W.5 ^{252}Cf Measurements of Single Event Effects in ADCs

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Mesure de SEU avec une source Cf^{252} dans des convertisseurs AD

Une source Cf^{252} a été utilisée pour détecter l'apparition d'aléas logiques dans des convertisseurs AD sousmis à un flux d'ions lourds. Les résultats préliminaires obtenus sur les convertisseurs AD676, AD7884 et AD7893 de chez Analog Device sont présentés. Des erreurs transitoires et des erreurs plus "permanentes" ont été mises en évidence.

Abstract

The preliminary results of heavy ion irradiation with ^{252}Cf for the detection of single event up-sets are presented for Analog Devices' ADC's AD676, AD7884 and AD7893. Both short-lived and "lingering" errors were found.

I. Introduction

Although there has recently been considerable interest in single event effects (SEE) in logic devices such as memories and processors, relatively little has been published on SEE in small signal analogue or mixed signal devices. However this is a subject of increasing interest as the trend for higher performance in space borne instruments leads to the use of faster and more precise signal processing electronics. This paper presents the first results from a programme to study single event effects in ADCs, DACs and precision amplifiers with a view to selection for use on future space missions. Presented here are the results on 12 and 16 bit ADCs. These have been tested with ^{252}Cf fission fragments as a prelude to comprehensive heavy ion testing at an accelerator. This preliminary investigation has been used to commission the test equipment, to identify the type of events that can occur and to establish a saturation event cross section.

II. Experimental

Testing was performed on de-lidded devices using the Californium-252 Assessment of Single-event Effects (CASE) facility at The European Space Research & Technology Centre (ESTEC). ^{252}Cf produces a wide range of fission particles with LET's in the range 42-45 MeVcm^2/mg at the surface of the die. [1, 2]. The devices tested were the 12 bit AD7893 and the 16 bit AD7884 and AD676, all manufactured by Analog Devices inc.

Each device under test, (ADC, DAC or amplifier) can be mounted in a dedicated daughter board interfaced to a motherboard containing a saw-tooth wave form generator, multiplexers, buffers and interface drivers and receivers. The motherboard is connected via a custom designed data memory board with four 64kword, 32 bit deep arrays to an Analog Devices 32 bit DSP ADSP-21020 EZ-Lab evaluation board. An ADSP-21020 EZ-ICE emulator tool was used for programme debugging and passage of data to a personal computer for later analysis.

III. Results

The AD7893 and AD7884 have not been previously tested as far as the authors are aware. Results for the AD676 have been reported in reference [3]. The AD676 is a parallel output version of the AD677. The results of testing the AD677 for SEE is reported in reference [4].

Each of the devices was tested using either a constant input of zero Volts (a ground input) or a saw-tooth wave input. When ground input testing, ADC conversions were continuously recorded in an ADC output code histogram. Ideally a fixed d.c. input should result in the same output code for repetitive conversions. All bins of the conversion histogram except the central bin of the distribution are the result of noise. Under control conditions the standard deviation of the ground input histograms for each ADC was consistently measured to be 1 LSB.

Of the three ADC types tested, each responded differently under irradiation with ^{252}Cf. The 12 bit AD7893 was the least susceptible to transient up-sets and the measured single event device cross section was low at approximately $3x10^{-6}$ cm^2/device. The data collected for the 16 bit AD7884 indicated that the single event up-set cross section was of the order of $6x10^{-3}$ cm^2/device. As might be expected, the relatively more complex self calibrating 16 bit AD676 was the most susceptible to upsets. This device package contains two die; one is an analogue circuit and the other a digital circuit. AD676 performance is optimised by correction of internal non-linearity by the digital chip auto-calibration circuit which adds a correction factor to the ADC output from the digital chip RAM. Data was collected for whole AD676 chip irradiation and for isolated irradiation of the digital and analogue circuits. The single event cross section was measured to be $1.5x10^{-3}$ cm^2/device for irradiation of the analogue chip alone. This is in reasonable agreement with the saturation cross section value, $1.1x10^{-4}$ cm^2 at an LET of 20 MeV cm^2/ mg for irradiation of the whole AD676, observed by LaBel et al [3]. Under whole chip or digital chip irradiation conditions an accurate measurement of the cross section proved difficult to obtain. The AD676 demonstrated problems with the self calibration circuitry on the digital chip.

Figure 1 illustrates a set of ground input histogram data all obtained for the same AD676 device. The first graph in the series is an ADC conversion output histogram recorded under control conditions, displayed on the same scale as the histograms recorded under radiation conditions for convenient comparison. The effects of radiation upon the AD676 are quite apparent. In one case (radiation #3) a possible bit flip has occurred, displacing almost the whole body of the histogram along the positive x axis (for all the remaining duration of the test until a calibration cycle is started). This type of "lingering error" has previously been observed by Wilson and Dorn [4] and Turflinger [5].

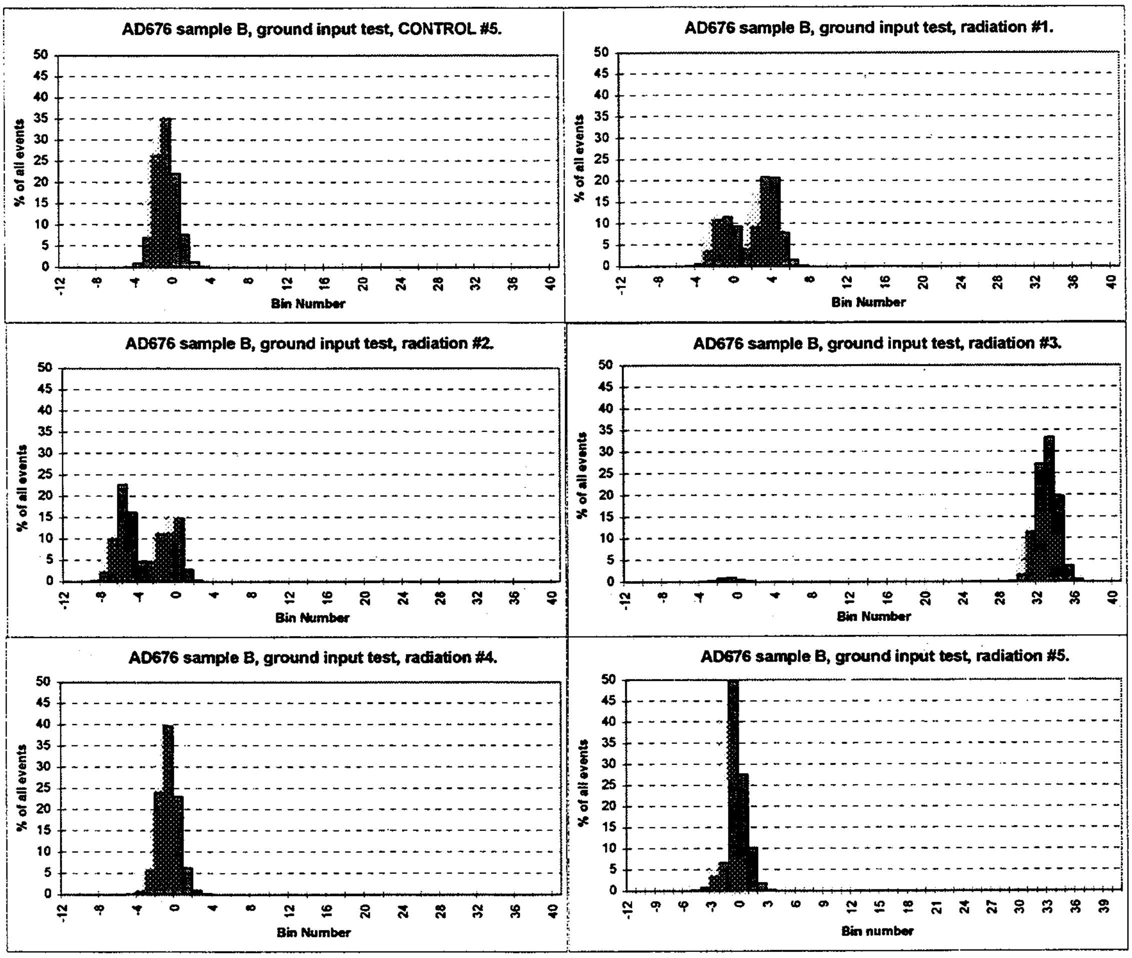

Figure 1 A selection of ground input histograms for the AD676. All tests illustrated are 15 minutes in duration under a flux of 3352 particles/cm^2/min, except radiation #5 which is 60 minutes duration and flux 924 particles/cm^2/min.

Similarly **figure 2** illustrates a set of ground input histograms recorded for the AD7884. In this case the number of events per ADC output bin has been plotted on a logarithmic scale. The incident flux was 3352 particles/cm^2/min. Transient upset events under irradiation conditions can clearly be seen to occur some distance from the central distribution. No events of this magnitude were ever observed under control conditions.

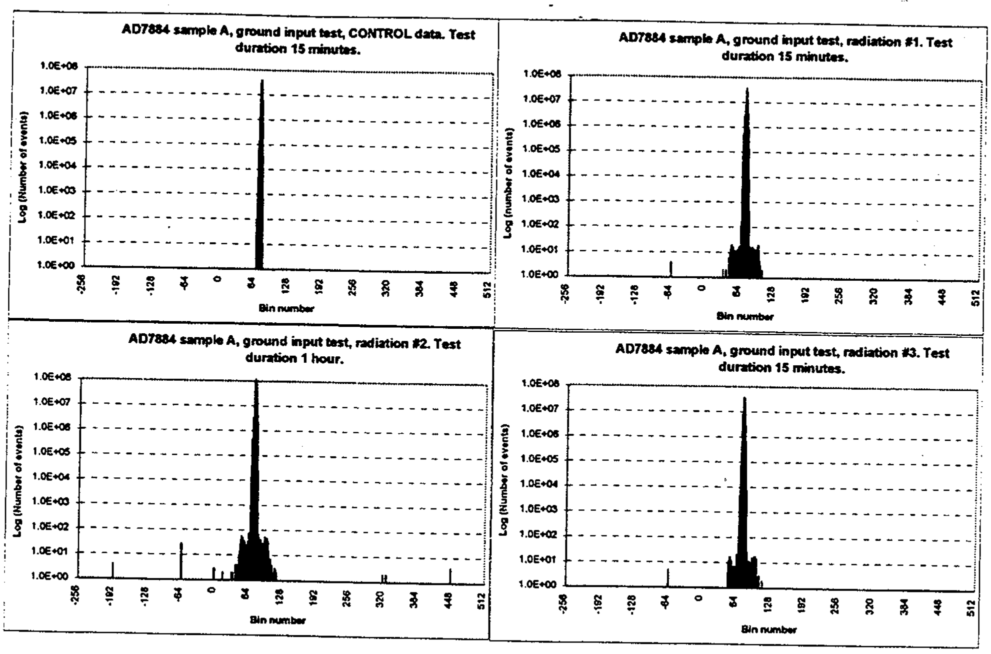

Figure 2 Ground input test data for the 16 bit ADC; AD7884. (Note logarithmic scale here).

ADC conversions resulting from the saw-tooth input test were recorded in a Differential Non-Linearity (DNL) histogram. The number of conversions for each output code of the ADC under test were recorded in a frequency histogram from 0 to 2^{16} bits (**figure 3**). This measurement yields a value for the DNL of the device, which is a measure of the width of each code relative to the ideal code width. A DNL of -1 indicates a missing code, 0 DNL is the ideal output code bin width and a DNL of +1 indicates an output code bin is twice as wide as it should be. In addition to the DNL measurement, a second measurement was simultaneously carried out. The expected value of the next conversion of the ADC was calculated in real time and compared with the actual conversion result. Any significant deviation from the expected value was recorded for closer examination as a potential transient event. A second histogram recorded the difference between the expected and the actual ADC conversion result. If the difference between the ADC conversion and the expected value exceeded a pre-set limit, the value of the ADC's conversion, the calculated expected value and the location of the conversion (ADC conversion increment count) during the test procedure were all recorded. **Figure 4** illustrates all three of these recorded measurements graphically.

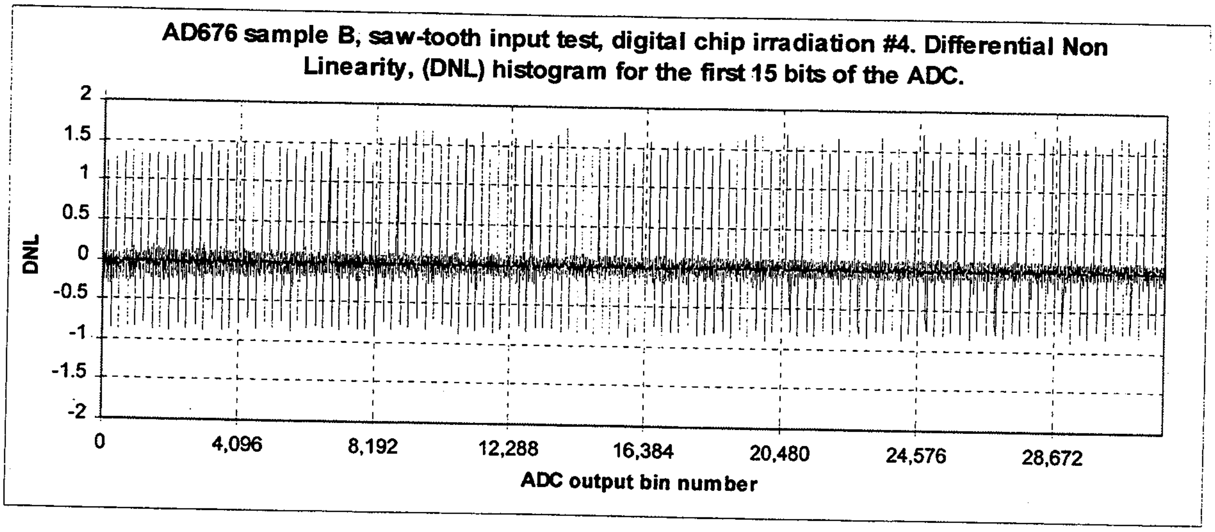

Figure 3 The DNL histogram for isolated irradiation of the digital chip on board the AD676. The test duration was 15 minutes under an incident flux of 3352 particles/cm^2/min. A single event has occurred which gives a large DNL value every 256th code.

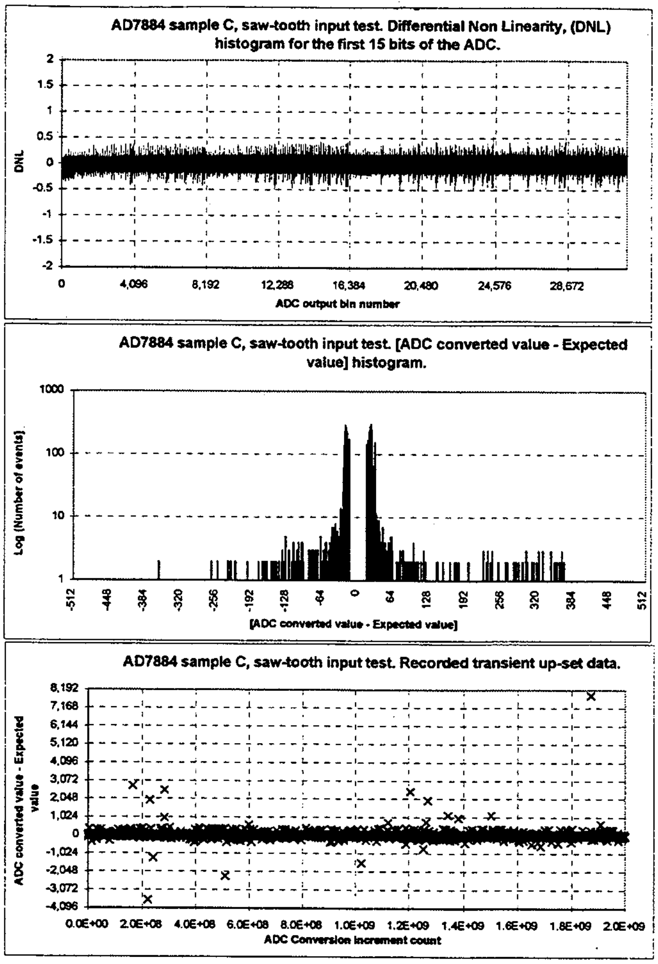

Figure 4 The DNL histogram, difference histogram and a plot of the difference between the ADC converted value and the expected value versus ADC conversion increment count for the 16 bit AD7884. The test duration was 446 minutes and the flux 3352 particles/cm^2/min. The central bins of the difference histogram indicated events within the normal noise distribution of ADC conversion and so were not recorded due to the memory capacity constraints of the test equipment. Hence the gap in the centre of the difference histogram plot.

The conversion rates of the three ADC types which were tested were not observed to alter significantly under ^{252}Cf irradiation. At a system level, the lingering errors observed in AD676 performance could result in unexpected output level shifts under static d.c. input operation, or changes in the DNL of certain output codes of the device.

IV. References

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