HEAVY ION SINGLE EVENT EFFECTS RADIATION TEST REPORT

Part Types : AT17LV010

EEPROM – 1M-bit Serial Memory

Manufacturers : ATMEL

Report Reference : ESA_QCA0208S_C

Issue : 02

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ESTEC Technical Officer: R. Harboe Sorensen

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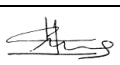
Prepared by :	J.G. LOQUET		Date :	January 23, 2003
Checked by :	F.X GUERRE		Date :	January 23, 2003
Approved by :	J. F. MOUNES		Date :	January 23, 2003

Heavy ion SEE characterization of AT17LV10 1M-bit serial EEPROM from ATMEL

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1 Abstract

Under ESA Contract No 13528/99/NL/MV COO-14 covering "Radiation Evaluation of COTS Semiconductor Components: SEE Radiation Evaluation of PROMs & SDRAMs", two different types EEPROM memories from ATMEL, were radiation Single Event Effects (SEE) assessed. Results from these assessments covering the AT28C0110E can be found in ESA_QCA0209S_C whereas here, in ESA_QCA0208S_C, the AT17LV010 will be covered.

2 INTRODUCTION

This report presents the results of a Single Event Effects (SEE) test program carried out on the AT17LV010, a 1M-bit FPGA Configurable EEPROM from ATMEL.
Test was conducted on samples delivered by ATMEL.
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-14.

3 REFERENCE DOCUMENTS

RD-1. AT17LV010 datasheet
RD-2. Single Event Effects Test method and Guidelines ESA/SCC basic specification No 25100
RD-3. The Heavy Ion Irradiation Facility at CYCLONE, UCL document, Centre de Recherches du Cyclotron (IEEE NSREC'96, Workshop Record, Indian Wells, California, 1996)

4 DEVICE INFORMATION

Relevant detailed device identification information is presented here after.

4.1 AT17LV010

Part type:	AT17LV010
Manufacturer:	ATMEL
Package:	8-pin PDIP
Quality Level:	Commercial
Die Size:	4.3 mm x 2.4 mm approximately
Die marking	ATMEL 2000 M AT35501
Serial number	SN1, SN2 (attributed by Hirex)

The AT17LV010 is a EE Programmable 1 048 576 x 1-bit Serial Memory Designed to Store Configuration Programs for Field Programmable Gate Arrays (FPGAs), 3.3V (-10%) Version.
Die identification is provided in Figure 1..

4.2 Samples preparation

AT17LV010 parts feature a plastic package, which had to be chemically opened (see Figure 1).

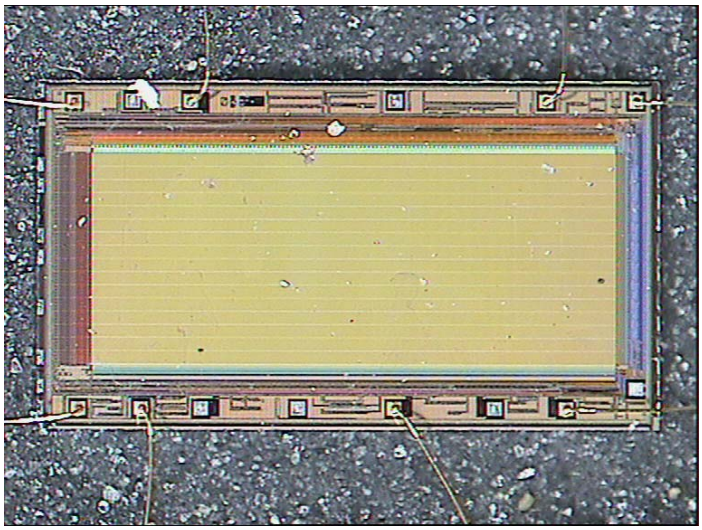

Photo 1

Die, full view

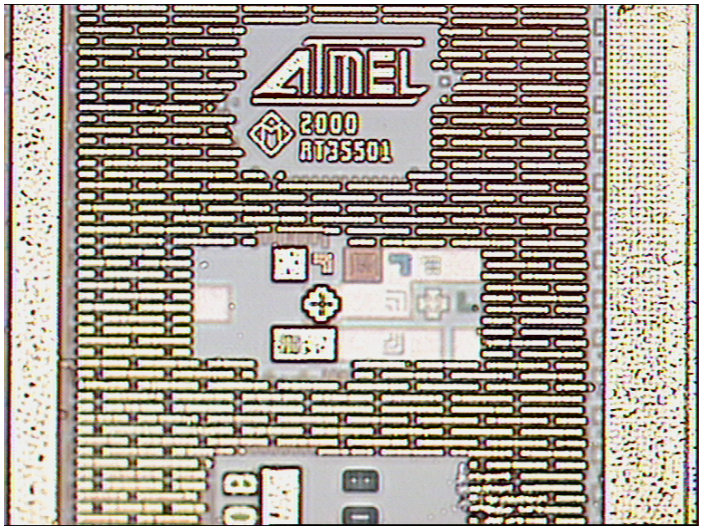

Photo 2

Die marking

Figure 1 - AT17LV010 die identification

5 Test Definition

5.1 Test Set-up

Hirex test equipment is composed of a modular rack coupled with a generic memory test board:

This modular rack is derived from Hirex BILT modular instrumentation system and presents 8 slots for modular instruments.
In addition to the existing power supply modules which cover the SEE test needs for precision measurements, remote control, LU detection, data storage, scope observation, etc, a specific modular board has been designed to provide:

- A high speed communication link with the test board under vacuum (up to 500 ko/s)
- Management of DUT positioning (mover)
- Particle and test time counting

Dedicated to the test of memories, the generic test board is based on a 12 MIPs on-board processor which controls the test sequence and the communication with the rack.
The board includes programmable logic circuits with a total capacity of 30000 cells and 960 macrocells. This logic circuitry can work at high speed (up to 100 MHz) while being compatible with thermal requirements imposed by vacuum environment.
Today, the board has a capacity of 80 pin-drivers, using transceivers able to interface memory devices with voltage supply requirements between 1 and 7 volts. The DUT can have two different power supplies.

5.2 Tests Configuration

Supply Voltage : 3V3 as specified in the AT17LV010 datasheets.

Test Temperature : room temperature

Two different sets of test conditions were used:

Static ON :

- Prior to exposure, write the entire memory with a given pattern (moving test pattern)
- Exposure
- After exposure, read the memory

Continuous Read :

- Prior to exposure, write the entire memory with a given pattern (moving pattern)
- During exposure, read continuously the memory

The table here below provides, for each group of 4 bits, the 14 words repetitive pattern.

	It k	It k+1	It k+2	It k+3	It k+4	It k+5	It k+6	It k+7	It k+8	It k+9	It k+10	It k+11	It k+12	It k+13	It k+14
address n	0000	1111	0101	0101	0110	1010	1001	0000	1111	1010	0101	0110	1010	1001	0000
address n+1	1010	1001	0000	1111	1010	0101	0110	1010	1001	0000	1111	0101	0101	0110	1010
address n+2	0101	0110	1010	1001	0000	1111	0101	0101	0110	1010	1001	0000	1111	1010	0101
address n+3	1111	0101	0101	0110	1010	1001	0000	1111	1010	0101	0110	1010	1001	0000	1111
address n+4	1001	0000	1111	1010	0101	0110	1010	1001	0000	1111	0101	0101	0110	1010	1001
address n+5	0110	1010	1001	0000	1111	0101	0101	0110	1010	1001	0000	1111	1010	0101	0110
address n+6	0101	0101	0110	1010	1001	0000	1111	1010	0101	0110	1010	1001	0000	1111	0101
address n+7	0000	1111	1010	0101	0110	1010	1001	0000	1111	0101	0101	0110	1010	1001	0000
address n+8	1010	1001	0000	1111	0101	0101	0110	1010	1001	0000	1111	1010	0101	0110	1010
address n+9	0101	0110	1010	1001	0000	1111	1010	0101	0110	1010	1001	0000	1111	0101	0101
address n+10	1111	1010	0101	0110	1010	1001	0000	1111	0101	0101	0110	1010	1001	0000	1111
address n+11	1001	0000	1111	0101	0101	0110	1010	1001	0000	1111	1010	0101	0110	1010	1001
address n+12	0110	1010	1001	0000	1111	1010	0101	0110	1010	1001	0000	1111	0101	0101	0110
address n+13	1010	0101	0110	1010	1001	0000	1111	0101	0101	0110	1010	1001	0000	1111	1010
address n+14	0000	1111	0101	0101	0110	1010	1001	0000	1111	1010	0101	0110	1010	1001	0000

Table 1 – Test pattern

5.3 Errors reporting

For each memory read cycle, the total number of words in error (one bit flip minimum) is recorded.

In addition the following information is recorded for each word in error with an upper limit of 6500 errors.

- Cycle iteration number
- Word address
- Awaited word pattern
- Word data in error

DUT power supply module is monitored and each time the current consumption exceeds a programmable threshold, a power reset cycle is done and latch-up error counter is incremented.
In addition the use of fast latch-up detection with a high speed comparator avoids the counting of SEU errors which could be induced by the latch-up condition.

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 different ions used are listed in the tables below.

The LET range is obtained by changing the ion species, 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 species
- Ion energy
- LET
- Range in Si
- Tilt angle
- Effective LET
- Averaged flux
- Fluence
- Equivalent dose received by the DUT sample

6.3 UCL Ion sources

The ions used at the HIF facility:

Ion Specie	Energy	LET	Range
	(MeV)	(MeV.cm²/mg)	µm
15-N	62	2.97	64
20-Ne	78	5.85	45
40-Ar	150	14.1	42
84-Kr	316	34	43

Table 2 – HIF ions

Tilting the DUT up to 60º, will result in effective LET values in-between the listed values.

7 RESULTS

The main findings are first summarised, then an analysis of the results per run is provided in Table 3.

7.1 Main findings AT17LV010

Errors were observed from an LET of 4.35 MeV/(mg/cm²) and on.

At a LET of 4.35MeV(mg/cm²), s/n 1 ‘Continuous Read’ tested, experienced a functional error affecting part of the memory, during a given read cycle but fully recovered at the following read cycle.

From an LET of 5.85 MeV/(mg/cm²) and above, most tests resulted in permanent functional errors (>10000 words) for both test configurations, ‘Static ON’ or ‘Continuous Read’. Each time, a power off of the DUT upon completion of the run, allows for the recovery of the sample functionality and the recovery of the data integrity (read with no error).

7.2 Detailed Results and Analysis per Run

Run #	S/N	Test	Ion	Energy (MeV)	LET MeV/(mg/cm²)	Range (µm)	Angle (deg.)	Eff_LET MeV/(mg/cm²)	Time (s)	Flux (ions/cm².s)	Sample eqv. cumulated dose (rad(Si))	Fluence (ions/cm²)	Comment
R25	1	Static ON	15-N	62	2.97	64	0	2.97	93	10800	1020	1.00E+06	No error
R26	1	Continuous Read	15-N	62	2.97	64	0	2.97	89	11200	1060	1.00E+06	No error
R27	1	Static ON	15-N	62	2.97	64	47	4.35	180	5560	1130	1.00E+06	No error
R28	1	Continuous Read	15-N	62	2.97	64	47	4.35	171	5850	1200	1.00E+06	At read cycle iteration 14, part of the memory in error, next iteration (it.15), no error anymore
R21	1	Static ON	20-Ne	78	5.85	45	0	5.85	441	2270	874	1.00E+06	Post exposure, functional error, all data to FF After DUT power-off, no error anymore
R22	1	Continuous Read	20-Ne	78	5.85	45	0	5.85	365	2740	968	1.00E+06	No error
R01	1	Continuous Read	40-Ar	150	14.1	42	0	14.1	38	8124	68	3.00E+05	Functional error (> 10000 words) during read op, at read cycle iteration no 6, offset in the pattern. Persistent error at the end of the run. After DUT power-off, no more error
R02	1	Continuous Read	40-Ar	150	14.1	42	0	14.1	13	9558	97	1.21E+05	Again, functional error at read cycle iteration no 2. All data read to 0, permanently (after test stop). After DUT power-off, no error anymore
R03	1	Continuous Read	40-Ar	150	14.1	42	0	14.1	179	963	136	1.72E+05	Flux has been lowered. Again functional error (>10000 words), offset in the pattern. Not all the memory is affected.
R06	1	Static ON	40-Ar	150	14.1	42	0	14.1	179	5590	333	1.00E+06	After exposure, functional error, all data to FF, second read idem. After DUT power-off, no error anymore
R43	1	Static ON	84-Kr	316	34	43	0	34	122	8200	1750	1.00E+06	At the very beginning of the run, a functional error at the 1st read under beam Then static on condition, no error
R29	2	Static ON	15-N	62	2.97	64	47	4.35	155	6450	990	1.00E+06	No error
R30	2	Continuous Read	15-N	62	2.97	64	47	4.35	157	6370	1060	1.00E+06	No error
R23	2	Static ON	20-Ne	78	5.85	45	0	5.85	327	3060	898	1.00E+06	No error
R24	2	Continuous Read	20-Ne	78	5.85	45	0	5.85	71	3370	920	2.39E+05	At read cycle iteration no 19, functional error, offset in the pattern permanent offset error. After DUT power-off, no error anymore
R04	2	Continuous Read	40-Ar	150	14.1	42	0	14.1	459	983	102	4.51E+05	Functional error, same behaviour
R44	2	Static ON	84-Kr	316	34	43	0	34	122	8200	1600	1.00E+06	No error
R45	2	Continuous Read	84-Kr	316	34	43	0	34	10	9580	1660	9.58E+04	Functional error at the first read cycle iteration, Pattern offset

Table 3 - AT17LV010 SEE detailed results per run

8 CONCLUSION

Heavy ion tests were conducted on samples of AT17LV010 1M-bit serial EEPROM memories from ATMEL, using the heavy ions available at the European Heavy Ion Irradiation Facility (HIF) at Cyclone, Université Catholique de Louvain, Belgium.

Two test configurations were used ‘Static ON’ and ‘Continuous Read’ running the EEPROM at 3.3 Volt. Errors were observed from a LET of 5.85 MeV/(mg/cm²).

In particular, permanent functional errors, which could affect the entire memory, have been observed for both test configurations from a LET of 5.85 MeV/(mg/cm²). However, at each time, a Power-off/on allows for recovering the data integrity.