Design of a Low-Cost Open Source FES System

Ryan A. Raasch, Jordan Edmunds, An H. Do

***Abstract*— Functional electrical stimulation (FES) systems can be cost prohibitive for patients and researchers. Here we describe the implementation of a low-cost FES system. The system was validated by demonstrating that it could induce bicep muscle contractions over approximately 1-minute period. Such a low-cost system can help facilitate future FES research.**

I. Introduction

Approximately 17,000 new cases of spinal cord injuries occur each year [1]. Functional electrical stimulation (FES) is an integral part of physical rehabilitation for people with spinal cord injuries and dropped foot [2]. FES is a process whereby electrical biphasic pulse waves are delivered to the neuromuscular complex to induce muscle contractions. Commercial FES systems can cost as much as $1,700-5,500 per system [3]. The development of a safe, low-cost and open source FES system can potentially ease the financial burden on the patients and facilitate FES research.

II. Methods

The overall FES circuit utilizes an NPN transistor, a transformer, a buffer, an audio jack, a 9 V source, and an Arduino Due. This circuit uses a digital-to-analog converter (DAC) pin on the Arduino Due to output a square pulse train with arbitrary amplitude (up to 3.3 V) and duration (up to 250 µs). This square pulse train was sent to a unity gain buffer amplifier, and subsequently to the base of the NPN transistor. A step-up transformer connected to the transistor is used to apply higher voltage stimulation, which is delivered to a human subject via commercial surface FES electrodes (connected to the system by a 3.5 mm audio jack).

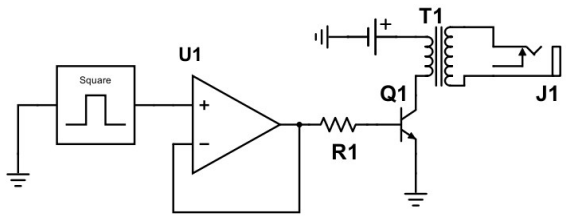

Figure 1. Square pulse waves are sent to the transistor Q1 via a buffer U1. A step-up transformer T1 with a 22.4:1 turn ratio sends the stimulation voltage to FES electrodes connected to the audio port J1.

To test the FES system, surface FES electrodes were placed over the bicep muscle of a healthy male subject. Stimulation was applied to the biceps for 5 s followed by a resulting period of 5 s, over approximately a 1 min period. A gyro sensor was placed proximate to the wrist to record elbow position.

III. Results

The total cost of the FES system was ~ $60. The stimulation was significant to cause involuntary contraction of the biceps, resulting in forearm flexion, as shown in Fig 2.

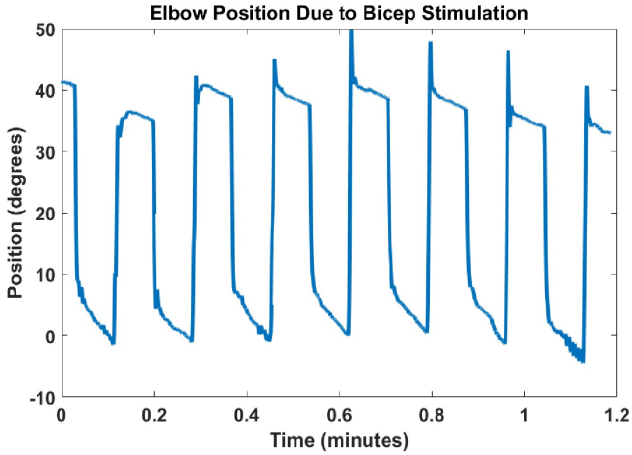

Figure 2. Peaks represent the times at which the bicep experienced involuntary contraction due to stimulation.

IV. Discussion and Conclusion

Our FES system demonstrated that it can generate adequate muscle stimulation in the biceps to cause muscle contraction and limb movement. Since the system is open source, it can be easily modified and programmed to fit a wide variety of potential applications. Furthermore, the low-cost nature of this system can potentially facilitate FES research and perhaps lower the cost of future commercial systems.

References

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R. A. Raasch is a Biomedical Engineering undergraduate at the University of California, Irvine, CA 92697 USA (email: raaschr@uci.edu).

J. Edmunds is an Electrical Engineering and Biology undergraduate at the University of California, Irvine, CA 92697 USA (e-mail: edmundsj@uci.edu).

A. H. Do is a faculty member for the Department of Neurology at the University of California, Irvine, CA 92697 USA (email: and@uci.edu)

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