Encoding/Decoding System for PAPPA Experiment

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Abstract

There has been a significant amount of research in the field of physical cosmology that attempts to explain the origins of the universe through scientific observation. A topic of interest of Dr. Mark Devlin of the University of Pennsylvania is the search for anisotropy in the Cosmic Microwave Background (CMB). The Primordial Anisotropy Polarization Pathfinder Array (PAPPA) balloon flight experiment, which uses a wide array of instruments to perform precise measurements of incident radiation, is a major component of Dr. Devlin's work.

In order to analyze the large amount of data that is generated from these measurements, the data must be transmitted from the remote collection points to stations on the ground. The transmission system used to send this data must include an encoding and decoding system, a component which the PAPPA experiment currently lacks.

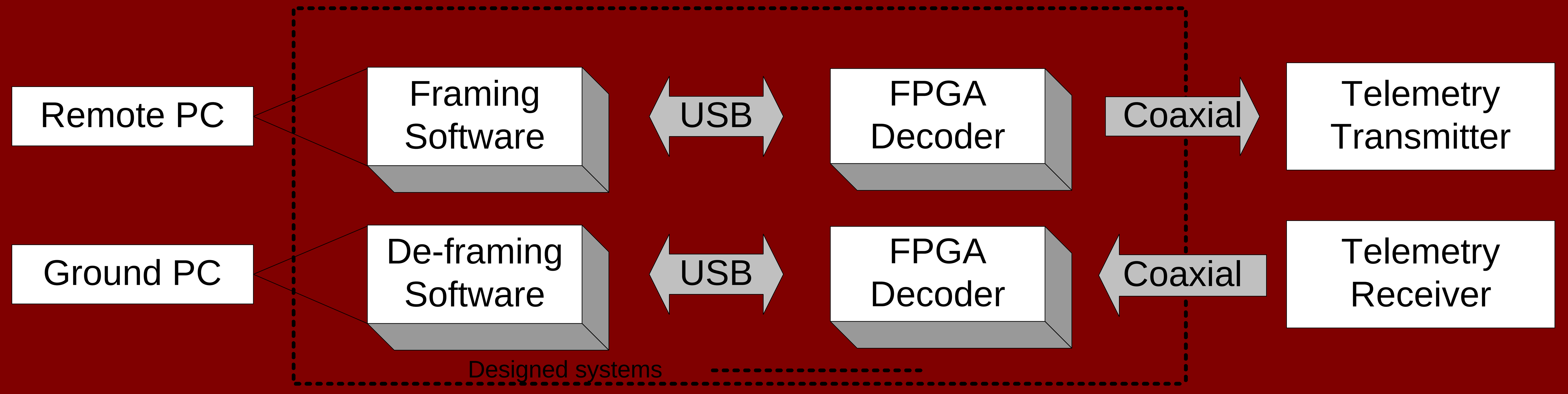
The chosen approach is to extract raw binary data from a PC and encode it for transmission, which is accomplished using existing transmitter and receiver hardware. The encoding process also efficiently separates the data into frames and implements an error control scheme. The encoded signal is decoded and restored to its original form after transmission so that it can be recorded in a PC at the receiving station.

The design incorporates two layers. The hardware layer is implemented on an FPGA through the use of the VHDL programming language, and consists of the Manchester encoding/decoding and a design of a FIFO buffer. The software layer is implemented in the C++ language and consists of the framing and error correction schemes.

Demo Day Times

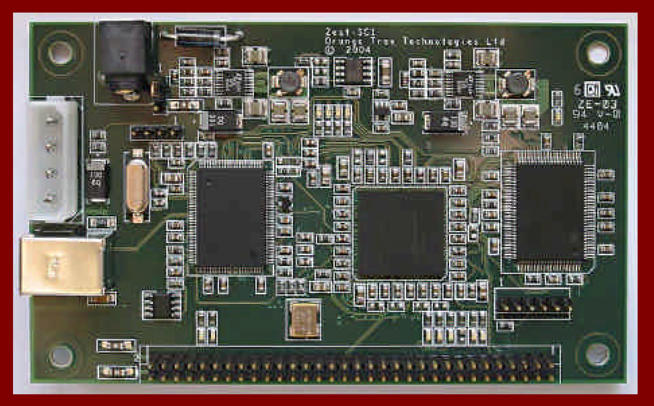
9:30 – 10:30, 1:30 – 2:30
Tuesday, April 18, 2006

System Block Diagram

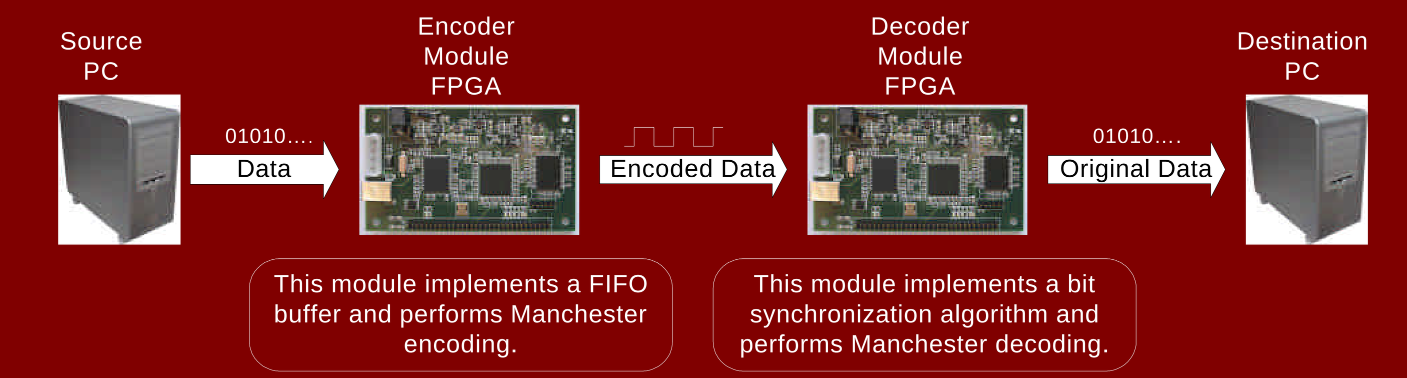


Hardware Overview

OrangeTree Technologies ZestSC1 FPGA



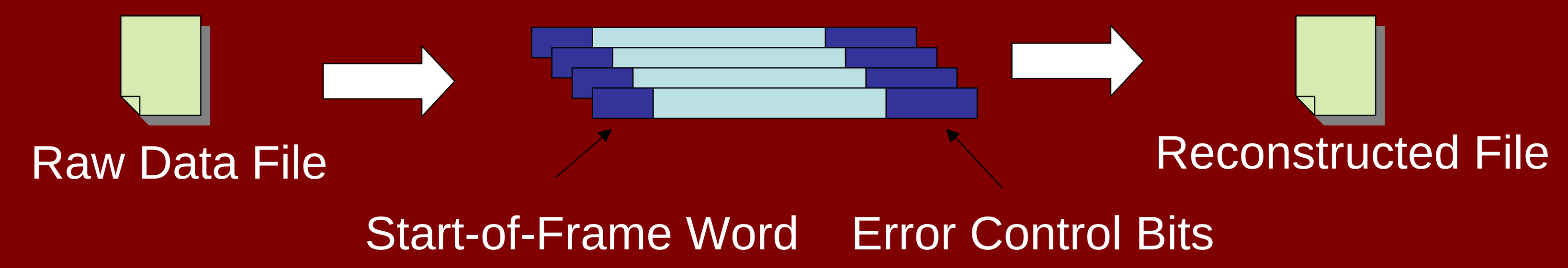
- Board is powered through the USB connection
- Quiescent power consumption of 1.35 W
- Uses Xilinx Spartan XC3S400-4 chip with 400,000 logic gates
- Can drive a maximum current of 25 mA
- Digital I/O at 3.3V signal level, 49 I/O pins
- On-board 1 MB of SRAM
- Sustained transfer rate of 34 MB/s with USB 2.0
- Nominal clock speed of 48 MHz, can be increased up to 240 MHz



System Specifications

- Encodes and decodes data at a rate that ranges from one to seven Mbps using the Manchester encoding scheme
- Operates continuously in real-time to support a constant stream of data in both sides.
- Continues transmission from last known success in the event of a power failure.
- Frame size is determined by the measurement rate of devices on the balloon, but is approximately 2 KB.
- Resynchronizes after interruption in data flow with a maximum loss of one frame.
- Provides a FIFO buffering module in the encoder module to accommodate at least one frame of data.
- Provides an efficient EC scheme that optimally balances the trade-off between robustness and throughput.

Software Overview



Raw data is extracted from a text file on the Remote PC and divided into frames. The software adds a predetermined Start-of-Frame word to the beginning of each frame. Special "escape" bits are also added in places where the Start-of-Frame word appears naturally in the data. Finally, error control bits are appended to each frame.

When the data is decoded and received by the ground PC, the de-framing program removes escape bits and recognizes the beginning of each frame. It can then perform error control and reconstruct the original file.

Design Theory – Manchester Encoding

Manchester Encoding's greatest advantage is that it guarantees a transition during every data cell. This is not the case if data is sent as just a series of high and low voltages (NRZ). In this case, two problems are introduced if there are long string of 1's and 0's: (1) difficulty in interpreting individual data cells and (2) distortion of the high/low voltage threshold (clock drift). However, there is a tradeoff associated with Manchester Encoding: it requires twice the bandwidth of simple NRZ data.

A few examples of Manchester Encoding are shown below. Although the original NRZ data signal takes several different forms (see labels), the encoded signal continues to have periodic transitions. The disadvantage of Manchester Encoding is also apparent, as the encoded signal has double the frequency of the original data (requires twice the bandwidth).

Advantages

- Transition during every data cell
- Can detect an idle state
- Prevents clock drift in signal
- Easier to decode string of 1's or 0's

Disadvantage

- Requires twice the bandwidth of NRZ