Standard Transcranial Direct Current Stimulation (tDCS) Model

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ABSTRACT

TDCS, the Transcranial Direct Current Stimulation is a non-invasive, painless brain stimulation treatment. It was originally developed to help patients who suffer from brain injuries or psychiatric conditions like major depressive disorder. We made advance tDCS device that can pass a little amount of current ranging between 0.1-2.5 mA at a voltage range ±0.064 voltage within the brain scalps as well as store the stimulation data in real time. In this device, we introduced a flexible headband which can easily fit everyone's head. This headband consists of two electrodes by which current is passed through the brain. We have developed an android application to control the current flow of the device smartly. It can be add new dimension in neurostimulation process.

Keywords: *Transcranial Direct Current Stimulation, tDCS, neurostimulation, electrodes, flexible headband, LM334, tDCS android app, MATLAB.*

1   INTRODUCTION

Transcranial Direct Current Stimulation **(**tDCS) is a form of neurostimulation. In this process, very low levels of constant current are passed to specifically targeted areas of the brain, often producing profound results. It was originally developed to help patients with brain injuries such as strokes, Alzheimer's disease, schizophrenia etc. However, this stimulation tests on healthy adults demonstrated that, tDCS can increase cognitive performance on a variety of tasks, depending on the area of the brain being stimulated. Scientific studies have shown that, tDCS has the ability to enhance language and mathematical ability, problem solving, memory, and co-ordination. Moreover, tDCS has also been documented as having impressive potential to treat depression, anxiety, as well as chronic pain [1].

1.1 Background

Electricity has played a vital role in the history of medicine. During the first century AD, the Roman physician Scribonius Largus applied electric torpedo fish to patients' bodies to treat headaches. From that time, electricity has been pursued as a cure for various kind of illness.

If we jump ahead to the early 20th century, the spread of electric power in America renewed popular interest in bodily betterment through electricity. The latest chapter in this long and colorful history involves something called transcranial direct current stimulation (tDCS).

In the last few years, this method of electrical brain stimulation has caught the attention of scientists at some of the world's leading universities. They think it has potential for treating disorders like depression and chronic pain, helping people recover faster from strokes, and even enhancing learning, memory, and creativity in healthy people [4].
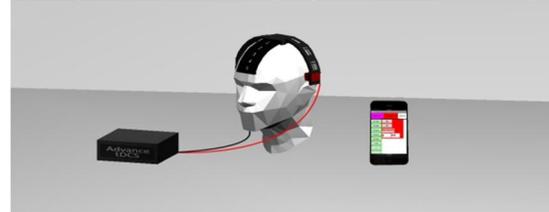

Fig. 1.1. Advance tDCS model.

1.2 Background

Hardware are used for this project are described below.

Headband is one of the major parts of this advance tDCS device. The headband is made of

metal bars. It comprises with a base. The base also consists of two hands. Among them, one is cathodal hand and other is anodal hand .These hands can move along with the base. There are two square boxes in each hand where electrodes are placed. These square boxes are also flexible to move. The headband has scaled up into numbers in order to find the perfect electrodes position.
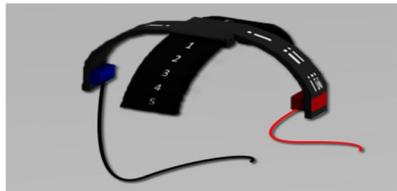

Fig. 2.1. Headband.

The electrodes used for tDCS are the critical components for a reliable and quality stimulation. There are many electrodes in the market. Among them, the cheapest and efficient option would be homemade sponge electrodes [5]. This can be done quite easily by taking a standard kitchen sponge, and attaching a conductive metal to the back such as stainless steel or copper.

Fig. 2.2. The Sponge Electrodes.

For processing the total system we used Arduino Uno which is based on Atmega328P [7].

LM334 is used as current regulating IC[8].

We have used DS1307 real time clock (RTC) module to count real time and date [9].

HC06 bluetooth module is used to to build a communication between device and android phone.

We have used a 7.4 V two cell battery with 1100mA capacity as power source for this tDCS device.

SD card module is used to store the neurostimulation data [10].

We also used resistors, power switch, battery charger, jumper wires, output socket and salt water and so on.

1.3 Software

Software used in this project is describe below.

Android Studio for developing an android app. This Matlab used to analyze the data.

Proteus used to design and simulate tDCS circuits..

Arduino IDE software is used to write program [11].

2   EXPERIMENTAL STUDIES

There are some measurements and analysis we did with some parts of this device. These topics are mentioned below.
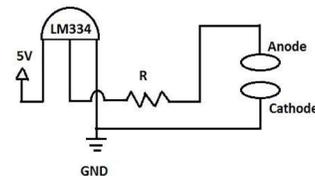
2.1 Current Regulation Circuit Using LM334

Fig. 3.1. Current regulating circuit.

We can regulate small amount of current using LM334 by changing resistor (R) values. From this circuit, we can get different amount of currents for different values of resistor (R). This is the basic principle to get desired amount of current at the electrodes of this device. We simulated this circuit in Proteus and also build this circuit on breadboard.

2.2 Comparison between Simulated and Measured Values from Regulating Circuit

After simulating the current regulating circuit in Proteus, we got different amount of current for the different values of resistors.
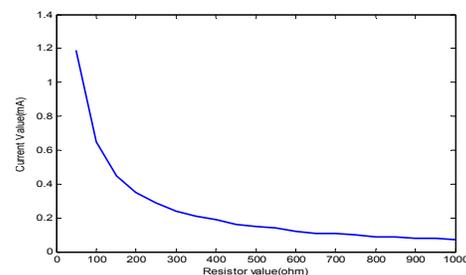

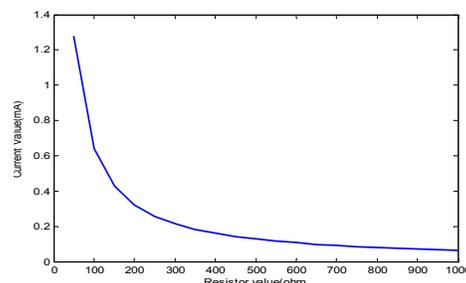*Fig. 2.1. Real, Resistance versus measured value of output current from current regulating circuit.*

Fig. 2.2. Simulated, Resistance versus output current from current regulating circuit.
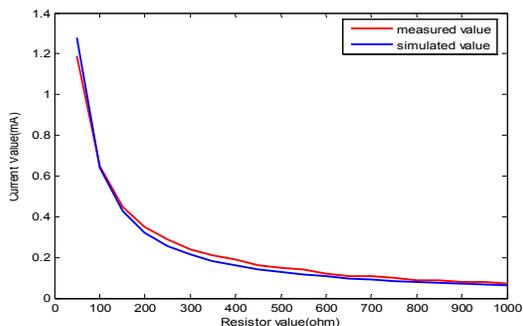
Fig. 2.3. Comparison between real and simulated values of output current from current regulating circuit.

From figure 3.3, we see that, the measured value indicates the red line and simulated value indicates the blue line. In this graph, the red line is slightly upper from the red one in most of the cases. That means, measured value is a bit higher than simulated value. Because, while measuring, the resistor values were not accurate in most of the times as those were supposed to be.

2.3 Operational Circuit of tDCS

In neurostimulation process, 0.1-2.0 mA current is used. Differenet types of treatment required differnet levels of current. We developed a circuit that can pass 0.1-2.5 mA current constantly. The circuit is given below
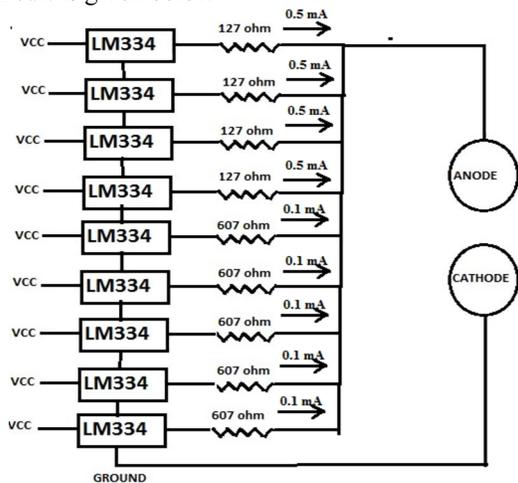

Fig. 2.4. tDCS Operational circuit.

The input voltage of LM334 is 5V and output voltage is 0.064V. In order to supply 0.1-2.5 mA current constantly , we added 9 LM334 IC parallely. Among them, four IC's are connected with 127 ohm resistors so that they can supply 0.5mA current each. Rest of the five IC's are connected with 607 ohm resistors so that they can pass 0.1mA current each. This combination helps to supply current between 0.1-2.5mA ranges.

2.4 Comparison between Simulated and Measured Value from Operational Circuit

Using Proteus, we simulated basic operational circuit, the simulation gave a specific resistor value in order to get a specific output current. But the practical circuit gave slightly different resistor value for specific output. Here, comparison between simulated circuit output and practical circuit output are given below
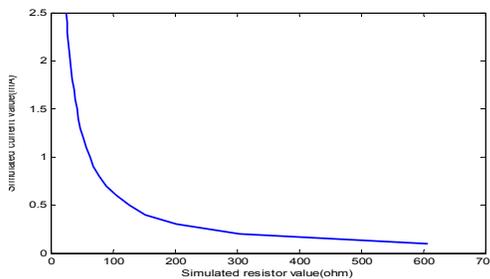

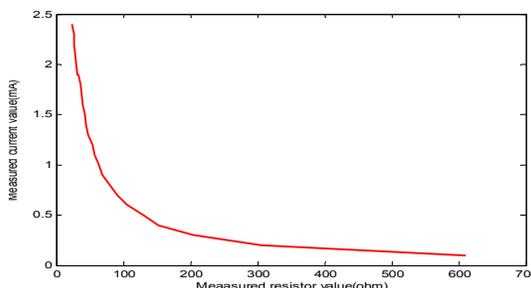*Fig. 2.5. Simulated current value from operational circuit.*

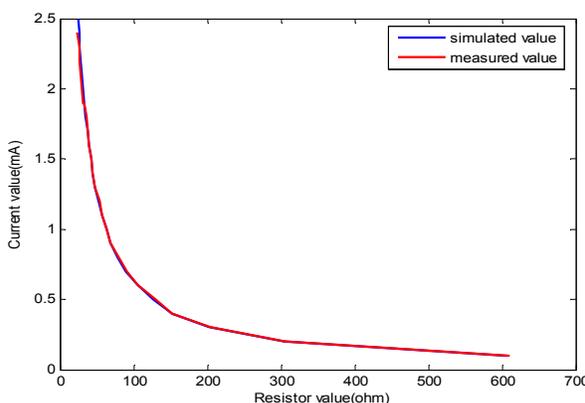*Fig. 2.6. Measured current value from operational circuit.*

Fig. 2.7. Simulated versus measured current value from operational circuit.

Figure 3.7 shows that, the red curve indicates measured current value and blue curve indicates simulated current value from the operational circuit of the device. We see that, measured current reached at 2.4mA from practical circuit. Simulated value always gives the exact value but practical circuit does not give the same. The shortage of

1mA current happened due to internal loss and not using exact resistances.

2.5 Input-Output Ratio of the Device

Our tDCS device is operated by an android app. We give command by this app to pass current. Against each command, we get the corresponding output current at the electrode. The output current is measured by multimeter.
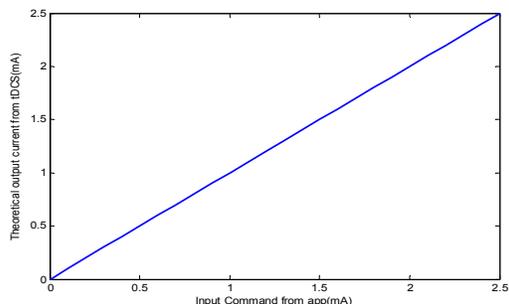

Fig. 2.8. Input command versus theoretical output current from tDCS
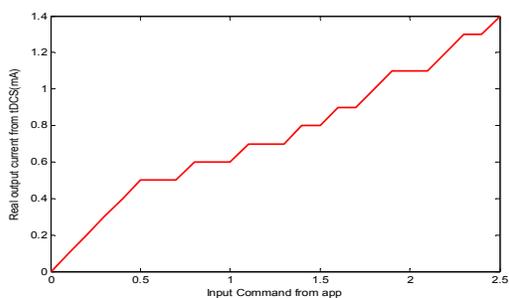

Fig. 2.9. Input command versus Real output current from tDCS
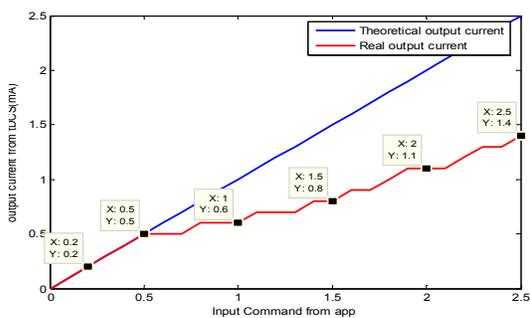

Fig. 2.10. Input output curve of tDCS device.

From figure 3.10, the input command and output current is same till the current level is 0.5 mA. As the current level increases, there is a discrepancy between input and output. The reasons for low output current are- the impure resistance, electrode conductivity loss and IC loss. We can improve this by using more accurate resistance and by using plastic headband instead of metal headband. In that case, the errors should be reduced. Here, the

maximum output current for the 2.5mA input is 1.4mA.

3 ADVANCE TDCS DEVICE

This tDCS device consists of three parts. These are Headband, circuit board and android app. This device has some unique features in three parts. These features provide a user to take more flexible and convenient tDCS session.

3.1 Advance tDCS Features

Headband is one most important part of this advance tDCS device. The headband comprises with a base which is numbered from (–V) to (+V). The base consists of two hands which are also numbered from (I) to (III). These two hands can move along with the base. There are two square boxes in each hand where electrodes are placed. These square boxes are also freely movable so that electrodes can be placed anywhere in user's head. Different diseases need specific and different electrode positions.
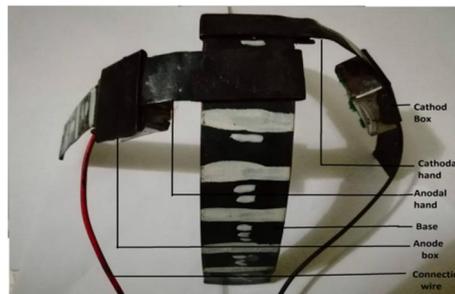

Fig. 3.1. Advance tDCS Headband

A real time clock and a SD card module added in the board so that the system is capable to store current passing data in real time and date in SD card. This stored data will be helpful for the user and the doctor as well for further treatment.
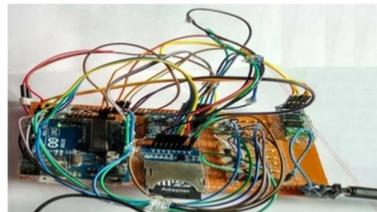

Fig. 3.2. The circuit board of the device

We developed an android app to operate this advance tDCS device. This app has to connect with the circuit board by Bluetooth.We can put commands for required current from this app.
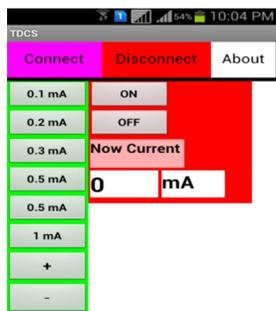
Fig. 3.3. Mobile app for the tDCS device when device is not connected.

3.2 Working Principle

Circuit board is the main part of tDCS device. This circuit board is processed by a processor ATMEGA328P. IC panel consists of some current regulating IC.   Different ICs supply different amount of currents. The processor controls the supply power to powers up the ICs on the basis of current requirement. Real time Clock and SD card module are connected with the processor. Real time clock counts the stimulation period. SD card module stores the current passing data with real time. A Bluetooth device is also connected with ATMEGA328P. The Bluetooth establish a communication between mobile app and circuit board. Anode is the positive part of electrodes. It is connected to the IC panel to supply the output into the brain scalp. Cathode is the negative part of the electrodes and it is connected to the ground. A power source is added with the board to supply required power of the system.
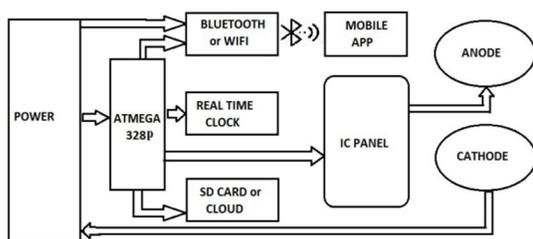

Fig. 3.4. Block diagram of the system

3.3 Transcranial Direct Current Stimulation Process

Neurostimulation session of this tDCS device starts with electrode placement finding. As we know, different treatment requires different position in head. As an example, figure 4.5 shows the electrode positions for treating depression. [12]
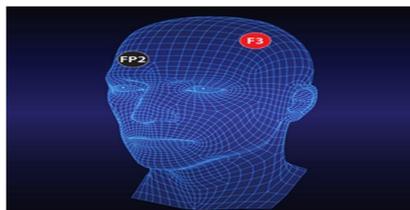

Fig. 3.5. Electrodes position for treating depression.

Electrode position need to be set according to the above figure and placed on user's head. After placing the electrode on head, the anode and cathode position were identified according to the headband scale. Anode position is (ii) in left hand of the headband. Cathode position is (i) in the right hand of the headband. The left hand position of the electrode is 0 and right hand position is (-V) with the base. In such way, the electrode position can be easily identified and user can able to recall the position in future.

Fig. 3.6. Headband placed on head.

After determining the electrode position, we have to saturate the upper part of the sponge electrode in salt water .This salt water soaked electrode facilitate the delivery of current from the stimulation device to the scalp.

After that, headband has to connect with the circuit board. By pressing the power button, circuit board will be turn on. Then the green light of ATMEGA328P will be on and red light of the Bluetooth module will be blinking.

From the android app, user has to find the Bluetooth module HC06 from Bluetooth search list and build the connection with it. As soon as the Bluetooth module connects with the app, the blinking of red light will be turn off.

Now, android app is connected with the circuit board and now user is ready to make desired current command. In the android app, there is an ON button. User has to press this ON button before putting a command to turn on data storage mode. Any amount of currents ranging from 0.1 mA to 2.5 mA can be supplied according to doctor's recommendation. The history of each session will be stored in text file form in SD card module. Figure 4.13 shows the data log of tDCS session.

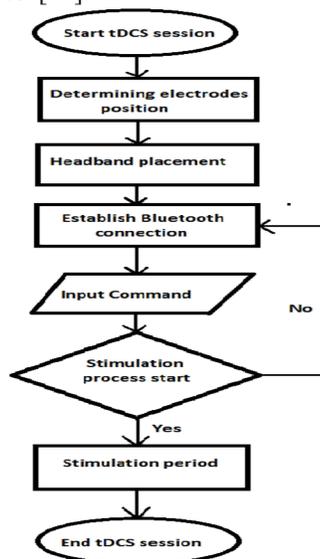The normal session time is anywhere between 5 to 30 minutes. [12]

Fig. 3.7. Flowchart of the tDCS process.

4 CONCLUSION

Our main focus was to build a model, which can give a user friendly solution to the users of this device.

4.1 Drawback

Working on this small limit of current(0.1mA - 2.5mA) was challenging. After the output current 0.5 mA, error arises. This problem arises due to the conduction loss, resistance loss and IC loss.

For 0.2 mA, we got practical value 0.2mA.
For 0.5 mA, we got practical value 0.5mA.
For 1 mA, we got practical value 0.6mA.
Error calculation for 1 mA,

Error (1mA) = ((Expected value-Real Value)/Expected value)*100%

= ((1mA-0.6mA)/1mA)*100%=40%

For 1.5 mA, we got practical value 0.8 mA.
Error calculation for 1.5 mA, Error (1.5mA)=46%

For 2 mA, we got practical value 1.1 mA. Here, there is some error.

Error calculation for 2 mA, Error (2 mA)=45%

For 2.5 mA, we got practical value 1.4 mA.
Error calculation for 2.5 mA, Error (2.5 mA) =44%

Average of all the errors from different output

$= \frac{0+0+40+46+45+44}{6} = 29$ %

The total experimental error of out project is 29%.

4.2 Project Outcome

The advance features of this project are,

- This device is user friendly and easy to operate through smart phone.
- User can easily place the electrode on their head anywhere within the pointed regions easily through using the scaling system in the electrode. At home use, users got confused to find the exact eletrodes position. Due to this scaling system, anyone can easily place the electrodes in the right place on head.
- We have included data storing system in this device to record the user history.

4.3 Doctors Opinion

Dr. Rama Biswas, Associate Consultant, Dept. of Neurology, Square Hospital Ltd,Bangladesh, said, "tDCS can be beneficial to initial stage in Parkinson's disease, strokes etc. I am optimistic about the future of tDCS in near future and this device is a user friendly device."

Dr. Md. Shafiqul Islam, Associate Professor and Neuro Sergeon of Dhaka Medical College and Hospital, Bangladesh, want to use this model of tDCS device for medical clinical trial.

4.4 Future Work

In future, our plan is to control the device by WiFi. As well as, we want to develop internet cloud based monitoring and storage system. So that, doctors will be able to monitor the system from anywhere in the world.

Project Demonstration

Demonstration video link:
https://www.youtube.com/watch?v=cvp-87lbAXA

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