HEAVY ION TEST REPORT

SINGLE EVENT EFFECTS
INA226AIDGSR
(DC2318)
High-Side or Low-Side Measurement, Bi-Directional Current and Power Monitor
From
Texas Instruments

TRAD/TI/INA226AIDGSR/2318/ESA/MMB/2308	Labège, December 20th, 2023
TRAD Tests & radiations a HEICO company — afaq ISO 9001 Qualité AFNOR CERTIFICATION	TRAD 907 voie l'occitane - 31670 Labège FRANCE Tel: +33 5 61 00 95 60 Email: trad@trad.fr Web site: www.trad.fr SIRET 397 862 038 00056 - TVA FR59397862038

Written by	Quality control by	Approved by
M. GAUTIER	**A. AL YOUSSEF**	**L. GOUYET**

Revision: 0		
To:	**R. KARPOV**	Project/Program: Ref:
Company:	**European Space Agency**	

DISCLAIMER

The information contained herein is presented for informational purposes only. ESA does not make, and disclaims, any representation or warranty, express or implied, of the correctness and completeness of this information, and its fitness for a particular purpose. This information does not constitute or imply an ESA endorsement or approval for the use of any tested part in ESA activities or third-party activities. In particular, but without limitation, this is due to traceability which cannot be guaranteed on commercial components but is an important pre-requisite for the reusability of TID, TNID and SEE radiation test results. The information herein can therefore not be reused without further justifications which may vary depending on the type of space activity concerned.

Reproduction of parts of the test summary is authorised on the condition that clear reference is made to the test report number and this disclaimer.

ESA reserves the right to alter, revise, or rescind this document due to subsequent developments or additional test results. ESA intends, but cannot guarantee, that the ESARAD database always contains latest versions of the test reports.

CONTENTS

Abbreviations and acronyms 5
Abstract 6
1. Introduction 7
2. Documents 7
 2.1. Applicable documents 7
 2.2. Reference documents 7
3. Organization of activities 7
4. Parts information 8
 4.1. Device description 8
 4.2. Identification 8
 4.3. Procurement information 8
 4.4. Sample preparation 8
 4.5. Sample pictures 9
  4.5.1. External view 9
  4.5.2. Internal view 9
5. Dosimetry and irradiation facility 10
 5.1. TRAD test facility 10
 5.2. Beam characteristics 10
 5.3. Heating system 10
6. Test procedure and setup 11
 6.1. Test method 11
 6.2. Test principle 11
  6.2.1. SEL test principle 11
 6.3. Test bench description 12
  6.3.1. Test bench overview 12
  6.3.2. Test equipment identification 13
  6.3.3. Test board description 13
  6.3.4. Test conditions and event detection thresholds 14
7. Test story 14
8. Non conformance 14
9. Results 15
 9.1. Test run summary 15
 9.2. SEL test results 16
  9.2.1. SEL LET threshold 16
  9.2.1. SEL worst case 16
10. Conclusion 17

FIGURES

Figure 1: Pictures of the package 9
Figure 2: Picture of the internal overall view 9
Figure 3: Picture of the die marking 9
Figure 4: VASCO picture 10
Figure 5: Thermal image of INA226AIDGSR heated to 125°C 10
Figure 6: Common SEL characteristic 11
Figure 7: Test bench description 12
Figure 8: Test board schematic 13
Figure 9: SEL worst case No. 1 16

TABLES

Table 1: Organization of activities 7
Table 2: Part identification 8
Table 3: Part procurement information 8
Table 4: Equipment identification 13
Table 5: SEL test conditions and detection thresholds 14
Table 6: INA226AIDGSR test run table 15

Abbreviations and acronyms

DUT	Device Under Test
ESA	European Space Agency
LET	Linear Energy Transfer
SEE	Single Event Effect
SEL	Single Event Latch-up
UCL	Université Catholique de Louvain
VASCO	VAcuum System for Californium Operation

Abstract

The main objective of this test was to evaluate the sensitivity of the INA226AIDGSR, a High-Side or Low-Side Measurement, Bi-Directional Current and Power Monitor with I²C Compatible Interface versus SEL.
The irradiation was performed at TRAD with a maximum LET of 43 MeV.cm²/mg.
The main conclusions are the following.

The SEL test was performed under SEL test conditions (see Table 5).

In SEL test configuration
Destructive event was observed with LET of 43 MeV.cm²/mg, Californium heavy ion.
Following this result, the heavy ion test campaign was cancelled.

1. Introduction

This report includes the test results of the heavy ion SEE test sequence carried out on the INA226AIDGSR, a High-Side or Low-Side Measurement, Bi-Directional Current and Power Monitor with I²C Compatible Interface from Texas Instruments, susceptible to show SEL induced by heavy ions.

This test was performed for ESA at TRAD. Irradiations were performed on October 11th, 2023. During this test campaign, 2 samples were irradiated.

2. Documents

2.1. Applicable documents

[AD1] Technical proposal: TRAD/P/ESA/AO17950/AR/131222 Rev 0 dated 13/11/2022

2.2. Reference documents

[RD1] ESCC Basic specification No. 25100 Issue 2 of October 2014
[RD2] Datasheet: INA226 SBOS547A, by Texas Instruments dated June 2011 Revised dated August 2015

3. Organization of activities

The devices were procured and delidded by TRAD. The testing board and testing software were developed by TRAD. Before the campaign the samples were checked-out and the test bench was validated with californium test at TRAD. The test campaign was performed by TRAD. The next table summarizes the responsible entity for each activity involved in this project:

1	Procurement of Test Samples	TRAD
2	Preparation of Test Samples (delidding)	TRAD
3	Preparation of Test Hardware and Test Program	TRAD
4	Samples Check out	TRAD
5	Accelerator Test	TRAD
6	Test Report	TRAD

Table 1: Organization of activities

4. Parts information

4.1. Device description

The INA226 is a current shunt and power monitor with an I²C™- or SMBUS-compatible interface. The device monitors both a shunt voltage drop and bus supply voltage. Programmable calibration value, conversion times, and averaging, combined with an internal multiplier, enable direct readouts of current in amperes and power in watts.
The INA226 senses current on common-mode bus voltages that can vary from 0 V to 36 V, independent of the supply voltage. The device operates from a single 2.7-V to 5.5-V supply, drawing a typical of 330 µA of supply current. The device is specified over the operating temperature range between –40°C and 125°C and features up to 16 programmable addresses on the I²C-compatible interface.

4.2. Identification

Part designation	INA226AIDGSR
Manufacturer	Texas Instruments
Part function	High-Side or Low-Side Measurement, Bi-Directional Current and Power Monitor with I²C Compatible Interface

Table 2: Part identification

4.3. Procurement information

Package	10-VSSOP
Date code	2318
Lot code No.	3077783HFT
Number of tested parts	2 irradiated samples

Table 3: Part procurement information

4.4. Sample preparation

5 parts were delidded, 2 samples have been damaged during this operation.
A functional test was performed on delidded samples to check that devices were not degraded by the delidding operation.
Among the 3 delidded samples available for the test campaign, 2 parts were irradiated and 1 was not used.

4.5. Sample pictures

4.5.1. External view

The Figure 1 shows an external view of the parts. Left and right pictures are respectively the top and the bottom views of the package.

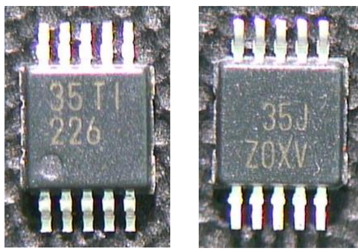


Figure 1: Pictures of the package

4.5.2. Internal view

Figure 2 gives an overview of the die. Figure 3 presents a view of the internal markings observed on the die (indicated by a red rectangle on Figure 2).

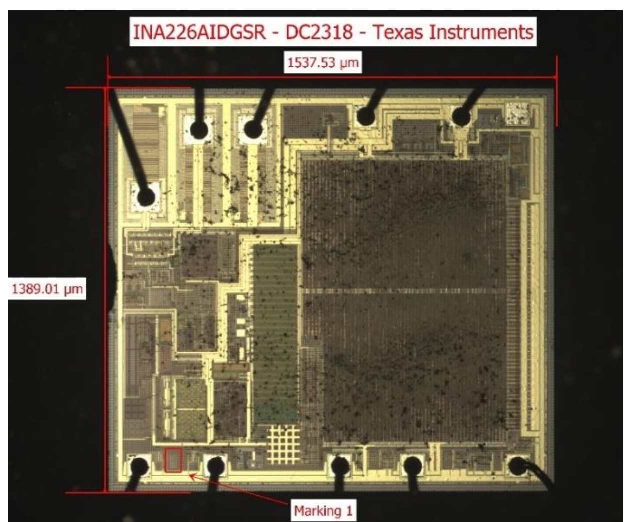


Figure 2: Picture of the internal overall view

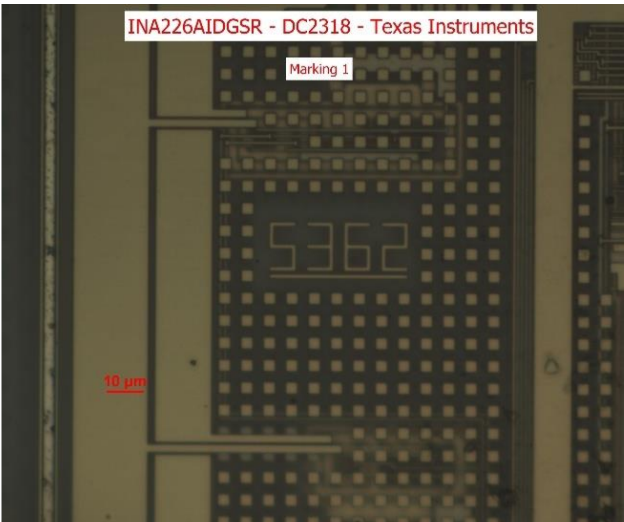


Figure 3: Picture of the die marking

5. Dosimetry and irradiation facility

5.1. TRAD test facility

The VASCO is a vacuum chamber developed by TRAD in order to test the complete setup in vacuum with all cables length and electrical feedthroughs as used on the irradiation site.
The VASCO main characteristics are:
Chamber dimensions: 400x400x400mm, pressure 5.10^{-2} mbar.
Electrical feedthroughs available:
16 isolated BNC, 16 isolated SMA, 16 isolated SMB, 4 DB25, 3 HE10-40.
Other possibility on request

Validation runs are performed using Californium-252 source.

Figure 4: VASCO picture

5.2. Beam characteristics

Californium-252 is a fissionable, transuranic radionuclide which decays by alpha particle emission with a half-life of 2.72 years.
The source emits alpha particles, fission fragments and fast neutrons. The fission fragments are used for SEE testing and these have a mean LET of 43 MeV.cm²/mg (Si) with 95% of the particles having LETs between 41 and 45 MeV.cm²/mg (Si). The mean range of the fission particles in silicon is 14.2µm.

5.3. Heating system

TRAD has developed a specific heating system to heat and regulate the temperature of the DUT. Figure 5 shows a thermal image taken during the heating calibration of the DUT, the temperature of the die was set to 125°C as shown on the picture. Californium tests were performed at 100°C and 60°C.

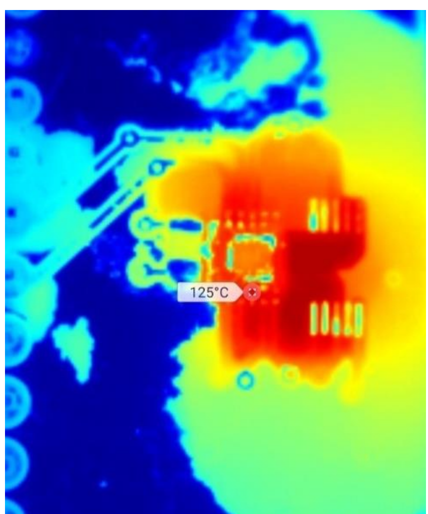


Figure 5: Thermal image of INA226AIDGSR heated to 125°C

6. Test procedure and setup

6.1. Test method

The irradiation was performed during the validation test with Californium-252 source. This test is useful to have a first estimation of the device's sensitivity and validate all operations performed by the test bench during irradiation. Nevertheless, the fluence deposited during irradiation can be estimated but no limit is mandatory, this process is fully done with the aim of test bench validation.

6.2. Test principle

6.2.1. SEL test principle

A SEL is a permanent event that results from the activation of a parasitic thyristor structure creating low impedance conduction path in the device. The consequent high current can potentially damage the device, possibly even leading to its destruction due to overcurrent. A power cycle is required to correct this situation.

GeV is a specific equipment developed by TRAD to protect the DUT and to perform SEL characterization. The power supply is applied to the DUT through GeV which protects the DUT against over consumption. Indeed, GeV continuously monitors and records the current. A programmable threshold current is set above the nominal operating value of the supply current. During irradiations, if the current consumption exceeds the threshold during a defined "hold time", a SEL is counted and the DUT is switched off during a defined "off time". Once the event is defused, the power supply is switched ON again with the nominal current consumption expected.

Figure 6 shows a common SEL characteristic, with and without the GeV system protection.

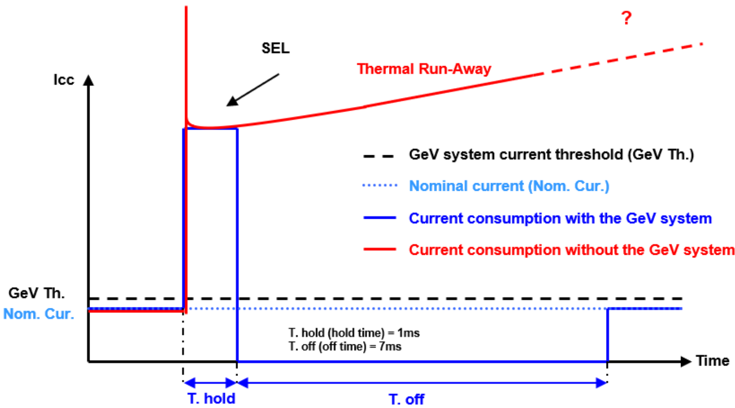


Figure 6: Common SEL characteristic

The SEL test was performed under SEL test conditions (see Table 5).
TRAD uses a dedicated system to heat and regulate the DUT temperature. The temperature is visualized and regulated from outside of the vacuum chamber during the irradiation.

6.3. Test bench description

6.3.1. Test bench overview

Figure 7 provides a global view of the test bench. It is composed by:

- A computer to control the test equipment and to record the SEE.
- A test board to bias and operate the DUT (schematic is shown in Figure 8).
- A power supply for the DUT and auxiliary components.
- A GeV System to protect the DUT, detect and record SEL.

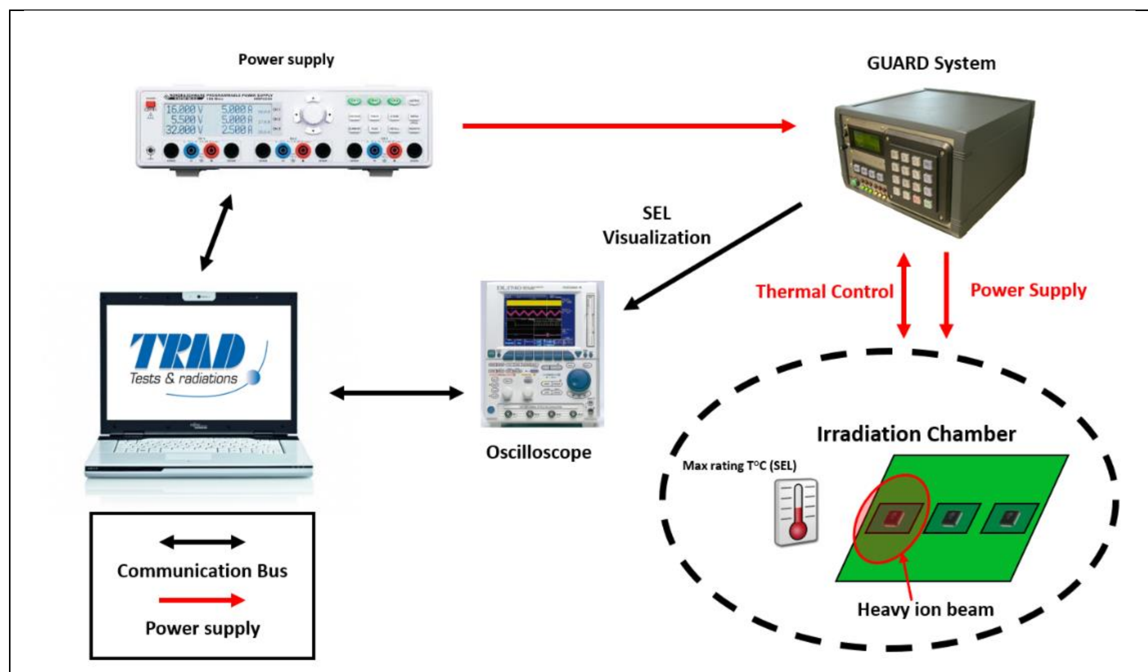


Figure 7: Test bench description

6.3.2. Test equipment identification

TEST BOARD	TRAD_CT1_I_INA226AIDGSR_VSSOP_MMB_2308
EQUIPMENT	SM-87; AR-94; ME-70
TEST PROGRAM	INA226AID_I_DC2318_BI_V10_SEL

Table 4: Equipment identification

6.3.3. Test board description

The TRAD test board schematic referenced "TRAD/TA1/I/INA226AIDGSR/VSSOP/MMB/2308" is illustrated in Figure 8.

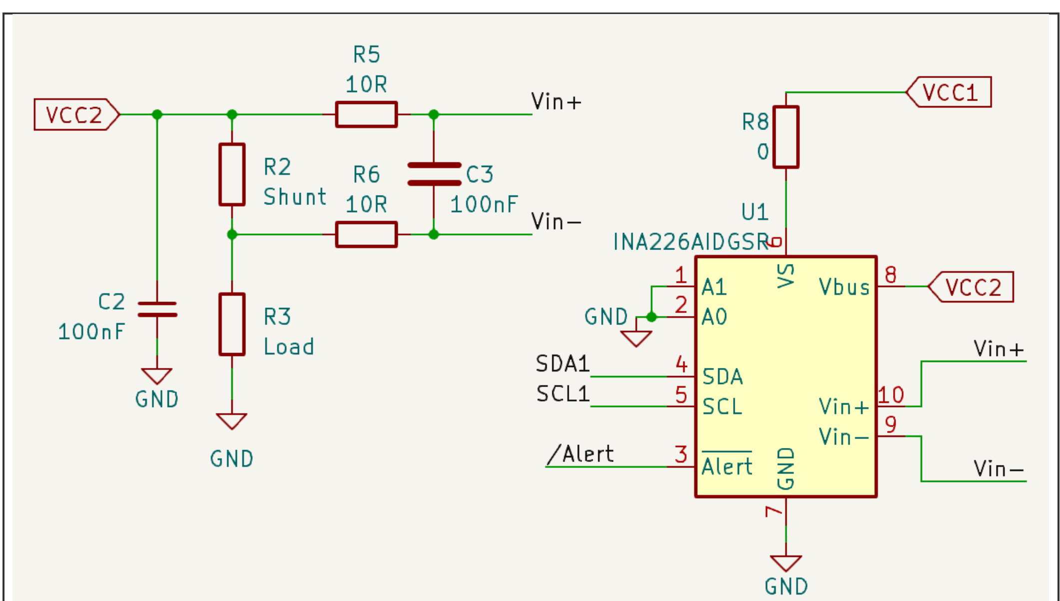


Figure 8: Test board schematic

6.3.4. Test conditions and event detection thresholds

SEL test

	VCC1	VCC2
Voltage	36V	5.5V
$I_{nominal}$	3.6 mA	1.2 mA
$I_{threshold}$	150 mA	20 mA
T_{hold}	1 ms	1 ms
$T_{cut off}$	7 ms	7 ms
Temperature	100°C / 60°C	

Table 5: SEL test conditions and detection thresholds

7. Test story

No atypical behaviour during the test to report.

8. Non conformance

Test sequence, test and measurement conditions were nominal.

9. Results

In this chapter are presented the SEE test results.
First, test runs summary tables provides details of the runs performed during this campaign, their parameters and results.
Then, for each event type are given their corresponding LET threshold, cross section and worst cases when it is applicable.
On the cross section curves are plotted their corresponding error bars.
The following formulas is used to calculate these error bars. It can be found in ESCC Basic specification No. 25100.

$$\delta\sigma \times F = \sqrt{(\delta Nevents)^2 + (\mathrm{Nevents} \times \frac{\delta \mathrm{F}}{F})^2}$$

where :

- F is the fluence
- $\sigma = N_{events} / F$
- δF/F is the uncertainty on the measured fluence (±10%).
- δN_{events} is the variance on the measured number of events.

Assuming that SEE events are random, the probability of events follows a Poisson distribution. The variance on the number of events is calculated from the chi-square distribution for a given confidence level. In this test report, we used a confidence level of 95%.

9.1. Test run summary

Run	Part	Config	T°	Time (s)	SEL
1	1	SEL	100	235	Destructive event
2	2	SEL	60	281	Destructive event

Table 6: INA226AIDGSR test run table

SEE detailed results are described in the following sections.

9.2. SEL test results

9.2.1. SEL LET threshold

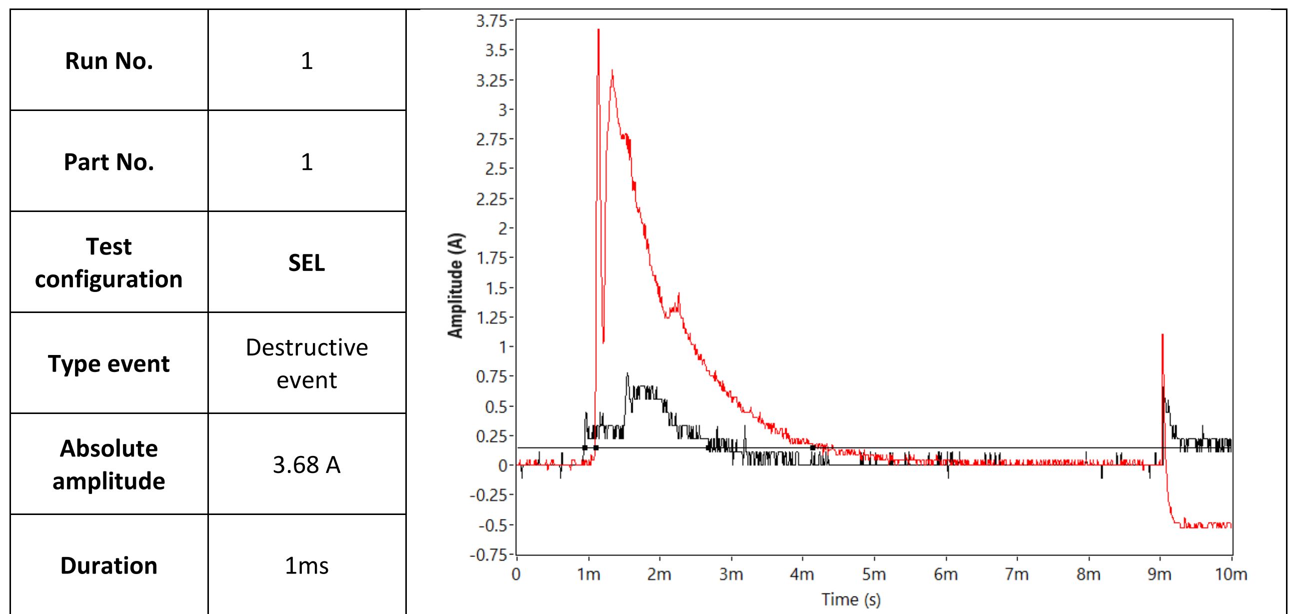
The SEL test was performed under SEL test conditions (see Table 5).

In SEL test configuration
Destructive event was observed with LET of 43 MeV.cm²/mg, Californium heavy ion.

9.2.1. SEL worst case

This section presents the current consumption recorded during the occurrence of a destructive event on the INA226AIDGSR.

In SEL test configuration
Destructive event was observed on VCC1 occurred during run No. 1.



Run No.	1
Part No.	1
Test configuration	SEL
Type event	Destructive event
Absolute amplitude	3.68 A
Duration	1ms

Figure 9: SEL worst case No. 1

10. Conclusion

The heavy ions test was performed on INA226AIDGSR. The aim of the test was to evaluate the sensitivity of the device versus SEL.

The SEL test was performed under SEL test configuration (see Table 5).

In SEL test configuration
Destructive event was observed with LET of 43 MeV.cm²/mg, Californium heavy ion.
Following this result, the heavy ion test campaign has been cancelled.