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

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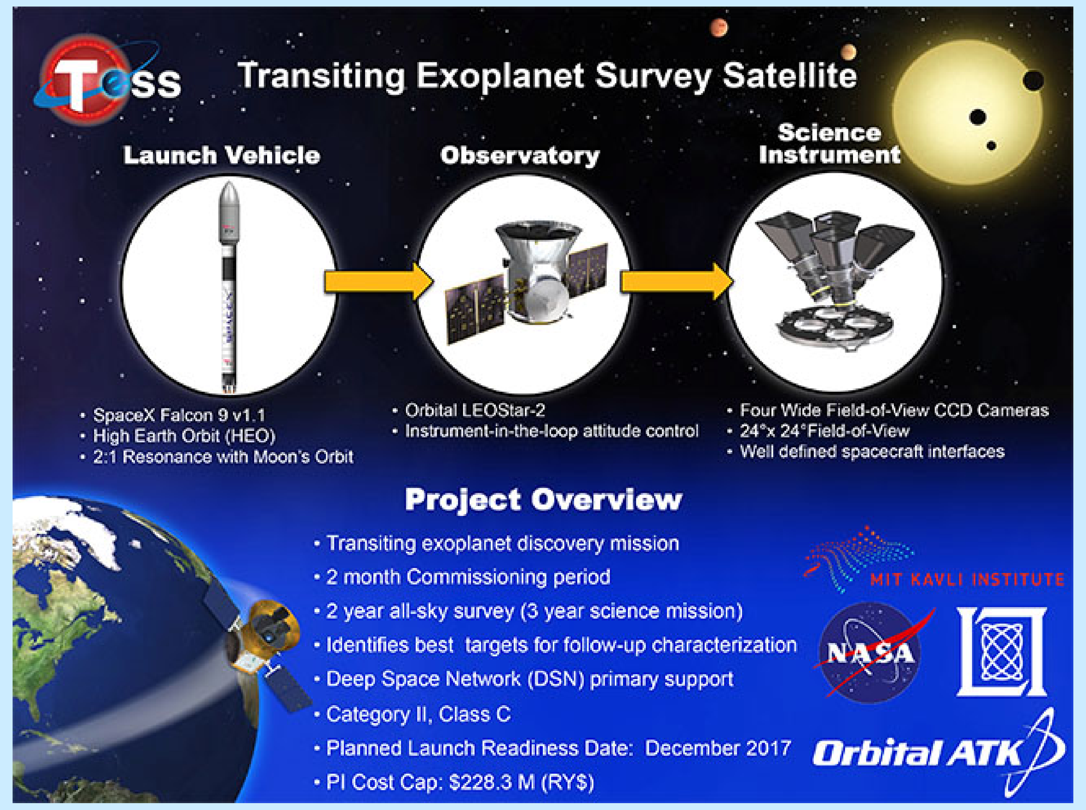
Abstract: Single event effect data is presented on the Analog Devices AD7984. The recent heavy-ion test results showcase application-specific results for the commercial part in its intended application.

Introduction

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. Destructive single events such as single event latch up (SEL) are of particular concern with commercial off-the-shelf (COTS) devices. Many data converters that have been tested have shown varied response to heavy ion upsets [1-4].

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].

TESS Mission Overview



http://tess.gsfc.nasa.gov/images/tess_project_summary_chart_05-03-2016.jpg

- Highly Eliptical Orbit 15-59 Earth Radii
- Launching During Solar Minimum
- 4 Cameras, Wide field of View
- Measuring transiting planets of other stars
- 2 Year Mission
- Low TID, focus on SEE

Device Preparation

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 shown in figure 2 and Figure 3.

Figure 1: Focal Plane Electronics Assembly

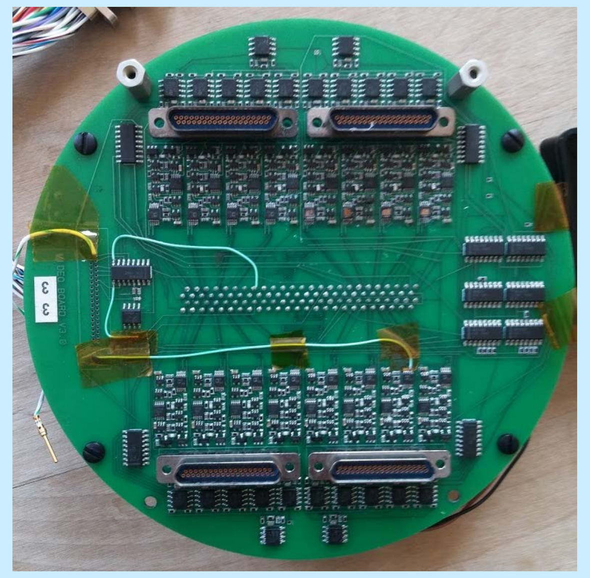


Figure 2: Focal Plane Electronics Subsytem board that houses the AD7984

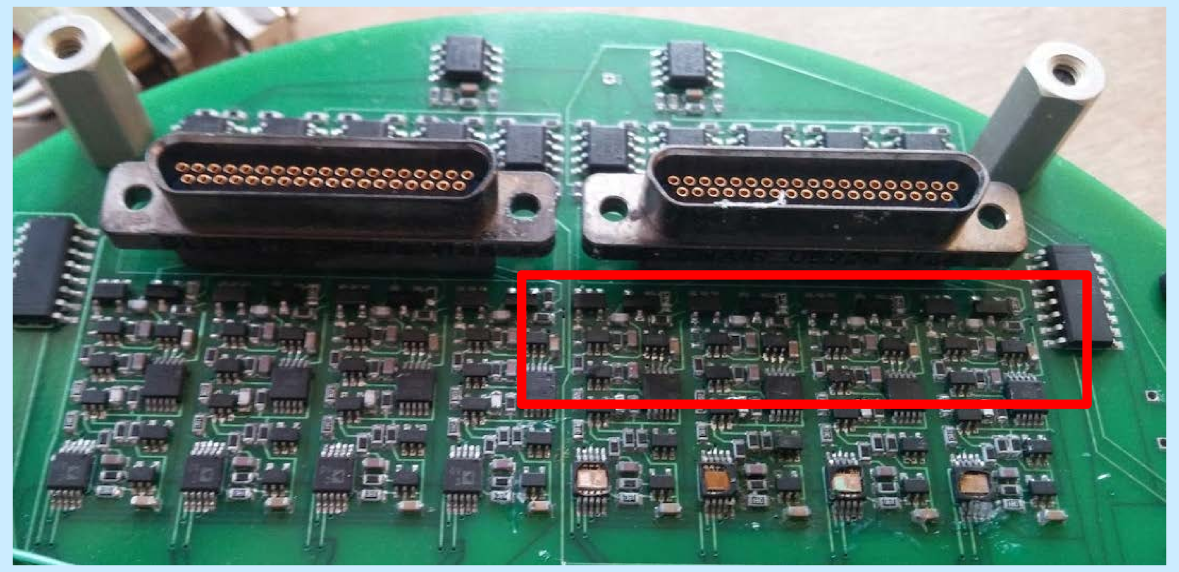


Figure 3: Boxed in red are the devices under test with the encapsulant removed to expose the die for heavy ion testing

Application

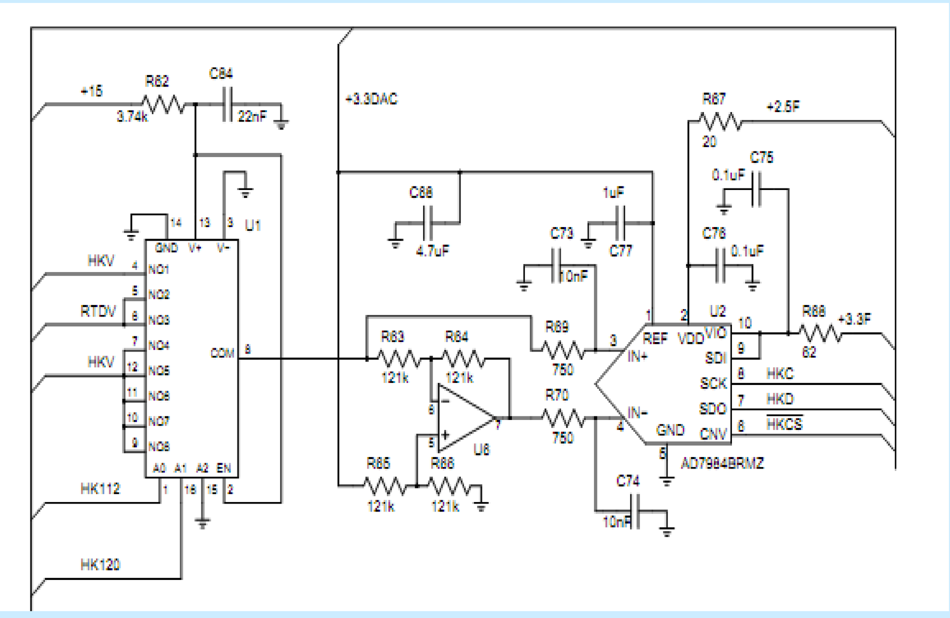


Figure 4: ADC application schematic for the Focal Plane Electronics Subsytem

As space-bound instruments demand sensors with increased density and higher resolution, higher speed and low power 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 COTS devices 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 circuit shown in Figure 4. The AD7984 is being used in the focal plane electronics of the TESS spacecraft. 4 CCD cameras will cycle through exposures, where this housekeeping ADC digitizes the cameras output.

Test Facility

SEE testing was performed at Texas A&M University Cyclotron Facility, Table 1 shows the Ion, angle, and effective LET that was used to experimentally determine the device response to heavy ions. Testing was performed in air at room temperature.

Angle	Ion and Linear Energy Transfer (MeV*cm²/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

Table 1. Ions used for heavy ion testing of the AD7984

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, data was then scaled to 100 frames and the results are plotted in Figure 2. The Weibull fit to the data has an onset of 23.4 MeV.cm²/mg, the last ion LET where no upset was recorded, and an estimated saturation of 3×10^{-4} cm²/device.

For the given application there were two types of 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 5 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.

For the single event rate calculations on the device, we categorized an event when a frame had >10 errors, a requirement for the mission.

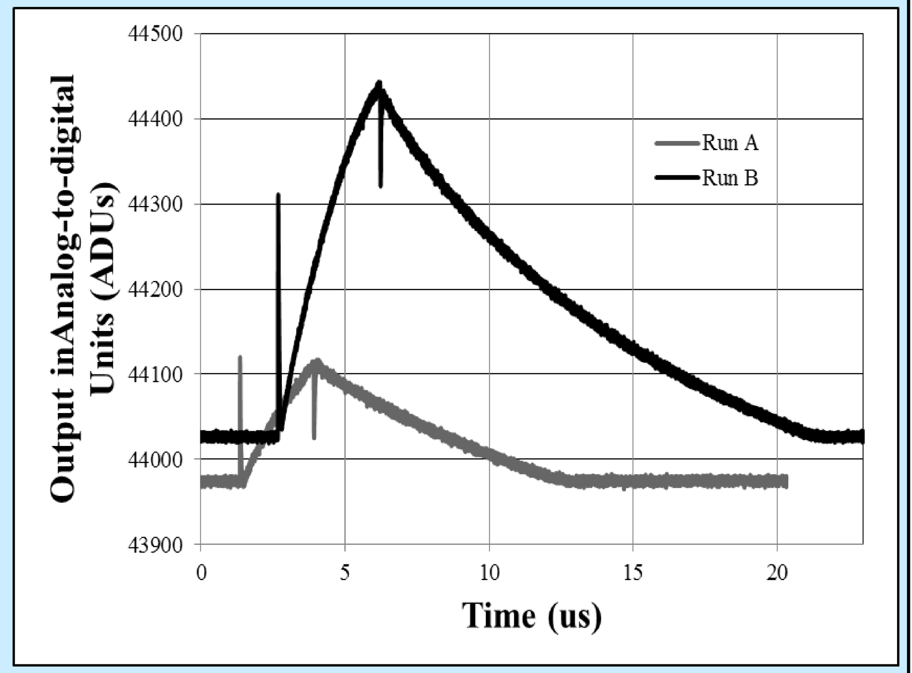


Figure 5: Board response to single event heavy ion strike for two different runs.

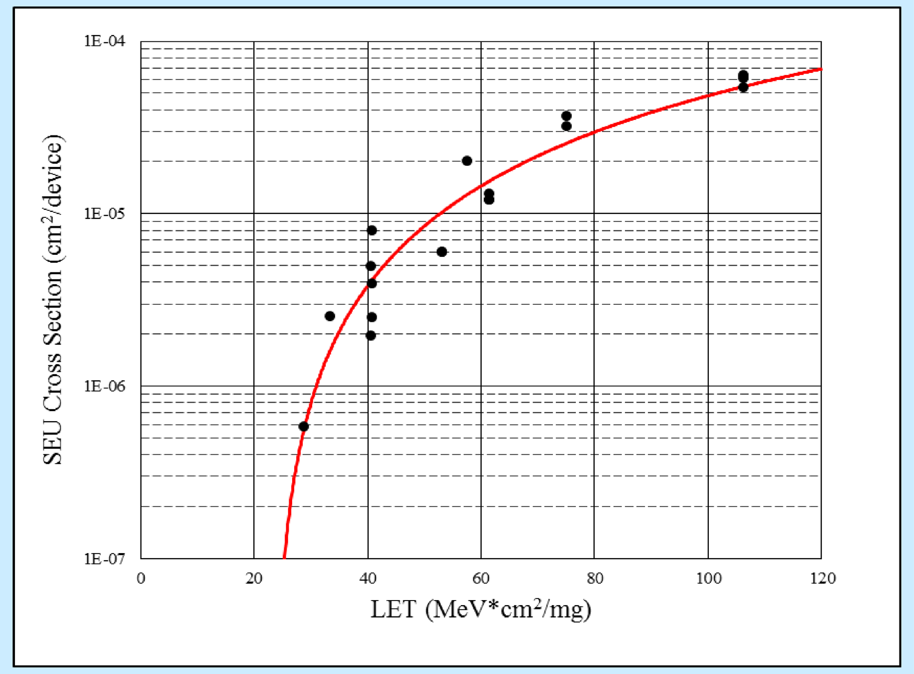


Figure 6: Single event cross section with Weibull fit

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 functional interruptions during nominal operation. As more COTS components are being used for flight applications, testing those parts has become more challenging. The response of the parts depend on the corresponding circuitry when investigating the system response.

In many cases users are not trying to characterize the part, or are limited in equipment that would allow them to do so. By stripping down the intended application to the bare minimum to mimic the application can help to understand the radiation effects. For single event effects testing this is made more simple by only bombarding one device at a time. In this experiment we were looking at board level response while one device was tested.

References

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Acknowledgments

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