Are Cosmic Neutrons a Threat to Pacemakers?- Testing SRAMs with an Am-Be Neutron Source

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SEE/MAPLD Preferred Session: Poster
**Note that all sessions require oral presentations with slides except the poster session*

Introduction

Effects of cosmic radiation can impair pacemakers and other active implanted medical devices (AIMDs). There are several publications about devices showing irregular function during or after air-travel most likely caused by subatomic particles from space (Clair, Williams, Hygaard, & Saavedra, 2013; Ferrick, Bernstein, Aizer, & Chinitz, 2008; Paz, Teodorovich, Kogan, & Swissa, 2017). Furthermore, numerous radiation related malfunctions of unknown origin have been reported in the Manufacturers and User Facility Device Experience (MAUDE) database in recent years, some of which caused symptoms or led to the exchange of the device.

These described malfunctions are most likely caused by SEE in the memory of the AIMD. Severe errors in the executed stimulation program are usually detected and corrected by the device itself through a power-on-reset. However, this procedure switches it to safety mode where stimulation parameters can be changed. Ultimately, this can lead to the pacemaker syndrome or unnecessary shocks of defibrillators.

The problem of the susceptibility to particle radiation of medical devices is already well-known from radiation therapy. Therefore, various protective measures have been established for patients in recent years to avoid complications in this radiation environment (Gauter-Fleckenstein et al., 2015). Nevertheless, for developing and applying radiation protection measures to patients with AIMDs in further radiation environments, such as at aviation altitudes or during severe space weather events, the assessment of the risk of malfunction for AIMDs is necessary.

Experimental Setup

For a better understanding of the interaction of memory with fast neutrons, a major component of the radiation field at aviation altitudes, three types of commercial of the shelf (COTS) SRAMs were tested with a Am-241/Be neutron source. The energy of the emitted neutrons ranged from 0.1 – 11 MeV. Seven 1 Mb (23LC1024 by Microchips), four 2 Mb (IS62/65WVS2568GALL by ISSI), and two 4 Mb (IS62/65WVS5128GALL by ISSI) SRAM chips were connected to a microprocessor which performed the writing, reading, and SEE detection within the chips. At first, a defined pattern of alternating bits ("10101010") was written to each byte of each chip and then continuously read out by the microprocessor during irradiation. Any alteration from the written pattern in a reading cycle was logged. Subsequently, the bit pattern in the chip was renewed. The setup was irradiated 24 h at a neutron flux of at least $2.13 \cdot 10^4 \frac{neutrons}{s}$.

Results & Discussion

A total of 609 bit flips was observed in the investigated chips after 24h of neutron irradiation. The results are summarized for each chip in table 1.

Table 1: Logged bit flips and calculated cross section for each chip type

Chip Type	Size	Bit Flips	Max. Cross Section/Device [cm²]
23LC1024 (7x)	1 Mb	122	9.4 E-9
IS62/65WVS2568GALL (4x)	2 Mb	202	2.7 E-8
IS62/65WVS5128GALL (2x)	4 Mb	212	5.8 E-8

A deeper analysis revealed a balanced ratio of bit flips from 1 to 0 and 0 to 1 in all chips. In addition, the bit flips were evenly distributed over the range of all addresses. The accumulated bit flip events for all types of chips used are normalized to 1 Mb and plotted over time in figure 1. While the 1 Mb chip is the least sensitive to bit flips, the response of the two larger storage devices is similar. In contrast to the 1 Mb chip, simultaneous bit flips in neighboring addresses were observed and classified as multiple bit upsets (MBU) in the 2 Mb and 4 Mb chips (figure 2). However, no permanent damage to any bit was found, as all bits could be read and written after the irradiation.

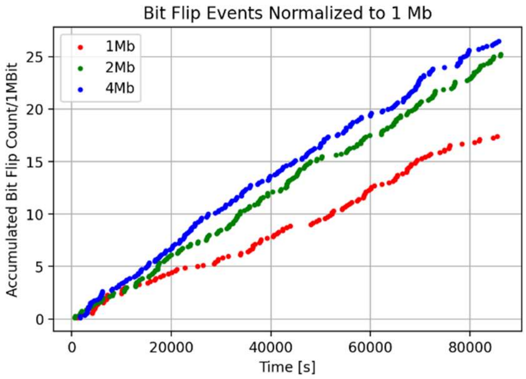

Figure 1: The accumulated bit flip events are normalized to 1Mb in dependence on the irradiation time.

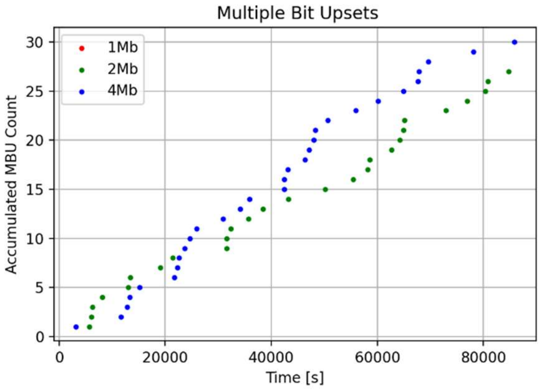

Figure 2: The accumulated multiple bit upsets over the irradiation time are shown.

The presented results show that the investigated chips are susceptible to neutrons with energies between 0.1 and 11 MeV. With increasing chip size, the probability of bit flips seems to increase, which is indicative of smaller structures in the two larger chips. Finally, the observed MBUs imply that the energy of neutrons with less than 11 MeV is sufficient to cause considerable effects in this kind of chips. Hence, for the assessment of the risk of malfunctions for AIMDs caused by neutrons, it is important to investigate effects of fast neutrons in the energy range down to 0.1 MeV.

References

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