# Functional Feedback Mechanisms for Image-Guided Tibial Neuromodulation

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## Abstract

Existing ultrasound tissue phantoms are passive, or contain integrated blood vessels to model arterial and venous flows. Although focused ultrasonic stimulation (FUS) is non-invasive, human or animal research is not an appropriate testbed for algorithm development because interactive time is limited. Therefore, a bench phantom enabling functional feedback is essential to rapidly demonstrate and iterate imaging and control algorithms. We will develop an advanced phantom for FUS research, which will mimic relevant anatomy such as bones and blood vessels, but will also react to FUS stimulation. This phantom is essential to develop accurate algorithms incorporating functional feedback and adaptive image processing to track and stimulate nerve targets in real time. While this phantom will be customized for FUS algorithm development, this advanced phantom would also be broadly useful for closed-loop electrical stimulation research.

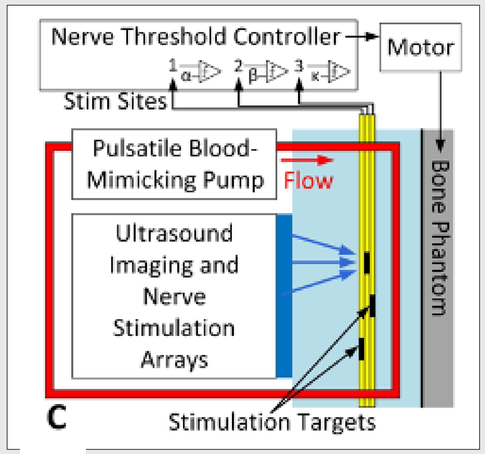


*Figure 1: Block diagram of closed loop ultrasound stimulation and imaging array.*

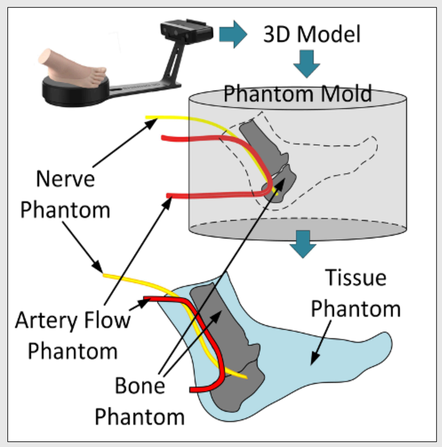


*Figure 2 : Active benchtop phantom will include bones, arteries and simulated nerves for a realistic model of the human anatomy*

## Circuit Simulations

- Ultrasonic element receives energy and produces a small current
- To simulate a nerve being stimulated, an interface circuit was designed to detect the small current and convert it into a digital pulse

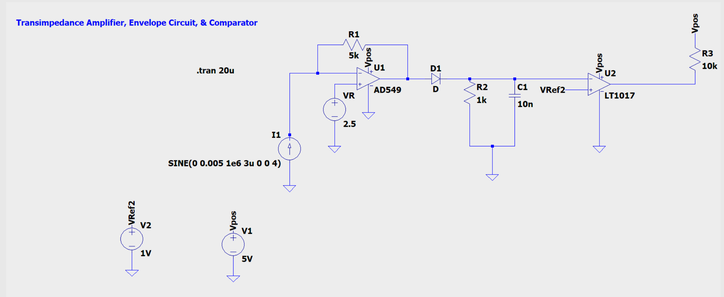


*Figure 3: LTSPICE Simulation Schematic*

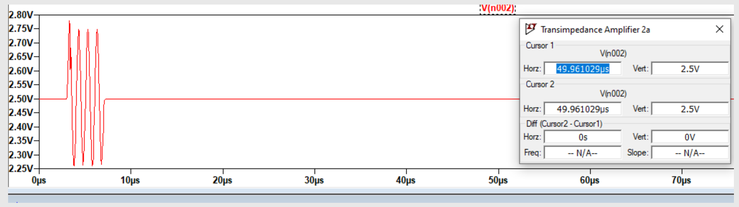


*Figure 4: Output of transimpedance amplifier showing amplification of ultrasonic current. The current is amplified and converted to a voltage by the amplifier.*


*Figure 5: Output of envelope detector smoothing the current pulse*

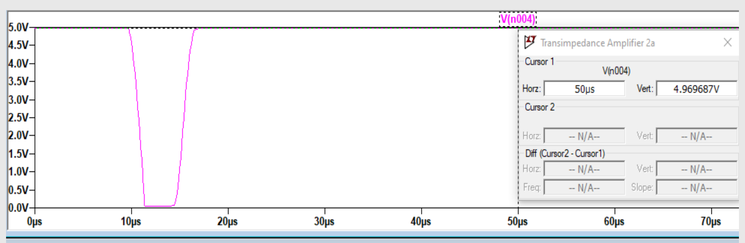


*Figure 6: Output of comparator showing conversion of the short ultrasonic current pulse into a digital waveform. The output is inverted because of the polarity of the transimpedance amplifier, but detection of the pulse duration is possible.*

## Background

- We will develop an advanced phantom for FUS research, which will copy relevant body parts like bones and blood vessels but will also react to FUS stimulation
- This phantom is essential to develop accurate algorithms incorporating functional feedback and adaptive image processing to track and stimulate nerve targets in real time
- While this phantom will be customized for FUS algorithm development, this advanced phantom would also be broadly useful for closed-loop electrical stimulation research

Goals:

- Simulate/ design a circuit to detect pulses of ultrasonic energy and produce pulses when energy exceeds a threshold (sensor interface)
- Design a printed circuit board with the sensor circuit connected to a microcontroller, and an interface to a stepper motor controller
- Fabricate, assemble, test

## Conclusions

- Transimpedance amplifier and envelope detector are an effective interface for converting small ultrasound pulses into measurable voltage signals
- Interface will allow detection and timing of pulses by a controller
- Controller can generate movements in the ultrasound phantom to simulate a human nerve being stimulated with ultrasound

## Next Steps

- Design printed circuit board for the interface circuit
- Using Eagle PCB Designer
- Circuit board will be fabricated and assembled for bench testing with the ultrasound phantom of the ankle

## Acknowledgements

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