Somatosensory Stimulation Apparatus for Rodent Cages

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ABSTRACT

An electrode device has been designed to address the problem of phantom limb pain, a neuropathic pain caused by nerve damage during limb amputation. The functional outcome of this electrode can be assessed in humans by asking the patient questions. Before this device can be tested in humans, however, it must prove successful in animal models. In order to receive functional outcome data from rats, a healthy rat can be trained to respond in a certain way to a somatosensory stimulus. A peripheral nerve can then be surgically severed and the electrode implanted. The device can then be used to apply what should be recognized as the same somatosensory stimulus the rat was trained with. The goal of this project was to produce the somatosensory stimulation necessary to train the rats. The device is able to apply a graded stimulus to the two hindlimbs individually. The device consists of a cage for the rat as well as a microcontroller to control the stimulus grade. The final design includes clear plastic cage walls on top with two platforms that vibrate via speaker actuators underneath. The pieces are connected using a vibration damping foam. Testing has shown that the current device is able to successfully output vibrational frequencies equal to those set by the user. The current design uses a square wave signal which causes unwanted noise. Further work to run the motors with a sine wave will allow this device to move into animal testing phases..

INTRODUCTION

Motivation:

- 185,000 amputee surgeries per year in US [1]
  - 42.2-78.8% of amputees suffer from phantom limb pain [2]
- New device to treat phantom limb pain and restore tactile sensation
  - Currently in need of method for testing device in rat models
- Current plan for rat testing
  - Train healthy rat to respond to somatosensory stimulus on hindlimbs
  - Amputate hindlimb and implant device
  - Stimulate hindlimbs with device and observe if rat responds as trained

Background:

- Somatosensory system: System of neurons connecting peripherals to brain
- Merkel cells
  - Mechanoreceptors on surface of skin
  - Sense low frequency vibrations 5-15Hz
- Tactile Corpuscles
  - Mechanoreceptors in skin
  - Sense 5-50Hz frequencies

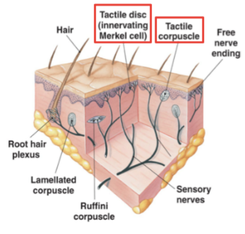

Figure 1. The cell types of the somatosensory system that must be stimulated to train the rats.

DESIGN CRITERIA

Performance:

- Stimulation isolated to individual hindlimbs
- Varying frequencies must be allowable
- Stimulation must not interfere with new device

Size:

- Cage must not limit rat's ability to respond to stimulation
- Weight under 5 lbs
- Dimensions 10in x 11in x 12in

FINAL DESIGN

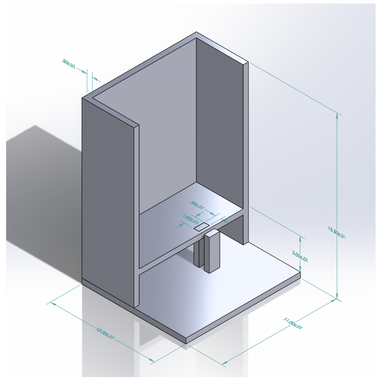

Figure 2. Cutaway view of the cage design.

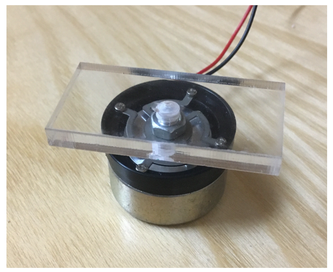

Figure 3. Surface actuator with platform attached

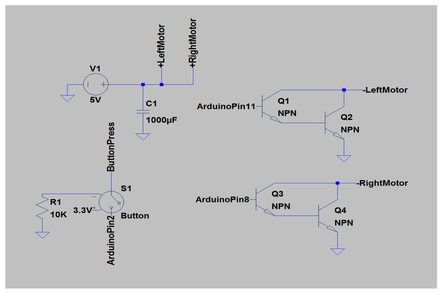

Figure 4. Circuit Diagram

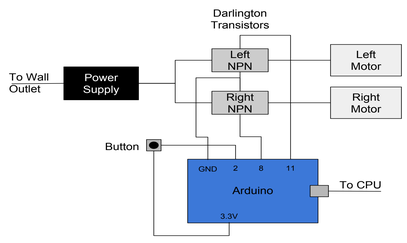

Figure 5. System Diagram

RESULTS

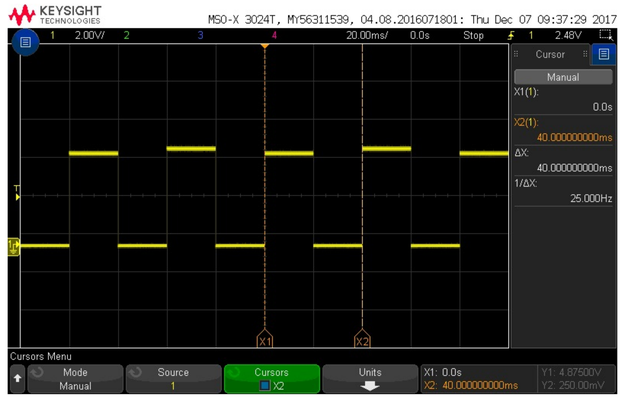

Figure 6. Square wave input from the Arduino to the circuit

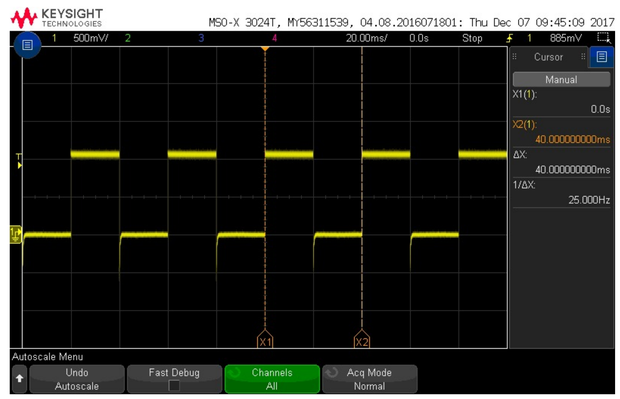

Figure 7. Square wave input from the circuit to the actuator

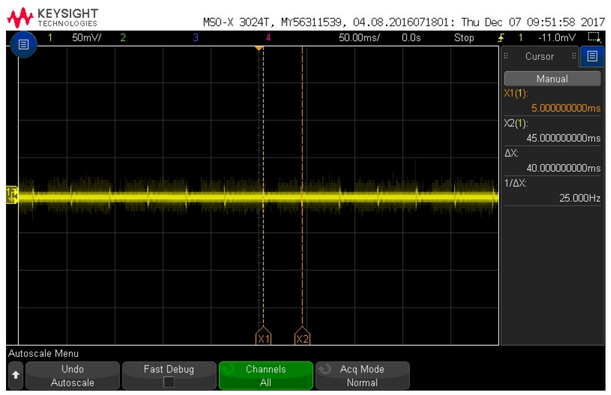

Figure 8. Frequency of the output of the surface actuator, measured using a bone transducer

FUTURE WORK

- Drive motors with sine wave to reduce harmonics
- Make frequency adjustment user friendly
- Test with rats
- Fabricate the entire cage using the laser cutter to improve asthetics

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REFERENCES

[1] "Limb Prosthetics Services and Devices", Semantic Scholar, 2017. [Online]. Available: https://pdfs.semanticscholar.org/c3ae/f3563844e2e2835411fcbc2b0fe3091ac30b.pdf. [Accessed: 20- Sep- 2017].
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