HEAVY ION SINGLE EVENT EFFECTS RADIATION TEST REPORT

Part Type :

UC1844A PWM Controller

Manufacturer :

Unitrode

Programme :

Rosetta

Report Reference : ESA_QCA0204S_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.
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Heavy ion SEE characterization of Unitrode UC1844A 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 UC1844A 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 hirel 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. ESA Fax 07/11/01 "ELTA Rosetta design for UC1844A SEE testing", (Encoder Flyback Converter, dwg No 8008-S41-01, ETEL SA).
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. UC1844A Unitrode datasheet

4 DEVICE INFORMATION

Relevant device identification information is presented here after.

Part type: UC1844A
Manufacturer: Unitrode
Package: 8-Lead Cerdip
Quality Level: Hirel
Date Code: 9917
Die Technology: Bipolar
Top Marking: UC1844A
8670407SPA
Δ U 2C 9917
Die Marking SWG 1844A U 87
S/Ns 031, 032, 033, 034

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.

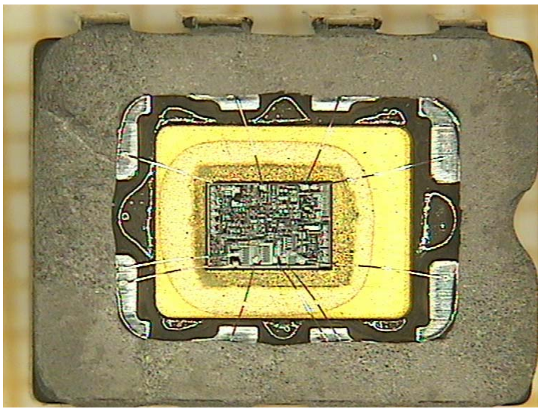


Photo # 1 :

Prepared Sample

Part Type : UC1844A

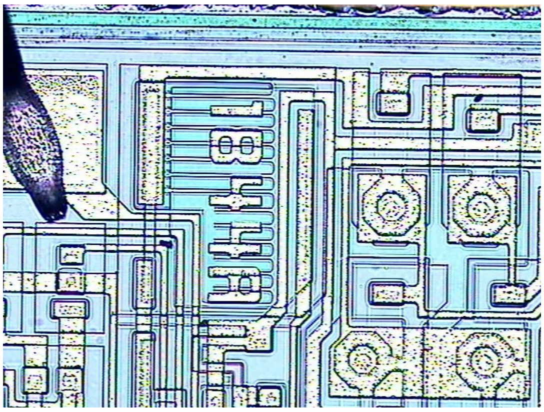


Photo # 2 :

Die Identification

Part Type : UC1844A

Figure 1 - UC1844A 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.

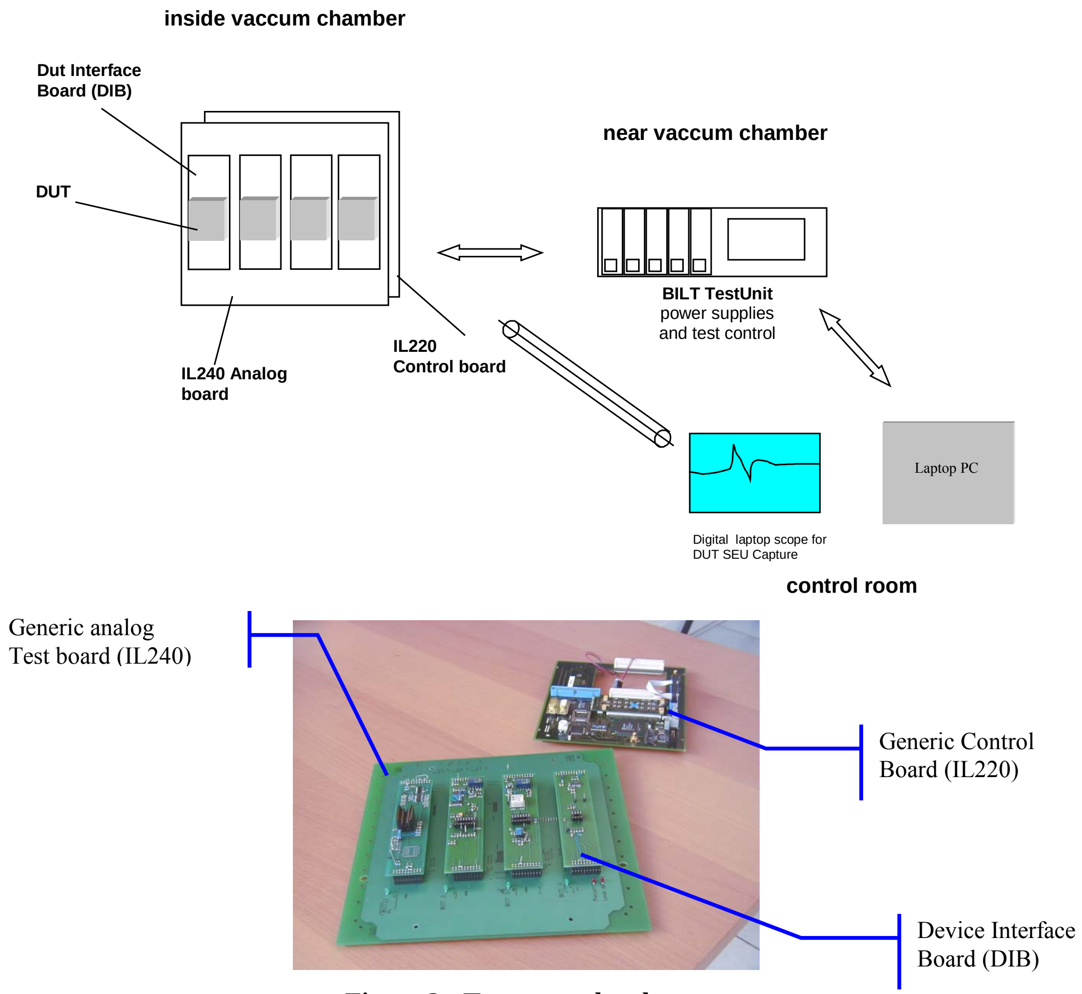
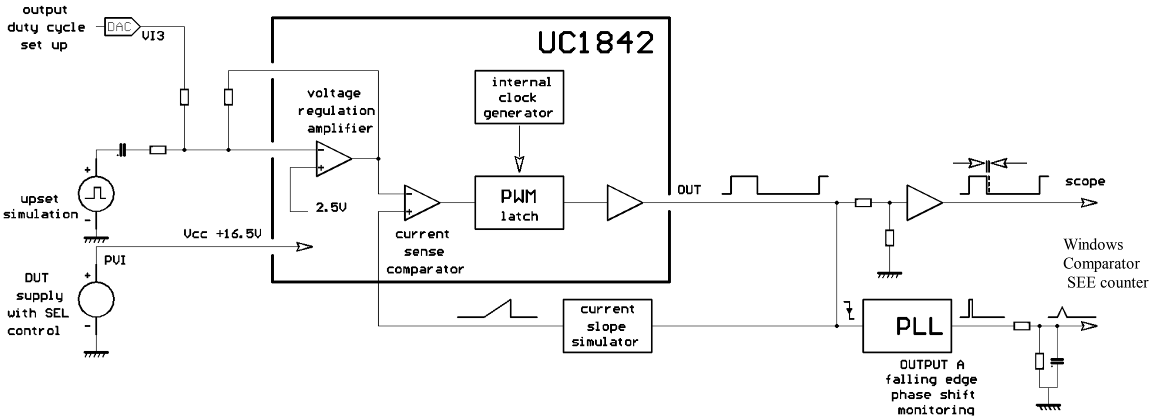


Figure 2 - Test set-up hardware

5.1 Tests Configuration

5.1.1 Test set up (IL116AM test board) (see RD-1)

- Only switched voltage monitoring, driver output is not used to generate a filtered mean voltage.
- The voltage regulation amplifier is operating with simple resistor feedback network.
- Current slope simulator deliver the same saw tooth signal than operating conditions.
- Duty cycle working point is programmable.
- Vcc voltage value is higher than 16V to accommodate internal under voltage lookout.



5.1.2 Main upset monitoring

A Phase Looked Loop is tracking the falling edge of the Output power transistor driver : Any disturbance in the signal phase, as a consequence of an upset, can be easily detected and upsets can then be counted. These phase disturbances could be the consequence of one of the following errors:

- Internal oscillator period error
- Latch error
- Voltage / duty cycle regulation error
- Current sense control error

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 analog detection thresholds.

5.1.3 Other monitoring features

- Scope monitoring of the Output signal
- Upset simulation with AC coupled narrow pulses at voltage regulation amplifier inverting input.

5.1.4 Working point description

- 140 KHz switching frequency, corresponding to ON time of 7µs maximum (100% period)
- The use of a 4.3V set up at VI3 DAC output (non inverting amplifier input voltage) allows :
  - 25% duty cycle at power driver output
  - 200mV saw tooth amplitude at current comparator input .
  - fast recovery time for voltage regulation (no RC stabilization network).

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

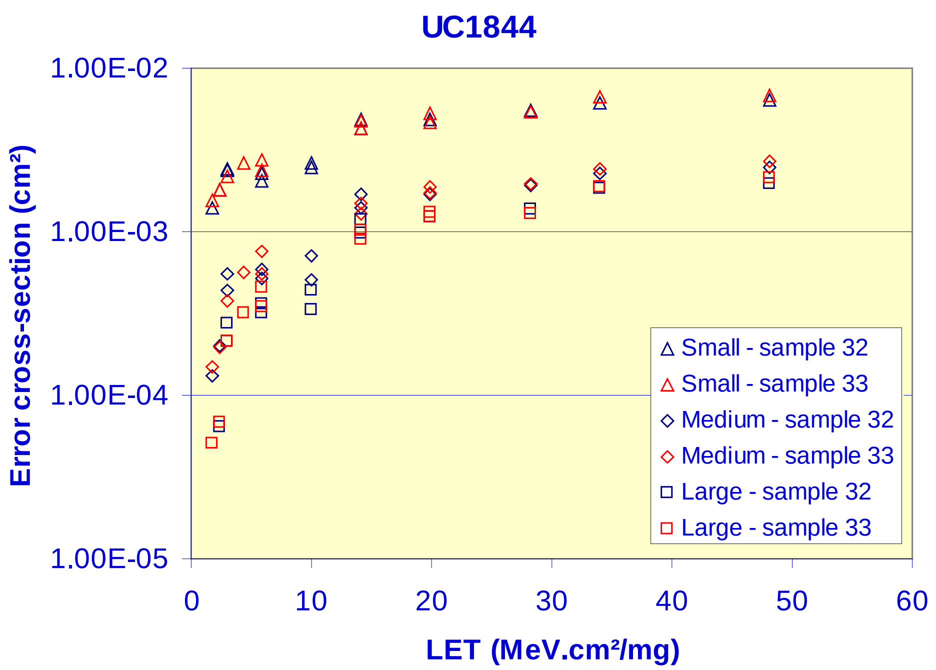
The LET range is obtained by changing the ion species and incident energy and changing the angle of incidence between the beam and the chip.

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 and the corresponding errors cross-sections are plotted in Figure 3 here below.



	Threshold (mV)
Small	80
Medium	400
Large	1000

Figure 3 - UC1844A SEU error cross-section versus LET

<u>Discussion :</u>

Two different types of upsets have been observed at the DUT output :

The first one 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. In this Figure, it can be seen that the upset is detected thanks to the use of the external PLL (see upper curve) and the corresponding phase shift at the DUT output is shown in the lower curve of the same figure..

Figure 4 –b shows a similar error than the one in Figure 4 –a , but with a lower time base value (50 µs). The complete response of the PLL can then be observed : several microseconds are needed for the PLL to be locked again on the new phase value.
Anyway, this phase shift very likely should have no impact on the operation of a switching power supply.

The second type of upset (see Figure 4 -c) consists in an increase of the width of one output pulse (at high level). Only an upset occurring in the voltage amplifier can induce this effect. Indeed, an upset in the limit current comparator would induce a reset of the flip-flop and then a decrease of the pulse width.
In the present test configuration, the impact is only an error in the pulse width. In an actual application configuration, the power supply output is always connected to a capacitor and then this upset type could induce a more important effect which might be visible on the supply output voltage.
However the very short duration of the upset indicates that the energy involved is quite small and then the output disturbance as well.

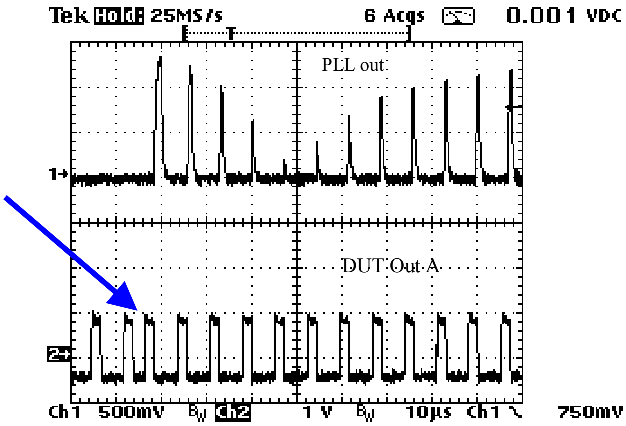


Figure 4- a

Event : Phase shift

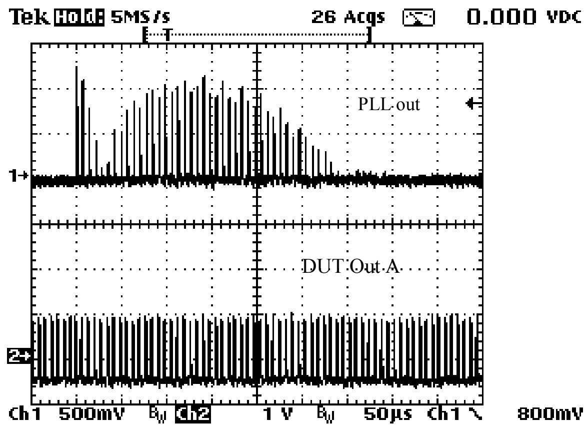


Figure 4 - b

PLL unlock due to a phase shift event as illustrated in Figure 4 - a, followed by the re-lock period

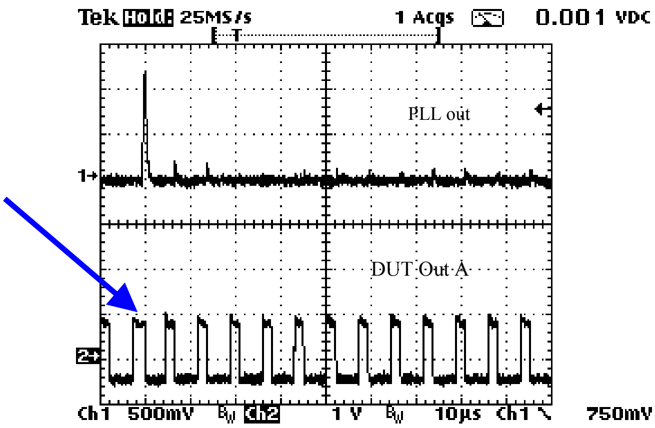


Figure 4- c

Event : Increase of the high level period signal width

Horizontal axis : Time base is 10µs for a) and c), 50µs for b).
Channel 1 (upper curve) corresponds to the signal observed at the output of the external PLL (refer to § 5.1.1) used to detect phase related events at the DUT output, Channel 2 (lower curve) corresponds to the DUT output A.
Figure 4 a) and b) show an upset which induces a permanent phase shift at the DUT output
Figure 4 c) shows an upset which induces an increase of one pulse period at the DUT output

Figure 4 - UC1844A, SEU scope records

7.1 UCL Detailed Results

Run #	Sample	Ion	Energy	LET	Range	Angle	Eff_LET	Time	Flux	Run TID	Sample TID	Fluence	Small errors	x/s Small	Medium errors	x/s Medium	Large errors	x/s Large
			MeV	MeV(mg/cm²)	µ	deg.	MeV(mg/cm²)	s	Ions/cm².s	Rads(Si)	Rads(Si)	Ions/cm²		cm²		cm²		cm²
R00082	32	10-B	41	1.7	80	0	1.7	109	9.17E+03	2.72E+01	7.04E+02	1.00E+06	1396	1.40E-03	133	1.33E-04	0	
R00083	32	10-B	41	1.7	80	43	2.32	155	6.45E+03	3.72E+01	7.42E+02	1.00E+06	1798	1.80E-03	201	2.01E-04	64	6.40E-05
R00045	32	15-N	62	2.97	64	0	2.97	82	6.16E+03	2.40E+01	4.21E+02	5.05E+05	1239	2.45E-03	277	5.49E-04	140	2.77E-04
R00046	32	15-N	62	2.97	64	0	2.97	111	9.01E+03	4.76E+01	4.68E+02	1.00E+06	2354	2.35E-03	436	4.36E-04	214	2.14E-04
R00052	32	20-Ne	78	5.85	45	0	5.85	51	5.94E+03	2.84E+01	4.97E+02	3.03E+05	627	2.07E-03	157	5.18E-04	97	3.20E-04
R00056	32	20-Ne	78	5.85	45	0	5.85	147	5.69E+03	7.85E+01	5.81E+02	8.37E+05	1916	2.29E-03	491	5.87E-04	305	3.64E-04
R00057	32	20-Ne	78	5.85	45	54	9.95	150	3.33E+03	7.97E+01	6.61E+02	5.00E+05	1250	2.50E-03	355	7.10E-04	220	4.40E-04
R00058	32	20-Ne	78	5.85	45	54	9.95	234	4.32E+02	1.61E+01	6.77E+02	1.01E+05	265	2.62E-03	51	5.05E-04	34	3.37E-04
R00003	32	40-Ar	150	14.1	42	45	19.9	194	4.64E+02	2.88E+01	3.36E+02	9.00E+04	439	4.88E-03	153	1.70E-03	112	1.24E-03
R00004	32	40-Ar	150	14.1	42	60	28.2	418	3.23E+02	6.10E+01	3.97E+02	1.35E+05	747	5.53E-03	258	1.91E-03	186	1.38E-03
R00089	32	84-Kr	316	34	43	0	34	258	7.75E+02	1.09E+02	8.51E+02	2.00E+05	1232	6.16E-03	452	2.26E-03	366	1.83E-03
R00090	32	84-Kr	316	34	43	45	48.1	182	5.49E+02	7.70E+01	9.28E+02	1.00E+05	643	6.43E-03	246	2.46E-03	198	1.98E-03
R00076	33	10-B	41	1.7	80	0	1.7	137	7.30E+03	2.72E+01	5.49E+02	1.00E+06	1545	1.55E-03	149	1.49E-04	51	5.10E-05
R00077	33	10-B	41	1.7	80	43	2.32	199	5.03E+03	3.72E+01	5.86E+02	1.00E+06	1791	1.79E-03	198	1.98E-04	68	6.80E-05
R00040	33	15-N	62	2.97	64	0	2.97	70	7.43E+03	2.47E+01	2.60E+02	5.20E+05	1147	2.21E-03	197	3.79E-04	111	2.13E-04
R00039	33	15-N	62	2.97	64	47	4.35	105	4.85E+03	3.55E+01	2.35E+02	5.09E+05	1358	2.67E-03	290	5.70E-04	161	3.16E-04
R00066	33	20-Ne	78	5.85	45	0	5.85	88	5.72E+03	4.71E+01	3.35E+02	5.03E+05	1186	2.36E-03	277	5.51E-04	174	3.46E-04
R00067	33	20-Ne	78	5.85	45	0	5.85	91	3.32E+03	2.83E+01	3.64E+02	3.02E+05	830	2.75E-03	228	7.55E-04	138	4.57E-04
R00024	33	40-Ar	150	14.1	42	0	14.1	225	8.89E+02	4.52E+01	4.52E+01	2.00E+05	954	4.77E-03	299	1.50E-03	206	1.03E-03
R00074	33	40-Ar	150	14.1	42	0	14.1	501	5.49E+02	6.21E+01	4.26E+02	2.75E+05	1173	4.27E-03	351	1.28E-03	250	9.09E-04
R00025	33	40-Ar	150	14.1	42	45	19.9	260	7.69E+02	6.39E+01	1.09E+02	2.00E+05	1058	5.29E-03	380	1.90E-03	266	1.33E-03
R00075	33	40-Ar	150	14.1	42	45	19.9	1116	2.69E+02	9.58E+01	5.22E+02	3.00E+05	1417	4.72E-03	523	1.74E-03	371	1.24E-03
R00026	33	40-Ar	150	14.1	42	60	28.2	305	6.56E+02	9.04E+01	1.99E+02	2.00E+05	1089	5.45E-03	392	1.96E-03	256	1.28E-03
R00097	33	84-Kr	316	34	43	0	34	145	6.90E+02	5.45E+01	6.41E+02	1.00E+05	670	6.70E-03	242	2.42E-03	189	1.89E-03
R00098	33	84-Kr	316	34	43	45	48.1	134	7.46E+02	7.70E+01	7.18E+02	1.00E+05	690	6.90E-03	269	2.69E-03	213	2.13E-03

8 CONCLUSION

Heavy ion tests were conducted on hirel samples of Unitrode UC1844A 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).