# Single Event Effects Qualification
# UT8Q512K8 (RQ02)
# Lot 6ZVL04 4Mbit SRAM
# 7/21/03

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***SUMMARY--Single event effects qualification testing was performed on the UTMC 4Mbit SRAM, (Samsung Rev C die), Lot 6ZVL04, at the Lawrence Berkeley Laboratory using heavy ion beams from their 88-inch Cyclotron. The SRAM was shown to be immune to single event latchup (SEL) from ions with a linear energy transfer (LET) of >84 MeV-cm$^2$/mg when tested at 125°C and 3.6V $V_{dd}$ (considered worst-case conditions for SEL). SEL was observed at an LET of 100 MeV-cm$^2$/mg, so the LET threshold for SEL lies between 84-100 MeV-cm$^2$/mg. The SRAM was also qualified for single event upset (SEU) at 25°C and 3.0V (considered worst-case conditions for SEU). The error-rate calculated using the Adams 90% worst-case geosynchronous environment (100 mils of Al shielding) [1] is approximately 1.14E-8 errors/bit-day.***

## Introduction

This report describes single event effects (SEE) test data collected on the Aeroflex UTMC 4Mbit SRAM, Lot 6ZVL04. The SEE testing consisted of monitoring for two SEE effects, single event latchup (SEL) and single event upset (SEU). It was performed with the Lawrence Berkeley National Laboratory (LBNL) 88-inch cyclotron and the Aerospace heavy ion test chamber. The SEU data was collected on April 4, 2003 and the SEL data on May 3, 2003.

## Experimental Conditions

Single event upset and single event latch-up characterizations were performed on the 4Mbit SRAM, Lot 6ZVL04, at the Lawrence Berkley Laboratory using their 88-inch Cyclotron facility. Both SEU and SEL were tested under worst-case temperature and voltage conditions. In accordance with EIA/JESD57, the device was tested for SEL at 125C and 3.6V and was tested for SEU at 25C and 3.0V. The devices were exposed to the ion beam in vacuum and were delidded and tested prior to insertion into the SEE test chamber.

In order to fully evaluate SEU, a broad range of LET values are required. To achieve this, a variety of different ions were selected from LBNL's 4.5-MeV/amu "nucleon cocktail" [2] and used at angles from a 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 ions and their LETs at normal incidence are shown in Table 1. The maximum effective LET for this test was approximately 126 MeV-cm$^2$/mg.

**Table 1 LBNL Cyclotron 4.5MeV/AMU cocktail ions, and their LETs**

| Ion | Energy (MeV) | LET (MeV·cm$^2$/mg) |
|---|---|---|
| Boron | 45 | 1.2 |
| Nitrogen | 67 | 3.2 |
| Neon | 90 | 5.6 |
| Argon | 180 | 15 |
| Cobalt | 266 | 25.8 |
| Copper | 293 | 30 |
| Krypton | 378 | 38 |
| Xenon | 603 | 64 |

During the SEL testing, all four-qualification units were placed in the test chamber on the same test board. The parts were biased statically and the current monitored during the duration of the test. Each component was exposed to a minimum effective fluence of 1.4E6 ions/cm$^2$.

**Results**

To verify the SEL hardness of the UTMC SRAM, xenon was chosen from LBL's "nucleon cocktail" and used at an oblique angle of incidence (the effective LET is equal to the LET at normal incidence multiplied by the secant of the angle of incidence). Two samples were first tested at an angle of 50° (effective LET of 99.6 MeV-cm$^2$/mg) and latchup events were recorded. The angle of incidence was decreased to 40° (effective LET of 83.5 MeV-cm$^2$/mg) and no latchup events were measured in all of the four samples that were exposed at this angle of incidence.

The parts were tested under worst-case temperature (+125°C) and supply voltage (3.6V) for inducing SEL. The devices were exposed to the ion beam in vacuum and were biased using a typical static SRAM configuration. Four devices were tested. Table 2 summarizes the results of the tests. As seen in Table 2, no single event induced latch-ups were measured in the four devices when exposed to Xe ions with a LET of 83.5 MeV-cm$^2$/mg at fluences which exceeded 1.4 x 10$^6$ ions/cm$^2$. However, two of the samples were tested at a larger angle of incidence, resulting in a LET of 99.6 MeV-cm$^2$/mg, and in both cases a latchup was induced. Thus the LET threshold for single event latchup lies between 83.5-99.6 MeV-cm$^2$/mg. Further, it can be stated that the device is immune from latchup for LET of < 83.5 MeV-cm$^2$/mg.

**Table 2 Single event latch-up results for Lot 6ZVL04 SRAM samples**

| S/N | Dev. | Temp (°C) | Ion | Angle, ° | LET (eff.) | Fluence (eff.) | DVM (V) | Latch-up |
|---|---|---|---|---|---|---|---|---|
| 1 | SRAM | 125 | Xe | 50 | 100 | 5.7E+4 | 3.6 | 1 |
| 2 | SRAM | 125 | Xe | 50 | 100 | 3.2E+5 | 3.6 | 1 |
| 1 | SRAM | 125 | Xe | 40 | 84 | 1.4E6 | 3.6 | 0 |
| 2 | SRAM | 125 | Xe | 40 | 84 | 1.3E7 | 3.6 | 0 |
| 3 | SRAM | 125 | Xe | 40 | 84 | 1.8E6 | 3.6 | 0 |
| 4 | SRAM | 125 | Xe | 40 | 84 | 1.4E6 | 3.6 | 0 |

The single event upset (SEU) response data is shown in Figure 1. This figure is a plot of SEU error cross-section as a function of LET for the 4 samples, and also includes a fit with a Weibull distribution (shown with a dashed line). As seen in Fig. 1, the SRAM exhibited upsets from very low values of LET up to the highest value. The saturated SEU cross section is approximately 7.83E-9 cm²/bit and is included in Table 3 which contains all of the Weibull fit parameters. The actual SEU cross section data that is plotted in Fig. 1 is tabulated in Table 4. An analysis of the data using SpaceRadiation 4.0 [3] yields an error rate of 1.14E-8 errors/bit-day in the Adams 90% worst-case geosynchronous environment with 100 mils of aluminum shielding. The SEU linear energy transfer (LET) threshold based on one-quarter of the saturated cross-section ($LET_{th}(0.25)$) for the SRAM is 11.4 MeV-cm$^2$/mg with a saturated cross-section of 7.83E-9 cm$^2$/bit.

**Figure 1 SEU Cross Section of Lot 6ZVL04 SRAM Data as a function of LET**

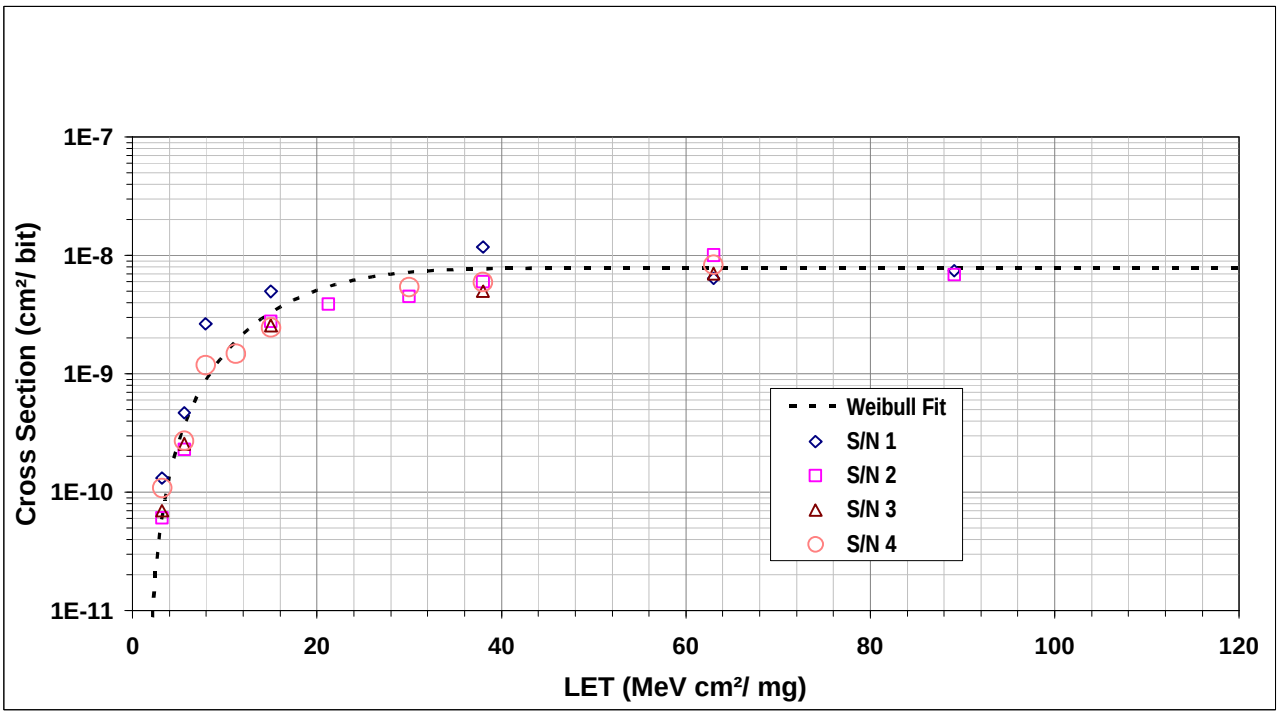


**Table 3. Weibull Fit Data and Associated Values**

| Parameter Description | Value |
|---|---|
| Saturated cross-section | 7.83E-9 cm$^2$/bit |
| Onset LET | 1.43 MeV-cm$^2$/mg |
| Width | 18.18 |
| Shape | 2.07 |
| $LET_{th}$ (0.25) | 11.4 MeV-cm$^2$/mg |
| Device depth | 0.25µm |
| Funnel depth | 0.25µm |
| Adams 90% GEO error rate | 1.14E-8 Errors/bit-day |

## Summary/Conclusions

Single event effects (SEE) qualification testing was performed on the UTMC 4Mbit SRAM, Lot 6ZVL04 at the Lawrence Berkeley National Laboratory using heavy ion beams from their 88-inch Cyclotron. The Lot 6ZVL04 SRAM was shown to be prone to SEL at very high values of linear energy transfer, LET, having a LET threshold for SEL within the range of 83.5-99.6 MeV-cm$^2$/mg. Further, the SRAM was shown to be immune to SEL for LET values of up to 83.5 MeV-cm$^2$/mg when tested at 125°C and 3.6V $V_{dd}$ (worst-case conditions for SEL). The Lot 6ZVL04 SRAM was also qualified for SEU at 25°C and 3.0V (worst-case conditions for SEU). The SEU error-rate for an Adams 90% worst-case geosynchronous environment (100 mil Al shielding) is approximately 1.14E-8 errors/bit-day.

**Table 4 Tabulation of SEU Cross Section Data in Lot 6ZVL04 SRAM Samples**

| Part # | Ion | Nom. LET | Angle, ° | Errors | Fluence | Eff. Fluence | Eff. LET | X-Sec, cm²/bit | DVM (V) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Xe | 63 | 60 | 674 | 4.0E+4 | 2.0E+4 | 126 | 8.1E-09 | 3.0 |
| 1 | Xe | 63 | 45 | 228 | 1.0E+4 | 7.3E+3 | 89 | 7.5E-09 | 3.0 |
| 1 | Xe | 63 | 0 | 1107 | 4.1E+4 | 4.1E+4 | 63 | 6.4E-09 | 3.0 |
| 1 | Kr | 38 | 0 | 935 | 1.9E+4 | 1.9E+4 | 38 | 1.2E-08 | 3.0 |
| 1 | Ar | 15 | 0 | 261 | 1.3E+4 | 1.3E+4 | 15 | 5.0E-09 | 3.0 |
| 1 | Ne | 5.6 | 45 | 277 | 3.5E+4 | 2.5E+4 | 8 | 2.6E-09 | 3.0 |
| 1 | Ne | 5.6 | 0 | 217 | 1.1E+5 | 1.1E+5 | 6 | 4.7E-10 | 3.0 |
| 1 | N | 3.2 | 0 | 130 | 2.4E+5 | 2.4E+5 | 3 | 1.3E-10 | 3.0 |
| 2 | Xe | 63 | 60 | 489 | 3.5E+4 | 1.7E+4 | 126 | 6.7E-09 | 3.0 |
| 2 | Xe | 63 | 45 | 258 | 1.3E+4 | 8.9E+3 | 89 | 6.9E-09 | 3.0 |
| 2 | Xe | 63 | 0 | 1522 | 3.6E+4 | 3.6E+4 | 63 | 1.0E-08 | 3.0 |
| 2 | Kr | 38 | 0 | 276 | 1.1E+4 | 1.1E+4 | 38 | 6.0E-09 | 3.0 |
| 2 | Ar | 15 | 60 | 338 | 3.6E+4 | 1.8E+4 | 30 | 4.5E-09 | 3.0 |
| 2 | Ar | 15 | 45 | 229 | 2.0E+4 | 1.4E+4 | 21 | 3.9E-09 | 3.0 |
| 2 | Ar | 15 | 0 | 304 | 2.6E+4 | 2.6E+4 | 15 | 2.8E-09 | 3.0 |
| 2 | Ne | 5.6 | 0 | 378 | 3.9E+5 | 3.9E+5 | 6 | 2.3E-10 | 3.0 |
| 2 | N | 3.2 | 0 | 682 | 2.7E+6 | 2.7E+6 | 3 | 6.1E-11 | 3.0 |
| 3 | Xe | 63 | 60 | 207 | 1.5E+4 | 7.7E+3 | 126 | 6.5E-09 | 3.0 |
| 3 | Xe | 63 | 0 | 228 | 7.8E+3 | 7.8E+3 | 63 | 7.0E-09 | 3.0 |
| 3 | Kr | 38 | 0 | 246 | 1.2E+4 | 1.2E+4 | 38 | 5.0E-09 | 3.0 |
| 3 | Ar | 15 | 0 | 323 | 3.0E+4 | 3.0E+4 | 15 | 2.6E-09 | 3.0 |
| 3 | Ne | 5.6 | 0 | 348 | 3.2E+5 | 3.2E+5 | 6 | 2.6E-10 | 3.0 |
| 3 | N | 3.2 | 0 | 273 | 9.3E+5 | 9.3E+5 | 3 | 7.0E-11 | 3.0 |
| 4 | Xe | 63 | 60 | 252 | 1.5E+4 | 7.3E+3 | 126 | 8.3E-09 | 3.0 |
| 4 | Xe | 63 | 0 | 227 | 6.5E+3 | 6.5E+3 | 63 | 8.3E-09 | 3.0 |
| 4 | Kr | 38 | 0 | 248 | 9.9E+3 | 9.9E+3 | 38 | 5.9E-09 | 3.0 |
| 4 | Ar | 15 | 60 | 314 | 2.8E+4 | 1.4E+4 | 30 | 5.4E-09 | 3.0 |
| 4 | Ar | 15 | 0 | 331 | 3.2E+4 | 3.2E+4 | 15 | 2.5E-09 | 3.0 |
| 4 | Ne | 5.6 | 60 | 326 | 1.1E+5 | 5.3E+4 | 11 | 1.5E-09 | 3.0 |
| 4 | Ne | 5.6 | 45 | 464 | 1.3E+5 | 9.3E+4 | 8 | 1.2E-09 | 3.0 |
| 4 | Ne | 5.6 | 0 | 342 | 3.0E+5 | 3.0E+5 | 6 | 2.7E-10 | 3.0 |
| 4 | N | 3.2 | 0 | 337 | 7.4E+5 | 7.4E+5 | 3 | 1.1E-10 | 3.0 |
| 4 | Xe | 63 | 60 | 252 | 1.5E+4 | 7.3E+3 | 126 | 8.3E-09 | 3.0 |

## References


1. J.H. Adams, Jr. “The Natural Radiation Environment Inside Spacecraft,” IEEE Trans. Nucl. Sci., NS-29, pp. 2095-2100 (1982).
2. M. A. McMahan “Cocktails and Other Libations-The 88-Inch Cyclotron Radiation Effects Facility,” IEEE Radiation Effects Data Workshop, pp.156-163 (1998).
3. Space Radiation Associates, Space Radiation 4.0 Users Manual.

# Single Event Effects Qualification
# UT9Q512K8 (RQ03)
# Lot 62C006 4Mbit SRAM
# 7/21/03

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***SUMMARY--****Single event effects qualification testing was performed on the UTMC Lot 62C006 4Mbit SRAM, (Samsung Rev C die), Lot 62C006, at the Lawrence Berkeley Laboratory using heavy ion beams from their 88-inch Cyclotron. The SRAM was shown to be immune to single event latchup (SEL) to a linear energy transfer (LET) of >82 MeV-cm$^2$/mg when tested at 125°C and 5.5V $V_{dd}$ (considered worst-case conditions for SEL). The SRAM was also qualified for single event upset (SEU) at 25°C and 4.5V (considered worst-case conditions for SEU). The error-rate calculated using the Adams 90% worst-case geosynchronous environment (100 mil of Al shielding) [1] is approximately 2.69E-8 errors/bit-day.*

## Introduction

This report describes single event effects (SEE) test data collected on the Aeroflex UTMC 4Mbit SRAM, Lot 62C006. The SEE testing consisted of monitoring for two SEE effects, single event latchup (SEL) and single event upset (SEU). It was performed with the Lawrence Berkeley National Laboratory (LBNL) 88-inch cyclotron and the Aerospace heavy ion test chamber. The SEL data was collected on July 2, 2002 and the SEU data on April 14, 2003.

## Experimental Conditions

Single event upset and single event latch-up characterization were performed on the 4Mbit SRAM, Lot 62C006 at the Lawrence Berkley Laboratory using their 88-inch Cyclotron facility. Both SEU and SEL were tested under worst-case temperature and voltage conditions. In accordance with EIA/JESD57, the device was tested for SEL at 125C and 5.5V and was tested for SEU at 25C and 4.5V. The devices were exposed to the ion beam in vacuum and were delidded and tested prior to insertion into the SEE test chamber.

In order to fully evaluate SEU, a broad range of LET values are required. To achieve this a variety of different ions were selected from LBNL's 4.5-MeV/amu "nucleon cocktail" [2] 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 ions and their LETs at normal incidence are shown in Table 1. The maximum effective LET for this test was approximately 126 MeV-cm$^2$/mg.

**Table 1 LBNL Cyclotron 4.5MeV/AMU cocktail ions, and their LETs**

| Ion | Energy (MeV) | LET (MeV·cm$^2$/mg) |
|---|---|---|
| Nitrogen | 67 | 3.2 |
| Neon | 90 | 5.6 |
| Argon | 180 | 15 |
| Cobalt | 266 | 25.8 |
| Copper | 293 | 30 |
| Krypton | 378 | 38 |
| Xenon | 603 | 64 |
| Gold | 887 | 82 |

During the SEL testing, all four-qualification units were placed in the test chamber on the same test board. The parts were biased statically and the current monitored during the duration of the test. Each component was exposed to a minimum effective fluence of 1E7 ions/cm$^2$.

**Results**

For qualifying the SEL immunity of the UTMC SRAM, four devices were tested, as discussed above. Table 2 summarizes the results of the tests. As seen in Table 2, no single event induced latch-ups were measured when exposed to a total fluence of Au ions which exceeded 1 x $10^7$ ions/cm$^2$.

The single event upset response data is shown in Figure 1. This figure is a plot of SEU error cross-section as a function of LET for the 4 samples, and also includes a fit with a Weibull distribution (shown with a dashed line). As seen in Fig. 1, the SRAM exhibited upsets from very low values of LET up to the highest value. The saturated SEU cross section is approximately 1.5E-8 cm²/bit and is included in Table 3 which contains all of the Weibull fit parameters. The actual SEU cross section data that is plotted in Fig. 1 is tabulated in Table 4. An analysis of the data using SpaceRadiation 4.0 [3] yields an error rate of 2.69E-8 errors/bit-day in the Adams 90% worst-case geosynchronous environment with 100 mils of aluminum shielding. The SEU linear energy transfer (LET) threshold based on one-quarter of the saturated cross-section ($LET_{th}(0.25)$) for the SRAM is 9.2 MeV-cm$^2$/mg with a saturated cross-section of 1.49E-8cm$^2$/bit.

**Table 2 Single Event latch-up results for Lot 62C006 SRAM samples**

| S/N | Dev. | Temp (°C) | Ion | Angle, ° | LET (eff.) | Fluence (eff.) | DVM (V) | Latch-up |
|---|---|---|---|---|---|---|---|---|
| 1 | SRAM | 125 | Au | 0 | 82 | 1.0E7 | 5.5 | 0 |
| 2 | SRAM | 125 | Au | 0 | 82 | 1.01E7 | 5.5 | 0 |
| 3 | SRAM | 125 | Au | 0 | 82 | 1.0E7 | 5.5 | 0 |
| 4 | SRAM | 125 | Au | 0 | 82 | 1.0E7 | 5.5 | 0 |

**Figure 1 SEU Cross Section of Lot 62C006 SRAM Data as a function of LET**

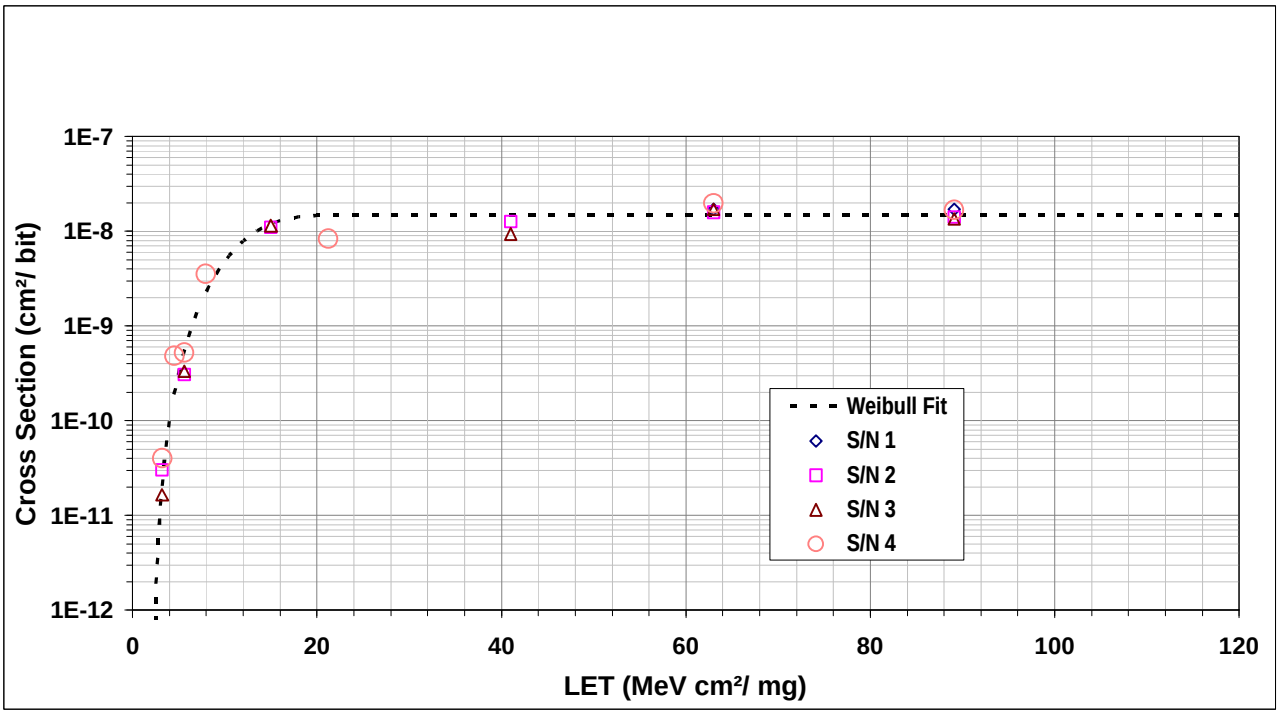


**Table 3 Weibull Fit Data and Associated Values**

| Parameter Description | Value |
|---|---|
| Saturated cross-section | 1.49E-8 $cm^2$/bit |
| Onset LET | 2.02MeV-$cm^2$/mg |
| Width | 11 |
| Shape | 2.92 |
| $LET_{th}$ (0.25) | 9.2 MeV-$cm^2$/mg |
| Device depth | 0.25 µm |
| Funnel depth | 0.25 µm |
| Adams 90% GEO error rate | 2.69E-8 Errors/bit-day |

## Summary/Conclusions

Single event effects qualification testing was performed on the UTMC Lot 62C006 4Mbit SRAM at the Lawrence Berkeley National Laboratory using heavy ion beams from their 88-inch Cyclotron. The SRAM was shown to be immune to SEL for LET values of up to 82 MeV-$cm^2$/mg when tested at 125°C and 5.5V $V_{dd}$ (worst-case conditions for SEL). The SRAM was also qualified for SEU at 25°C and 4.5V (worst-case conditions for SEU). The SEU error-rate for a Adams 90% worst-case geosynchronous environment (100 mil Al shielding) is approximately 2.69E-8 errors/bit-day

**Table 4 Tabulation of SEU Cross Section Data in Lot 62C006 SRAM Samples**

| Part # | Ion | Nom. | Angle, ° | Errors | Fluence | Eff. | Eff. | X-Sec, | DVM |
|---|---|---|---|---|---|---|---|---|---|

| | | LET | | | | Fluence | LET | cm²/bit | (V) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | N | 3.2 | 0 | 109 | 5.8E+5 | 5.8E+5 | 3.2 | 4.5E-11 | 4.5 |
| 1 | Ne | 5.6 | 0 | 155 | 9.5E+4 | 9.5E+4 | 5.6 | 3.9E-10 | 4.5 |
| 1 | Kr | 41 | 0 | 122 | 3.5E+3 | 3.5E+3 | 41.0 | 8.3E-09 | 4.5 |
| 1 | Xe | 63 | 0 | 419 | 6.0E+3 | 6.0E+3 | 63.0 | 1.7E-08 | 4.5 |
| 1 | Xe | 63 | 45 | 196 | 3.8E+3 | 2.7E+3 | 89.1 | 1.7E-08 | 4.5 |
| 2 | N | 3.2 | 0 | 91 | 7.2E+5 | 7.2E+5 | 3.2 | 3.0E-11 | 4.5 |
| 2 | Ne | 5.6 | 0 | 113 | 8.8E+4 | 8.8E+4 | 5.6 | 3.1E-10 | 4.5 |
| 2 | Ar | 15 | 0 | 240 | 5.2E+3 | 5.2E+3 | 15.0 | 1.1E-08 | 4.5 |
| 2 | Kr | 41 | 0 | 128 | 2.4E+3 | 2.4E+3 | 41.0 | 1.3E-08 | 4.5 |
| 2 | Xe | 63 | 0 | 262 | 3.9E+3 | 3.9E+3 | 63.0 | 1.6E-08 | 4.5 |
| 2 | Xe | 63 | 45 | 225 | 5.4E+3 | 3.8E+3 | 89.1 | 1.4E-08 | 4.5 |
| 3 | N | 3.2 | 0 | 67 | 9.7E+5 | 9.7E+5 | 3.2 | 1.6E-11 | 4.5 |
| 3 | Ne | 5.6 | 0 | 153 | 1.1E+5 | 1.1E+5 | 5.6 | 3.3E-10 | 4.5 |
| 3 | Ar | 15 | 0 | 376 | 7.8E+3 | 7.8E+3 | 15.0 | 1.1E-08 | 4.5 |
| 3 | Kr | 41 | 0 | 704 | 1.8E+4 | 1.8E+4 | 41.0 | 9.3E-09 | 4.5 |
| 3 | Xe | 63 | 0 | 1899 | 2.7E+4 | 2.7E+4 | 63.0 | 1.7E-08 | 4.5 |
| 3 | Xe | 63 | 45 | 248 | 6.2E+3 | 4.4E+3 | 89.1 | 1.3E-08 | 4.5 |
| 3 | Xe | 63 | 60 | 183 | 7.9E+3 | 3.9E+3 | 126.0 | 1.1E-08 | 4.5 |
| 4 | N | 3.2 | 0 | 101 | 6.0E+5 | 6.0E+5 | 3.2 | 4.0E-11 | 4.5 |
| 4 | N | 3.2 | 45 | 178 | 1.2E+5 | 8.8E+4 | 4.5 | 4.8E-10 | 4.5 |
| 4 | Ne | 5.6 | 0 | 220 | 1.0E+5 | 1.0E+5 | 5.6 | 5.2E-10 | 4.5 |
| 4 | Ne | 5.6 | 45 | 457 | 4.4E+4 | 3.1E+4 | 7.9 | 3.5E-09 | 4.5 |
| 4 | Ar | 15 | 45 | 116 | 4.7E+3 | 3.3E+3 | 21.2 | 8.3E-09 | 4.5 |
| 4 | Xe | 63 | 0 | 256 | 3.1E+3 | 3.1E+3 | 63.0 | 2.0E-08 | 4.5 |
| 4 | Xe | 63 | 45 | 128 | 2.6E+3 | 1.8E+3 | 89.1 | 1.7E-08 | 4.5 |

## References


4. J. H. Adams, Jr. “The Natural Radiation Environment Inside Spacecraft,” IEEE Trans. Nucl. Sci., NS-29, pp. 2095-2100 (1982).
5. M. A. McMahan “Cocktails and Other Libations-The 88-Inch Cyclotron Radiation Effects Facility,” IEEE Radiation Effects Data Workshop, pp.156-163 (1998).
3. Space Radiation Associates, Space Radiation 4.0 Users Manual.