SINGLE EVENT EFFECTS RADIATION TEST REPORT

Part Type : K6R4008C1D

4 Mb SRAM

Manufacturer : SAMSUNG

Report Reference : ESA_QCA0218S_C

Issue : 01

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Heavy ion SEE characterization of K6R4008C1D SRAM

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1 Abstract

Under ESA Contract No 13528/99/NL/MV COO-13 dated 11/10/02 covering "Radiation Evaluation of COTS Semiconductor Components: “Radiation evaluation of parts for new VME design", K6R4008C1D SRAM memories were radiation assessed.

Results from these assessments, primarily focusing on the sensitivity of these devices to Single Event Effects (SEE), are reported in this report.

2 INTRODUCTION

This report presents the results of a Single Event Effects (SEE) test program carried out on K6R4008C1D SRAMs, from SAMSUNG.

Test was conducted on commercial 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-13 dated 11/10/02.

3 REFERENCE DOCUMENTS

RD1. K6R4008C1D 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)

4 DEVICE INFORMATION

4.1 K6R4008C1D

Relevant device identification information is presented here after.

Part type:	K6R4008C1D	
Manufacturer:	SAMSUNG	
Package:	36-SOJ	
Quality Level:	Commercial	
Date Code:	019	
Top Marking:	SAMSUNG	019
	K6R4008C1C-JC12	
	T2A017R3	KOREA
Die marking	SAMSUNG ELECTRONICS C 2001	
	K6R4016C1D	
Serial number	SN1, SN2 (attributed by Hirex)	

Die identification is provided in Figure 1.

512K x 8 Bit High-Speed CMOS Static RAM, Single 5.0V±10% Power Supply, Center Power/Ground Pin Configuration

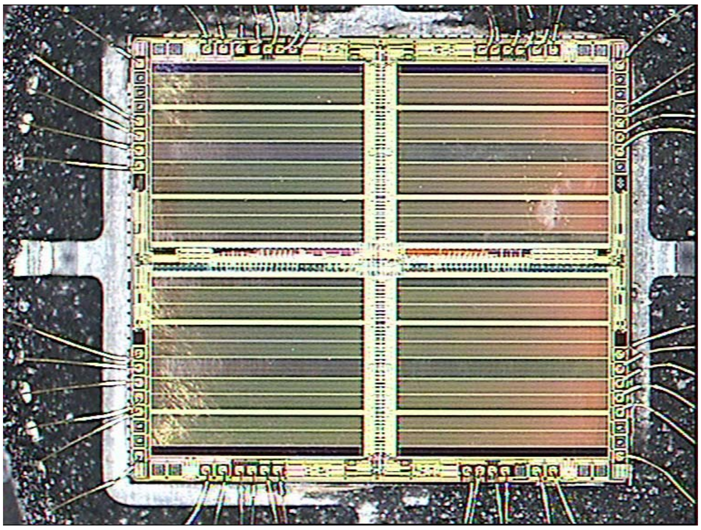

Photo 1

Die, full view

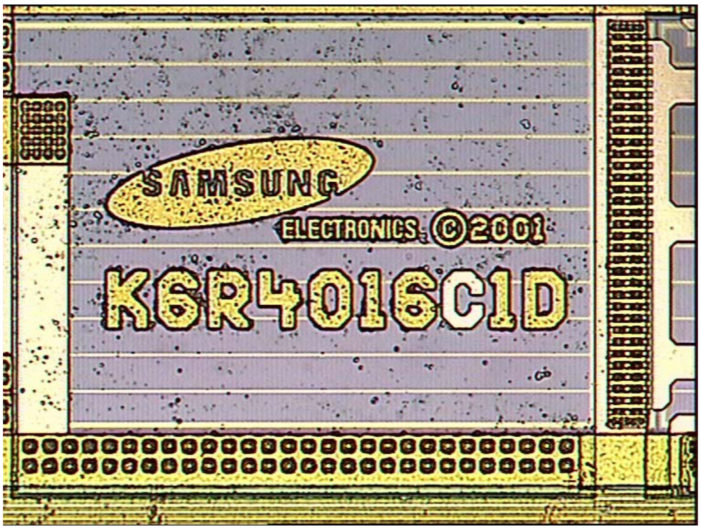

Photo 2

Die marking

Figure 1 - K6R4008C1D 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 iTest 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)
- 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 Test Configuration

Two basic configurations were used:

STATIC TEST MODE:
1. Device initialization
2. Write the test pattern in the memory and perform a read to check eventual stuck bits
3. Expose the device to the beam for a given time (typically 45s)
4. Read the memory and count the errors. Write the memory. At each sequence, an offset is done on the test pattern and the number of errors is cumulated.
5. Loop with step 2, etc

DYNAMIC TEST MODE:
1. Device initialization
2. Write the test pattern in the memory and make a read to detect eventual stuck bits
3. Expose the device to the beam for a given time and perform continuous read-write operations. At each sequence, an offset is done on the test pattern and the number of errors is cumulated.
4. Loop with step 2, etc

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

Errors which can be detected and counted are the following:

- Any single error in the memory block with identification of the transition (1->0 or 0->1)
- Any word with at least one bit flip with the identification of the word address

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 errors which could be induced by the latch-up condition.

DUT power supply is 5V.

6 TEST FACILITIES

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

6.1 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.

6.2 Beam Set-up

6.2.1 <u>Ion Beam Selection</u>

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 table in paragraph 7.

6.2.2 <u>Flux Range</u>

For each run, the averaged flux value is provided in the detailed results table of paragraph 7.

6.2.3 <u>Particle Fluence Levels</u>

Maximum fluence level was set to 1 E6 ions/cm²

6.2.4 <u>Dosimetry</u>

The current UCL Cyclotron dosimetry system and procedures were used.

6.2.5 <u>Accumulated Total Dose</u>

For each run, the equivalent cumulated dose received by the DUT sample is computed.

6.2.6 <u>Test Temperature</u>

Tests have been performed at 22 deg. C.

6.3 Available ions

The most commonly used ions at the UCL HIF facility are listed along with some of their features in the table here below:

Ion Specie	Energy	LET	Range
	(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

Table 2 – HIF ions

The use of a tilt angle allows intermediate effective LETs.

7 RESULTS

The detailed results per run for each device are presented in Table 3.

The device turns out to be very sensitive to SEL. Indeed, SEL were observed from a LET of 2.40 MeV/(mg/cm²).

Therefore, very few runs could be performed on this device type.

A quite high amount of SEUs were detected with an LET of 1.70 MeV/(mg/cm²). An example of the repartition of errors is presented on Figure 2. No disproportion between the numbers of up and down transitions was observed.

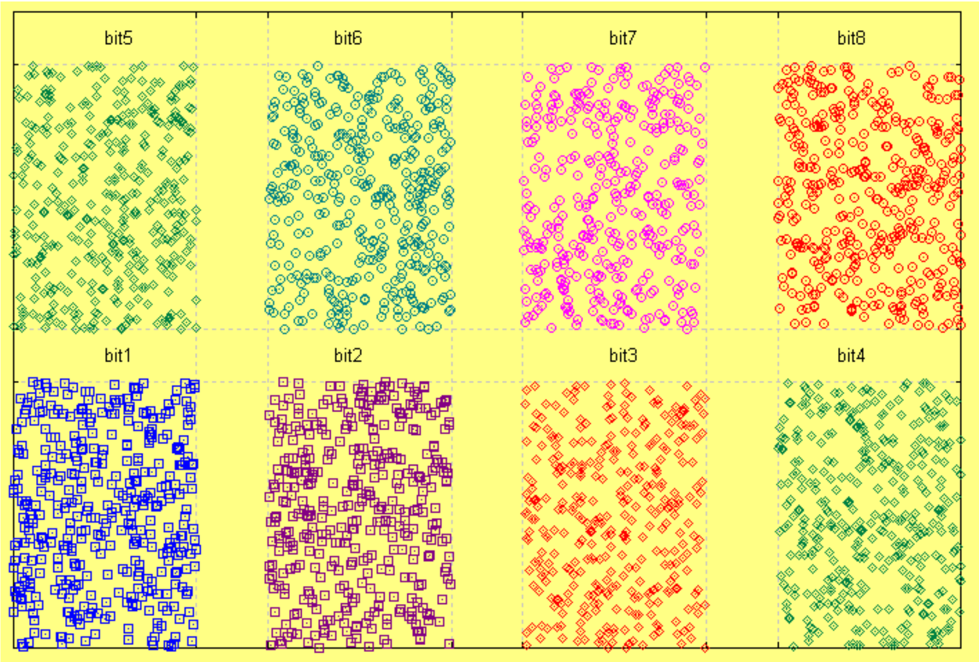

Figure 2 - Distributions of errors in (row, column) coordinates for each bit. In that case (run 104) all errors (each represented by a single symbol) are randomly distributed.

Run #	Test mode (*)	S/N	Ion	LET (MeV.cm²/mg)	Angle (°)	Eff LET (MeV.cm²/mg)	Time (s)	Fluence (/cm²)	Flux (/cm²/s)	SEU (words)	Bits up (0 to 1)	Bits down (1 to 0)	Total bits (up + down)	SEL	SEU cross-section (/cm²)	Comment
1	S	1	Ar	14.10	0	14.10										Too many SELs
3	D	1	Ar	14.10	0	14.10										Too many SELss
70	S	1	Ne	5.85	0	5.85										SELs as soon as under beam
71	S	2	Ne	5.85	0	5.85										Same
103	S	1	B	1.70	0	1.70	140	1.00E+06	7143	3075	-	-	-	0	3.08E-03	Log error file not recorded
104	S	1	B	1.70	0	1.70	140	1.00E+06	7143	2981	1471	1511	2982	0	2.98E-03	
105	S	1	B	1.70	60	3.40										SELs as soon as started
106	S	1	B	1.70	45	2.40	205	1.00E+06	4878	4287	2110	2178	4288	3	4.29E-03	

(*) S stands for STATIC TEST MODE; D for DYNAMIC TEST MODE

Table 3 - Heavy ion detailed results per run

8 CONCLUSION

Heavy ion tests were conducted on commercial samples of K6R4008C1D memories from SAMSUNG, using the heavy ions available at the European Heavy Ion Irradiation Facility (HIF) at Cyclone, Université Catholique de Louvain, Belgium.

This device type was found to be very sensitive to SEL with a latch-up LET threshold between 1.7 and 2.4 MeV/(mg/cm²).