SINGLE EVENT EFFECTS
RADIATION TEST REPORT

Part Type : KM684002A

Package : 36-SOJ

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

Manufacturer : Samsung

Report Reference : ESA_QCA0101S_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

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SINGLE EVENT EFFECTS RADIATION TEST REPORT on 512Kx8 Bit High Speed Static RAM(5V Operating) , KM684002A, 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) KM684002A from Samsung.

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

These devices were tested 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 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)

4 DEVICE INFORMATION

Relevant device identification information is presented here after.

Part type :	KM684002A
Manufacturer :	Samsung
Package :	36-SOJ
Quality Level :	Commercial
Date Code :	-
Die Technology :	CMOS
Top Marking:	SEC KOREA 734 KM684002AJ-15 SDE043DA
Die Size :	10.1 mm x 7 mm approximately
Die Marking :	Logo ©1995.9 KM68 4002A

External and Internal Photos are shown in Figure 1.

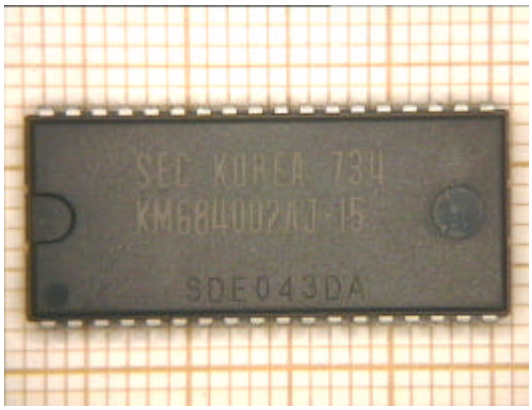

Photo # 1 :

Part Type : KM684002A

S/N

Magnification : 4.0

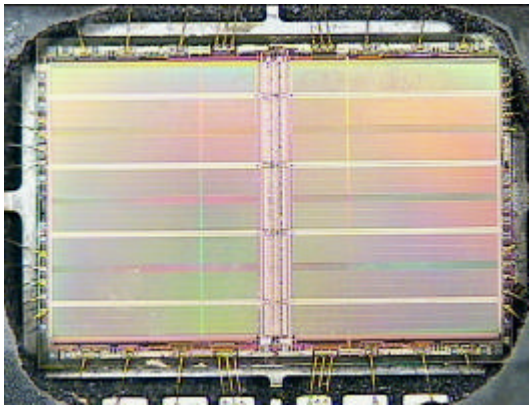

Photo # 2 :

Part Type : KM684002A

S/N 1

Magnification : 7.3

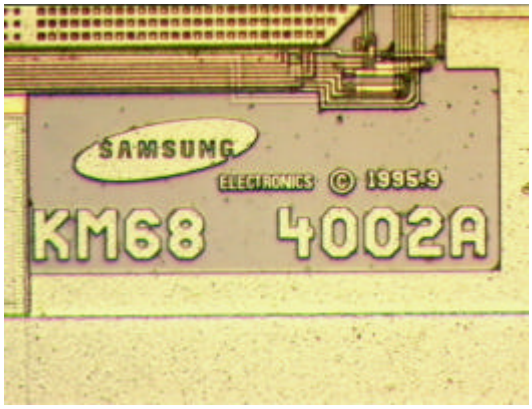

Photo # 3 :

Internal Visual Inspection

Part Type : KM684002A

S/N 1

Magnification : 342.5

Figure 1 – KM684002A 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.

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 118 has 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 different response as shown in Figure 2 and Table 1.

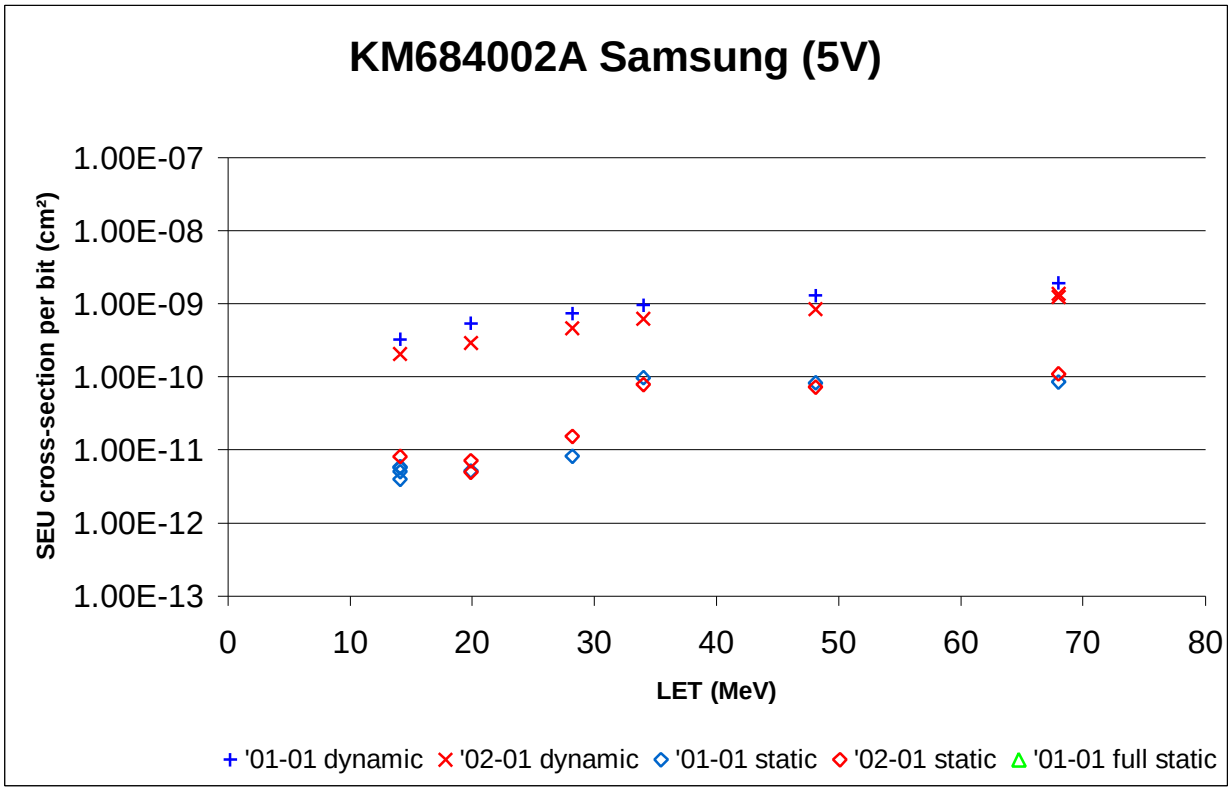

Figure 2 – KM684002A SEU error cross-section per bit versus LET

Run #	Sample	Eff_Fluence (p/cm²)	SEUs	Eff_ MeV/(mg/cm²)	sigma SEUs (per bit) (cm²)
dynamic					
R00006	01-01	1.00E+06	1368	14.1	3.26E-10
R00010	01-01	1.00E+06	2266	19.9	5.40E-10
R00007	01-01	9.95E+05	3077	28.2	7.37E-10
R00114	01-01	3.00E+05	1209	34	9.61E-10
R00115	01-01	3.00E+05	1630	48.1	1.30E-09
R00118_trunc.	01-01	1.52E+05	1216	68	1.91E-09
R00014	02-01	1.00E+06	856	14.1	2.04E-10
R00011	02-01	1.00E+06	1218	19.9	2.90E-10
R00015	02-01	1.00E+06	1941	28.2	4.63E-10
R00119	02-01	3.00E+05	784	34	6.23E-10
R00122	02-01	3.00E+05	1052	48.1	8.36E-10
R00123	02-01	3.00E+05	1552	68	1.23E-09
R00124	02-01	1.70E+05	970	68	1.36E-09
full static					
R00005	01-01	1.00E+06	18	14.1	4.29E-12
static					
R00001	01-01	8.49E+05	21	14.1	5.89E-12
R00002	01-01	8.44E+05	14	14.1	3.95E-12
R00003	01-01	8.82E+05	21	14.1	5.68E-12
R00004	01-01	8.04E+05	17	14.1	5.04E-12
R00009	01-01	8.77E+05	19	19.9	5.16E-12
R00008	01-01	8.69E+05	30	28.2	8.23E-12
R00113	01-01	1.76E+05	72	34	9.73E-11
R00116	01-01	2.70E+05	93	48.1	8.22E-11
R00117	01-01	2.68E+05	96	68	8.54E-11
R00013	02-01	7.93E+05	27	14.1	8.12E-12
R00012	02-01	8.21E+05	17	19.9	4.94E-12
R00017	02-01	4.00E+05	12	19.9	7.15E-12
R00016	02-01	8.39E+05	54	28.2	1.53E-11
R00120	02-01	2.30E+05	76	34	7.86E-11
R00121	02-01	2.33E+05	71	48.1	7.27E-11
R00125	02-01	2.69E+05	123	68	1.09E-10

Table 1 – KM684002A 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
R00001	Static	#01-01	40-Ar	150	14.1	42	0	14.1	385	327	2600	226	226	1.00E+06	8.49E+05	0	11	10	21	0	21
R00002	Static	#01-01	40-Ar	150	14.1	42	0	14.1	154	130	6490	226	452	1.00E+06	8.44E+05	0	8	6	14	0	14
R00003	Static	#01-01	40-Ar	150	14.1	42	0	14.1	144	127	6940	226	678	1.00E+06	8.82E+05	0	11	10	21	0	21
R00004	Static	#01-01	40-Ar	150	14.1	42	0	14.1	153	123	6540	226	904	1.00E+06	8.04E+05	0	11	6	17	0	17
R00005	Full Static	#01-01	40-Ar	150	14.1	42	0	14.1	258	258	3880	226	1130	1.00E+06	1.00E+06	0	9	9	18	0	18
R00006	Dynamic	#01-01	40-Ar	150	14.1	42	0	14.1	154	154	6490	226	1360	1.00E+06	1.00E+06	0	646	722	1368	0	1368
R00007	Dynamic	#01-01	40-Ar	150	14.1	42	60	28.2	214	213	4670	452	1810	1.00E+06	9.95E+05	0	1552	1643	3195	4	3077
R00008	Static	#01-01	40-Ar	150	14.1	42	60	28.2	175	152	5710	452	2260	1.00E+06	8.69E+05	0	25	33	58	5	30
R00009	Static	#01-01	40-Ar	150	14.1	42	45	19.9	106	93	9430	319	2580	1.00E+06	8.77E+05	0	38	15	53	6	19
R00010	Dynamic	#01-01	40-Ar	150	14.1	42	45	19.9	116	116	8620	319	2900	1.00E+06	1.00E+06	0	1307	1291	2598	7	2266
R00011	Dynamic	#02-01	40-Ar	150	14.1	42	45	19.9	554	554	1810	319	319	1.00E+06	1.00E+06	0	541	677	1218	0	1218
R00012	Static	#02-01	40-Ar	150	14.1	42	45	19.9	385	316	2600	319	639	1.00E+06	8.21E+05	0	12	5	17	0	17
R00013	Static	#02-01	40-Ar	150	14.1	42	0	14.1	222	176	4500	226	865	1.00E+06	7.93E+05	0	14	13	27	0	27
R00014	Dynamic	#02-01	40-Ar	150	14.1	42	0	14.1	196	196	5100	226	1090	1.00E+06	1.00E+06	0	400	456	856	0	856
R00015	Dynamic	#02-01	40-Ar	150	14.1	42	60	28.2	316	316	3160	452	1540	1.00E+06	1.00E+06	0	1058	1459	2517	11	1941
R00016	Static	#02-01	40-Ar	150	14.1	42	60	28.2	143	120	6990	452	1990	1.00E+06	8.39E+05	0	55	76	131	15	54
R00017	Static	#02-01	40-Ar	150	14.1	42	45	19.9	36	31	12900	148	2140	4.65E+05	4.00E+05	0	13	26	39	13	12
R00113	Static	#01-01	84-Kr	316	34	43	0	34	68	60	2940	109	3010	2.00E+05	1.76E+05	0	41	52	93	6	72
R00114	Dynamic	#01-01	84-Kr	316	34	43	0	34	86	86	3490	163	3170	3.00E+05	3.00E+05	0	675	745	1420	6	1209
R00115	Dynamic	#01-01	84-Kr	316	34	43	45	48.1	109	109	2750	231	3400	3.00E+05	3.00E+05	0	957	1163	2117	16	1630
R00116	Static	#01-01	84-Kr	316	34	43	45	48.1	119	107	2520	231	3630	3.00E+05	2.70E+05	0	76	106	182	16	93
R00117	Static	#01-01	84-Kr	316	34	43	60	68	179	160	1680	327	3960	3.00E+05	2.68E+05	0	375	429	804	108	96
R00118_trunc.	Dynamic	#01-01	84-Kr	316	34	43	60	68	109	104.03	1460	173	4130	1.59E+05	1.52E+05	0	3167	3412	6579	156	1216
R00119	Dynamic	#02-01	84-Kr	316	34	43	0	34	147	147	2040	163	2310	3.00E+05	3.00E+05	0	369	415	784	0	784
R00120	Static	#02-01	84-Kr	316	34	43	0	34	82	63	3660	163	2470	3.00E+05	2.30E+05	0	36	45	81	1	76
R00121	Static	#02-01	84-Kr	316	34	43	45	48.1	116	90	2590	231	2700	3.00E+05	2.33E+05	0	45	59	104	10	71
R00122	Dynamic	#02-01	84-Kr	316	34	43	45	48.1	146	146	2050	231	2930	3.00E+05	3.00E+05	0	959	1065	2023	25	1052
R00123	Dynamic	#02-01	84-Kr	316	34	43	60	68	172	172	1740	327	3260	3.00E+05	3.00E+05	0	3492	3069	6560	145	1552
R00124	Dynamic	#02-01	84-Kr	316	34	43	60	68	89	83	2050	198	3460	1.82E+05	1.70E+05	0	3019	2943	5962	205	970
R00125	Static	#02-01	84-Kr	316	34	43	60	68	125	112	2400	327	3780	3.00E+05	2.69E+05	0	927	970	1897	286	123

Table 2 – KM684002A heavy ion detailed results per run

8 CONCLUSION

Heavy ion test has been conducted on commercial samples of 512Kx8 Bit High Speed Static RAM(5V Operating) KM684002A from Samsung, using the heavy ions available at the European Heavy Ion Irradiation Facility (HIF) at Cyclone, Université Catholique de Louvain, Belgium.

Only argon and krypton have been used as the main purpose of the present test was to be used as a reference in a comparison exercise with die release revision C.

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

Lastly it is interesting to observe the different responses of the two dynamic and static conditions.