DEVELOPMENT OF A LOW-COST AND USER-FRIENDLY NEUROREHABILITATION TOOL TO TREAT STRESS, DEPRESSION, ANXIETY USING AN ARDUINO AND EEG

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Abstract
The main objective of the paper is to realize the implementation of a cheap and user-friendly neurorehabilitation tool which will be accustomed treat stress, anxiety, depression, using EEG signal analysis. The analysis and therefore the detection of the EEG may be achieved with the assistance of a home-made neurorehabilitation-built system. The clinical and technical EEG signals may be subdivided into – Alpha, Beta, Theta and Gamma ranges. The report will concentrate on the frequencies of the Beta band in accordance to the analysis of the ability values and therefore the output of the EEG analysis are required to manage the video and-or audio feedback.Keywords—BCI, EEG, Neuro-feedback, Beta wave, Arduino, Low cost

I. INTRODUCTION

Neurorehabilitation (NR) is an automatic control process that has feedback which is real-time data of patient's electrical brain activity, the aim is to develop self-learning strategies which may adjust the brain waves. During neurorehabilitation treatment, the electroencephalography (EEG) is carefully recorded during a real-time manner. This kind of approach has been proven to be quite efficient in alleviate a spread of the symptoms by which patients with different disorders, like anxiety, depression, and stress. Through the utilization of Neurorehabilitation, patients could also be ready to develop personal strategies that benefit self-regulating areas of the brain and its electrical activity which are usually directly linked to representational process supported the received signal-feedback which is assumed to disclose the pattern of neural signal. By targeting one or more areas of the brain we will measure the neuro feedback or by simply examining signals all-across the brain.

Neurorehabilitation training focuses on brain development, measuring in real-time certain areas of neural activity and, accordingly, sending feedback to the trainee. this could be successfully put in practice through visual, auditory or audio-visual stimulation of the subject therefore the precise assumed neural substrates which are characteristic of particular pathological conditions or actions start self-regulating.

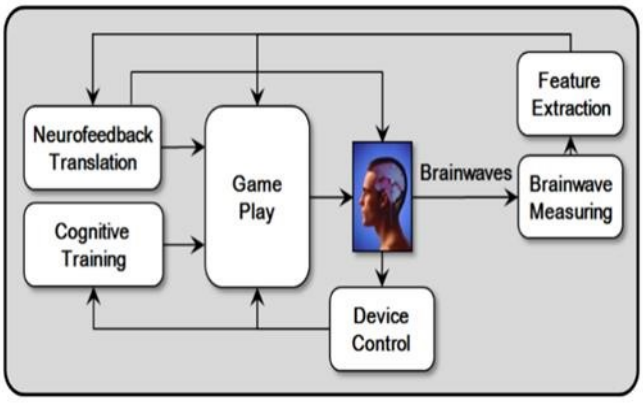

Fig. 1. Description in block form

1.1 Electroencephalography (EEG)

Electroencephalography (EEG) may be a clinical imaging system that detects scalp electrical action created by the brain

structures. The EEG (Electroencephalogram) is characterized because the electrical movement of alternating type recorded from the scalp after being picked-up by metal terminals/electrodes and conductive media.

Electroencephalographic reading is a wholly non-intrusive system that patients and neuro-typical children and adults will be connected to repeatedly with moderately no hazard or constraint. Measuring is accomplished by the electrodes that are looped down the lead-wires with the amplified inputs where the amplification is allotted. When electrodes are used, the space between the electrode terminal and also the skin has got to be loaded with conductive paste so on reduce the prospect of contact impedance at electrode skin interface.

1.2Brain waves

At the bottom of each one amongst our thoughts, emotions and behaviours are often interpreted because the communication between neurons inside our brains. Brainwaves are formed when electrical pulses are synchronized from different masses of neurons exchanging information with one another.

Brainwaves are detected using EEG sensors placed on the forehead and ground terminal to ear. They are classified into different bandwidth ranges to explain their functions, but are the simplest thought of as never-ending spectrum of consciousness; from slow, loud and functional - to fast, subtle, and complicated. Our brainwaves change as indicated by what we're doing and feeling. Usually, when deliberate brainwaves are frequent, we feel tired, slow, lazy, or dreamy.

Speed of Brainwave is estimated in Hertz (cycles/second) and is isolated into groups of moderate, direct, and fast waves. samples of brain neurons have rich data about neuronal exercises. When neurons are active, they deliver electrical pulses. By setting terminals on the scalp, the electrical movement of the brain, called EEG, is recorded.

Thus, EEG is made by a selected reasonably synchronous movement of neurons, which are called pyramidal neurons, and therefore the electrical yield is therefore reflected within the accompanying regions of the skin where the cathodes are found. Their amplitudes and frequencies can perceive distinctive samples of electrical movements, called brain waves.

The quickness of the waves waver is shown by recurrence which is estimated by the number of waves every second (Hz), while the energy of those waves is estimated by microvolt (μV).

1.2.1Brainwave interpretation

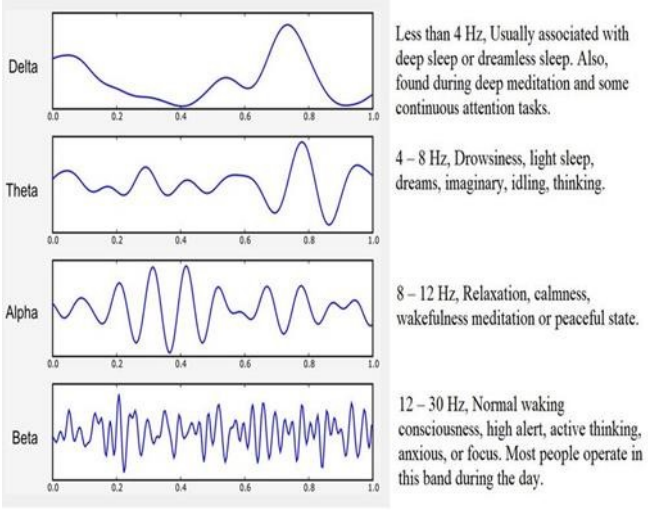

Fig. 2. Brainwave Interpretation

1.2.1 INFRA-LOW (<.5Hz)

Infra-low Frequency (ILF) neurorehabilitation to coach the very slowest brainwaves (less than .5Hz) are considered to be the basic cortical rhythms that underlie our higher brain capacities. These basic cortical rhythms of the brain control our higher brain functions. The slower frequencies are linked to the faster ones through harmonics this suggests that by training the lower frequencies you'll be able to affect the upper ones, and vice-versa.

1.2.2 Delta waves (.5 TO 3 Hz)

Delta brainwaves are slow, big brainwaves (low frequency and deeply biting, type of a drumbeat) that bring out in inmost meditation and dreamless sleep. Delta waves suspend external awareness and are the source of recognition. Healing and regeneration are inspired during this state, which is why deep restorative sleep is so essential to the healing process.

1.2.3THETA WAVES (3-7 Hz)

Theta brainwaves occur mostly in sleep but are seen in deep meditation. Theta is our egress to memory, learning. In theta, our senses are often drawn from the skin world and focused on signals originating from within. it's that dimness state which we normally only experience fleetingly as we wake or dope off to sleep. It's where we hold our 'stuff', our fears, bothered history, and bad dreams. Theta waves occur mostly within the parietal and temporal regions. Theta occurrence is abnormal

1.2.4ALPHA WAVES (8 – 12Hz)

Alpha brainwaves are occurred during quietly flowing thoughts and in some meditative states. Alpha is that the calming state for the brain. Alertness, mind/body integration, Mental coordination, calmness, resting, and learning are aided by alpha waves.

Alpha waves will be noticed mainly from the lobe but also from the parietal and frontal regions. they're produced when an individual is in an exceedingly conscious, relaxed state with closed eyes

1.2.5BETA WAVES (13 - 38 Hz)

Beta wave, or beta rhythm, is a neural oscillation in the brain are responsible for consciousness of awareness when consideration is coordinated towards cognitive. It is displayed when we are cautious, occupied with critical thinking, judgment, basic roles, or other demanding mental activities.

Beta brainwaves are additionally separated into three groups; Lo-Beta (Beta1, 12-15Hz) can be thought of as a 'quick sit out of gear'. Beta (Beta2, 15-22Hz) appears when one is engaged in a demanding activity or trying to make sense of something. Beta (Beta3, 22-38Hz) appears when the mental process is in an exceedingly clamorous state, coordinating new encounters, high nervousness, or excitement. Beta waves (13-30) Hz are acquired from the parietal, central and frontal lobes. They occur in alert or anxious states.

1.2.6 GAMMA WAVES(38 – 42Hz)

Gamma brainwaves are the fastest of brain waves and identify with in sync preparing of knowledge from different brain territories. Gamma brainwaves passes data quickly and unobtrusively. The most camouflaged of the brainwave frequencies, the brain must be calm to urge to gamma. Gamma is likewise over the continuously occurrences of neuronal terminating, so how it's created remains a puzzle. It's theorized that gamma adjust judgement and awareness, which a more noteworthy nearness of gamma identifies with extended cognizance.

1.3 Comparison of EEG Bands

When our brainwaves are in disarray, issues will surface in our enthusiastic or neuro-physical activity as a response. Research shows brainwave designs associated with a large range of neurological conditions. Over-excitement in certain brain regions is connected with nervousness, rest issues, nightmares, hyper-watchfulness, imprudent conduct, hostility, unsettled despondency, ceaseless nerve torment and fulfilment. Under excitement in certain zones of brain prompts discouragement, thoughtlessness, interminable torment and a sleeping disorder. a mix of under-excitement and over-excitement is found in instances of tension.

1.4 EEG characteristics

This can be characterized by contrasts in Theta and Beta (Sensory Motor Rhythm SMR, Beta, High Beta) waves. EEG has slower and better theta waves in frontal and focal districts in Stress as compared to others. Contradict with neuro-typical subjects, while the amplitude of SMR (12-15) is minor, the frequency of high Beta waves (22-30) is larger beta waves. the traditional overabundance is 32%. It likewise does block enough quick beta waves (15-18) in frontal, focal and fleeting locales.

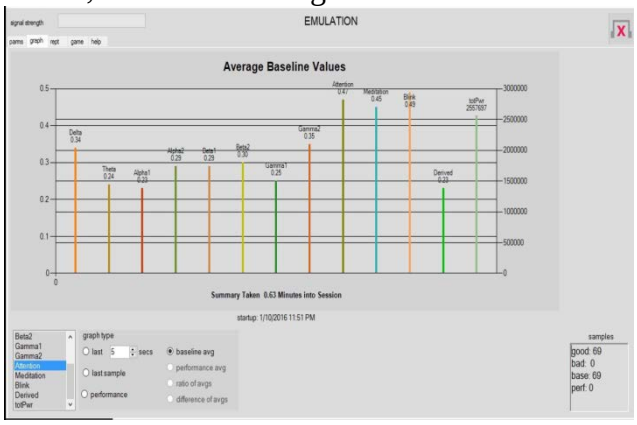

Fig. 3. Android Application showing the output test

1.5 Music Therapy for stress

Music listening has been suggested to stress-reducing effects for a beneficial impact on health. However, the prevailing literature presents itself with a limited number of investigations and with discrepancies in reported findings which will result from methodological shortcomings. it had been the aim of this study to handle this gap in knowledge and overcome previous imperfections by efficiently examining music effects across, cognitive, internal secretion, autonomic and emotional domains of the human stress response

II.METHODOLOGY

2.1 Main Components of EEG

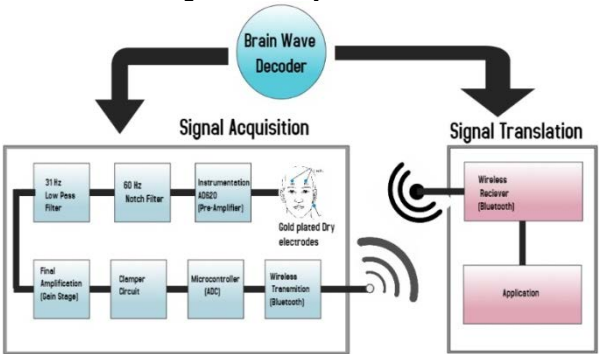

Fig. 4. Looping

Fig. 5. Waveform output

2.2 Materials and Methods

The tools that are used in this report are the EEG acquisition circuit and EEG processing unit.

2.2.1EEG acquisition circuit

The process of EEG signal reading process consists of five main section that's based upon amplifying and filtering. The five sections have a crucial purpose that helped to scale back noise. To control the Arduino microcontroller, we are going to need a clamper circuit for operating voltages of Arduino. we are going to discuss about this intimately in coming section within the five sections include filtering,signal picking, amplifying, offsetting the AC signal and clamper to form the brain signal readable.

The five section of EEG amplifier circuit:

- Instrumentation amplifier AD620
- 60 HZ Notch filter
- 31 HZ second order low pass filter
- Final amplifier and DC offsetting
- Clamper circuit

III. AMPLIFICATION/FILTERING (CIRCUIT DIAGRAM)

3.1.1 First stage of amplification/filtering

Instrumentation Amplifier AD620 (Pre-amplification)

The first a part of the circuit configuration is that the instrumentation amplifier. The instrumentational amplifier takes a differential AC signal, this part is named a difference amplifier. to create the system portable we've got decided rather than making a circuit with three operational amplifiers (Op-Amps) there's a pre-built instrumentational amplifier package that's the AD620 IC that only requires a resistor within the configuration for adjusting the gain of the circuit.

The resistance RG of the instrumentation amplifier circuit has to be tuned.

This is the equation for adjusting the gain of AD620.

$$G = \frac{49.4k\Omega}{R_G} + 1$$

The resistance of 2kΩ has been used for our circuit that outputs a gain of 25.7 V/V. This gain will multiply with the ultimate gain of the ultimate amplification so, we've got to regulate the foremost suitable gain consistent with the circuit.

This a part of the circuit picks the microvolt signal from electrodes and takes the difference and reject the common mode and make the signal readable by the remainder of

the circuit. The signal isn't visible on the oscilloscope thanks to the noise but using the function generator signal it gives the wave at the output after this part.

The instrumentation AD 620 has 8-lead SOIC and DIP-packages. The instrumentation AD 620 is high accuracy low-cost IC.

Search the pinout of the AD620. That resistor balance the gain. The circuit needs positive and negative power. because the pin 4 is negative and that we should make a three-channel supply. this is often the very first part and it's the foremost important role because it capture the signal and also the remainder of the circuit is merely the signal processing data. The electrodes are connected in keeping with the pinout defined in figure 6-9. As pin 2 shows the negative part the negative electrode goes into this. The positive part is 3 the positive electrode goes into this and also the ground are on pin 5. the bottom are the identical because the complete circuit. Remember this is often the bottom not the negative circuit. The output is on identification number 6 and so goes to the following a part of the circuit.

3.1.2 The Notch filter

This filter is employed to get rid of any noise present at 60 Hz. A notch filter may be made of 4 Op-Amps. The Notch filter has also come up in an IC package that's UAF42 that needs some simple resistors to calibrate at 60 Hz. Making a notch filter using amps could be a time taking work. we'd like the shortest circuitry to urge the low noise EEG signal.

A notch filter is employed to get rid of a selected point of frequency. At the purpose of the notch, the actual frequency has been rejected. As in our case we'd like to get rid of 60 Hz line noise so, we'd like to get rid of the frequency coming at 60 Hz.

If we glance at the acknowledgment of the notch filter the response at 60 Hz are going to be a flat wave. Because there's a notch at 60 Hz. It allows the upper or lower frequencies but not the 60 Hz. Any signal that's passing after the notch circuit will lose any 60Hz noise that's generated. we'd like another filter to get rid of further noise. Further, we'll discuss the notch filter within the simulation section of the notch filter..

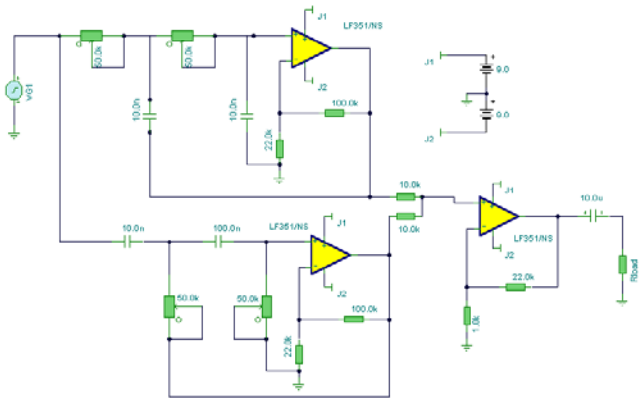

Fig. 6. Notch Filter

3.1.3Low-Pass filter

The next stage is that the low-pass filter to get rid of the upper frequencies. we want a brain wave for our circuit. The brain wave includes a frequency range of 12 to 30 Hz so need a second order low pass filter. The TL084 operational amplifier used.

There are different filter topologies for expanding a decent response circuit for EEG. we are able to use any of them to construct a 31 Hz low pass filter. The filter equations are quite simple and straightforward to search out resistors and capacitors' values. we are able to also use online filter values calculators to search out the precise resistor and capacitor values. As they only required the bring to an end frequency and provides the corresponding values at the specified cut-off.

We have also developed and checked different Low pass filters to test the response of our EEG signal. we've got made a simulation of second-order low pass filter on MATLAB and tested other ways that suit most to our circuit

The Fig- shows the circuit of a second-order low pass filter on MATLAB simulation that we've got tested before using the other constructed circuit. The MATLAB is just used for designing and analyzing the response of filters. As we've got designed and tested before making on the hardware.

The simulation on the MATLAB is due to identifying the transfer function and values of the components. we are able to plot any of the specified responses in it as we compared to the opposite simulation software like multisim. we are able to also produce noise within the circuit using MATLAB to check the results.

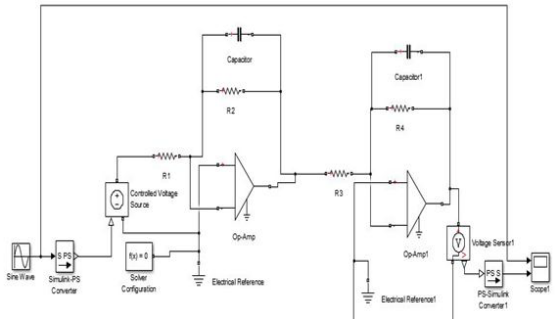

Fig. 7. Low pass Filter

After the notch filter, the signal suffered a second-order low pass filter. At this instance, the circuit should answer the movements of the limbs or eyes. If it doesn't respond meaning the system remain noise. The circuit reacts at this stage it absolutely was a decent response. If the circuit doesn't react at this stage, this implies there's still enough noise available within the circuit that's affecting the EEG circuit. we've got placed the electrode on the lobe. The signal reacts either within the positive edge amplitude pulse changing or negative edge amplitude pulse, whenever we move an eye fixed to the left or right.

We are using the multiple circuit topology for Our low pass filter designing.

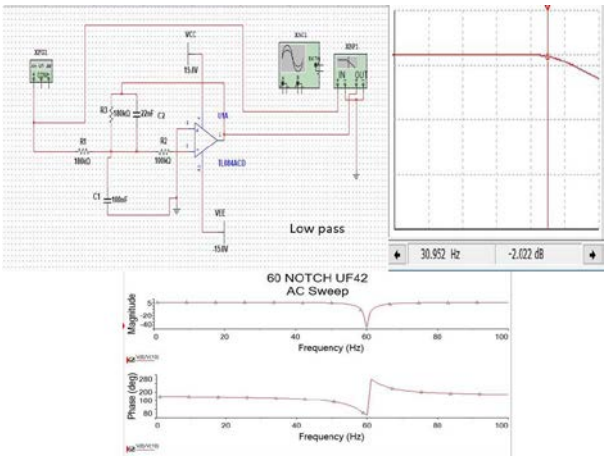

Fig. 8. Multiple feedback loop topology for LPF

We will discuss more the circuit within the simulator view section. At this point, the circuit will weigh down much of the noise. the subsequent stage is that the gain stage the ultimate amplification part. After amplification, the circuit involves a stage where we are able to see the signal on an oscilloscope. there's a desire to test each and each part separately for an honest response. we are able to check using the function generator signal the waveform on the oscilloscope is lower on higher frequencies

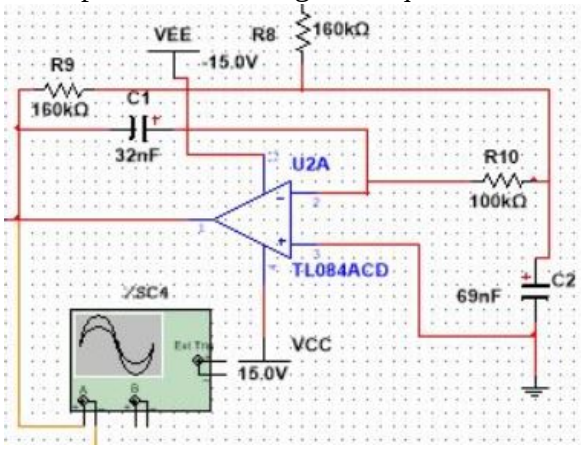

Fig. 9. Amplification stage of LPF

3.1.4Gain Stage and DC offsetting Final Amplification

To adjust the ultimate gain of the circuit the Gain Stage section is employed. To multiply with the ultimate gain of the circuit the initial gain would be 25 V/V, The signal will amplify after this part and it'll easily readable and detected by oscilloscope. So, the ultimate gain was approximately 200 V/V. we are able to increase or decrease the gain of the circuit for better response and in step with the behaviour of the circuit. All the circuit are made with the Op-Amps. The Quad Op-Amps used for the circuits. The TL084 IC is employed which have 4 operational amplifiers in it. just one TL084 IC used for all the stages rather than using 4 Op-Amps and to cut back noise and complexity of the circuit. Clamper Circuit The final a part of the circuit is that the clamper circuit.

This can be where we only used for Arduino microcontroller. Here we are becoming the output at the analog input of the Arduino board and Arduino has only 5V operating voltages. For the rationale we used a clamper circuit. The clamper circuit are offset every voltage from below 5 volt and above zero so the Arduino can read with none high voltage spike. By the definition of clamper, the clamper changes the DC level of an indication to the specified level. with none change it'll be changing of original signal shape. In our case the clamper will keep the signal voltage within the range from above 0 and below 5 volts.

There are differing kinds of clamper Positive, negative and biased clampers. After this a part of the circuit we are ready to take the signal to the Arduino microcontroller. The Arduino board reads the signal and converts it into digital form to perform any task or to manage any thing that's connected to the Arduino board or wirelessly. We are using MATLAB for real signal plotting and analysing through Arduino board.

3.2Power supply and reference

A 9V battery and a controller were employed in the circuit. The controller is crucial in instances of little motions within the information voltage. It prompts a 5V yield voltage. In our work, the voltage controller 7805 chip was used. it's then associated (pin3) to a splitter 7905 that drives (0.5*5)V to a virtual ground and maintains a vital distance from unequal states [2,20,21] as showed in Figure 9. Finally, the oscilloscope displays the analog output.

3.3Arduino Microprocessor

Arduino could be a low-cost open source physical computing platform supported a straightforward input/output (I/O) board and a development environment that implements the processing language. Arduino are often accustomed develop stand-alone interactive objects likewise on convert measured data from analog to digital and send it to a PC using (com 3). It reads the worth from the required analog pin and converts it with a 10-bit analog to digital converter and backbone up to 4.9 mV per unit (Figure 10). To read an analog input it takes about 0.0001s. This leads to maximum reading rate of about 9600 times persecond. it's a pertinent option to acquire accurate EEG signal in step with the Shannon Theorem. The Arduino chip reads the analog input on pin 0 and print the result to the serial monitor. The chip pin A0 is connected to the centre pin of a potentiometer and outside pin to +5V and ground. within the presented work, the Arduino chip has been programmed with the assistance of a PC via a USB cable. By using the open-source Arduino Software (IDE) with its rich library enables the writing of the code and uploads it to the board. The waves are often displayed directly through TFT LCD, Interfacing unit and its software.

3.4Determination of the threshold

Keeping in mind the tip goal, that is, to work out the edge we've got compared between the patient and control group on the premise of EEG data amplitudes and spectra, the primary thing to try and do is use the Fourier Transform to vary information from time-space to recurrence area.

The acquired spectra are then separated into EEG groups. Thereafter, just sifted EEG spectra divide identified with the range 12-18 Hz are contemplated in light of the very fact that ordinary volunteer waves have a bent to be more than Stressed condition waves in SMR and beta groups, and so as to cancel artifact.

The trigger is consequently initiated when the relative power esteem diminishes beneath a selected limit. the sting esteem has been tentatively concentrated with a selected end goal to be embedded within the programming code considering the conventional and variance of intensity region esteems to be more than Stressed brain waves in SMR and beta bands, and so as to cancel the artifact.

The spectral power curve has been finally calculated through the squared Fourier Transform magnitude over a real-time moving window. The window length will be changed within the code in step with the user. Finally, the realm under the spectral power curve of the Beta band was calculated via integration. Relative Power of Beta band (Beta power/ overall signal power) was used because of the trigger to change off a connected device.

3.5Validation of spectral analysis accuracy

With the expectation of verifying the Arduino results, the EEG spectral power values resulted from the Arduino processor has been contrasted with values computed by Arduino IDE and respective interfacing EEG software.

3.6Connecting audio and video system with Arduino

To finish the Feedback framework, a minimal effort handheld computer music system comfort, with direct CPU execution and decision, has been connected to the Arduino chip by means of a transferred segment. within the recommended circuit and

programming codes, if the EEG information sufficiency achieves the limit or less at the frequencies 12-15 Hz or 15-18 Hz respectively, the amusement will quit working until the patient builds their concentration capacity to attain the most effective pinnacle of a neuro-average tyke. Only after this can be achieved, does the music therapy restart.

IV.VALIDATION OF EEG RECORDING ACCURACY

4.1 Processing part

By testing each deficiency, there's less Beta movement. In our work, we founded a Beta action voltage edge with the goal that, when the EEG Beta adequacy progresses becomes below the sting, an associated straightforward amusement is delayed by the framework. the overall handling framework, which might be observed in Figure 8, is created out of: good quality yield flag issued from the beforehand itemized EEG Circuit, Arduino chip, workstation and a complicated diversion. A programming stage has been accomplished using Arduino IDE coding/library.

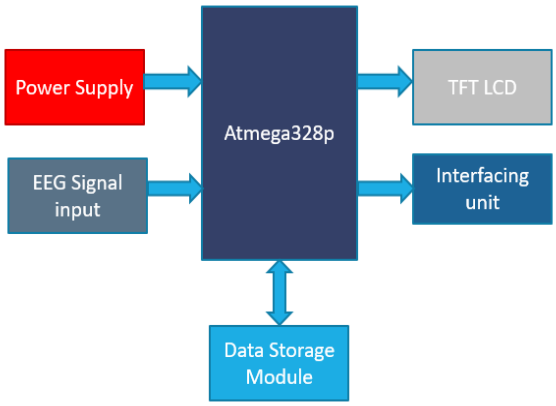

Fig. 10. Activity Block Diagram

A/D convertor

In the wake of coming up with the securing circuit, there's a requirement for an A/D convertor, keeping in mind the tip goal to alter over the straightforward yield flag issued from our outlined circuit into a sophisticated frame which will be exchanged with the preparing unit. An Arduino processor module has been utilized for that reason.

V. UML DIAGRAM/STRUCTURE

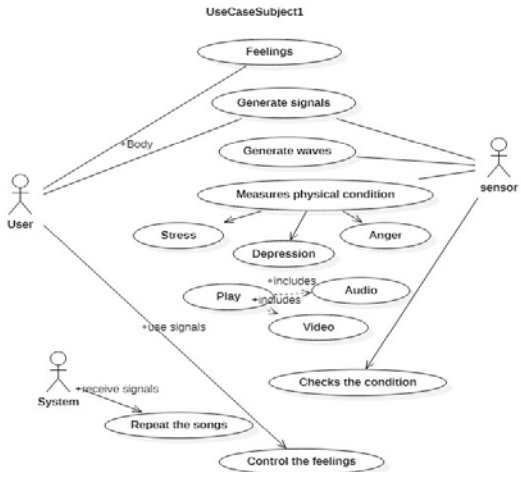

Fig. 11. UML Diagram

VI. MOTIVATION

the main motivation of the project has come from fiction. it's always been intrigued by the utilization of brain-controlled devices in books and films. For having the ability to be controlled telepathically, a tool must be capable of differentiating between different mental conditions. As a pre-requisite to it, the device must first be able to differentiate between the parameters of the electrical activity of the brain which will be related to certain brain disorders. This backward simplification from a fictional application is what gave me the subject for my project. Often, the so-called waveband training is employed within the treatment of Insomnia, Anxiety, ADHD and other brain disorders.

In short, different frequency bands are active within the brain, which successively are each related to different states. Thus, high alpha-band activity indicates a slight relaxed state, while beta waves are related to attention and concentration.

Advantages

1. The sensors used have a high sensitivity and are easy to handle.
2. Low cost system providing maximum functionalities.
3. The user has real-time knowledge of what's happening in some state, thereby having the choice of manual override.
4. Low maintenance and low power consumption.
5. The system is more compact compared to the prevailing ones, hence it's easily portable.
6. are often easily modified to boost the setup and add new features.
7. Time saving.
8. Provides a user-friendly interface, hence it'll have a greater acceptance rate by the technologically unskilled users.
9. Feedback for each command is given by the system.
10. Malfunctioning of one sensor won't affect the entire system.

Disadvantages

1. For detection of malfunctioning of sensors there is no self-system.
2. Requires uninterrupted power supply(UPS).
3. Limited Range.
4. The system doesn’t have deciding capability.

CONCLUSION

The aim of the project is now to alter the ratio of the various EEG frequency bands to at least one another so as to attain a relaxed but concentrated state. For instance, if this succeeds, the energy content of the beta band is increased which should promote increased attention and is reduced within the so-called theta band, which should reduce distractibility. By using user-friendly feedback types, the motivation for therapy is stimulated and maintained among young clients. this training may be done by using Music therapy. So while the youngsters practice their skills with fun in body-controlled PC games, the therapist records the values and accompanies the therapy. Other biofeedback modalities like skin conductance training or EMG training may be supportive within the future.

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