Bulletin of the *Transilvania* University of Braкov ÅVol. 9 (58) No. 2 - Special Issue ï 2016
Series I: Engineering Sciences

TRAINING SYSTEM FOR BRAIN ACTIVITY MONITORING

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Abstract: *The most common instrument for monitoring the electric activity of the brain is the electroencephalograph. For students' training in construction and maintenance of these type of medical instruments, commercial integrated items are not enough illustrative and, also, they are expensive for operations like repetitive disassembly and parts testing. For the purpose of learning in Medical engineering a scholar low-cost alternative was designed and built in The Medical Engineering laboratory. The paper presents this practical solution, having as background basic knowledge on the brain electric activity.*

Key words: *Electroencephalography, brain, EEG, electrodes, amplifier.*

1. Introduction

The human brain is the known most complex organic material and is, not surprisingly, the subject of extensive research.

An early discovery established that brain activity is associated with the generation of electricity. Richard Caton demonstrated in 1875 that electrical signals in mV range can be recorded on the cerebral cortex of rabbits and dogs. [2] A few years later, Hans Berger recorded the first *brain wav*es by attaching electrodes on the human scalp, waves having an oscillatory behaviour that varies with time, which differ in form from one location on the scalp to another.

Electroencephalography (EEG) is a medical imaging technique that reads scalp electrical activity generated by brain structures. The EEG is defined as electrical activity of an alternating type recorded from the scalp surface after being picked up by metal electrodes and conductive media [9].

When brain cells (neurons) are activated, local current flows are produced. EEG measures mostly the currents that flow during synaptic excitations of the dendrites of many pyramidal neurons in the cerebral cortex [10]. Differences of electrical potentials are caused by summed postsynaptic graded potentials from pyramidal cells that create electrical dipoles between soma (body of neuron) and apical dendrites (neural branches). Brain electrical current consists mostly of Na^+, K^+, Ca^{++}, and Cl^- ions that are pumped through channels in neuron membranes in the direction governed by membrane potential [10].

Brain patterns form wave shapes that are commonly sinusoidal. Usually, they are measured from peak to peak and normally range from 0.5 to 100 µV in amplitude,

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which is about 100 times lower than ECG signals [11]. By means of Fourier transform power spectrum from the raw EEG signal is derived. In power spectrum contribution of sine waves with different frequencies are visible.

Brain waves (Fig. 1) have been categorized into five basic groups: alpha (8-13 Hz), beta (>13 Hz), gamma (33 - 55 Hz), delta (0.5-4 Hz), and theta (4-8 Hz).

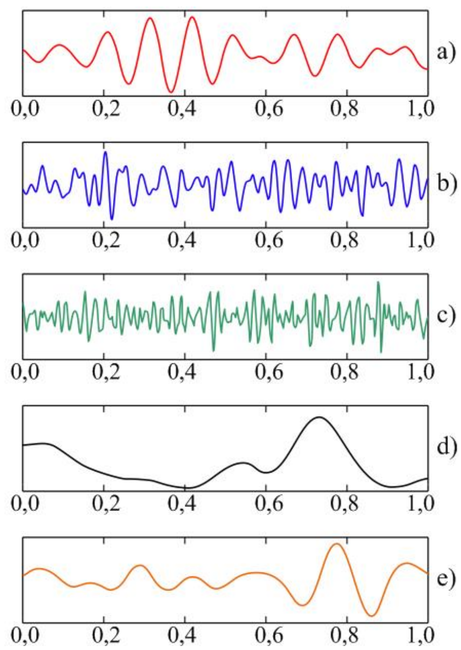


Fig. 1. *Brain wave samples with dominant frequencies belonging to: alpha (a), beta (b), gamma (c), delta (d), and theta (e) band*. [4].

2. Design and construction of EEG

An EEG machine is a device used to create a picture of the electrical activity of the brain. It has been used for both medical diagnosis and neurobiological research [1]. The essential components of an EEG machine include electrodes, amplifiers, a computer control module, and a display device. Manufacturing typically involves separate production of the various components, assembly, and final packaging [1].

Only large populations of active neurons can generate electrical activity recordable on the head surface. Between electrode and neuronal layers current penetrates through skin, skull and several other layers. Weak electrical signals detected by the scalp electrodes are massively amplified, and then displayed on paper or stored to computer memory [11].

The EEG subject of this paper was designed and built in the Laboratory of Medical Engineering.

It consists of two subsystems:

- hardware subsystem contains the electrodes, cables, amplifier and, a development microcontroller platform Arduino Mega2560;
- software subsystem consisting in: the code and the software for signal acquisition and Processing code for displaying it.

The used electrodes are disposable medical electrodes, connects easily via cable, can be removed easily, and are silver/silver chloride (Ag/AgCl) covered. They are round in shape with a 24 mm diameter and 452 mm^2 total area of. Gel coated surface is 201 mm^2 and the adhesive's one is 251 mm^2. The area in which we find sensor signal sampling is about 80 mm^2.

A pair of electrodes detects the electrical signal from the body. Wires connected to the electrodes transfer the signal to the first section of the amplifier, the buffer amplifier. Here the signal is electronically stabilized and amplified by a factor of five to 10. A differential pre-amplifier is next in line and it filters and amplifies the signal by a factor of 10-100 [1]. Amplifiers (Fig. 2), which receive direct signals from the patient, are isolated as to prevent the possibility of accidental electric shock [1]. The primary amplifier is found in the main power circuit. In this powered amplifier the analogue signal is converted to a digital signal, which is more suitable for output [1].

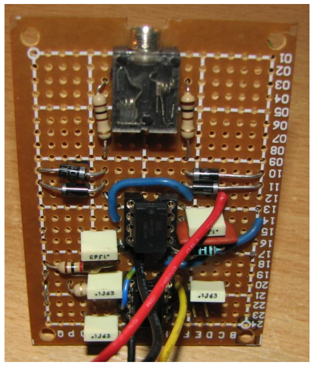


Fig. 2. *Amplifier*.

The electrical circuit of the system was designed in EAGLE 7.3.0 software, details of the case on the implementation of the electric amplifier (calculation of passive components) being presented in [8].

Arduino is an open-source platform for prototyping and physical computing based on a simple microcontroller board and a development environment for writing software for the board.

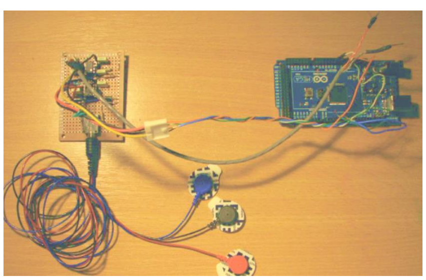


Fig. 3. *Electrodes connected to the amplifier and this one to Arduino Mega 2560 board*.

Arduino Mega 2560 is a microcontroller board based on the ATmega2560 with: 54-pin digital input / output (of which 15 can be used as PWM outputs), 16 analogue inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, an USB connection, a power jack and, a reset button, being connected to a laptop via USB. [6] The amplifier is connected to Arduino MEGA board shown in the figure 3.

Software Arduino is an open source tool available for extension through C ++ libraries and through the AVR C programming language on which it is based. If necessary, other AVR-C codes can be added directly into Arduino programs.

Processing is a programming language open source, development environment and online community for viewing the signal. He was chosen because is Arduino compatible, easy to use and because it is compatible with GNU / Linux, Mac OS X and Windows and has more than 100 libraries.

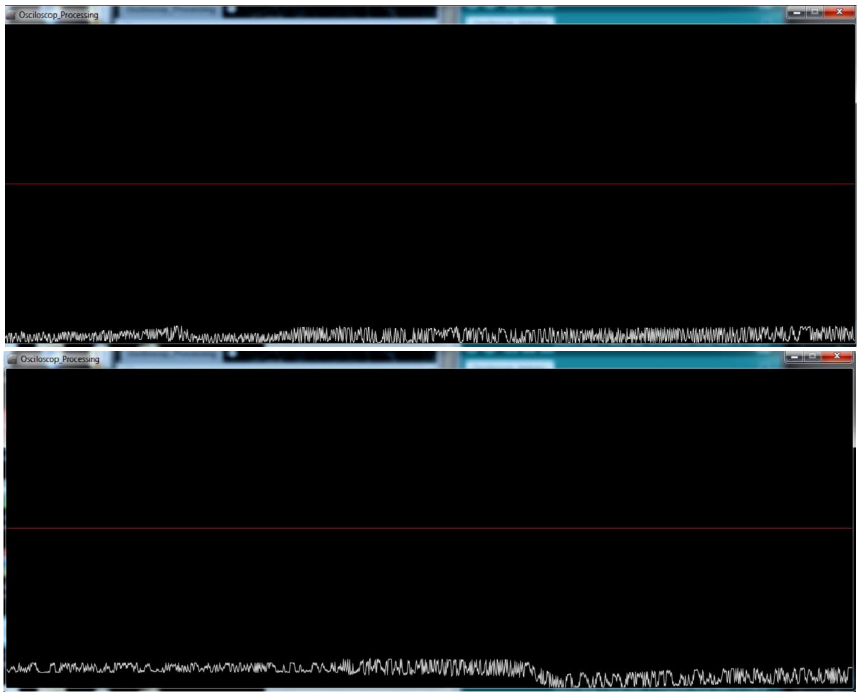
3. Results

To see if this system is functional and if indeed, the signals taken from the skull surface are displayed, it was tested on three human subjects, simply named below as Subject 1, Subject 2 and, Subject 3.

The potential difference between the back of the head (occipital area) and by ear (temporal area - mastoid bone) was recorded. For all three subjects, three electrodes were placed in the same areas on the skull surface as follows:

- positive electrode (+blue) was placed on the occipital area;
- negative electrode (- black) was placed on the mastoid bone, namely temporal area;
- electrode GND (red) was placed on the other mastoid bone, but can be placed anywhere, including on the forehead.

Recording the potential difference between the occipital and temporal area, a signal from the visual cortex was recorded in form of alpha waves with subjects having open or closed eyes (Fig. 4, 5, 6, 7).



a)

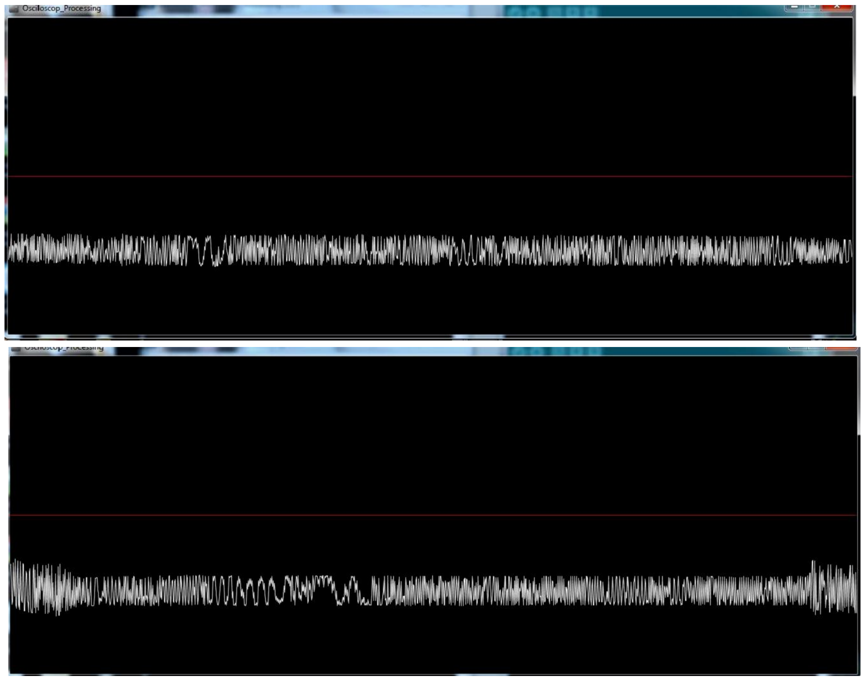
b)

Fig. 4. *Recordings on the Subject 1: open eyes (a); partially with closed eyes (b).*

(a)

b)

Fig. 5. *Recordings on the Subject 2: open eyes (a); closed eyes (b).*



(a)

b)

Fig. 6. *Recordings on the Subject 3: open eyes (a); closed eyes (b).*

Fig. 7. *Subject 1: cerebral inactivity (removing electrodes).*

The observed alpha waves were different from a subject to another in both situations as well as for the same subject having open or closed eyes.

In the figure 4, a can be seen the brain activity of Subject 1 when he has his open eyes.

For this recording new electrodes were used and the signal is the clearest we obtained.

In Fig. 4, b can be seen the signal difference when Subject 1 close his eyes, after a stabilization duration. A small slope down signal is visible as a result of a lower cerebral activity.

The same recordings were performed for the Subject 2 (Fig. 5, a, b) but, this one had, in the second part of the test, closed eyes. The signal is less strong because the conductive gels ensure a weaker contact.

The signal for both subject 1 and for subject 2, while the eyes are closed is much lower, typically alpha waves during relaxation.

For the last subject was done the same (Fig. 6), but also, the medical electrode has not been changed and, thus a comparison between the signals collected with new and used medical electrodes can be made.

After completing signal sampling of Subject 1, electrodes (the new ones) were removed and it can be seen that brain signal stops, as in inactivity.

4. Conclusion

The monitoring system has the advantage of being very easy to use for educational purposes for viewing different brain rhythms.

Although the tests focused on monitoring electric signals taken from the brain, this system can be used to monitor any electrical signal (EMG, ECG, etc.).

Another advantage is the system low cost; its price is given by the cost of electronic components, for the construction of the amplifier and Arduino board, software and drivers for this system is open - source. Also, the system can connect to any single PC, laptop or other hardware that can support Arduino board drivers and communication with the user as well as, Processing to display the signal.

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