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SIMPLE CIRCUIT FOR MONITORING BRAIN ACTIVITY

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Abstract: *This paper presents the design and construction of an EEG (a low-cost alternative teaching) but also a number of issues on monitoring brain activity. They are also presented and brain waves with their most important characteristics.*
Keywords: *Electroencephalography, brain, EEG, electrodes, amplifier*

1. INTRODUCTION

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 [1].
The EEG measured directly from the cortical surface is called electrocortiogram while when using depth probes it is called electrogram. In this article, we will refer only to EEG measured from the head surface. Thus device is a completely non-invasive procedure that can be applied repeatedly to patients, normal adults, and children. 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 [2]. 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 [2]. 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 [3].

2. BRAIN ELECTRICAL ACTIVITY

Researchers have established certain correspondence between the different states of the human being and characteristics of brain electrical activity, objectified in the form of waves occurring celebrities each state. These brain waves are received by electrodes placed on the scalp and routes EEG is recorded on the variation of potential differences between pairs electrodes selected by the examiner [4]. Plotted brain electrical activity falls by certain sequences where sinusoidal or sharp, synchronous or asynchronous, rhythmic or seemingly random, allowing characterization of the route as physiological (normal) or with amendments lesions or irritative [4].
The trail has several types of electroencephalographic where, following investigations establishing relationships based clinical statistically significant differences between the clinical phenomena and these waveforms, differentiated bands [4]. For obtaining basic brain patterns of individuals, subjects are instructed to close their eyes and relax. 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, which is about 100 times lower than ECG signals [3]. 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 have been categorized into four basic groups: beta (>13 Hz), alpha (8-13 Hz), theta (4-8 Hz), and delta (0.5-4 Hz) - Figure 1 and Table 1. The adult man awake, alert, EEG recorded bipolar junction presents usually two types of waves: alpha and beta.

Alpha waves can be usually observed better in the posterior and occipital regions with typical amplitude about 50 µV (peak-peak)- Table 1. Alpha activity is induced by closing the eyes and by relaxation, and abolished by eye opening or alerting by any mechanism (thinking, calculating). Most of the people are remarkably sensitive to the phenomenon of “eye closing”, i.e. when they close their eyes their wave pattern significantly changes from beta into alpha waves [2].

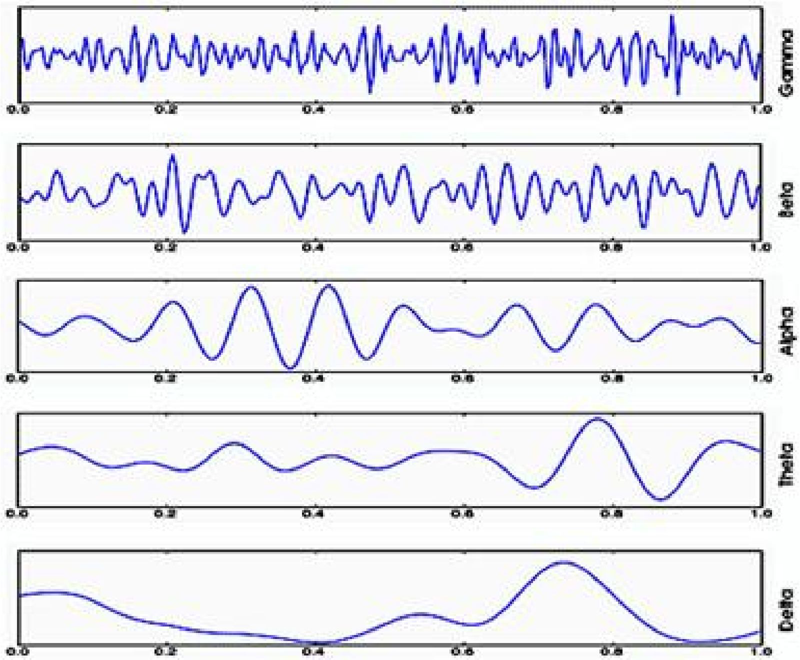

Figure 1: Brain wave samples with dominant frequencies belonging to beta, alpha, theta, and delta band. [5]

Table 1: Brain waves features. [6]

State	**Frequency (cps)**	**Amplitude (µV)**	**Comment**
Gamma	25-60	0.5-2	Hyper-aroused and quite dangerous to the brain
Beta	12-25	1-5	Conscious brain state. Fast dysnchronous activity.
Alpha	8-12	20-80	Conscious brain state. Synchronous activity.
Theta	4-8	5-10	Usually unconscious. Slow rhythmic activity.
Delta	0.5-4	100-200	Usually unconscious. Very large rhythmic activity.

Beta waves are known as high frequency low amplitude brain waves that are commonly observed while we are awake. They are involved in conscious thought, logical thinking, and tend to have a stimulating affect. Having the right amount of beta waves allows us to focus and complete school or work-based tasks easily. Having too much beta may lead to us experiencing excessive stress and/or anxiety. The higher beta frequencies are associated with high levels of arousal [7].

Gamma waves are involved in higher processing tasks as well as cognitive functioning. Gamma waves are important for learning, memory and information processing. It is thought that the 40 Hz gamma wave is important for the binding of our senses in regards to perception and are involved in learning new material. It has been found that individuals who are mentally challenged and have learning disabilities tend to have lower gamma activity than average [7].

Theta waves particular frequency range is involved in daydreaming and sleep. Theta waves are connected to us experiencing and feeling deep and raw emotions. Too much theta activity may make people prone to bouts of depression and may make them “highly suggestible” based on the fact that they are in a deeply relaxed, semi-hypnotic state. Theta has its benefits of helping improve our intuition, creativity, and makes us feel more natural. It is also involved in restorative sleep [7].

Delta waves are the slowest recorded brain waves in human beings. They are found most often in infants as well as young children. As we age, we tend to produce less delta even during deep sleep. They are associated with the deepest levels of relaxation and restorative, healing sleep [7]. They have also been found to be involved in unconscious bodily functions such as regulating heart beat and digestion. Adequate production of delta waves helps us feel completely rejuvenated after we wake up from a good night's sleep [7].

3. DESIGNED AND CONSTRUCTION OF EEG

3.1 Introduction

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 [8]. 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 [8]. The function of an EEG machine depends on the fact that the nerve cells in the brain are constantly producing tiny electrical signals. Nerve cells, or neurons, transmit information throughout the body electrically. They create electrical impulses by the diffusion of calcium, sodium, and potassium ions across the cell membranes. When a person is thinking, reading, or watching television different parts of the brain are stimulated. This creates different electrical signals that can be monitored by an EEG. The electrodes on the EEG machine are affixed to the scalp so they can pick up the small electrical brainwaves produced by the nerves. As the signals travel through the machine, they run through amplifiers that make them big enough to be displayed. Depending on the design, the EEG machine then either prints out the wave activity on paper (by a galvanometer) or stores it on a computer hard drive for display on a monitor [8].

3.2 Design

The basic systems of an EEG machine include data collection, storage, and display. The components of these systems include electrodes, connecting wires, amplifiers, a computer control module, and a display device. In the United States, the FDA (Food and Drug Administration) has proposed production suggestions for manufacturers of EEG machines [8]. The electrodes, or leads, used in an EEG machine can be divided into two types including surface and needle electrodes. In general, needle electrodes provide greater signal clarity because they are injected directly into the body. This eliminates signal muffling caused by the skin. For surface electrodes, there are disposable models such as the tab, ring, and bar electrodes [8]. There are also reusable disc and finger electrodes.

The EEG was designed and built in the Laboratory of Medical Engineering (Faculty of Product Design and Environment) in a works license in 2015. The shape of the electrodes used in this project is round with a diameter of Ø 24 mm and a total area of 452 mm^2. Gel coated surface is 201 mm^2 and the adhesive is 251 mm^2. The area in which we find sensor signal sampling is 80 mm^2. These are disposable medical electrodes, connects easily via cable and can be removed easily. The sensor is a polymer clad in silver / silver chloride (Ag/AgCl) and connector is Stainless.

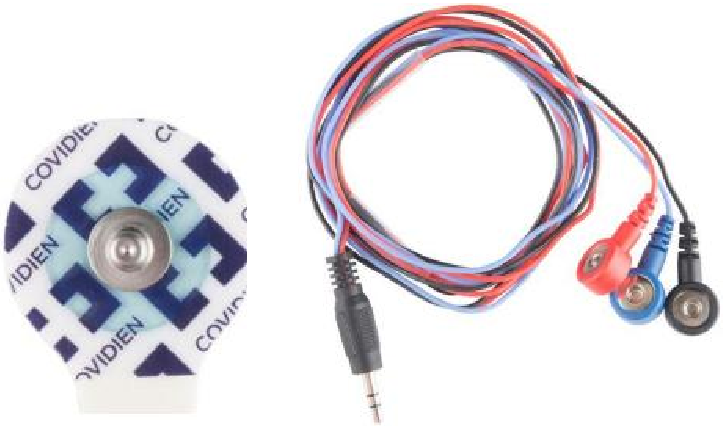

Figure 2: Type of EEG electrodes and wires contact used in this project

The EEG amplifiers convert the weak signals from the brain into a more discernable signal for the output device. They are differential amplifiers that are useful when measuring relatively low-level signals. In some designs, the amplifiers are set up as follows. 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 that filters and amplifies the signal by a factor of 10-100 [8]. After going through these amplifiers, the signals are multiplied by hundreds or thousands of times. This section of the amplifiers, which receive direct signals from the patient, use optical isolators to separate the main power circuitry from the patient. The separation prevents the possibility of accidental electric shock [8]. The primary amplifier is found in the main power circuitry. In this powered amplifier the analog signal is converted to a digital signal, which is more suitable for output [8]. In this project we used an instrumentation amplifier (INA 126U) and operational amplifier (TL071P) as basic components of the system.

The INA126 (Figure 3) are precision instrumentation amplifiers for accurate, low noise differential signal acquisition. Their two-op-amp design provides excellent performance with very low quiescent current (175µA/channel). This, combined with a wide operating voltage range of ±1.35V to ±18V, makes them ideal for portable instrumentation and data acquisition systems [9].

The electrical circuit of the system was designed in software EAGLE 7.3.0 and shown in Figure 4. Details of the case on the implementation of the electric amplifier (calculation of passive components) are presented in Reference [4]. In the first stage amplifier was conducted on a test plate as shown in Figure 5.

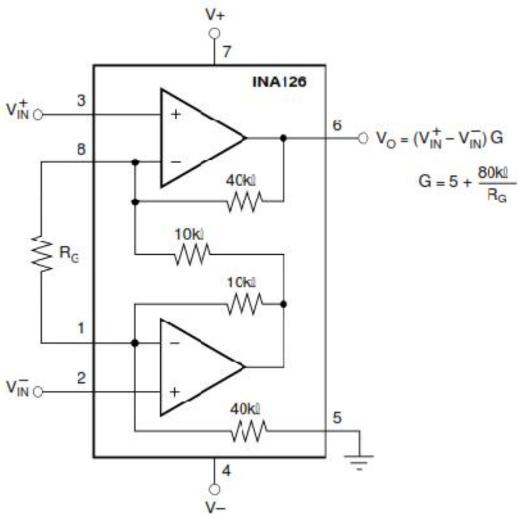

Figure 3: INA 126 - Electric circuit [9].

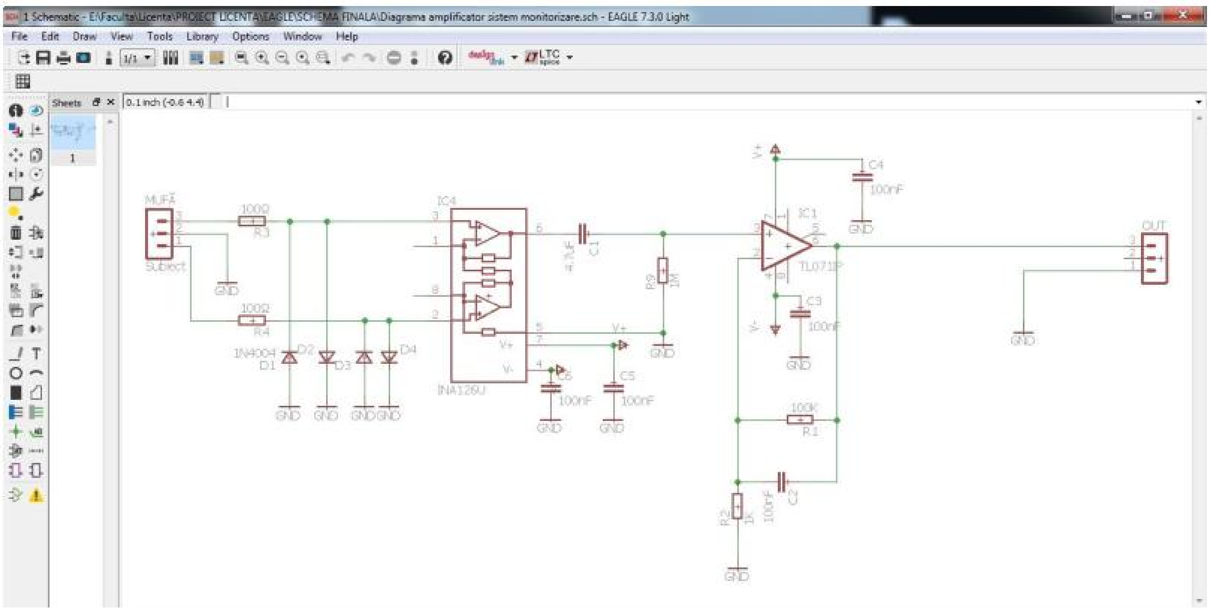

Figure 4: Amplifier- electric circuit.

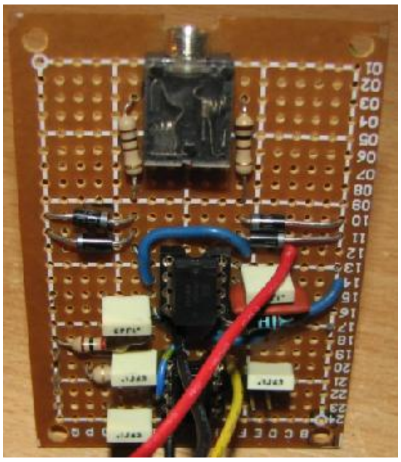

Figure 5: Amplifier realized on a test plate.

The amplifier built is connects to Arduino MEGA 2560 board as shown in Figure 6.

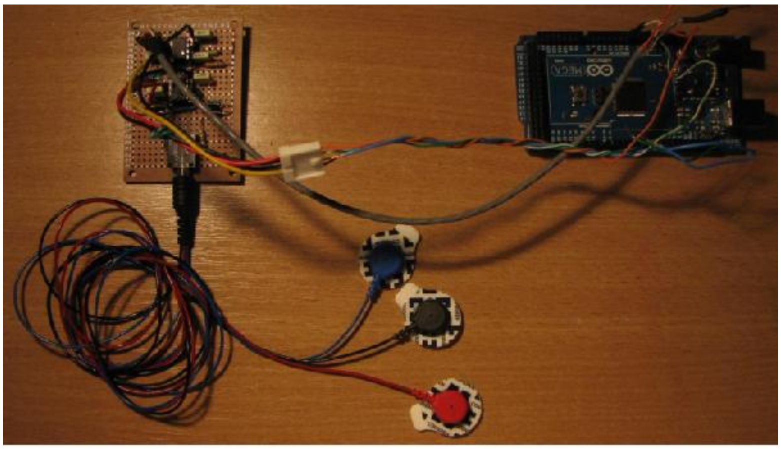

Figure 6: The monitoring system (EEG). Connect the electrodes to the amplifier and after to the Arduino MEGA 2560.

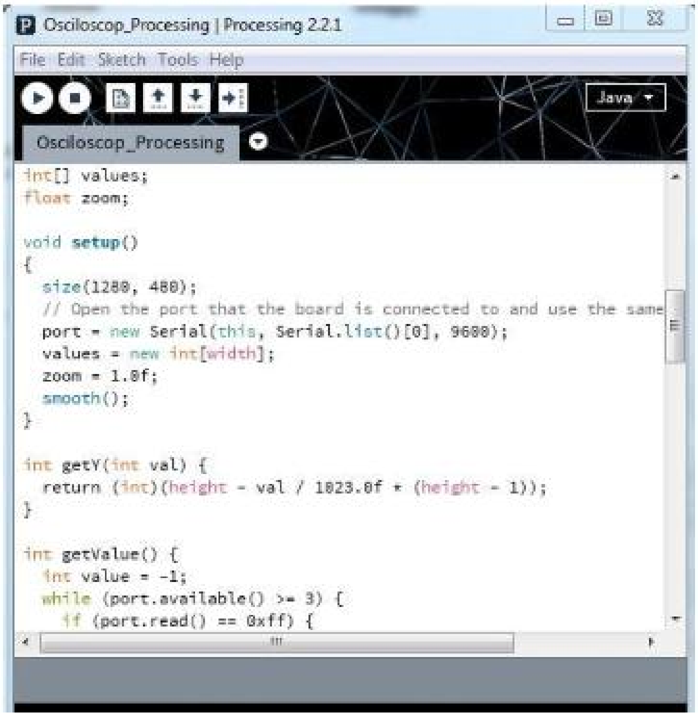

Figure 7: Procceing software interface.

For vizualiarea signals from amplifier to use Proccesing software that is compatible with Arduino boards. Processing is a flexible software sketchbook and a language for learning how to code within the context of the visual arts.
Processing is an open source language/development tool for writing programs in other computers. Useful when you want those other computers to "talk" with an Arduino, for instance to display or save some data collected by the Arduino (Figure7).
After loading the codes should have a series of tests with the device in the Laboratory of Medical Engineering. The first results obtained with this device can be found in reference [4].

3. CONCLUSION

This system was built for educational purposes and not clinical. EEG is a low-cost variant used in the Laboratory of Medical Engineering to familiarize students with this type of medical equipment. Currently working on a new system with superior performance.

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