Preliminary Radiation Testing of a State-of-the-Art Commercial 14nm CMOS Processor / System-on-a-Chip

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Abstract: Radiation test results of Intel state-of-the-art 14nm "Broadwell" U-series processor / System-on-a-Chip (SoC) for total dose are presented, along with exploratory results from trials at a medical proton facility. Investigation builds upon previous collaborative efforts [1] by utilizing commercial laptop motherboards and software stress applications as opposed to traditionally automated test equipment (ATE).

Introduction

Commercial processors have been designed to be robust for operation in the space community. As technologies and manufacturing processes have advanced in complexity, so too have the requirements to ensure that onboard electronics are capable of withstanding the radiation environment of orbit. We present an evaluation of the Intel® Core™ Processor "Broadwell" U-series (6th Gen), fabricated using a 14nm CMOS process, in a typical consumer laptop setting. Results are compared to the last generation of Intel® Core™ Processor "Haswell" (5th Gen) using a 22nm CMOS process, in the same setting.

Device Description

The DUT utilized is a state-of-the-art 14nm processor from Intel Corporation [2]. The device consists of a processor system, memory, and related support components. The processor is an Intel® Core™ Processor "Broadwell" U-series (6th Gen) using a 14nm CMOS process. The device is a multi-chip module based on the Core MAX die. The Core MAX die is a 3D chip, consisting of the processor (Core) and the memory (L3 cache). The device is packaged in a 475-ball Flip Chip Ball Grid Array (FCBGA) package, with a total of 475 balls. The package is assembled using an Advanced Technology Attachment (ATA) interface and is powered via an external power connector.

Total Ionizing Dose (TID) Testing

- **System**:
  - 24 Bin total ionizing dose (TID) exposure to 302,024 rad(Si)
  - 20 Krad(Si) per bin
  - Test fixture mounted in a Berkeley 1290A TID chamber
  - Test fixture mounting method: Ground potentials with external vacuum bellows
  - Test fixtures were enclosed in a radiation shielding chamber, and ionizing radiation was generated using an electron linear accelerator
  - The ion beam was a rapidly pulsed 5 MeV electron beam

- **System Output**:
  - No hard device failures occurred despite encountering FE
  - No NFE Cross Ray (DUT) for Single Event Effects
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Failure Between Levels and Readings

- **System**:
  - System using a 285,000 rad(Si) total ionizing dose (TID) exposure
  - Test fixture mounted in a Berkeley 1290A TID chamber
  - Test fixture mounting method: Ground potentials with external vacuum bellows
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Proton Facility and "Testing"

- **System**:
  - SCRIPPS Proton Therapy Center is a medical facility located in San Diego, CA, USA
  - Processor was installed on an Intel® Core™ Processor "Broadwell" U-series (6th Gen) laptop
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Summary and Takeaway Thoughts

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References available in final paper.