National Semiconductor Corporation

Hi-Rel Group

Radiation Engineering/RHA Programs
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Final Report

Single-Event Latch up Testing of Advanced Analog to Digital Converter ADC08DL1000

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1.0 Introduction

1.1 Test Objectives

As technology progressively goes towards smaller feature sizes and newer process techniques, Single-Event Effects (SEE) have become more predominant, particularly for Single-Event Latch Up (SEL), Single-Event Upset (SEU) and Single-Event Transient (SET) when using pure CMOS fabrication process. While these products may be immune to electrical latch up, this does not correlate to being SEL immunity since the cause and mechanisms are different. This increase in SEE sensitivity is due to packing density, reduction in gate oxide thickness, the lack of design rule sensitivity to SEE effects, power distribution and the starting material (wafer material characteristics).

The ADC08D1000 to be evaluated is manufactured on a commercial CMOS-Shallow Trench Isolation (STI) using a p+ substrate and p-epi thickness of 5.5 um and utilizing a 0.18 um fabrication process

2.0 Description of Product-Type

The ADC08D1000 is a dual, high performance, low power monolithic analog to digital converter capable of converting analog input signals into 8-bit words at 1 Gigasample per second (GSPS). It employs a two 1.9V dc power supplies. The ADC08D1000 achieves 7.5 ENOB at nyquist and consumes 1.6W at 1 GSPS. The device also has a Power Down feature that reduces the power consumption to 20 mW.

The differential inputs provide a full scale differential swing, selectable, of 600mVp-p or 800mVp-p input. The digital outputs from the two ADCs are available on separate 4 separate differential (Low Voltage Differential Signal) 8-bit buses (current and previous sample for each channel clocked out at ½ the sampling rate. The output format is offset binary.

3.0 Test Facility and Personnel

The test facility that was used for this Single-Event Latch up testing was the 88" Cyclotron Facility at Lawrence Berkely National Laboratory located at Berkeley, California. The 88" Cyclotron provides heavy ion beams to perform SEE testing in a controlled environment. The facility generates ion beams for about a dozen different ion species at three energies per nucleon, 4.5MeV, 10Mev, and 16MeV. The 88" Cyclotron is located in Building 88 at 1 Cyclotron Road in Berkeley, CA.

Test FacilityPersonnel :

(a) Peggy McMahan
Operations Supervisor
(510) 486-5980

(b) Michael Johnson
Technical Support
(510) 486-4389

4.0 Pertinent Test Information

4.1 Date: June 28 and 29, July 18, 2005

4.2 Time: 4:00 PM to 12:00 AM each day (June 28 and 29)
8:00 AM to 6:00PM (July 18)

4.3 Name of Testers:

(a) Dick Sorensen
(b) Mark Gonzales
(c) Tom Santiago

5.0 Type of Test Equipment

(a) Power Supply – Agilent – Model 6624A – 4 Outputs
(b) Oscilloscope – Tektronix -- Model TDS5054 – 500 MHz – 4 Channels – 5GS/S –400K
(c) Source Generator – Hewlett Packard – Model HP 8642A – 100 kHz to 1.05 GHz
(d) Pulse Function Generator – Agilent – Model 8116A – 1 mHz to 50 MHz
(e) Lakeshore Temperature Controller, Model 332
(f) Personal Computer – Executes WAVE Vision Software
(g) Current Probes – Tektronix – Model TCP 202 – 50 MHz BW
(h) ADC08D1000 Evaluation Board

6.0 Test Method

The test method utilized was the EIA/JEDEC Standard, EIA/JESD 57 and entitled “Test Procedures for the Measurement of Single-Event Effects in Semiconductor Devices from Heavy Ion Irradiation”. This test method defines the requirements and procedures for Earth-based single-event effects testing of integrated circuits. The test method is only valid when using a Van de Graaff or Cyclotron Accelerator. This method does not apply to SEE testing that uses neutrons, protons and other lighter particles.

This test method assumes that the accelerator test facilities have the ability to mount and position the device-under-test (DUT) in a vacuum chamber, provide heavy ion dosimetry; etc. When employing a vacuum chamber, all DUTs must be de-lidded. This test method addresses SEE of soft or hard errors induced by a single ion strike. Such errors would be single-event upset (SEU), multiple bit upset (MBU), single-event transients (SET), single-event latch up (SEL) and other effects.

7.0 Test Plan and Procedures

7.1 Single-Event Latch up Test Plan

Purpose: The objective of this test plan is to evaluate the Single-Event Latch up (SEL) response of National Semiconductor's Analog-to-Digital Converter, ADC08D1000.

Normally, the SEL test would start with use of the heaviest ion available to establish the saturated cross-sectional area, first. However, in this test plan, the procedure began with a medium LET ion and proceeded in sequence to the lowest LET ion that did not cause a latch up.

The SEL testing was performed at two (2) different temperatures as follows: 35º C (Room Temp), and 85º C (Hot Temp, measured on top of package by thermistor, assumed typical hot ambient operating temp provided for electronics on the flight platform).

SEL testing was also to be performed at three (4) different angles, when needed for finer determination of energy levels of incidence as follows: 0º, 25º, 35º, and 45º. The other than 0º angles were utilized only to determine more accurately the threshold LET.

7.2 Pertinent Information Associated With This Test Plan

(a) Facility:
Lawrence Berkeley National Laboratory
1 Cyclotron Road
Berkeley, CA 94720

(b) Test Method: EIA/JESD 57 – "Test Procedures for the Measurement of Single-Event Effects in Semiconductor Devices from Heavy Ion Irradiation", December, 1996

© Sample Size: 2

(d) Bias Voltage: 1.9 Vdc

(e) Frequency: 1 GHz

(f) Temperatures to Be Tested: 35º C and 85º C.

(g) Selected LET Values (at 0º incident angle and 10MeV per nucleon): 9.74, 14.52, 21.33, 31.28, 58.72, 50, 60 and 80 (MeV-cm²/mg)

(h) Potential Ions To Be Used: Boron, Neon, Argon, Vanadium, Copper, Krypton, Xenon.

(i) Fluence: 1x10^2 to 5x10^7 ions/ cm²

(j) Flux: 1x10^3 to 1x10^6 ions/ cm² x s

(k) Calculate Total Ionizing Dose (TID): Not done

(l) Accumulative Total Ionizing Dose: Not done

7.3 Basic Test Procedures

(a) Set-up test equipment and checked-out test circuit with test sample. Verified correct operation.
(b) Checked with facility's personnel for correct ion, beam characteristics, energy, flux and fluence.
(c) Powered up Device-Under-Test (DUT). Recorded all pertinent data at pre-exposure.
(d) Exposed the DUT to the ion beam
(e) Recorded all pertinent data after exposure including if DUT latched-up or not.
(f) Repeat steps "b" through "e" for samples #2 and #3 if time permitted.

(g) These procedures were modified at the time of test, based upon the responses of the previous exposure results and test time remaining.
(h) Analyzed data and generated final test report.

8.0 Description of Test Setup

The test circuit for the ADC08D1000 consisted of an ADC Evaluation board driven by WaveVision 4 software. The board was then secured to the vacuum chamber fixture board to be mounted in the vacuum chamber.

The input to the ADC08D1000 device was a 600mVp-p, sine wave at 1 MHz frequency utilizing the A-8116 Pulse Function Generator. This input signal was clocked in at a frequency of 1 GHZ. Two separate power supply lines were employed to provide power to the Evaluation board. A current probe (TCP-202) was connected to each power line to monitor a latch up event. These current probes were connected to the oscilloscope to observe and record the latch up condition. A Lakeshore Temperature Controller, Model 332, was connected to the thermistors and to resistive heaters to provide both temperature measurement and heater control as required.

A personal computer was connected to the Eval Board to communicate using a RS-232 connection. The Eval Board receives the ADC clock and output data of the ADC08D1000 device. The captured data is stored in memory and eventually uploaded to the personal computer for signal analysis.

9.0 Description of Bias and Temperature Conditions

Each part-type was biased to its nominal Vdd value. The input to each ADC was 600mVp-p sine wave signal. A clock signal, a 1 GHz sine wave, was utilized. Ambient temperature of part (as measured by a thermistor glued to the printed circuit board very near the part) was approximately 35° C. Testing was meant to be conducted at an ambient temperture of 25° C (Room Temperature) however ambient temperature in the vacuum chamber rose to approximately 35° C and no means for cooling the part in the vacuum chamber was provided.

10.0 Ions to be Used

(a) Xenon – 129 (b) Krypton – 86 (c) Copper – 65
(d) Vanadium – 51 (e) Argon – (f) Neoon – (g) Boron –10

11.0 Test Data

11.1 Table 1 – ADC08D1000 Test Data Log

See Attachment "A"

11.2 ADC08D1000 Graph

See Attachment "B"

12.0 Summary of Results

The ADC08D1000 product-type was exposed to five different ions plus angular exposures. The device was operated at its nominal frequency of 1 GHz and its operational voltage of 1.9 volts. During the entire SEL testing, the temperature at the package surface was measured between 34 ºC and 37 ºC. Originally, the SEL testing was to be performed at 25 ºC but this could not be accomplished in the vacuum chamber.

A medium LET-value ion was chosen to initiate the SEL testing. The ion selected was Copper (Cu-65) with a calculated LET of 21.33 MeV/(mg/cm²) at the sensitive node area. This value of LET (21.33) did generate a latch up in the device. Therefore, an additional ion was selected with a lower LET value, Vanadium (V-51). Vanadium had an LET value of 14.56MeV/(mg/cm²), respectively. This ion did not cause a latch up. Incident angle of the Vanadium was increased until latch up occurred, which happened at 45°, with an LET of 20.59MeV/(mg/cm^2)

Additional SEL testing was accomplished utilizing Krypton and Xenon to find the "saturated" energy levelan angle.

Attachment "A" is the Test Log recording all the pertinent data collected during the test session. **The data indicates an effective threshold LET of approximately 21 MeV/(mg/cm²) for the ADC08D1000.**

13.0 Conclusions

The test results for the ADC08D1000 indicates that this device can be used in the space environment applications that require a threshold LET of 21 MeV/(mg/cm²) or less with a cross section at threshold of 1.7395x10^-7 cm2 (averaging DUT #1 and DUT #3), and a saturated cross section of about 1x10^-6 cm^2. The Hot Temperature Data for DUT #3 (with the top of the package at 85 deg C) indicates that this device can be

used in the space environment applications that require a threshold LET of 21 MeV/(mg/cm²) or less with a cross section at threshold of 2x10^-7 cm2 (averaging DUT #1 and DUT #3), and a saturated cross section of about 4.6x10^-6 cm^2.

Attachment "A"

Table 1 – Test Log

Date: 28/29 June 2005
Facility: Lawrence Berkely National Laboratory
Product Type: ADC08D1000

Board #
1 (No latch up occurred with Vanadium-51 at an incident angle of 45°, LET = 20.59MeV, or any lesser LET)

Species	Incident	LET	Flux	Fluence	#events	Total	Cross
	Angle	MeV	#/cm2*sec	#/cm2		Fluence	Section
V	0°	14.56	2.40E+04	6.00E+06	0		
V	0°	14.56	2.50E+04	6.01E+06	0	1.20E+07	0.00E+00
V	45°	20.59	2.10E+04	6.30E+06	0	6.30E+06	0.00E+00
Cu	0°	21.33	2.00E+05	3.31E+07	1		
Cu	0°	21.33	1.60E+05	3.30E+05	1		
Cu	0°	21.33	1.60E+05	7.74E+06	1	4.1170E+07	7.2869E-08
Kr	0°	31.28	2.00E+05	5.63E+06	0		
Kr	0°	31.28	2.00E+05	7.79E+06	0		
Kr	0°	31.28	4.00E+03	4.62E+05	0		
Kr	0°	31.28	2.00E+05	4.53E+05	1	1.4335E+07	6.9759E-08
Xe	0°	58.72	4.00E+04	7.62E+06	0		
Xe	0°	58.72	9.00E+04	3.16E+06	0		
Xe	0°	58.72	9.00E+04	9.83E+06	1	2.0610E+07	4.8520E-08
Xe	35°	71.68	8.80E+04	3.23E+05	0		
Xe	35°	71.68	8.80E+04	7.42E+05	1	1.0650E+06	9.3897E-07
Xe	45°	83.04	8.00E+04	4.99E+05	1		
Xe	45°	83.04	9.00E+04	5.12E+06	1	5.6190E+06	3.5594E-07

Board #
2 (No latch up occurred with Copper-65 at an incident angle of 0°, LET = 21.33MeV, or any lesser LET)

Species	Incident	LET	Flux	Fluence	#events	Total	Cross
	Angle	MeV	#/cm2*sec	#/cm2		Fluence	Section
Ar	0°	9.74	5.50E+03	6.92E+05	0	6.92E+05	0.00E+00
V	0°	14.56	8.00E+02	1.75E+05	0	1.75E+05	0.00E+00
Cu	0°	21.33	1.30E+04	1.61E+06	0	1.61E+06	0.00E+00
Cu	25°	23.54	5.40E+03	3.45E+05	0		
Cu	25°	23.54	5.40E+03	1.39E+05	1		
Cu	25°	23.54	1.20E+04	2.27E+06	0	2.75E+06	3.63E-07
Xe	0°	58.72	1.80E+04	2.60E+06	1		
Xe	0°	58.72	9.00E+03	1.18E+06	0	3.78E+06	2.65E-07

Board #
3 (No latch up occurred with Vanadium-51 at an incident angle of 45°, LET = 20.59MeV, or any lesser LET)

Species	Incident	LET	Flux	Fluence	#events	Total	Cross
	Angle	MeV	#/cm2*sec	#/cm2		Fluence	Section
V	0°	14.56	5.00E+04	1.80E+07	0		
V	0°	14.56	5.00E+04	1.50E+07	0	3.30E+07	0.00E+00
V	45°	20.59	5.00E+04	1.06E+07	0	1.06E+07	0.00E+00
Cu	0°	21.33	1.50E+04	4.26E+06	0		
Cu	0°	21.33	2.30E+04	4.46E+06	1		
Cu	0°	21.33	2.30E+04	8.10E+05	1		
Cu	0°	21.33	3.00E+04	1.37E+06	1	1.0900E+07	2.7523E-07
Kr	0°	31.28	5.00E+04	4.14E+06	1		
Kr	0°	31.28	5.00E+04	7.13E+06	1		
Kr	0°	31.28	5.00E+04	1.57E+06	1	1.2840E+07	2.3364E-07
Xe	0°	58.72	1.00E+04	4.92E+05	1		
Xe	0°	58.72	1.00E+04	2.79E+06	1		
Xe	0°	58.72	1.00E+04	7.77E+05	1	4.0590E+06	7.3910E-07

Board #
3 (85C, No latch up occurred with Vanadium-51 at an incident angle of 45°, LET = 20.59MeV, or any lesser LET)

Species	Incident	LET	Flux	Fluence	#events	Total	Cross
	Angle	MeV	#/cm2*sec	#/cm2		Fluence	Section
V	45°	14.56	1.50E+04	4.89E+06	0		
V	45°	14.56	1.70E+04	5.61E+06	0	1.05E+07	0.00E+00
Cu	0°	21.33	5.70E+03	1.79E+06	1		
Cu	0°	21.33	8.00E+04	3.64E+06	1		
Cu	0°	21.33	3.00E+04	4.44E+06	1		
Cu	0°	21.33	5.00E+04	2.75E+06	1		
Cu	0°	21.33	8.00E+04	1.12E+07	1	2.3820E+07	2.0991E-07
Kr	0°	31.28	4.00E+04	1.44E+06	1		
Kr	0°	31.28	4.00E+04	3.84E+06	1		
Kr	0°	31.28	4.00E+03	6.29E+06	1	1.1570E+07	2.5929E-07
Xe	0°	58.72	1.00E+04	1.04E+06	1		
Xe	0°	58.72	1.00E+04	8.01E+05	1		
Xe	0°	58.72	1.00E+04	1.03E+05	1		
Xe	0°	58.72	1.00E+04	1.08E+05	1		
Xe	0°	58.72	1.00E+04	4.99E+05	1	2.5510E+06	1.9600E-06
Xe	45°	83.04	1.00E+04	7.96E+04	1		
Xe	45°	83.04	1.00E+04	2.01E+05	1		
Xe	45°	83.04	1.00E+04	3.68E+05	1	6.4860E+05	4.6253E-06

Conditions: Board #01, #02 Bias Volt = 1.9V, Dyn. = 1GHz, Temp = 34 ºC-37 ºC

Attachment "B"

ADC08D1000 Graph

Date: 28/29 June, 18 July, 2005
Facility: Lawrence Berkely National Laboratory
Product Type: ADC08D1000