Pulse-Echo Ultrasound Brain Imaging

Design Document

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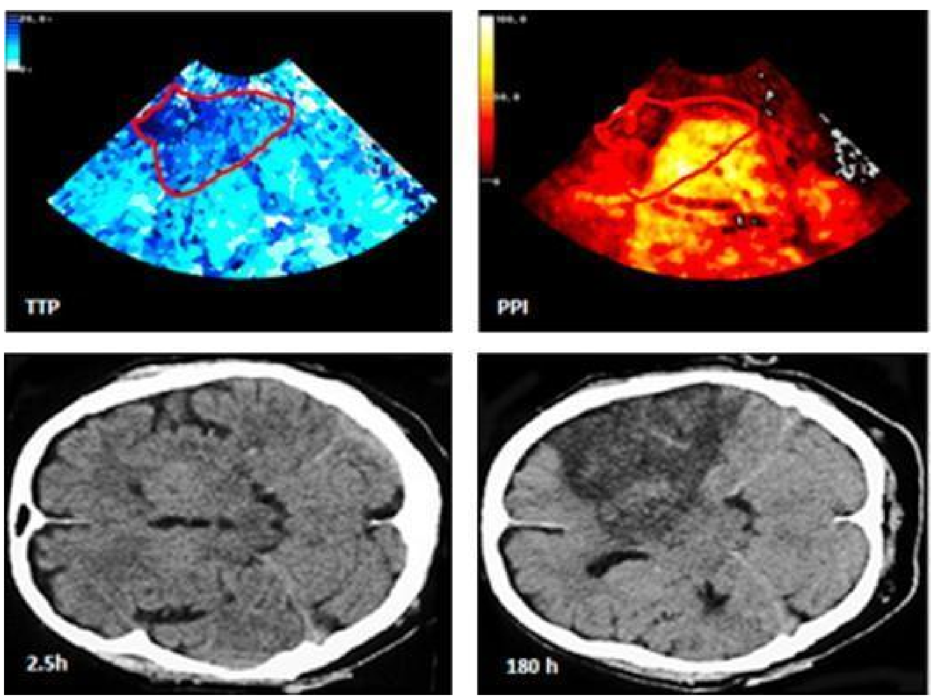

http://www.sciencedirect.com/science/article/pii/S2211968X12000484

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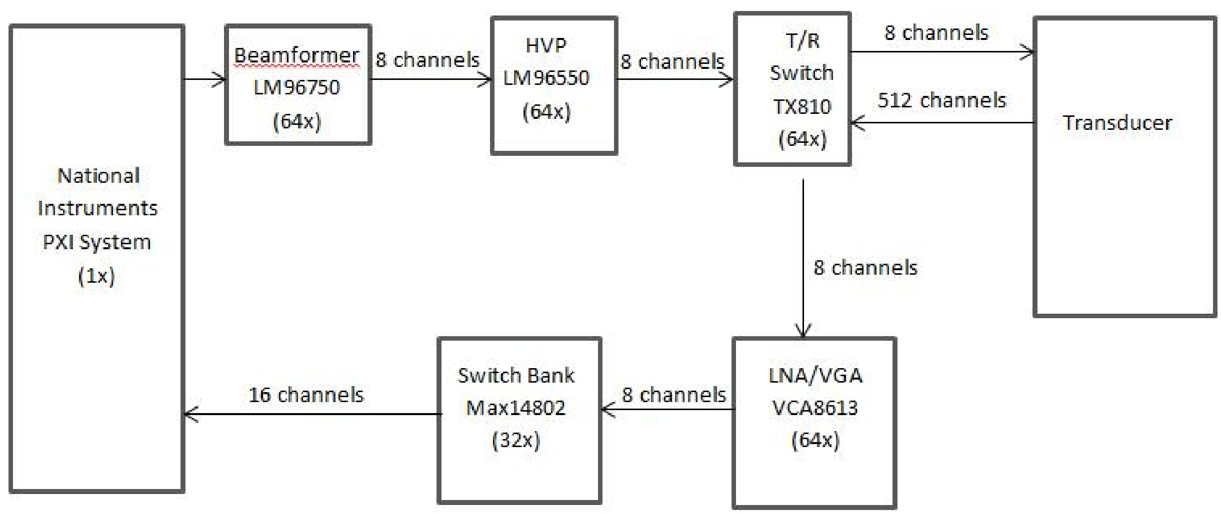
Executive Summary

The goal of this project is 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 following report will contain the design for a transmission circuit and a receive circuit for the fMRI machine. The transmit circuit will be able to send high voltage pulses (+/-50V) over 512 channels to a transducer. The receive circuit will then receive the signals from the transducer and amplify them before sending them to a computer interface.

System Block Diagram



Detailed System Design

Transducer

The transducer is the part of the system that will come in contact with the patient. It is able to receive a high voltage pulse which it then converts into an ultrasonic pulse at a pre-determined frequency. The ultrasonic pulse is then sent into the body and the reflected pulses are captured by the transducer and converted into electrical signals that can be processed to form images.

Computer Interface System

We will be using the National Instruments PXI System to receive the signals back from the transducer and to control our high voltage pulser. The PXI system has a modular design which allows us to different boards based on our needs. Our team will use the NI PXI-7813R Virtex-II

3M Gate R Series Digital RIO Module to send control signals to the Beamformer. For the receive circuit we will be using the NI 5752 board.

Parameter	NI PXI-7813R Specification	Required Specification
Digital Control Signals	160 bits (will need 2)	320 bits (64*5)

Parameter	NI 5752 Specification	Required Specification
Receive Channels	32 channels (we will need 4)	128 channels

Beamformer

We will be using the Texas Instruments LM96570 Transmit Beamformer. It offers eight output P and N channels at an individual delay from .78 ns to 102.4 µs at a max pulse rate of 80 MHz. The National Instruments PXI system will send five control bits to the Beamformer which will then interpret these control bits and send the appropriate signal to the high voltage pulser to create a high voltage pulse over each of the 8 channels.

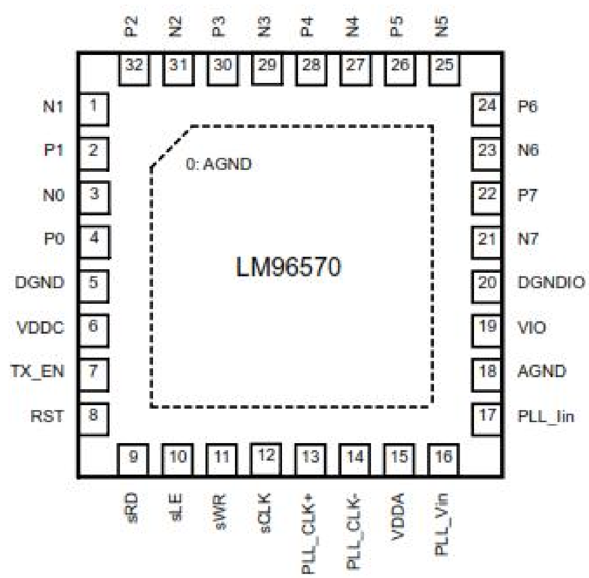


Figure 1 LM 96570 Pin layout

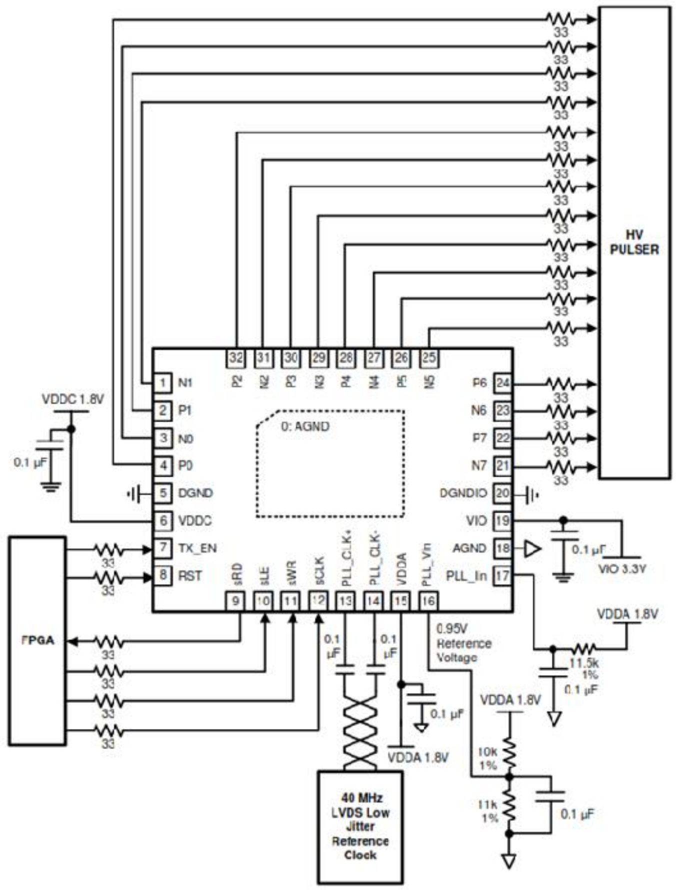


Figure 2 Reference Circuit

High Voltage Pulser

The High Voltage Pulser is the component of our system that will generate the excitations of the transducer. These excitations will be in the form of both positive and negative square pulses. It will be controlled by the LM96570 Beamformer.

We will be using the Texas Instruments LM96550 Ultrasound Transmit Pulser. As you may notice in the following table, we desire 512 channels of operation, but the LM96550 supplies only 8. Therefore, we will be using 64 pulsers in conjunction with one another to achieve the desired 512 channels.

Parameter	LM96550 Specification	Required Specification
Voltage Output	+/- 50 V	+/- 50 V
Frequency Range	Up to 15 MHz	1.1 MHz
Number of Channels	8	512 (8x64)
Switching Delay Time	32 ns	Less than 167 ns

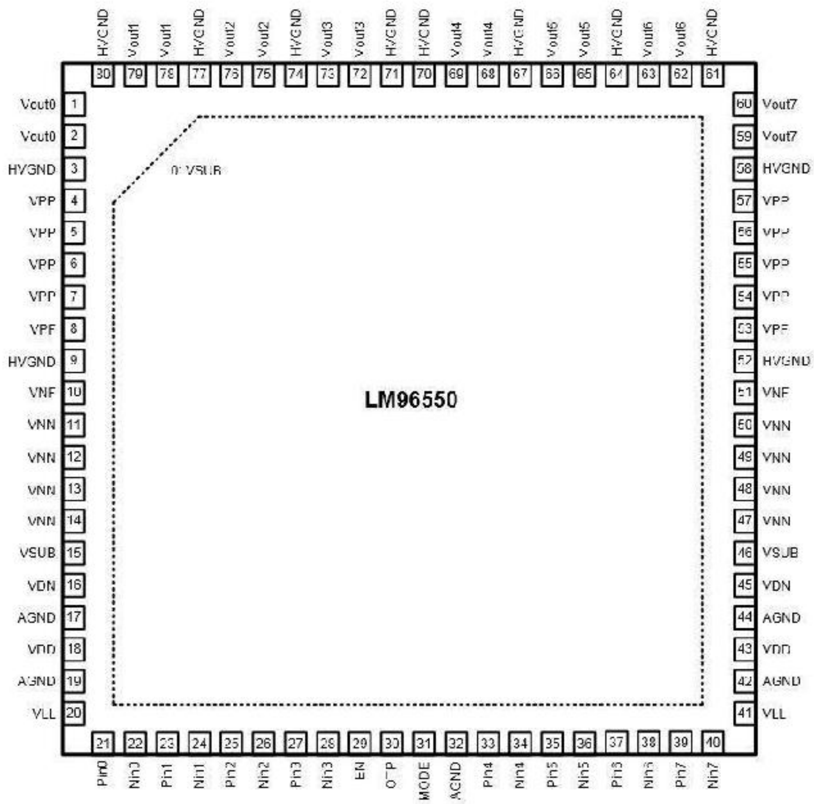


Figure 3 LM96550 Pin Layout

The pulser will only operate when the EN pin is driven HI. If the pulser is enabled, driving PIN or NIN HI will generate a positive or negative pulse, respectively, at Vout. Vout will be pulled to the positive supply (VPP) or the negative supply (VNN) by power MOSFETs. If both PIN and NIN are LO the output Vout will be pulled to GNDHI (0 V). It is important to never drive both PIN and NIN HI as this will cause damage to the circuit. The following figure is a block diagram of a single channel of the pulser.

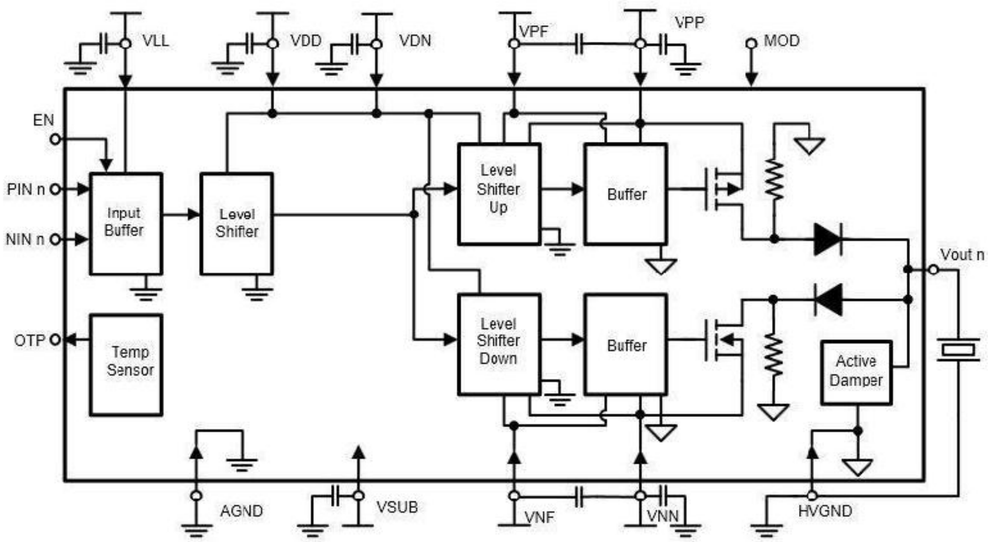


Figure 4 Block diagram of single LM96550 channel

T/R Switch

The T/R switch will act as an interface between the transmit and the receive sides of our system. It will allow high-voltage signals from the High Voltage Pulser to be passed to the transducer in the transmit stage, while also passing the low voltage signals from the transducer during the receive stage. Thus, the T/R switch's primary purpose is to act as a buffer between the systems' Low Noise Amplifier and the High Voltage Pulser as the Low Noise Amplifier can be permanently damaged by high voltages.

We will be using the Texas Instruments TX810 part in our system. The TX810 supports 8 channels and has three digital control bits (B1, B2, and B3) that determine its biasing current; increasing the biasing current decreases the switch's impedance. Some properties of the system may be optimized by introducing different values of load inductance and resistance, but this may also lower the system's sensitivity. We will determine what values we will use once sufficient testing has taken place.

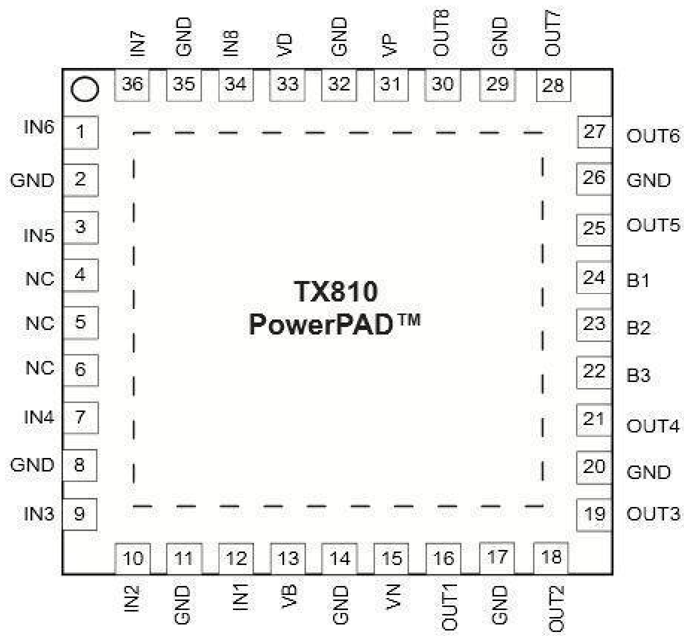


Figure 5 TX810 Pin Layout

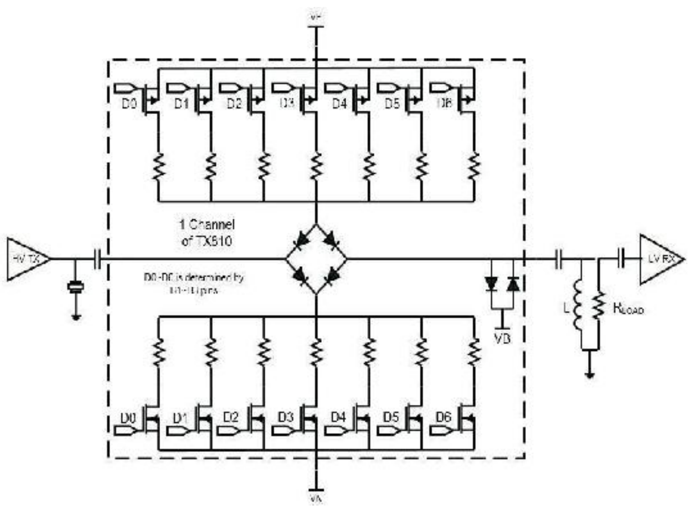


Figure 6 Block diagram of single TX810 channel

Low Noise Variable Gain Amplifier

The low noise variable gain amplifier amplifies the heavily attenuated reflected signals from the T/R switch, so that the signals can be sampled and processed for imaging.

Parameter	TX810 Specification	Required Specification
VGA Gain	24.5 dB	10 – 20 dB
Number of Channels	8	8-16

Switch Bank

In order to reduce how many NI 5752 boards we would need to buy, we decided to use Max14802 switch banks to multiplex our receive signal from 512 channels down to 128 channels.

Parameter:	MAX14802 Specifications:	Desired Value:
Number of Available Switches	16 integrated SPST switches	An integrated array of 16-32 switches
Serial Interface	Each device features a 20MHz serial interface that operates at 5V. Serial interfaces between devices can be daisy-chained for simplified control. "Latch Enable" pins control whether the devices retains its currently programmed state or loads a new state in.	The device will feature an interface that will allow for each switch to be controlled individually.

PCB Design:

To save money our group plans on limiting ourselves to 60 in^2 for all printed circuit board designs. The reason for this is that senior design groups at Iowa State receive a discount on printed circuit boards under 60 in^2. To accomplish this task we plan on dividing our circuit up into two separate groups as follows:

Transmit Boards:

Device	Number of Devices per Board; 16 Boards Total
LM96550	4
LM96570	4
TX810	4

Receive Boards:

Device	Number of Devices per Board; 4 Boards Total
VCA8613	16
Max1402	8

Testing

Phase 1

For the first phase of testing our group plans on ordering the TX-SDK-V2 Evaluation Board[1] from TI. The board contains all the parts needed for an 8-channel transmit circuit for an ultrasound system. We are then going to order the VCA8613 T/R and TX810 chip to make sure the receive side of our design will work well with the LM series chips, in the evaluation board.

Phase 2

The second phase of our testing will involve checking our PCB designs for functionality. We plan on ordering one board from each PCB group to make up a 16 channel send and receive circuit. Once we obtain these boards we plan to individually test each group, before testing all the groups as a whole. This way we can reduce the risk of ordering too many non-working boards.

[1] The TX-SDK-V@ Evaluation board can be found at the following link; http://www.ti.com/tool/tx-sdk-v2.