SINGLE EVENT EFFECTS
RADIATION TEST REPORT

Part Type : K6R4008C1C

Package : 36-SOJ

512Kx8 Bit High Speed Static RAM(5V Operating)

Manufacturer : Samsung

Report Reference : ESA_QCA0102S_C

Issue : 01

Date : January 19th, 2001

ESA Contract no. 13528/99/NL/MV CCN N°3 dated 24/11/00

European Space Agency Contract Report

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

Hirex reference :	HRX/SEE/0028	Issue : 01	Date :	January 19th, 2001
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SINGLE EVENT EFFECTS RADIATION TEST REPORT on 512Kx8 Bit High Speed Static RAM(5V Operating) , K6R4008C1C, from Samsung

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1 Abstract

Under ESA Contract no. 13528/99/NL/MV CCN N°3 dated 24/11/00, covering "Radiation Evaluation of COTS semiconductor Components", four different commercially available 4Mb Static RAM device types were radiation assessed. Results from these assessments, primarily focussing on the sensitivity of these devices to Total Ionizing Dose (TID) and Single Event Effects (SEE), are reported in individual TID and SEE reports. The below summary table lists manufacturer and evaluated types, and gives references to the various reports issued.

Manufacturer	Type	TID Report	SEE Report
Hitachi	HM6216255H	ESA_QCA0104T_C	ESA_QCA0104S_C
Samsung	KM684002AJ	-	ESA_QCA0101S_C
Samsung	K6R4008C1C	ESA_QCA0102T_C	ESA_QCA0102S_C
Samsung	K6R4008V1C	ESA_QCA0103T_C	ESA_QCA0103S_C

2 INTRODUCTION

This report presents the results of a Single Event Effects (SEE) test program carried out on 512Kx8 Bit High Speed Static RAM(5V Operating) K6R4008C1C from Samsung.

Test was conducted on commercial samples procured from Samsung and provided to HIREX by ESA.

For heavy ion test, these 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 low energy OPTIS area of Paul Scherrer Institute in Villingen, Switzerland.

This work was performed for ESA/ESTEC under ESA Contract no. 13528/99/NL/MV CCN N°3 dated 24/11/00.

3 REFERENCE DOCUMENTS

RD1. Samsung 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)
RD4. Radiation Effects Testing Facility in PSI Low Energy OPTIS Area, IEEE 1998, Radiation Effects Data Workshop, p. 152

4 DEVICE INFORMATION

Relevant device identification information is presented here after.

Part type :	K6R4008C1C
Manufacturer :	Samsung
Package :	36-SOJ
Quality Level :	Commercial
Date Code :	-
Die Technology :	CMOS
Top Marking:	SAMSUNG 019 K6R4008C1C-JC12 T2A017R3 KOREA
Die Size :	7 mm x 4.8 mm approximately
Die Marking :	Logo KM616 4002C ©1998

External and Internal Photos are shown in Figure 1.

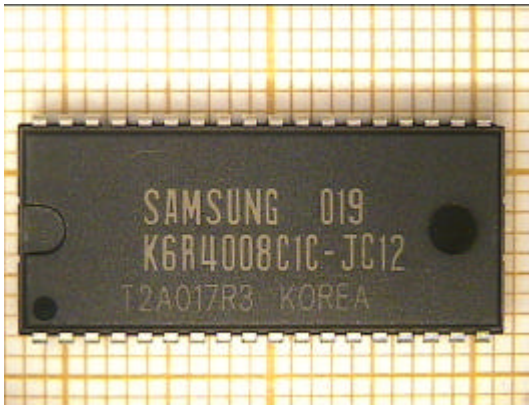

Photo # 1 :

External Visual Inspection

Part Type : K6R4008C1C

S/N -

Magnification : 3.3

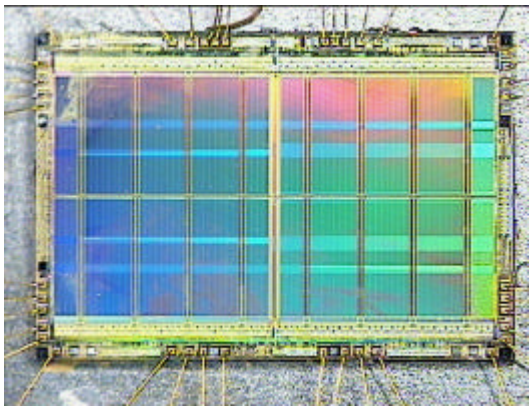

Photo # 2 :

Part Type : K6R4008C1C

S/N 2

Magnification : 11.3

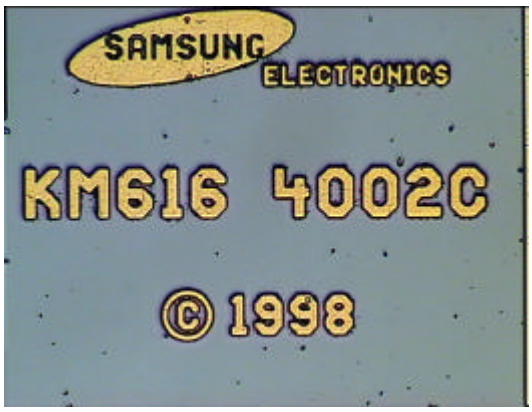

Photo # 3 :

Part Type : K6R4008C1C

S/N 2

Magnification : 432.3

Figure 1 – K6R4008C1C External and Internal Photos

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 present 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 include programmable logic circuits with a total capacity of 30000cells 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 50 pin-drivers (this number can be extended if needed), using transceivers able to interface memory devices with voltage supply requirements between 1 and 7 volts. The DUT can have two different power supplies.
A mechanism called mover allows positioning the DUT under or outside the beam within less than 100ms. During translations, particles count and test time is automatically stopped. This solution has been selected mainly for proton tests where the DUT can be translated behind a lead shielding for instance.

5.2 Test Configuration

Two main different test conditions can been used:

Cond 1: Dynamic conditions, which consist in the following test sequence:
Write the entire memory
Then read/write the memory sequentially by page of 128 words
Under dynamic conditions the device is continuously exposed to the beam

Cond 2: Static conditions, which consist in the following cycle, repeated continuously:
Write the entire memory with the device not exposed to the beam
Expose the memory for a given time period
Read the memory outside the beam

An additional condition, cond 3, can also be used, called "full static", which consist in the here above static conditions but with only one cycle. The beam exposure time corresponds then to the run duration.

Advantage of cond 2 over cond 3 is that the occurrence of temporary or permanent stuck bits can be easily detected.

Test principle is based on the use of a rotating pattern, which allows checking that at each cycle every word has been effectively rewritten with new data.

The table here below provides the repetitive pattern of 14 different words in a 8 bits organisation.

D7	D6	D5	D4	D3	D2	D1	D0
0	0	0	0	0	0	0	0
1	0	1	0	1	0	1	0
0	1	0	1	0	1	0	1
1	1	1	1	1	1	1	1
0	1	0	0	1	0	0	1
1	0	1	1	0	1	1	0
0	1	0	1	0	1	0	1
0	0	0	0	0	0	0	0
1	0	1	0	1	0	1	0
0	1	0	1	0	1	0	1
1	1	1	1	1	1	1	1
0	1	0	0	1	0	0	1
1	0	1	1	0	1	1	0
1	0	1	0	1	0	1	0

At each cycle, the here above table is shifted by three positions :

	address 0	address 1	address 2	address 3	etc.
cycle 1 :	0101…	1010…	0000…	1111…	…
cycle 2 :	0000…	1111…	0110…	1100…	…

Only the 4 first bits of each 8-bit word are represented here above

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 a fast latch-up detection with a high speed comparator avoid the counting of errors which could be induced by the latch-up condition.

DUT power supply is 5V.

6 TEST FACILITIES

6.1 Heavy Ions

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 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.

6.1.2 Beam Set-up

6.1.2.1 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 table provided in paragraph 7.1.

6.1.2.2 Flux Range

For each run, the averaged flux value is provided in the detailed results table of paragraph 7.1.

6.1.2.3 Particle Fluence Levels

Maximum fluence level was set to 1 E6 ions/cm²

6.1.2.4 Dosimetry

The current UCL Cyclotron dosimetry system and procedures were used.

6.1.2.5 Accumulated Total Dose

For each run, the computed equivalent cumulated doses received by the DUT sample, are provided in the detailed results table of paragraph 7.1.

6.1.2.6 Test Temperature

Tests have been performed at 22 deg. C.

6.2 Protons

6.2.1 Beam Source

The description of the beam source is given in RD4.
Irradiation is carried out in air.

6.2.2 Beam Set-up

6.2.2.1 Proton Beam Selection

The following monoenergetic proton beams have been selected

Energy (MeV)	LET(Si) (MeV/mg/cm²)
60.9	8.5 E-3
40.6	1.17 E-2
33.3	1.36 E-2
23.3	1.8 E-2
17.6	2.25 E-2
12.4	2.95 E-2
7.3	4.43 E-2

For each run, information is provided on the beam characteristics in the detailed results tables provided in paragraph 7.2.

6.2.2.2 Flux Range

Particle flux was set between 1 to 2 E8 protons/cm²/sec under normal operations (tilt 0°).

6.2.2.3 Particle Fluence Levels

Fluence level was set to 1 E10 protons/cm².

6.2.2.4 Dosimetry

The current OPTIS dosimetry system and procedures were used.

6.2.2.5 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 7.2.

6.2.2.6 Test Temperature

Tests have been performed at 22 deg. C.

7 RESULTS

7.1 Heavy Ions

The detailed results per run are presented in Table 2.
First occurrences of stuck bits can be observed with Argon. Errors generated by these stuck bits have been retrieved in each run memory file and Table 2 has been updated accordingly.
Runs 19, 20 and 93 have been truncated to take into account the limited size of the corresponding run memory file which contains for each error, the word address, the error mask within the word and the iteration number.
Only single events upset (SEU) errors have been detected.
Lastly no SEL was detected for the complete set of runs.
The two test conditions dynamic and static give the same SEU error cross-section as it can be seen in Figure 2 and Table 1.

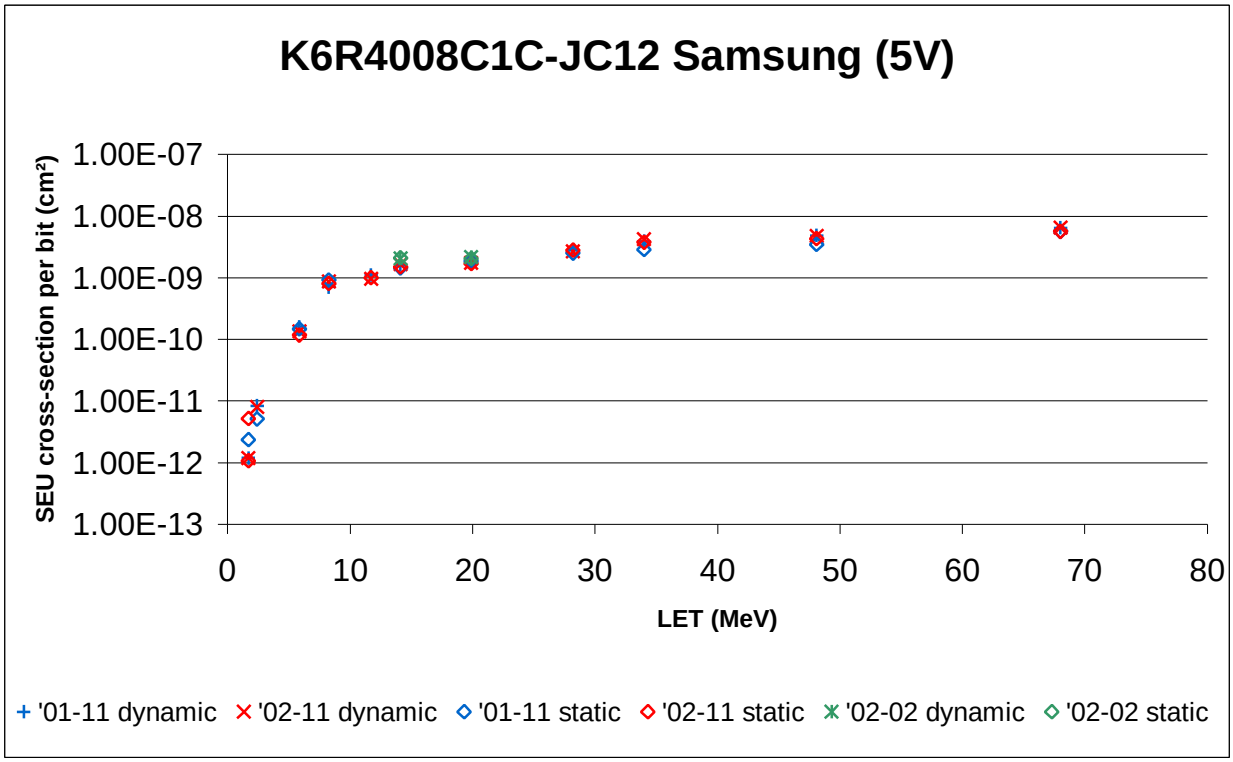

Figure 2 – K6R4008C1C heavy ion SEU error cross-section per bit versus LET

Run #	Sample	Eff_Fluence (p/cm²)	SEUs	Eff_ MeV/(mg/cm²)	sigma SEUs (per bit) (cm²)
Dynamic					
R00018	02-02	3.08E+05	2639	14.1	2.04E-09
R00021	02-02	5.05E+05	4616	19.9	2.18E-09
R00053	01-11	1.00E+06	5	1.7	1.19E-12
R00056	01-11	9.94E+05	35	2.4	8.40E-12
R00028	01-11	5.00E+05	336	5.85	1.60E-10
R00031	01-11	3.00E+05	889	8.27	7.07E-10
R00032	01-11	3.00E+05	1406	11.7	1.12E-09
R00083	01-11	3.00E+05	2037	14.1	1.62E-09
R00086	01-11	3.00E+05	2276	19.9	1.81E-09
R00087	01-11	3.00E+05	3501	28.2	2.78E-09
R00089	01-11	3.00E+05	4930	34	3.92E-09
R00092	01-11	2.00E+05	4047	48.1	4.82E-09
R00093_trunc.	01-11	1.75E+05	4751	68	6.46E-09
R00052	02-11	1.00E+06	5	1.7	1.19E-12
R00049	02-11	9.87E+05	33	2.4	7.97E-12
R00023	02-11	5.00E+05	280	5.85	1.34E-10
R00027	02-11	3.00E+05	1090	8.27	8.66E-10
R00024	02-11	3.00E+05	1215	11.7	9.66E-10
R00078	02-11	3.00E+05	2068	14.1	1.64E-09
R00079	02-11	3.00E+05	2204	19.9	1.75E-09
R00082	02-11	3.00E+05	3351	28.2	2.66E-09
R00096	02-11	2.00E+05	3521	34	4.20E-09
R00097	02-11	2.00E+05	4024	48.1	4.80E-09
R00100_trunc.	02-11	1.51E+05	4127	68	6.52E-09
Static					
R00019_trunc.	02-02	7.33E+05	6443	14.1	2.10E-09
R00020_trunc.	02-02	7.33E+05	6326	19.9	2.06E-09
R00054	01-11	8.07E+05	8	1.7	2.36E-12
R00055	01-11	8.83E+05	19	2.4	5.13E-12
R00029	01-11	4.43E+05	273	5.85	1.47E-10
R00030	01-11	2.31E+05	892	8.27	9.21E-10
R00084	01-11	2.65E+05	1615	14.1	1.45E-09
R00085	01-11	2.47E+05	1923	19.9	1.86E-09
R00088	01-11	2.52E+05	2661	28.2	2.52E-09
R00090	01-11	2.00E+05	2413	34	2.88E-09
R00091	01-11	1.94E+05	2830	48.1	3.48E-09
R00094	01-11	1.80E+05	4293	68	5.70E-09
R00050	02-11	7.85E+05	17	1.7	5.16E-12
R00051	02-11	8.96E+05	4	1.7	1.06E-12
R00022	02-11	2.38E+05	118	5.85	1.18E-10
R00026	02-11	2.32E+05	787	8.27	8.10E-10
R00025	02-11	2.37E+05	990	11.7	9.94E-10
R00077	02-11	2.75E+05	1730	14.1	1.50E-09
R00080	02-11	2.44E+05	1727	19.9	1.69E-09
R00081	02-11	2.38E+05	2787	28.2	2.79E-09
R00095	02-11	1.79E+05	2848	34	3.78E-09
R00098	02-11	1.82E+05	3287	48.1	4.31E-09
R00099	02-11	1.78E+05	4211	68	5.65E-09

Table 1 – K6R4008C1C heavy ion SEU error cross-section per bit

Run #	Test	Sample	Ion	Energy (MeV)	LET MeV/(mg.cm²)	Range (µm)	Angle (deg.)	Eff_LET MeV/(mg.cm²)	Time (s)	Eff_Time (s)	Flux (p/cm².s)	Run TID (rads (Si)	Sample TID (rads (Si)	Fluence (p/cm²)	Eff_Fluence (p/cm²)	Sel	Up (0 to 1)	Down (1 to 0)	Words	Stuck bits	SEUs
R00018	Dynamic	#02-02	40-Ar	150	14.1	42	0	14.1	53	52	5920	70.9	70.9	3.14E+05	3.08E+05	0	1316	1329	2645	2	2639
R00019 trunc.	Static	#02-02	40-Ar	150	14.1	42	0	14.1	186	136.3	5380	226	297	1.00E+06	7.33E+05	0	3232	3225	6453	3	6443
R00020 trunc	Static	#02-02	40-Ar	150	14.1	42	45	19.9	306	224.2	3270	319	616	1.00E+06	7.33E+05	0	3211	3163	6374	11	6326
R00021	Dynamic	#02-02	40-Ar	150	14.1	42	45	19.9	125	125	4040	161	778	5.05E+05	5.05E+05	0	2581	2389	4970	18	4616
R00022	Static	#02-11	20-Ne	78	5.85	45	0	5.85	78	62	3850	28.1	28.1	3.00E+05	2.38E+05	0	64	54	118	0	118
R00023	Dynamic	#02-11	20-Ne	78	5.85	45	0	5.85	146	146	3420	46.9	75	5.00E+05	5.00E+05	0	144	136	280	0	280
R00024	Dynamic	#02-11	20-Ne	78	5.85	45	60	11.7	155	155	1940	56.2	131	3.00E+05	3.00E+05	0	622	596	1218	1	1215
R00025	Static	#02-11	20-Ne	78	5.85	45	60	11.7	163	129	1840	56.2	187	3.00E+05	2.37E+05	0	509	481	990	0	990
R00026	Static	#02-11	20-Ne	78	5.85	45	45	8.27	114	88	2630	39.8	227	3.00E+05	2.32E+05	0	375	412	787	0	787
R00027	Dynamic	#02-11	20-Ne	78	5.85	45	45	8.27	115	115	2610	39.8	267	3.00E+05	3.00E+05	0	522	568	1090	0	1090
R00028	Dynamic	#01-11	20-Ne	78	5.85	45	0	5.85	136	136	3680	46.9	46.9	5.00E+05	5.00E+05	0	155	181	336	0	336
R00029	Static	#01-11	20-Ne	78	5.85	45	0	5.85	122	108	4100	46.9	93.7	5.00E+05	4.43E+05	0	133	140	273	0	273
R00030	Static	#01-11	20-Ne	78	5.85	45	45	8.27	113	87	2650	39.8	133	3.00E+05	2.31E+05	0	415	477	892	0	892
R00031	Dynamic	#01-11	20-Ne	78	5.85	45	45	8.27	117	117	2560	39.8	173	3.00E+05	3.00E+05	0	548	583	1131	1	889
R00032	Dynamic	#01-11	20-Ne	78	5.85	45	60	11.7	171	171	1750	56.2	229	3.00E+05	3.00E+05	0	707	699	1406	0	1406
R00049	Dynamic	#02-11	10-B	41	1.7	80	45	2.4	155	153	6450	38.5	306	1.00E+06	9.87E+05	0	18	15	33	0	33
R00050	Static	#02-11	10-B	41	1.7	80	0	1.7	163	128	6130	27.2	333	1.00E+06	7.85E+05	0	6	11	17	0	17
R00051	Static	#02-11	10-B	41	1.7	80	0	1.7	106	95	9430	27.2	360	1.00E+06	8.96E+05	0	1	3	4	0	4
R00052	Dynamic	#02-11	10-B	41	1.7	80	0	1.7	126	126	7940	27.2	387	1.00E+06	1.00E+06	0	5	0	5	0	5
R00053	Dynamic	#01-11	10-B	41	1.7	80	0	1.7	109	109	9170	27.2	257	1.00E+06	1.00E+06	0	2	3	5	0	5
R00054	Static	#01-11	10-B	41	1.7	80	0	1.7	119	96	8400	27.2	284	1.00E+06	8.07E+05	0	2	6	8	0	8
R00055	Static	#01-11	10-B	41	1.7	80	45	2.4	154	136	6490	38.5	322	1.00E+06	8.83E+05	0	13	6	19	0	19
R00056	Dynamic	#01-11	10-B	41	1.7	80	45	2.4	158	157	6330	38.5	361	1.00E+06	9.94E+05	0	16	19	35	0	35
R00077	Static	#02-11	40-Ar	150	14.1	42	0	14.1	96	88	3130	67.8	455	3.00E+05	2.75E+05	0	847	886	1733	1	1730
R00078	Dynamic	#02-11	40-Ar	150	14.1	42	0	14.1	46	46	6520	67.8	523	3.00E+05	3.00E+05	0	1031	1057	2088	2	2068
R00079	Dynamic	#02-11	40-Ar	150	14.1	42	45	19.9	63	63	4760	95.8	619	3.00E+05	3.00E+05	0	1168	1136	2304	7	2204
R00080	Static	#02-11	40-Ar	150	14.1	42	45	19.9	75	61	4000	95.8	714	3.00E+05	2.44E+05	0	857	877	1734	2	1727
R00081	Static	#02-11	40-Ar	150	14.1	42	60	28.2	131	104	2290	136	850	3.00E+05	2.38E+05	0	1426	1393	2819	6	2787
R00082	Dynamic	#02-11	40-Ar	150	14.1	42	60	28.2	113	113	2650	136	986	3.00E+05	3.00E+05	0	1810	1854	3663	19	3351

Run #	Test	Sample	Ion	Energy (MeV)	LET MeV/(mg.cm²)	Range (µm)	Angle (deg.)	Eff_LET MeV/(mg.cm²)	Time (s)	Eff_Time (s)	Flux (p/cm².s)	Run TID (rads (Si)	Sample TID (rads (Si)	Fluence (p/cm²)	Eff_Fluence (p/cm²)	Sel	Up (0 to 1)	Down (1 to 0)	Words	Stuck bits	SEUs
R00083	Dynamic	#01-11	40-Ar	150	14.1	42	0	14.1	46	46	6520	67.8	429	3.00E+05	3.00E+05	0	1291	1138	2429	22	2037
R00084	Static	#01-11	40-Ar	150	14.1	42	0	14.1	43	38	6980	67.8	497	3.00E+05	2.65E+05	0	895	769	1664	19	1615
R00085	Static	#01-11	40-Ar	150	14.1	42	45	19.9	68	56	4410	95.8	592	3.00E+05	2.47E+05	0	1020	975	1994	18	1923
R00086	Dynamic	#01-11	40-Ar	150	14.1	42	45	19.9	93	93	3230	95.8	688	3.00E+05	3.00E+05	0	1681	1325	3006	25	2276
R00087	Dynamic	#01-11	40-Ar	150	14.1	42	60	28.2	134	134	2240	136	824	3.00E+05	3.00E+05	0	2562	2111	4673	28	3501
R00088	Static	#01-11	40-Ar	150	14.1	42	60	28.2	113	95	2650	136	959	3.00E+05	2.52E+05	0	1445	1344	2789	26	2661
R00089	Dynamic	#01-11	84-Kr	316	34	43	0	34	51	51	5880	163	1120	3.00E+05	3.00E+05	0	2812	2533	5340	37	4930
R00090	Static	#01-11	84-Kr	316	34	43	0	34	33	0	6060	109	1230	2.00E+05	0.00E+00	0	1201	1212			2413
R00091	Static	#01-11	84-Kr	316	34	43	45	48.1	33	32	6060	154	1390	2.00E+05	1.94E+05	0	1490	1399	2886	25	2830
R00092	Dynamic	#01-11	84-Kr	316	34	43	45	48.1	56	56	3570	154	1540	2.00E+05	2.00E+05	0	2872	2578	5445	91	4047
R00093 trunc	Dynamic	#01-11	84-Kr	316	34	43	60	68	61	53.5	3280	218	1760	2.00E+05	1.75E+05	0	3352	3204	6555	123	4751
R00094	Static	#01-11	84-Kr	316	34	43	60	68	69	62	2900	218	1980	2.00E+05	1.80E+05	0	2350	2353	4701	122	4293
R00095	Static	#02-11	84-Kr	316	34	43	0	34	39	35	5130	109	1090	2.00E+05	1.79E+05	0	1454	1449	2900	21	2848
R00096	Dynamic	#02-11	84-Kr	316	34	43	0	34	44	44	4550	109	1200	2.00E+05	2.00E+05	0	2108	1813	3919	33	3521
R00097	Dynamic	#02-11	84-Kr	316	34	43	45	48.1	51	51	3920	154	1360	2.00E+05	2.00E+05	0	2508	2211	4719	56	4024
R00098	Static	#02-11	84-Kr	316	34	43	45	48.1	44	40	4550	154	1510	2.00E+05	1.82E+05	0	1734	1671	3404	41	3287
R00099	Static	#02-11	84-Kr	316	34	43	60	68	63	56	3170	218	1730	2.00E+05	1.78E+05	0	2282	2192	4473	77	4211
R00100	Dynamic	#02-11	84-Kr	316	34	43	60	68	86	64.877	2330	218	1950	2.00E+05	1.51E+05	0	3514	2977	6489	135	4127

Table 2 – K6R4008C1C heavy ion detailed results per run

7.2 Protons

Table 4 provides the detailed results per run.
Only static conditions have been considered.
No stuck bit has been observed.
Proton SEU error cross-section per bit versus proton energy is plotted in Figure 3. Corresponding values are provided in Table 3.

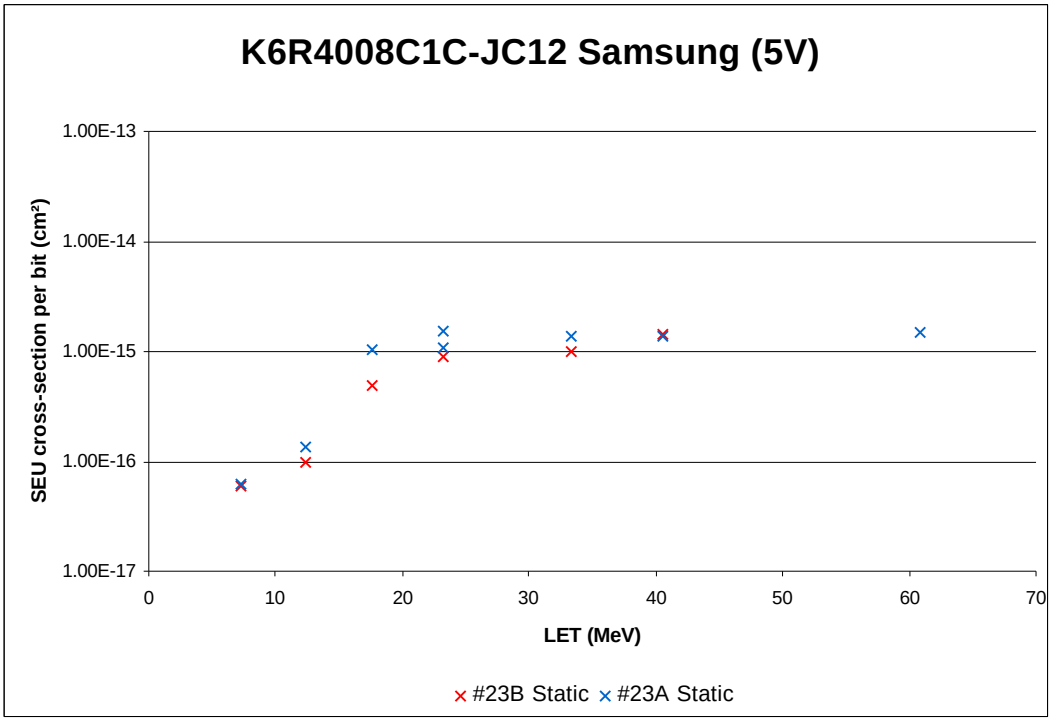

Figure 3 - K6R4008C1C Proton error cross-section per bit versus proton incident energy

Run #	Sample	Time	Eff_Time	Fluence	Eff_Fluence	SEUs	ProtonEnergy	Sigma per bit
				Static				
R00046	#23A	90	48	1.00E+10	5.33E+09	3	12.4	1.34E-16
R00045	#23A	79	64	1.00E+10	8.10E+09	35	17.6	1.03E-15
R00043	#23A	73	59	1.00E+10	8.08E+09	36	23.3	1.06E-15
R00044	#23A	71	56	1.00E+10	7.89E+09	50	23.3	1.51E-15
R00047	#23A	102	80	1.00E+10	7.84E+09	2	7.3	6.08E-17
R00042	#23A	63	48	1.00E+10	7.62E+09	44	33.3	1.38E-15
R00041	#23A	62	48	1.00E+10	7.74E+09	45	40.6	1.39E-15
R00040	#23A	52	42	1.00E+10	8.08E+09	60	60.9	1.77E-15
R00054	#23B	99	80	1.00E+10	8.08E+09	2	7.3	5.90E-17
R00053	#23B	87	64	1.00E+10	7.36E+09	3	12.4	9.72E-17
R00052	#23B	78	64	1.00E+10	8.21E+09	17	17.6	4.94E-16
R00051	#23B	67	56	1.00E+10	8.36E+09	31	23.3	8.84E-16
R00050	#23B	61	50	1.00E+10	8.20E+09	34	33.3	9.89E-16
R00049	#23B	58	48	1.00E+10	8.28E+09	50	40.6	1.44E-15
R00048	#23B	50	40	1.00E+10	8.00E+09	50	60.9	1.49E-15

Table 3 - K6R4008C1C proton SEU error cross-section per bit

Run #	Test	Sample	Proton Energy (MeV)	LET (MeV)/(mg.cm²)	Range (µm)	Angle (deg.)	Time (s)	Eff_Time (s)	Flux (p/cm².s)	Run TID rads(Si)	Sample TID rads(Si)	Fluence (p/cm²)	Eff_Fluence (p/cm²)	Bits up (0 to 1)	Bits down (1 to 0)	Words	Stuck bits	SEUs
R00040	Static	#23A	60.9	8.50E-03	17300	0	52	42	1.92E+08	1360	1360	1.00E+10	8.06E+09	26	34	60	0	60
R00041	Static	#23A	40.6	1.17E-02	8410	0	62	50	1.61E+08	2720	4090	1.00E+10	8.05E+09	26	19	45	0	45
R00042	Static	#23A	33.3	1.36E-02	5910	0	63	54	1.59E+08	2180	6260	1.00E+10	8.59E+09	24	20	44	0	44
R00043	Static	#23A	23.3	1.80E-02	3130	0	73	59	1.37E+08	2880	9150	1.00E+10	8.08E+09	18	18	36	0	36
R00044	Static	#23A	23.3	1.80E-02	3130	0	71	59	1.41E+08	2880	12000	1.00E+10	8.32E+09	27	23	50	0	50
R00045	Static	#23A	17.6	2.25E-02	1910	0	79	65	1.27E+08	3600	15600	1.00E+10	8.26E+09	15	20	35	0	35
R00046	Static	#23A	12.4	2.95E-02	1030	0	90	75	1.11E+08	4730	20400	1.00E+10	8.33E+09	1	2	3	0	3
R00047	Static	#23A	7.3	4.43E-02	411	0	102	87	9.80E+07	7100	27500	1.00E+10	8.53E+09	2	0	2	0	2
R00048	Static	#23B	60.9	8.50E-03	17300	0	50	40	2.00E+08	1360	1360	1.00E+10	8.00E+09	19	31	50	0	50
R00049	Static	#23B	40.6	1.17E-02	8410	0	58	48	1.72E+08	2720	4090	1.00E+10	8.26E+09	31	19	50	0	50
R00050	Static	#23B	33.3	1.36E-02	5910	0	61	50	1.64E+08	2180	6260	1.00E+10	8.20E+09	12	22	34	0	34
R00051	Static	#23B	23.3	1.80E-02	3130	0	67	58	1.49E+08	2880	9150	1.00E+10	8.64E+09	14	17	31	0	31
R00052	Static	#23B	17.6	2.25E-02	1910	0	78	65	1.28E+08	3600	12800	1.00E+10	8.32E+09	6	11	17	0	17
R00053	Static	#23B	12.4	2.95E-02	1030	0	87	73	1.15E+08	4730	17500	1.00E+10	8.40E+09	3	0	3	0	3
R00054	Static	#23B	7.3	4.43E-02	411	0	99	83	1.01E+08	7100	24600	1.00E+10	8.38E+09	2	0	2	0	2

Table 4 – K6R4008C1C proton detailed results per run

8 CONCLUSION

Both heavy ion and proton tests have been conducted on commercial samples of 512Kx8 Bit High Speed Static RAM(5V Operating) K6R4008C1C from Samsung, using the heavy ions available at the European Heavy Ion Irradiation Facility (HIF) at Cyclone, Université Catholique de Louvain, Belgium and the OPTIS proton beam at the Paul Scherrer Institut, Switzerland.

K6R4008C1C responses to both heavy ion and proton exposures have been characterized and the corresponding cross-section curves have been plotted.

It may be worthwhile to note that this device does not exhibit Multiple Upset errors (MEUs) nor Single Event Latch-ups (SELs)