Single Event Effect and Total Ionizing Dose Testing of CULPRiT Reed Solomon Encoders

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I. Introduction

These tests were undertaken to evaluate the single event effect and total ionizing dose susceptibility of **C**MOS **U**ltra-**L**ow **P**ower **R**adiation **T**olerant (**CULPRiT**) Reed Solomon (RS) Encoders. These encoders are being considered for use on NASA's Space Technology 5 (ST-5) mission.

II. Devices Tested

The ultra-low power approach advocated in CULPRiT technology is accomplished by aggressively scaling the transistor threshold voltage and supply voltages so that the circuit performance, in principle, remains constant. Threshold voltages are tuned to give optimal circuit performance by the application of back-bias. Typically, threshold voltages are around 100 mV in this 0.5 V CMOS/epi technology. A Single Event Radiation Topology (SERT) cell design developed at the University of Idaho was used for single event upset (SEU) mitigation. The RS Encoder circuits were custom fabricated at AMI Semiconductor (AMIS). This is the fourth processing run of CULPRiT RS Encoders at AMIS. A sample size of 2 encoders was used for SEE tests and 4 for TID tests. An encoder contains 2048 bits.

III. Test Facilities

SEE Facility: Brookhaven National Laboratory tandem Van de Graaff accelerator
Flux: Between 10^4 and 10^5 ions/cm^2/s

Ion:	**Energy (MeV)**:	**LET (MeV-cm^2/mg)**:
Ti-48	192	19.8
Ni-58	265	26.6
Br-79	278	37.3

TID Facility: NASA Goddard Co-60 gamma ray facility
Dose Rate: 0.1 to 0.5 rad(Si)/s

IV. Test Methods

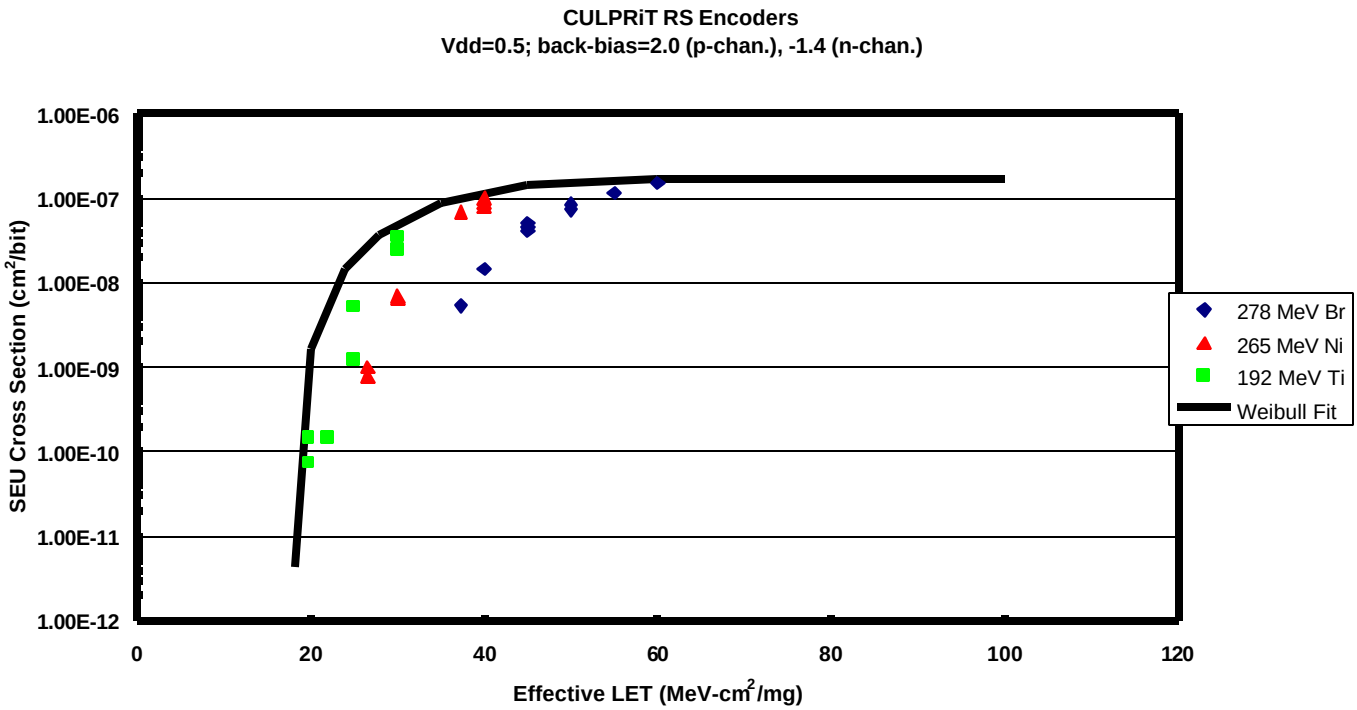
SEE Methods: The RS Encoder test board was developed within code 561. It utilizes a simple UART interface for test board configuration and control and contains a Xilinx FPGA that exercises the RS encoder and signals miscompare errors and proper operation. V_{dd} = 0.5 V was used during the tests. The encoders operate for a range of p-channel and n-channel back-biases so the dependence of the SEU sensitivity on these biases was measured. P-channel back-biases of 2.0 and 2.5 V were used. N-channel back-biases of –1.4, -1.9 and –2.4 V were used. The encoders operate optimally for V_{dd} = 0.5 V at a p-channel back-bias of 2.0 V and an n-channel back-bias of –1.4 V.

TID Methods: The back-bias conditions discussed above for optimal encoder operation with V_{dd} = 0.5 V were used during irradiation and anneal. Leakage current between V_{dd} and ground, RS Encoder functionality and timing were measured.

V. Results

SEE: No latch-up was observed under any bias condition up to LET values of 60 MeV-cm^2/mg. This was consistent with laser tests previously conducted at the Naval Research Laboratory in which latch-up could not be induced with a laser.

The SEU results were more complex. The data show an ion or angle dependent effect as indicated in the figure below. A worst case Weibull fit has been made to the data and is also shown in the figure. According to this fit, the LET threshold for SEU is 18 MeV-cm^2/mg and the saturated cross section is 17 μm^2/bit. Varying the back-bias had little effect on the SEU cross sections.



TID: Irradiations were carried out to doses of 100 krad(Si) on 4 encoder chips. All encoders remained fully functional and there was no significant change in leakage current or timing.

VI. Recommendations

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

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

CULPRiT RS Encoders are Category 2 integrated circuits.

In addition, CULPRiT RS Encoders are total dose tolerant to at least 100 krad(Si). There should be few limitations of their usage in most flight applications from a total dose perspective.