Ultrasound Brain Imaging System

Dec13-01
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Problem Statement

The goal of this project was to expand upon a previous group's design for a pulse echo ultrasound system for brain imaging, which could be used as a low cost alternative to fMRI. The group was tasked with designing a transmit/receive board which could be scalable up to 512 transmit/receive channels.

The objective of the project was to design and implement a working 8-channel transmit/receive board. The transmit circuit should be able to send high voltage pulses (+/-50 V) over 8 channels. The design also needs to be easily scalable to up to 512 channels. The receive circuit will then receive the signals from the transducer and amplify them before sending them to a computer interface. Though it was not within the scope of our design, a computer interface will also be responsible for controlling the pulses sent to the transducer. Our group will also designed a protection circuit to limit the voltage amplitude of the signals reaching the computer interface.

System Block Diagram

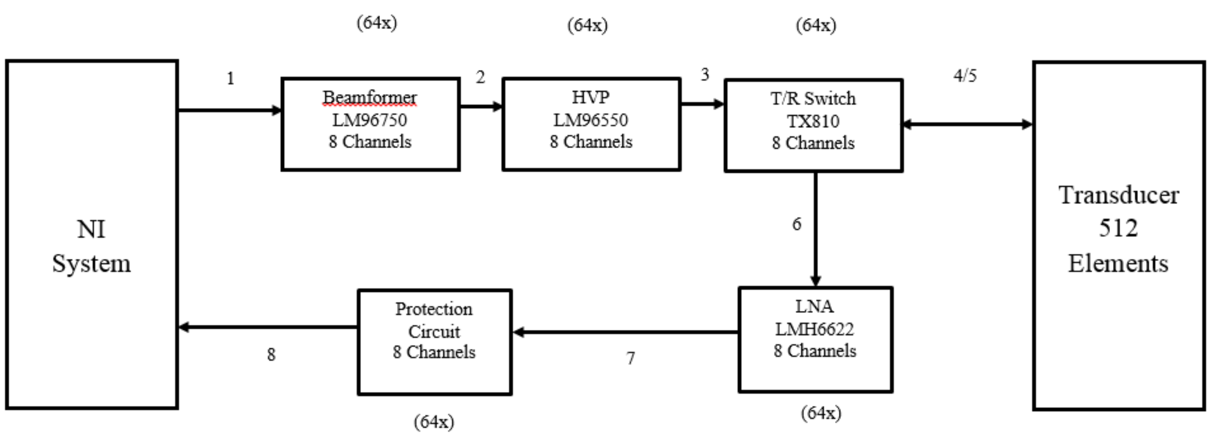

Figure 1: Overall block diagram

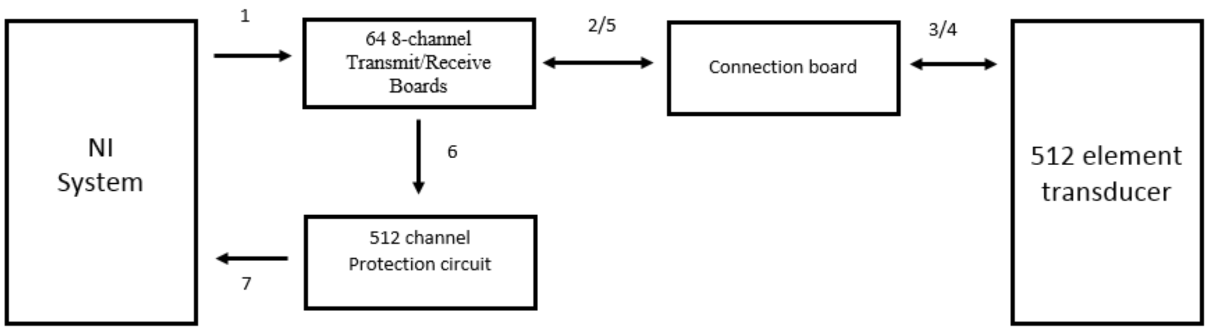

Figure 2: **Board Break Down block diagram**

System description

Waveform Generator

The waveform generator generates digital samples of 1.0 MHz ultrasound pulses. A high-speed DAC will be used to convert the digital waveforms to the analog domain. In total, 512 individual signals will be generated by this functional block.

Beamformer

The beamformer works in concert with the high voltage pulse. Its purpose is to send a control signal to each input channel of the high voltage pulser to configure the output channels to 1.0MHz and the proper delay.

Protection Circuit

The protection circuit is placed after in between the NI PXI system and our receive circuitry. It attenuates all voltages greater than 2 Vpp volts in order to protect the NI PXI system from unintended voltage spikes.

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 50 Vpp.

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.

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 will be capable of controlling the pulser IC in order to produce high-voltage signals. Each output must be individually controllable in order to implement a phased-array system.
Waveform Generator	**PXI-NI PXI-7811R Specifications:** 160 Digital I/O lines At speeds up to 40MHz
Beamformer	The beamformer needs to be able to easily interface with the LM96550(high voltage pulser) and NI-PXI-7811R module
Beamformer	**LM96570 Specifications:** The LM96570 is the part recommended by Texas Instruments to use in conjunction with the LM96550 high voltage pulser. Provides 16 logic outputs to control the high voltage

	pulser. Controllable by 5 digital input channels.
High Voltage Pulser	**High Voltage Pulser Requirements:** Bipolar output voltage: +/-50V Operating Frequency: 1MHz Number of Channels: 4-32 channels Switching delay time: Less than 167ns
High Voltage Pulser	We will use the LM96550 in our design.
High Voltage Pulser	**LM96550 Operating Specifications:** Bipolar output voltage limit: +/-50V 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. The T/R circuit shall only allow a signal with maximum amplitude of X V to enter the receiver circuit.
T/R Circuit	We will be using the TX810 to meet these requirements.
Low Noise Amplifier	Required Specification: Gain: ~100V/V Input Voltage Noise: ~<10nV/sqrt(Hz)
Low Noise Amplifier	**LMH6622 Specifications:** GBW: 320MHz

	Input Voltage Noise: 1.6nV/sqrt(Hz)
Protection circuits	Required specifications: Voltage attenuation at <±2 volts No alteration of voltages >2 volts
Analog Front End	The Analog Front End should contain a variable gain amplifier with an adjustable gain and an ADC that produces LVDS data at the output.
Analog Front End	**PXI-NI5752 Module Specification:** 32 analog Input channels 16 digital I/O channels Variable Gain range of -5dB to 30dB 12-bit ADC
Transducer	Operates in the 1.5 MHz frequency range
Transducer	Linear array with 512 elements

Non-functional requirements

For our ultrasound system we will try to fit our design on 60in^2 double sided boards, to take advantage of the student discount. This means we will have to split up our final design into smaller 8-channel circuits. From there, connecting the boards in an effective yet aesthetically pleasing way for the users, will be one of the end goals.

Ease of access for repair and diagnostics is a problem we are looking to fix as we create our circuits. By making sure things are organized and arranged in logical working order we can ensure that future engineers who need to fix the boards will be able to easily to replace the parts or build replacement boards for broken parts.

Work Plan

Spring Semester 2013:

1/21/13 - 2/18/13:

- Introduction to Project
- Read previous group's documentation
- Develop a thorough understanding on what we can use from the previous group's research/design

2/18 - 3/14:

- Research parts needed for design
- Choose which parts we can use from the previous design
- Find new parts for our design

3/14-4/28:

- Design schematic for 8 channel transmit receive board
- Design PCB for 8 channel transmit/receive board
- Order parts needed for 8 channel transmit receive board
- If time allows solder board during finals week so it is ready for fall semester

Fall Semester 2013:

8/26 - 9/2:

- Finish soldering board and fix any bridging
- New requirement: need a protection circuit for the output of the transmit receive board

9/2 - 10/13:

- Test board from previous semester
- Correct any errors found for new PCB order
- Design a protection circuit

10/13 - 11/4:

- Continue testing/troubleshooting board
- Order new board with any fixes and corrections
- Continue work on the protection circuit

11/4 - 12/12:

- Final testing
- Final documentation

Deliverables

First Semester

Research list of parts that meet design requirements. PCB design of 8 channel board with researched parts. Documentation of design work, errors, and testing data.

Second Semester

Physical board with soldered parts and accompanying design. Tested protection circuit. Working LNA circuitry with test data. Working TX810 also with accompanying test data. Detailed information on testing of HVP and new LNA circuitry testing. Detailed information on the power up sequence.

A working high frequency pulser that is able to send on 512 channels and receive on 512 channels at ~1.0 MHz. The final version of the system will be put into a case to hold the transmit and receive boards 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

Soldering the PCB with a solder mask reduces the amount of bridging on the more pin dense ICs. Research into more methods and industry rules for PCB design will aid future engineers in board design and keep them from running into errors that the programs don't explicitly state. Detailed documentation on how to power up the HVP to keep it from being shorted. Design of PCB with labels to help know where proper voltages need to go.

Assigned Tasks:

Zach Bertram	Webmaster/PCB design
Michael McFarland	Leader/PCB design
Jonathan Runchey	Communication/Multisim
Maurio Mckay	Communication/Document Writing

Client/Faculty Advisor Information

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