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Radiation Damage Threshold of Satellite COTS Components: Raspberry Pi Zero for OPAL CubeSat

Jonh Mojica Decena
Utah State University

Brian Wood
Utah State University

Ryan J. Martineau
Utah State University

Michael Tayor
Utah State University

JR Dennison
Utah State University

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Introduction

The purpose of this experiment is to study the radiation survivability of a Raspberry Pi Zero in a simulated space environment to determine the amount of ionizing radiation that the memory and processor of this commercial off-the-shelf (COTS) unit can be exposed to before they exhibit radiation-induced damage or stop working altogether.

Motivation

The Raspberry Pi is an inexpensive and tiny computer, about the size of a credit card that normally runs with the Raspbian OS (Figure 1). A Raspberry Pi Zero will be placed inside the Space Survivability Test (SST) chamber, where it will be radiated by an Sr90 source (0.2 - 2.5 MeV) until the computer stops working (Figure 2).

The Sr90 source produces a TID of 0.1 krad/hr (Figure 3). For a commercial off-the-shelf (COTS) unit can be exposed to before they exhibit Single-event latch-up (SEL) which are critical errors. (For the proposed experiment we will look for Single-event latch-up (SEL) which are critical errors)

Procedure

In our experiment we will put a Raspberry Pi inside of the SST for a period of 8.4 hours at a dose rate of 0.4 krad/hr to simulate the LEO TID (~2 krad/yr).

To monitor the performance of the Raspberry Pi we will be using the Wi-Fi connection to control it from the outside via secure shell. When connection has been established, we will use a stress test to look for errors on the CPU, RAM and USB connections (Figure 4). Once an error has been detected, a look at the RAM and processor will allow to identify the origin of the error and the data acquisition will determine the type of error produced.

Results

Under environmental conditions, the Raspberry Pi has been fully operational for a period of 10 days, but the source of error was undetermined. The period of testing under environmental conditions indicates that the Raspberry Pi is a good candidate for this mission. The implications of determining the impact of radiation exposure will be directly used in the creation of the USU OPAL CubeSat, and could be of benefit for consumers and manufacturers since determining what areas are most affected will provide a guide to which area to focus on when building or using these microcontrollers. And what areas would benefit most from additional shielding.

Conclusions and Future Work

Conclusions:

Previous experiments done by the MPG with an Arduino shows that the TID to see the first SEL occurs at ~150 krad, but where the error occurred was undetermined. The period of testing under environmental conditions indicates that the Raspberry Pi is a good candidate for this mission. The implications of determining the impact of radiation exposure will be directly used in the creation of the USU OPAL CubeSat, and could be of benefit for consumers and manufacturers since determining what areas are most affected will provide a guide to which area to focus on when building or using these microcontrollers. And what areas would benefit most from additional shielding.

Future Work:

• Add peripheral components (GPIO connections) for testing.
• Add a camera to analyze the radiation effect on the pixels (see AWE FPA radiation test from SDL).
• Understand the property of Si-based ICs and memory to create a model for radiation effect on electronics components.
• Predict the proper amount of shielding necessary to ensure a component survivability.
• Test Solar effects on electronics with the Solar simulator (x-ray, and UV radiation).

References