Ultrasound Brain Imaging System

Dec13-01
Michael McFarland
Zach Bertram
Jonathan Runchey
Maurio Mckay

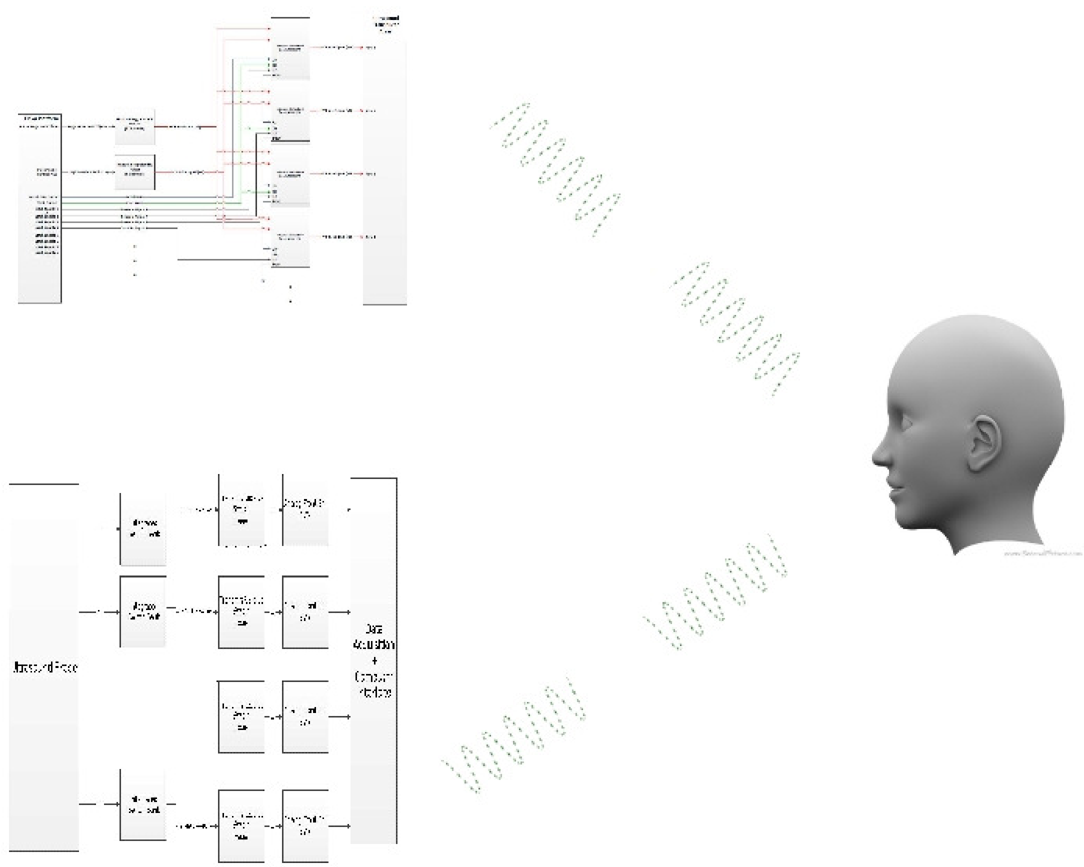
Advisor:
Dr. Timothy Bigelow

Problem Statement

The goal of this project is to design and build a revolutionary new pulse echo ultrasound system for brain imaging as a low cost alternative to fMRI. The project will use an existing 1.1 MHz ultrasound transducer with 512 elements. The phase and amplitude of each channel must be independently controlled. In addition, the data from each channel must be individually accessible. The circuit can be broken down into 2 stages. The first stage is a transmit stage while the second stage is a receive stage. A version of the transmit stage (~16 elements) has already been designed and placed on a PCB board by an earlier senior design team. The earlier team also designed a version of the receive stage. The students will be expected to review and test the existing transmit stage. They will then modify the design for the transmit and receive stage so that they can interface with a custom National Instruments DAQ system which will communicate with a pc for data acquisition and imaging. Success in the project will be demonstrated by functional hardware. Real-time imaging of the brain is beyond the scope of the project.

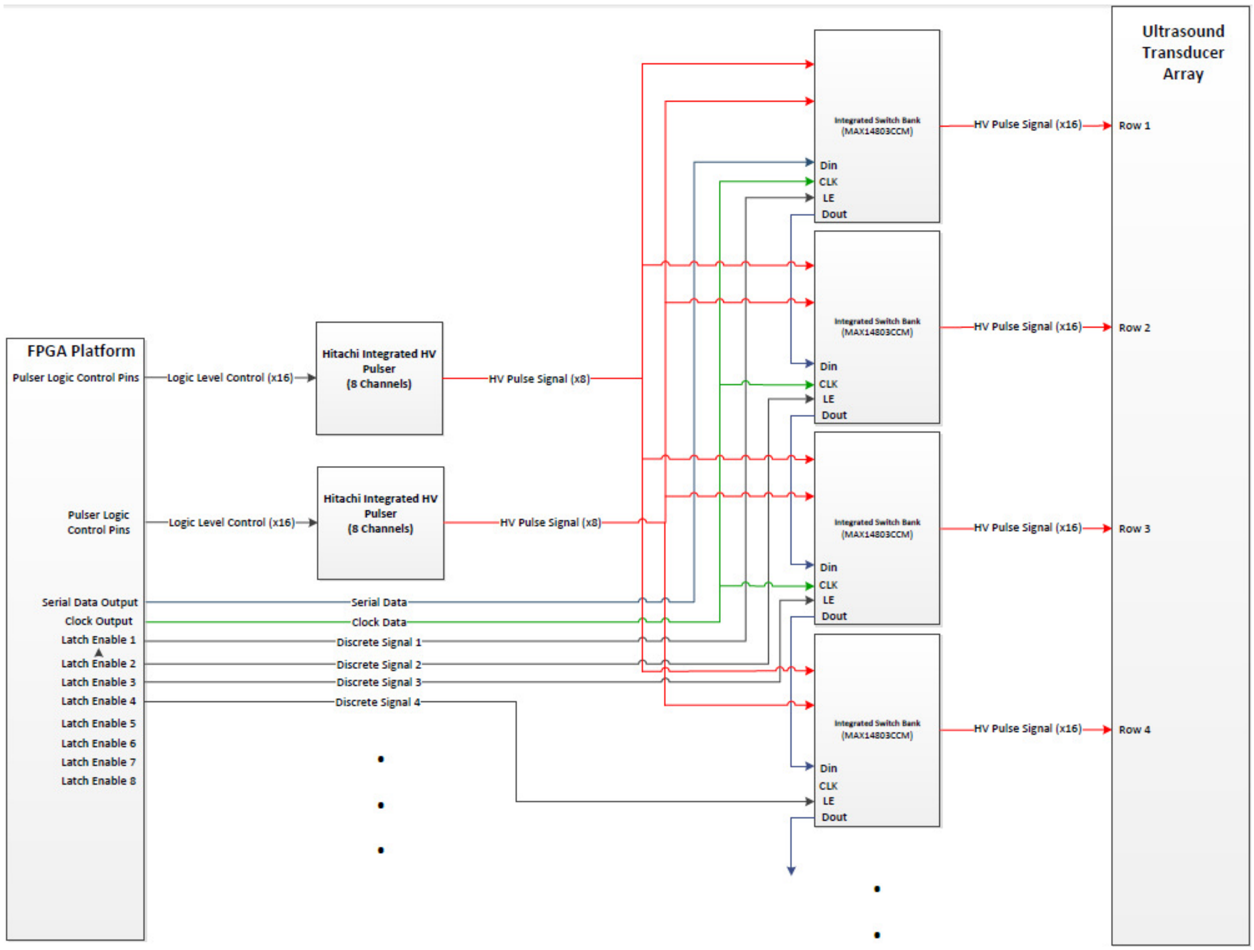
Our group will be focusing implementing and testing a previous group's design. The previous group designed and ordered the parts for a 128-channel transmit side, but was unable to test their design. Our group's first task will be to test their initial design and then expand on their design, so that the system can transmit 512 channels. The previous group also started the design for a 128-channel receive circuit. Our group will be responsible for finishing and implementing their design.

Concept sketch

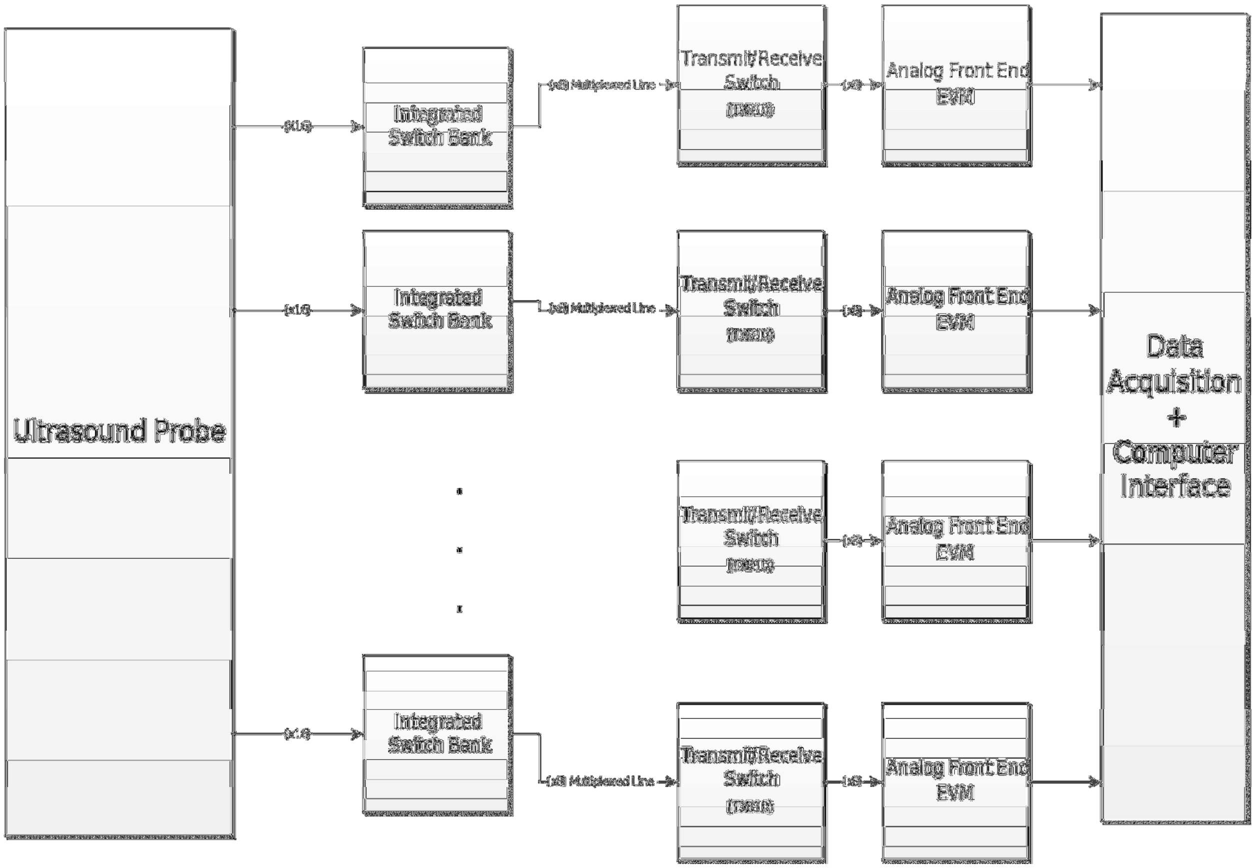


System Block Diagrams

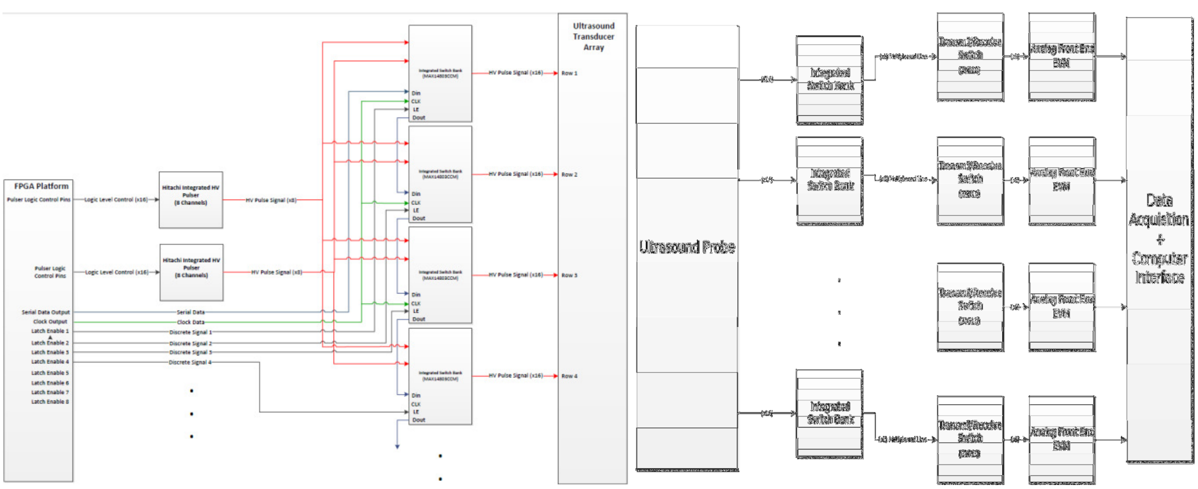
Transmit Side:



Receive Side:



Combined:



System description

Waveform Generator

The waveform generator generates digital samples of 3 MHz ultrasound pulses. A high-speed DAC will be used to convert the digital waveforms to the analog domain. In total, 128 individual signals will be generated by this functional block.

High Voltage Amplifier

High voltage amplification of the generated pulses is necessary in order to provide enough energy to the ultrasound transducer (due to poor electrical to acoustic energy conversion within the transducer). A stronger signal means that there is less opportunity for signal loss while being transmitted. The maximum voltage that this component will generate is 100 VDC, or 200V peak-peak.

Transmit/Receive Circuit

The transmit/receive circuit will transmit the amplified pulses to the ultrasound transducer. It will receive the reflected low voltage signals from the transducer and use them for the signal processing of the ultrasound. The transmit/receive circuit will also prevent high-voltage pulses from entering the receiver circuitry.

Low-Noise Amplifier

The low-noise amplifier will amplify the weak reflected signals that the transmit/receive circuit receives from the ultrasound transducer. It's placement after the receiver is to recover the low-power reflected ultrasonic signal in the presence of significant noise.

Variable-Gain Amplifier

A variable-gain amplifier is placed after the low-noise amplifier and is used to map the signal into the appropriate dynamic range for signal processing. Computerized control of this device will allow for the gain to be adjusted appropriately over time.

Computer Interface

A computer interface will be used to control the phase and magnitude of the waveform generator channel outputs. The delay range is 10 ns – 20 us. Additionally, recovered signals will be sent to the computer interface for signal processing and recovery.

Signal Processing

Recovered (reflected) ultrasound pulses will be amplified and communicated to the computer interface for digital signal processing and imaging. All signal processing will be done in the computer interface.

Transducer

The transducer, otherwise known as the probe, is the component in the system that has contact with the body. The basic function of the transducer is to receive an electrical pulse and convert it into an acoustic vibration at a pre-determined frequency. Ultrasonic pulses reflected off of the body are captured by the transducer and converted into electrical signals that can be processed to form images.

Functional requirements

Table 1 - Resource Requirement Descriptions

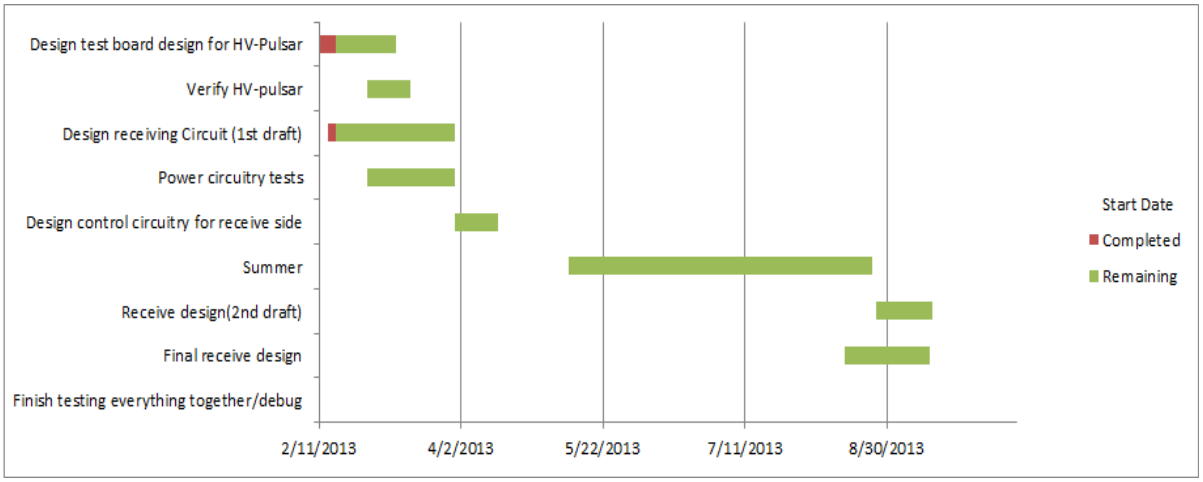
System Component:	**Requirement Description:**
Waveform Generator	The waveform generator shall be capable of controlling the pulser integrated circuits in order to produce high-voltage signals. Each output must be individually controllable in order to implement a phased-array system.
Waveform Generator	The waveform generator shall be capable of being controlled by the user interface.
High Voltage Amplifier (Pulser)	required to use HDL6V8851
HDL6V8851 Operating Specifications	Bipolar output voltage limit: +/-105V Frequency range of operation: 1 MHz-25 MHz Number of channels: 8 Switching delay time: 24 ns
T/R Circuit	The T/R circuit shall function as protection against high-voltage transients for the receiver. However, the T/R circuit shall allow high-voltage transmitted signals to propagate to the Ultrasound Transducer.
T/R Circuit	The T/R circuit shall only allow a signal with maximum amplitude of X V to enter the receiver circuit.
T/R Circuit	The T/R circuit shall have impedance matching with the Ultrasound Transducer.

T/R Circuit	We will be using the TX810 to meet these requirements.
Analog Front End	The Analog Front End shall contain a low-noise amplifier to recover a small-magnitude signal from the transducer output.
Analog Front End	The Analog Front End shall contain a variable gain amplifier with an adjustable gain.
Analog Front End	The Analog Front End shall contain an ADC capable of sampling at 50MSPS and that produces serial LVDS data at the output.
Transducer	Operates in the 3 MHz frequency range
Transducer	Linear array with 128 elements

Non-functional requirements

For the fMRI ultrasound system, not all parts need to be handled by the user; this hardware can be gathered together in one area for convenience of storage. An example of such hardware would be; T/R circuit, waveform generator, and the switch bank circuits. Also, since senior design groups get a discount on boards under 60 in^2, we limiting ourselves to 60 in^2 boards to help improve cost efficiency.

Work Plan



Deliverables

A working high frequency pulser that is able to send on 512 channels and receive on 128 channels at 3.0 MHz. The final version of the system will be put into a case to hold the switch banks, pulse controller, and any other parts that, upon completion of the project will no longer need user interaction.

Accompanying the completed physical machine will be documentation of the project, including data sheets and layouts for all parts of the machine. A detailed write up will be provided for future engineers who wish to modify or elaborate on our design. We will also include a detailed instruction manual for the end user. This will contain information on hazardous operating conditions and the limitations for the hardware will be included.

Risk management

If we are unable to get the previous group's design to work with the HDL6V8851 our group would have to redo the previous group's transmission side design to meet the specifications listed in the functional requirement section on page 6.

Assigned Tasks:

Zach/Maurio	Receive Side
Michael/Jonathan	Transmit Side