Neuromuscular Electrical Stimulator Design

Andrew Bulman, Andrew Mastele, Patrick Deeney, Brian Narby (ECE 1896)
Advisor: Dr. Nitin Sharma

Background Motivation

The primary motivation for this project is to support research for restoring lower limb function in paraplegics. There are approximately 12,000 accidents each year in the United States that result in spinal cord injuries [1]. Of the 12,000 individuals effected by spinal cord injuries 21.6% are diagnosed with complete paraplegia, which is the loss of lower limb function [2]. However, research has shown that neuromuscular electrical stimulation (NMES) can be used to produce gait motion in the lower limbs [2]. NMES is an application of low level electric potential to the human muscle to elicit desired muscle contractions. Controlling the frequency and pulse width are important for NMES because changing the parameters can help to reduce muscle fatigue. Additionally, creating a portable neuromuscular stimulator will be conducive to future research on paraplegics because the current stimulation equipment is not portable.

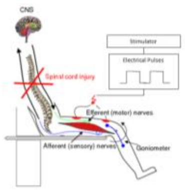

Figure 1: Model of NMES [3]

Project Goals

The objective of this project was to design a portable neuromuscular stimulator that would send desired input stimulation parameters to the muscle via bipolar surface electrodes attached to the human skin. The completed neuromuscular stimulator system was expected to achieve the following goals:

- Output monophasic or biphasic stimulation square pulses with the following parameters: electric current in the range of 0 – 120 mA (for a given skin resistance), frequency of 0 – 100 Hz, and a pulse width of 100 – 500 µS.
- Allow the user to set the pulse width and frequency via MATLAB before the system starts.
- Electrically stimulate the muscle based on the set stimulation parameters.
- Have an even number of channels.
- Use a power supply with smaller physical dimensions compared to the previous power supply.
- Outputs via BNC connectors.

System Design

Figure 2: Stimulator Design Process

User Interface

The user interface was created in MATLAB/Simulink and fulfills the goal that the user would set the desired parameters via MATLAB before running the system. The following figure shows the user interface to input the frequency and pulse width:

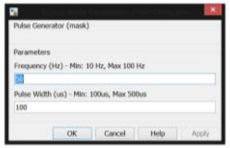

Figure 3: MATLAB User Interface

Arduino Mega 2560

The Arduino is a microcontroller and is controlled in the system using the user interface designed in MATLAB/Simulink. The following single-channel model was created in Simulink to create a pulse with user-specified parameters (frequency and pulse width):

Figure 4: Simulink Model

Amplifier Circuit

The amplifier circuit was used to step-up the voltage and current of the output from the Arduino. The following schematic was produced to output the desired pulse:

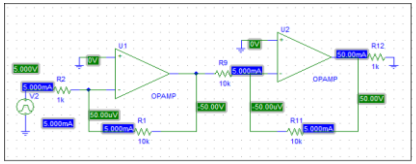

Figure 5: Amplifier Circuit Schematic

Results

To test the circuit the output of the pulsed output of the Arduino and the output of the amplifier circuit were observed. Figure 6 shows the output for a 5V input with a frequency of 50Hz and a pulse width of 400µs. Figure 7 shows the 40V peak output of the amplifier circuit compared to the 5V output of the Arduino.

Figure 6: Pulsed Arduino Output

Figure 7: Amplifier/Arduino Output

The tests confirmed proper generation of the pulsed signal in terms of frequency and pulse width. However, with the available power supply, 80% of the desired voltage gain was achieved.

Conclusion

Due to the problem that the system was only reaching 80% of the desired voltage from amplifying the signal output of the Arduino, additional analysis is necessary before this system can be used for research involving lower limb function in paraplegics.

Acknowledgments

Dr. Nitin Sharma — Nick Kirsch and Naji Alibeji — Dr. Irvin Jones Jr.

References

[1] National Spinal Cord Injury Statistical Center, "Spinal cord injury facts and figures at a glance," *The Journal of Spinal Cord Medicine*, vol. 36, no. 1, pp. 1-2, 2013.
[2] R. Kobetic, R. Triolo, and E. Marsolais, "Muscle selection and walking performance of multichannel FES systems for ambulation in paraplegia," *IEEE Transactions on Rehabilitation Engineering*, vol. 5, no. 1, pp. 23-29, 1997.
[3] Seel, Thomas, "Controlled Functional Electric Stimulation for Rehabilitaion Purposes," *Technische Universität Berlin*, 2013.