SINGLE EVENT EFFECTS
TEST REPORT

Test Type: Heavy Ion
Test facility: RADEF/JYFL, FINLAND
HIF/UCL, BELGIUM
Test Date: June 2012
Part Types: ADS5463MHFG-V
Part Description: 12-Bit, 500-MSPS Analog-to-Digital Converter
Part Manufacturer: Texas Instruments

Texas Instruments Purchase Order No 4512326671 dated 15/03/2012 item 020

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<th>Issue : 01</th>
<th>Date : June 26, 2012</th>
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<tr>
<td>Written by :</td>
<td>M. Mazurek</td>
<td>Design Engineer</td>
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</tr>
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HIREFX Engineering SAS au capital de 180 000 € - RCS Toulouse B 389 715 525
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RESULTS SUMMARY

Facility
RADEF/JYFL, Finland
HIF/UCL, Belgium

Test date
June 2012

Device description

Part type: ADS5463MHFG-V
Description: 12-Bit, 500-MSPS Analog-to-Digital Converter
Package: CQFP 84
Die dimensions: 5123 µm x 5135 µm

SEL Results
No SEL was observed up to LET of 86 MeV/(mg/cm²) at 85°C and 125°C temperatures, a bias voltage $AV_{DD} = +5.25V$, $DV_{DD} = +3.6V$, $AV_{DD} = +3.6V$ and a fluence of $1.0E+07$ ions/cm² for two samples.

SET on the reference voltage
140 SETs on the reference voltage signal were observed. They started to appear from Nitrogen ion (LET of 1.8 MeV/(mg/cm²)).

SEU Cross-Section
The SEU cross-section reaches its highest value at $1.8E-04$ cm²/device while the LET threshold below $1.8$ MeV/(mg/cm²).

SEU Results Details
555 events have been detected over the whole LET range from 1.87 to 85.9 MeV/(mg/cm²)
SEU events were classified in three main categories depending on the SEU duration:
- SEU ‘A’ – short conversion errors with maximum 10 consecutive samples in error
- SEU ‘B’ – long conversion errors with more than 10 consecutive samples in error with digital signature, and for which an SET on $V_{ref}$ signal occurred at the same time
- SEU ‘C’ – long conversion errors with more than 10 consecutive samples in error with analog signature, and for which an SET on $V_{ref}$ signal occurred at the same time

<table>
<thead>
<tr>
<th>ADS5463MHFG-V</th>
</tr>
</thead>
<tbody>
<tr>
<td>$AV_{DD} = +4.75V$, $DV_{DD} = +3.0V$, $AV_{DD} = +3.0V$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>S</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>50</td>
</tr>
<tr>
<td>x0</td>
<td>0.9</td>
</tr>
<tr>
<td>A</td>
<td>$1.80E-04$</td>
</tr>
</tbody>
</table>
**DOCUMENTATION CHANGE NOTICE**

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**Contributors to this work:**

- **Maria Mazurek**
  - Hirex Engineering
- **Bertrand Forgerit**
  - Hirex Engineering
- **F.X. Guerre**
  - Hirex Engineering
SEE TEST REPORT

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1 Introduction
This report presents the results of Heavy Ion test program carried out on Texas Instruments 12-Bit, 500-MSPS Analog-to-Digital Converter referenced ADS5463MHFG-V.

Two devices were heavy ion tested at RADEF, University of Jyväskylä, Department of Physics, Jyväskylä, Finland in June 2012.
Additional tests with Xenon ion were performed at HIF, UCL University of Louvain, Belgium.

This work was performed for Texas Instruments Purchase Order No 4512326671 dated 15/03/2012 item 020

2 Applicable and Reference Documents

2.1 Applicable Documents
AD-1. 12-Bit, 500-MSPS Analog-to-Digital Converters datasheet ; Revised July 2009

2.2 Reference Documents
RD-1. Single Event Effects Test method and Guidelines ESA/SCC basic specification No 25100
### 3 DEVICE INFORMATION

#### 3.1 Device description

The ADS5463MHFG-V is a 12-bit 500-MSPS analog-to-digital converter (ADC) that operates from 5V supply and 3.3V supply, while providing LVDS-compatible digital outputs from a 3.3V supply.

- **Part Type:** ADS5463MHFG-V
- **Manufacturer:** Texas Instruments
- **Package:** CQFP 84
- **Samples Used:** #027, #166
- **Top Marking:** 5962 – 0720801VXC ADS5463MHFG-V THA 8AAR 1121A Q
- **Die dimensions:** 5123 µm x 5135µm

#### 3.2 Sample identification

Texas Instruments has delivered four ADS5463MHFG-V samples with the lot datecode of “1121A”. Three of them were prepared to be tested to heavy ions. The fourth part was used for a die microsection.

A die size is small comparing to the device cavity, so package shadowing is not an obstacle. The test was performed on two samples.

![Photo 1 - Top Marking (ADS5463MHFG-V)](image1)

![Photo 2 - Die Marking (ADS5463MHFG-V)](image2)

![Photo 3 – Full view (ADS5463MHFG-V)](image3)

**Figure 1:** Device identification for the ADS5463MHFG-V part
3.3 Stack Construction Analysis

Die microsections were performed on the ADS5463MHFG-V part in order to check ion penetration. Dead layer was measured and will be taken into account for computing the effective LET value.

<table>
<thead>
<tr>
<th>Layer ID</th>
<th>Material</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passivation</td>
<td>Si3N4/ SiO2 /SiO2</td>
<td>1µm/ 0.3µm/ 0.5µm</td>
</tr>
<tr>
<td>Metal 4</td>
<td>Al Cu, TiW liner</td>
<td>1.5µm /0.18µm</td>
</tr>
<tr>
<td>Via plug</td>
<td>W</td>
<td>0.6µm diam.</td>
</tr>
<tr>
<td>Inter Layer Dielectric 4</td>
<td>SiO2 / SOG / SiO2 cap</td>
<td>0.8µm / 0 to 0.8µm / ~60nm</td>
</tr>
<tr>
<td>Metal 3</td>
<td>TiW ARC , Al (Cu), TiW liner</td>
<td>50nm/0.57µm/ 150nm</td>
</tr>
<tr>
<td>Via plug</td>
<td>W</td>
<td>0.6µm diam</td>
</tr>
<tr>
<td>Inter Layer Dielectric 3</td>
<td>SiO2 / SOG / SiO2 cap</td>
<td>0.2µm/0 to 0.2µm/~60nm</td>
</tr>
<tr>
<td>Metal 2</td>
<td>TiW ARC , Al (Cu), TiW liner</td>
<td>~50nm/0.57µm/ 200nm</td>
</tr>
<tr>
<td>Via plug</td>
<td>W</td>
<td>0.6µm diam</td>
</tr>
<tr>
<td>Inter Layer Dielectric 2</td>
<td>SiO2 / SOG / SiO2 cap</td>
<td>0.2µm/0 to 0.2µm/~60nm</td>
</tr>
<tr>
<td>Metal 1</td>
<td>TiW ARC , Al (Cu), TiW liner</td>
<td>50nm/0.57µm/ 150nm</td>
</tr>
<tr>
<td>Contact plug</td>
<td>W</td>
<td>0.6µm diam</td>
</tr>
<tr>
<td>Inter Layer Dielectric 1</td>
<td>SiO2</td>
<td>0.46 to 0.85µm</td>
</tr>
<tr>
<td>Nitride liner</td>
<td>Si3N4</td>
<td>~ 50nm</td>
</tr>
<tr>
<td>Poly 2</td>
<td>Polysilicon</td>
<td>270nm</td>
</tr>
<tr>
<td>Poly 1</td>
<td>Polysilicon</td>
<td>Thickness 325nm, Cd's 950-500 nm</td>
</tr>
<tr>
<td>Gate oxide</td>
<td>Under Detection Limit</td>
<td>Under Detection Limit</td>
</tr>
<tr>
<td>STI</td>
<td>SiO2</td>
<td>480nm ( Ox trench 1.6µm)</td>
</tr>
<tr>
<td>Epitaxy</td>
<td>Silicon</td>
<td>1µm</td>
</tr>
<tr>
<td>Burried oxide</td>
<td>Thermal oxyde</td>
<td>123nm</td>
</tr>
</tbody>
</table>

**Figure 2: Material identification and thickness measures for the ADS5463MHFG-V part**
Figure 3: Die microsection for the ADS5463MHFG-V part
3.4 **Effective LET calculation**

Taking into account passivation, metals, and dielectric layers, effective LET values at active DUT surface are computed with the use of SRIM2006\(^1\).

![Effective LET definition for min and max cases](image)

**Figure 4: Effective LET definition for min and max cases**

<table>
<thead>
<tr>
<th>Used ions Ion energy</th>
<th>Nitrogen (139 MeV)</th>
<th>Neon (235MeV)</th>
<th>Argon (372MeV)</th>
<th>Iron (523MeV)</th>
<th>Krypton (756MeV)</th>
<th>Xenon (420MeV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LET @ DUT surface (MeV)</td>
<td>1.8</td>
<td>3.6</td>
<td>10.2</td>
<td>18.5</td>
<td>32.2</td>
<td>69.0</td>
</tr>
<tr>
<td><strong>Min Case</strong> Eff. LET (MeV)</td>
<td>1.8</td>
<td>3.7</td>
<td>10.4</td>
<td>19.1</td>
<td>33.0</td>
<td>67.7</td>
</tr>
<tr>
<td><strong>Max Case</strong> Eff. LET (MeV)</td>
<td>1.8</td>
<td>3.9</td>
<td>10.9</td>
<td>20.5</td>
<td>34.9</td>
<td>58.0</td>
</tr>
<tr>
<td><strong>Bragg Peak</strong> Eff. LET (MeV)</td>
<td>5.9</td>
<td>9.0</td>
<td>19.6</td>
<td>29.3</td>
<td>41.0</td>
<td>69.2</td>
</tr>
</tbody>
</table>

**Figure 5: Effective LET values at active DUT area computed with SRIM2006**

\(^1\) [http://www.srim.org/SRIM/SRIMLEGIL.htm](http://www.srim.org/SRIM/SRIMLEGIL.htm)
4 Test Set-up

4.1 Test system

Figure 6 shows the principle of the Heavy Ion test system.

The test system is based on a Virtex5 FPGA (Xilinx). It runs at 50MHz. The test board has 168 I/Os which can be configured using several I/O standards.

The test board includes the voltage/current monitoring and the latch-up management of the DUT power supplies up to 16 independent channels.

A temperature control system is used to heat the DUT. Tests are executed at ambient temperature.

The communication between the test chamber and the controlling computer is effectively done by a 100 Mbit/s Ethernet link which safely enables high speed data transfer.

![Figure 6: Heavy Ion test set-up](image)

4.2 ADC Test principle

A test chain formed by a 14-bit DAC and the DUT is used for this experiment. The main principle of the test consists in applying the digital words to the DAC inputs and then monitoring words at the DUT outputs.

![Figure 7: The DAC-ADC test chain](image)
Test chain calibration
Before starting the experiment a calibration of the DUT in real test conditions is performed (under vacuum and at test temperature).
This test chain calibration consists in acquiring for each input step (16384 steps of the 14-bit DAC), the 13-bit ADC output value.
For each input step 2.0E+6 conversions are performed and min and max ADC output values are recorded. These min and max levels thresholds form an error range for each input word.
Figure 9 shows a calibration example used in Run 10. Min value, max value and delta (max-min) are plotted for each DAC word.
It can be observed that for most of the DAC inputs the delta conversion error is between 12 and 16 ADC LSBs.

![Calibration example (used in RUN 10)](image)

**Figure 8: Example of initial calibration results**

SEU
Each run consists in continuously applying 16384 (2^14) words at the DAC inputs. Each word is converted 4.0E+6 times at a conversion sampling frequency of 400MSPS, which corresponds to 10ms.
For each input word, the ADC outputs are compared with the min and the max values recorded during the calibration stage increased by 12 LSB to prevent from noisy events (Min - 12LSB, Max + 12LSB). If these values are exceeded, a conversion error is detected and counted.

Reference voltage monitoring
The internal reference voltage is measured at VREF pin. The signal is digitized with a 12-bit ADC converter (1LSB= 0.977 mV) at 40MSPS and 2 thresholds (low and high) are programmed.

SEL
SEL detection is performed by monitoring the DUT supply currents. When a SEL occurs (over 1A), then device is switched off during 1 second, and the SEL event is registered in the log file.
The SEL threshold can be adjusted during the test, but in general it is adjusted before starting the test. During all irradiation time, the supply currents of each DUT are measured.
Test conditions

Runs are performed with selected ions: 15N+4, 20Ne+6, 40Ar+12, 56Fe+15, 82Kr+22, 124Xe25+ and at two different tilt angles (0 deg. and 38 deg.)
The tests are done at three different temperatures: room temperature, 85°C and 125°C. All values of the voltage supplies are presented in Figure 9.

<table>
<thead>
<tr>
<th>Test</th>
<th>Test condition number</th>
<th>AVDD</th>
<th>DVDD</th>
<th>AVDD</th>
<th>Tilt angle (°)</th>
<th>Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEU</td>
<td>1</td>
<td>+4.75V</td>
<td>+3.0V</td>
<td>+3.0V</td>
<td>0°</td>
<td>room</td>
</tr>
<tr>
<td>SEU</td>
<td>2</td>
<td>+4.75V</td>
<td>+3.0V</td>
<td>+3.0V</td>
<td>38°</td>
<td>room</td>
</tr>
<tr>
<td>SEL</td>
<td>3</td>
<td>+5.25V</td>
<td>+3.6V</td>
<td>+3.6V</td>
<td>0°</td>
<td>85°C</td>
</tr>
<tr>
<td>SEL</td>
<td>4</td>
<td>+5.25V</td>
<td>+3.6V</td>
<td>+3.6V</td>
<td>38°</td>
<td>85°C</td>
</tr>
<tr>
<td>SEL</td>
<td>5</td>
<td>+5.25V</td>
<td>+3.6V</td>
<td>+3.6V</td>
<td>0°</td>
<td>125°C</td>
</tr>
<tr>
<td>SEL</td>
<td>6</td>
<td>+5.25V</td>
<td>+3.6V</td>
<td>+3.6V</td>
<td>38°</td>
<td>125°C</td>
</tr>
</tbody>
</table>

Figure 9: Test conditions for the ADS5463MHFG-V part

Figure 10: DUT bias description
5 RADEF Test Facility

Test at the cyclotron accelerator was performed at University of Jyvaskyla (JYFL) (Finland) under HIREX Engineering responsibility.

The facility includes a special beam line dedicated to irradiation studies of semiconductor components and devices. It consists of a vacuum chamber including component movement apparatus and the necessary diagnostic equipment required for the beam quality and intensity analysis.

The cyclotron is a versatile, sector-focused accelerator of beams from hydrogen to xenon equipped with three external ion sources: two electron cyclotron resonance (ECR) ion sources designed for high-charge-state heavy ions, and a multicusp ion source for intense beams of protons. The ECR's are especially valuable in the study of single event effects (SEE) in semiconductor devices. For heavy ions, the maximum energy attainable can be determined using the formula

\[ 130 \frac{Q^2}{M}, \]

where Q is the ion charge state and M is the mass in Atomic Mass Units.

Test chamber

Irradiation of components is performed in a vacuum chamber with an inside diameter of 75 cm and a height of 81 cm.

The vacuum in the chamber is achieved after 15 minutes of pumping, and the inflation takes only a few minutes. The position of the components installed in the linear movement apparatus inside the chamber can be adjusted in the X, Y and Z directions. The possibility of rotation around the Y-axis is provided by a round table. The free movement area reserved for the components is 25 cm x 25 cm, which allows one to perform several consecutive irradiations for several different components without breaking the vacuum.

The assembly is equipped with a standard mounting fixture. The adapters required accommodating the special board configurations and the vacuum feed-throughs can also be made in the laboratory’s workshops. The chamber has an entrance door, which allows rapid changing of the circuit board or individual components.

A CCD camera with a magnifying telescope is located at the other end of the beam line to determine accurate positioning of the components. The coordinates are stored in the computer’s memory allowing fast positioning of various targets during the test.

Beam quality control

For measuring beam uniformity at low intensity, a CsI(Tl) scintillator with a PIN-type photodiode readout is fixed in the mounting fixture. The uniformity is measured automatically before component irradiation and the results can be plotted immediately for more detailed analysis.

A set of four collimated PIN-CsI(Tl) detectors is located in front of the beam entrance. The detectors are operated with step motors and are located at 90 degrees with respect to each other. During the irradiation and uniformity scan they are set to the outer edge of the beam in order to monitor the stability of the homogeneity and flux.

Two beam wobblers and/or a 0.5 microns diffusion Gold foil can be used to achieve good beam homogeneity. The foil is placed 3 m in front of the chamber. The wobbler-coils vibrate the beam horizontally and vertically, the proper sweeping area being attained with the adjustable coil-currents.

Dosimetry

The flux and intensity dosimeter system contains a Faraday cup, several collimators, a scintillation counter and four PIN-CsI(Tl) detectors. Three collimators of different size and shape are placed 25 cm in front of the device under test. They can be used to limit the beam to the active area to be studied.

At low fluxes a plastic scintillator with a photomultiplier tube is used as an absolute particle counter. It is located behind the vacuum chamber and is used before the irradiation to normalize the count rates of the four PIN-CsI(Tl) detectors.

JYFL facility is an ESA qualified heavy ion facility. Compliance for beam uniformity and fluence dosimetry to ESA/SCC 25100 requirements are under JYFL responsibility.

For the present test, beam rectangular collimator was set to 20mm by 40 mm.

Used ions

The RADEF ion used is listed in the table below.
Test at the cyclotron accelerator was performed at “Université Catholique de Louvain” (UCL) (Louvain-La-Neuve, Belgium) under HIREX Engineering responsibility. 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:

\[
110 \frac{Q^2}{M}
\]

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.

Dosimetry

The current UCL Cyclotron dosimetry system and procedures were used.

Used ions

The UCL ions used are listed in the table below.

<table>
<thead>
<tr>
<th>Ion</th>
<th>Energy (MeV)</th>
<th>LET (MeV.cm²/mg)</th>
<th>Range (Si) (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>124 Xe 25+</td>
<td>420</td>
<td>69.7</td>
<td>37</td>
</tr>
</tbody>
</table>

Table 2: HIF, Used ion and features thereof; UCL June 2012
7 SEE Test Results

Two samples have been exposed over a LET range from 1.87 to 85.9 MeV/(mg/cm²) at ambient temperature for SEU characterization.

In addition, tests with Xenon at 38 degrees and two different temperatures (85°C, 125°C) have been performed for SEL identification.

Detailed results per run are presented in Table 3. The corresponding single event cross-section per device is shown in Figure 11 and the Weibull parameters are summarized in Figure 12.

The SEU cross-section reaches its highest value at 1.8E-04 cm²/device while the LET threshold below 1.87 MeV/(mg/cm²).

![Figure 11: SEU X-section/device for the ADS5463MHFG-V part; JYFL, UCL June 2012](image)

<table>
<thead>
<tr>
<th>ADS5463MHFG-V</th>
</tr>
</thead>
<tbody>
<tr>
<td>AV&lt;sub&gt;DD&lt;/sub&gt; = +4.75V, DV&lt;sub&gt;DD&lt;/sub&gt; = +3.0V, AV&lt;sub&gt;DD&lt;/sub&gt; = +3.0V</td>
</tr>
<tr>
<td>S</td>
</tr>
<tr>
<td>W</td>
</tr>
<tr>
<td>x0</td>
</tr>
<tr>
<td>A</td>
</tr>
</tbody>
</table>

Figure 12: Weibull parameters for the ADS5463MHFG-V part; JYFL, UCL June 2012

7.1 SEL

No SEL was observed up to LET of 86 MeV/(mg/cm²) at 85°C and 125°C temperatures, a bias voltage AV<sub>DD</sub> = +5.25, DV<sub>DD</sub> = +3.6V, AV<sub>DD</sub> = +3.6V and a fluence of 1.0E+07 ions/cm² for two samples.
7.2 SET on the reference voltage

A threshold of +/- 5 mV was used when monitoring the reference voltage output. SETs smaller than 5mV could not be detected. 140 SETs on the reference voltage signal were observed. They started to appear from Nitrogen ion (LET of 1.8 MeV/(mg/cm^2)).

Figure 13 presents an example of the transient on the Vref signal and a conversion error caused by this transient.

![Typical SET on Vref signal; RUN 48](image)

Figure 13: Typical SEU events; JYFL, UCL June 2012

7.3 SEU

Conversion events were detected over the LET range from 1.8 to 85.9 MeV/(mg/cm^2), resulting in a total of 555 events.

SEU events were classified in three main categories depending on the SEU duration:
- SEU ‘A’ – short conversion errors with maximum 10 consecutive samples in error
- SEU ‘B’ – long conversion errors with more than 10 consecutive samples in error with digital signature, and for which an SET on Vref signal occurred at the same time
- SEU ‘C’ – long conversion errors with more than 10 consecutive samples in error with analog signature, and for which an SET on Vref signal occurred at the same time

To better understand the difference between these three SEUs typical events for each category are plotted in Figure 14.

In addition an example of conversion errors versus DAC amplitude is also shown for RUN49.
Figure 14: Typical SEU events for each category; JYFL, UCL June 2012

All recorded events are presented in Table 3, while Figure 15 shows proportion of the event types for each ion.

<table>
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<th>Ion</th>
<th>Run</th>
<th>Fluence</th>
<th>SEU 'A'</th>
<th>SEU 'B'</th>
<th>SEU 'C'</th>
<th>SET on Vref</th>
<th>Total</th>
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<tr>
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<td>3</td>
<td>10</td>
<td>23</td>
</tr>
<tr>
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Figure 15: Events types for each used ion; JYFL, UCL June 2012
SEU amplitude and SEU duration definition

The SEU Amplitude value for each type of error results from the difference between the maximum sample value of the error and the minimum sample value of the error (see Figure 16). The SEU Duration for each type of error is defined by the difference between the maximum time and the minimum time when the amplitude has reached the detection threshold (see Figure 16).

![Figure 16: Definition of SEU Amplitude and SEU Duration](image)

Figure 17 represents SEU amplitude versus SEU duration for all SEU types and for all used ions.
Figure 17: Amplitude versus duration at all used ions; JYFL, UCL June 2012
8  **Glossary**

Most of the definitions here below are from JEDEC standard JESD89A

**DUT**: Device under test.

**Fluence** (of particle radiation incident on a surface): The total amount of particle radiant energy incident on a surface in a given period of time, divided by the area of the surface. In this document, Fluence is expressed in ions per cm².

**Flux**: The time rate of flow of particle radiant energy incident on a surface, divided by the area of that surface. In this document, Flux is expressed in ions per cm²*s.

**Single-Event Effect** (SEE): Any measurable or observable change in state or performance of a microelectronic device, component, subsystem, or system (digital or analog) resulting from a single energetic particle strike.

**Single-Event Transient** (SET): A soft error caused by the transient signal induced by a single energetic particle strike.

**Single-Event Latch-up** (SEL): An abnormal high-current state in a device caused by the passage of a single energetic particle through sensitive regions of the device structure and resulting in the loss of device functionality. SEL may cause permanent damage to the device. If the device is not permanently damaged, power cycling of the device (off and back on) is necessary to restore normal operation. An example of SEL in a CMOS device is when the passage of a single particle induces the creation of parasitic bipolar (p-n-p-n) shorting of power to ground. Single-Event Latch-up (SEL) cross-section: the number of events per unit fluence. For chip SEL cross-section, the dimensions are cm² per chip.

**Error cross-section**: the number of errors per unit fluence. For device error cross-section, the dimensions are cm² per device. For bit error cross-section, the dimensions are cm² per bit.

**Tilt angle**: tilt angle, rotation axis of the DUT board is perpendicular to the beam axis; roll angle, board rotation axis is parallel to the beam axis.

**Weibull Function**:

\[ F(x) = A \left(1-\exp\left(-\frac{(x-x_0)}{W}\right)^s\right) \]

- \( x \) = effective LET in MeV-cm²/milligram;
- \( F(x) \) = SEE cross-section in square-cm²/bit;
- \( A \) = limiting or plateau cross-section;
- \( x_0 \) = onset parameter, such that \( F(x) = 0 \) for \( x < x_0 \);
- \( W \) = width parameter;
- \( s \) = a dimensionless exponent.
Detailed results per run

SEL run results table:

- Laboratory: Place of executed test
- Hirex RUN: Hirex test run number
- Test SEL/SEU: Test type
- Test condition number: Test configuration number according to Figure 9
- DUT: Reference of tested device
- Sample number: TI sample number
- DVDD3: Output driver power supply (V)
- AVDD5: Analog power supply (V)
- Temperature: DUT temperature (°C)
- Ion: Ion specie
- Energy: Ion energy (MeV)
- Range: Ion range (micron)
- Base LET: Linear Energy Transfer (MeV/(mg/cm²))
- Tilt: DUT tilt angle with beam direction (deg)
- Eff LET: LET / (cos(tilt angle) (MeV/(mg/cm²))
- Fluence: Cumulated number of ions over the test run (cm⁻²)
- Flux: Effective Fluence (cm⁻² x s⁻¹)
- Beam Time: Time with beam (s)
- Dose: 1.6E-19 *1.0E+14 * EffLET*Fluence
- SEL events: Number of SELs
- SEU events: Number of SEUs
- SET on Vref signal: Number of SETs on Vref signal
- SEL X-Section: Cross-Section for SEL events
- SEU X-Section/Device: Cross-Section for SEU events
9.1 Detailed run table

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<th>Test condition number</th>
<th>DUT</th>
<th>Sample number</th>
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<th>DVDD3</th>
<th>AVDD5</th>
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<th>Ion</th>
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<th>Range [μm]</th>
<th>Base LET [MeV/μm²]</th>
<th>LET</th>
<th>Flux</th>
<th>Flux Beam Time</th>
<th>Dose</th>
<th>SEL Events</th>
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<th>Device</th>
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Table 3: Run Table for the ADS5463MHFG-V part; JYFL, UCL June 2012