SINGLE EVENT EFFECTS RADIATION TEST REPORT

Part Type : GAL22V10

Manufacturer : LATTICE

Report Reference : ESA_QCA0214S_C

Issue : 01

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ESA Contract No 13528/99/NL/MV COO-13 dated 11/10/02

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The work described in this report was done under ESA contract.
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Heavy ion SEE characterization of GAL22V10

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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", GAL22V10 parts 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 GAL22V10 parts, from LATTICE.

Test was conducted on hi-rel 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. GAL22V10 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 GAL22V10

Relevant device identification information is presented here after.

Part type:	GAL22V10
Manufacturer:	LATTICE
Package:	28-LLC
Quality Level:	hi-rel
Date Code:	D0A0028
Top Marking:	LATTICE 5962-89841063A
Die Size:	2.4 mm x 1.8 mm approximately
Die marking	22V10DQ-00 M 1996 GAL R
Serial number	14, 15

The GAL22V10 is a programmable logic device (PLD) which combines a high performance CMOS process with Electrically Erasable (E^2) floating gate technology

Die identification is provided in Figure 1.

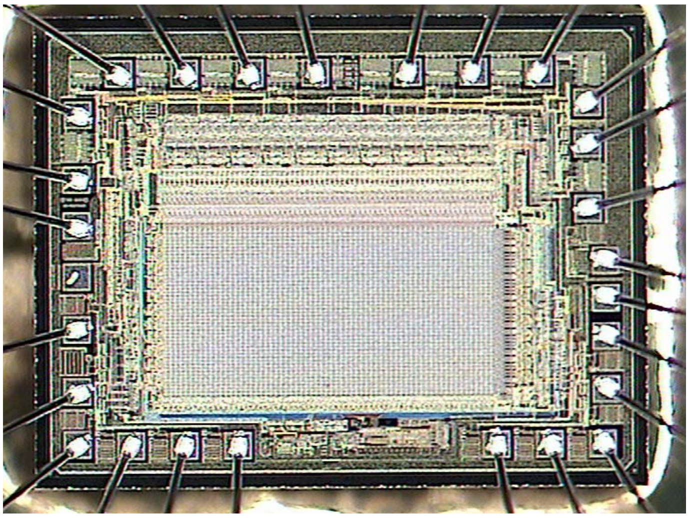

Photo 1

Die, full view

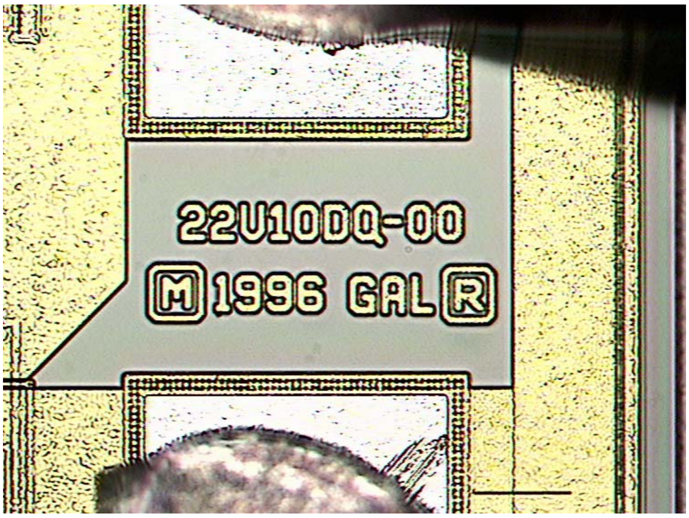

Photo 2

Die marking

Figure 1 - GAL22V10 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

Each DUT was programmed in advance using a standard commercial programmer. No new programmation was foreseen during the test.
The program developed allows for testing both the SET sensitivity of DUT combinatorial logic and the SEU sensitivity of DUT flip-flops.
Combinatorial logic part of the circuit was constituted by a 5 by 5 adder with the results on 5 bits. For this circuit, 10 inputs were used, 45% of the possible product terms, 5 cells at the output plus one cell for an internal node.
The four remaining cells are used as a four bit register. One single input bit is copied on the 2 flip-flops, and the inverted bit on two others.
The program has been developed using VHDL with the generic Xilinx tools for 22V10.

Each test cycle consists in the following steps:

1. provide the new inputs to the DUT
2. wait for a programmable time period (typically 10 ms)
3. then compare the DUT outputs to the awaited output pattern.
4. go to 1

5.3 Error detection

The test principle is given in Figure 2.
The two types of errors which can be detected and counted are described here below:

- SET error:
  The 5 outputs bits of the adder are connected to 5 toggle latches. These latches are programmed at each test cycle iteration in such a way that the triggering active edge will be in line with the awaited value (for instance, rising edge if the awaited value is 0). At each new cycle iteration, input adder data are changed. (a pattern of 10 different words with the same averaged weight of 0 and 1 in total).
- SEU error:
  The 4 output bits of the register are compared with the awaited value. At each iteration cycle the input bit of the 4-bit register is inverted .

Each test run consists in a continuous sequence of test cycles (as described in section 5.2), each iteration cycle lasting 10ms. Both events can be detected simultaneously.
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 or SET errors induced during latch-up events.

DUT power supply is 5V.

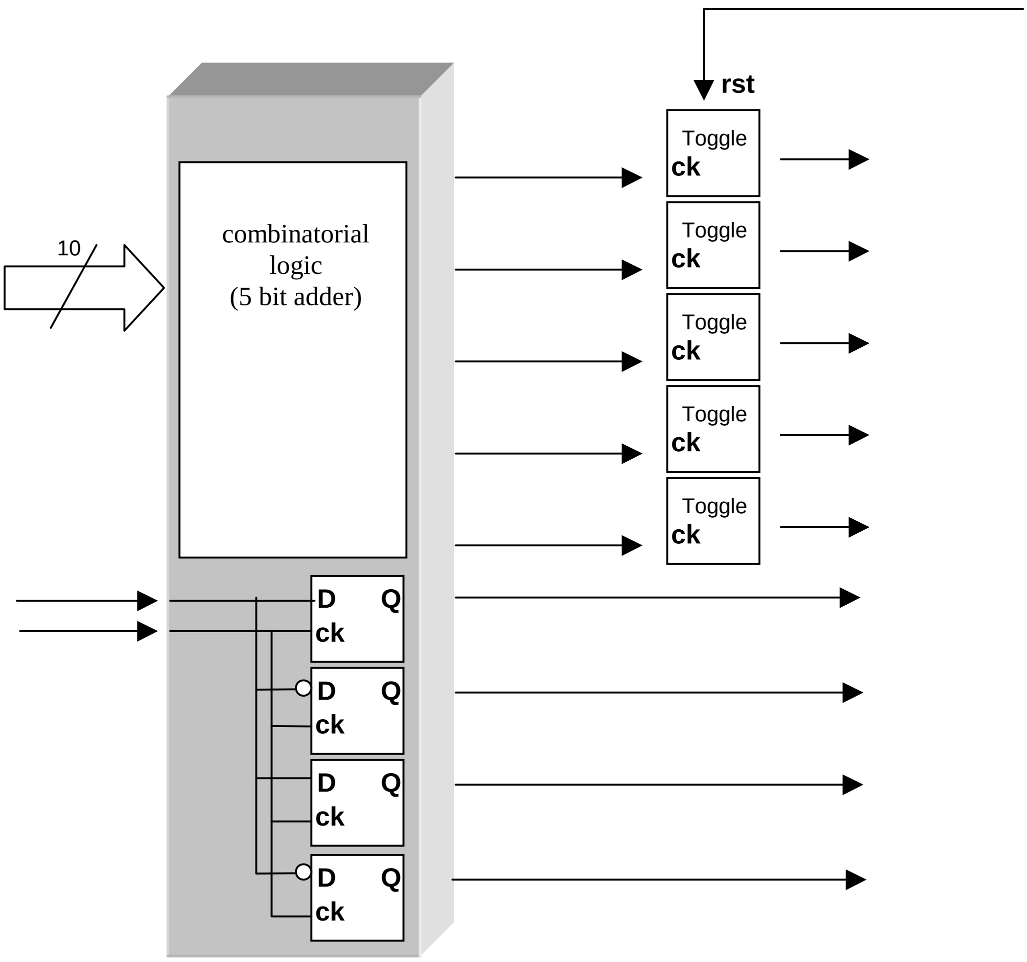

Figure 2 – Test principle

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 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 in paragraph 7.

6.2.2 Flux Range

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

6.2.3 Particle Fluence Levels

Maximum fluence level was set to 1 E6 ions/cm²

6.2.4 Dosimetry

The current UCL Cyclotron dosimetry system and procedures were used.

6.2.5 Accumulated Total Dose

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

6.2.6 Test Temperature

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 Table 1 here below:

Ion Specie	Energy	LET	Range (in Silicon)
	(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 1 – 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 2.

The corresponding SEE (sum of SEU errors and SET errors) error cross-section vs. Effective LET curve is plotted on Figure 3.

As one can see in Table 2, SET were observed with LET of 8 MeV.cm²/mg and higher. SEU with LET of 14 MeV.cm²/mg and higher, and SEL with LET of 34 MeV.cm²/mg.

Very few errors were counted, and thus the results may be subject to statistical fluctuations.

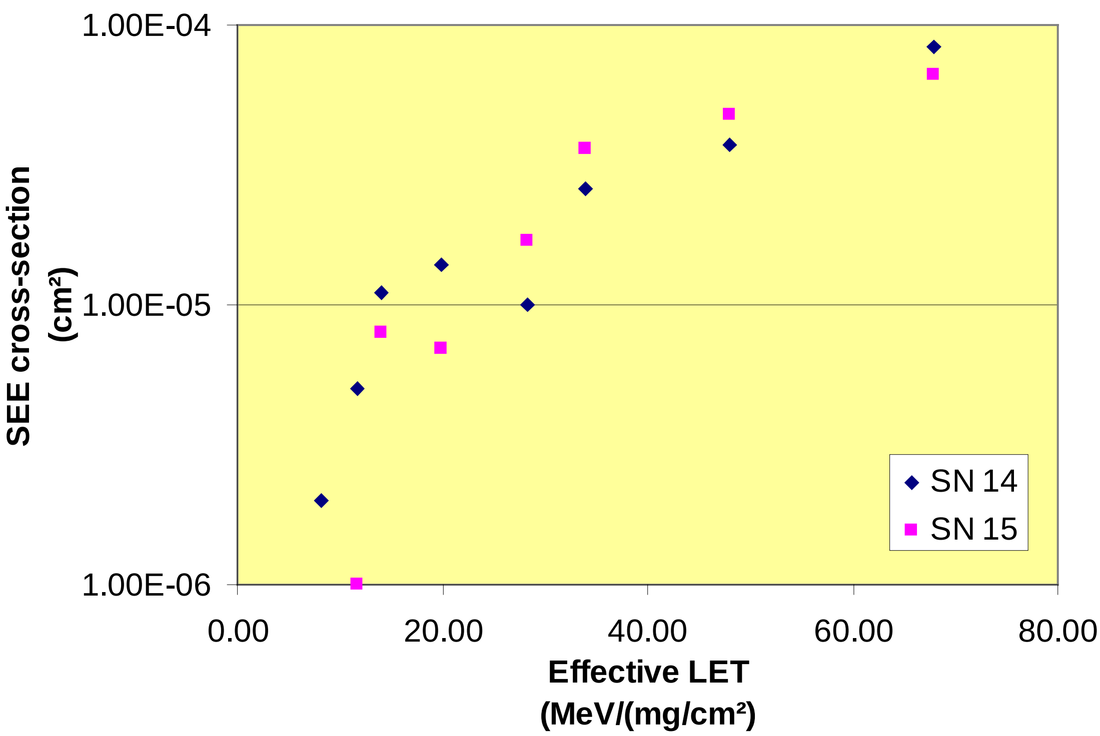

Figure 3- SEE (SEU+SET) cross-section vs. effective LET for GAL22V10

Run #	S/N	Ion	LET (MeV.cm²/mg)	Angle (°)	Eff LET (MeV.cm²/mg)	Time (s)	Fluence (/cm²)	Flux (/cm²/s)	SET	SEU	SEL	SEE cross-section (/cm²)
67	14	Ne	5.85	0	5.85	117	1.00E+06	8547	0	0	0	0.00E+00
68	14	Ne	5.85	45	8.27	162	1.00E+06	6173	2	0	0	2.00E-06
64	14	Ne	5.85	60	11.70	227	1.00E+06	4405	5	0	0	5.00E-06
40	14	Ar	14.10	0	14.10	173	2.00E+05	1156	0	0	0	0.00E+00
47	14	Ar	14.10	0	14.10	228	1.00E+06	4386	9	2	0	1.10E-05
44	14	Ar	14.10	45	19.94	266	1.00E+06	3759	13	1	0	1.40E-05
41	14	Ar	14.10	60	28.20	203	1.00E+05	493	0	0	0	0.00E+00
43	14	Ar	14.10	60	28.20	434	1.00E+06	2304	6	4	0	1.00E-05
114	14	Kr	34.00	0	34.00	918	1.00E+06	1089	21	5	2	2.60E-05
115	14	Kr	34.00	45	48.08	468	1.00E+06	2137	29	8	13	3.70E-05
116	14	Kr	34.00	60	68.00	581	1.00E+06	1721	57	27	15	8.40E-05
66	15	Ne	5.85	0	5.85	113	1.00E+06	8850	0	0	0	0.00E+00
69	15	Ne	5.85	45	8.27	145	1.00E+06	6897	0	0	0	0.00E+00
65	15	Ne	5.85	60	11.70	228	1.00E+06	4386	1	0	0	1.00E-06
46	15	Ar	14.10	0	14.10	237	1.00E+06	4219	8	0	0	8.00E-06
45	15	Ar	14.10	45	19.94	299	1.00E+06	3344	6	1	0	7.00E-06
42	15	Ar	14.10	60	28.20	707	1.00E+06	1414	16	1	0	1.70E-05
119	15	Kr	34.00	0	34.00	263	1.00E+06	3802	29	7	3	3.60E-05
118	15	Kr	34.00	45	48.08	352	1.00E+06	2841	42	6	12	4.80E-05
117	15	Kr	34.00	60	68.00	574	1.00E+06	1742	55	11	23	6.60E-05

Table 2 - Heavy ion detailed results per run

8 CONCLUSION

Heavy ion tests were conducted on hi-rel samples of GAL22V10 parts from LATTICE, using the heavy ions available at the European Heavy Ion Irradiation Facility (HIF) at Cyclone, Université Catholique de Louvain, Belgium.

SETand SEU were observed on this type at a fluence of 1E6 particles/cm².
LET threshold for SEL was found between 28 and 34 MeV/(mg/cm²)
