Electrotactile Sensory-Substitution Method for Trans-Radial Amputees

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Introduction

Limb loss significantly impacts an individual's quality of life by disrupting both sensory perception and motor function. While modern prosthetic technology has made advancements in enhancing motor abilities, the importance of sensory feedback is often overlooked. Incorporating sensory feedback through mechanotactile, vibrotactile, and electrotactile feedback has shown great potential in improving motor control and promoting more natural prosthetic integration [1]. This project focuses on developing an electrotactile feedback device to address this need. The device was subsequently used to assess the effect of certain stimulation parameters on the sensations experienced by users.

Materials and Methods

First, SPICE simulations were conducted to ensure the correct behavior of critical electronic components before the hardware design stage. A prototype was subsequently developed to test and compare various electronic elements under real-world conditions. Following this, a final device was designed with integration into an arm prosthesis in mind. The resulting experimental setup aimed to determine sensation and discomfort thresholds, as well as to characterize sensation descriptions based on waveform shape and stimulation current amplitude.

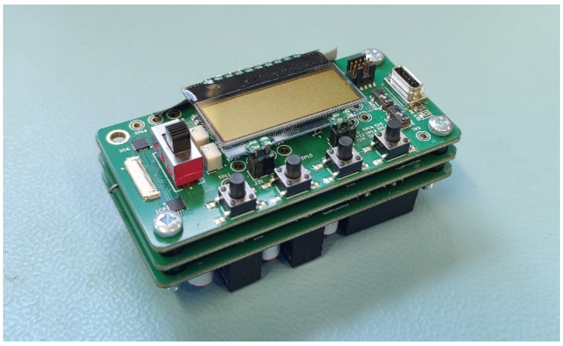

Fig. 1 Portable 16-channel electrotactile feedback device, capable of producing arbitrary waveforms.

Results

The outcome of this project is a functional, portable electrotactile feedback device, measuring 42 mm x 25 mm x 15 mm and weighing 82 grams, with 16 stimulation and sensor channels capable of producing arbitrary waveforms (Fig. 1). However, the required connectors were not compatible with the provided electrodes. Experimental results using the device showed that waveform shape significantly impacts evoked sensations, with sinusoidal waveforms being more comfortable than square ones. Sinusoidal waveforms also had a higher usable stimulation range on average compared to square waveforms (Fig. 2).

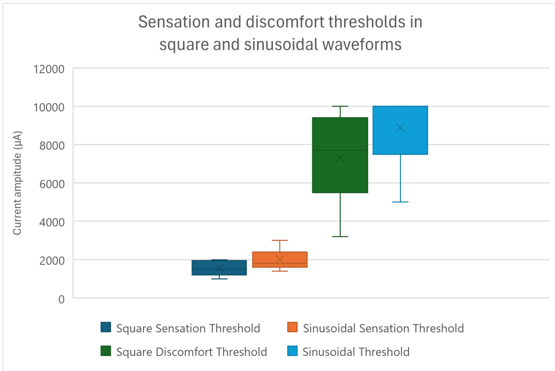

Fig. 2 Sensation and discomfort thresholds for square and sinusoidal waveforms.

Discussion

Unlike most equivalent devices seen in previous research, 16 stimulation channels are available natively, enabling research into complex stimulation patterns while remaining portable. While promising, the device has limitations, such as fragile connectors, the lack of current and voltage measurement of the stimulation signal. Experimental results showed waveform shape significantly impacts perceived sensations, with sinusoidal waveforms being more comfortable than square ones. Future iterations of the device aim to address existing issues, improve design robustness, and explore new features such as selectable ground channels on concentric electrode arrays and dynamic waveform synthesis.

References

[1] B. Stephens-Fripp et al. A review of non-invasive sensory feedback methods for transradial prosthetic hands. 6:6878-6899. Conference Name: IEEE Access

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