

# Neurofeedback Prototype with Electroencephalography for Stimulation and Control, Using the Alpha Wave

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**Abstract**—This document is the result of a research project called design and implementation of a prototype EEG Neurofeedback for control and stimulation of alpha wave, where, Neurofeedback is identifier as a therapeutic technique that was development by the Chicago University, to reduce conditions such as stress, insomnia, physical exhaustion, and hallucinogens dependence. In the design and implementation of real-time Neurofeedback, were used instrumentation amplifiers (INA 128), and low-pass active filters, aiming to detect the alpha wave; which is in low frequency ranges, for analog operation was also used, the TL 084 amplifier and FPGA card, the module pmodAD1 with 12 bits of resolution, and the visualization is presented in a 7 inch VGA screen with a resolution of 640x480 pixels, and for recording the EEG signal was used cup electrodes. The prototype (Neurofeedback) is distinguished by features such as: Easy, Integrated viewing screen, rechargeable batteries, feedback and binaural sound with low cost compared with commercial Neurofeedback, allowing reducing the effects of stress and many symptoms more.

**Index Terms**—alpha wave, electroencephalography, FPGA, neurofeedback, therapeutic technique.

## I. INTRODUCTION.

The following research was called “prototype of neurofeedback with electroencephalography for control and stimulation, using alpha wave” its a prototype of therapeutic stimulation equipment and it based on a record of two channels EEG, and the use of the “Biofeedback ”; technique that was discovered in 1960, acts conditioned through the alpha wave. The software is used today for this type of methods, which unlike others, this prototype is able to process and show over a display LCD, and showing electroencephalography signal in real time and that from binaural sounds and visual stimuli obtains a bio-feedback according to the variations in the frequency of the signal work. These changes occur when the work signal adopts a range of frequencies below 12 Hz, while these frequencies not are produced these stimuli are not generated, but once the system detects the working signal then displays visual responses of different colors that indicating that the person is improving the

cerebral conditioning to lessen discomfort such as stress, insomnia, physical exhaustion and helps reduce dependence on hallucinogens.

## II. METHODOLOGY AND RESULTS.

Bio-feedback system, permits to acquire analog signals from the brain, specifically the alpha wave, for this are designed. The method is to convert these analog signals to digital and then store them in memory of an FPGA and graph them on one VGA screen. According to the detected wave are generated stimuli both visual and audibles across this algorithm in VHDL and of a circuit capable of generating binaurals sounds, those that will be used.

The system basically has the following phases of operation: the conditioning phase, adaptation and protection, control and processing phase and the last phase is visualization of stimuli. See Fig. 1.

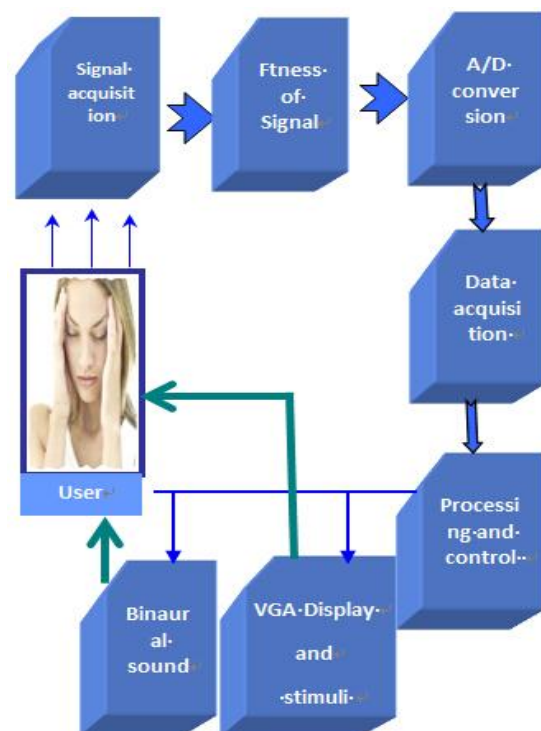


Figure 1. Proposed system. (Source: made by the authors)

**A. Power Supplies**

The circuit is powered by rechargeable batteries with positive and negative voltages, using a voltage regulator for a constant supply.

**B. Signal Acquisition**

For signal acquisition, an instrumentation amplifier is used to achieve so high common mode rejection. The electrodes act as sensors that can capture signals from the brain.

For the sake of getting better biopotential with the electrodes is used conductive paste for electroencephalography, called "ten20". See Fig. 2.



Figure 2. Conductive paste. (Source: <http://www.weaverandcompany.com/ten20.html>)

Sensors are used in total of three cup-shaped electrodes with gold washing, designed by brand Cadwell. See Fig. 3. The first electrode of red color, is called F as it is located in the frontal lobe of the brain (which usually generates beta waves), the second electrode of white color, is called O as it is located in the occipital lobe (which usually generates alpha waves) and the third electrode of black color, is called as R and is the reference of the system [1].



Figure 3. EEG electrodes (Source: Compiled by the authors.)

For amplification of the signal is used an amplifier with a gain of 10,000 times, for it was necessary to design two identical stages with gain of 100 times each and configure in mode cascade to boost profits, ie,  $100 \times 100 = 10000$  times [2].

Amplifier:

$$A_v = R_f / R_i$$

Assuming  $R_i$  1 K, we have:

$$100 = R_f / 1K\Omega$$

where  $R_f$  is a variable resistor, to modify the amplitude of the signal on the display screen.

$$R_f = 100 \text{ Kohm}$$

A second amplifier generates gain of approximately 10 times is and the level is adjusted to change the vertical position on the screen with a variable resistor.

**C. Fitness Signal.**

At this stage filters for each of the waves to be processed is designed. In the first instance an RC high pass mesh to remove 0.5Hz DC voltage level and low frequency noise, using active filters type Butterworth.

To get a signal without external noise interference was made an active second order low-pass filter of 30 Hz, that due to the characteristics of the beta wave is usually lower than this frequency, and the following calculations were used: Second order filter with a gain of 1,152 is used:

$$A_v = R_f / R_i + 1$$

Assuming  $R_i$  10 k we have:

$$R_f = 12.38K\Omega$$

To calculate the resistances of the filter, a 100nF capacitor is assumed and the Thevenin resistance is found using the following equation:

$$R_{th} = 1 / ( 2\pi \cdot f \cdot c )$$

$$R_{th} = 1 / ( 2\pi \cdot 100\text{nf} \cdot 30\text{Hz} )$$

$$R_{th} = 53.05K\Omega$$

$$A_v = R_f / R_i$$

$$R_f = 100 \text{ Kohm}$$

The level adapter is coupled to the amplifier with a voltage divider as shown in the above figure, which shows differences in amplification calculations, because in the previous stage was set enough gain, see fig. 4. The whole design was tested simulated using Proteus 7 Professional, and thus have greater security to implement a real circuit [3].

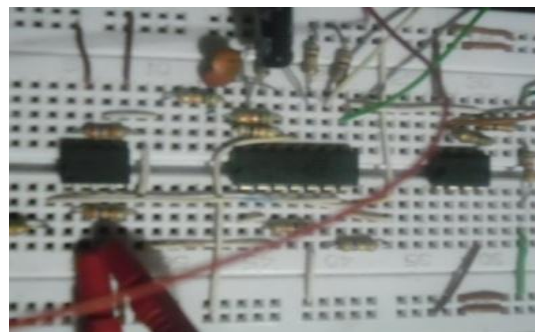


Figure 4. Test circuits and signals acquired. (Source: Made by authors)

After various tests and checks conditioning circuit operation to be performed, plate design was performed for actual assembly ensuring proper operation [4]. See Fig. 5.

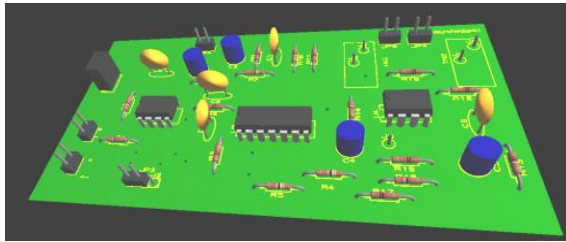


Figure 5. End plate design with Proteus and ARES. (Source: made by the authors)

#### D. Analog to Digital Conversion.

The analog to digital conversion was performed using the conversion system FPGA, with a resolution of 12 bit conversion. This software was also used to process the signal with digital filters. VHDL program called "control.vhd". Offered the general control system and allowed control of the prototype based on:

- Controlling the sampling rate of the A / D.
- Check that the signal is properly displayed.
- Show some parameters of the prototype and the modifications made by the user.
- Switching between the modes of operation of the prototype.

Converter (The PMOD AD1) module converts the signals to a maximum sampling rate of one million samples per second, fast enough for biomedical applications such as this. The AD1 uses a 6-pin connector, enough to be located in the signal source. See Fig. 6.

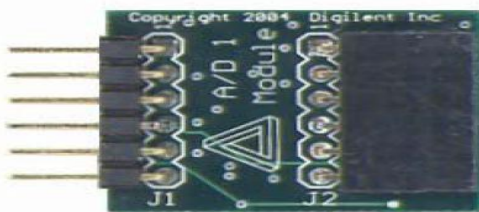


Figure 6. A/D converter. (Source: Digilent Systems)

#### E. Control and Processing.

The processor of the system is handled with the FPGA schematic and consisted of various stages in VHDL programming.

Initially programming containing a step of storing data in the RAM of the FPGA , and implementing a step of displaying signals capable of generating the required horizontal and vertical synchronization , taking data from the memory and then analyzing the data according to the analysis and generate stimuli. The stimuli are created by another program within the FPGA to generate an audible low frequency oscillation. The design using design methods for VHDL, schematic and library from Xilinx Spartan 3E FPGA for -100. Note that in this case, a description of the logic that I control signal monitoring

system in time and subsequent stimulation was performed.

The control system and processing occurs in different phases: the acquisition phase which is based on generating synchronous data input, phase filtering which was performed using the Matlab FDA\_TOOL, a phase control which processes and coordinates all required times, generating a phase oscillations for binaural sound reproduction and display design which stored in video memory and processes the data and visual stimuli to be viewed on a standard VGA monitor. See Fig. 7. Once completed the design of the acquisition card using fiberglass, looking to keep the circuit isolated from external noise.

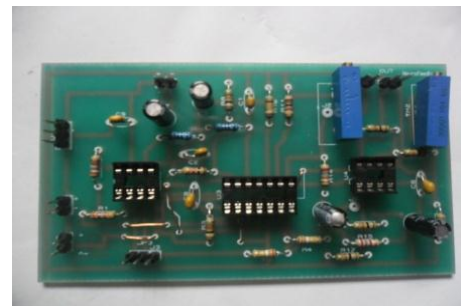


Figure 7. Final design of acquisition board. (Source: Made by authors)

To control the conversion module is an entity called AD1RefComp able to convert serial data to parallel, in addition to controlling the oscillations of peripheral PmodAD1 card and its activation was performed. Matlab with an entity called a filter, which operates as a digital low pass filter of 30 Hz, using for this purpose the tool FDA\_TOOL performed.

#### F. Display

The entity called "vgamemory" (implemented in VHDL source file called "vga\_mem.vhd" programming) represents a memory module dual port where the values obtained from the A / D are stored and then displayed on the screen, capacity of the memory array is 640 bytes and there every value in the memory array represents a pixel on the screen to obtain a resolution of 640x480 pixels.

Each entry in the memory corresponds to one column on the screen , where the value denotes the vertical coordinate of the pixel to be lit in the column , for example if the index value of 20 in the memory array is 42, means that the pixel referred to is the intersection of 20th column and row number 42 .

The contents of the entity called "vgamemory " is written by AD1RefComp module and is then read by the VGA controller, the disclosure will be detailed later. In the design, the memory usage of VGA is essential because the values stored in it are used for the operation of the various operating modes such as normal and pause, as these modes use the memory address data to display on the screen.

The entity VGA (implemented in the source VHD file named "vga.vhd ") is a video controller that handles video signals ("hs ", "v" and a byte capacity color levels). It based on these signals display module called Display is

composed of two entities: the memory block called VGA ("vgamemory") and the block called "VGA".

The Monitor can create a color image which is displayed on the screen. Logic horizontal coordinate (x) denotes a column on the screen. Its value is taken to the driver through the targeting signal and is used to direct the video memory and logic represents the vertical coordinate that denotes a row on the screen. Therefore, the signal trace on the screen consists of pixels on the same coordinates with matching pairs [x, data]. See fig. 8.

Furthermore, this entity is equipped to detect the frequency of 12 Hz characteristic of alpha waves, which is again detected by the system will be generated within the grid display different colored rectangles with a motion effect that is capable of stimulating these same [5]. When the system detects this box often stay one color. See Fig. 8.

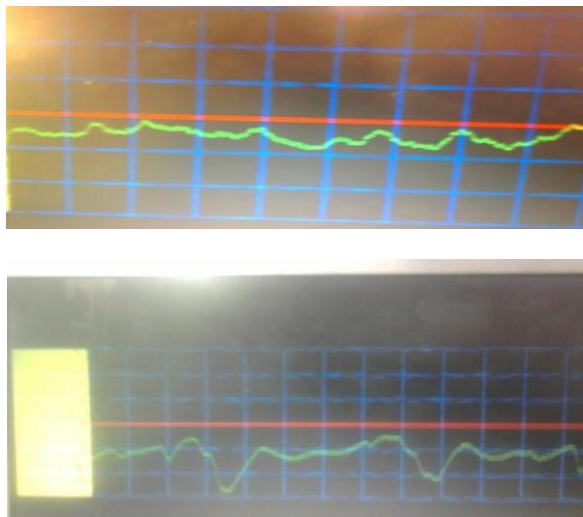


Figure 8. Colors of stimulation and visual signals. (Source: Made by authors)

G. Sound

The entity responsible for generating the binaural sound which works using different counters using internal FPGA glass, generated in three different entities called sound, and sound2 sound1 turn controlled by another entity called selson. This design loops three binaural sounds of different frequencies, the first of 200Hz, the second and third 150HZ 90Hz [6].

Each of these sounds has its complement 12Hz stereo were added in order to stimulate that frequency, allowing the sound change whenever an alpha wave is detected and will be synchronized with the visual stimuli already mentioned, for dual feedback [7].

III. EXPERIMENTAL RESULTS

To observe the characteristics of a basic prototype test run was performed, performing 20 sessions of stimulation to 30 individuals to analyze the results obtained with this prototype. The conditions under which this test the subjects assure being in an environment without noise concerns distract them, increasing their ability to concentrate was performed.

The test subjects, male gender, with ages being 23 and 30 years, underwent to 15 minute sessions, always in the afternoon, with the results shown in Table I and fig. 9 were obtained (Average).

As can be seen in very few sessions, about 12, is possible to obtain the 100 % of effectiveness in the process, it looks great apprehension of stimuli and the actual outcome for relaxation of the individual concerned. See Table I.

From the graphs (Fig. 9) above show that a greater number of sessions attracting stimuli becomes more efficient with a loss of less than 7% stimuli, thereby ensuring the effectiveness of the device and treatment.

TABLE I. SESSIONS AND STIMULUS MADE.

SESSIONS	Indiv. No. 1	Indiv. No. 2	Indiv. No. 3	Indiv. No. 4
	STIMULUS RAISED	STIMULUS RAISED	STIMULUS RAISED	STIMULUS RAISED
1	2	1	5	5
2	3	4	6	5
3	3	4	7	5
4	4	5	8	5
5	4	5	8	6
6	5	6	8	7
7	7	8	9	7
8	7	8	9	8
9	8	9	9	8
10	9	9	10	9
11	9	10	10	9
12	10	10	10	10
13	10	10	10	10
14	10	10	10	10
15	10	10	10	10
16	10	10	10	10
17	10	10	10	10
18	10	10	10	10
19	10	10	10	10
20	10	10	10	10

Source: Make by the authors in Excel.

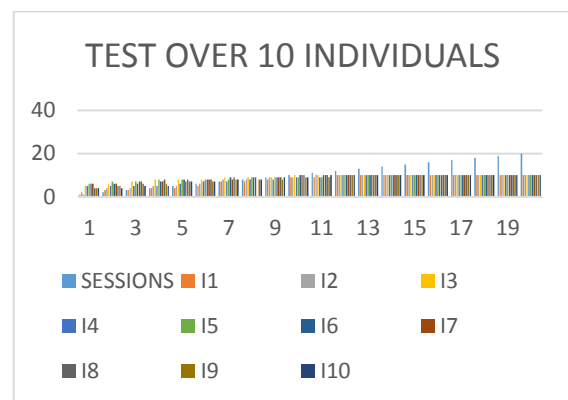


Figure 8. Graph of stimuli. (Source: Make by the authors in Excel.)

IV. CONCLUSIONS

The proper recording of biological signals from the brain and its use as an activator of stimuli with different colors and display purposes, that achieve a relaxed state of the patient, improving conditions such as drug, tobacco, alcohol, stress, depression, insomnia, anxiety, ADHD (inattention deficit disorder and hyperactivity)

among others, as well as improve their powers of concentration, attention and memory, it is possible with the prototype of Neurofeedback.

The use of digital filtering in recording brain electrical potentials, is a good solution to eliminate interfering elements as the common mode noise and low frequency.

Digital systems without significant solution for medical applications and clinical potential recording and filtering and processing, ensuring acceptable short-term results and independent little controllable external noises.

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