RTAX-S SEE Report–Analysis of NASA/Goddard High Speed SET/SEU Data

August 17, 2006

J.J. Wang and S. Rezgui
(650) 318-4576
jih-jong.wang@actel.com

Acknowledgements

The data in this report was collected by the NASA/Goddard radiation group with some Actel engineering support. Special thanks to the major contributors: Melanie Berg, Hak Kim, and Ray Ladbury.

I. INTRODUCTION

The objective of this report is to predict the SEU rates for running RTAXS at high speed—between 15 MHz to 150 MHz—in any radiation environment. The Weibull parameters for SEU-rates prediction are generated from heavy-ion-beam-test data collected by the NASA Radiation Effects and Analysis Group. The details of the experiment are in "An Analysis of Single Event Upset Dependencies of High Frequency and Architectural Implementations within Actel RTAX-S Family Field Programmable Gate Arrays," by M. Berg, J. J. Wang, R. Ladbury, S. Buchner, H. Kim, J. Howard, K. Label, A. Phan, T. Irwin and M. Friendlich, IEEE NSREC06, July 2006.

In the following sections, a brief description of the testing is followed by the analysis of the measured data to extract the Weibull parameters for the rate prediction. Then the SEU rates per flip-flop for several designs and running at various speeds in a geosynchronous environment are calculated by CRÈME96 to bench-mark the SEU tolerance of the device, and also to show the technique to calculate the SEU rates in any radiation environment.

II. HEAVY-ION-BEAM TESTING

A. Device-Under-Test

The devices-under-test (DUT) include RTAX1000S and RTAX2000S devices; they are 0.15-µm antifuse FPGAs manufactured by the UMC foundry.

B. Heavy Ion Beam Source

The heavy-ion-beam facility is the cyclotron at TAMU. Irradiations used ions with an energy of 15 MeV/amu and effective LETs from 8.5 to 74.5 MeV•cm^2/mg. The effective fluence for each run is 1×10^7 cm^{-2}.

C. Test Logic Design and Signal Pattern

The DUT design consists of three (3) shift-register-based designs: 0F0L, 0F4L and 4F8L. As shown in Fig. 1, 0F0L has 800 DFFs and zero levels of combinational logic; 0F4L has 700 DFFs and 4 levels of combinational logic; and 4F8L has 700 DFFs and 8 levels of combinational logic. The test-signal patterns are checkerboard patterns running at clock speed of 15, 37.5, 75 and 150 MHz.

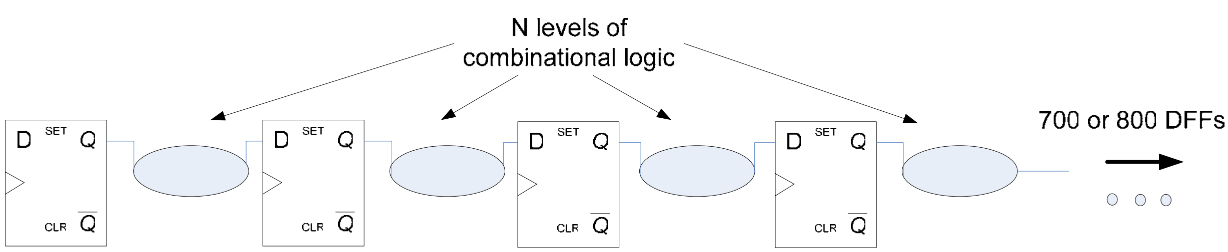

Fig. 1 Block diagram showing the DUT logic design: 0F0L has 800 DFFs and zero levels of combinational logic; 0F4L has 700 DFFs and 4 levels of combinational logic; 4F8L has 700 DFFs and 8 levels of combinational logic.

III. RESULTS AND ANALYSES

A. Data and Weibull Fit

Fig. 1 to 3 displays the typical cross-section versus LET plot for 0F0L, 0F4L and 4F8L respectively. Each plot has four (4) sets of data obtained at 15, 37.5, 75 and 150 MHz respectively. Figures 2, 3 and 4 show that each set of data is fitted by a Weibull curve; and Table I lists the fitted Weibull parameters (shape S, width W, Limit-σ, and Onset LET) for each curve.

B. SEU Rates Prediction for Geosynchronous Orbit

CREME96 conducts the SEU rate prediction. The environmental parameters are: GEO orbit, Solar Min, and 100-mil Al shielding. The device, or RPP, parameters are: X = Y = √Limit-σ; Z = 0.5 µm with no funneling. The resulting SEU per bit-day for each shift register running at the particular frequency is listed in Table II.

Table I Weibull parameters

	S	W (MeV•cm^2/mg)	Limit σ per bit (cm^2)	Onset LET (MeV•cm^2/mg)
0F0L_15MHz	2	48	7.13×10^{-9}	5
0F0L_37.5MHz	2	45	2.50×10^{-8}	4
0F0L_75MHz	2	80	1.44×10^{-7}	2
0F0L_150MHz	1.9	70	1.88×10^{-7}	2
0F4L_15MHz	3.1	60	3.14×10^{-8}	2
0F4L_37.5MHz	3	40	4.28×10^{-8}	2
0F4L_75MHz	2.6	48	8.31×10^{-8}	2
0F4L_150MHz	2.3	48	1.73×10^{-7}	2
4F8L_15MHz	2.7	48	3.43×10^{-8}	2
4F8L_37.5MHz	2.7	48	4.57×10^{-8}	2
4F8L_75MHz	2.3	48	1.14×10^{-7}	2
4F8L_150MHz	2.3	48	2.14×10^{-7}	2

Table II Predicted SEU rate (upsets/bit/day) in radiation environment of GEO-min and 100-mil Al shielding

	15 MHz	37.5 MHz	75 MHz	150 MHz
0F0L	6.08×10^{-10}	5.14×10^{-9}	2.84×10^{-8}	5.84×10^{-8}
0F4L	2.01×10^{-9}	8.71×10^{-9}	1.89×10^{-8}	6.29×10^{-8}
4F8L	5.31×10^{-9}	7.88×10^{-9}	3.75×10^{-8}	8.17×10^{-8}

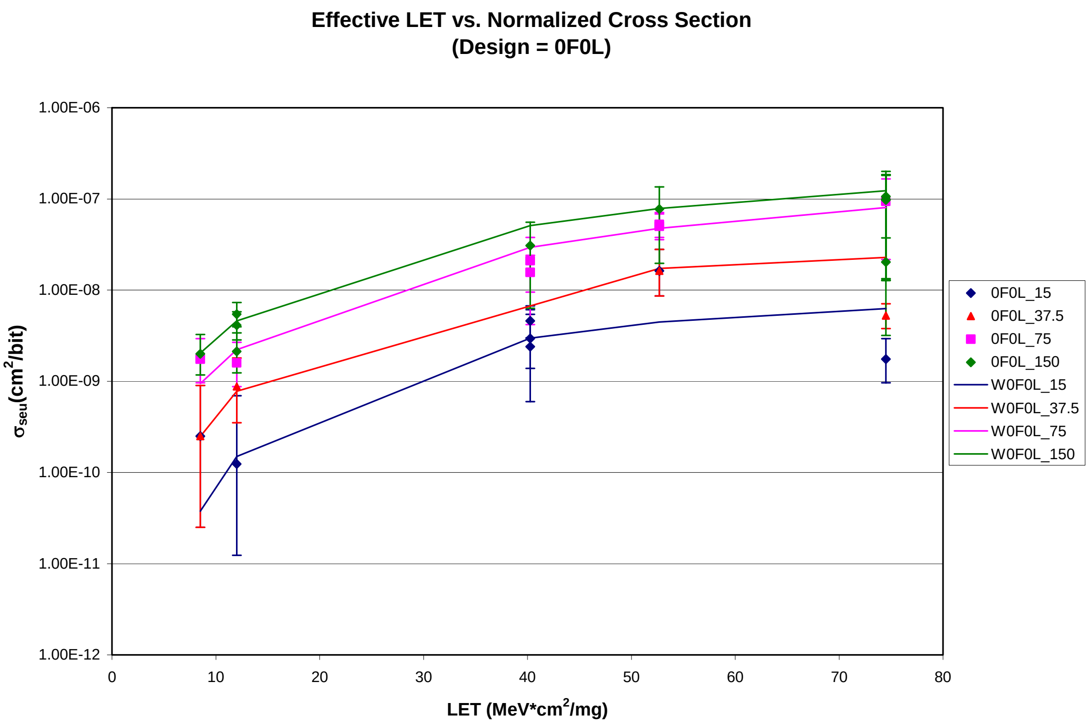

Fig. 2 Plot showing SEU cross section (σ_{SEU}) per bit versus effective LET for 0F0L design. Signal patterns are checkerboard running at 15, 37.5, 75, and 150 MHz. Data points and Weibull-fitting curves are displayed.

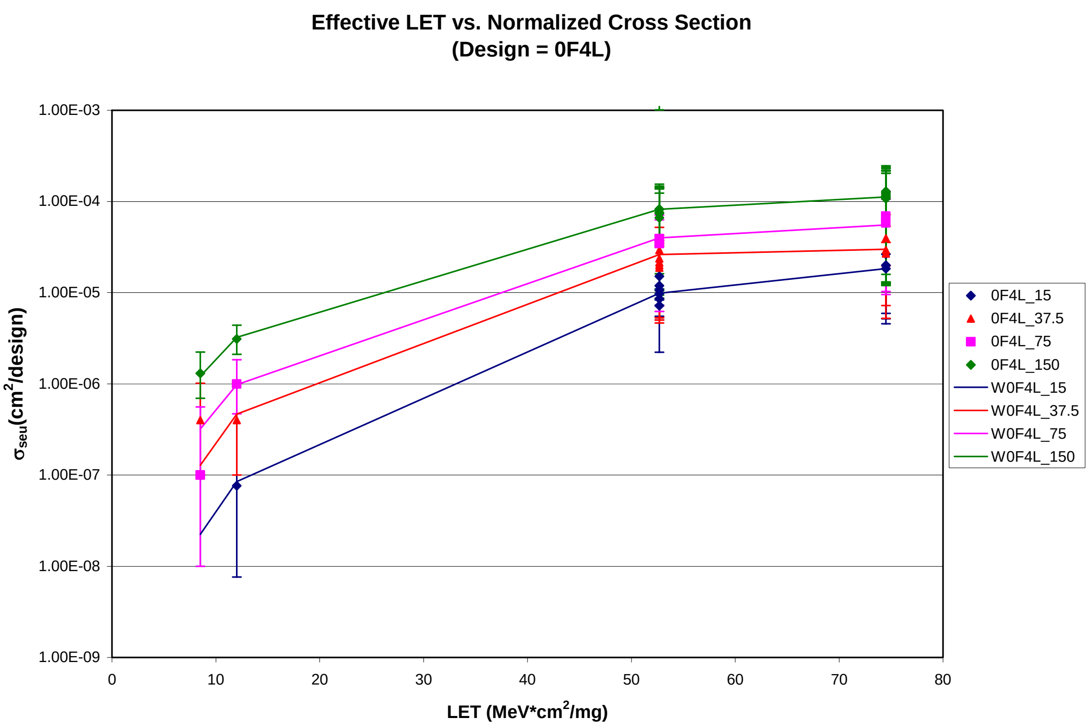

Fig. 3 Plot showing SEU cross section (σ_{SEU}) per design versus effective LET for 0F4L design. Signal patterns are checkerboard running at 15, 37.5, 75, and 150 MHz. Data points and Weibull-fitting curves are displayed.

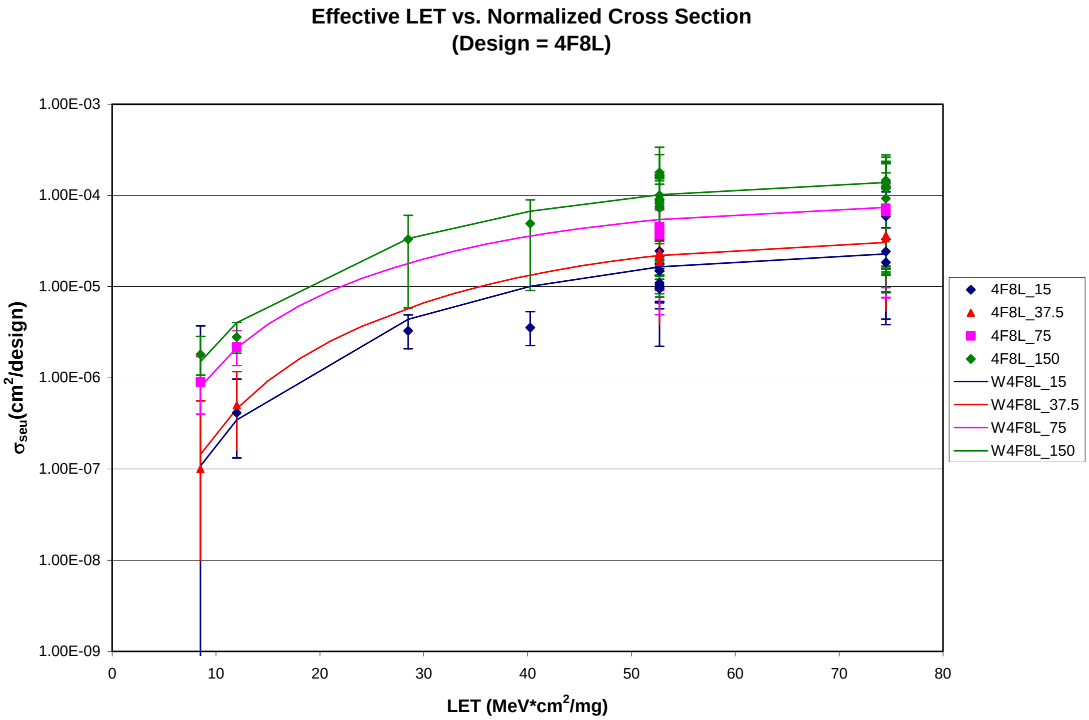

Fig. 4 Plot showing SEU cross section (σ_{SEU}) per design versus effective LET for 4F8L design. Signal patterns are checkerboard running at 15, 37.5, 75, and 150 MHz. Data points and Weibull-fitting curves are displayed.