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ARDUINO BASED CONFIGURABLE LED STIMULUS DESIGN FOR MULTI-FREQUENCY SSVEP-BCI

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Abstract - Steady state visually evoked potentials (SSVEP) are extensively used in the research of brain-computer interface (BCI) and require a configurable light source flashing at different frequencies. Precise control of simultaneous multiple frequencies are essential for SSVEP studies and also for reducing the visual fatigue. Instead of LCD based stimulus which requires more resources and power, light emitting diodes (LEDs) are used as a light source as they are energy efficient, consume lower power, have higher contrast, less tiring visually, have multi-chromatic function and supports wider frequency ranges. In this paper, we propose a visual stimulator using off-shelf components to build a simple and yet customisable LED stimulus for testing the performance and qualitative user comfort using SSVEP electroencephalogram (EEG) data.

I. INTRODUCTION

Brain-computer interface (BCI) gives the user the capabilities to communicate and control various devices by establishing a direct communication channel between human brain and the external device, and does not depend on muscular actions [1, 2]. Signals produced by brain activity (known as electroencephalogram, EEG) are recorded non-invasively from the scalp using electrodes positioned at various locations. Several non-invasive BCI methods exist such as P300, motor imagery and steady state visual evoked potential (SSVEP). SSVEP is a repetitive sinusoidal like waveform with its frequency synchronised with the frequency of the visual stimulus and it is generated in human visual cortex [3, 4]. Researches in BCI have identified that SSVEP based BCI requires less training time, gives faster response and higher information transfer rate [5, 6]. Flashing stimuli of different patterns and sources has been used in the past to evoke brain potentials [7]. Here we present the design of a compact yet versatile light emitting diode (LED) visual stimulus hardware which is capable of producing simultaneous multiple frequency flickers suitable for a wide range of SSVEP paradigms.

II. MATERIALS AND METHODS

SSVEP are extensively used in the research of BCI and require a controllable and

configurable light source. SSVEP requires appropriate control of visual stimulus parameters, such as flicker frequency, light intensity, multi-frequency light source and multi-spectral compositions. LEDs are extensively used as a light source as they are energy efficient, consume low power, have higher contrast and multi-chromatic function and support a wider range of frequencies.

The flicker hardware is based on open-source Arduino platform which supports on-the-fly reprogramming with easily configurable user interface via USB [8]. The design provides fourteen independent high output channels with customisable output voltages. The flicker frequencies can be easily customised within the frequency range 5 Hz to 50 Hz, using a look-up table. The LED flickers are generated with RGB single LEDs which generate the required colour or frequency combinations for combined multi-frequency flicker to generate SSVEP.

A. Visual Stimulus

The platform is designed to accommodate various flicker requirements for SSVEP studies that need wide range of frequencies for RGB LEDs without altering or redesigning the hardware. Arduino platform has been adapted by many researchers to implement either a practical or functional requirement of the study. Arduino uses single board computing concept which is completely open source and reduces the programming complexity.

However, RGB LED's require more current than the conventional types. The current has to be maintained throughout the experiment to get the optimum results. The prototype used here for SSVEP EEG recording is RGB LED with output power of 1 Watt.

The complete Arduino code used to generate ten simultaneous flickers can be downloaded and could be customised to generate any desired frequency flicker (www.ssvp.co.uk/files/multichannelflicker.zip).

B. EEG Recording

The EEG data recording system used for this study is g.Mobilab+ from g.tec (<http://www.gtec.at>). It is a portable bio-signal

acquisition and analysis system capable of recording multimodal signals on a standard PC or other mobile computing devices. The system can communicate to host via Bluetooth or using customised serial cable in case of Bluetooth connectivity issues. g.Mobilab+ is equipped with low-noise bio-signal amplifier and a 16-bit analogue to digital converter with 256 Hz sampling. An external switch signal can also be used to control the start and stop of signal capture. This device is battery powered to avoid any external interference from the mains. EEG electrodes were positioned at O_z and F_{pz} with A_2 mastoid as reference.

For testing the proposed visual stimulus hardware, it was programmed for selected frequencies between 5 and 50 Hz and the output was connected to high power RGB LED via the shield. Five subjects participated in this study. The subjects were seated comfortably at a distance of 60 centimetres from the visual stimulus which was placed at eye level. The visual stimulus hardware is capable of producing 14 different frequency flickers simultaneously for complex SSVEP applications. The stimulus is activated and the data is recorded using the g.tec EEG hardware. The power spectral density (PSD) analysis of two simultaneous flickers of 7 Hz and 9 Hz using two different colours is shown in Fig 1 (the shown frequencies are normalised).

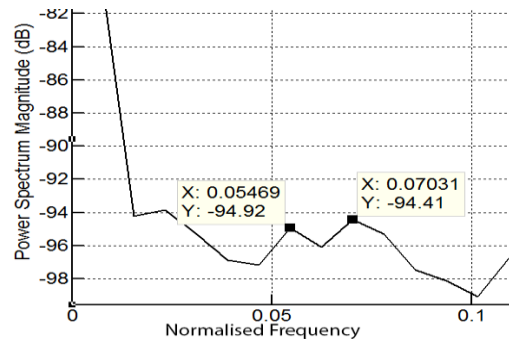


Fig 1. Visible peaks for two different frequencies in recorded EEG with SSVEP

III. RESULTS AND DISCUSSION

The SSVEP visual stimulator met all the criteria that it was designed. The system is easily configurable for any desired frequency with the look-up table and can be updated through USB. The system can be easily customised for different type of LED's with varying operating voltages and power requirements. It can simultaneously provide fourteen different frequency outputs without reprogramming.

For analysis, each 30 seconds of EEG recording was filtered with a band-pass filter and segmented into one second EEG segments

and analysed with Fast Fourier Transform (FFT). FFT was employed rather than advanced features as the aim here is to test the working design only. Table 1 shows the filter parameters used in this analysis.

TABLE I
VALUES OF PARAMETERS USED IN DATA PROCESSING

Frequency (Hz)	Order	Pass band edge frequencies	Stop band edge frequencies	Max pass band ripple (dB)	Min stop band attenuation (dB)
7	4	6,8	5,9	0.1	30
8	4	7,9	6,10	0.1	30
9	4	8,10	7,11	0.1	30
10	4	9,11	8,12	0.1	30

IV. CONCLUSION

The visual stimulator was tested successfully for colour, frequency, portability and design simplicity. The prototype platform is easy to build with off-shelf components and economical for many different areas of vision research. Using the platform, further research would be able to develop complex signal processing algorithm for real-time feature extraction of EEG data to control external applications or devices accurately and efficiently with multiple visual stimulus.

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