FPGA based Spectral Domain OCT System

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Spectral domain optical coherence tomography (OCT) depicts high speed acquisition with a high resolution depth measurement of sample structures. Key factors such as high speed image acquisition, high sensitivity, compact design of the system, high throughput and a competitive price are essential for many OCT applications. In this project, the desired properties are merged into a System-on-a-Chip (SoC).

Introduction

OCT is a contactless imaging technique used for depth measurement of biological tissues. The application area of OCT is primarily in ophthalmological medicine. The optical signal is focused by a lens on the charge coupled device (CCD), which converts the incident light into electric current using the photoelectric effect. Currently, data is acquired by an expensive data acquisition card (DAQ) and processed in a central processing unit (CPU) or a graphic processing unit (GPU). The Institute for Human Centered Engineering (HuCE) uses a compact System-on-a-Chip (SoC) approach that combines a state of the art microcontroller unit (MCU) with a field programmable gate array (FPGA). This forms an embedded system that provides hardware/software co-design processing, which allows high speed data processing, due to an adaptable hardware algorithm.

Method

The proposed Zynq UltraScale+ SoC and the optical hardware make it possible to realize the SD-OCT processing. Still, an additional custom defined printed circuit board (PCB) is needed (Figure 1). The data is acquired using CCD technology of 1024x1 pixels and transferred to the SoC via a differential signal transmission through an analog-to-digital converter (ADC). OCT is characterized by many processing steps which are implemented in the programmable logic (PL) of the SoC. The entire processing is controlled by the processing system (PS) of the SoC. The additional PCB is attached to an optical system by a bendable connection. In contrast to conventional rigid-flexible PCB's, this flexibility is achieved by a thin flame retardant (FR) core with two copper layers instead of the usual polyamide core. Due to the flexible PCB, movements caused by installation and handling of the system can be absorbed so that the sensor is not affected.

Results

The interaction between the SoC and the additional PCB allows the interferences of the OCT system to be acquired and read out at a frequency of 54 MHz and a minimal exposure time of 25 us, resulting in an A-scan rate of 40 KHz. With the implementation of the processing in PL, it is possible to realize the entire OCT processing chain in a resource-efficient manner and to control the entire data stream through PS. This combination of semi-flex PCB and SoC has the maximum size of a credit card, which is smaller and more compact compared to any state of the art solution such as GPU based processing.

Conclusion

In conclusion, we are proud to present a fully functional, highly integrated OCT system that fulfills the design goals. The decision to use a flexible PCB provides good protection against mechanical movements. Future work will be to use one of the versatile state of the art interfaces to stream the data wireless to external devices.

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Figure 1: Semi-Flex PCB with the CCD line sensor