Saab Ericsson Space

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ESA-QCA9901TS-C

PROJECT

RADIATION EVALUATION OF ACTEL A14100A FPGA

Esa Contract No 11356/95/NI/Fm, Ccn-1

TITLE

WP-1A Final Report, FPGA Summary Report 3

EUROPEAN SPACE AGENCY
CONTRACT REPORT

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SUMMARY

Heavy Ion, Proton and Total Dose tests performed on Actel A14100A FPGA on ESA - High Density Memory Semiconductor Mass-Memory Program, ESA Contract No 11356/95/NL/FM, CCN-1.
Total dose tests have been performed on 3 samples of each 3.3V and 5V biasing condition using Cobalt-60 source at a dose rate of 500 rad(Si)/hour. No functional failure was observed to 50 krad(Si). Standby supply current had increased with a factor 4-6 for 3.3V and a factor 10-12 for 5V at 50 krad(Si). Increase in the standby supply current with 10% occurred at 10 krad(Si) (5V) and 20 krad(Si) (3.3V). Large spread in current values were observed among the test samples.

Single Event Upset tests have be performed with heavy ions in the LET range of 5.8 - 112 MeV and with protons of 300 MeV. Cross sections and LET threshold values have been determined for the C-, S- and I/O-modules for both 3.3V and 5V supply voltage. No latch-up was observed.

DOCUMENT CHANGE RECORD

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1. SUMMARY

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PROJECT DETAILS

PROJECT : High density Memory Semiconductor Mass-Memory
CUSTOMER : ESA/ESTEC

TEST SAMPLE DETAILS

PART TYPE : A14100A
FUNCTIONAL ASSIGNMENT : FPGA
TECHNOLOGY : ONO Antifuse 0.8μm CMOS, Accelerator family
MANUFACTURER : Actel
QUALITY LEVEL : Mil temp
DATE CODE : 9743
PACKAGE : 256 pin CQFP
SAMPLE SIZE : 18
SERIAL NUMBER, SEU : S/N#4, S/N#5, S/N#6
SERIAL NUMBER, P : S/N#7, S/N#8, S/N#9
SERIAL NUMBER, TID (HDR) 5V : S/N#10, S/N#11, S/N#12B
SERIAL NUMBER, TID (HDR) 3.3V : S/N#16, S/N#17, S/N#18
SERIAL NUMBER, TID (LDR) 5V : S/N#13, S/N#14, S/N#15
SERIAL NUMBER, TID (LDR) 3.3V : S/N#19, S/N#20, S/N#21

ELECTRICAL TEST DETAILS

DEVICE LAYOUT DESIGN : Shift Registers for C,S, I/O Modules >97% Utilization
TEST PARAMETERS : During all tests, function and supply current
: Heavy Ion/proton Upset tests of logical modules
C-modules 8x64 bits shift registers = 512 bits
S-modules 4x64 bits shift registers = 256 bits
I/O modules 1x64 bits shift register = 64 bits
TEST EQUIPMENT : Test PC + dedicated test board
TEST TEMPERATURE : room temperature

2. TEST SAMPLES

The A14100A is a third generation FPGA, "accelerator series" (ACT3), from Actel. The tested devices were manufactured by Matshushita. The devices employ antifuse technology implemented in ONO gate, 0.8 µm, two-level metal CMOS. This device is a 10000-gate FPGA with 1153 dedicated flip-flops (697 S- and 680 C-modules) and a maximum of 228 I/O's.

Screening level:	Commercial Temp
Date code:	9743
Chip manufacturer:	Matshushita
Package:	256 - CQFP

Marking / *Top side*	Marking / *Bottom side*
Actel logo	UCL049
A14100A	001
CQ256C 9743	USA

Chip Marking
1993 Actel logo
214100.OM © Ⓜ

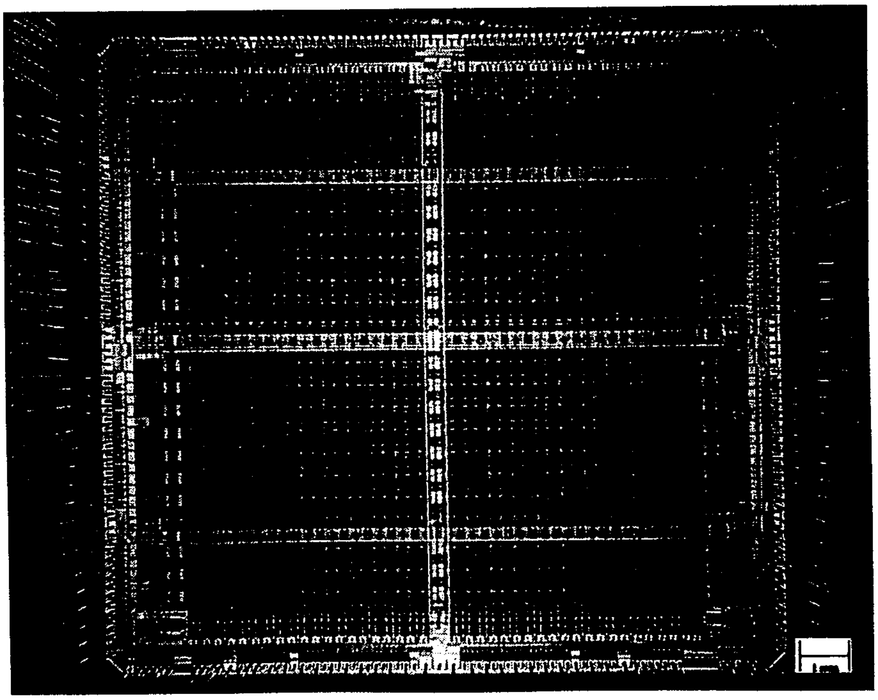


Fig 2.1 Overview of chip A14100A , Magnification 6,5 X
Chip size 12.7 mm x 11.8 mm

3. TEST TECHNIQUES

3.1. General

The general concept is to load data into the DUT's, pause for a pre-set time and thereafter read data and check for errors. A schematic picture is shown in Fig 3.1.1.

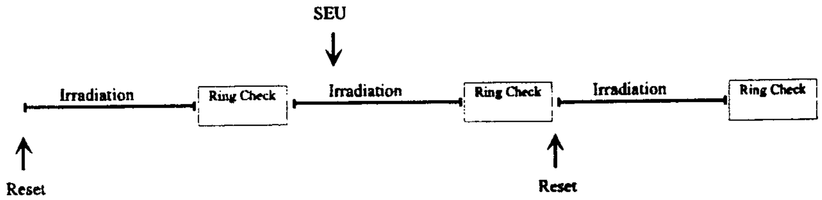


Fig 3.1.1 Schematic view of test sequence.

A flow chart of the test sequence is given in the Fig 3.1.2. Any detected errors will be store in memory, the DUT will be reseted and new data will be loaded again. The cycle will then be repeated. Failing read/write operations from/to the DUT will determine the functionality criteria. The clock speed will be 50 kHz. For each DUT errors can be traced down to logic module, logic value and position.

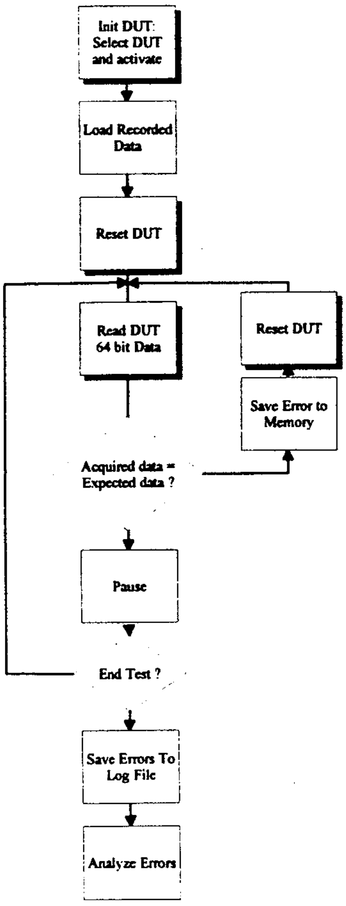


Fig 3.1.2 Flow chart of the test sequence.

3.2. Test Boards

A printed circuit board for the A14100A type were designed and manufactured. The test board can house three Device Under Test (DUT). Illustration of the test board is given in Fig 3.2.1. The design and lay-out are similar to what have been used in previous studies under ESA contract [SE/REP/0042/K]. To verify functionality of the programmed DUT's, test boards and software monitoring system, one DUT was subjected to irradiation by ^{252}Cf.

The DUT's are tested using a "virtual golden chip" test method. The principal of the measuring technique is to compare each output from the DUT with the correct data controlled via a PC. The general concept of the error detection and test sequence is shown in Fig 3.1.2. The DUT is continually cycled while the outputs of selected ring counters are compared by the "golden chip" with three times over sampling. When an error is found (when outputs do not match), the state of all outputs and position in cycle of the failing ring counter will be temporarily stored in the memory. The ring counters (DUT) are then reseted. After each test run the data are analysed and stored in a database by the controlling PC. The PC can be remote controlled via thin Ethernet network in order to cope with long distance transmission if required. For all tests, the devices were clocked at frequency of 50 kHz.

A14100 RVT Board Layout

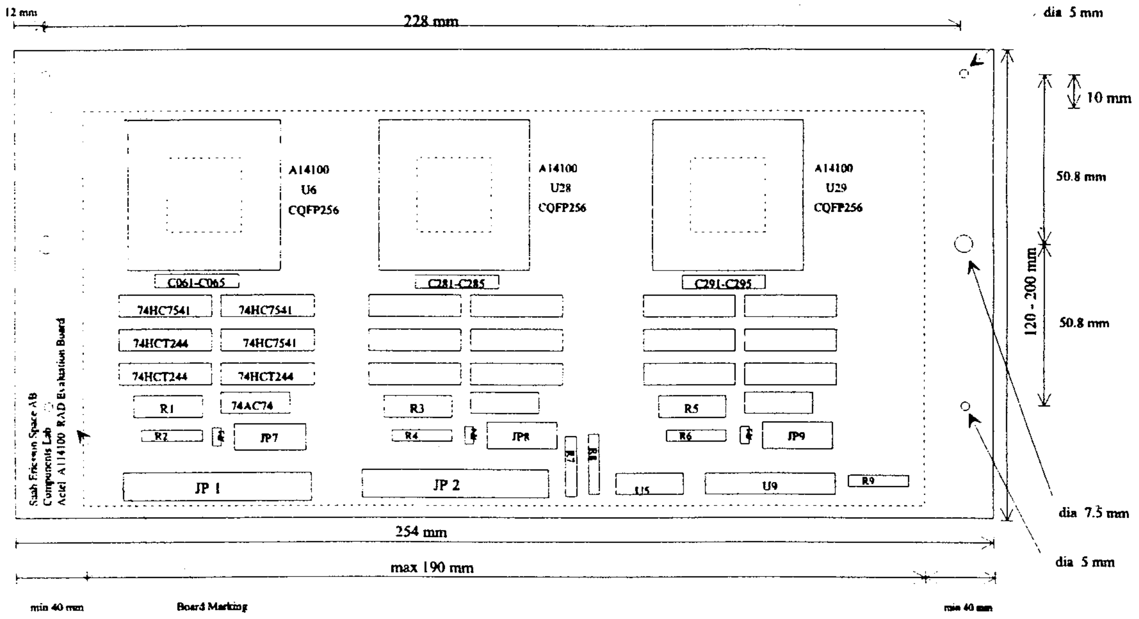


Fig 3.2.1 Lay-out of the A14100A test board. The test board is prepared for both 5V and 3.3 V power on the DUT's. The DUT's are powered individually.

4. ^{252}Cf TEST RESULTS

A dedicated vacuum system for SEU test by ^{252}Cf at Saab Ericsson Space/Components Lab. was used to verify functionality of programmed DUT's, test boards and software monitoring system. The ^{252}Cf source consist of a thin evaporated layer of Californium on metal backing. The source activity was at the time of test 30 kBq. The average nominal stopping power value for the fission fragments is LET=43 MeV/cm^2/mg. However, due to low penetration depth in Si (~13µm), metal and polysilicon layers, the real stopping power value is more likely around a LET of 20- 25 MeV/cm^2/mg. Test results are given in Table 4.1 below.

Table 4.1 Test result from ^{252}*Cf.*

A14100A Power	Flux ion/s	Test Time [h]	Module	Number of SEU's	Cross Section/bit [cm^2/bit]
5V (S/N#4)	65	6	C	8	1. E-8
			S	217	6.1E-7
			I/O	32	3.6E-7
3.3V (S/N#5)	17.4	14.5	C	42	9. E-8
			S	389	1.7E-6
			I/O	58	9.9E-7

5. HEAVY ION TEST

5.1. Equipment & Facility

Heavy ion test was performed at the CYClotron of LOuvain la NEuve (CYCLONE) ,Belgium. This accelerator can cover an energy range of 0.6 to 27.5 MeV/AMU for heavy ions produced in an double stage ECR source. The use of an ECR source allow the acceleration of an ion "cocktail" composed of ions with very close mass over charge ratio. The preferred ion is selected by fine tuning of the magnetic field or a slight change of the RF frequency. Within the same cocktail it takes only a few minutes to change ion species.

The facility provides beam diagnostic and control with continuous monitoring of beam fluence and flux via plastic scintillators. The irradiations were performed in a large vacuum chamber with the test board mounted on a movable frame.
Three samples were delidded and mounted on the board and serialised as S/N #4, S/N #5 and S/N #6. Each device were individually biased. During irradiation the samples were monitored for latch-up.

Table 5.1.1 Ion Beam Data

Ion Specie	Energy (MeV)	Tilt Angle (Degree)	LET (MeV/mg/cm2)	Range (µm)
Ne-20	78	0	5.8	45
		45	8.3	
		60	11.7	
Ar-40	150	0	14.1	42
		45	20	
		60	28.2	
Kr-84	316	0	34	43
		45	48	
		60	68	
Xe-132	459	0	55.9	43
		45	79	
		60	112	

5.2. Results

The results are presented in graphical form showing the SEU cross section per cm^2 per bit versus the LET values. Figure 5.2.1. show the average upset probabilities for all modules, whereas Fig 5.2.2 to Fig 5.2.4 show the sensitivity for C, S and I/O modules, respectively. The LET range was obtained by changing the ion species and the angle of incidence between the beam and the chip. Table 5.1.1 provide the data of the ions used. Cross sections given in the figure captions is taken to be the average value of logical "0" and "1" at ^{132}Xe, 0° LET= 55.9 MeV/mg/cm^2. The threshold value is taken to be the value at 1 % of the cross section value. A summary of the data are given in the conclusion, section 9. No latch-up was observed

The layout of the devices under tests have been a bit pattern consisting of consecutive 0 1 0 1 etc in individually controlled 64-bit ring counters (shift registers) for each logical module C, S and I/O. The C- and S- module rings have been designed using the two macros, DFPC and DFC1B, respectively. I/O modules has been designed with macros IR and ORH for input and output, respectively. The device design of all shift registers has been auto place & route using Actel Designer software. The used design take 97,8 % of available space in the devices. The number of bits subjected for tests are summarized in Table 5.2.1 below.

For S-modules, the high SEU sensitivity resulted in good statistical accuracy. Good homogeneity in the data between the sample were observed. The average SEU sensitivity for I/O is very similar to the S-module, however, for the I/O modules the sensitivity between "1" and "0" are much smaller. The logical "1" (high) SEU cross sections are a factor 3-4 higher than the logical "0" (low) cross sections for the S-modules. The average values for 3.3 V are about a factor 2 higher than the 5 volt values. For C modules, the SEU sensitivity are lower which results in limited statistics particular for the lower LET values and the least sensitive "0" state. No latch-up was observed.
During the Xe-ion irradiation , LET=56 Mev/cm^2/mg, (Run #86, S/N#6, 0°, flux=1500 ions/cm^2/s and Run #89, S/N#4, 45°, flux= 1000 ions/cm^2/s) with the samples biased to 5V, the I/O ring in S/N#6 and one S ring in S/N#4 indicated permanent errors.
The I/O ring show 32 bit errors each time it was read independent of beam on/off. The expected data should be "1" , while "0" was read out in 32 bits. The remaining 32 bits of the shift register should be "0". The behaviour indicated that one logical module failed to hold a "1" but worked to transfer data.
The S-ring showed 64 bit errors each time it was read independent on beam on/off. The results indicate that the clock signal to this particular S-ring are coming out of phase one clock cycle. Both failures seem to be of permanent character.

Table 5.2.1 Number of bits tested

	C-Module	S-Module	I/O-Module
A14100A	512 (8 ring counters)	256 (4 ring counters)	64 (1 ring counter)

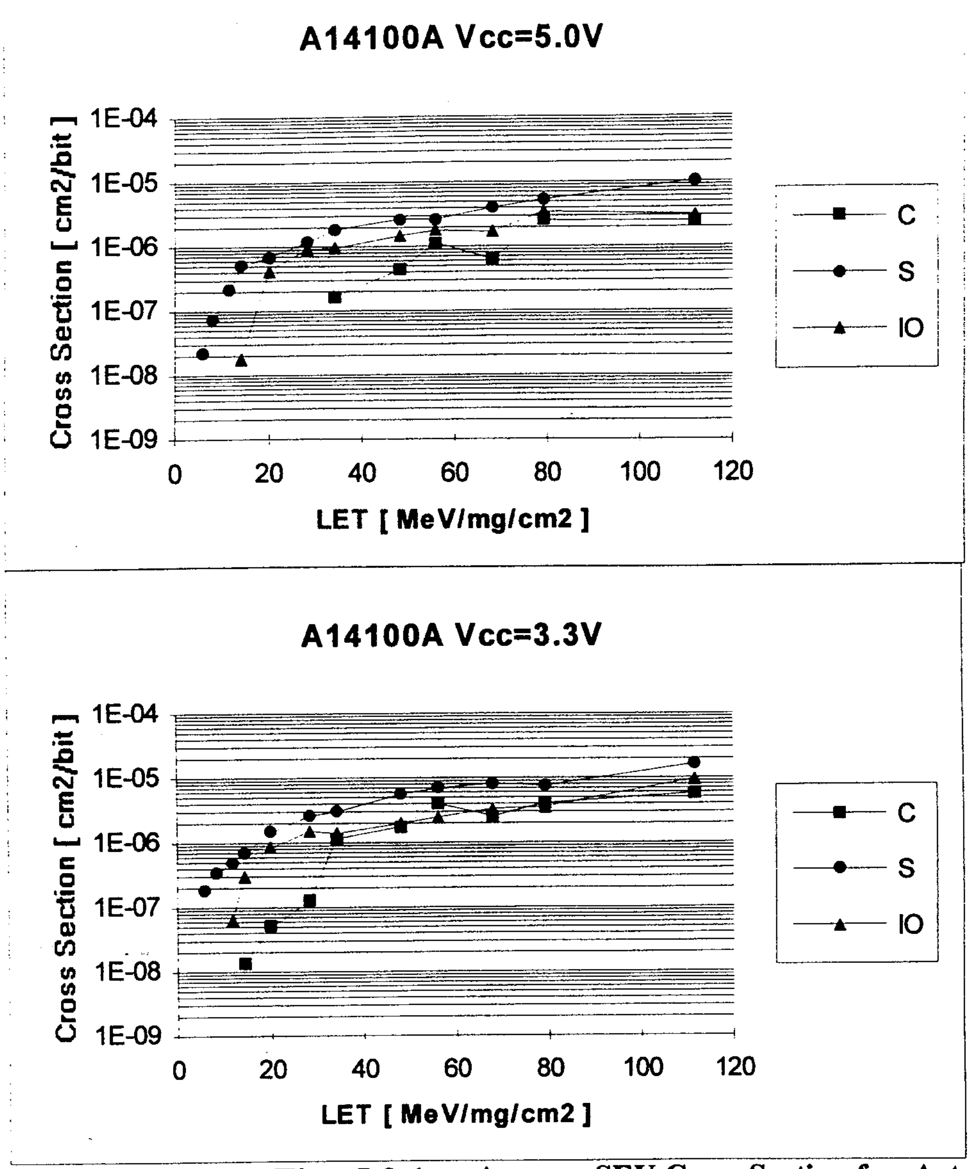


Fig 5.2.1 : **Average SEU Cross Section for Actel A14100A C, S and I/O-Modules**

Test Condition :	Static, Vcc = 5V & 3.3V, T_{amb}= Room Temp	
Test Samples :	A14100A, 256-pin CQFP, S/N #4, #5, #6	
C-Module , Cross Section (σ) :	5V	1 E-6 cm^2 /bit
	3.3V	3 E-6 cm^2 /bit
Threshold :	5V	30 MeV/mg/cm^2
	3.3V	15 MeV/mg/cm^2
S-Module , Cross Section (σ) :	5V	3 E-6 cm^2 /bit
	3.3V	7 E-6 cm^2 /bit
Threshold :	5V	5 MeV/mg/cm^2
	3.3V	3 MeV/mg/cm^2
I/O-Module , Cross Section (σ) :	5V	2 E-6 cm^2 /bit
	3.3V	2.5 E-6 cm^2 /bit
Threshold :	5V	15 MeV/mg/cm^2
	3.3V	10 MeV/mg/cm^2

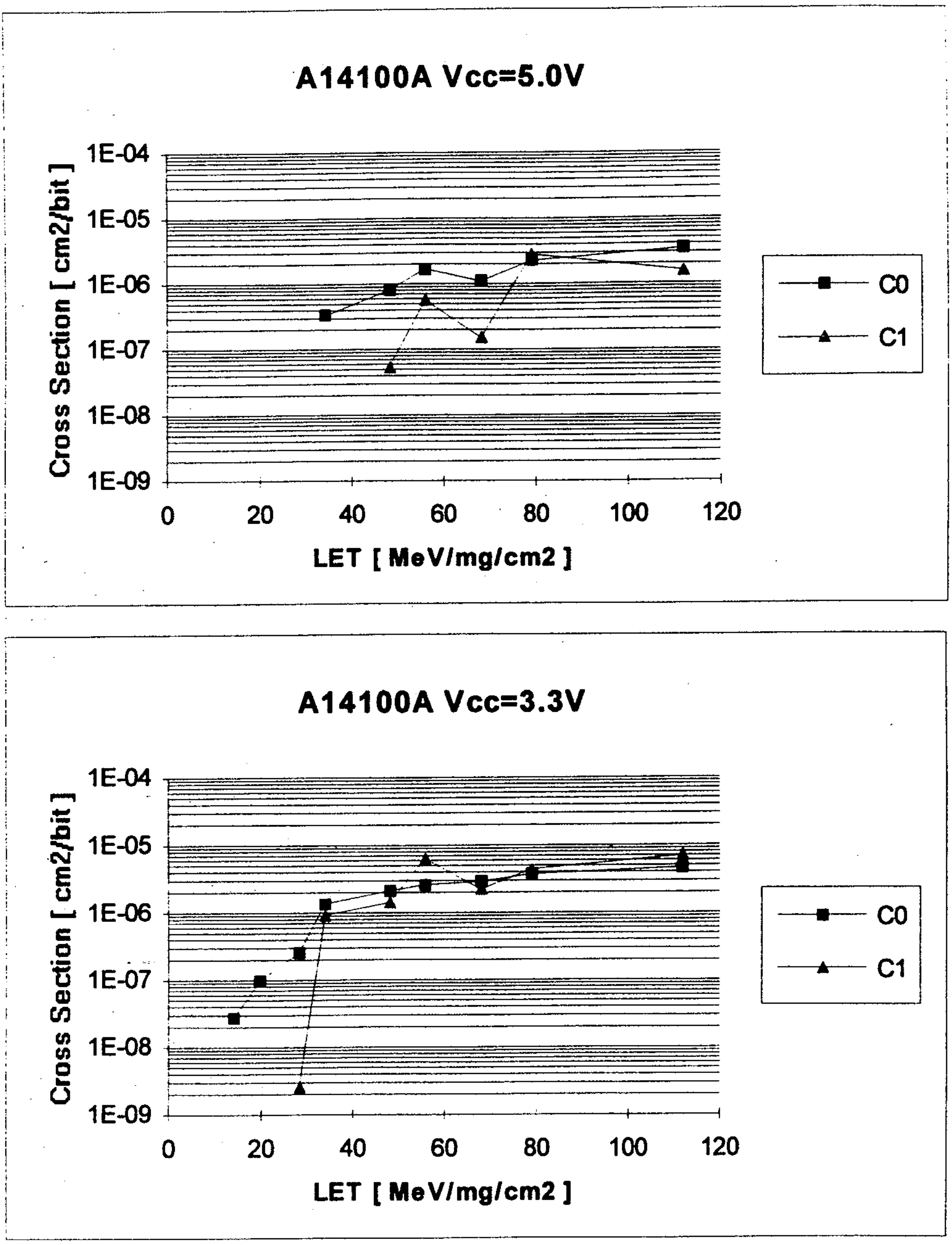
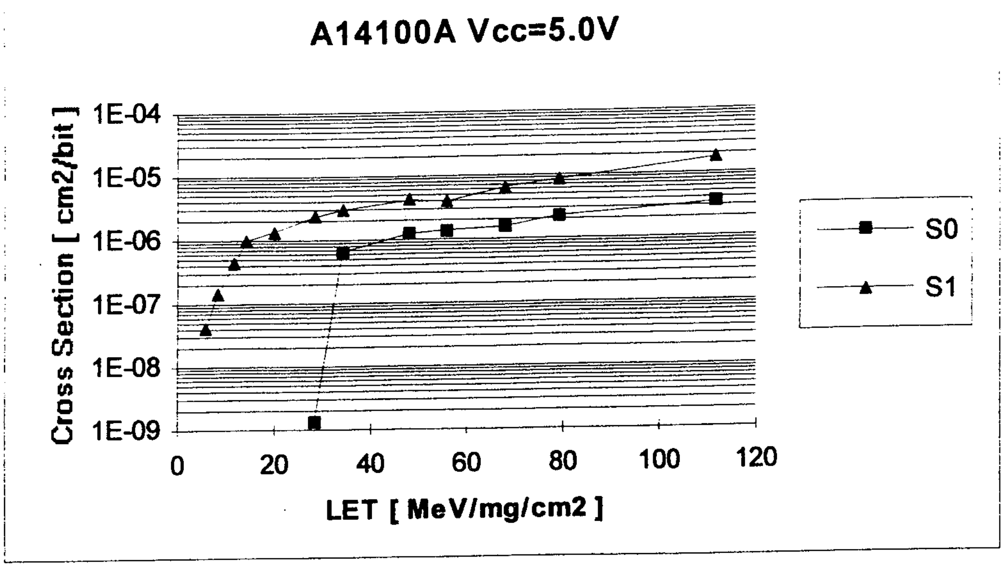


Fig 5.2.2 : **SEU Cross Section for Actel A14100A C-Modules**

S/W Macro :	DFPC
Test Condition :	Static, Vcc = 5V & 3.3V, T_{amb}= Room Temp
Test Samples :	A14100A, 256-pin CQFP, S/N #4, #5, #6
C-Module Comments :	The differences in sensitivity between "1" and "0" are very small and only evident at low LET values.



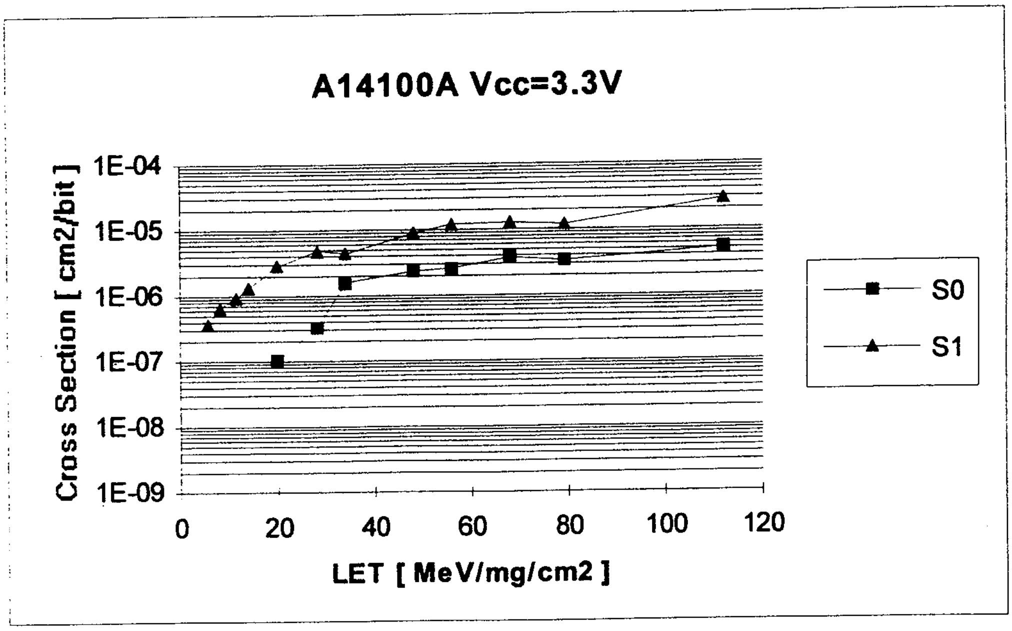
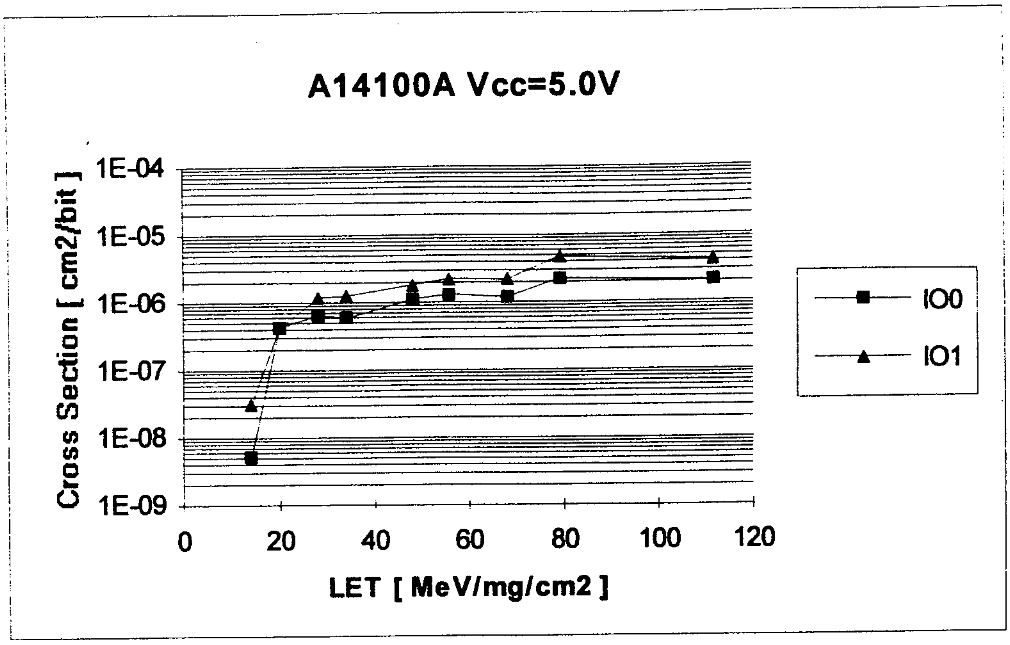


Fig 5.2.3 : **SEU Cross Section for Actel A14100A S-Modules**

S/W Macro :	DFC1B
Test Condition :	Static, Vcc = 5V & 3.3V, T_{amb}= Room Temp
Test Samples :	A14100A, 256-pin CQFP, S/N #4, #5, #6
S-Module Comments :	The differences in sensitivity between "1" and "0" are about a factor 3-5 for both 5V and 3.3 V at large LET. The number of detected errors for "0" at low LET are very small which give statistical uncertain values for the lowest LET.



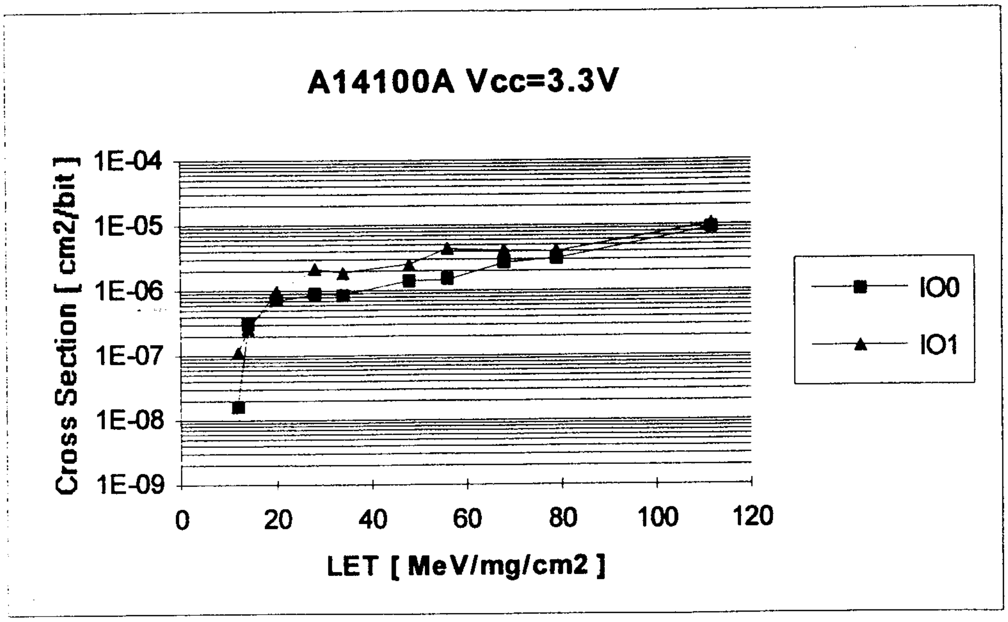


Fig 5.2.4 : SEU Cross Section for Actel A14100A I/O-Modules

S/W Macro :	ORH for logic "1" , IR for logic "0"
Test Condition :	Static, Vcc = 5V & 3.3V, T_{amb}= Room Temp
Test Samples :	A14100A, 256-pin CQFP, S/N #4, #5, #6
I/O-Module Comments :	

6. PROTON RESULTS

6.1. Equipment & Facility

Proton test was performed at the Proton Irradiation Facility (PIF) at Paul Scherrer Institute, Villigen, Switzerland. Proton energy of 300 MeV can be achieved in a flux of maximum 10^8 protons/s / cm^2. The DUT is irradiated in air at normal incident angle. The facility provides beam diagnostic and control with continuous monitoring of beam fluence and flux via plastic scintillators. The ion energy on target can instantly and continuously be attenuated by Aluminium slides from maximum energy down to about 30 MeV. Energy attenuation of the proton beam results in strongly reduced flux. Due to the limited number of proton induced upsets, the present tests were only performed at proton energies of 300 and 150 MeV.

Three samples, S/N #7, #8, #9 were prepared for the test. Sample #9 was damage by handling during debugging of test board at the beam line. Due to spurious events interrupting the data acquisition system and to problem with the proton beam, the allocated beam time did not allow proton test of all samples at 150 MeV and 300 MeV for both 5V and 3.3V.
The irradiation cave is prohibited area during "beam on", which require controlling equipment to be placed about 50 meters away from the DUT. The PC acquisition system was placed close to the DUT in the irradiation area and remote controlled by a second monitoring computer in the control room using thin Ethernet network. The heavy background of neutrons in the irradiation cave give rise to upsets in the accusation computer. Because of the very low count rate of proton upsets, any interruption in the network system was difficult to observed. In these low count rate tests, the acquisition system should be able to read the fluence periodically.

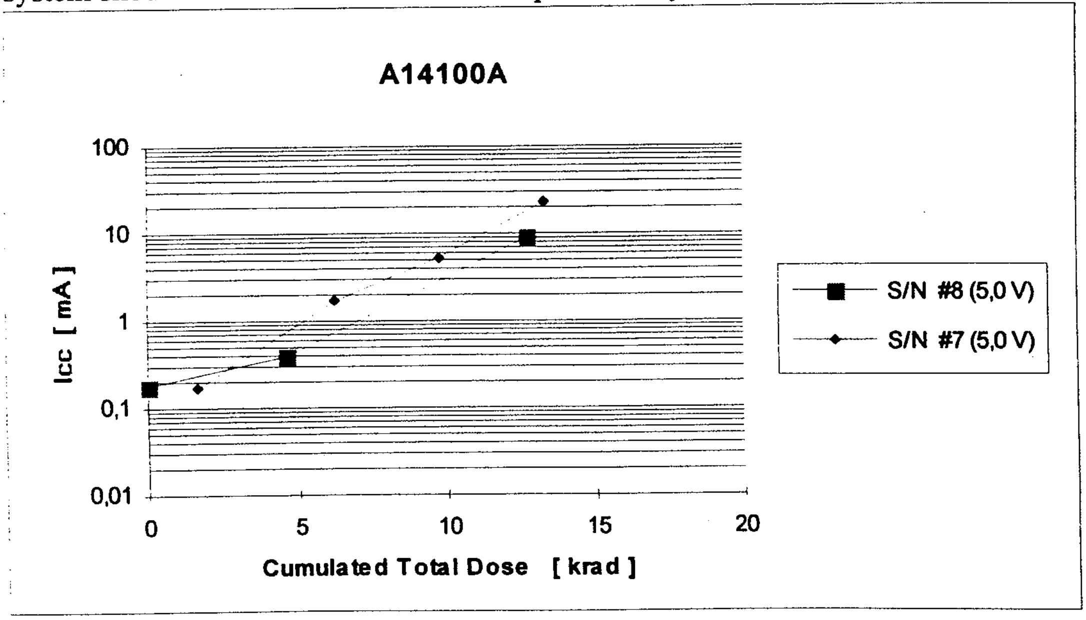


Fig 6.2.1 Supply current as a function of cumulated total dose received by the test samples during proton irradiation. For 10^{11} protons/ cm^2 of 300 MeV, the theoretically calculated total dose value is 4,5 krad(Si). For 150 MeV, the same amount of protons give 7 krad(Si). S/N #8 failed to function during 3,3V 300 MeV irradiation at accumulated dose of 17 krad(Si). No current measurement was performed after functional failure.

6.2. Results

The results are summarised in Table 6.2.1 and illustrated in Fig 6.2.2. Proton upsets were observed at 300 MeV protons for flip-flops made out of both S- and I/O- modules. Due to problems with the acquisition system, five test runs were affected by uncertain proton fluence data and have therefore been omitted. The total dose seen by the two tested samples as a function of supply current are given in Fig. 6.2.1. Protons of 300 MeV give 4,5 krad per 10^{11} protons. Device S/N #7 failed to work during the 3.3V, 300 MeV irradiation period likely due to total dose damage. S/N #8 had obtained 17 krad cumulated dose from 300 Mev and 150 MeV protons at failure.

The results are similar to the results earlier obtained for A1460A. The point that clearly differs are at 3,3V, which in the present test is a factor four lower than in the A1460A case.

Table 6.2.1 Test results of proton induced upsets on A14100A. Maximum flux obtained was 10^8 protons/cm^2. The 300 MeV data points at 5V are very similar to earlier tested A1460A. No data on 150 MeV exist for A1460A. The 3,3V data points at 300 MeV are a factor 4 lower than the A1460A data.

Device S/N	Vcc	Energy Mev	Fluence	S-Module # upsets	I/O-Module #upsets	S-Module Cross Section (cm2/bit)	I/O-Module Cross Section (cm2/bit)
#8	5	300	1,0E+11	8	1	3,1E-13	1,6E-13
#7	5	300	1,0E+11	3	0	1,2E-13	
#7	5	150	4.5E+10	1	0	8,8E-14	
#8	3,3	300	1,0E+11	6	0	2,3E-13	
#7	3.3	300	7,7E+10	3	0	1,5E-13	

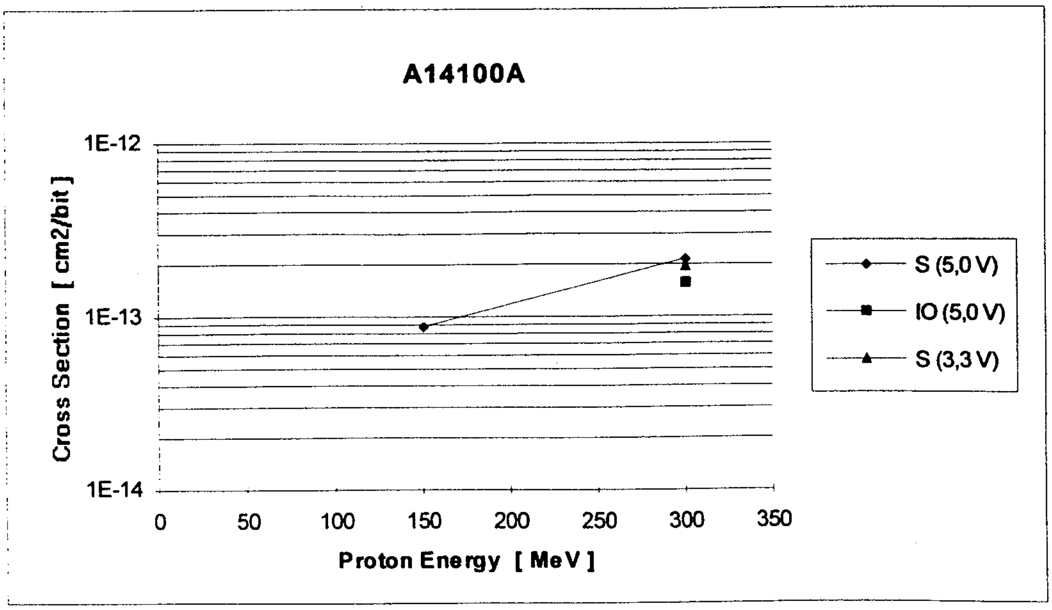


Fig 6.2.2 Graphical illustration of proton cross sections given in Table 6.2.1

7. TOTAL DOSE TEST

7.1. Equipment & Facility

The total dose tests were performed at the hospital Sahlgrenska Sjukhuset, Göteborg. This facility has a ^{60}Co gamma source suitable for low dose rate testing. The dosimetry calibration are taken care of by the local medicine physicist. The dosimetry detectors undergoes calibration to a substandard on regular basis and the determined dose is correct within 5 %.

Three samples biased at 5V, (S/N#10, S/N#11, S/N#12B) and three samples biased at 3,3V, (S/N#16, S/N#17, S/N#18) were tested under steady state irradiation at a dose rate of 500 rad(Si) per hour. All devices were programmed with the test pattern presented in section 3.
The supply current was measured in situ and the function was monitored once every minute by clocking in data followed by subsequent read out and comparison.
The definition of functional failure is when read data do not match with pre-defined data. Functional tests were performed at 50 kHz for each V_{CC}.
Before each functional test, the devices were powered OFF/ON and allowed to stabilised for 2 seconds before the measurement. The test was perused up to 50 krad(Si) total dose. After irradiation, the devices were subjected to biased room temperature anneal for one week.

7.2. Total Dose Results

No functional failure was detected during irradiation by ^{60}Co at a dose rate of 500 rad(Si)/hour. The devices were powered on/off before each functional test in order to verify that the charge pump or the charge distribution didn't cause unpredictable operation.
Figs 7.2.1 , 7.2.2 and 7.2.3, 7.2.4 show the supply current and the room temperature anneal as a function of cumulated dose for 5V and 3.3V biasing condition, respectively. The current measurement were performed with non-operating devices and thus representing a standby current. The increase in the current is substantially smaller at 3.3V than at 5V biasing. The maximum increase in current at 50 krad(Si) was a factor of 5-6 for 3.3V while it is the double for 5V.
The measurements show a large spread in the current values for the various devices as a function of cumulated dose. Different layout and utilization of the device may give different behaviour of the current as a function of cumulated dose.

Biased room temperature anneal with the devices subjected to the normal functional test indicated no functional failure after one week. The supply current decreased with about a factor 3-4 for 5V, which indicate that the there are a dose rate effect included in the current response on irradiation at the present dose rate. The biased room temperature anneal test is considered to be static.

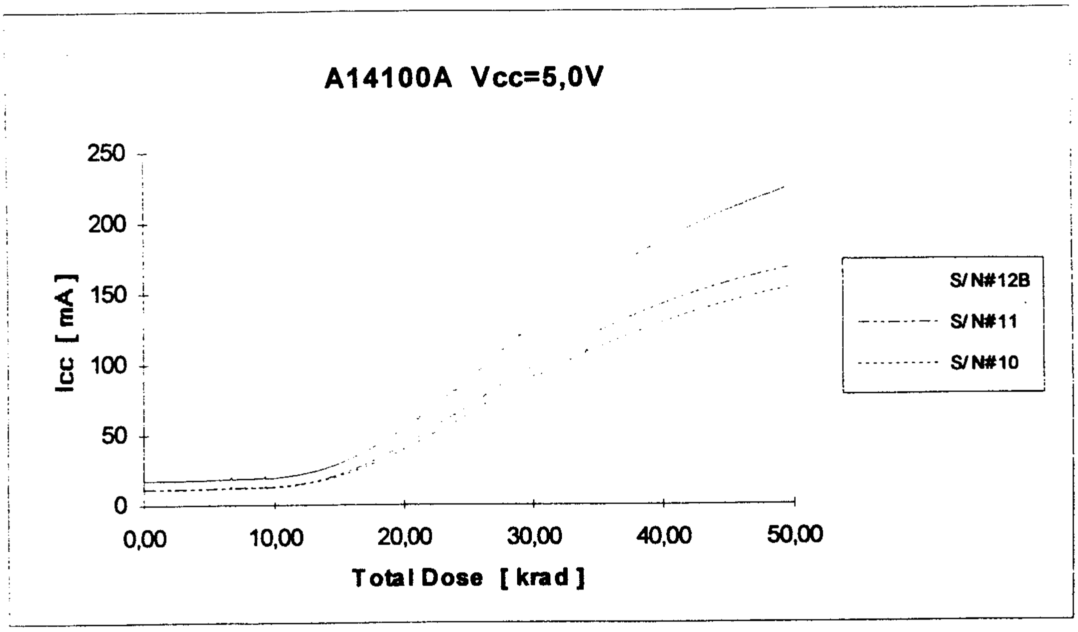


Fig. 7.2.1 Supply current as a function of cumulated total dose for A14100A biased at 5V. The devices were powered off/on before each functional test. At around 10 krad(Si) cumulated dose the current of the devices has increased with 10% of the pre-irradiation value.

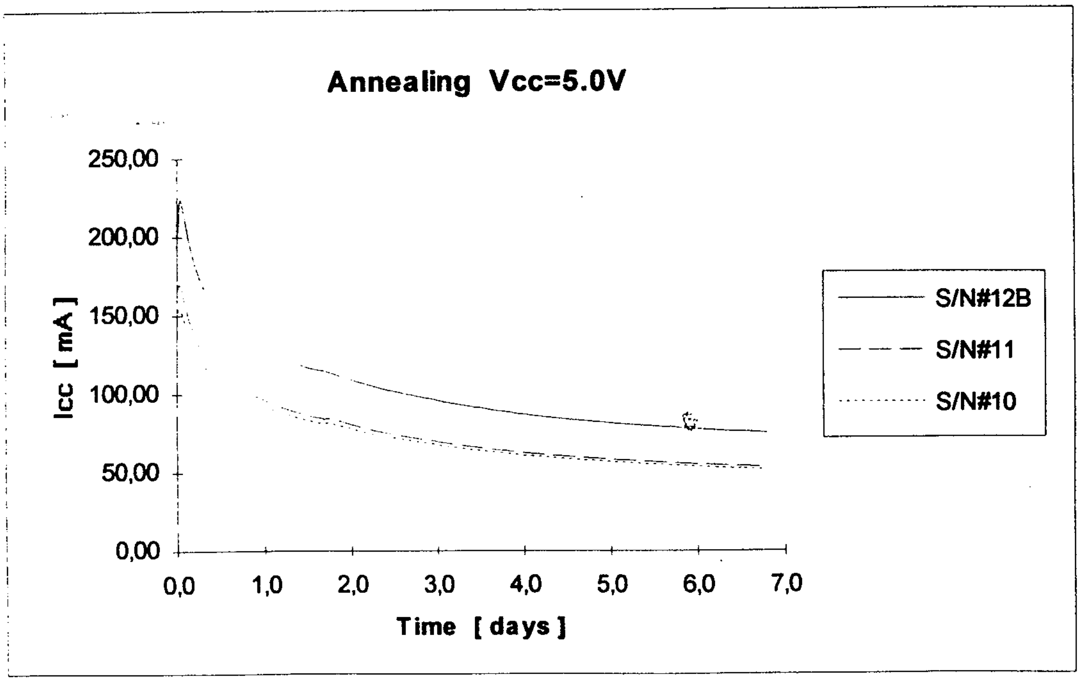


Fig. 7.2.2 Supply current as a function of room temperature anneal for A14100A biased at 5V. The devices were powered off/on before each functional test. After one week of biased room temperature anneal the standby current has decreased with about a factor 4 resulting in about the same value as for 20 krad(Si) cumulated total dose at a dose rate of 500 rad(Si)/hour.

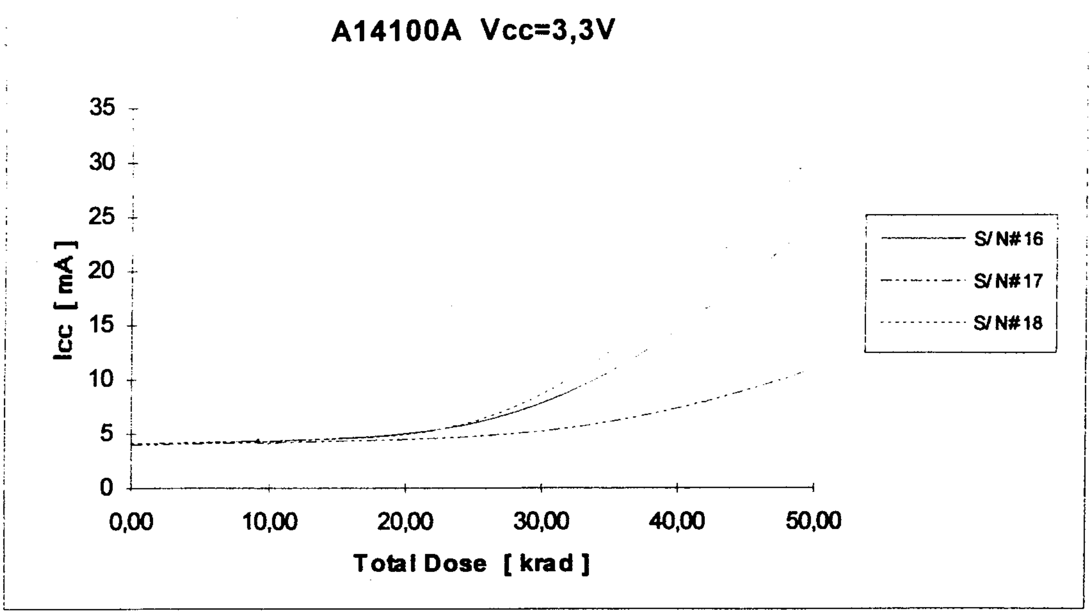


Fig. 7.2.3 Supply current as a function of cumulated total dose for A14100A biased at 3.3V. At 18-20 krad(Si) cumulated dose the current of the devices has increased with 10% of the pre-irradiation value.

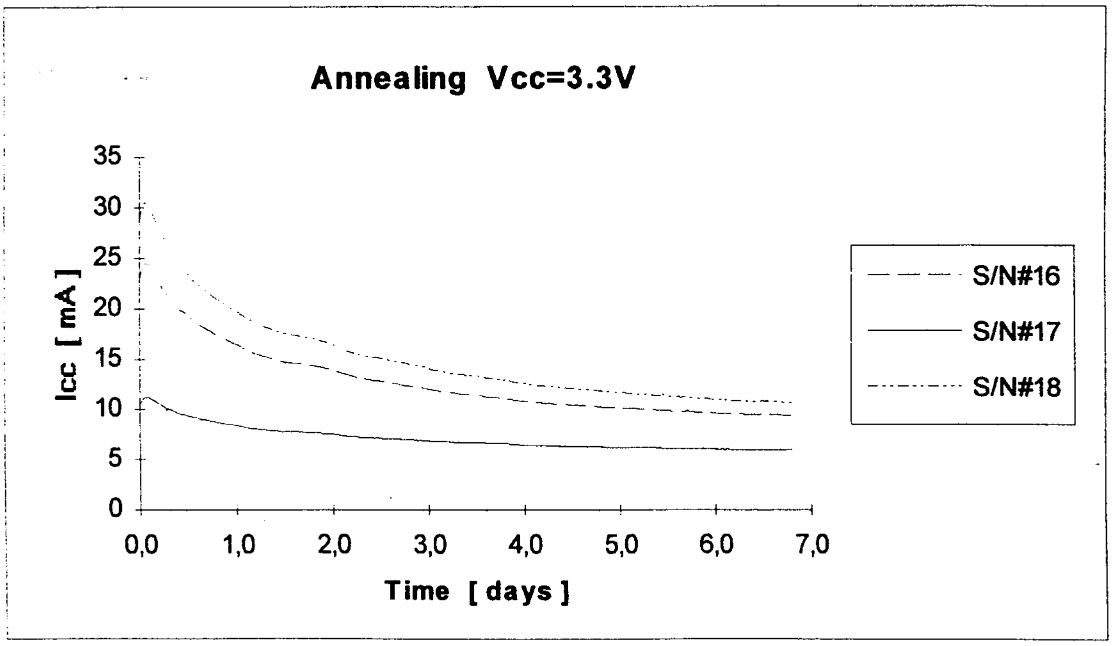


Fig. 7.2.3 Supply current as a function of room temperature anneal for A14100A biased at 3.3V.

8. CONCLUSION

Actel A14100A is manufactured by Matshushita (MEC) in antifuse ONO gate 0.8 µm, two-level metal CMOS technology. Actel FPGA's from MEC have in general shown good radiation tolerance. No screening has been performed on the devices prior to radiation tests apart from the manufacturer screening.
The present total dose test indicate no functional problems up to 50 krad(Si) cumulated total dose for both 5V and 3.3V supply voltage. Under 3.3V biasing conditions the supply current increased in average with a factor 5-6 to about 25 mA at 50 krad(Si) while at 5V, Icc increase about 10-12 times for the same total dose.
A large spread in current values was observed for the tested devices. Increase in standby supply current with 10% occurred around 10 Krad(Si) for 5V biasing condition and around 18-20 krad(Si) for 3.3 biasing condition.
In the proton test, one of the tested devices failed to function at around 17 krad(Si) generated by 300 and 150 MeV protons equivalent to 3.8 10^{11} protons. The course of the failure is likely a combination of high dose rate and displacement damage from particle irradiation.

The proton cross sections are based on very small error numbers. Compared to earlier tests for A1460A, the present results indicate a little lower cross section for 5V and a factor 3-4 lower for 3.3V. Taken into account the low statistics of errors for the proton tests, this is in line with the observed average difference in cross section between the two device types.

The results from the heavy ion tests indicate about the same or less sensitivity for heavy ions than previously tested MEC manufactured A1460A. Particularly for 3.3V biasing, the SEU cross sections for the S-module seem to be lower for the A14100A type. Large difference in sensitivity between logical high values "1" and logical low values "0" are observed, particularly for S modules. No latch-up was observed.

During irradiation with Xe ions, LET=56 Mev/cm^2/mg at normal incidence, indication of permanent errors due to heavy ion irradiation were observed i two of the three test samples. The failures occurred in the last test sequence with the samples biased to 5V. All samples had been tested at 3.3V with Xe ions before the 5V test. Sample S/N#6 indicated I/O ring failure at 0° with a flux of 1500 Xe-ions/cm^2/s. The Xe irradiation on S/N#6 started at 45° with a fluance of 2 10^5 Xe-ions/cm^2. Sample S/N#4 indicated permanent error in one S-ring in the first test run with Xe ions (45°, flux= 1000 ions/cm^2/s).

The two errors seem to be of different origin. In the I/O case, the expected data should be "1" , while "0" was read out in 32 bits. The remaining 32 bits of the shift register should be "0". Only one cell need to be damaged to get this result. In the S-ring case, one full shift register 64 bits, was read out each time the register was accessed independent of beam on/off. The results indicate that the clock signal to this particular S-ring are coming out of phase one clock cycle. Both failures seem to be of permanent character.

The S-ring failure may be explained with a heavy ion creating a micro-dose damage around the clock distribution to the specific S-ring which course the signal to be delayed. All shift registers has been auto place & route using Actel Designer software. The I/O error indicated that one logical I/O module failed to hold a "1" but worked to transfer data.

SEU cross section and threshold values averaged over all test samples are summarised in Table 9.1 below. For C and I/O modules Table 9.1 show average values over "1" and "0" , while for S-module only "1" cross section and threshold are shown due to the absence of data for A1460A for "0".

Table 9.1 Summary of average cross section and LET threshold values for A1400A and A1460A. S-module data are given for "1" only.

S-Module	A14100A		A1460A	
	3.3V	5V	3.3V	5V
Cross Section* (cm2)	1 E-5	4 E-6	1.5 E-5	7 E-6
LET Threshold* (MeV/mg/cm2)	4	6	6	8
C-Module				
Cross Section (cm2)	3 E-6	1 E-6	3 E-6	8 E-7
LET Threshold (MeV/mg/cm2)	15	30	20	30
I/OModule				
Cross Section (cm2)	2.5 E-6	2 E-6	3 E-6	2 E-6
LET Threshold (MeV/mg/cm2)	10	15	10	15

* Only "1" Data

9. APPENDIX A, Heavy ion data

Test data on A14100A for each test run at UCL, 1997.11.08

Component:	A14100A
Facility	UCL
Source:	Heavy Ion
Date	1997-11-08
Test time, start	13:38:00
Test time, end	21:53:00

Run#	**device#**	**LET**	**Fluence**	**Flux**	**Cumulated**	**Ion**	**Tilt**	**Errors:**						**Note**	
				(typcial)	**Total Dose**			**C_0**	**C_1**	**S_0**	**S_1**	**IO_0**	**IO_1**		
		[MeV/mg/cm2]	*[#/cm2]*	*[p/cm2/sec]*	[rad]										
1	4	14	0		9	Ar40	0	0	0	0	0	0	0		Calibration
2	4	14	1005297	8000	236	Ar40	0	0	0	0	107	0	1	Vcc=5,0	
3	4	14	1002728	800	462	Ar40	0	0	0	0	108	1	0	Vcc=5,0	
4	4	20	1003974	5000	782	Ar40	45	0	0	0	175	15	13	Vcc=5,0	
5	4	20	1003427	5000	1102	Ar40	45	0	0	0	166	19	14	Vcc=5,0	
6	4	28	500524	3000	1328	Ar40	60	0	0	0	149	14	17	Vcc=5,0	
7	4	28	501843	3000	1555	Ar40	60	0	0	0	147	11	23	Vcc=5,0	
8	5	28	500725	3000	226	Ar40	60	45	3	37	305	27	30	Vcc=5,0	; UNBIASED
9	5	28	503314	3000	453	Ar40	60	0	0	0	161	13	15	Vcc=5,0	
10	5	28	502472	3000	680	Ar40	60	0	0	0	153	8	20	Vcc=5,0	
11	5	20	507263	5000	842	Ar40	45	0	0	0	90	6	8	Vcc=5,0	
12	5	20	502730	5000	1002	Ar40	45	0	0	0	94	5	10	Vcc=5,0	
13	5	14	1003142	8000	1228	Ar40	0	256	256	128	241	32	32	Vcc=5,0 ;clock error	clock error not used
14	4	14	27676			Ar40	0	0	0	0	0	0	0		Calibration
15	5	14	1000882	8000	1460	Ar40	0	0	0	0	145	0	1	Vcc=5,0	
16	5	14	1006833	8000	1687	Ar40	0	0	0	0	130	0	0	Vcc=5,0	
17	6	14	1002018	8000	226	Ar40	0	0	0	0	138	0	3	Vcc=5,0	
18	6	14	1001645	8000	452	Ar40	0	0	0	0	133	0	1	Vcc=5,0	
19	6	20	502325	5000	612	Ar40	45	0	0	0	96	5	4	Vcc=5,0	
20	6	20	503060	5000	773	Ar40	45	0	0	0	86	5	5	Vcc=5,0	
21	6	28	500509	3000	999	Ar40	60	0	0	0	147	10	23	Vcc=5,0	
22	6	28	502258	3000	1225	Ar40	60	0	0	0	139	7	17	Vcc=5,0	
23	6	28	501853	3000	1452	Ar40	60	41	0	24	304	16	42	Vcc=3,3	
24	6	20	501790	5000	1612	Ar40	45	21	0	10	169	12	16	Vcc=3,3	
25	6	14	503071	8000	1725	Ar40	0	7	0	0	86	3	4	Vcc=3,3	
26	5	14	501759	8000	1348	Ar40	0	5	0	0	79	6	7	Vcc=3,3	
27	5	20	500726	5000	1507	Ar40	45	9	0	6	201	11	17	Vcc=3,3	
28	5	28	502001	3000	1734	Ar40	60	28	0	24	329	11	24	Vcc=3,3	

29	4	28	503064	3000	1791	Ar40	60	29	0	16	313	16	37	Vcc=3,3	
30	4	20	501427	5000	1951	Ar40	45	9	0	4	174	11	14	Vcc=3,3	
31	4	14	1005407	8000	2178	Ar40	0	2	0	0	184	11	6	Vcc=3,3	
32	4	6	0		2178	Ne20	0	0	0	0	0	0	0		calibration
33	4	6	0		2178	Ne20	0	0	0	0	0	0	0		calibration
34	4	6	0		2178	Ne20	0	0	0	0	0	0	0		calibration
35	4	6	1001533	10000	2271	Ne20	0	0	0	0	42	0	0	Vcc=3,3	
36	4	8	1006127	7000	2404	Ne20	45	0	0	0	85	0	0	Vcc=3,3	
37	4	12	1000453	5000	2592	Ne20	60	0	0	0	108	0	4	Vcc=3,3	
38	5	12	501258	5000	1828	Ne20	60	256	256	128	184	32	32	Vcc=3,3	Not used
39	5	12	501760	5000	1922	Ne20	60	0	0	0	63	1	0	Vcc=3,3	
40	5	8	504704	7000	1989	Ne20	45	0	0	0	34	0	0	Vcc=3,3	
41	5	6	1001794		2082	Ne20	0	0	0	0	43	0	0	Vcc=3,3	
42	6	6	1000562	11500	1819	Ne20	0	0	0	0	52	0	0	Vcc=3,3	
43	6	8	1006107	8000	1952	Ne20	45	0	0	0	96	0	0	Vcc=3,3	
44	6	12	502917	5000	2046	Ne20	60	0	0	0	75	0	3	Vcc=3,3	
45	6	12	1003884	5000	2234	Ne20	60	0	0	0	49	0	0	Vcc=5,0	
46	6	8	1002272	8000	2367	Ne20	45	0	0	0	20	0	0	Vcc=5,0	
47	6	6	1008378	10000	2461	Ne20	0	0	0	0	0	0	0	Vcc=5,0	
48	0	6	1003838	11000	2176	0	0	0	0	0	0	0	0		Not used
49	5	8	1006297	7000	2309	Ne20	45	0	0	0	17	0	0	Vcc=5,0	
50	5	12	1005031	6000	2498	Ne20	60	0	0	0	60	0	0	Vcc=5,0	
51	4	12	1001259	6000	2788	Ne20	60	0	0	0	56	0	0	Vcc=5,0	
52	4	6	1002793	8000	2921	Ne20	45	0	0	0	16	0	0	Vcc=5,0	
53	4	6	1002657	12000	3015	Ne20	0	0	0	0	0	0	0	Vcc=5,0	
0	4	0	0		0	Ne20	0	0	0	0	0	0	0		Calibrate
55	4	34	541144	6000	3309	Kr84	0	46	0	46	197	9	25	Vcc=5,0	
56	4	48	501401	3700	3695	Kr84	45	103	11	83	275	17	29	Vcc=5,0	
57	4	68	501805	2000	4241	Kr84	60	128	13	86	407	25	27	Vcc=5,0	
58	5	68	501629	2000	3043	Kr84	60	154	26	113	421	13	43	Vcc=5,0	
59	5	48	501033	2500	3429	Kr84	45	105	3	76	262	19	30	Vcc=5,0	
60	5	34	501710	3000	3702	Kr84	0	44	0	37	193	8	21	Vcc=5,0	
61	6	34	507698	3000	2737	Kr84	0	42	0	48	205	12	17	Vcc=5,0	
0	6	0	0	5000	0	Kr84	45	115	10	82	279	17	41	Vcc=5,0	Data missing
0	6	0	0	4000	0	Kr84	60	184	30	106	388	24	37	Vcc=5,0	Data missing
64	6	68	501369	5000	4214	Kr84	60	467	355	292	647	57	97	Vcc=3,3	
65	6	48	501829	5500	4600	Kr84	45	250	195	147	602	22	39	Vcc=3,3	
66	6	34	501682	9500	4873	Kr84	0	179	111	104	294	14	32	Vcc=3,3	
67	5	34	500494	11500	3974	Kr84	0	181	149	108	283	14	30	Vcc=3,3	
68	5	48	501646	4000	4360	Kr84	45	304	197	156	706	15	36	Vcc=3,3	
69	5	68	502937	3500	4907	Kr84	60	325	270	217	874	40	47	Vcc=3,3	
70	4	68	500923	4000	4795	Kr84	60	316	234	214	934	31	51	Vcc=3,3	

71	4	48	500984	4500	5180	Kr84	45	260	157	150	408	31	48	Vcc=3,3	
72	4	34	502088	4500	5453	Kr84	0	170	98	94	267	14	30	Vcc=3,3	
73	4	56	0		5453	Kr84	0	0	0	0	0	0	0		Calibration
74	4	56	200766	1500	5633	Xe132	0	118	349	71	416	8	13	Vcc=3,3	
75	4	56	49902		5678	Xe132	0	5	250	9	119	0	29	Vcc=3,3	No run
76	4	56	201325	1500	5858	Xe132	0	145	113	78	173	14	11	Vcc=3,3	
77	4	79	200361	980	6111	Xe132	45	216	166	79	253	23	25	Vcc=3,3	
78	5	79	200026	1000	5160	Xe132	45	178	181	93	251	24	25	Vcc=3,3	
79	5	56	200933	1500	5340	Xe132	0	150	363	69	298	9	18	Vcc=3,3	
80	4	56	6208		5345	Kr84	0	0	0	0	0	0	0		Calibration
81	5	56	200327	1600	5525	Xe132	0	146	287	63	326	10	52	Vcc=3,3	
82	6	56	200838	1500	5053	Xe132	0	143	346	58	301	8	24	Vcc=3,3	
83	6	79	200960	1100	5307	Xe132	45	181	331	85	405	13	27	Vcc=3,3	
84	6	112	200665	700	5666	Xe132	60	238	358	131	716	58	67	Vcc=3,3	
85	6	79	200508	800	5920	Xe132	45	121	313	64	332	16	55	Vcc=5,0	
86	6	56	163477	1500	6066	Xe132	0	66	31	27	105	22	3457	Vcc=5,0	Not used
87	5	56	200833	1500	5704	Xe132	0	76	31	44	119	9	16	Vcc=5,0	
88	5	79	200806	1100	5958	Xe132	45	114	66	57	190	14	18	Vcc=5,0	
89	4	79	89745	1000	6234	Xe132	45	45	16	607	669	4	11	Vcc=5,0	Not used
90	4	79	200616	1000	6487	Xe132	45	115	57	52	128	13	18	Vcc=5,0	
91	4	56	200222	1300	6666	Xe132	0	98	27	27	84	8	13	Vcc=5,0	
92	6	56	200603	1500	6245	Xe132	0	89	283	44	261	0	0	Vcc=5,0	Not used
93	5	112	200431	700	6317	Xe132	60	174	80	87	440	13	27	Vcc=5,0	
94	5	56	200487	1200	6496	Xe132	0	94	30	47	135	7	19	Vcc=5,0 ;tid_fs3	Not used

10. APPENDIX B, proton data

Test data for A14100A for each run at PSI, 1997.11.25

Component:	A14100A
Facility	PSI
Source:	proton
Date	1997-11-25
Test time, start	01:50:00
Test time, end	06:43:00

Run#	**Device#**	**Vcc**	**Energy**	**<Flux>**	**Total Dose**	**Fluence**	**Errors:** C	S	IO	**Comments**
		(V)	*(MeV)*	*[p/cm2/sec]*	*[rad]*	*[#/cm2]*	*[#]*	*[#]*	*[#]*	
1	8	5	300	1,0E+08	4,58E+03	1,00E+11	0	8	1	
2	8	3,3	300	9,9E+07	9,17E+03	1,00E+11	0	6	0	
3	8	5	150	1,9E+07	1,27E+04	?	0	0	0	
4	7	5	300	1,1E+08	1,65E+03	?	0	1	0	
5	7	5	300	1,0E+08	6,23E+03	1,00E+11	0	3	0	
6	7	5	150	2,1E+07	9,75E+03	?	0	0	0	
7a	7	5	150	1,3E+07	1,33E+04	4,45E+10	0	1	0	Retrieved data from crash
7b	7	5	150	0,0E+00	1,33E+04	?	0	0	0	
8	7	3,3	300	1,1E+08	1,68E+04	7,67E+10	0	3	0	Retrieved data from crash (device broke down)