HEAVY IONS RADIATION TEST REPORT

Part Type : LTC1414

Package : 28-Pin SSOP

14-Bit, Sampling A/D Converter

Linear Technology

Report Reference : ESA_QCA991202S_C

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HEAVY IONS RADIATION TEST REPORT
on
Linear Technology LTC1414 **14-Bit A/D Converter.**

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1 Abstract

Under ESA/ESTEC contract n° 13602/99/NL/GD dated 18/06/99 covering "Radiation Pre-screening of High-resolution High-speed ADC's", three different 14-bit Analog to Digital converters were radiation assessed. Results from these assessments, primarily focused on the radiation sensitivity of the ADC's to Total Ionizing Dose (TID) and Single Event Effects (SEE), are reported in individual TID and SEE reports. Below summary table lists manufacturer and evaluated types, and gives references to the various reports issued.

Manufacturer	Type	TID Report	SEE Report
Analog Devices	AD9243	ESA_QCA991201T_C	ESA_QCA991201S_C
Linear Technology	LTC1414	ESA_QCA991202T_C	ESA_QCA991202S_C
National Semiconductor	ADC14161	ESA_QCA991203T_C	ESA_QCA991203S_C

2 Introduction

This report presents the results of a heavy ion Single Event Effects (SEE) test program carried out on Linear Technology LTC1414 14-bit, 2.2 MSPS, Sampling A/D Converter.

Standard devices were tested at the European Heavy Ion Irradiation Facility (HIF) at Cyclone, Université Catholique de Louvain, Belgium.

Test set-up allowed for the detection of both Single Event Latch-up (SEL) errors and Single Event Upset errors (SEU)

This work was performed for ESA/ESTEC under ESA Contract No 13602/99/NL/GD dated 18/06/99

3 Documents

3.1 Applicable documents

AD1. SOW Radiation Pre-screening of High-resolution High-Speed ADC's
Ref. APP-JP/99-02-057/PS/ps

3.2 Reference documents

RD1. Linear Technology, LTC1414 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 Device Description

14-bit, 2.2 MSPS, Sampling A/D Converter

4.2 Procurement of test samples

12 free samples have been delivered to Hirex by Linear Technology.

4.3 Preparation of samples

5 devices were selected for the SEE testing and serialized from #1 to #5.
#1 was used as the golden chip.
#2 as control sample.
#3 and #4, and #5 were chemically opened (by Hirex Lab).
#5 was non-functioning after opening (lifted wire bonds)
Further each test sample was then mounted on individual adapter boards.

4.4 Functional Test of samples

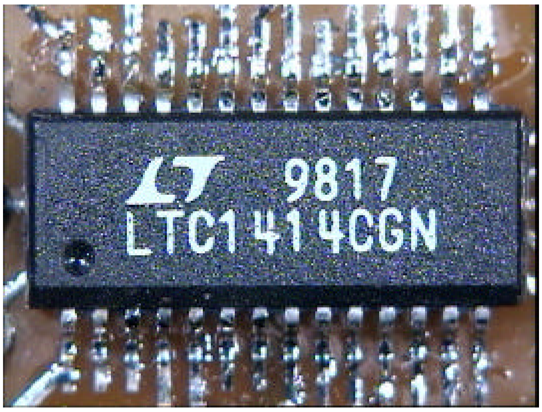
All opened samples were functional tested before use.

4.5 Device description

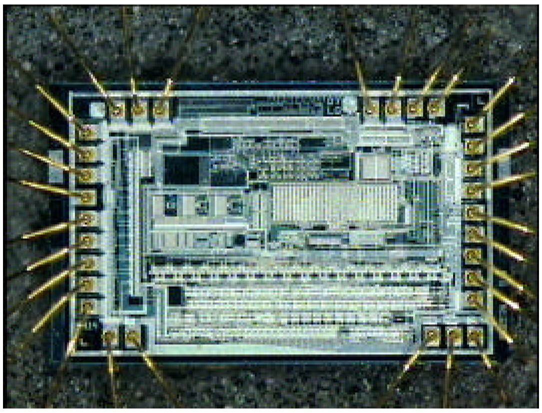
Description of the devices is as follows:

Part type :	LTC1414CGN
Manufacturer :	Linear Technology
Package :	28-Lead Plastic SSOP
Quality Level :	Standard
Date Code :	9817
Serial Number :	#001, #002, #003, #004, #005
Die Technology :	CMOS
Top Marking:	LT 9817 LTC1414CGN
Die Size :	2.85 mm x 1.75 mm approximately
Die Marking :	1414
Heavy ion test samples (delidded) :	2, #003, #004

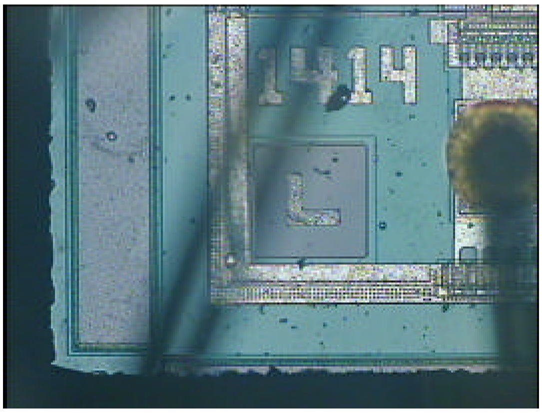
External and Internal Photos are shown in Figure 1.



(x 10)
Top view



(x 32)
Die, Full view



(x 200)
Die, Marking

Figure 1 – LTC1414 External and Internal Photos

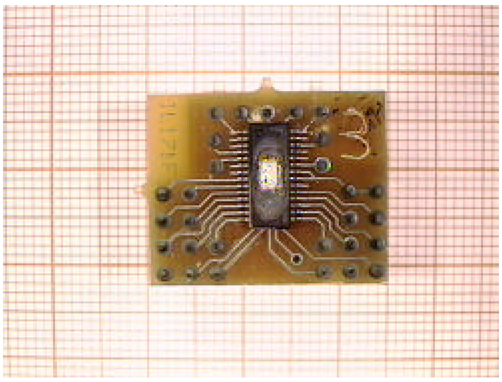


Figure 2 – DUT Adapter Board

5 Device TEST PATTERN DEFINITION

5.1 Preparation of Test Hardware and Program

Overall device operation, SEU and Latch-up detection, data storage and processing were implemented using an in-house test hardware and application specific test boards.

The generic in-house test equipment is driven by a PC computer through a RS232 line. All power supplies and input signals are delivered and monitored by the in-house equipment which also stores in its memory the output data from the device under test.

The application specific test board allowed to interface the standard test hardware with the device under test, in order to correctly test the relevant part, to record all the different type of errors during the irradiation and to set output signal for processing and storage by the standard test equipment.

At the end of each test run, data are transferred to the PC computer through the RS232 link for storage on hard disk or floppies.

5.2 Generic Test Set-up

Generic device test set-up is presented in Figure 3 and is constituted of the following equipment units:

- A PC computer (to configure and interface with the test system and store the data),
- An electronic rack with the instrumentation functions provided by a set of electronic modules,
- A mother board under vacuum. This board provides the electronics needed for each test sequence, calibration, simulation and test.
- A digital oscilloscope to store analog upset waveform

5.2.1 Mother board description (ref. IL170A)

Main board characteristics are :

- Specially designed to test up to 16-bit ADC at a sampling frequency of 20 Mhz,
- Based on a golden chip approach.
- On-board analog pattern generator
- A common analog signal (linear ramp for calibration, sinus during test) is applied to both DUT and reference device inputs.
- Possibility to calibrate the DUT with the reference device by recording the errors values for each output word.
- Possibility to adjust a programmable voltage Vref to compensate for gain dispersion between DUT and ref. device.
- Both outputs are compared numerically thanks to the use of on-board CPLDs. For each comparison, the error value previously recorded for the output Ref. device word is substracted.
- DUT output and comparison signals are converted with high-speed 8-bit DACs to allow for scope observation.
- Three on-board counters are used to sort the errors in the following categories, small, medium and large (A medium error is also counted as a small, a large error is also counted as a medium and a small error)

Mother board synoptic is shown in Figure 4.

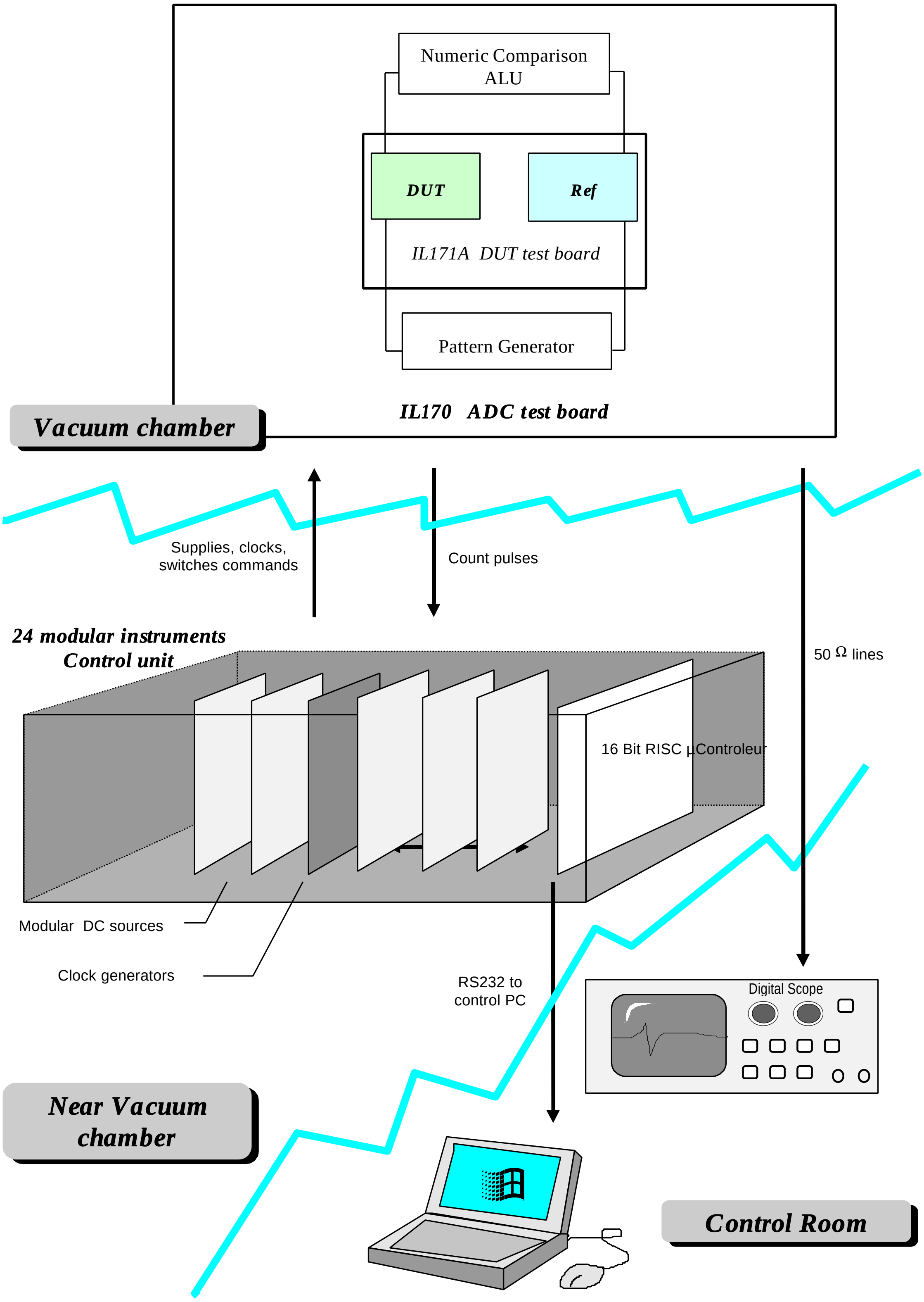


Figure 3 - Generic Device Test Set-up

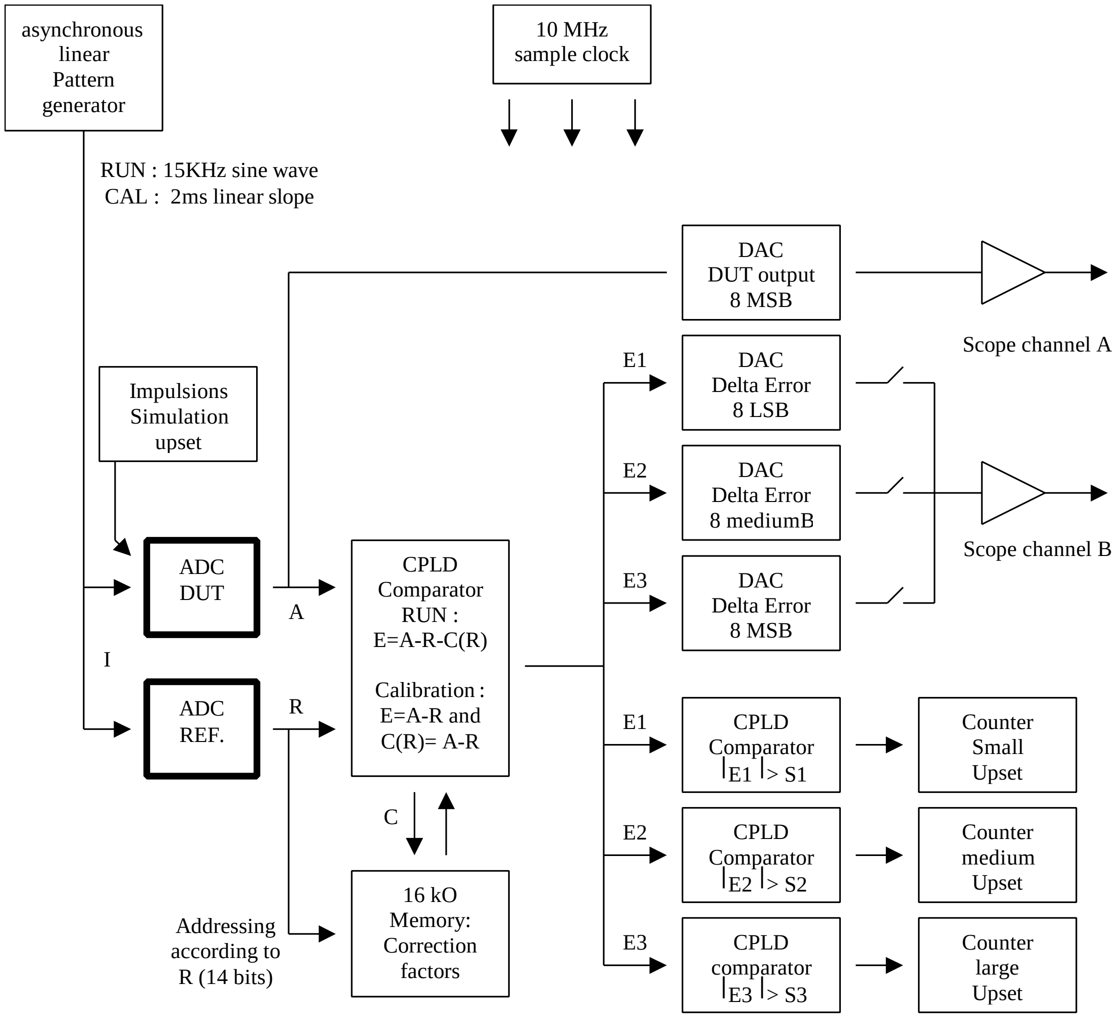


Figure 4 - Mother board synoptic

5.2.2 DUT Test board description

Both the DUT and the reference device (golden chip) are mounted on adapters PCBs for easy interchangeable motherboard set-up.

This approach allows cost effective SEE testing of different ADC devices and types at the same time. Figure 2 show the DUT arrangement for LT1414 #3

Note : Beam focus diameter is limited to maximum 25 mm, to prevent the exposure of others devices which might be sensitive.

5.3 Test configuration

The test configuration is as follows :

Sampling frequency is set to 2 MHz

Prior to the irradiation, a calibration run is performed which allows to record into the on-board memory the error value found for each output reference device word. This is done with a slow linear ramp (2ms period) applied to the inputs of both DUT and reference devices.
Calibration duration is such that, for each word, corresponding error is averaged on more than 20 values.
Eventually, DUT Vref is adjusted to minimize the error range.
With this approach, it is possible to match both output devices with a precision of ± 5 LSBs.

Each irradiation run is performed with a 15 kHz sine waveform applied at both DUT and ref. inputs.

The different errors which can be detected are :

- Single errors which can be classified as small (threshold = +/- 6 LSBs), medium (threshold = +/- 96 LSBs) or large (threshold = +/-768 LSBs).
- Permanent errors : This was not considered for this device which does not present an internal calibration.
- Latch-up errors : each power supply (Analog +, Analog – and Logic) is monitored separately.

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.

6.1.2.2 Flux Range

For each run, the averaged flux value is provided in the detailed results table of paragraph7.

6.1.2.3 Particle Fluence Levels

Fluence level was set to 1 x10E6 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.

6.1.2.6 Test Temperature Range

All the tests performed were conducted at ambient temperature.

7 Heavy ions Results

The detailed results per run are presented in Table 1.

It must be outlined that no latch-up has been detected during this set of runs.

The Figure 5, here below, gives the plot of the different single errors cross-sections (small, medium and large) versus LET for the two samples tested.

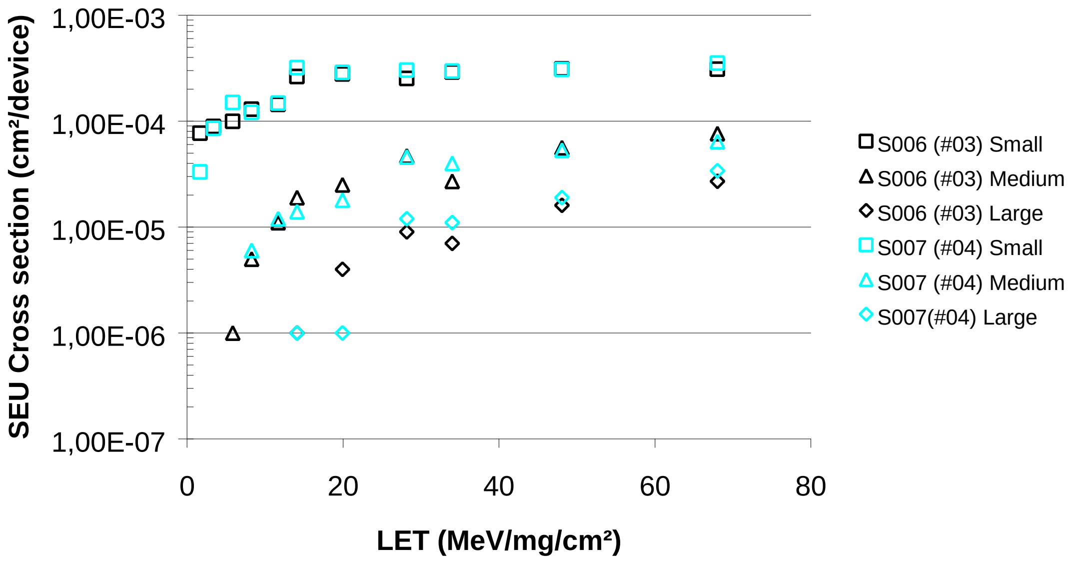


Figure 5 – LTC1414 SEU device error cross-section versus LET

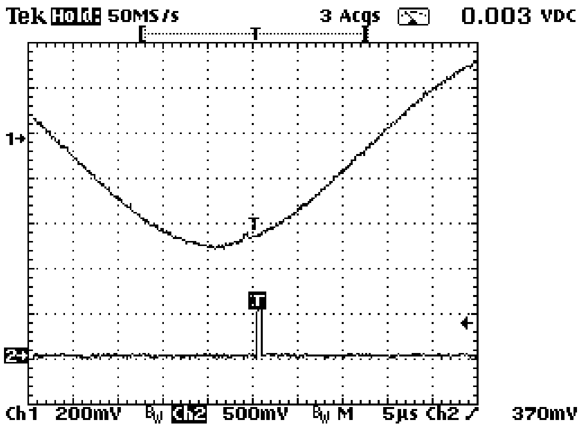
Observation with the digital scope during the different runs, allowed to characterize the different error waveforms.

This is illustrated in the Figure 6 here after.

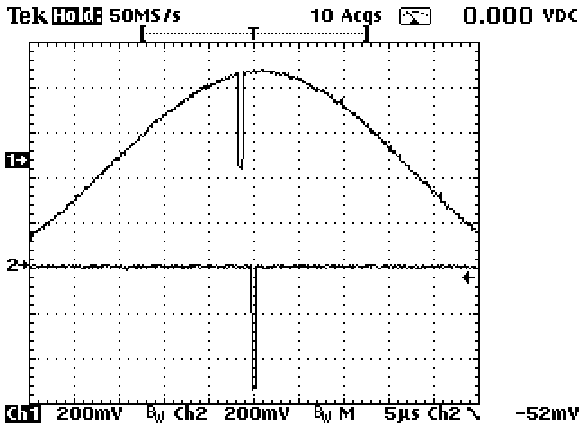
Most of the errors observed affect only one conversion cycle as illustrated Figure 6 a), b), c)

Figure 6 e) show a particular case of two consecutive small errors.

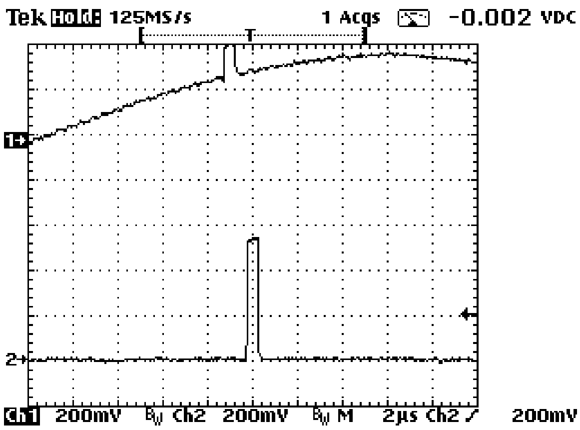
Lastly, in few occasions, small analog events which could last several tens of microseconds have been observed and an example is presented in Figure 6 d). These types of errors were much less frequent than the other errors and are assumed to be generated in an analog part of the circuit (ref. area, for instance). Each error of this type was counted as one "small" error (counter hold-off was set to 1 ms).



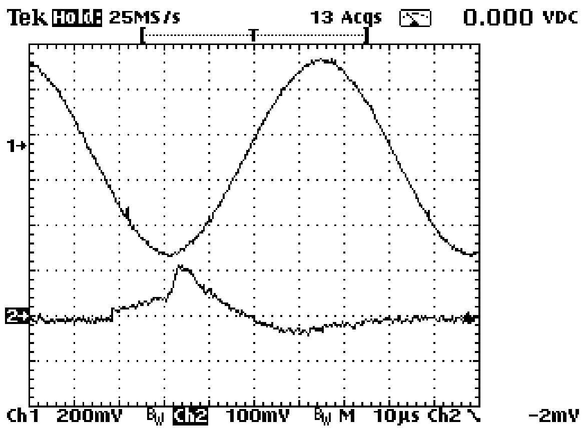
a) Run 18, small channel



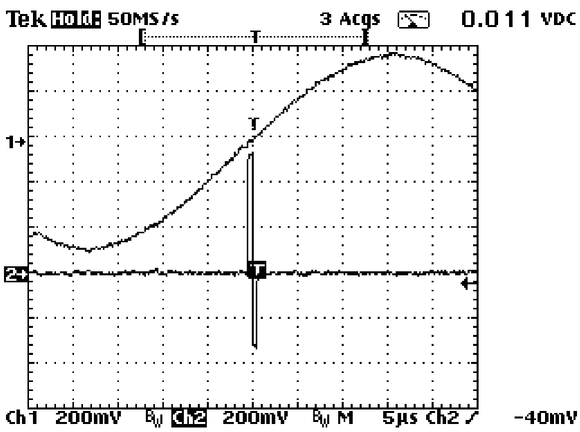
b) Run 72, large channel



c) Run 21, Medium channel (saturated)



d) Run 73, small channel, small analog event



e) Run 19, small channel, two consecutive small events

On each scope view presented herein, the curve at the top, correspond to the DUT output converted with a 8-bits fast DAC (see Figure 4), while the curve at the bottom of the view, represent either the small, medium or large error converted also with a similar fast 8-bit DAC (see Figure 4) :

Verror = Vout(Ref)-Vout (DUT)-V(Calib)

For each error channel, +/- 500 mV corresponds to +/- 7 bits

Figure 6 – Scope observation of error waveforms

Run parameters														SEU Errors						SEL Errors					
														Small		Medium		Large		Analog +		Analog -		Logic	
Run #	Sample	Ion	LET (MeV/mg/cm²)	Range (µm)	Angle (°)	Time (s)	Eff. Time (s)	Flux (p/cm²s)	Run TID (Rad)	Sample TID (Rad)	Fluence (P/cm²)	Eff. Fluence (p/cm²)	Eff. LET (MeV/mg/cm²)	Nb	Cross-section (cm²)	Nb	Cross-section (cm²)	Nb	Cross-section (cm²)	Nb	Cross-section (cm²)	Nb	Cross-section (cm²)	Nb	Cross-section (cm²)
R00052	03	10-B	1,7	80	0	170	-	5,88E+03	2,72E+01	5,39E+03	1,00E+06	-	1,7	77	7,70E-05										
R00051	03	10-B	1,7	80	60	346	-	2,89E+03	5,45E+01	5,36E+03	1,00E+06	-	3,4	89	8,90E-05										
R00039	03	20-Ne	5,85	45	0	64	-	1,56E+04	9,37E+01	4,99E+03	1,00E+06	-	5,9	99	9,90E-05	1	1,00E-06								
R00040	03	20-Ne	5,85	45	45	112	-	8,93E+03	1,33E+02	5,12E+03	1,00E+06	-	8,3	129	1,29E-04	5	5,00E-06								
R00041	03	20-Ne	5,85	45	60	137	-	7,30E+03	1,87E+02	5,31E+03	1,00E+06	-	11,7	144	1,44E-04	11	1,10E-05								
R00016	03	40-Ar	14,1	42	0	266	-	3,76E+03	2,26E+02	4,12E+03	1,00E+06	-	14,1	263	2,63E-04	19	1,90E-05	1	1,00E-06						
R00017	03	40-Ar	14,1	42	45	367	-	2,72E+03	3,19E+02	4,44E+03	1,00E+06	-	19,9	278	2,78E-04	25	2,50E-05	4	4,00E-06						
R00018	03	40-Ar	14,1	42	60	605	-	1,65E+03	4,52E+02	4,89E+03	1,00E+06	-	28,2	253	2,53E-04	47	4,70E-05	9	9,00E-06						
R00071	03	84-Kr	34	43	0	199	-	5,03E+03	5,45E+02	5,93E+03	1,00E+06	-	34,0	289	2,89E-04	27	2,70E-05	7	7,00E-06						
R00072	03	84-Kr	34	43	45	289	-	3,46E+03	7,70E+02	6,71E+03	1,00E+06	-	48,1	311	3,11E-04	56	5,60E-05	16	1,60E-05						
R00073	03	84-Kr	34	43	60	391	-	2,56E+03	1,09E+03	7,79E+03	1,00E+06	-	68,0	309	3,09E-04	76	7,60E-05	27	2,70E-05						
R00054	04	10-B	1,7	80	0	191	-	5,24E+03	2,72E+01	5,39E+03	1,00E+06	-	1,7	33	3,30E-05										
R00053	04	10-B	1,7	80	60	386	-	2,59E+03	5,45E+01	5,36E+03	1,00E+06	-	3,4	85	8,50E-05										
R00036	04	20-Ne	5,85	45	0	194	-	5,15E+03	9,37E+01	4,99E+03	1,00E+06	-	5,9	150	1,50E-04										
R00037	04	20-Ne	5,85	45	45	210	-	4,76E+03	1,33E+02	5,12E+03	1,00E+06	-	8,3	121	1,21E-04	6	6,00E-06								
R00038	04	20-Ne	5,85	45	60	314	-	3,18E+03	1,87E+02	5,31E+03	1,00E+06	-	11,7	148	1,48E-04	12	1,20E-05								
R00019	04	40-Ar	14,1	42	0	351	-	2,85E+03	2,26E+02	4,12E+03	1,00E+06	-	14,1	319	3,19E-04	14	1,40E-05	1	1,00E-06						
R00020	04	40-Ar	14,1	42	45	647	-	1,55E+03	3,19E+02	4,44E+03	1,00E+06	-	19,9	287	2,87E-04	18	1,80E-05	1	1,00E-06						
R00021	04	40-Ar	14,1	42	60	745	-	1,34E+03	4,52E+02	4,89E+03	1,00E+06	-	28,2	302	3,02E-04	46	4,60E-05	12	1,20E-05						
R00068	04	84-Kr	34	43	0	203	-	4,93E+03	5,45E+02	5,93E+03	1,00E+06	-	34,0	297	2,97E-04	40	4,00E-05	11	1,10E-05						
R00069	04	84-Kr	34	43	45	293	-	3,41E+03	7,70E+02	6,71E+03	1,00E+06	-	48,1	307	3,07E-04	53	5,30E-05	19	1,90E-05						
R00070	04	84-Kr	34	43	60	408	-	2,45E+03	1,09E+03	7,79E+03	1,00E+06	-	68,0	353	3,53E-04	64	6,40E-05	34	3,40E-05						

Table 1 – Detailed results per run on LTC1414

8 Conclusion

SEU test have been conducted on 14-bit, 2.2 MSPS, Sampling A/D Converter, LTC1414 from Linear Technology, using the heavy ions available at the European Heavy Ion Irradiation Facility (HIF) at Cyclone, Université Catholique de Louvain, Belgium.

This device is not sensitive to SEL when tested with an LET of up to 68 MeV/mg/cm²

Heavy ion SEU susceptibility was obtained through the error cross section versus LET curve for three different errors magnitudes.

LET threshold and asymptotic cross-section for each error amplitude, are given inTable 2 here below.

	Error Amplitude (LSBs)	LET Threshold (MeV/mg/cm²)	Asymptotic cross-section (cm²)
Small	+/- 6	1,7	3,5 E-4
Medium	+/- 96	5,9	7 E-5
Large	+/- 768	11,7	3 E-5

Table 2 – SEU errors characterization summary