Software Defined Radio for Communication Between CubeSats

Abstract

Cube satellites, or CubeSats, are small satellites that have become increasingly common for academic, amateur, commercial, and scientific applications over the past five to ten years. There is potential for CubeSats to be deployed in swarms and clusters, and a need for communication between satellites in these missions.

The purpose of this project is to design and demonstrate proof-of-concept for a Software Defined Radio (SDR) for communication between CubeSats. The preliminary design has focused on two main components: electrical and software design of the radio, and the mechanical packaging that will encase the radio chip-set and mount within the satellite.

Functional Diagrams

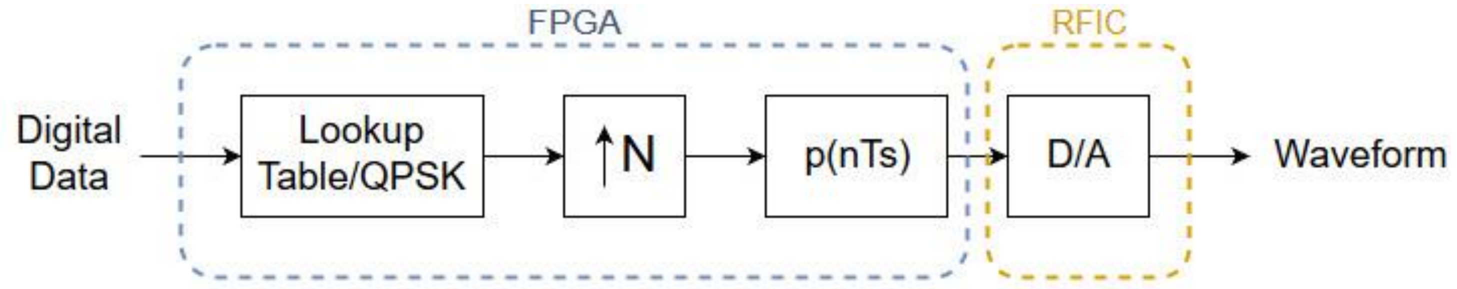

Figure 3: Transmitter Subsystem Diagram

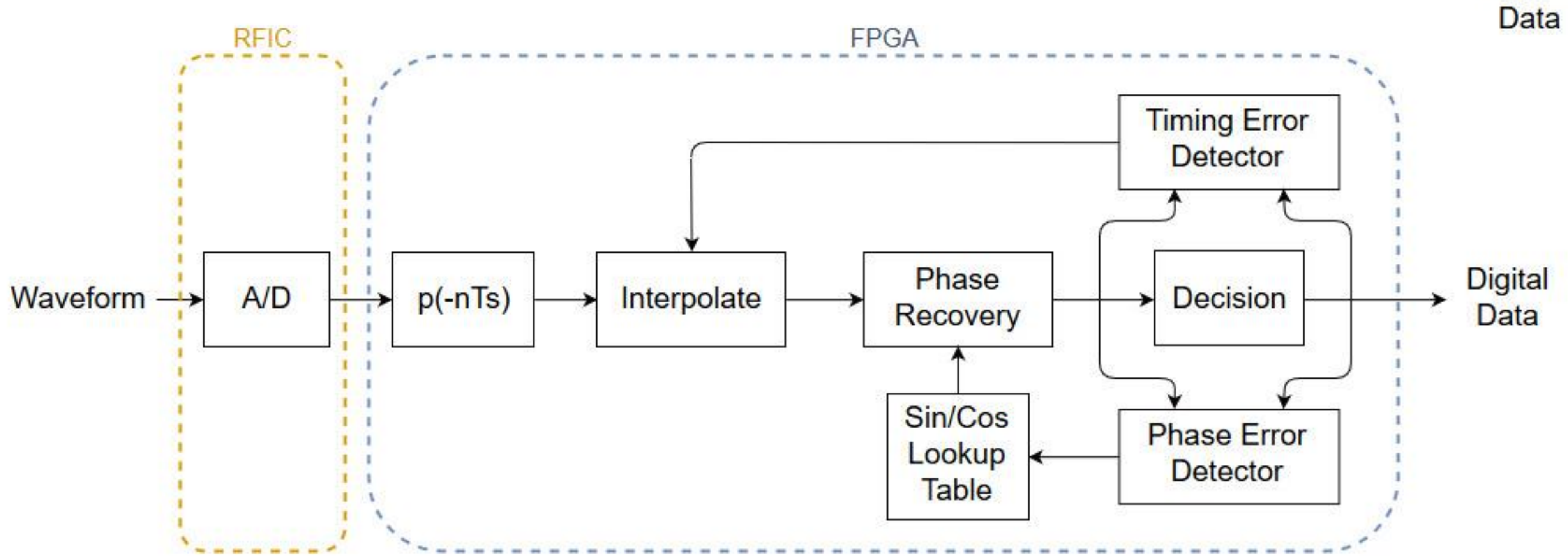

Figure 2: Receiver Subsystem Diagram

Figures 2 and 3 detail the receiver and transmitter subsystems. Digital data is modulated through QPSK, upsampled, filtered, and transmitted as an analog waveform. Received waveforms are sampled, filtered, interpolated, and processed for timing and phase error recovery before being converted to digital data.

System Overview

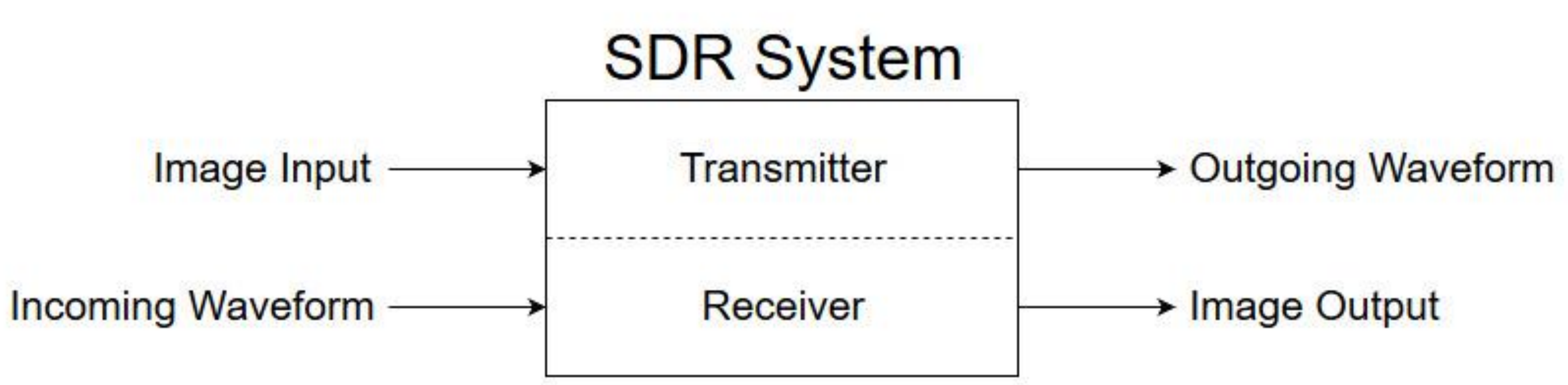

Figure 1: System Overview

- Hardware components:
  - Analog Devices AD9361 RFIC chip
  - Xilinx ZYNC-7000 FPGA development board (ZC706)
- Operate at variable frequencies: 70 MHz to 6 GHz (RF range)
- Transmit and receive at variable data rates: 100 Kbps to 20 Mbps
- Bit error rate at or below 10^{-6}
- Power consumption less than 4 watts
- Use QPSK modulation scheme
- Maintain temperature of electronic components between -40°C and 85°C
- Withstand steady state loads of 8g
- Withstand static and dynamic loads of 60g
- Meet random vibration qualifications in GFSC Standard 7000
- Have max. dimensions of 100 mm by 100 mm by 50 mm
- Have max. mass of 0.3 kg

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Mechanical Packaging

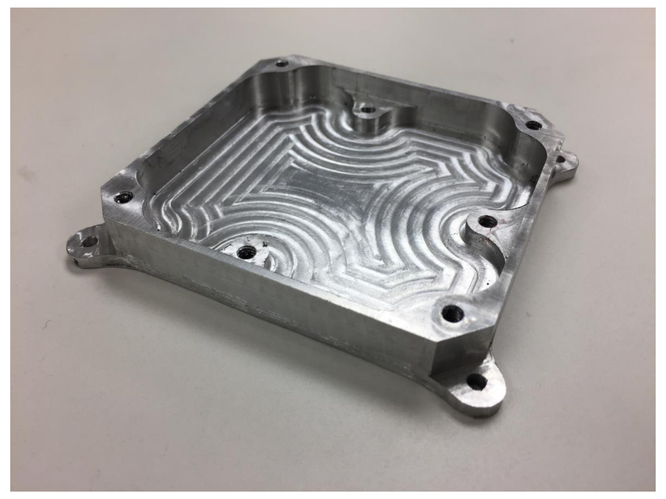
Figure 4: Packaging Base


Figure 5: Packaging Lid


Figure 6: Complete Packaging

Figures 4, 5, and 6 detail the mechanical packaging for the device. The packaging was designed to withstand launch loads, steady-state loads, and meet random vibration requirements as set forth in the GFSC Standard 7000 [1]. Thermal analysis was performed to ensure the packaging maintains the proper temperature of the internal components. After being designed, a prototype was 3D printed for further analysis. The latest prototype was machined from 2024 T4 Aluminum (see figures 4, 5, and 6).

Results and Conclusion

The results of this project yielded working simulations of the complete software design, working HDL code for implementation on an FPGA, and a fully machined metal packaging prototype.

This project detailed the design for a software defined radio capable of transmitting and receiving images for use in communication between CubeSats. The first phase included the software design of the radio, including a modulator and demodulator with timing and phase error detection and recovery, implementation on an FPGA, and design of the mechanical packaging.

The project will be continued in subsequent phases by students in the design course to create a working, packaged prototype for Harris Corporation. These phases will include custom design of a PCB, further development and testing of the software and user interface, and the final packaging.

References

[1] G. E. V. Standard and A. Revision, "Nasa goddard space flight center," tech. rep., GSFC-STD-7000, 2005..

[2] PC/104 Specification Version 2.6. (2018). [ebook] PC/104 Embedded Consortium, pp.3, A-2, A-3, D-2. Available at: http://pc104.org/hardware-specifications/pc104/ [Accessed 28 Apr. 2018].

HARRIS®

Arden Barnes, MAE
ardenbarnes@aggiemail.usu.edu

Tyler Gardner, MAE
tyler.j.gardner@aggiemail.usu.edu

Tia Bradley, EE
tia.bradley@aggiemail.usu.edu

Sarah Watkins, EE
sarah.watkins@aggiemail.usu.edu

Caleb Young, EE
caleb.young@aggiemail.usu.edu

Emily Clark Young, EE
emily.clark314@aggiemail.usu.edu

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