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Synopsis V1.0

Agile-Input Single Event Upset Testing of the SPT7760 Analog to Digital Converter from Signal Processing Technologies

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I. Introduction

This study was undertaken to determine whether agile input can affect the upset susceptibility of the gigasample per second (GSPS) SPT7760 Analog to Digital Converter (ADC), manufactured by Signal Processing Technologies. This device was tested previously using a variety of fixed-input and frequency conditions. In those tests, no destructive conditions were observed, although a single-event functional interrupt mode was observed at high LET. For this test, the part was exposed to a number of heavy ion beams at the Texas A&M University Cyclotron Institute's Single Event Effects Test Facility.

II. Devices Tested

Devices were manufactured by Signal Processing Technologies, Inc. in an ECL bipolar process. In order to achieve GSPS conversion speeds, the SPT7760 is designed with two multiplexed output sections, A and B, such that consecutive outputs always go to different output sections. All devices were characterized electrically prior to exposure. Two devices were used in this testing. All devices were marked with the identifying number: ???????.

III. Test Facility

Facility: Texas A&M University Cyclotron Institute Single Event Effects Test Facility

Flux: 2.0×10^3 to 4×10^5 particles / cm^2 / s.

Ion	LET* (MeVcm^2/mg)
Ne	2.81
Ar	8.76
Kr	29.2
Xe	54

*after passage through kapton window and 5 cm of air

IV. Test Methods

A block diagram of the hardware setup for this testing is shown in Figure 1. In this test, the ADC output was passed through a high-speed Digital-to-Analog Converter, and a high-speed oscilloscope compares the resulting analog signal to the original analog input signal. If the converted signal deviates outside an preset envelope around the input signal, the oscilloscope was triggered and a window of conversions around the trigger point was captured and stored by the oscilloscope. After a trigger, the test setup was insensitive to additional upsets for about 100 msec, so for each run, there is a deadtime that is roughly proportional to the number of errors observed. For the fluxes and error rates used in this experiment, this deadtime is estimated to be 10-20%.

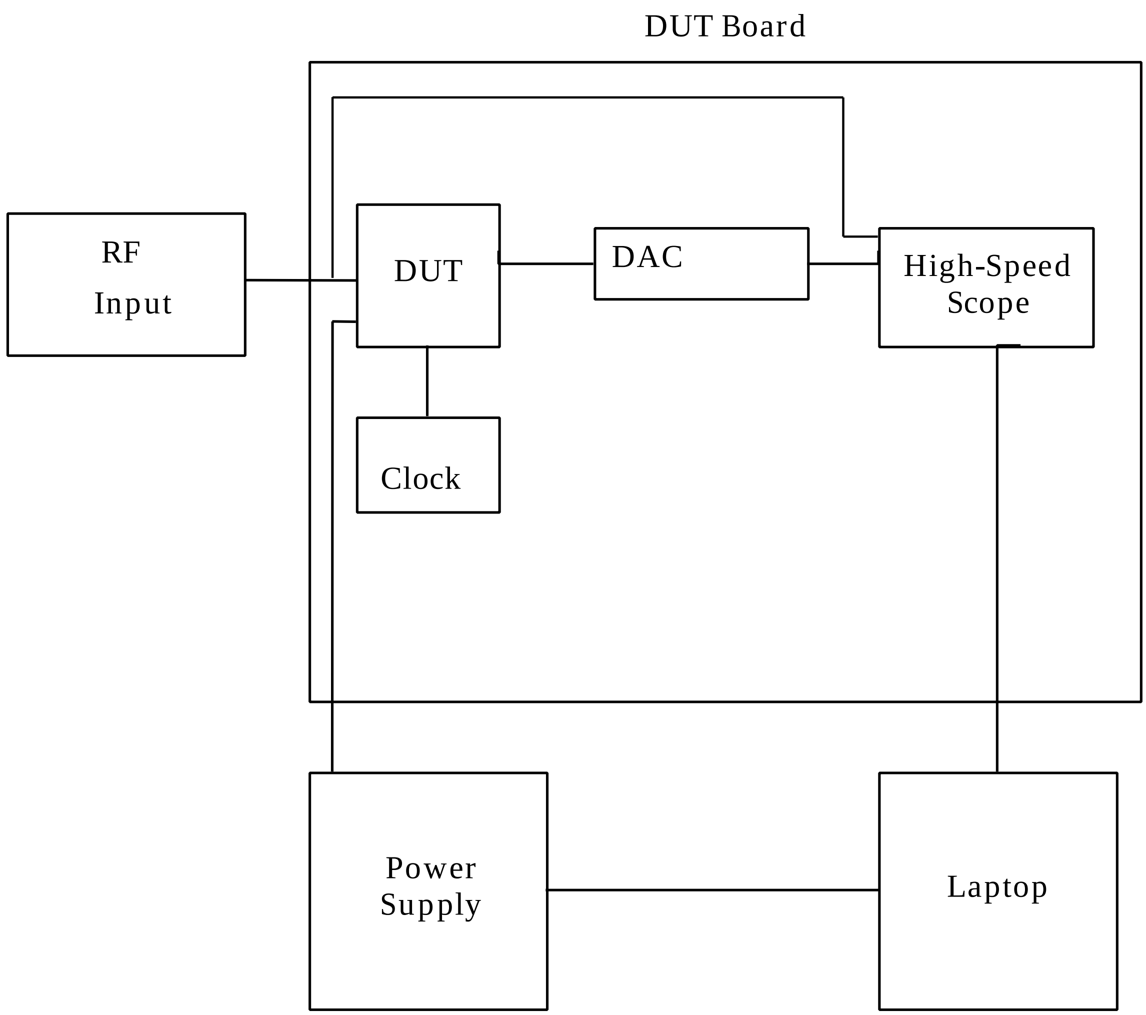

Figure 1. Block diagram of the experimental setup for testing the SPT7760 ADC.

The conversions within the time window around the error were stored on the laptop for later analysis, and the error count was incremented by one.

Using this test setup, the DUT was exposed to a normally incident or obliquely incident ion beam. The data recorded for each test run included: (1) the ion characteristics, (2) the effective LET (normal incident LET divided by the cosine of the angle of incidence), (3) the time and fluence for the run's exposure, and (4) the number of the different events and their associated cross sections. Because the SPT7760 tends to run hot, testing was performed in air at the TAMU Radiation Effects Facility at ambient temperature.

Although the SPT7760 had been tested previously with fixed input, the current test setup is sufficiently different from that used previously the it was decided to use the current test setup for both fixed input and agile-input tests, making comparison of the two conditions more straightforward. For all test runs, the device bias was -5.2 volts.

V. Results

Single Event Upset (SEU) and Single Event Functional Interrupt (SEFI)

Two SPT7760 devices were used throughout this testing in the DUT position numbered 1 and 2. Cross sections measured for the two devices were comparable, so the data from both were combined. As the parts were irradiated, it became apparent that the errors often occurred in bursts. In several cases, the conversion errors continued to occur after the irradiation had been stopped. Initially, a faulty cable was suspected. However, we noticed similar errors occurring after the cable had been changed. We also observed that the errors only occurred when the device was converting an agile input signal—not when the input signal was fixed. Unfortunately, at this time it is not clear whether the errors observed result from an artifact in the test setup or from the SEE response of the ADC. This is because similar errors were seen in one case when the part was not being irradiated. At the time, the part was being rotated, and the engineer thinks that the movement of the card may have placed additional stress on the clock cable causing an error. However, until the test setup is more thoroughly understood, the causes of the observed errors remain uncertain. If we assume that we are seeing a single-event effect, then the threshold for these events is less than 2.8 MeVcm / mg, and the limiting cross section is on the order of 1E-5 cm^2 (See figure 1).

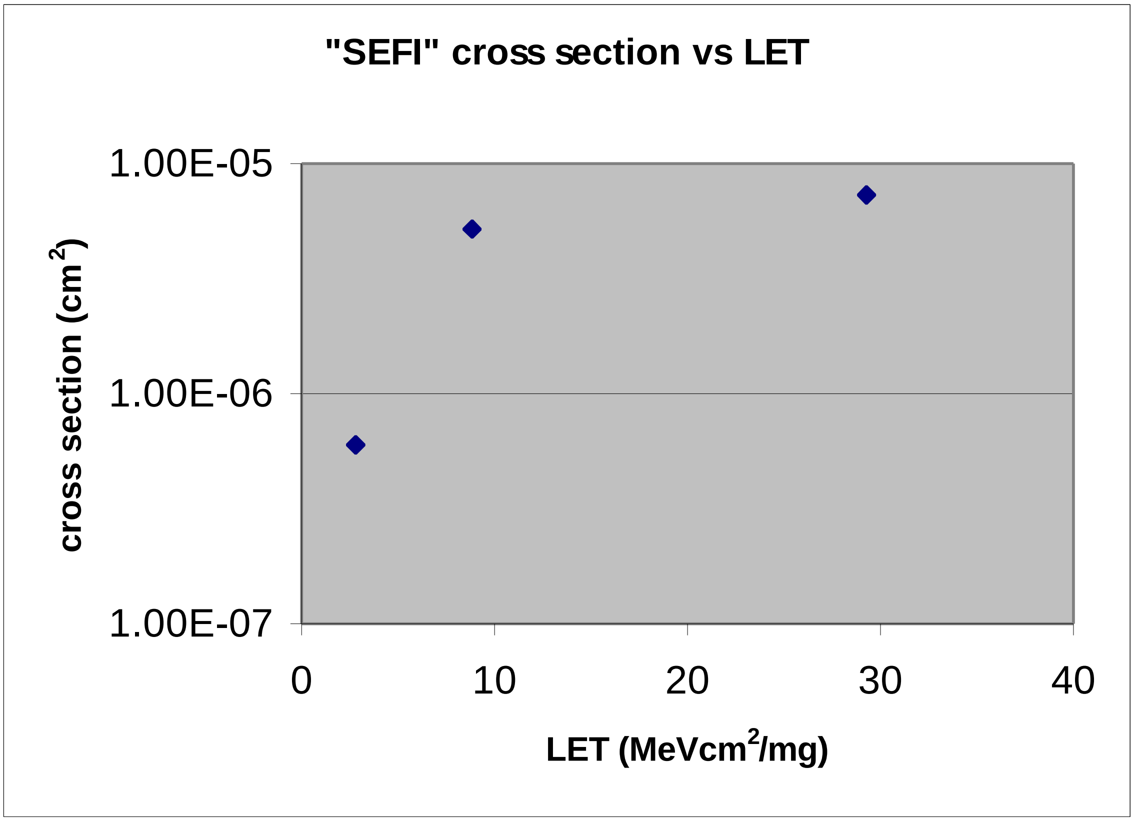

Figure 1. Cross section for functional interrupt errors assuming SEE cause.

The cross section values graphed in figure 1 represent averages of several runs and have statistical error bars on the order of 20-30%. Considerable time was devoted to observing the behavior of the ADC when these bursts of errors occurred. As mentioned above, they only occurred with agile input conditions. In all but one case, the errors occurred only when the part was being irradiated. In some cases, normal functionality would be restored spontaneously after several seconds, but usually, a power cycle was needed to restore functionality.

The occurrence of error bursts, even at low LET, makes it difficult to quantify the occurrence of upsets within the ADC. Moreover, the fact that these errors do not occur for fixed input conditions introduces a systematic error that makes it difficult to look for agile input effects on the upset cross section. To try to ascertain whether such effects are significant for the SPT7760, we used the few runs for which no significant occurrences of functional interrupts were observed. Although the occurrence of relatively short-duration error bursts cannot be ruled out for these runs, we are confident that the contamination due to these bursts is not worse than a factor of 2. Within these error bars, there is no significant difference between the SEU rates observed for agile and fixed input conditions.

Frequency effects were also investigated to a limited extent. However, because the test setup only took 2 readings per cycle, running the test at 100 MHz results in a significantly higher dead time. Accounting for this deadtime, the results at 100 MHz and 1000 MHz are consistent within errors.

Given the results to date, drawing firm conclusions about the agile-input behavior of the SPT7760 is a fraught proposition. The association of the functional interrupts with agile-input conditions is strong, but the occurrence of one such error when the part was not being irradiated casts doubt on the phenomenon being radiation related. Additional investigation of the experimental setup will be necessary to either strengthen or refute the correlation. If it is found that events associated with the setup can cause these errors, it will then be necessary to determine whether these causes could also account for the observations under irradiation. If it is found that the setup-related causes cannot account for the observations under irradiation, the setup-related causes may provide some insight into the behavior of the devices under irradiation.
Provided the setup checks out, it may be interesting to do some laser testing under agile-input and fixed-input conditions.

VI. Validation of Agile-Input Test Method

In addition to looking for agile-input effects in high-speed ADCs these tests had the goal of validating the approach used here—namely, converting of the digital output of the ADC back to an analog signal and comparing the resulting signal to the input signal. In spite of the difficulties encountered in the current effort, we feel that the basic approach has been validated as a method to search for agile-input effects in ADCs. In general, the test hardware performed well, and the resolution on the output signal was less than an LSB. However, there are some significant limitations to the method. The most significant limitation on this technique is the amount of information it yields. One knows when an error has occurred, but without information on the individual digital outputs, it is not possible to determine in what portion of the device the error has occurred (i.e. in the analog portion, digital portion or some other portion of the device).
This shortcoming probably cannot be rectified for the current setup, since the timing involved in preserving the digital information would be quite tricky. Another limitation involves to store readings around a triggering event. One lesson derived from tests of the SPT7760 and the MAX108 is that some events can last for many cycles. For this type of testing, test engineers cannot know the error duration in advance, so it would be nice to develop the capability of rapidly or automatically increasing the envelope around the triggering event.

VII. Conclusions

Although the current test data are not sufficient to eliminate the concern over agile input effects in high-speed ADCs, they do indicate that SEU rates will probably not be an order of magnitude higher than for fixed input. SEFIs were observed for fixed input testing at high LET. If the events observed here are SEFIs, they will occur at a higher rate, given the low LET threshold observed. However, a worst-case rate calculation suggests that the rate will not exceed once a year. Provided that the application is designed to diagnose and recover from these errors, such a rate is not likely to significantly impact performance.

The ambiguous test results delivered by the test method used here make interpretation difficult—both for part performance and for validation of the test method. For this reason, without substantial modification, the test method used in these investigations will not yield sufficiently reliable results to draw definite conclusions about agile-input effects in high-speed ADCs.

VII. Recommendations

In general, devices are categorized based on heavy ion test data into one of the four following categories:

Category 1 – Recommended for usage in all NASA/GSFC spaceflight applications.
Category 2 – Recommended for usage in NASA/GSFC spaceflight applications, but may require mitigation techniques.
Category 3 – Recommended for usage in some NASA/GSFC spaceflight applications, but requires extensive mitigation techniques or hard failure recovery mode.
Category 4 – Not recommended for usage in any NASA/GSFC spaceflight applications.

Based on previous test results, the SPT7760 from Signal Processing Technologies was rated as a Category 2 device. The current data do not change this categorization.