Radiation Effects Characterization of TI AFE11612-SEP High-Density General-Purpose Monitor and Control Systems (July 2024)

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Abstract— **AFE11612-SEP highly integrated analog monitor and control device released for space applications. It passed total Dose of 20Krads and is latch-up immune upto 48 MeV-cm2/mg at 125C. Single Event Upset cross section was 9.33E-5 cm2/Ions.**

I. INTRODUCTION

The AFE11612-SEP is a highly integrated analog monitor and control device designed for high-density, general-purpose monitor and control systems. It includes 12-channel, 12-bit digital-to-analog converters (DACs) and a 16-channel, 12-bit, analog-to-digital converter (ADC). The device also incorporates eight general-purpose inputs and outputs (GPIOs), two remote temperature sensor channels, and a local temperature sensor channel, being released in space enhanced package for space applications.

The device has an internal 2.5 V reference that sets the DAC to an output voltage range of 0 V to 5 V. The device also supports operation from an external reference. The device supports communication through both SPI-compatible and I2C compatible interfaces.

The device high level of integration significantly reduces component count and simplifies closed-loop system design, thus making the device a great choice for high-density applications where radiation-tolerance and board space are critical.

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II. TOTAL DOSE RADIATION EFFECTS

AFE11612-SEP was studied for Total Ionizing Dose (TID) Effects. In accordance to MIL-STD-883J, test method 1019.9. Devices were exposed at low dose rate of 0.01rad/sec under unbiased condition and high dose rate of 260rad/sec under biased conditions up to 20Krads.

For the biased configuration, the device was setup with max operating supply or rail voltage of 5.5V. These devices were irradiated using Co-60 source for both biased and unbiased conditions up to 20Krads. Pre and post electrical tests were performed using TI Automated Test Equipment. The following plot Figure 1 and 2 shows the trend of critical offset error parameter across accumulated Total Ionizing Dose (TID). Offset error and Gain Error which are key parameters for this device are drifting very less and within datasheet limits after 20Krad LDR and HDR.

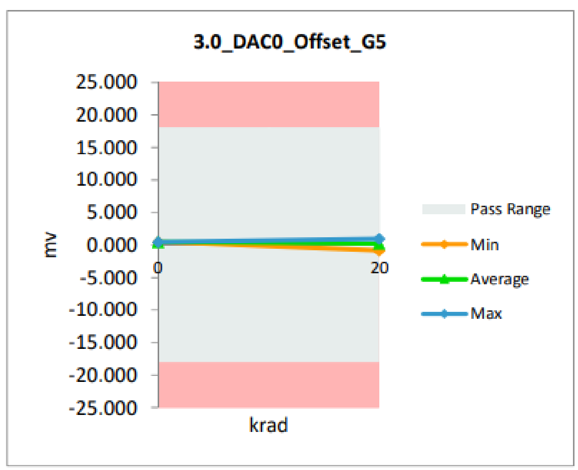

Fig. 1 Offset drift

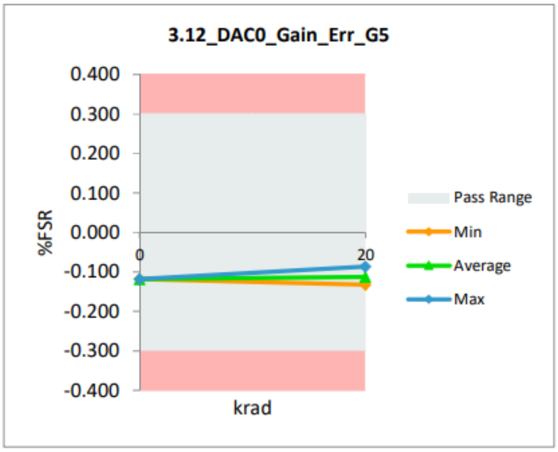

Fig. 2 Gain Error drift

III. ELDRS CHARACTERIZATION

Parametric drift between 0 rad and 20Krad was analyzed for ELDRS study. Per MIL-STD-883J, test method 1019.7, median parametric drift for each test condition was compared between HDR and LDR. If for any of the parameters, the ratio of median LDR drift to median HDR drift is greater than 1.5 and the parametric reading is outside pre-radiation test limits; the part is considered to be ELDRS susceptible. Based on the detail study of AFE11612-SEP, all datasheet parameters had median drift ratio of less than 1.5. hence AFE11612-SEP is not ELDRS susceptible and HDR will be used for Radiation Lot Acceptance Testing (RLAT).

IV. SINGLE EVENT EFFECTS

Single Event Effects occur under the influence of Heavy ions and are usually split into SEL and SET. SEL Study was done using evaluation board. The board was powered using a separate NI PXIe precision power supply.

V. SINGLE EVENT LATCHUP

SEL (Single Event LatchUp) is critical to ensure no catastrophic system level latch-up events happen in space applications. SEL study was performed at TAMU cyclotron facility. The device was heated using external heating equipment and thermal to test at 125C. The supply voltage was set to a max value of +5.5V and the supply current was continuously monitored for latch-up.

An ion flux of 105 ions/sec-cm2 to reach a Fluence of 107 ions/cm2 was used for the SEL test. Ion beam of Ag was used with an angle of 0 degrees to achieve required LETEff of 48 MeV-cm2/mg.

AFE11612-SEP did not exhibit Latch-up under the worst-case rail voltage of 5.5V and Ambient Temperature of 125C upto LETEff of 48 MeV-cm2/mg. The supply current excursions seen were due to register flips experienced by device which resulted in configuration change of device as shown in the Figure 3 & 4. The supply currents returned back to pre-beam levels after reconfiguring the device to original register settings.

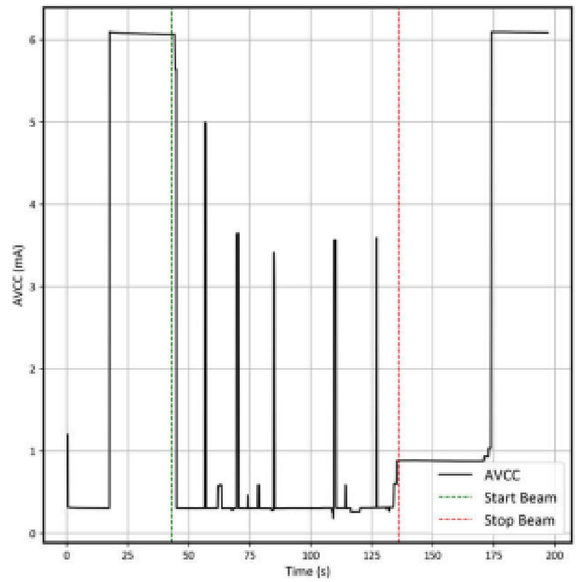

Fig. 3 AVCC Transient during SEL Test

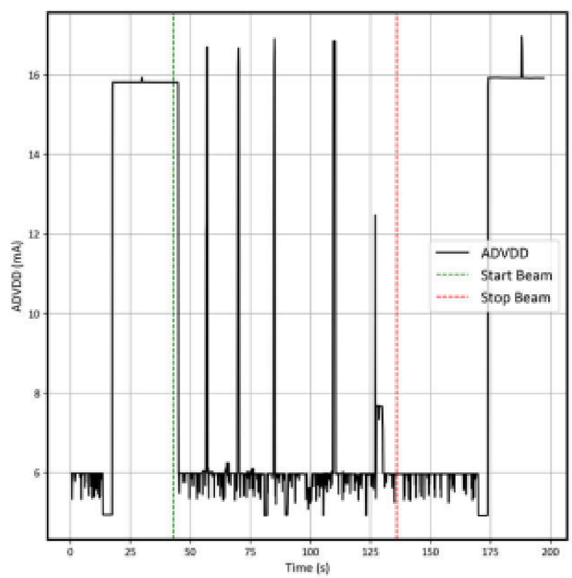

Fig. 4 AVDD Transient during SEL Test

The table below shows the Ion species and angles used to test SEL. For the Single Event Latch up testing, Silver (Ag) ions with angle of 0 degrees were used.

Table. 1 Details of SEL Test

Run #	Distance (mm)	Temp (°C)	Ion	Angle (Degrees)	LET (MeV·cm²/mg)	Flux (ions/cm²/s)	Fluence (Total # of Ions)
25	40	125	Ag	0	48	1.09E+05	1.00E+07
26	40	125	Ag	0	48	1.09E+05	1.00E+07

VI. Single Event Transient

For SET (Single Event Transient), the EVM setup was biased as shown in below figure. The EVM was controlled using GUI through PC.

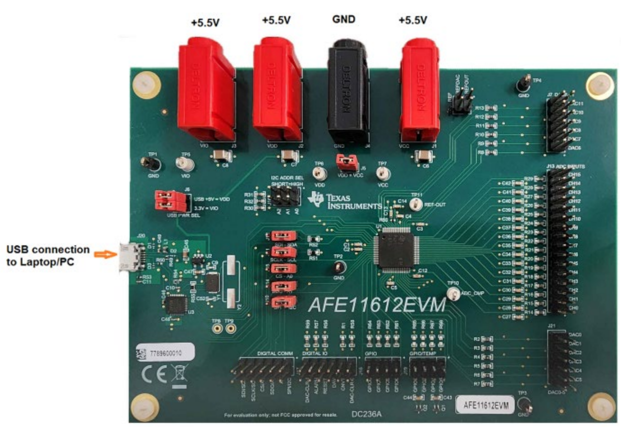

Fig. 5 EVM setup with capture card

The GUI is used to configure the device input channel for conversion and setup for ADC and DAC modes. The SEU was primarily characterized by monitoring the DAC output for a preset value. The DAC output was set at max value of 5V and trigger was set at 4V. The variation in the output in the cave without beam was characterized to make sure the chosen trigger limits were ok. The scope was used to continuously monitor the output during beam. Any transient value under 4V was counted as 1 event. The scope captured 1000 samples around the trigger point and then this data was post processed to obtain the time taken for recovery from each event. Most of the events recovery time was around 2us. The picture of typical event captured is as shown below.

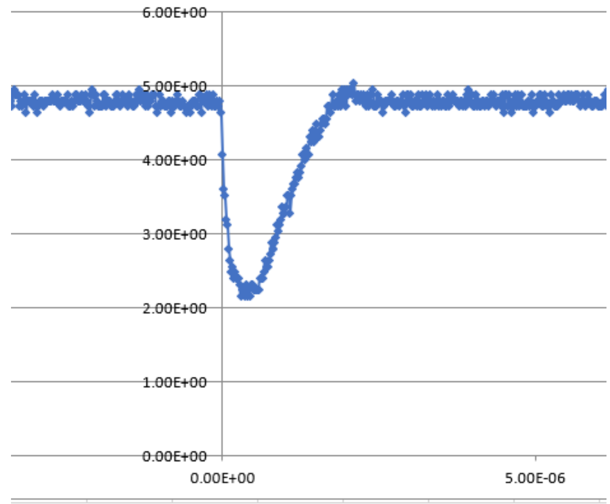

Fig. 6 Captured Event and its recovery time

The table below shows the Ion species and angles used to test SEU. During Run # 11, we observed 3 events and for Run#12 there were 24 events observed that resulted in cross section 9.33E-5 cm2/Ions; DAC was still running.

Table. 3 Details of SEU Test

Run #	Distance (mm)	Temp (°C)	Ion	Angle (Degrees)	LET (MeV·cm²/mg)	Flux (ions/cm²/s)	Fluence (Total # of Ions)
11	40	25	Ag	0	46	3.00E+02	4.50E+04
12	40	25	Ag	0	46	3.00E+02	2.00E+05

A. Abbreviations and Acronyms

ELDRS – Enhanced Low-Dose Rate Sensitivity
SEU – Single Effect Upsets
EVM – Evaluation Module
TAMU – Texas A&M University
PXI – PCI eXtensions for Instrumentation
PCI – Peripheral Component Interconnect
GUI – Graphical User Interface
LETEff – Effective Linear Energy Transfer

VII. Conclusion

Radiation effects on AFE11612-SEP; a highly integrated analog monitor and control device was studied. This device passed Total dose rate of upto 20Krads and is Latch-up immune upto 48 MeV-cm2/mg. The device had effective SET cross section of 9.33E-05 cm2/Ions at 46 MeV-cm2/mg.

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