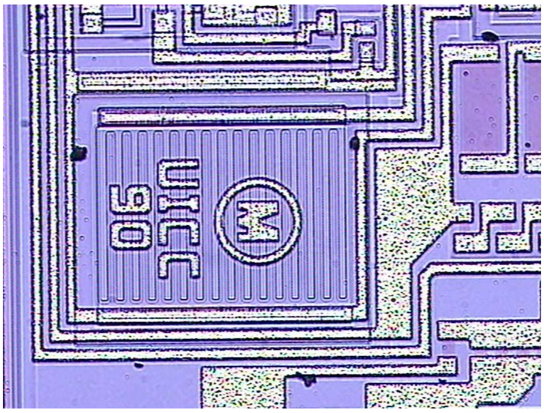


Photo # 2 :

Die Identification

Figure 1 - UC1823 Unitrode sample photos

5 Test Set-up

Hirex test equipment is composed of a modular rack coupled with a generic test board plus a specific device interface board which provides the desired test configuration :

- This modular rack is derived from Hirex BILT modular instrumentation system and presents 8 slots for modular instruments. In addition to the power supply modules which cover the SEE test needs for precision measurements, this rack allows for remote control, LU detection, data storage, via a communication link with a generic control board (IL220 : 25MIPS 16-bits micro-controller, 100kgates FPGA) installed inside the test chamber and close to the DUT.
- Inside the chamber and dedicated to the test of analog devices, a generic test board (IL240) can be coupled with the control board. The IL240 board can receive 4 device interface boards (DIBs) and assure :
  - The multiplex operation of the DIBs
  - The DUT power supply with latchup detection and process,
  - The monitoring of one DIB output analog signal with a triple window comparator (with three programmable detection thresholds)
  - The amplification of one DIB output signal for a remote scope observation with an adequate bandwidth.
- Each Device Interface Board (DIB) is specifically designed to provide a test configuration representative of the actual application (bias conditions, load, etc)

Figure 2 here below gives a synoptic of the test hardware used for this set-up as well as a photo of the boards.

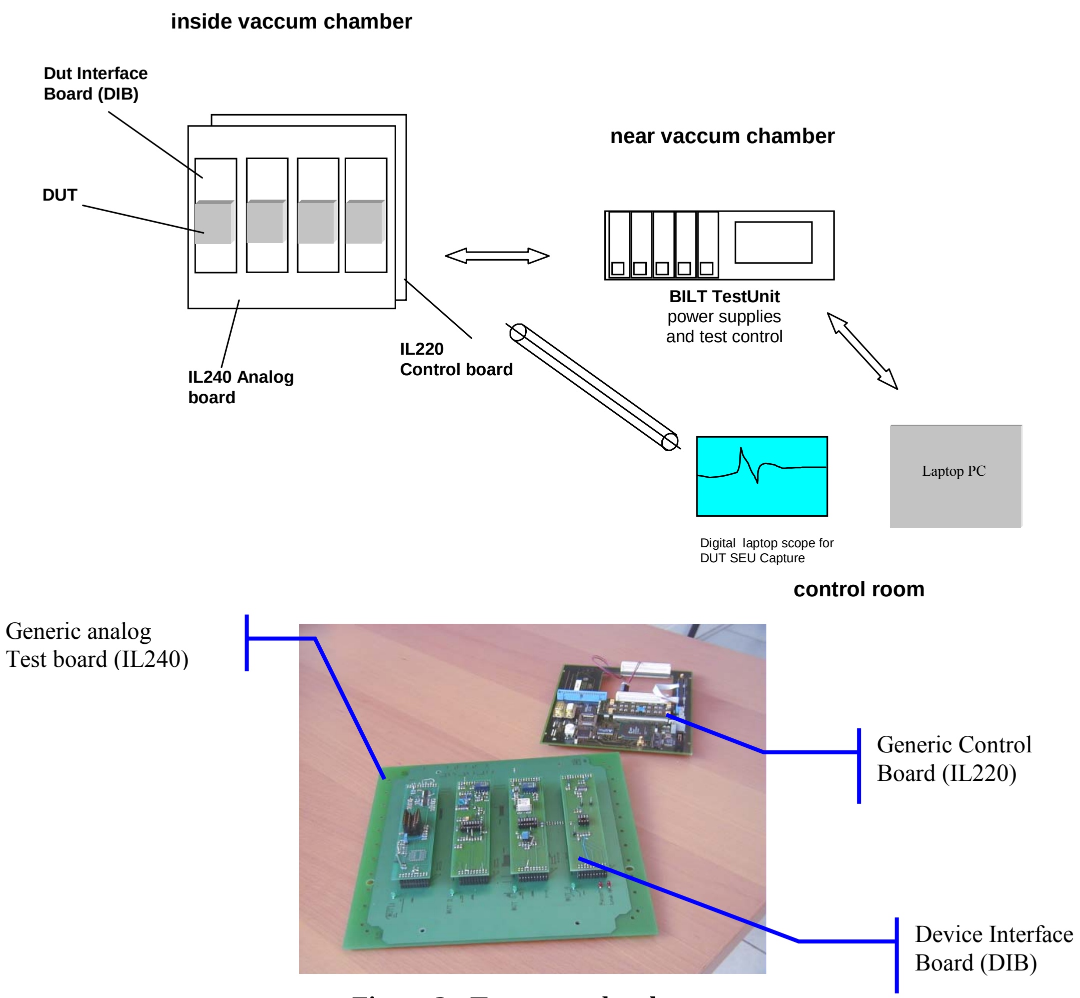
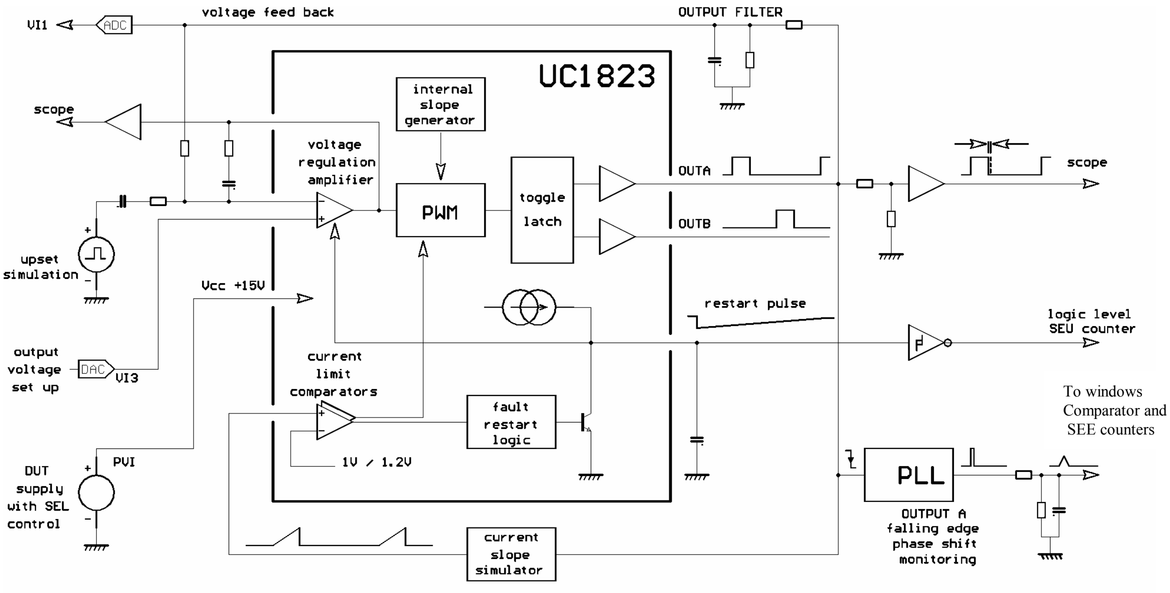


Figure 2 - Test set-up hardware

5.1 Tests Configuration

5.1.1 Test set up (IL241 test board) (see RD-1)

- Only one power output is used to generate a simple RC filtered mean voltage.
- The voltage regulation amplifier is operating with is nominal RC stabilization network.
- Duty cycle working point corresponds to the programmable output voltage setup point.
- Current slope simulator allows the current limit comparator inputs to go periodically closed to the internal threshold values.



5.1.2 Main upset monitoring

A Phase Looked Loop is tracking the falling edge of the Output A power transistor driver.
This allows for counting upsets due to:

- Internal oscillator period failure
- Toggle latch failure
- Voltage / duty cycle regulation failure
- Current limit control failure

A small low pass filter at the absolute phase comparator output allows :

- Normal jitter narrows pulses to be ignored (100ns max, 300mV after low pass filter)
- The use of a windows comparator which will deliver separate SEU count for small, medium and large amplitude by setting three different programmable detection analog thresholds.

5.1.3 Other monitoring features

- Logic level SEU counter at softstart output for over current comparator upsets
- Scope monitoring of the Output A signal
- Scope monitoring of the voltage regulation amplifier output
- DC measurement of output filter feedback voltage allows to verify the duty cycle working point.
- Upset simulation with AC coupled narrow pulses at voltage regulation amplifier inverting input.

5.1.4 Working point description

- 130 KHz switching frequency, corresponding to 3.5µs maximum ON time for each driver output.
- Using 2.2V set up at VI3 DAC output (non inverting amplifier input voltage) allows :
- 30% duty cycle at each power driver output (70% total duty cycle for both A & B drivers)
- 2.2V at VI1 ADC input: 15V * 30% * ½ resistor divider. (DC output voltage monitoring ±100mV)
- 0.9V saw tooth amplitude at current comparator input .
- 50µs recovery time for voltage regulation (RC stabilization network).
- 300µs delay time for restart after over current trig.

6 TEST FACILITIES

6.1 UCL

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

6.1.1 Beam Source

In collaboration with the European Space Agency (ESA), the needed equipment for single events studies using heavy ions was 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 producing 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.

6.1.2 Dosimetry

The current UCL Cyclotron dosimetry system and procedures were used.

6.2 Beam set-up

The UCL ions used are listed in the table below.

Ion Species	Energy	LET	Range in Si
	(MeV)	(MeV.cm²/mg)	µm
10-B	41	1.7	80
20-Ne	78	5.85	45
40-Ar	150	14.1	42
84-Kr	316	34	43
132-Xe	459	55.9	43

The LET range is obtained by changing the ion species and incident energy and changing the angle of incidence between the beam and the chip.

For each run, the following information is given in the detailed results tables provided in the next paragraph (paragraph 7):

- Ion type
- Ion energy
- LET
- Range
- Tilt angle
- Effective LET
- Averaged flux
- Fluence
- Equivalent dose received by the DUT sample

7 RESULTS

Detailed results per run are presented in paragraph 7.1 .

Different kind of upsets have been observed at the PLL output.

First type corresponds to a phase shift (this shift is permanent, the device will not get back to the initial phase).
This upset could very likely be originated in the internal ramp generator.
This phase shift is illustrated in
Figure 4 -a, (lower curve).
This phase shift very likely should have no impact on the operation of a switching power supply.

Second upset type, the occurrence of which is much lower, is shown in
Figure 4- b and consist in a transient at the output of the voltage amplifier. The enable signal from the soft start circuit being filtered by an external capacitor, this transient is originated inside the amplifier itself. However, such an event with this short duration, although a capacitor is present at the amplifier input, will not affect the operation of an actual application like a switching power supply.

Then, Soft start errors which are directly counted at the SS pin are also detected at the PLL output as shown in Figure 5.
Two types of PLL unlock events have been observed.

For the first one (see Figure 5- a), a phase error is present before the soft start. It means that the soft start event is the normal response of the DUT following an upset affecting the DUT output.
The second one (see Figure 5- b) does not present any phase error before the unlock event : very likely, the upset had occurred inside the soft start circuit itself.

The corresponding errors cross-sections are plotted in Figure 3 here below where the Out A SEU errors correspond to all the errors detected with the PLL at the DUT output A (including soft start errors). Soft-start SEUs have also been plotted as counted directly at SS pin.

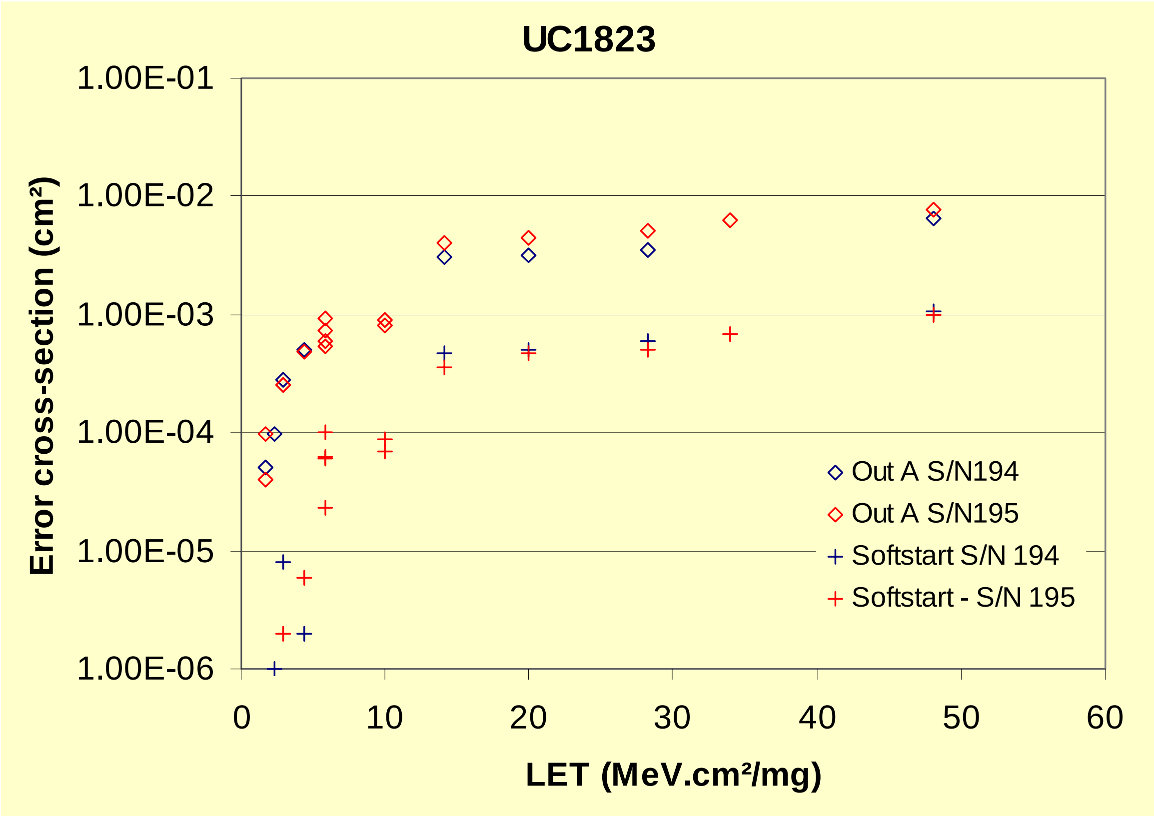


Figure 3 - UC1823 SEU device error cross-section versus LET

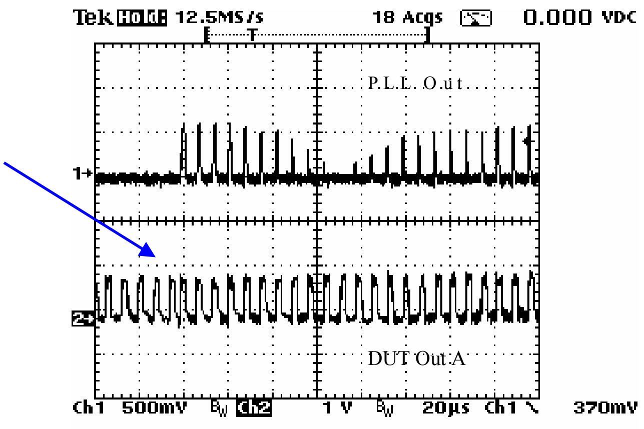


Figure 4 – a – Phase shift error

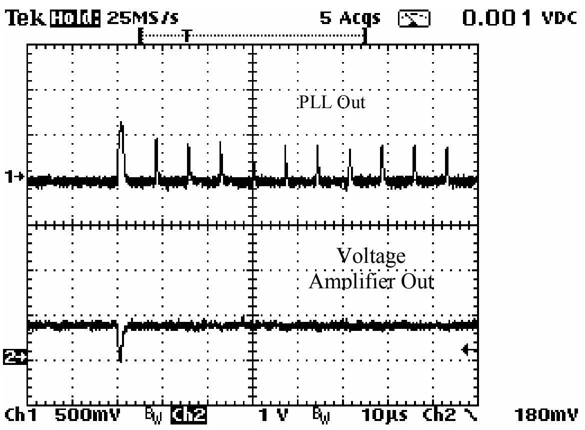


Figure 4 – b – Error at Amplifier output

Figure 4 - UC1823, PLL detection at Out A, SEU scope records

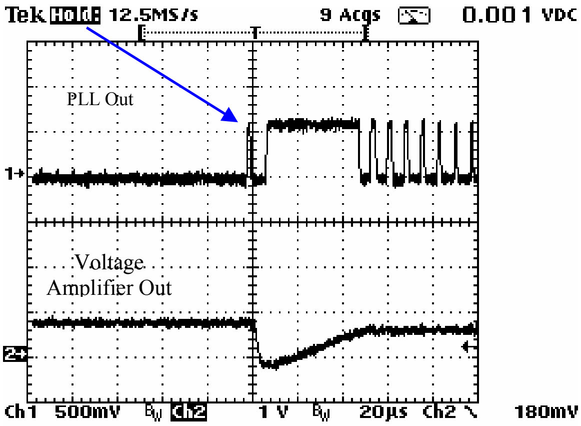


Figure 5 - a

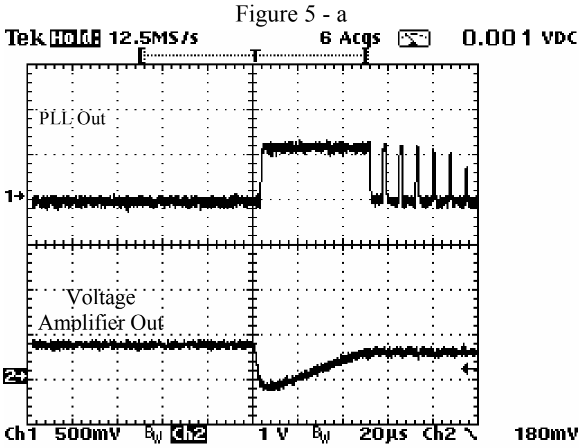


Figure 5 - b

Figure 5 - UC1823, PLL detection at Out A, SEU soft start errors, scope records

7.1 UCL Detailed Results

Run #	Sample	Ion	Energy	LET	Range	Angle	Eff_LET	Time	Flux	Run TID	Sample TID	Fluence	Out A SEU errors	x/s Medium	Soft start SEU errors	x/s Soft start
			MeV	MeV(mg/cm²)	µ	deg.	MeV(mg/cm²)	s	Ions/cm².s	Rads(Si)	Rads(Si)	Ions/cm²		cm²		cm²
R00086	194	10-B	41	1.7	80	0	1.7	108	9.26E+03	2.72E+01	4.65E+02	1.00E+06	50	5.00E-05	0	
R00085	194	10-B	41	1.7	80	43	2.32	265	3.77E+03	3.72E+01	4.38E+02	1.00E+06	97	9.70E-05	1	1.00E-06
R00048	194	15-N	62	2.97	64	0	2.97	102	9.80E+03	4.76E+01	3.63E+02	1.00E+06	281	2.81E-04	8	8.00E-06
R00047	194	15-N	62	2.97	64	47	4.35	81	6.23E+03	3.52E+01	3.16E+02	5.05E+05	251	4.97E-04	1	1.98E-06
R00006	194	40-Ar	150	14.1	42	0	14.1	298	7.85E+02	5.29E+01	1.40E+02	2.34E+05	718	3.07E-03	109	4.66E-04
R00007	194	40-Ar	150	14.1	42	45	19.9	367	5.50E+02	6.45E+01	2.04E+02	2.02E+05	652	3.23E-03	103	5.10E-04
R00008	194	40-Ar	150	14.1	42	60	28.2	486	3.48E+02	7.64E+01	2.81E+02	1.69E+05	589	3.49E-03	102	6.04E-04
R00091	194	84-Kr	316	34	43	45	48.1	201	4.98E+02	7.70E+01	5.42E+02	1.00E+05	646	6.46E-03	106	1.06E-03
R00078	195	10-B	41	1.7	80	0	1.7	190	5.26E+03	2.72E+01	5.23E+02	1.00E+06	97	9.70E-05	0	
R00079	195	10-B	41	1.7	80	0	1.7	132	7.58E+03	2.72E+01	5.50E+02	1.00E+06	40	4.00E-05	0	
R00042	195	15-N	62	2.97	64	0	2.97	125	8.00E+03	4.76E+01	2.82E+02	1.00E+06	250	2.50E-04	2	2.00E-06
R00041	195	15-N	62	2.97	64	47	4.35	96	5.29E+03	3.54E+01	2.35E+02	5.08E+05	245	4.82E-04	3	5.91E-06
R00054	195	20-Ne	78	5.85	45	0	5.85	38	7.84E+03	2.79E+01	3.10E+02	2.98E+05	162	5.44E-04	7	2.35E-05
R00060	195	20-Ne	78	5.85	45	0	5.85	52	6.12E+03	2.98E+01	4.39E+02	3.18E+05	190	5.97E-04	19	5.97E-05
R00068	195	20-Ne	78	5.85	45	0	5.85	85	3.53E+03	2.81E+01	4.67E+02	3.00E+05	283	9.43E-04	30	1.00E-04
R00069	195	20-Ne	78	5.85	45	0	5.85	54	5.65E+03	2.86E+01	4.95E+02	3.05E+05	224	7.34E-04	19	6.23E-05
R00055	195	20-Ne	78	5.85	45	54	9.95	91	3.31E+03	4.80E+01	3.58E+02	3.01E+05	245	8.14E-04	21	6.98E-05
R00059	195	20-Ne	78	5.85	45	54	9.95	120	2.64E+03	5.05E+01	4.09E+02	3.17E+05	285	8.99E-04	28	8.83E-05
R00027	195	40-Ar	150	14.1	42	0	14.1	94	2.13E+03	4.52E+01	4.52E+01	2.00E+05	794	3.97E-03	71	3.55E-04
R00028	195	40-Ar	150	14.1	42	45	19.9	150	1.33E+03	6.39E+01	1.09E+02	2.00E+05	885	4.43E-03	94	4.70E-04
R00029	195	40-Ar	150	14.1	42	60	28.2	213	9.39E+02	9.04E+01	1.99E+02	2.00E+05	1022	5.11E-03	101	5.05E-04
R00100	195	84-Kr	316	34	43	0	34	82	1.22E+03	5.45E+01	6.81E+02	1.00E+05	625	6.25E-03	69	6.90E-04
R00099	195	84-Kr	316	34	43	45	48.1	124	8.06E+02	7.70E+01	6.27E+02	1.00E+05	781	7.81E-03	98	9.80E-04

8 CONCLUSION

Heavy ion tests were conducted on hirel samples of Unitrode UC1823 PWM Controller used in Rosetta programme, using the heavy ions available at the European Heavy Ion Irradiation Facility (HIF) at Cyclone, Université Catholique de Louvain, Belgium.

Test configuration was closed as possible to the actual application and the different error signatures have been identified and analysed.

Results obtained allowed for plotting the Single Event Upset error cross-section over an LET range from 2 to 50 MeV(mg/cm²).