EPSC
European Planetary Science Congress

Thermal Radiometer Signal Processing using Radiation Hard CMOS Application Specific Integrated Circuits for use in Harsh Planetary Environments

G. Quilligan, J. DuMonthier, S. Aslam, B. Lakew, I. Kleyner, and R. Katz
NASA Goddard Space Flight Center, Greenbelt, MD 20771; gerard.t.quilligan@nasa.gov

Abstract

Thermal radiometers such as proposed for the Europa Clipper flyby mission [1] require low noise signal processing for thermal imaging with immunity to Total Ionizing Dose (TID) and Single Event Latchup (SEL). Described is a second generation Multi-Channel Digitizer (MCD2G) Application Specific Integrated Circuit (ASIC) that accurately digitizes up to 40 thermopile pixels with greater than 50 Mrad (Si) immunity TID and 174 MeV-cm^2/mg SEL. The MCD2G ASIC uses Radiation Hardened By Design (RHBD) techniques with a 180 nm CMOS process node.

1. Introduction

Thermopile pixels provide a linear voltage response to infrared wavelengths in the 7-200 µm range making them suitable for thermal radiometers. A radiometer sensor with a custom designed 2D array and eight ASICs arranged in a hybrid Focal Plane Assembly (FPA) is shown in Figure 1. The hybrid package size is 86.3 mm x 63.5 mm x 8 mm. This implementation has 5 line arrays on one substrate giving a total of 320 pixels. Each 64-pixel line array has a unique passband. The spectral passbands are 7-10 µm, 12.5–25 µm, 25-50 µm, 50-100 µm and 100-200 µm. The different passbands allow the measurement of endogenic heat flux, hotspot detection and day/night surface temperatures of an icy moon such as Europa. Sub-microvolt outputs from the pixels necessitate gains in the region of several thousand. The thermal noise of the pixel outputs and the 1/f noise [2] of the amplifiers must be filtered in order to achieve adequate signal to noise ratio before digitization. The thermopiles are operated at cryogenic temperatures so as to minimize thermal noise. The front-end electronics must also operate at temperatures as low as 150 K in the high TID environment present in the Jovian orbital system.

Sampled analog signal processing is used in the custom ASIC to accurately amplify and digitize the outputs of thermopile pixels.
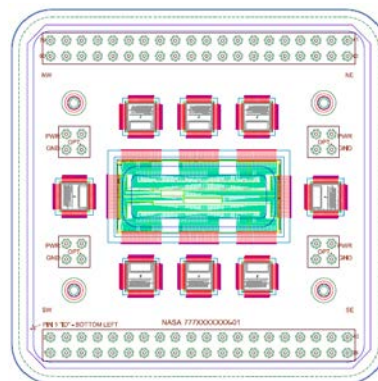

Figure 1: Radiometer focal plane assembly, showing the layout of thermopile line arrays and ASICs.
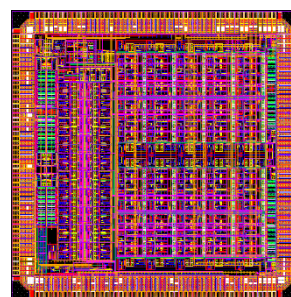

Figure 2: MCD2G ASIC (5 mm x 5 mm) will digitize up to 40 thermopile pixel voltage outputs.

2. Multi-Channel Digitizer

The MCD2G ASIC digitizes multiple thermopile pixels. It was built in a commercial 180 nm CMOS node using RHBD techniques to achieve TID/SEL immunity [3]. The first generation MCD ASIC digitizes up to 18 pixels while the second generation MCD2G accommodates up to 40 pixels, Figure 2. Figure 3 shows a block diagram for the MCD2G.

Each channel combines chopper stabilization with filtering to amplify the microvolt level signals from the thermopiles. A 16-bit Sigma-Delta Analog-Digital Converter (SDADC) then digitizes the resulting signals. The approximate channel gain is defined in the following equation (in the z-domain) where G is user programmable:

$$A_z \cong \frac{G}{1.05 - z^{-1}} \qquad (1)$$

G can have the following values: 6.25, 12.5, 39, 156 and 625. The channel frequency response is plotted for $G = 156$ and $T_{clk} = 4$ µs in Figure 4. The channel outputs can also be averaged by the SDADCs. A plot of V_{out} vs V_{in} for one channel measured before-after 50 Mrad (Si) of TID is shown in Figure 5.
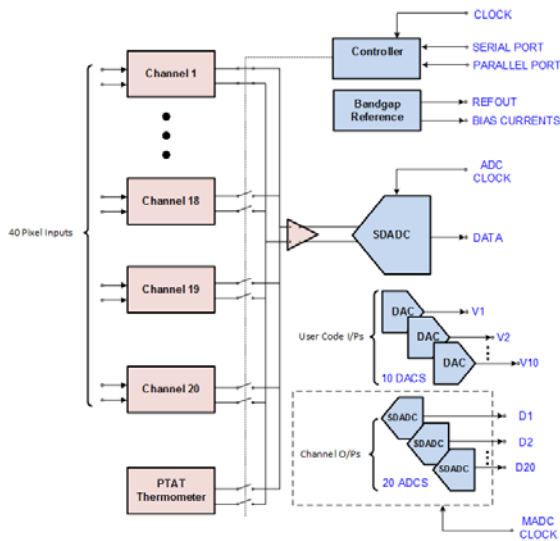
the user to calibrate the thermopile pixel measurements. It also provides ten general-purpose variable voltage outputs, which may be used for bias and control of the FPA. The ASIC's serial port allows the instrument designer to minimize cable mass with only several wires needed to control multiple ASICs. The ASIC also outputs all of its data through an LVDS signal pair.

Figure 5: Gain before (green) and after (red) 50 Mrad (Si) gamma-ray TID.

Figure 3: MCD2G block schematic.

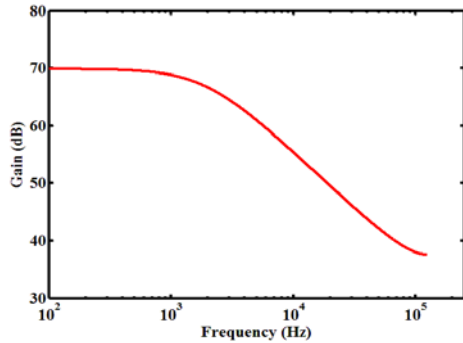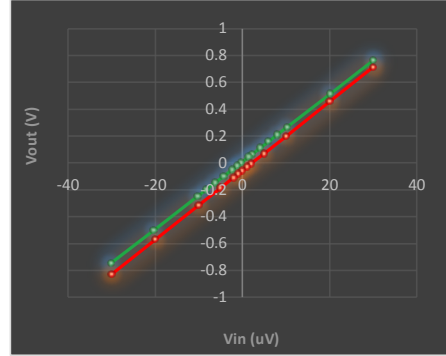Figure 4: Channel Bode plot ($G = 156$, $T_{clk} = 4$ µs).

The ASIC measures its own junction temperature which, when in close proximity to the array, allows

3. Summary and Conclusions

A radiation hard multi-channel digitizer ASIC, built in a 180 nm commercial CMOS node, interfaces directly between a radiometer's thermopile line arrays and a digital controller with very high immunity to TID and SEL. The ASIC provides variable gains with filtering for $1/f$ and thermal noise.

Acknowledgements

References

[1] Europa Clipper Proposal Information Package: JPL D-92256, 2014.

[2] Hanel, R., Conrath, B., Jennings, D. and Samuelson, R.: Exploration of the Solar System by Infrared Remote Sensing 2nd Edition, Cambridge University Press, 2003.

[3] Quilligan, G., Aslam, S., and Lakew, B.: A 0.18 µm CMOS Thermopile Readout ASIC Immune to 50 Mrad (Si) Total Ionizing Dose and Single Event Latchup to 174 MeV-cm²/mg, IWIPM 2014, 4-7 November 2014, Pasadena, California, USA, 2014.