

ELECTROENCEPHALOGRAM: CONTROL DEVICES WITH MIND-WAVES

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Abstract: Due to an increase in number of paralyzed patients, encephalon-controlled environment is important in order to facilitate automated assistance and mobility to accomplish complex tasks in realistic environments. It includes the development of navigation strategies and personalized interactive assistance to enable the patients to move and live effectively and easily. In this paper, a research on how to control certain devices like lights, fans, computer mouse-pointer, and a wheelchair, using our own thought process, is shown. It is achieved by the means of an electroencephalogram, which is an electrophysiological monitoring device that records the electrical activities of the brain.

Index Terms: Electroencephalography, Brain, Mind waves, Cognition, Microcontrollers

I. INTRODUCTION

In 1929 Hans Berger published his observations on what he termed ‘*das Elektrenkephalogramm*’ which would become the influential paper highlighting the beginning of examination on the human electroencephalogram also abbreviated as EEG. In his first experiments he documented the EEG from his son Klaus and described extensively the approaches he used and what he observed. He stated 2 things.

Firstly, it was possible to record the frail electric currents generated on the brain, without opening the skull, and to portray them graphically onto a strip of paper. Berger termed this new form of recording as the **electroencephalogram** (EEG, for short) and second that this action altered according to the functional status of the brain, such as in sleep, anaesthesia, hypoxia (lack of oxygen) and in certain nervous diseases, such as in epilepsy.

Fundamentally, the entire system works on the principle of Electroencephalography. It is typically non-invasive, with the electrodes positioned along the scalp, although invasive electrodes are sometimes used in specific applications. EEG measures voltage variations resulting from ionic current inside the neurons of the brain.

Diagnostic applications generally focus on the spectral content of EEG, that is, the type of neural oscillations (popularly called "brain waves") that can be observed in EEG signals.

We're going to use two very accurate values.

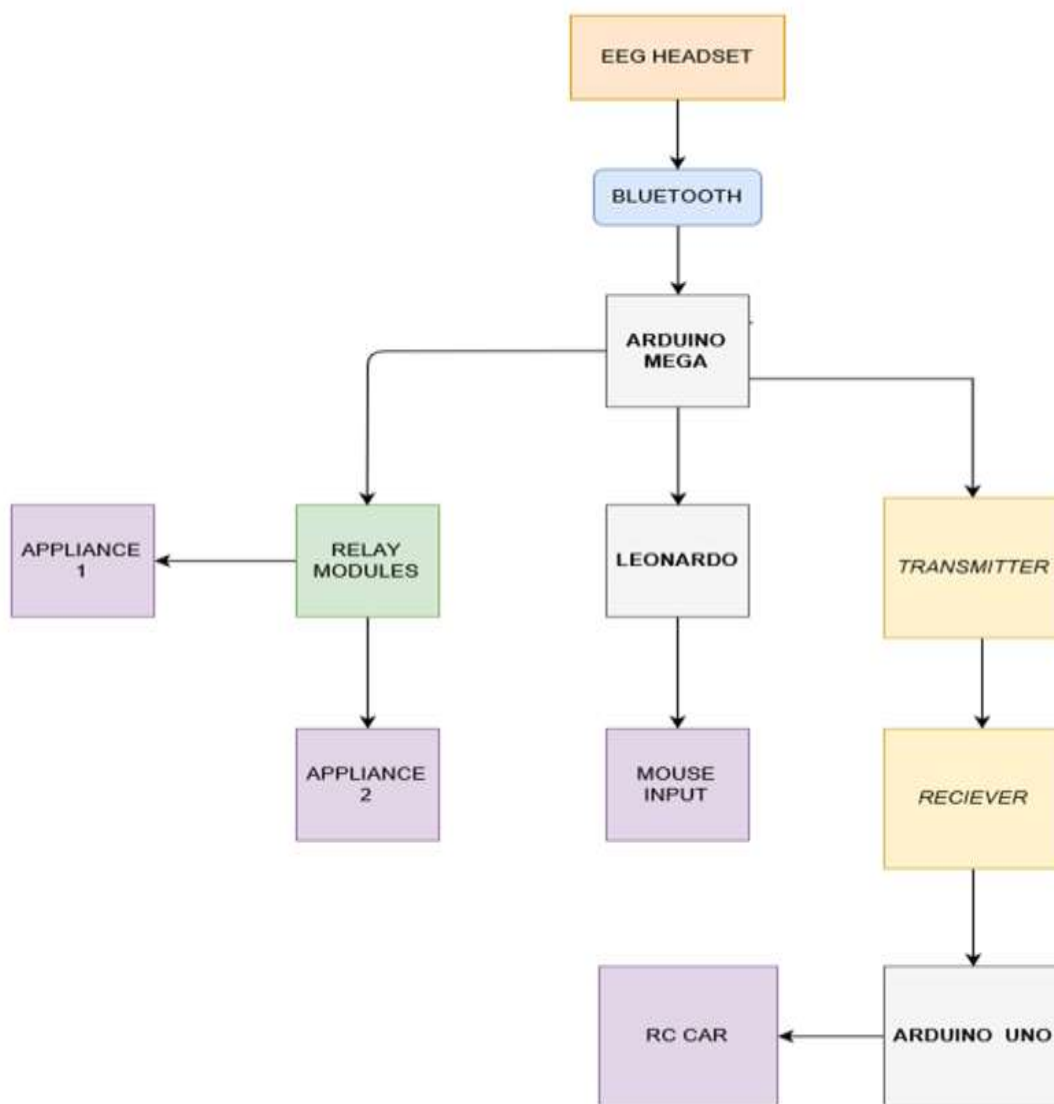
- A. Alpha is the frequency range from 7 Hz to 14 Hz. It emerges with closing of the eyes and with relaxation and attenuates with eye opening or mental exertion.
- B. Beta is the frequency range from 15 Hz to about 30 Hz. Low amplitude beta with multiple and varying frequencies is often associated with active, busy or anxious thinking and active concentration.

II. AIM AND OBJECTIVE

The aim of this project is to classify the EEG signal to control a three-way system: - (1) A couple of appliances, (2) the mice of a computer and (3) controlling a basic wheelchair's movement. The specific objectives are:

- A. To acquire and process the EEG-signal from a non-evasive BCI i.e. the Neurosky Mindwave device using an Arduino Mega.
- B. To analyze the EEG signal in terms of Meditation and Attention level by using their peak and average values.
- C. To classify the EEG into different parts to perform a specific task of all the 3 above mentioned modules.
- D. To actuate the task according to the EEG signal parameter mentioned by the user.

III. BLOCK DIAGRAM



IV. COMPONENT DESCRIPTION

- I. **EEG Headset- NeuroSky Mindwave +:** The NeuroSky MindWave Mobile Plus is a wireless EEG headset that uses dry electrodes to read your brainwaves. The MindWave headset turns your computer, phone and tablet into a brain activity monitor. The headset safely measures brainwave signals and monitors attention and meditation levels.

The headset is based off a very modern chip known as the TGAM1 chip or the ThinkGear AM 1 chip. The TGAM is NeuroSky’s primary brainwave sensor ASIC module designed for mass market applications. The TGAM processes and outputs EEG frequency spectrums, EEG signal quality, raw EEG, and three NeuroSky eSense meters attention; meditation; and eyeblinks. With simple dry electrodes. Its advanced filtering technology allows for high noise immunity, making the device usable for almost all individuals and in almost all settings.



The module returns the following information:

1. signal quality
2. attention value
3. meditation value
4. EEG power band values for the following brain waves as 24-bit unsigned integers:
 - a. delta
 - b. theta
 - c. low-alpha
 - d. high-alpha
 - e. low-beta
 - f. high-beta
 - g. low-gamma
 - h. mid-gamma

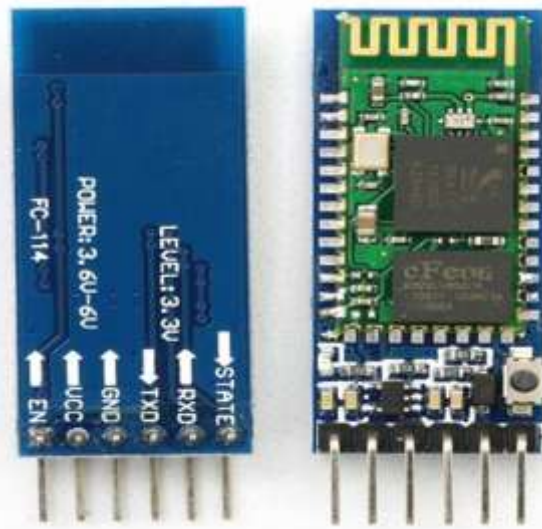
II. Bluetooth HC-05 Module : HC-05 module is an easy to use Bluetooth SPP (Serial Port Protocol) module, designed for transparent wireless serial connection setup. The HC-05 Bluetooth Module can be used in a Master or Slave configuration, making it a great solution for wireless communication. This serial port Bluetooth module is fully qualified Bluetooth V2.0+EDR (Enhanced Data Rate) 3Mbps Modulation with complete 2.4GHz radio transceiver and baseband. It uses CSR Bluecore 04-External single chip Bluetooth system with CMOS technology and with AFH (Adaptive Frequency Hopping Feature).

Hardware Features

- Typical -80dBm sensitivity.
- Up to +4dBm RF transmit power.
- 3.3 to 5 V I/O.
- PIO (Programmable Input/Output) control.
- UART interface with programmable baud rate.
- With integrated antenna.
- With edge connector.

Software Features

- Slave default Baud rate: 9600, Data bits:8, Stop bit:1, Parity: No parity.
- Auto-connect to the last device on power as default.
- Permit pairing device to connect as default.
- Auto-pairing PINCODE:"1234" as default.



- III. Arduino Mega:** The Arduino Mega is a microcontroller board based on the ATmega2560. It has 54 digital input/output pins (of which 14 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.

The Arduino Mega2560 has several facilities for communicating with a computer, another Arduino, or other microcontrollers. The ATmega2560 provides four hardware UARTs for TTL (5V) serial communication. The Arduino software includes a serial monitor which allows simple textual data to be sent to and from the board. The RX and TX LEDs on the board will flash when data is being transmitted via the ATmega8U2 chip and USB connection to the computer.

- IV. Arduino UNO:** Arduino Uno is a microcontroller board based on the ATmega328P. It has 14 digital input/output pins (of



which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. "Uno" means one in Italian and was chosen to mark the release of Arduino Software (IDE) 1.0. The Uno board and version 1.0 of Arduino Software (IDE) were the reference versions of Arduino, now evolved to newer releases. The Uno board is the first in a series of USB Arduino boards, and the reference model for the Arduino platform

- V. Arduino Leonardo:** The Arduino Leonardo is a microcontroller board based on the ATmega32u4. It has 20 digital input/output pins (of which 7 can be used as PWM outputs and 12 as analog inputs), a 16 MHz crystal oscillator, a micro USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery.

The Leonardo differs from all preceding boards in that the ATmega32u4 has built-in USB communication, eliminating the need for a secondary processor. This allows the Leonardo to appear to a connected computer as a mouse and keyboard, in addition to a virtual (CDC) serial / COM port. It also has other implications for the behaviour of the board.



- VI. I2C LCD (Liquid Crystal Display):** LCD (Liquid Crystal Display) screen is an electronic display module and find a wide range of applications. A 16x2 LCD display is very basic module and is very commonly used in various devices and circuits. These modules are preferred over seven segments and other multi segment LEDs. The reasons being: LCDs are economical; easily programmable; have no limitation of displaying special & even custom characters (unlike in seven segments), animations and so on.

A 16x2 LCD means it can display 16 characters per line and there are 2 such lines. In this LCD each character is displayed in 5x7 pixel matrix. This LCD has two registers, namely, Command and Data. The I2C 1602 LCD module is a 2 line by 16-character display interfaced to an I2C daughter board. The I2C interface only requires 2 data connections, +5 VDC and GND to operate.



- VII. Relay Module:** The relay module is an electrically operated switch that allows you to turn on or off a circuit using voltage and/or current much higher than a microcontroller could handle. There is no connection between the low voltage circuit operated by the microcontroller and the high-power circuit. The relay protects each circuit from each other.

Each channel in the module has three connections named NC, COM, and NO. Depending on the input signal trigger mode, the jumper cap can be placed at high level effective mode which 'closes' the normally open (NO) switch at high level input and at low level effective mode which operates the same but at low level input.

We have used a LOW Level 5V 2-channel relay interface board, and each channel needs a 15-20mA driver current. It can be used to control various appliances and equipment with large current. It is equipped with high-current relays that work under AC250V 10A or DC30V 10A. It has a standard interface that can be controlled directly by microcontroller. This module is optically isolated from high voltage side for safety requirement and also prevent ground loop when interface to microcontroller.



- VIII. RF RX/TX 315 MHz Module:** As the name suggests the RX/TX module is used to transmit and receive data over a certain area. The TX module transmits the data whereas the RX module receives the data. The excellent performance of the receiver module, using a digital process technology, with a strong anti-interference, stable performance, high reliability, non-directional, long life, undisturbed Japan imported chips, high stability, low power consumption similar remote control does not have any interference garbled phenomenon, the transmitted signal of the wireless receiver, remote control distance, can pass through walls, no direction. Supporting the use of any of the same frequency remote control can be and market fixed code, learning code.

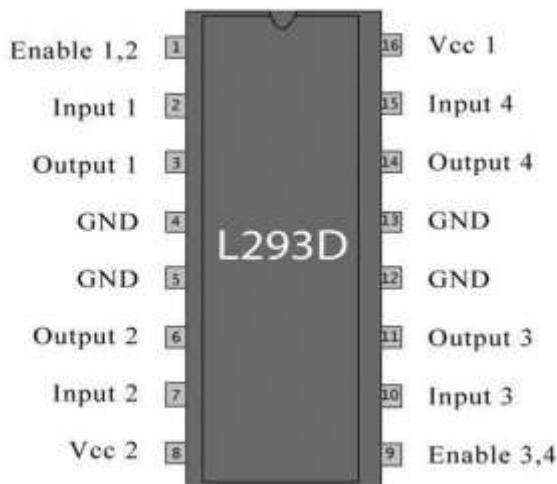
Super-regenerative receiver module LC oscillator circuit includes amplifier shaping output data signals to TTL level directly to the decoder, the use of extremely easy, and inexpensive, it is widely used. The small size, high sensitivity; frequency point debugging easy, short lead times; consistency of product quality, cost-effective, wireless remote-control market, the largest amount the most widely used as a high-frequency receiver module.



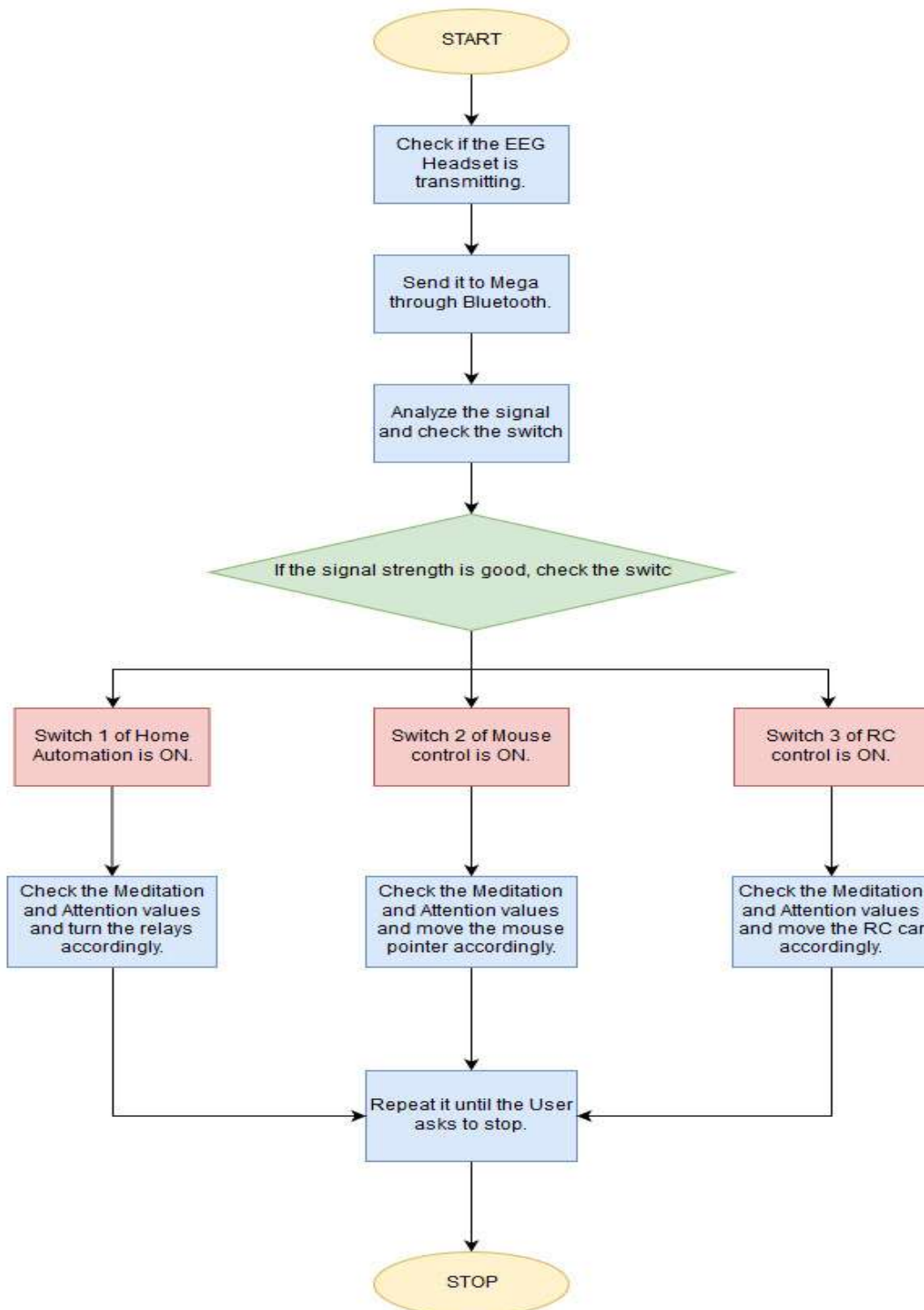
- IX. Motor Driver Circuit:** L293D is a typical Motor driver or Motor Driver IC which allows DC motor to drive on either direction. L293D is a 16-pin IC which can control a set of two DC motors simultaneously in any direction. It means that you can control

two DC motor with a single L293D IC. In a single L293D chip there are two h-Bridge circuit inside the IC which can rotate two dc motor independently. H-bridge is a circuit which allows the voltage to be flown in either direction. H-bridge IC are ideal for driving a DC motor. Due its size it is very much used in robotic application for controlling DC motor. There are 4 input pins for l293d, pin 2,7 on the left and pin 15 ,10 on the right as shown on the pin diagram. Left input pins will regulate the rotation of motor connected across left side and right input for motor on the right-hand side. The motors are rotated on the basis of the inputs provided across the input pins as LOGIC 0 or LOGIC 1.

For rotating the motor in clockwise direction, the input pins have to be provided with Logic 1 and Logic 0. Enable pins 1 and 9 (corresponding to the two motors) must be high for motors to start operating. When an enable input is high, the associated driver gets enabled. As a result, the outputs become active and work in phase with their inputs. Similarly, when the enable input is low, that driver is disabled, and their outputs are off and in the high-impedance state.



V. FLOWCHART



VI. IMPLEMENTATION AND METHODOLOGY

I. Basic Operation Scheme

The Whole system is first checked properly and the loose connections (if any) are primarily mended. The complete system along with the test results are explained prior to the operation and the components are tagged for easy understanding. The microcontrollers are always reset before their first use and then the program is then again uploaded.

The switches are checked first to ensure all of them are in the closed state. The same is done with the TX/RX switch as well. After a positive result, the functionality of the setup is activated, and the system is then after ready to use.

II. Operation Sequence

First the EEG headset is switched ON and is checked if it has proper amount of battery in it. After turning the headset ON, the System is switched ON. In a period of around 6-7 seconds, the headset will directly connect to the system via the inbuilt Bluetooth. As soon as the Bluetooth is connected, the system is ready for use. The User is given Three switch choices to operate the system in. The first being the Home Automation system where the user can turn ON/OFF the device of his choice.

The penultimate module is that of a computer mouse, where the user can operate the mouse pointer using his/her neural oscillations. The third and the last module is the Wheelchair, where the user can control the movement of his wheelchair via his/her Meditative/Attentive powers. If the user turns on the Switch 1, the Home Automation feature turns ON. Here the user can turn ON/OFF the desired appliance/device by increasing or decreasing their Attention/Meditation power. The attention levels would increase when the user is more focused, and the meditative levels will increase when the user is more relaxed. For this feature, several relays are attached directly to the Arduino Mega which acts as a switch for the same.

If the user wishes to operate the mouse of his/her computer, the switch 2 must be turned ON. Here the user can move the cursor/pointer of the mice in a 2D grid of 4 directions i.e. up, down, left and right. Here again the predefined Meditative and Attentive states are used to operate the system. The Med/Att states are transmitted from the Arduino Mega to the Arduino Leonardo. If the user wants to move their wheelchair, they must turn ON the last Switch 3. Again, here the movement is predefined into the 3 basic movements i.e. Forward, Turn and Stop. The values from the Arduino Mega is transmitted to the Arduino Uno using a 315 MHz TX/RX module. It should be ensured that to use a particular feature, the switches of the other 2 features should be turned OFF.

III. During Operation

Initially the LCD reads “Electroencephalogram” and the Name of the Author. Then a “Blue” light on the headset ensures that is turned ON whereas an “Orange” light denotes that it has low battery. A “Green” light on the System ensures that the System is turned ON. A continuous blinking “Red” light on the Bluetooth module means the Bluetooth module is turned ON but is not yet connected to anything. A stable double blink every 2 seconds means that the module is not connected to the headset and is receiving data.

Three switches along with its corresponding LEDs refer to the 3 modules or featurettes it can process or do. If the switch 1 is turned ON, the LCD would first show “Home Automation selected” and then show the user the meditation and attention values. Similarly, it would show which feature is turned ON against the other corresponding 2 switches. If none of the switches are turned ON, it would ask the user to switch them ON at certain intervals and if nothing is selected, it would just show the current Meditation and Attention values.

When the Home automation is selected, the LCD would show the name of the particular device that is turned ON/OFF. Else when the other 2 features are selected, the LCD would just show “Transmitting” which corresponds to the logic that the data is being transmitted from the Arduino Mega and is being received by the Arduino UNO or Leonardo respectively.

VII. RESULT ANALYSIS

The Arduino Serial Plotter takes incoming serial data values over the USB connection and is able to graph the data along the X/Y axis, beyond just seeing numbers being written out on to the Serial Monitor. The vertical Y-axis auto adjusts itself as the value of the output increases or decreases, and the X-axis is a fixed 500-point axis with each tick of the axis equal to an executed Serial.println() command. In other words, the plot is updated along the X-axis every time the Serial.println() is updated with a new value.

The main purpose of having the Serial plotter is that you do not need to be connected to the Internet in-order to visualize the data from a sensor or your project. And hence for the purpose of Data Visualization the Serial plotter excels at its job.

Whether it's a singular wave or a multiple plot graph the Serial Plotter auto-resizes itself and color codes each wave. In-order to test the Data Visualization function you can follow the following steps:

- I. Connect a couple of sensors to your Arduino
- II. Print the values of the sensors & Upload the code.
- III. Open the Serial Plotter.

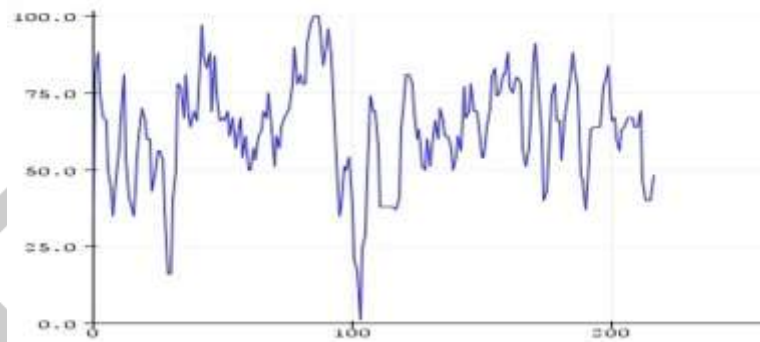
1. **eSense™ Meter values:** For all the different types of Senses (i.e. Attention, Meditation), the meter value is reported on a relative eSense scale of 1 to 100. On this scale, a value between 40 to 60 at any given moment in time is considered “neutral” and is similar in notion to “baselines” that are established in conventional EEG measurement techniques (though the method for determining a

ThinkGear baseline is proprietary and may differ from conventional EEG). A value from 60 to 80 is considered “slightly elevated” and may be interpreted as levels being possibly higher than normal (levels of Attention or Meditation that may be higher than normal for a given person). Values from 80 to 100 are considered “elevated”, meaning they are strongly indicative of heightened levels of that eSense.

Similarly, on the other end of the scale, a value between 20 to 40 indicates “reduced” levels of the eSense, while a value between 1 to 20 indicates “strongly lowered” levels of the eSense. These levels may indicate states of distraction, agitation, or abnormality, according to the opposite of each eSense. An eSense meter value of 0 is a special value indicating the ThinkGear is unable to calculate an eSense level with a reasonable amount of reliability. This may be (and usually is) due to excessive noise as described in the POOR_SIGNAL Quality section above.

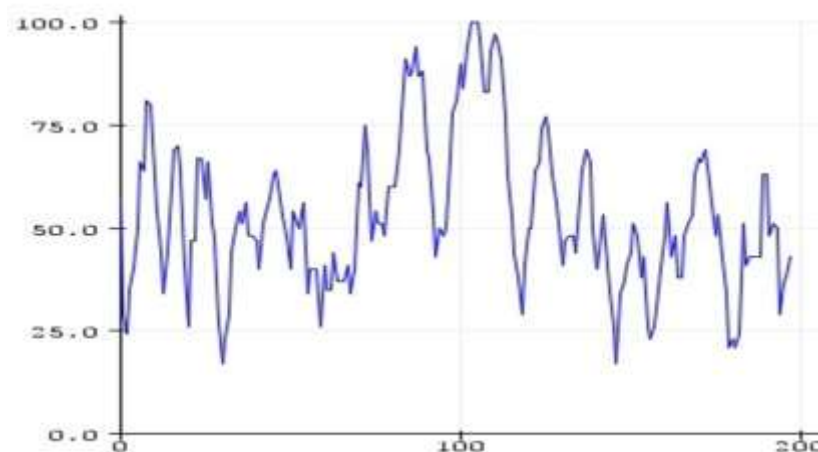
- A. Meditative State:** The Meditation Meter algorithm indicates the level of mental “calmness” or “relaxation.” The value ranges from 0 to 100 and increases when users relax the mind and decreases when they are uneasy or stressed. The Meditation Meter quantifies the ability to find an inner state of mindfulness and can thus help users learn how to self-correct and find inner balance to overcome the stresses of everyday life. Meditation is a measure of a person's **mental** levels, not **physical** levels, so simply relaxing all the muscles of the body may not immediately result in a heightened Meditation level. However, for most people in most normal circumstances, relaxing the body often helps the mind to relax as well.

Meditation is related to reduced activity by the active mental processes in the brain, and it has long been an observed effect that closing one's eyes turns off the mental activities which process images from the eyes, so closing the eyes is often an effective method for increasing the Meditation meter level. Distractions, wandering thoughts, anxiety, agitation, and sensory stimuli may lower the Meditation meter levels.



- B. Attention State:** The Attention Meter algorithm indicates the intensity of mental “focus” or “attention.” The value ranges from 0 to 100. The attention level increases when a user focuses on a single thought or an external object and decreases when distracted. Users can observe their ability to concentrate using the algorithm. In educational settings, attention to lesson plans can be tracked to measure their effectiveness in engaging students.

This unsigned one-byte value reports the current eSense Attention meter of the user, such as that which occurs during intense concentration and directed (but stable) mental activity. Distractions, wandering thoughts, lack of focus, or anxiety may lower the Attention meter levels.



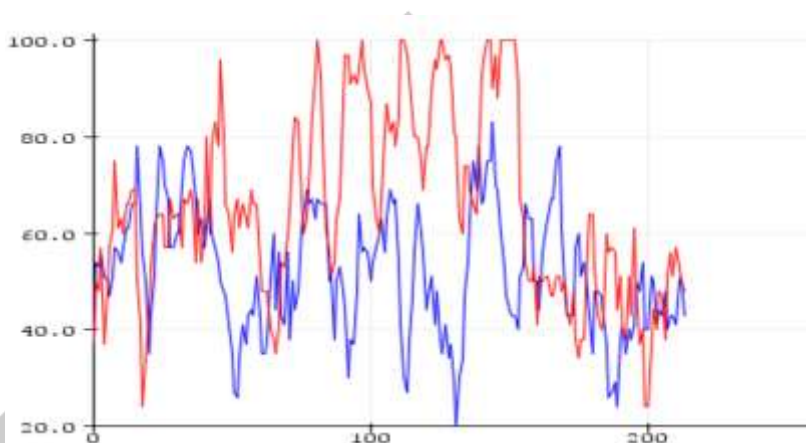
In the second graph, the RED graph represents Attention values whereas BLUE graph represents Meditation values. When the Attention value is high we can see that sometimes the Meditation value is the lowest. This exhibits a link that they are inversely proportional to each other.

2. Acquisition of EEG using OpenViBE

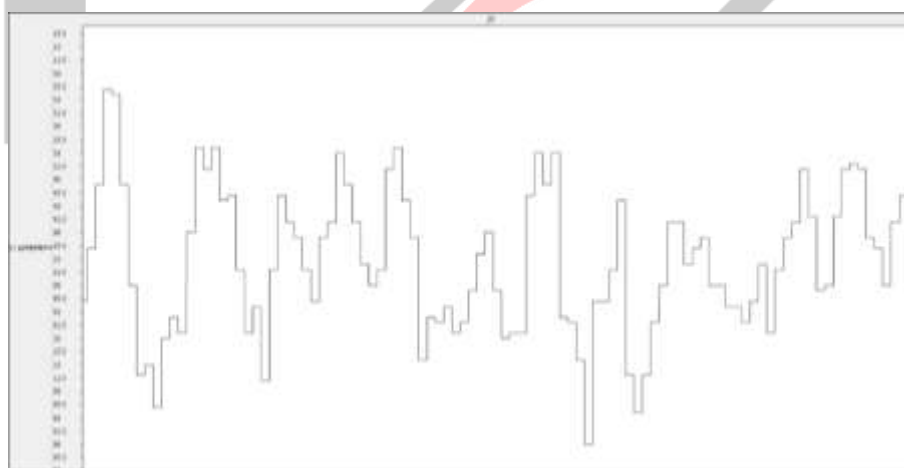
OpenViBE stands for “**Open Virtual Brain Environment**”. It is a software platform that enables to design, test and use Brain-Computer Interfaces (BCIs). OpenViBE can also be used as a generic real time EEG acquisition, processing and visualization system.

In more detail, BCIs are communication systems that enable users to send commands to computers only by means of their brain activity. One potential application of BCIs is to provide alternative communication channels for disabled people, but BCIs can also be attempted for rehabilitation or neurofeedback training.

Although an exciting and active research field, further improvements in BCI techniques are needed before they can be considered as viable alternatives for traditional controllers such as mouse or keyboard. Currently BCI techniques often rely on EEG (electroencephalogram) signals but are not limited to such



- A. Meditation:** These values were tested for two different scenarios, them being: (1) While the human was doing his regular work and (2) While he was trying to relax his mind. We could notice that when he was in his regular state, the meditation values hardly went above 70 whereas when he tried to relax his mind, they were mostly above 70.



- B. Attention:** gain, these values were tested for the same two scenarios. We could notice that when he was in his regular state, the Attention values hardly went above 70 whereas when he tried to relax his mind, they were mostly above 70.



VIII. CONCLUSION

Comparisons of our data to previous works have produced favorable results. Our results closely replicate analyses of single channel EEG research projects. This shows that the commercially available dry EEG devices produced by NeuroSky are a viable solution for use in real-world applications. These devices' ability to integrate with open source software's, and flexible script languages, such as MATLAB or Arduino, make them suitable candidates for further research in the detection of vigilance states. Of the three devices tested, the MindWave produced the most accurate data due to its physical and technical properties.

On further analyzing a human behavior we concluded that, Both Attention and Meditation individually never went above the value of 60-70 while the person was in his regular state, whereas when he was either focused or relaxed, the values almost stated above 70 usually. When the user was either subjected to distractions, wandering thoughts, lack of focus, agitation, sensory stimuli or anxiety he showed lower Attention and Meditation levels. The Attention levels were mostly high when the meditation levels were low and vice versa. More research will give clear option in this area as the devices generates Big data, so we have the opportunity to analyze and synchronize data from multiple users at the same time to see the correlation about the different brainwaves. The Alpha waves were a strong finding while there were change in emotions. Other than that, other spectral changes such as Beta, Theta, Gamma, Delta were also reported to spike during an emotion change.

Advantages and Disadvantages of EEG:

EEG has the following advantages:

- Hardware costs are significantly lower than those of most other techniques,
- It has very high temporal resolution, of the order of milliseconds rather than seconds,
- Extremely non-invasive, i.e. there is no need of inserting electrodes and needles into the brain,
- It is silent, which allows for better study of the responses to auditory stimuli,
- It does not involve exposure to high-intensity magnetic fields,
- It is comparatively compact than others, so it is easily portable.

With the above advantages, an EEG system has its disadvantages also. They are:

- It has a poor spatial resolution, as the measurements are taken at the scalp,
- It determines neural activity that occurs below the upper layers of the brain poorly,
- It often takes a long time to connect a subject to EEG,
- Signal-to-Noise Ratio (SNR) is poor.
- If we transmit data at long distances then unwanted disturbances is there,

Future Scope of the System:

A lot of research is currently being carried out to make EEG devices smaller, more portable and easier to use. In the future it can be updated so that the size of the whole system reduces and works at a higher speed without any physical buttons. It can be expanded into an open-source project where the user can add or remove modules of his choice and need.

We can add an online data logging device to it so that the user can check his neural values any time and from any where in the world. Such prolonged and easy-to-use monitoring could make a step change in the diagnosis of chronic conditions such as epilepsy, and greatly improve the end-user acceptance of BCI systems. Algorithms can be added in order to detect strokes or epilepsies and diagnose them before they become severe.

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