UTMC Application Note

A Radiation Tolerant 4M SRAM for Space Applications

Abstract

Total ionizing dose and heavy ion single event effects data are presented for a radiation tolerant 100ns 4M SRAM (UT7Q512). The SRAM is shown to be resistant to between 20 and 35krad(Si) of total dose radiation (depending on the particular lot examined) at a relatively high dose rate of 46rad(Si)/s. The SRAM is immune to single event latch-up (SEL) to a LET of 128MeV-cm^2/mg and exhibits a heavy ion upset rate of 1.1 x 10^{-8} errors/bit-day in the Adams 90% worst case geostationary orbit.

Introduction

The space radiation environment is highly variable. Over the course of a 10-year mission, integrated circuits within a satellite may see anywhere from a few krad(Si) to many Mrad(Si) depending on the orbit dynamics and the mass of material between the component and the external environment.

Because many systems require only radiation tolerant components to successfully complete their mission, UTMC Microelectronic Systems (UTMC) has made a radiation tolerant 100ns 4M SRAM available. This 100ns 4M SRAM is resistant to between 20 and 35krad(Si) of total ionizing radiation, is immune to single event latch-up, and has a heavy ion upset rate of 1.1 x 10^{-8} errors/bit-day.

Total Ionizing Radiation Test Results

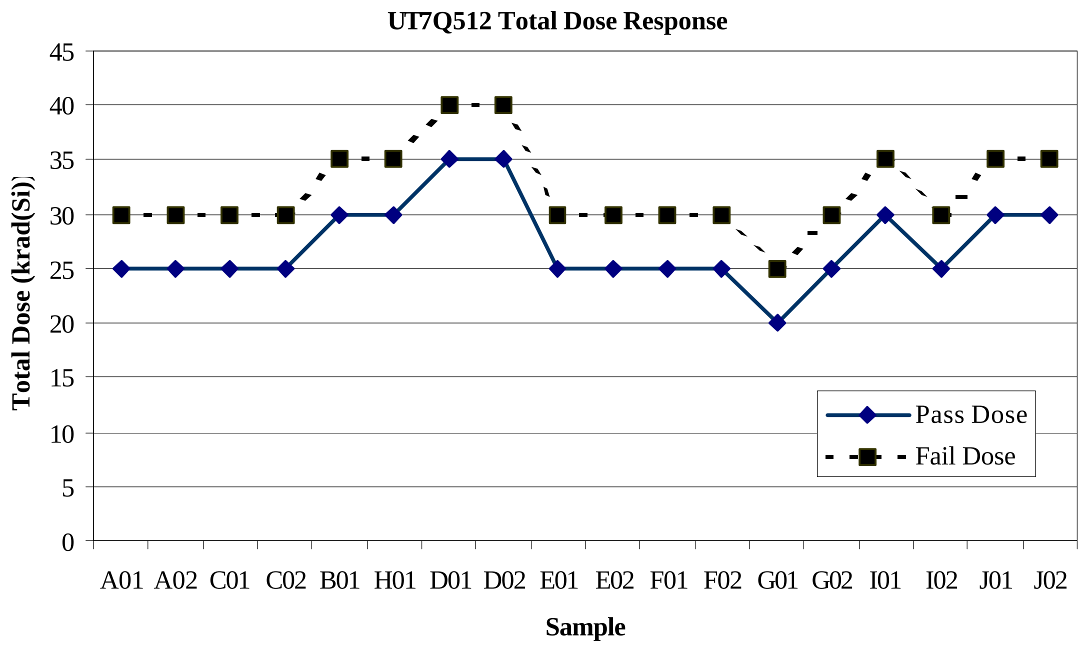
The radiation tolerance of 35 devices were tested using Co-60 radiation, these devices represented 10 unique lots of material. Table 1 summarizes the radiation response of the devices irradiated under the worst case bias conditions (static bias with V_{dd} at 5.5V). As the data shows, the softest material failed at a total dose of 25krad(Si) while the hardest lot of material failed at 40krad(Si).

Table 1. Total Dose Radiation Results for the UTMC UT7Q512 512K x 8 SRAM

Sample	Pass Dose	Fail Dose	Sample	Pass Dose	Fail Dose
A01	25	30	E02	25	30
A02	25	30	F01	25	30
C01	25	30	F02	25	30
C02	25	30	G01	20	25
B01	30	35	G02	25	30
H01	30	35	I01	30	35
D01	35	40	I02	25	30
D02	35	40	J01	30	35
E01	25	30	J02	30	35

Figure 1 shows a plot of the total dose data shown in Table 1. The dotted line shows the fail dose while the solid line shows the pass dose. The production units will be screened, on a lot by lot basis into 2 radiation hardness assurance levels, 10 and 30krad(Si). The typical radiation hardness assurance level will be 90% survivable probability at 90% confidence, similar to what is achieved by using Mil. Std. 883 TM 1019.5. Higher survival probabilities (as high as 99.99%) can be achieved through additional testing and screening.

Figure 1. Total ionizing dose response of the UT7Q512 512K x 8 SRAM.



Single Events Effects Test Results

To fully evaluate SEE a broad range of LET values are required. To achieve this, six different ions were selected from LBL's "nucleon cocktail" [1] and used at angles from normal incidence to a maximum of 60× (the effective LET is equal to the LET at normal incidence multiplied by the secant of the angle of incidence). The minimum ion energy available for this test was nitrogen (0× angle of incidence) with a LET of 2.8MeV-cm^2/mg. The highest LET was obtained with xenon at a 60× angle of incidence, giving 128MeV-cm^2/mg. The ions and their respective energies, Effective LETs, and ranges in silicon used for this test are shown in table 2.

All SEU and SEL data were obtained at worst-case temperatures, i.e., room temperature for SEU data and 125×C for SEL data. SEU testing on the 4M SRAM was performed at 4.5V. 4.5V is the worst case condition (within the specified operating range) for evaluating SEU. Single event latch-up data was taken only at 5.5V, again, worst case within the allowed operating range of the component.

Prior to heavy ion beam exposure the lids were removed and the functionality of the parts verified. The devices were exposed to the ion beam in vacuum and were continuously exercised prior to and during beam exposure using a UTMC owned, Boeing designed and built test system.

Table 2. Ions, and their effective LETs, used at Berkeley to test the UTMC UT7Q512 4M SRAM

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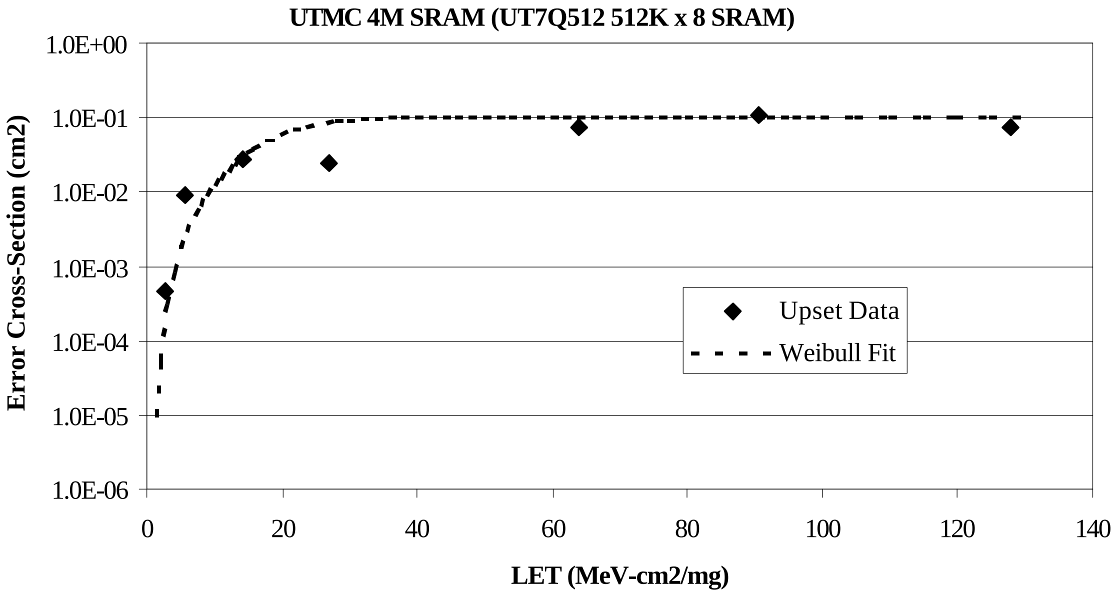
Ion	**Angle**	**LET Effective ($MeV\text{-}cm^2/mg$)**
N	0	2.8
Ne	0	5.5
Ar	0	14.3
Kr	0	38
Kr	45	53.7
Kr	60	76
Xe	0	64
Xe	45	90.5
Xe	60	128

Table 3 summarizes the SEE data for the 4M SRAM. The first 9 rows show SEU data (4.5V V_{dd} and room temperature). The last 3 rows show the results of the SEL test (125 ×C and 5.5V V_{dd}). Figure 2 is a plot of the cross-section versus LET for the data shown in Table 3. This figure shows an onset of upset at less than 2.8 MeV·cm^2/mg (the smallest LET available for this test) and a saturated cross section (s_{sat}) of 1 x 10^{-1}. Using a conservative measure for upset threshold of 0.25*s_{sat} , we can estimate the SEU threshold to be 15MeV-cm^2/mg [2].

Table 3. Single event effects data summary for the UTMC UT7Q512 4M SRAM

Temp Degrees C)	**Ion**	**Angle**	**Effective LET ($MeV\text{-}cm^2/mg$)**	**Effective Fluence**	**Time (sec)**	**Latchup**	**Upset**	**DVM**	**Section (cm^2)**
25	Kr	0	38	1.20E+00	10	0	21	4.50E+00	1.75E+01
25	Kr	0	38	7.79E+04	159	0	104	4.50E+00	1.34E-03
25	Xe	60	128	6.29E+02	118	0	46	4.50E+00	7.31E-02
25	Xe	45	90.5	1.07E+03	83	0	113	4.50E+00	1.06E-01
25	Xe	0	64	1.48E+03	80	0	109	4.50E+00	7.36E-02
25	Co	0	27	4.30E+03	83	0	105	4.50E+00	2.44E-02
25	Ar	0	14.3	3.23E+03	82	0	89	4.50E+00	2.76E-02
25	Ne	0	5.5	2.15E+04	74	0	188	4.50E+00	8.74E-03
25	N	0	2.8	4.25E+05	109	0	197	4.50E+00	4.64E-04
125	Xe	0	64	1.01E+06	127	0	N/A	5.50E+00	N/A
125	Xe	45	90.5	1.01E+06	134	0	N/A	5.50E+00	N/A
125	Xe	60	128	1.02E+06	126	0	N/A	5.50E+00	N/A

Figure 2. Upset cross section data and Weibull fit for the UTMC 4M SRAM.



The following parameters were used to obtain the Weibull fit shown in Figure 2:

Shape Parameter 2.5
Width Parameter 20
Saturated Cross-Section 1 x 10^{-1} cm^2
Onset LET 1MeV-cm^2/mg

Heavy Ion Error Rate Calculations

To calculate the device error rate in the Adams 90% worst-case geostationary orbit [3] we use Space Radiation 4.0 [4]. The Weibull model is used (with the above parameters) along with an estimated device depletion and funnel depth of 0.8mm. Space Radiation yields an error rate of:

1 1 x 10^{-8} errors/bit-day (Adams 90% Worst Case Geo Orbit)

References

1. M. A. McMahan, “Cocktails and Other Libations-The 88-Inch Cyclotron Radiation Effects Facility, IEEE Radiation Effects Data Workshop, pp. 156-163 (1998).

2. E. L. Peterson, J. B. Langworthy, and S. E. Diehl, “Suggested Single Event Upset Figure of Merit,” IEEE Trans. Nucl. Sci., **NS-30**, pp. 4533-4539 (1983).

3. J. H. Adams, Jr. “The Natural Radiation Environment Inside Spacecraft,” IEEE Trans. Nucl. Sci., **NS-29**, pp. 2095-2100 (1982).

4. Space Radiation Associates, Space Radiation 4.0 Users Manual.