Detection and Classification of High Energy Beta Radiation Induced Damage of Raspberry Pi Zero Intended for OPAL CubeSat

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Detection and Classification of High Energy Beta Radiation induced Damage of Raspberry Pi Zero intended for OPAL CubeSat

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Overview

- Purpose of the Experiment
- The Space Environment
- Ionizing Radiation
- Experimental Design
- Equipment
  - Space survivability Test (SST) Chamber
  - The Raspberry Pi Zero
- Testing Procedures
  - Dose Rate and Time of Exposure
  - Thermal Conductivity
- Questions
Purpose of the Experiment

To determine the amount of ionizing radiation that the memory and processor units of a Raspberry Pi Zero can be exposed to before they exhibit radiation-induced damage or stop working altogether.
The Space Environment
• Space debris
• Neutral Thermosphere
• Thermal Environment
• Plasma
• Solar Environment
• Magnetic Field
• Ionizing Radiation
Ionizing Radiation (IR)
IR Generate electron hole pairs in semiconductors and insulators. The accumulated effect of ionizing radiation is called the total ionizing dose (TID). TID can cause single even effects (SEE) in electronics components.
Single event upsets (SEU) are unexpected bit changes in the memory.

Single event latch-up (SEL) can be manifested in unexpected high currents that will radically affect the device.
Experimental Design

- TC-MUX
- SST Chamber With Sr90 source
- R-pi Zero
- Aluminum Plate
- Computer interface
- Power supply
- Peripheral connections
Equipment
Space Survivability Test (SST) chamber
  - Sr$^{90}$ source
  - TGMUX
  - Power supply monitor program
Raspberry Pi Zero
  - SEU detector program
Peripheral connections
SST Chamber
Can simulate various aspects of a space environment.

Sr$^{90}$
Is a beta radiation source emitting particles of 0.2 to 2.5 MeV.

Thermocouple Multiplexer (TC-MUX)
Is an eight-channel multiplexer for type K thermocouples.
The Raspberry Pi Zero

- Small, inexpensive, reliable
- Commonly used for CubeSat and robotics
- Commonly operated with Raspbian
Testing Procedure
Dose Rate and Time of Exposure.

- The OPAL CubeSat mission will last 1-2 years in Low Earth Orbit (LEO).
- For LEO the TID is \( \sim 1 \frac{\text{krad}}{\text{yr}} \).
- The Dose Rate of the Sr\(^{90}\) is \( 0.1 \frac{\text{krad}}{\text{hr}} \) at 12in distance and falls as \( \frac{1}{r^2} \) in an area with 6in diameter.
Thermal conductivity

\[ Q = \frac{tkA\Delta T}{d} \]

- \( t = \) time
- \( k = \) thermal conductivity
- \( A = \) surface area
- \( \Delta T = \) change in temperature
- \( d = \) thickness of the material
- \( K_{Si} = 149\, W/mK \)
- \( K_{Al} = 237\, W/mK \)
- \( A_{Al} = 4\frac{1}{2} \times 4\frac{1}{2} \text{ in} \)
- \( A_{Si} = \frac{1}{2} \times \frac{1}{2} \text{ in} \)
- \( d_{Al} = \frac{1}{4} \text{ in} \)
- \( d_{Si} = \frac{1}{40} \text{ in} \)
What’s next?

- In the upcoming weeks we will proceed to our test run in the chamber.
- Determining the probability of SEU and their location in the SRAM
- Determining the thermal conductivity to determine the reliability of COTS component
References

Thanks!