An Implementation of Firmware for Non-Invasive Charge-Coupled Brain Stimulation

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Introduction
Transcranial direct current stimulation (tDCS) systems have shown success in applications ranging from stroke rehabilitation to cognitive enhancement [1, 2]. However, tDCS does not provide localized stimulation of brain regions necessary for many applications. We propose a Spatio-Temporal Switched Capacitor (STSC) brain stimulator to selectively stimulate or inhibit specific brain regions.

System Architecture

Firmware

Use Case:
1) User selects electrodes and voltages
2) User enables system on Teensy 3.6
3) TinyFPGA sends start signal to Teensy 3.6
4) Teensy 3.6 uses SPI to program DAC and send switch and MUX configurations to TinyFPGA
5) TinyFPGA generates state machine control signals
6) Repeat steps 3 through 5 until user disables system on Teensy 3.6

Experimental Setup

-0.5 V DC Test
- Voltage: 1V
- +V: Electrode 1 (E1)
- -V: Electrode 2 (E2)

+/− 0.5 V AC Test
- For 12 ms:
  - Voltage: 1 V
  - +V: E1
  - -V: E2
- For 13 ms:
  - Voltage: -1 V
  - +V: E1
  - -V: E2

Results

Clock Error: 2%

DAC Limits: +/- 2.63 V

Voltage Difference:
Caused by losses in the brain model’s RC network

Switching Capacitor Limitations:
Negate voltage by changing electrodes instead of voltage

AC Example Modified:
13 ms with 1V, +V: E2, -V: E1

Future Work
The preliminary tests demonstrate that the design can successfully generate DC and AC spatial patterns. Future work will utilize more complex patterns on an anatomically correct head phantom with the aim of eventually integrating the system into a compact, portable headband for brain stimulation applications.

References