System for Personalized Inference of Transcranial Current Stimulation Waveforms

Jacob M. Wheelock[1], Matthew F. Singh[1,2], ShiNung Ching[1] & Todd S. Braver[2]

1. Department Electrical and Systems Engineering, Washington University in St. Louis
2. Department of Psychology , Washington University in St. Louis

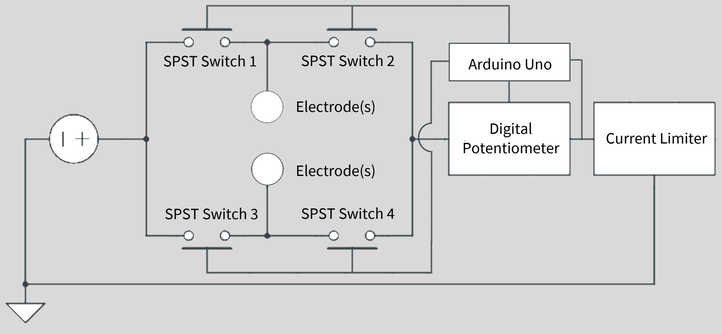
Washington University in St. Louis

Background

Transcranial electrical current stimulation (tCS) is a non-invasive technology for manipulating brain electrical activity. tCS has been shown to modify or enhance cognitive functions, including working memory, making it an attractive candidate for development in rehabilitation contexts. However, a major challenge of contemporary tCS paradigms has been the reliance upon predetermined, open-loop protocols which prohibit robust engineering designs based upon adaptation or feedback.

In the current work, we developed a novel tCS device capable of real-time stimulation and control via an embedded microcontroller. We established performance specifications on our device and its interactions with concurrently recorded EEG. We used impulsive tCS waveforms to test the spatial and temporal extent of artifacts generated by our device on concurrent EEG. We then conducted a pilot experiment to verify the operation of the device in a practical format.

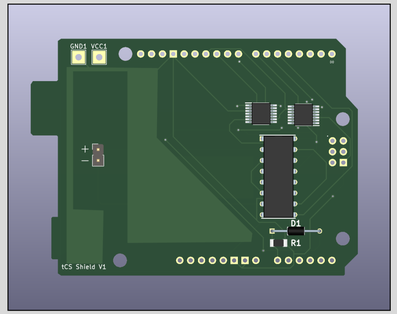
Design & Specifications



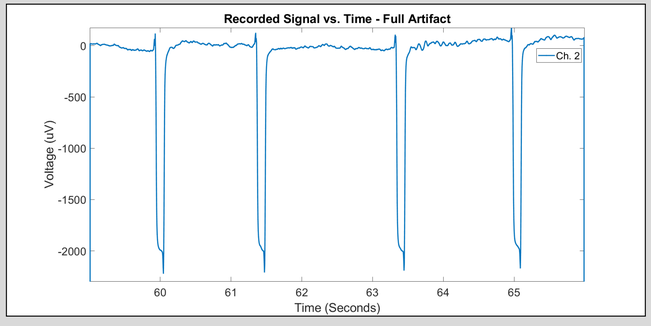
Our novel tCS device utilizes a Quad-SPST switch design in conjunction with a digital potentiometer to modulate the amplitude and polarity of the delivered waveform in real time. A hardware-based current limiter ensures a safe level of current delivery and allows for real-time impedance tracking.

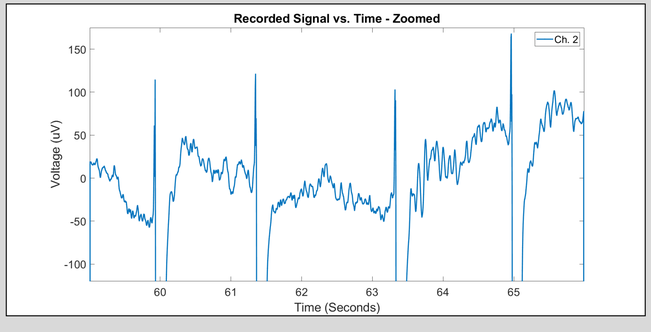
Device Results

- 115200 Baud (Maximum) allows for real time host to tCS device communication
- Arduino Uno shield design increases ease of use and allows for full programmability
- 1 millisecond resolution for arbitrary waveform shaping

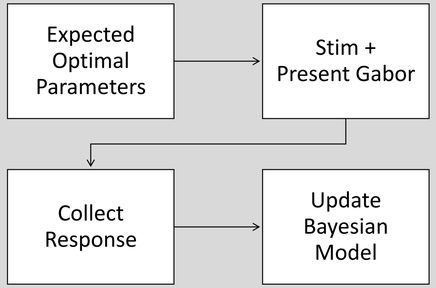


Stimulation Artifacts

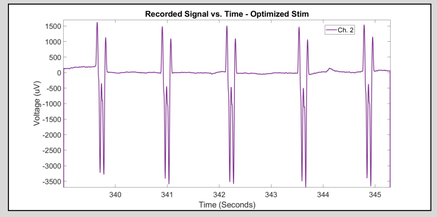




Pilot Experiment



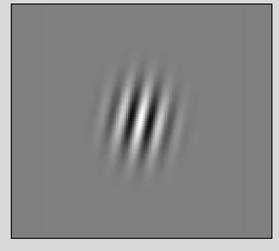
The stimulator was run in conjunction with an EEG cap to demonstrate the short-lived stimulation artifact and feasibility of a combined EEG/tCS system.



A Bayesian optimization was run on two parameters of a ramped sine signal described by I(t)* to attempt to increase task performance relative to a sham signal.

$* I(t) = \alpha \sin(((2.5)2\pi t) + 0.5 \sin((\beta)2\pi t)$

Experiment Task



Rotated Gabor gratings were presented for 650-750 milliseconds to participants who were then asked to identify the direction of rotation as quickly as possible.

Electrical stimulation was delivered in blocks before and during grating presentation with each stimulation pattern being interleaved with sham blocks.

Task performance is evaluated by the difference of the average response times for the real and sham waveforms.

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Portions of this work are protected by provisional patent.