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SEE Acceptance Test of the Radiation Testbed for Memory Components (RTMC-3).

Performed at the HIF, Université Catholique de Louvain, Louvain la Neuve, Belgium, April 2004.

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ESTEC Technical Officer: R. Harboe-Sørensen

1. Introduction

This is a summary of the test data collected at UCL in April 2004. Main intention of this test was to verify the handling and performance of the new built test system, RTMC-3. Thus, four of the six DUTs were already tested before. Only two DUTs, AT61 and AT62, are new revisions and are tested for the first time.

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2. Devices

Table 1 shows all tested devices with their markings.

Table 1: Tested Devices

Manufacturer	ID	Package	Туре	Remarks
Atmel	AT61	FP36 0.5"	АТ60142-Е	Sample; Rad Hard
Atmel	AT62	FP36 0.5"	АТ60142-Е	Sample; Rad Hard
MHS	MH41	CerDIP28 0.3"	MMDP65656EV-45	
MHS	MH51	SOJ28 0.4"	MMDP65656FV-55	
White	WH33	SOJ32 0.4"	WMS512K8-70DEM	
White	WH28	SOJ32 0.4"	WMS512K8-45DEM	

The devices AT61 and AT62 from Atmel have a new die revision and are tested here, because during former tests the old die revision showed latch-ups. The devices MH41, MH51 from MHS and WH28, WH33 from White Electronic Designs have been tested already in 1998-99, so previous SEE data is available.

3. Heavy Ion Test Facility

The heavy ion tests were performed at UCL, Université Catholique de Louvain, Louvain la Neuve, Belgium. The HIF beam line with the ion cocktail M/Q=5 was used to irradiate the DUTs. In particular, the following ions and incidence angles have been used:

Ion	Energy [MeV]	Tilt Angle	Range [µm(Si)]	LET [MeV/mg/cm ²]
¹⁵ N ³⁺	62	0°	64	2.97
¹⁵ N ³⁺	62	45°	45.3	4.2
¹⁵ N ³⁺	62	60°	32	5.94
²⁰ Ne ⁴⁺	78	0°	45	5.85
²⁰ Ne ⁴⁺	78	45°	31.8	8.27
²⁰ Ne ⁴⁺	78	60°	22.5	11.7
⁴⁰ Ar ⁸⁺	150	0°	42	14.1
⁴⁰ Ar ⁸⁺	150	45°	29.7	19.94
$^{40}{\rm Ar}^{8+}$	150	60°	21	28.2
⁸⁴ Kr ¹⁷⁺	316	0°	43	34
⁸⁴ Kr ¹⁷⁺	316	45°	30.4	48.08
⁸⁴ Kr ¹⁷⁺	316	60°	21.5	68
132 Xe ²⁶⁺	459	45°	30.4	79.05
132 Xe ²⁶⁺	459	60°	21.5	111.8

Table 2:	Ions	and	LETs	used	for	Heavy	Ion	Tests
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Unfortunately, no boron was available at UCL in the test period and therefore no low LET values could be taken.



Fig. 1 shows the range distribution over the LET of the used ions in a diagram.

Fig. 1: Range and LET of used Ions

4. Single Event Upsets (SEUs)

No latch-ups occurred during the test.

Fig. 2 to Fig. 7 shows the cross sections of each device over the LET.

During each test run the error distribution over the memory array is displayed and shows some events with errors in multiple cells (physically neighboured) especially at higher LET value and incidence angle. Because this phenomenon produces more than one erroneous cell per event, test data has to be filtered. But for now, the evaluation software isn't capable to do this. If needed, an extra evaluation can be made. This might be useful for future tests because this effect produces an error in cross section of a few percent.



Fig. 2: Cross section for AT61



Fig. 3: Cross section for AT62





Fig. 4: Cross section for MH41



Fig. 5: Cross section for MH51





Fig. 6: Cross section for WH33



Fig. 7: Cross section for WH28

Table 3 shows the occurrence of 8-bit errors (the full output word is wrong) in the various tests. This type of error can be attributed to events hitting the address decoder or read/write control. Remarkable is the fact that this type of error occurs only at low (< 6) LET or at high (> 34) LET. This leads to an assumption that in fact two different mechanisms causing this effect. Further analysis of the test data could show which type of the above described error mechanisms are responsible.

LET	AT61	AT62	MH41	MH51	WH33	WH28
2.97	6	4	0	7	8	2
4.20	2	4	0	0	19	0
5.85	0	0	0	0	0	0
5.94					18	2
8.27	0	0	0	0	0	0
11.70	0	0	0	0	0	0
14.10	0	0	0	0	0	0
19.94	0	0	0	0	0	0
28.80	0	0	0	0	0	0
34.00	0	2	0	0	0	0
48.08	0	0	0	0	0	1
68.00	0	0	0	0	0	0
79.05	0	0	4	0	4	0
111.80	0	0	10	2	6	0

Table 3: Full Word Errors

5. Multiple Event Upsets (MEUs)

Table 4 shows the amount of two single bit errors in the same output word and the statistically expected amount of each device and run. This type of error is normally caused by two independent events hitting the geometrically distant bit planes. Most of these figures are within their expected value, values marked in green are slightly above the expectancy. There are two remarkable outliers coloured in yellow and red at device MH51 with an LET of 79.05 and 111.8, which cannot be explained. The recorded data sets from these two runs look quite normal and do not differ from other runs.

No three or more bit error occurred during the test.

	AT	61	АТ	62	MF	1 41	MF	1 51	WI	133	WI	H28
LET	Read	Exp.	Read	Exp.	Read	Exp.	Read	Exp.	Read	Exp.	Read	Exp.
2.97	4	5.51	1	4.81	0	0.01	0	0.03	5	11.5	0	6.76
4.20	3	6.52	3	8.32	0	0.02	0	0.19	5	10.2	3	7.32
5.85	0	2.18	1	5.7	4	3.74	4	3.29	12	25.4	8	22.4
5.94									7	10.1	4	8.32
8.27	3	2.58	1	4.45	2	2.94	0	3.06	23	33.6	8	23.1
11.70	1	3.75	3	4.03	0	3.19	1	3.58	18	40.5	9	22.2
14.40	4	4.94	2	3.95	0	1.82	1	1.01	5	7.55	0	2.37
19.94	3	4.48	0	3.7	1	2.53	1	2.92	4	8.88	4	4.8
28.80	3	4.46	5	3.96	0	1.83	0	1.95	1	6.66	1	5.37
34.00	4	8.06	5	6.61	8	12.1	10	11	41	61.7	5	8.73
48.08	2	6.82	1	4.08	7	9.29	5	7.85	3	12.6	2	6.9
68.00	1	6.34	2	9.3	8	6.89	4	7.97	4	9.94	5	6.73
79.05	4	7.19	2	10.2	0	5.07	17	2.04	3	5.69	0	5.57
111.80	2	6.07	4	7.33	2	4.75	6	3.77	2	3.94	1	4.12

Table 4: Double Bit Upsets

6. Conclusion

During the SEE test, the radiation testbed runs stable and reliable. It is capable to record and display the DUT data even at higher fluxes. The resulting cross section diagrams are very similar to those measured earlier. One big advantage over the old test system is the in-situ evaluation and visualisation of the test data during the irradiation. Additionally, an advantage is the offline playback of the recorded test data to do a deeper analysis. Working with the new radiation testbed revealed a few things that had to be improved:

- The black background colour of the error map display is chosen unfavourable: Blue dots showing single errors are poorly visible. The background colour is now changed to light grey, so error dots are clearly shown.
- Operating the test system turned out to be very intricate and error-prone. Improvements in the test software have been made to get a safer user interface.

Finally, Fig. 8 shows an example of cross section results obtained using two different test systems but using the same ion species and the same Atmel (MHS) memory type. As shown below, good correlation can be reported between the Testbed SEU data and earlier obtained results. Further correlation results as well as a Testbed summary presentation can be found on ESA's www pages detailing the 6th QCA presentation day, May 11th, 2004.

https://escies.org/public/radiation/esa/database/qcaday6data/Presentations/VME_BOARD_QCADA Y.pdf (correlation data pages 33-35)

https://escies.org/public/radiation/esa/database/qcaday6data/Presentations/Rad_Days_Presentation_I DA.pdf (Testbed presentation)



Fig. 8: Comparison of test results for MH51

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08 AT62 4194304 110 93000 26434 26432 1 0 0 4.08 0.000539 6 58 AT62 4194304 99 76600 29199 29195 2 0 0 9.3 0.00254 9 05 AT62 4194304 63 50600 23868 23864 2 0 0 9.3 0.00375 1 0.8 AT62 4194304 63 50600 23868 23864 2 0 0 10.2 0.00375 1 .8 AT62 4194304 81 37800 22868 22860 4 0 0 7.33 0.00201 1	0		34 /	AT62	4194304	06	108600	22805	22779	9	0	2	6.61	0.00164	5.01E-08
38 AT62 4194304 99 76600 29199 29195 2 0 0 0 9.3 0.00254 9 35 AT62 4194304 63 50600 23868 23864 2 0 0 10.2 0.00375 1 .8 AT62 4194304 81 37800 22868 22860 4 0 0 7.33 0.00201 1	45 48.(48.(38 <i>i</i>	AT62	4194304	110	93000	26434	26432	L	0	0	4.08	0.000539	6.78E-08
05 AT62 4194304 63 50600 23868 23864 2 0 0 10.2 0.00375 1 . .8 AT62 4194304 81 37800 22868 22860 4 0 0 7.33 0.00201 1	60		68 /	AT62	4194304	99	76600	29199	29195	2	0	0	9.3	0.00254	9.09E-08
1.8 AT62 4194304 81 37800 22868 22860 4 0 0 7.33 0.00201 1	45 79.	79.	05/	AT62	4194304	63	50600	23868	23864	2	0	0	10.2	0.00375	1.12E-07
	60 111	111	.8	AT62	4194304	81	37800	22868	22860	4	0	0	7.33	0.00201	1.44E-07

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Run	lon	⊥iit ⊡	LET [MeV·cm²/mg]	DUT	Capacity	Time [s]	Fluence [/cm²]	Errors	Single Bit	Double Bit	Triple Bit	8 bit	Exp. Double	Exp. Triple	Xsection [/am²]
48	N-15	0	2.97	MH41	262144	111	1.00E+06	845	845	0	0	0	0.0104	1.10E-07	3.22E-09
47	N-15	45	4.2	MH41	262144	166	1.00E+06	1533	1533	0	0	0	0.0233	3.03E-07	5.85E-09
26	Ne-20	0	5.85	MH41	262144	190	843500	20799	20791	4	0	0	3.74	0.000576	9.41E-08
27	Ne-20	45	8.27	MH41	262144	178	508800	18920	18916	2	0	0	2.94	0.000391	1.42E-07
28	Ne-20	60	11.7	MH41	262144	155	356500	17398	17398	0	0	0	3.19	0.000503	1.86E-07
12	Ar-40	0	14.1	MH41	262144	123	206800	12073	12073	0	0	0	1.82	0.000235	2.23E-07
11	Ar-40	45	19.94	MH41	262144	155	178000	15863	15861	L	0	0	2.53	0.000347	3.40E-07
10	Ar-40	09	28.8	MH41	262144	144	140400	13717	13717	0	0	0	1.83	0.00021	3.73E-07
59	Kr-84	0	34	MH41	262144	137	256200	32716	32700	8	0	0	12.1	0.00382	4.87E-07
60	Kr-84	45	48.08	MH41	262144	115	148200	25668	25654	2	0	0	9.29	0.00288	6.61E-07
61	Kr-84	60	68	MH41	262144	97	104400	21907	21891	8	0	0	6.89	0.00186	8.00E-07
78	Xe-132	45	79.05	MH41	262144	109	100900	19113	19081	0	0	4	5.07	0.00116	7.23E-07
77	Xe-132	60	111.8	MH41	262144	128	87500	19948	19864	2	0	10	4.75	0.000973	8.70E-07
_															
45	N-15	0	2.97	MH51	262144	130	1.00E+06	1680	1624	0	0	7	0.0331	5.79E-07	6.41E-09
46	N-15	45	4.2	MH51	262144	152	1.00E+06	4190	4190	0	0	0	0.189	7.32E-06	1.60E-08
31	Ne-20	0	5.85	MH51	262144	145	531200	17067	17059	4	0	0	3.29	0.000545	1.23E-07
30	Ne-20	45	8.27	MH51	262144	153	392000	17294	17294	0	0	0	3.06	0.000463	1.68E-07
29	Ne-20	60	11.7	MH51	262144	142	331800	18586	18584	1	0	0	3.58	0.00059	2.14E-07
7	Ar-40	0	14.1	MH51	262144	178	176500	10714	10712	1	0	0	1.01	8.20E-05	2.32E-07
8	Ar-40	45	19.94	MH51	262144	132	163400	15391	15389	1	0	0	2.92	0.000476	3.59E-07
6	Ar-40	60	28.8	MH51	262144	121	100400	12049	12049	0	0	0	1.95	0.00027	4.58E-07
64	Kr-84	0	34	MH51	262144	80	174000	24456	24436	10	0	0	11	0.00426	5.36E-07
63	Kr-84	45	48.08	MH51	262144	81	123000	21513	21503	5	0	0	7.85	0.00246	6.67E-07
62	Kr-84	60	68	MH51	262144	130	129600	26665	26657	4	0	0	7.97	0.00204	7.85E-07
75	Xe-132	45	79.05	MH51	262144	295	106800	19131	19097	17	0	0	2.04	0.000187	6.83E-07
76	Xe-132	09	111.8	MH51	262144	170	98400	19775	19747	9	0	2	3.77	0.000618	7.67E-07
44	N-15	0	2.97	WH33	4194304	57	284700	24256	24182	5	0	8	11.5	0.00467	2.03E-08

	Xsection	/מוו-]	3.04E-08	4.90E-08	4.25E-08	6.79E-08	1.00E-07	7.22E-08	1.04E-07	1.47E-07	1.46E-07	2.02E-07	2.34E-07	2.14E-07	2.18E-07	1.55E-08	2.48E-08	3.38E-08	3.65E-08	4.85E-08	7.64E-08	5.68E-08	8.46E-08	1.26E-07	9.53E-08	1.36E-07	1.69E-07	1.78E-07	2.00E-07
	Exp. Triple	_	0.00382	0.0181	0.00377	0.0238	0.0321	0.00198	0.00266	0.00161	0.062	0.00555	0.00325	0.00135	0.000677	0.00159	0.00211	0.0125	0.00256	0.0121	0.013	0.000285	0.000691	0.0011	0.00261	0.00183	0.00172	0.00122	0.00072
	Exp.	Double	10.2	25.4	10.1	33.6	40.5	7.55	8.88	6.66	61.7	12.6	9.94	5.69	3.94	6.76	7.32	22.4	8.32	23.1	22.2	2.37	4.8	5.37	8.73	6'9	6.73	2.57	4.12
	8 bit		19	0	18	0	0	0	0	0	0	0	0	4	9	2	0	0	2	0	0	0	0	0	0	۱	0	0	0
	Triple	Bit	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Double	Bit	5	12	7	23	18	5	4	~	4	e	4	e	2	0	n	ω	4	ω	6	0	4	~	5	2	5	0	Ļ
	Single	Bit	23312	30462	23211	40633	43789	24710	25378	23554	52671	24591	26052	20561	19609	24654	21765	34580	23201	37756	32422	16898	28583	22484	25061	22273	22549	21769	20253
	Errors		23474	30486	23369	40679	43825	24720	25386	23556	52753	24597	26060	20599	19661	24670	21771	34596	23225	37772	32440	16898	28591	22486	25071	22285	22559	21769	20255
	Fluence	/cm-]	184300	148200	131000	142900	104000	81600	58000	38143	86000	29100	26500	23000	21500	380304	209000	244200	151500	185600	101200	70900	80600	42700	62700	39200	31900	29200	24100
	Time	[s]	60	39	53	22	53	93	82	89	50	54	82	85	130	104	74	53	73	20	52	140	200	108	22	82	62	86	115
	Capacity		4194304	4194304	4194304	4194304	4194304	4194304	4194304	4194304	4194304	4194304	4194304	4194304	4194304	4194304	4194304	4194304	4194304	4194304	4194304	4194304	4194304	4194304	4194304	4194304	4194304	4194304	4194304
-	DUT	[6111/-1	4.2 WH33	5.85 WH33	5.94 WH33	3.27 WH33	11.7 WH33	14.1 WH33	9.94 WH33	28.8 WH33	34 WH33	3.08 WH33	68 WH33	9.05 WH33	11.8 WH33	2.97 WH28	4.2 WH28	5.85 WH28	5.94 WH28	3.27 WH28	11.7 WH28	14.1 WH28	9.94 WH28	28.8 WH28	34 WH28	3.08 WH28	68 WH28	9.05 WH28	11.8 WH28
-	It LET	liviev cri	15	i 0	30	15 8	, 0	` 0	15 19	00	0	15 48	30	15 79	30 1	0	15	4 0	i 0	15 8	, 0	` 0	15 16	00	0	15 48	30	15 79	30 1
	Ξ	2	5	20	5 6	20 4	20 6	0	0	0	4	4	4	32 4	32 6		4	0	6	20	<u>20</u>	0	0	0	4	4	4 6	32 4	32 6
-	Run lon		43 N-15	32 Ne-2	42 N-15	33 Ne-2	34 Ne-2	6 Ar-4	5 Ar-4	4 Ar-4	65 Kr-8	66 Kr-8	67 Kr-8	74 Xe-1	73 Xe-1	39 N-15	40 N-15	38 Ne-2	41 N-15	36 Ne-2	35 Ne-2	1 Ar-4	2 Ar-4	3 Ar-4	70 Kr-8	69 Kr-8	68 Kr-8	71 Xe-1	72 Xe-1
- L																				•		•		•					

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