

Proton Single Event-Upset Cross-Section of an SRAM-Based FPGA

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Abstract

We have measured the proton induced single-event upset (SEU) cross-section of a Xilinx 4036XLA FPGA. The FPGAs were irradiated with protons of energy between 18 MeV and 105 MeV at the proton irradiation facility at TRIUMF in Vancouver. The cross-sections for the configuration logic blocks and the configuration switches were determined separately. The total device upset cross-section has been used to predict error rates for some low altitude orbit environments and inside the ATLAS detector at CERN in Geneva.

Summary

To reduce the costs of electronics for military, aerospace, and high-energy physics applications, components off the shelf can be used provided they have been shown to be radiation tolerant to the levels decided upon by the particular projects or agencies. To begin this certification process for a high-energy physics application, we are studying the radiation resistance of the digital control logic of the detector readout system. This paper reports on our initial proton induced single event effect (SEE) studies of a Xilinx 0.25/0.35 μm hybrid SRAM-based FPGA.

The device under test (DUT) was monitored while configured with its high-energy physics application operating at a 40 MHz clock frequency. The circuit occupied approximately 90% of the configurable logic within the device. The DUT was mounted on a small printed circuit test board which contained an oscillator, switches, connectors, and various passive components. The power supply current of the DUT was monitored to observe any total ionizing dose or latch-up effects, while the circuit behaviour was monitored by a remote computer.

The devices under test were irradiated with proton fluxes between 10^6 p/cm²/s and 10^8 p/cm²/s over periods of approximately two hours at each energy value. The proton flux was adjusted in order to obtain exposures with a minimum of 100 upsets and a probability of one or more upsets occurring during the circuit reconfiguration time of less than 10%.

The DUT is comprised of various components, such as configuration logic blocks, configuration switches, and I/O blocks. We determined the proton SEU cross-section for two of these components: the configuration logic blocks and the configuration switches. The configuration logic blocks contained our circuit comprising of roughly 50% RAM, and 50% combinatorial and sequential logic. We could distinguish between the proton induced SEUs occurring in the user circuit and those occurring in the configuration switches, enabling us to determine the corresponding cross-sections. If an upset occurred in the configuration logic, it could be cleared by providing a reset pulse to the circuit. If an error occurred in the configuration switches, the circuit could not be reset and would have to be reconfigured.

The upset rates were estimated by convoluting the cross-section (for the entire device) with the anticipated proton energy spectrum inside the ATLAS detector at CERN, as well as, for low altitude orbit environments, such as the inner Van Allen Belt.