Comprehensive Ultrasound Research Platform

Functional Description and System Block Diagram

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Introduction

The goal of this project is to create a prototype ultrasound research platform that will test theoretical developments on methods that use coded pulses to excite ultrasound transducers. These theoretical developments can then be compared to the current methods to conclude that a clearer ultrasound image is obtained. This prototype will test arbitrary waveforms on a multi-pin device, to compare experimental results with theoretical predictions. The preliminary results obtained in this project, by using devices that are already available or at a reasonable cost, will be used to guide the development of a future system (outside of this project's scope) using higher end components.

System Block Diagram

While a more detailed description of the project follows, the basics are outlined here. The steps are as follows: create an arbitrary waveform that will be used to excite an ultrasonic transducer, receive the backscattered echoes, process, and display an image. The excitation waveform must be initially transformed to sigma-delta modulation form to synthesize a digital-to-analog converter. As shown in Figure 1 below, the sigma-delta waveform will be stored in a memory device that is connected to an FPGA. The FPGA will be used to excite the transducer with the arbitrary waveform. Analog circuitry will be required to amplify and filter the digital output from the FPGA pins. After exciting the transducer with a voltage waveform, a pressure wave will propagate through the medium being imaged. The echo received by the transducer will be processed by the analog front end and stored on an embedded device. Finally, the stored data will be sent to a PC, processed, and displayed.

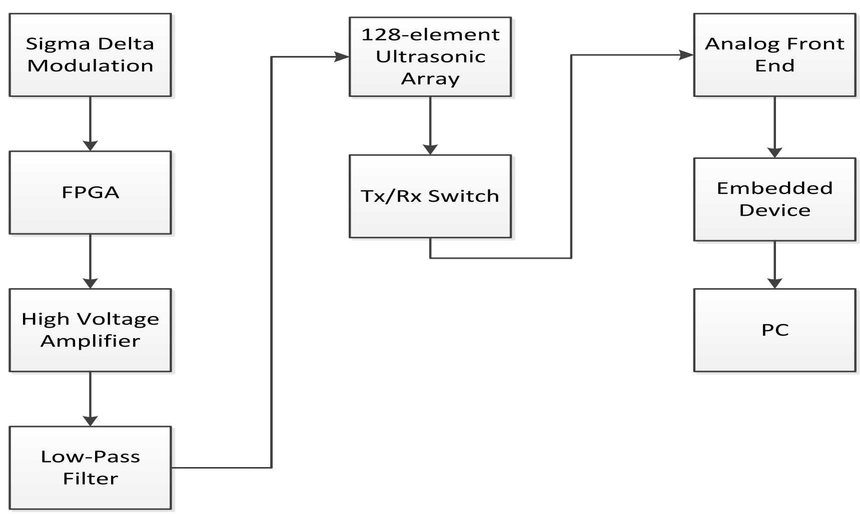

Figure 1: System Block Diagram

Functional Description

Sigma Delta Modulation

Sigma delta modulation is an analog to digital conversion technique that includes quantization error compensation. This technique will be used to store, in digital form, the arbitrary waveform that will be sent to the ultrasound transducers. A software-based analog to digital converter is initially used to round the input to either one or negative one. This value is then subtracted from the initial input creating an error value. The error is subtracted from the next input value, providing conversion error compensation. The adjusted input is again pushed through a software-based analog to digital converter to round to one or negative one. The overall output expresses an input of analog values as a series of ones and negative ones. This process can be seen in Figure 2 below.[1]

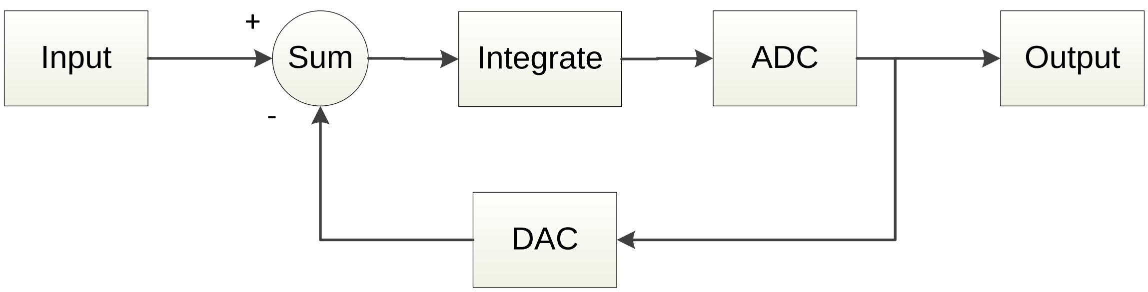

Figure 2: Sigma Delta Modulation Subsystem Block Diagram[1]

FPGA

The purpose of the FPGA excitation block is to accomplish the parallel task of sending waveforms to multiple ultrasound transducer pins. The FPGA excitation block encompasses three basic steps. First, the input waveform data from the P.C. is transmitted and stored to the DDR2 memory of the FPGA. Next, the waveform data is retrieved from the DDR2 memory and parallelized. Last, the data is transmitted to the FPGA pins at a high speed.

High Voltage Amplifier

The purpose of this amplifier is to amplify the output from the FPGA, which is approximately 1V peak-to-peak, to approximately 100V peak-to-peak. This increase in voltage will allow the transducer to produce more pressure since the pressure produced is proportional to the input voltage. For amplification a Zetex ZXMHC10A07N8 will be used.

Low-Pass Filter

The low-pass filter is used to convert the sigma delta signal into its analog representation, which is then sent to the 128-element ultrasonic array. A simple RC low-pass circuit will be used to apply this filtering. This subsystem may not be necessary as the bandpass nature of the source could potentially be used as the filtering mechanism. Additional research will determine if this is the case.

128-element Ultrasonic Array

The ultrasound transducer receives a high voltage input signal that is converted into a pressure waveform that will propagate throughout the medium. As the pressure waveform encounters objects, reflections that contain a fraction of the transmitted energy will be received by the transducer. A transmit/receive (T/R) switch will switch between transmitting a high voltage and capturing the return signal with the A/D converter. The device currently specified is the TX810 by Texas Instruments.

Analog Front End

The amplitude from the received signal will be small for far away objects. Consequently, amplification of the echoes is required. The noise amplification must be limited to produce a clear received signal. The device currently specified is the VCA2618 by Burr-Brown from Texas Instruments.

The analog to digital (A/D) converter will sample the analog signal amplified by the LNA to be recorded. The signal will be quantized and encoded into digital data by the device.

Receiving End Embedded Device

The receiving end embedded device will capture and store the data from the A/D converter. This data will then be sent to a PC over an Ethernet connection so that the ultrasound data can be processed.

PC

The steps performed on the PC are shown in figure 3 on the next page. This block receives the raw data from the FPGA as an input. It also receives settings from the GUI for the data processing. First, pulse compression is performed on the signal. To achieve this, a Weiner filter is used. This filter compares the received signal to the expected signal. This is used to reduce noise in the signal and increase the resolution of the image [2]. Next, delay sum beam forming is performed to focus the different signals sent and received in parallel through the ultrasound device on a particular area. Time-gain compensation is performed to compensate for attenuation of the received signal due to attenuation of the sound waves due to the depth of the echoing substance. Envelope detection then determines the bounds of the processed signal. This detected width will contain the information about the tissue that is being tested. Finally, log compression of the result is performed to give useful data to be displayed. This data is then sent to the graphical user interface.

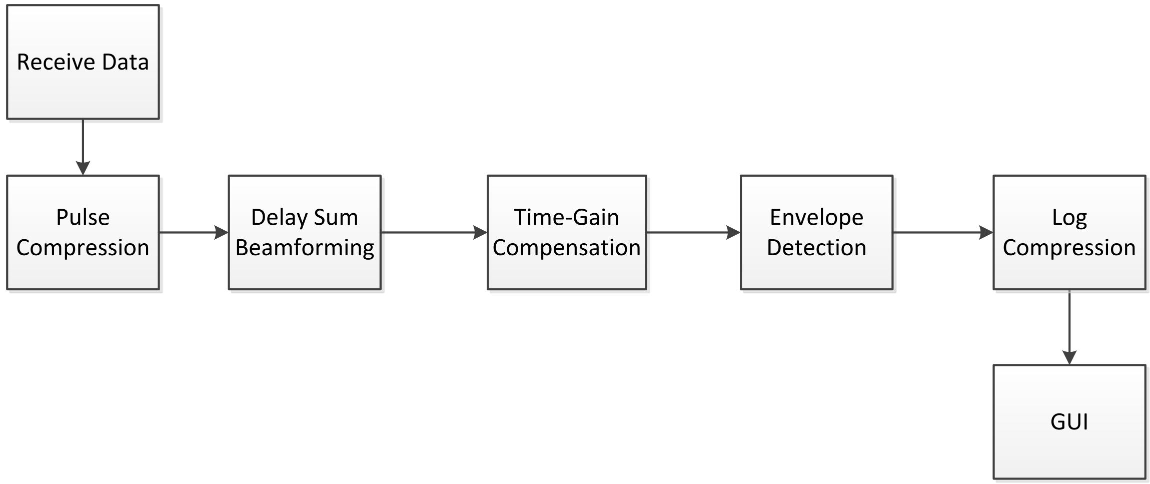

Figure 3: Processing Data Subsystem Block Diagram

The graphical user interface allows the user to select the data that is displayed. The inputs include dynamic range and depth settings. Depth allows the user to view all data from a start range to a stop range. Although the data is still available for all depths, this option allows the user to zoom in on areas that require a closer observation. Dynamic range sets the maximum compactness to be observed. All objects with compactness greater than the maximum appear black, while objects with less compactness range from gray to white based on the degree of their compactness. This allows the user to view objects of both high and low compactness clearly. The signal processing block accepts these inputs of depth and dynamic range and presents the data in the form requested as the user changes the data display settings.

References

[1] R. Schreier and G. C. Temes. *Understanding Delta-Sigma Data Converters,* John Wiley & Sons, Inc., 2005.

[2] T. Misaridis and J. A. Jensen. "Use of Modulated Excitation Signals in Medical Ultrasound," IEEE Trans. Ultrason., Ferroelectr. Freq. Contr., vol. 52, no. 2, pp. 177-191, Feb. 2005.