ULTRASOUND BRAIN IMAGING, DRIVE CIRCUITRY

GROUP DEC16-19

Client and Faculty Adviser : Dr. Timothy Bigelow

TEAM MEMBERS

Miguel Mondragon, Team Leader and Communications

Zechariah Pettit, Webmaster

Honghao 'Tom' Liu, Key Concept Holder

INTRODUCTION

Our group's goal is to engineer the hardware for a pulse echo ultrasound system. This device will serve as a brain imaging system and a low cost alternative to traditional fMRI devices. While the device can cater to the needs of all users of traditional fMRI brain imaging techniques it can also serve as an alternative for users for whom fMRI does not work. These users, such as as individual with claustrophobia, children, individuals with PTSD, and individuals with metal implants, can use this device without the drawbacks of fMRI machine usage. The device works by converting numerous variable voltage and phase altered signals into ultrasound waves which then interact with the object being scanned and returned. Based on these return signals, an image can then be formed. Our group was tasked with developing the beamformer and high voltage pulser of the system.

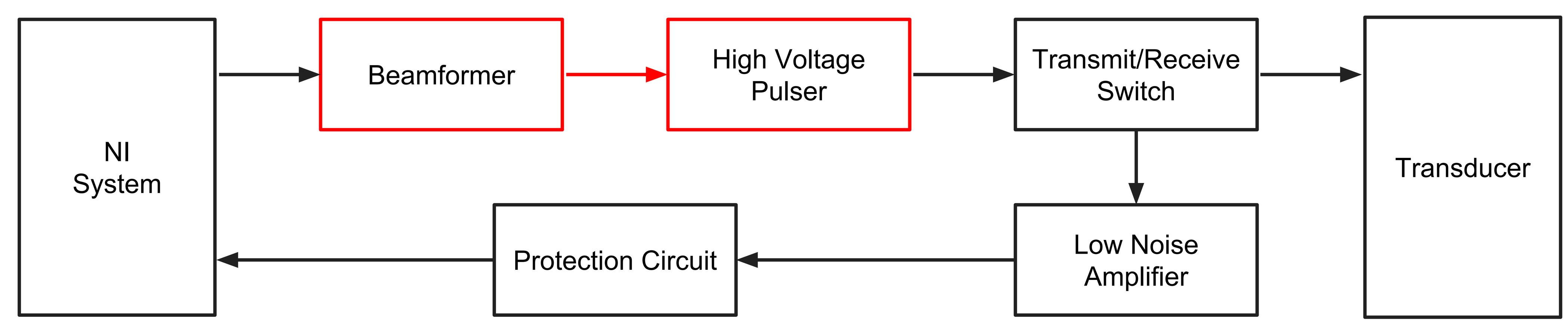
Our objective was the design an 8-channel transmit board that can then be scaled up to the necessary 512-channels of the transducer. This board will receive a serial input which will encode a base signal (this input is still under development) then our board will use this signal to generate seven altered signals based upon either phase shift or duty cycle. It will then send these seven pulse width modulated signals along with the original signal to a filter segment which will convert the signals into sinusoidal waves. These waves will then be amplified by a gain of 16 V/V to create the necessary voltage to create the ultrasonic waves that will be emitted from the transducer.

DESIGN GOALS

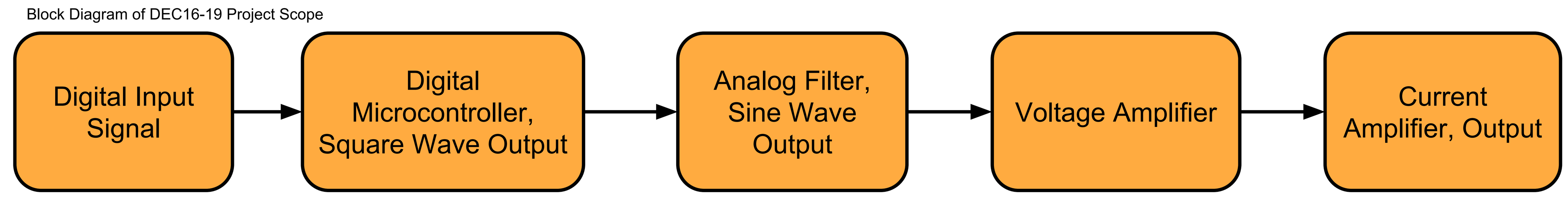
- Transmit up to 8 signals by duplicating and altering an initial signal.
  - Signals must be capable of precision variable phase delay and duty cycle alteration.
- Be cable of converting these signals into an sinusoidal wave.
  - Phase difference must be maintained.
  - Variable voltage based upon duty cycle.
- Capable of function at operating frequency of 1.5 MHz.
- A scaleable system of up to 512 channels.
  - Final system for this project requires only 8 channels.
- Capable of receiving serial input from NI computer interface.
  - This will program the initial signal for the 8 channels.

DESIGN APPROACH

- The device functions begin by an initial serial signal generated by a NI system that contains the parameters of an initial signal and what phase delay and duty cycle are required for the material being imaged.
- It then proceeds to the beamformer which based on the serial input generates a set of signals (for this project 8 but for the final device 512) that are generated as PWM square wave signals.
- These signals are then converted to sine waves and amplified to a voltage level high enough to be received by the transducer.
- The transducer then converts these signals to ultrasonic waves that interact with the image being scanned and return. These returned signals are then converted into altered signals.
- These altered signals pass back through the transmit/receive circuit and are amplified again to a usable voltage it then passes through a protection circuit to prevent any damaging signals.
- It then returns to the NI system through an analog to digital converter so that the signals may undergo digital signal processing to convert them into a usable image of the object.



Block Diagram of DEC16-19 Project Scope



Block Diagram of Brain Imaging Device

TI LAUNCHPAD

- TI Launchpad C2000
- Clock freq. 60 MHz; 8 ePWM channels; 6K on-board SAPAM; 32K flash
- I/O pins Digital(GPIO) transmitted through USB
- To achieve desired PWM, the value in the active CMPX register is continuously compared to the time-base counter. When the values are equal, the counter-compare module generates a time-base counter equal to counter compare A event. This event is sent to the action-qualifier where it is qualified and converted it into more actions.

SOFTWARE

- TI Code Composer Studio IDE with C
- Project based on TI provided DSP library
- Signal generated using Time-Base Period Register (TBPRD) (to set frequency)
- Duty cycle control using Counter-Compare Registers

DAC LOWPASS FILTER

- Active Lowpass Filter using the AD826AR Op Amp
  - Selected for high slew rate, speed, and maximum capacitance load.
- Butterworth Filter with 3-stage Sallen Key Design
  - Reasonable number of stages while maintaining fast settling speed.
  - Filter uses duty cycle to alter voltage levels while converting PWM to sine wave.
- -3dB frequency set so that signals exceeding maximum desired frequency (1.5 MHz) are reduced.
  - Gain set to output a 2Vpp signal at the highest duty cycle (50%).

DAC HIGHPASS FILTER

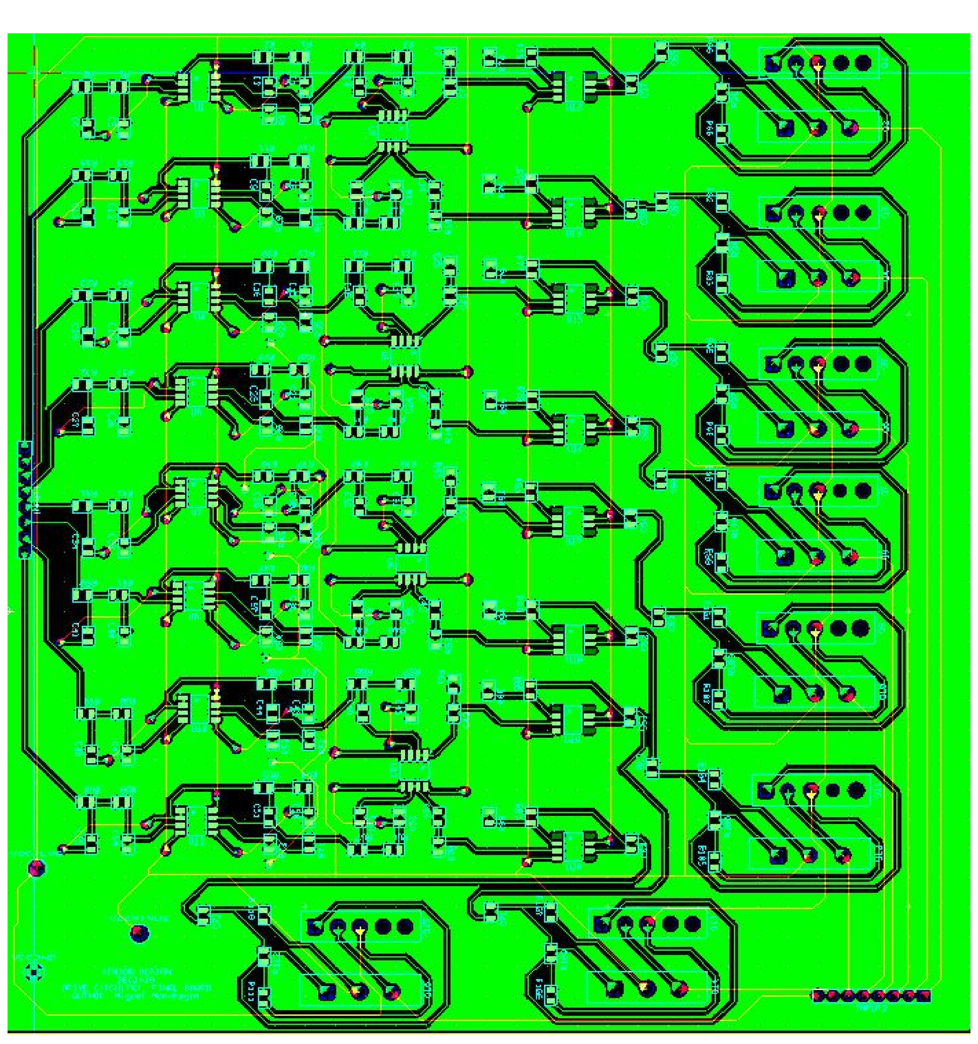
- Passive Highpass Filter
- Low cutoff frequency.
- Serves to filter out the remaining DC element of the signal after filtering.
  - This prevents a voltage offset based on the duty cycle.

VOLTAGE AMPLIFIER

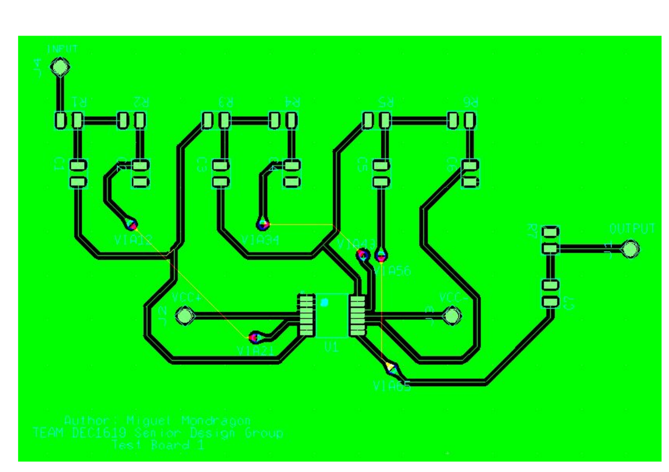
- Single channel voltage amplifier powered by high-speed TI THS3001 Op Amp
- Excellent slew rate : 6500-V/μs
- Low distortion for 1.5 Mhz wave
- Non-inverting design provides 32V at maximum duty cycle

CURRENT AMPLIFIER

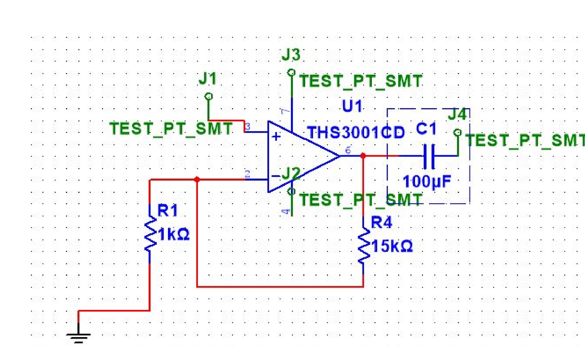
- Powered by BJT pairMJL1302AGOS-ND and MJL3281AGOS-ND
- BJTs are capable of outputting 15A and 200W
- Common-collector configuration functions as a voltage buffer and provides massive current gain to drive the transducer



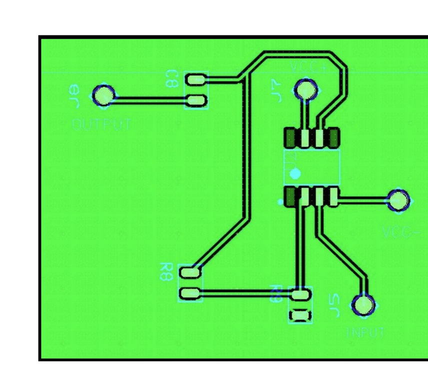
Final 8-Channel PCB



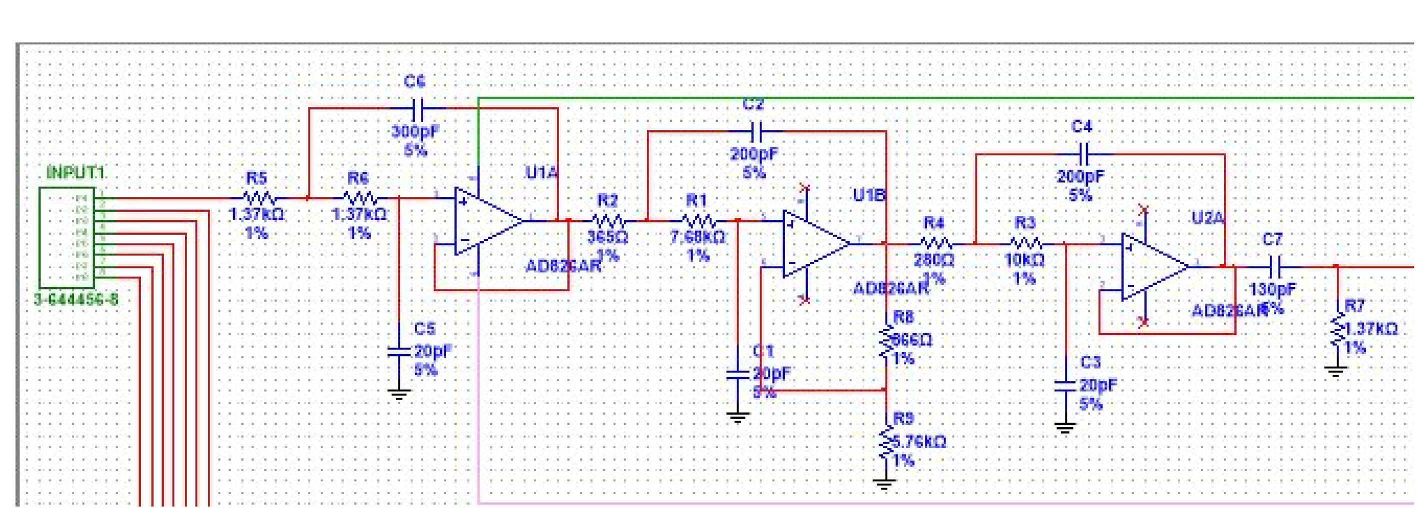
Initial Filter PCB



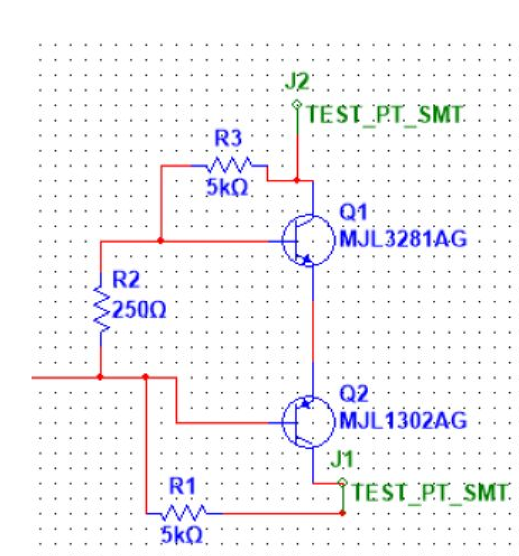
Simulation Model of Voltage Amplifier



Initial Voltage Amplifier PCB

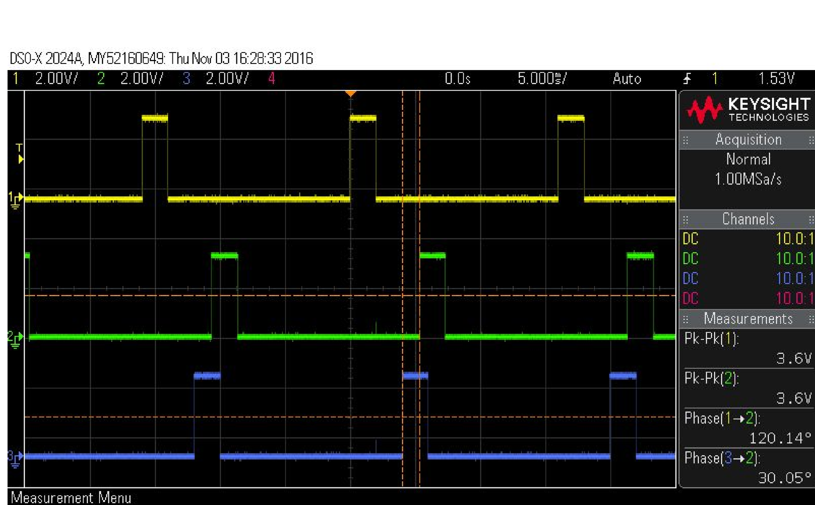


Simulation Model of DAC Filter

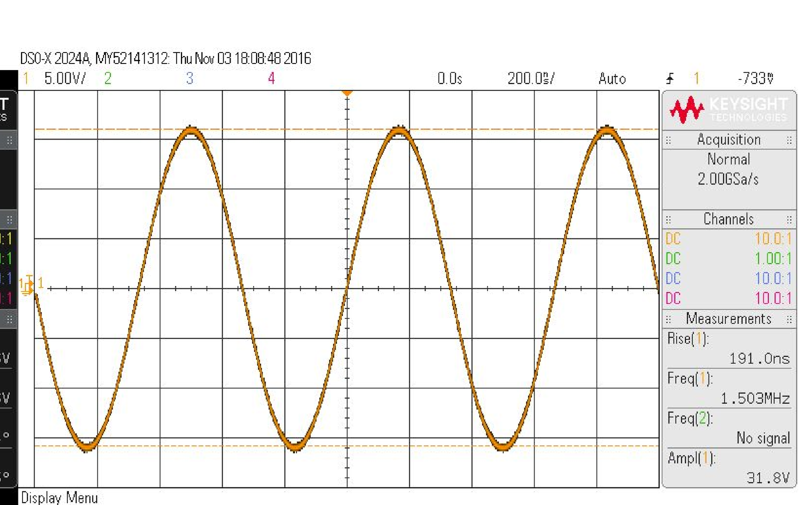


Simulation Model of Current Amplifier

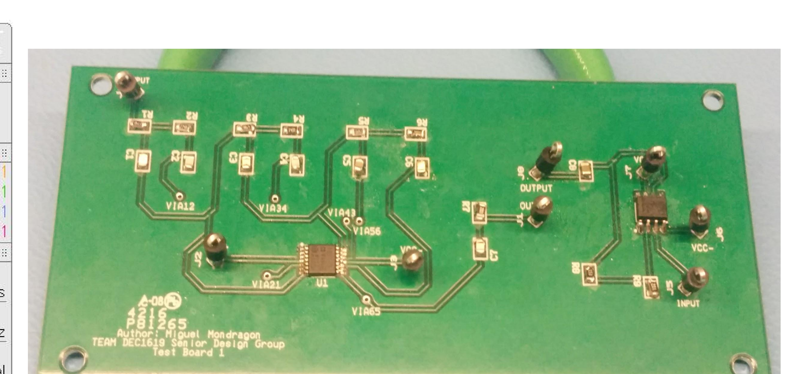
TESTING AND RESULTS



Output of launchpad displaying multiple channels with phase shift



Output of Voltage Amplifier at maximum duty cycle



Initial single channel PCB Board

RESULTS

- TI C2000 LaunchPad performed as designed, delivering stable and accurate reference signals, as well as controlled phase delay and duty cycles.
- Filter segment is functional in simulations but requires additional physical testing.
- Voltage amplifier is functional in both simulation and physical perspective.
- Current amplifier design is finalized, and is functional in simulation.