Radiation Sensing and Interface Circuitry in Support of High Performance Computation in a Small Satellite Payload

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Overview

Low earth orbit is a harsh environment for electronics.Transistors commonly found in Graphics Processing Units, CPU's, and various other IC's often fail due to single event effects caused by energetic particles and breakdown of current conducting regions in BJT or FET devices due to an ionizing dose of radiation (Faccio). Single event effects can be dealt with both in hardware and software utilizing a modular redundancy of possible corrupted devices, like data paths or memory. This is done on the UGA Small Satellite Research Laboratory's (SSRL) Multi-view Onboard Computational Imager (MOCI) satellite using a primarily software approach. Ionizing dose can be quantified and used to determine likelihood of failure using radiation sensing circuitry which is processed on board the spacecraft and transmitted as telemetry. The hardware presented here to be implemented on the MOCI satellite addresses radiation sensing as well as the challenge of interfacing dual image sensing payloads with high performance processing components on board so high computational load image processing may be carried out in orbit.

Circuitry

The circuitry in question consists of two basic parts:

1. Camera/Processor Interface Circuitry
2. Radiation Detection Circuitry

Data lines in this circuit are either:

1. USB (camera and TX2i data path)
2. SPI (On Board Computer data path)

The OBC (On Board Computer) does not contain a USB interface so a USB controller peripheral (MAX3421) has been placed in the circuit for communication to take place. Firmware is currently in development for this peripheral. The OBC will have control over the MAX3421 via the SPI interface. Processors are multiplexed so a simple GPIO can be used to select the processing unit, the case is similar for camera select as the multiplexed data lines also contain device enable pins. All data paths contain redundant circuitry so mission life may be extended.

Radiation detection circuitry is also implemented here. The circuit makes use of the Varadis RADFET, which has a predictable voltage response curve to ionizing radiation. Current source circuitry and response conditioning circuitry are included to protect readout ADC and provide accurate measurements. Anti Aliasing circuitry or a moving average filter will also be included in the ADC data path to prevent noise from various sources such as RF transceivers, power supplies, etc.

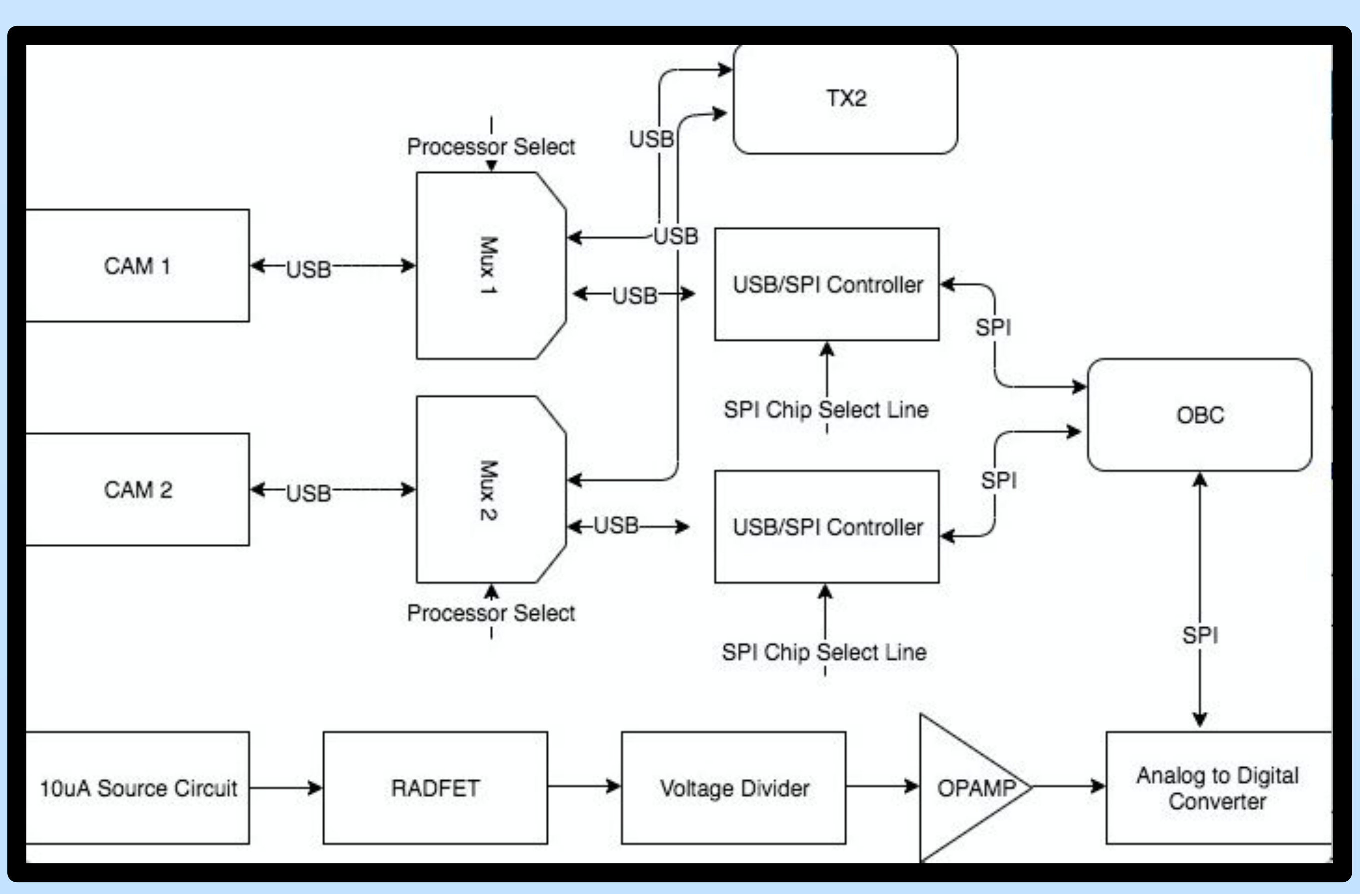

Figure 1: Block diagram of circuitry

Discussion

The circuitry presented here solves the two issues of total ionizing dose measurement and processor data path selection for the MOCI satellite. All parts are selected following a careful COTS (Commercial Off the Shelf) approach (Sinclair, Dyer), though limited availability of proton/Cobalt-60 testing means part failure states are largely undetermined, however there has been discussion of use of most selected IC's in literature on space missions, namely the IC of prime concern, the MAX3421E (Van Der Linden). It should be noted failure states of common devices such as MOSFET and BJT devices are well studied (Sinclair, Dyer).

All discrete logic circuitry is implemented using BJTs with flight heritage as logic level MOSFETs are more likely to experience catastrophic radiation effects (Löchner) (higher threshold voltage, sometimes on the order of over 100% (Faccio), vs. slightly increased collector emitter leakage current). This is due to radiation damage occurring in MOSFET oxide layers (Löchner). Load switches are implemented using MOSFETs, though all load switches have flight heritage.

Possible improvements in the circuitry include a full characterization of IC failure states, data path watch dogs, or single event effect protection circuitry. The SSRL is also looking into partnership with the Johns Hopkins Applied Physics Lab to begin radiation testing on selected IC's.

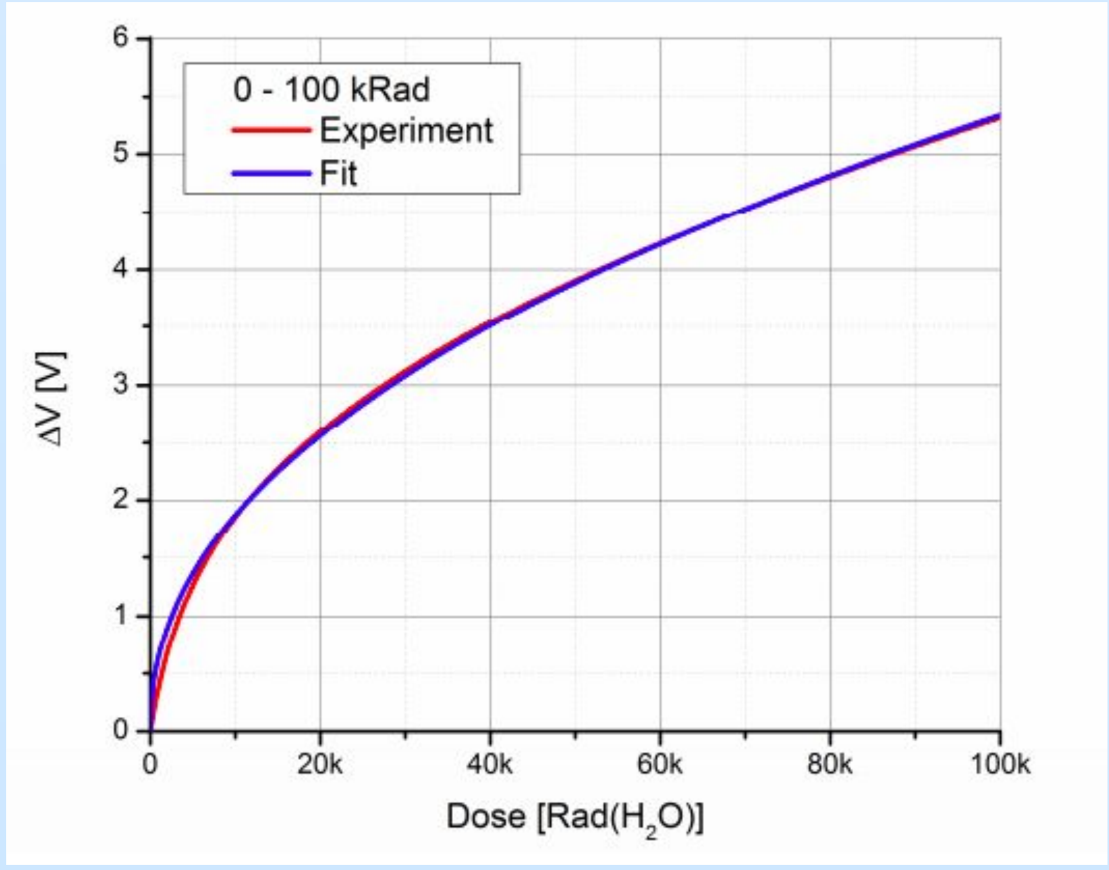

Figure 2: RADFET calibration data, courtesy of Varadis (Varadis)

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