An Instrument for Monitoring Proton Induced Upsets in Space Electronics

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Un instrument de suivi des aléas logiques induits par les protons dans les électroniques spatiales
Cette étude présente un moniteur de proton de petite taille et de faible puissance utilisant une DRAM sensible aux SEU comme détecteur. Ce moniteur, conçu pour fonctionner sur les satellites STRV-1c/d, permet de mesurer la vulnérabilité du satellite aux erreurs mémoires catastrophiques.

1. INTRODUCTION

Originally, only heavy ions were thought to cause *S*ingle *E*ffect *E*vents (SEE) in space, however with transistors being scaled down to smaller dimensions, VLSI circuits are also becoming more susceptible to SEE's from incident protons (through nuclear reactions).[1,2,3] This paper describes a small, low mass and low power *P*roton *S*ingle *E*vent *U*pset *M*onitor (PSEUM) that utilizes a proton sensitive 256k DRAM. The upset monitor, which is scheduled to fly on STRV 1c/d in 1998, is designed to be a generic instrument capable of inclusion onto any satellite for real time monitoring.

2. PROTON MONITOR

The PSEUM is shown schematically in Fig. 1. The monitor consists of a proton sensitive 256k DRAM, as well as read/write and I/O circuitry. The read/write circuit is comprised of 54HC digital components which reads a selected element and compares the logic value to what was previously written to that particular element. If an upset has occurred then a 16 bit digital counter is updated. Following each element read, it is immediately refreshed to make it *S*ingle *E*vent *U*pset (SEU) susceptible. It takes 140 msecs to read/write all 262,144 elements.

The proton monitor is designed to serially output the number of counts or upsets to the satellite's *O*n *B*oard *D*ata *H*andling *S*ubsystem (OBDH) through an RS422 interface as shown in Fig. 2. The output field size is two words long with each word comprised of 8 bits plus a start, stop and parity bit. On command from the OBDH the 16 bit counter is shifted out via three 8 bit shift registers following which the 16 bit counter is nulled.

An analog temperature sensor (AD540) is utilized on board the PSEUM for housekeeping purposes.

Table 1 lists some of the measured parameters for the PSEUM. The monitor is designed to accept input voltage ranging from +12 V to 50 V through an on board EMI filter which is surge protected to MIL-STD-704A. Current consumption with 28 V input is 31 mA.

Table 1 Measured parameters for the PSEUM.

parameter	value
input voltage	12 V to 50 V
power	800 mW
dimensions	10 cm x 10 cm x 2.5 cm
mass	150g

A typical DRAM memory cell works by storing charge on a capacitor which is isolated by a FET access transistor. During the write operation, the FET is on and either V_{dd} or 0 V is applied to the cell capacitor. The larger V_{dd} is the greater amount of injected charge required to cause a cell to change logic levels. During charge retention the access FET is turned off. The read operation occurs as the access transistor is turned on and the stored charge is applied to the cell's bit line. If the bit line is moved enough from the half V_{dd}, the sense amplifier detects the change and forces its completion to V_{dd} or ground. It is important to note that some of the memory cells are tied to inverted bit lines, which switch the logic value of the physical charge stored. Table 2 shows the difference in cross section when irradiated with 240 MeV Ni for a device set at logic 0 and logic 1. To maximize the efficiency of the DRAM as a SEU monitor it is important to write the correct logic level to each cell which makes it susceptible to injected charge from a particle strike. The read/write digital electronics associated with the PSEUM is optimized to make every cell vulnerable to injected charge.

Table 2 Cross section for DRAM set at logic level 1 and logic level 0. 240 MeV Ni (irradiation performed at Chalk River, Canada)

Logic level	cross section
1	1.1×10^{-7} cm^2/bit
0	8.7×10^{-6} cm^2/bit

Proton calibration, as shown in Fig. 2, was performed at the Paul Scherrer Institute. Proton energies used in the calibration were 20 MeV-300 MeV, which is typical of that found in *L*ow *E*arth *O*rbit (LEO).[4] State of the art SRAM and DRAM structures have measured proton cross section much less than the PSEUM, with values of 10^{-14} to 10^{-16}.[5]

As indicated in Fig. 2. the PSEUM sensitivity is independent of proton rate. This is important since the trapped proton flux in space range from 10 to 10^4 particles/cm^2/s.

3. CONCLUSION

A new proton upset monitor comprised of a 256k DRAM has been designed and especially built for monitoring upset rates on board spacecraft. The PSEUM is 100 to 1000 times more sensitive to a proton induced upset than is most sensitive microcontrollers, DRAM's or SRAM's. The monitor is not designed to detect all proton strikes, but act as a housekeeping aid to help determine when a satellite may be prone to memory failures. The first monitor is scheduled to fly on STRV-1c/d in 1998.

REFERENCES

[1] R. Harboe-Sorenson, E.J. Daly, C.I. Underwood, J. Ward and L. Adams, "The behaviour of SEU at low altitude during periods of high solar activity," IEEE Trans. Nuclear Sci. NS-37, No. 6, 1990, p. 1938.

[2] W.L. Bendel and E.L. Petersen, "Proton upsets in orbit," IEEE Trans. Nucl. Sci. NS-30, No. 6, 1983, p. 4493.

[3] L. Adams, E.J. Daly, R. Harboe-Sorensen, R. Nickson, J. Haines, W. Schafer, M. Conrad, H. Griech, T. Schwall, R. Henneck, "A verified proton induced latch-up in space," IEEE Trans. Nucl. Sci. NS-39, No. 6, 1992, p. 1804.

[4] T.P. Ma, "Ionizing radiation effects in MOS devices and circuits," John Wiley & Sons, 1989, p. 446.

[5] E. Normand, D.L. Oberg, J.L. Wert, J.D. Ness and P.P. Majewski, "Single Event Upset and charge collection measurements using high energy protons and neutrons," IEEE Trans. Nucl. Sci. NS-41, No. 6, 1994, p. 2203.

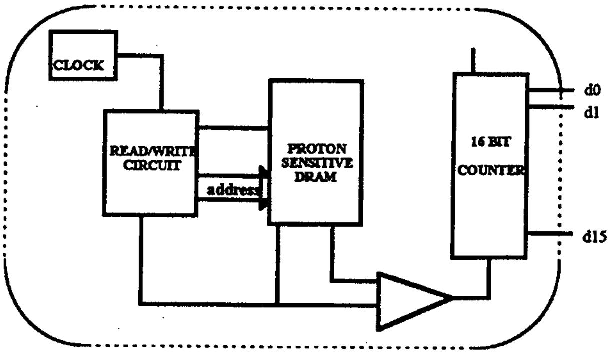

Figure 1 Schematic of the 256k DRAM configured to count upsets. All 262,144 elements are read and compared every 140 msec. Each upset is recorded on a 16 bit counter.

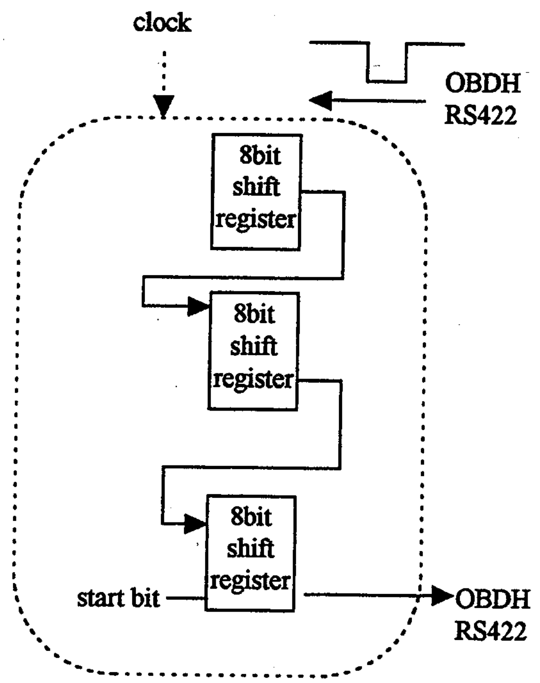

Figure 2 Schematic RS422 serial interface to the On Board Data Handling System (OBDH). An output field consists of two 8 bit words. Each word is 8 bits plus a start, stop and parity bits.

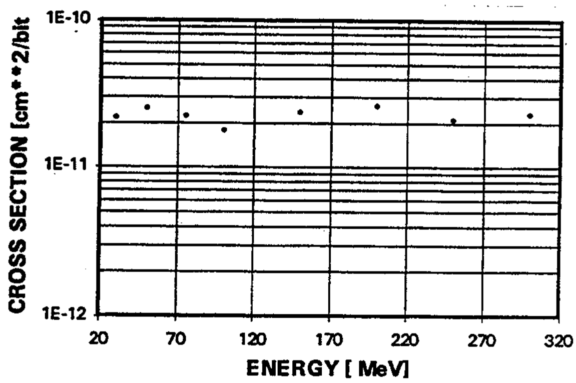

Figure 3 Cross section measurements for 256k DRAM used as sensing element in Proton Monitor. Irradiations performed at the Paul Scherrer Institute.

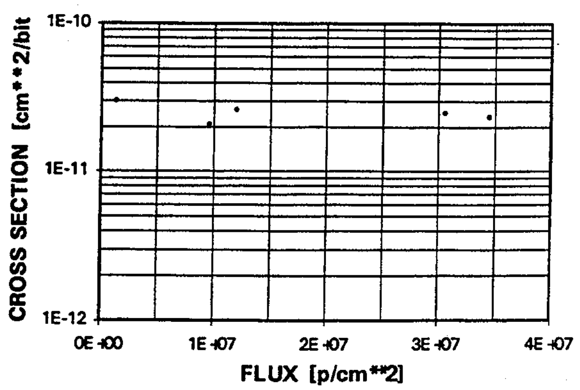

Figure 4 Cross section measurements for the Proton Monitor as a function of proton flux.