Single Event Effects Testing of a Commercial-Off-The-Shelf Analog-to-Digital Converter in a Camera Application

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***Abstract*-- Single event effect data is presented on the Analog Devices AD7984. The recent heavy-ion test results showcase application-specific results for the commercial part in its intended application.**

Index Terms- Heavy-Ion, Commercial-Off-The-Shelf, Single Event Effects, and Space Radiation.

I. INTRODUCTION

As space-bound instruments demand sensors or cameras with increased density and higher resolution, higher speed and lower power components are needed to pass data frames efficiently from the instrument to on-board computers. Many radiation-hardened data converters are not able to meet the combination of affordability and performance of commercial alternatives. The radiation response of a COTS device is not easily compared to previous results on other parts, even in the same device family; this investigation was conducted to capture any destructive events or major functionality interruptions for an intended camera assembly shown in Figure 1.

Radiation-induced upsets are a concern for microcircuit designs in the space environment. Charged particles that deposit energy within the sensitive node of a device may cause the output to fluctuate from expected values or damage the semiconductor. Destructive single events such as single event latch up (SEL) are of particular concern with commercial off-the-shelf (COTS) devices that have not been designed with radiation effects in mind. Many data converters tested have shown varied response to incident heavy ions [1-4]. These upsets are dependent on the Linear Energy Transfer (LET) that the heavy-ion has in the given semiconductor material. Other test parameters such as angle of incidence, ion species, temperature, device architecture, applied voltage, operating frequency, etc. all play a role in the part response. In an effort to vet the application, this testing was done to capture destructive failure modes of the device with as many of the test parameters matched to the intended application.

Fig. 1: Camera interface board

II. DEVICES UNDER TEST

The Analog Devices AD7984 is an 18-bit, successive approximation, analog-to-digital converter (ADC) that operates from a single power supply. It contains a low-power, high-speed, 18-bit sampling ADC and a versatile serial interface port [5]. The devices were tested at the Texas A&M University Cyclotron Facility with the ion, incident angle and effective LET listed in Table 1. Testing was performed in air at room temperature.

TABLE I
TAMU ION & LET INFORMATION

Angle	Ion and Linear Energy Transfer (MeV*cm^2/mg)		
	Ar	Kr	Xe
0°	8.6	28.8	53.1
30°	9.9	33.2	61.3
45°	12.2	40.8	75
60°	17.2	57.6	106.2

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A partially populated interface board containing the AD7984 and peripheral passive components were used to mimic the application circuit. The etched parts on board are shown in Figure 2. Device preparation for the facility requires that the commercial plastic encapsulant be removed such that the range of particles is sufficient through the semiconductor to penetrate through to the sensitive volumes within the device. Chemical etching was of particular concern because the parts were on a flight like board populated with other actives and the traces on the PWB could not be damaged if we were to retain functionality. The challenges associated with these parts is the small package, and the parts that surround. A silicone mask was set overnight before acid etching to protect the board and support circuitry. To remove the encapsulant we used H_2SO_4 at an elevated temperature and an acetone wash. The approach was done and repeated on multiple parts seen on the board

Fig. 2: Acid Etched AD7984 parts on board, lower right, four parts

With no CCD in the test circuit a noise floor signal level was supplied to the input, and the output was taken through a remote computer in the Flexible Image Transport System (FITS) format. The recorded output from the FITS is translatable into Analog-to-Digital Units (ADUs) which are independent of the camera gain and representative of voltage from charge collected. The ADU can be read as a count.

III. Test Results and Discussion

The parts were tested for a given LET to a predetermined fluence of ions. During beam exposure the current levels and an image output were monitored from the control room. After each ion beam exposure post processing of the image file was done to determine the count of single events. For this test, a single event upset was defined as a data frame containing more than 10 pixels at least 10 standard deviations beyond the noise floor, a requirement for the mission. The data was then scaled to 100 frames and the results are plotted in Figure 3.

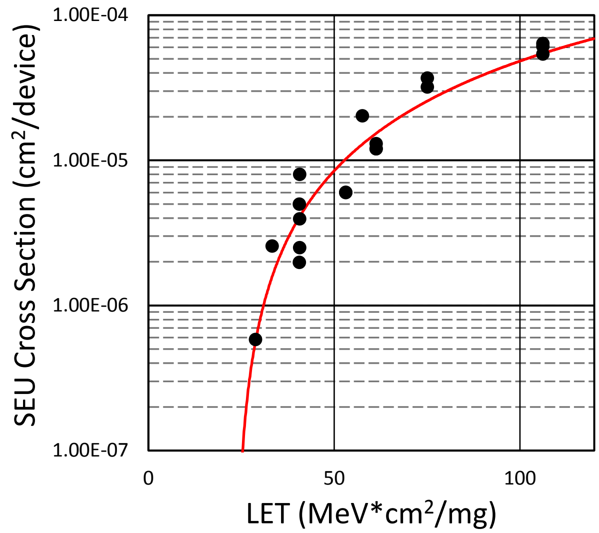

Fig. 3: Single event upset cross section and Weibull fit for AD7984 in application

For the single event rate calculations on the device, a Weibull fit to the datahas an onset of 23.4 MeV·cm^2/mg, the last ion LET where no upset was recorded, and an estimated saturation of 3.2x10^{-4} cm^2/device. The other parameters were determined using least squares approximation to minimize error. The best fit information is given in Table 2.

TABLE II
WEIBULL FIT PARAMETERS

LET_{th}	23.4 MeV·cm^2/mg
$Sigma_{asm}$	3.2 x 10^{-4} cm^2
Shape	1.7
Width	220.8 MeV·cm^2/mg

For the given application there were two types of manifesting radiation responses: short output transients (glitches seen at the beginning and end of the rising edge) and large scale transients that correspond with false readings of saturation on the input. No destructive events were recorded. Supply voltage to the system was not varied from nominal application levels. Figure 4 shows digital output levels of the ADC following a single event heavy-ion strike. The two curves shown are an upper and lower bound for the amplitude of the captured transient events.

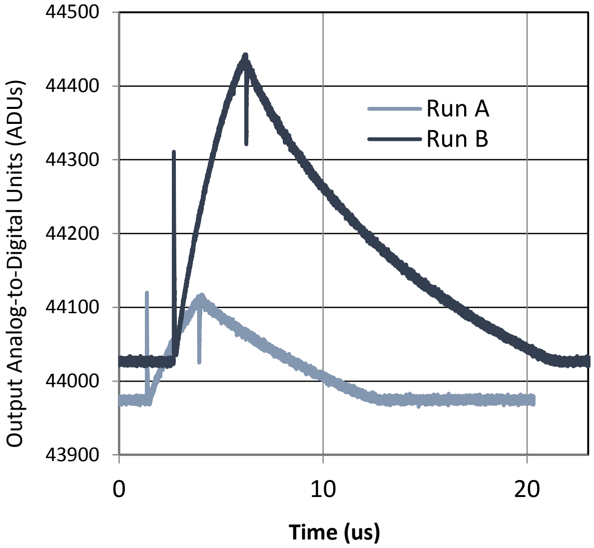

Fig. 4: Time dependent response of the circuit, digital output levels of the ADC following a single event heavy-ion strike. The two curves shown are an upper and lower bound for the amplitude of the captured transient events.

The short transients signify an ion strike, while the transient rise and decay are the system response to that strike. This is not categorized as a Single Event Funtional Interrupt (SEFI), as the device returns to nominal operation without any intervention. For all runs, the rise and fall time were under 20us. The transient response that preceded these strikes were on the order of 100ns, shown in Figure 5.

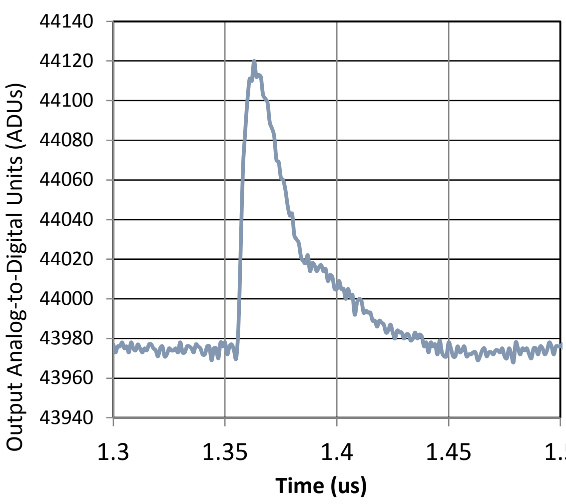

Fig. 5: Transients spikes that precede the system response

To be clear, the upset cross section information that is reported for this investigation is that of the system response and not of the device itself. If every small transient were recorded the error cross section would be much higher, and posibly have an earlier onset. This is similar to single event transient testing that has a trigger level set high. One cannot use the rate information as anything more than a reference for one application if it is not employed in the same configuration.

IV. Summary

The use of semiconductor devices in hostile environments demands thorough understanding of the environmental conditions faced and the device's expected performance. These initial results were application-specific and show a susceptibility to interruptions during nominal operation that are transient and do not require power cycling.

In many cases end users are not able to fully characterize a part with respect to radiation response. They are limited in equipment or funding that would allow them to do so. By stripping down the intended application to the bare minimum able to mimic the application, system level response can help to understand the radiation effects and threats. For single event effects testing this is simplified by only bombarding one device at a time, with known bias and operation information. In this experiment we were looking at board level response while one device was tested.

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VI. References

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