

EEG BASED SMART HOMES

SMART HOMES OF FUTURE



Javeria Riaz 2016-CS-251

Rahama Tahir 2016-CS-264

Summen Zahid 2016-CS-270

Bisma Amir 2016-CS-269

Ayesha Tasadduq 2016-CS-255

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**Abstract**

The Brain Computer Interface (BCI), called also often a Mind Machine Interface (MMI), or in other cases called a Brain Machine Interface (BMI), is a direct communication link or a communication pathway between the human brain and an external device. In case of the BCI system, user’s communication channels do not rely on peripheral nerves and muscles. This is especially significant for those disabilities who have lost capacity of movement.

The smart home systems are designed to improve human quality of life. The work deals with the smart home network controlled directly using the human physiological state. Brain computer interface (BCI) systems offer communication and control capabilities to people with severe disabilities. BCI’s use electroencephalographic (EEG) signals recorded from scalp to start or stop different household devices like fan, LED light and to control speed of fan.

CHAPTER 1

HUMAN BRAIN

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1.1 Brain’s Electrical Activity…A Biological Review\*

1.2 Classes of Wave Groups

1.3 Standard Positions of Electrodes

1.4 Standard Positions of Electrodes

1.5 Applications of EEG

**1.1 Brain’s Electrical Activity…A Biological Review\***

Brain the main control-room for the nervous system in all vertebrate, and most invertebrate, animals. The brain controls the other organ systems of the body, either by activating muscles or by causing secretion of chemicals such as hormones. This centralized control allows rapid and coordinated responses to changes in the environment. Some basic types of responsiveness are possible without a brain: even single-celled organisms may be capable of extracting information from the environment and acting in response to it.

* **Brain’s Architecture**

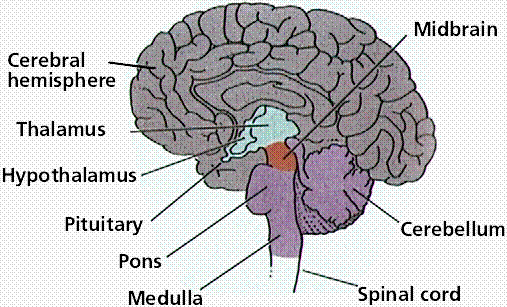
Brain’s architecture is somewhat complex [1] It comprises of three major separate components [2]: cerebrum, cerebellum and

Figure 1.1.0 Major components of Brain

Brain stem as shown in figure 1.1.0.

* **Cerebrum**

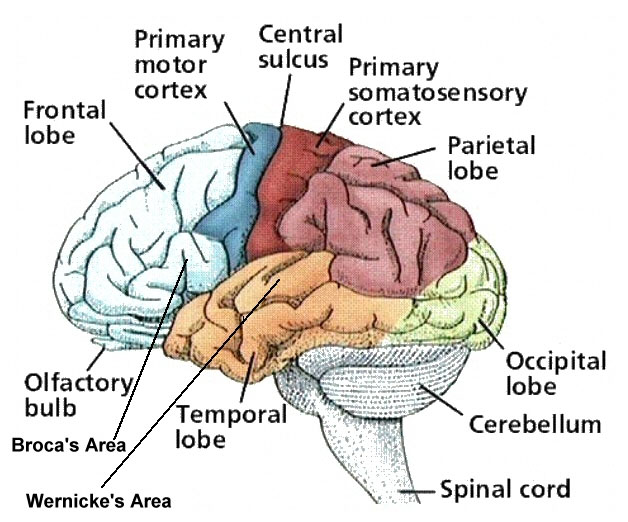
The cerebrum or cortex is the dominant part of the central nervous system and has centre for conscious appreciation of sensation, initiation of movement, complex analysis and expressions of emotions and behaviour.

Figure 1.1.1 Gyri and Sulci of Cerebrum

The cerebrum consists of two hemispheres. The right one senses information from the left side of the body and controls movement on the left side. Similarly the left hemispheres is connected to the right side of the body. The cerebrum consists of several layers. The outer layer, approximately one centimetre thick, consists mostly of neuron cell bodies, which give it a grey appearance. The surface is highly convoluted with ridges (gyri) and valleys (sulci) as mentioned in figure 2 .The main, deeper sulci are called fissures. Beneath the outer layer are axons, which have a white appearance. Embedded in the white matter are further collections of cell bodies called nuclei. Some of the functions of the cerebrum are localized within specific anatomical structures, some are more widely distributed [3].

The cerebral cortex contains six layers. There are two types of neuron cell bodies: pyramidal cells and stellate (granule) cells. The pyramidal cells are large and tend to connect to distant structures in other parts of the cerebrum, thalamus, cerebellum and spinal cord. There are many feedback connections. Granule cells are smaller and only connect with other cells in their immediate vicinity.

* **Cerebellum**

The cerebellum coordinates voluntary muscle movements and maintains balance. The cerebellum integrates information from the cerebral cortex, the spinal cord and the vestibular system of the inner ears. The information from the cerebral cortex is motor information concerning where the brain is moving consciously the body and limbs. Information from the spinal chord originates in the position sensors in the joints, tendons and muscles of the body. Information from the vestibular system concerns the orientation of the head in three dimensional space and its movement. The cerebellum thereby serves to coordinate movement and maintain posture [4].

* **Brain Stem**

The brain stem is the oldest part in evolutionary terms, and its structure, size and function have changed little in the evolution of the vertebrates. It is an extension of the spinal chord and has three main functions:

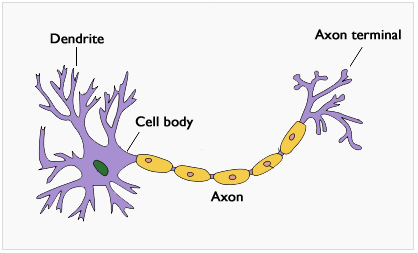
1. Connecting link between the cerebral cortex, cerebellum and spinal chord,
2. Control centre for basic body functions such as respiration, heart and blood flow regulation,

Integration centre for complex reflexes, such as maintenance of body position and posture.

There are four regions: medulla oblongata, pons, midbrain and diencephalon. Each contains nuclei (groups of neuron cell bodies) and bundles of axons. The pons is a bulge at the upper end of the medulla. The medulla has motor and sensory areas for the mouth, neck and throat, and also controls the respiratory and cardiovascular systems. The pons contains cranial nerve nuclei associated with motor and sensory functions of the face. The midbrain contains the major nuclei that control eye movement, blinking and the pupillary light reflex. The diencephalon is at the upper end of the brain stem. It contains the thalamus that integrates sensation, before passing signals onto the cerebrum, and is the site where pain can be consciously appreciated [5].

**1.2 Electrical Recordings from the Brain**

Electrical activity of brain is monitored by **Electroencephalogram (EEG)** [6], which is made from electrodes placed directly over the surface of the brain or from needle electrodes inserted into the brain.

The recordings are the summation of volume conductor fields produced by millions of interconnecting neurons. The neuron components producing the currents are the dendrites, axons and cell bodies as shown in figure 3.The architecture of the brain is not uniform but varies with different locations. Thus the EEG can vary depending on the location of the recording electrodes.

Sensory information is transmitted to the brain by frequency modulated trains of action potentials which cause neuron activity in particular regions of the brain depending on the type of sensory information and the site of stimulus in the body.

Figure 1.2.0 Neuron Structures

Similarly the decision to initiate a movement, in response to sensory information, arises in various parts of the brain, depending on the type of movement and its location in the body, and gives rise to electrical activity at the corresponding sites.

Recordings made from an electrode on the surface of the scalp, using a distance reference electrode, are the resultant field potential at the boundary of a large volume conductor containing many active neurons. Action potentials in axons contribute little to scalp surface records as they are asynchronous and the axons run in many different directions. Surface records are the net effect of local postsynaptic potentials of cortical cells. These may be both excitatory and inhibitory.

Each pyramidal cell acts as a radially oriented dipole. The total contribution at the surface depends on the staggered summation in space and the degree of activity at any given time. The orientation of the dipole reverses when most of the input at the dendrites is inhibitory.

**1.3 Classes of Wave Groups**

EEGs show continuous oscillating electric activity. The amplitude and the patterns are determined by the overall excitation of the brain which in turn depends on the activity of the reticular activating system in the brain stem. Amplitudes on the surface of the brain can be up to 10micro V, those on the surface of the scalp range up to 100micro V.Frequencies range from 0.5 to 100 Hz.The pattern changes markedly between the states of sleep and wakefulness. Distinct patterns are observed in various actions of body. Five classes of wave groups are described: alpha, beta, gamma, delta and theta.

* **Alpha Waves**

Alpha waves contain frequencies between 8 and 13 Hz with amplitude less than 10 micro V.They are found in normal people who are awake and resting quietly, not being engaged in intense mental activity. Their amplitude is highest in the occipital region.

When the person is asleep, the alpha waves disappear. When the person is alert and their attention is directed to a specific activity, the alpha waves are replaced by asynchronous waves of higher frequency and lower amplitude.

* **Beta Waves**

Beta waves have a frequency range of 14 to 22 Hz, extending to 50 Hz under intense mental activity. They have their maximum amplitude (less than 20 micro V) on the parietal and frontal regions of the scalp.

* There are two types: beta I waves, lower frequencies which disappear during mental activity, and beta II waves, higher frequencies which appear during tension and intense mental activity.
* **Gamma Waves**

Gamma waves have frequencies between 22 and 30 Hz with amplitude of less than 2micro V peak-to-peak and are found when the subject is paying attention or is having some other sensory stimulation.

* **Delta Waves**

Delta haves have frequency content between 0.5 and 4 Hz with amplitude less than 100 micro V.They occur during deep sleep, during infancy and in serious organic brain disease. They will occur after trans-sections of the upper brain stem separating the reticular activating system from the cerebral cortex. They are found in the central cerebrum, mostly the parietal lobes.

* **Theta Waves**

Theta waves have a frequency range between 4 to 7 Hz with amplitude of less than 100 micro V.They occur mainly in the parietal and temporal regions in sleep and also in children when awake, and during emotional stress in some adults, particularly during disappointment and frustration. Sudden removal of something causing pleasure will cause about 20 s of theta waves.

Frontal, Temporal, Occipital, Parietal lobes and various patterns of wave classes as shown in figure 4.The production of any of these rhythmic waveforms requires that areas of cerebral cortex be connected to other areas and the reticular activating system in the brain stem [7].

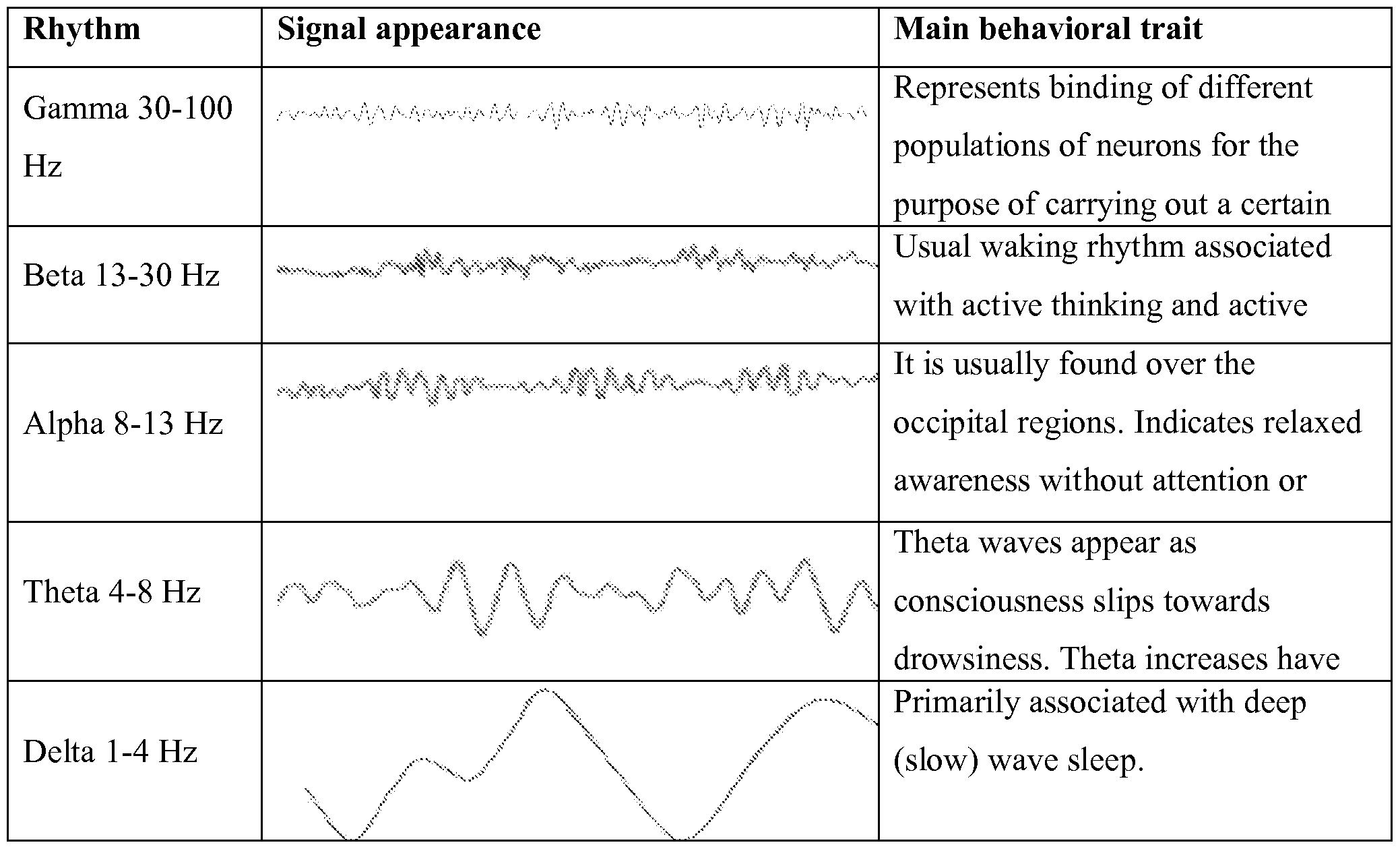


Figure 1.3.0 Various Patterns (Rhythms) of Wave Classes

**1.4 Standard Positions of Electrodes**

The most commonly used placement standard is the International Federation 10-20 system as shown in figure 5.Three types of electrode connections are used which are as follows:

1. Bipolar: between pairs of electrodes, usually adjacent.
2. Mono-polar: between one electrode and a distant reference electrode usually attached to one or both earlobes.
3. Mono-polar: between one electrode and a reference formed by averaging all the other electrodes by connecting them through resistors.

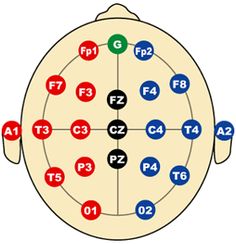
Electrodes are small, disposable and self-adhesive and contain their own electrode gel .The EEG is usually recorded with the subject awake but resting on a bed with their eyes closed. Records may also be made with subject asleep or when hyperventilating (over breathing).Both these conditions may give rise to abnormal patterns which may not be present in the resting state. During sleep the patterns are high amplitude, low frequency; except during REM (rapid eyes movement) sleep when low amplitude, high frequency component, similar to patterns when awake. During REM sleep the person is dreaming, the eyes are moving rapidly, as they might when awake and alert, and muscle tone is diminished through the body, except for the eye muscles [8].

Figure 1.4.0 Standard Placement of Electrodes

Blue shows right hemi-sphere. Red shows left hemi-sphere. Black shows mid line.

Where F: Frontal Lobe: Temporal Lobe, C: Central Lobe, P: Parietal Lobe, O: Occipital Lobe, Z: Mid Line.

**1.5** **Applications of EEG**

EEG recording systems are frequently used with peripheral nerve, auditory and visual stimulation to produce “evoked potentials”, Nerve stimulation is via needle electrodes inserted through the skin adjacent to the nerve or via skin electrodes.

Recordings may be made in other nerves as well as the EEG.Auditory stimulation is made with “clicks” or bursts of single frequency tones. Visual stimulation is via fixed or moving patterns, usually checkerboard, displayed on a monitor for the patient.

The response is of very low amplitude and is typically lost in the pseudo-random patterns from the rest of the brain. To overcome this problem, the stimulus is repeated many times (typically 128) in quick succession and the responses sum and averaged by computer.

The EEG is sometimes recorded when the patient is asleep or performing normal daily tasks. In order not to disturb the patient, only the electrodes, pre-amplifiers and stimulators are with the patient. Telemetry is used to communicate with the rest of the equipment in a different room.

* **Neuromarketing:**

In the field of neuromarketing, economists use EEG research to detect brain processes that drive consumer decisions, brain areas that are active when we purchase a product/service, and mental states that the respective person is in when exploring physical or virtual stores. Nowadays, studies can be conducted in mobile setups to gain insights into shopping habits and decision-making in real-world scenarios.

* **Human Factors:**

Originating from Psychology, the field of Human Factors focuses on workplace optimization; both with respect to tools and interfaces as well as social interaction. In this area, EEG research is used to identify brain processes related to specific personality traits such as intro-/extroversion or social anxiety. Additionally, brain processes reflecting cognitive and attentional states during human-machine-interaction are heavily studied using EEG, primarily using [wireless headsets](https://imotions.com/hardware/eeg-headsets/) with long-term monitoring capabilities.

* **Social Interaction:**

Humans are social agents – we spend a majority of our lives interacting with others. In social interaction research, brain processes related to social perception, self-evaluation, and social behaviour are investigated. Importantly, social interactions and communication are not passive forms of processing incoming stimuli. Whenever we talk to others or solve problems together, we have to “sync up” with our partners. To study the brain processes underlying the synchronization of conversations and actions, EEG researchers use a method referred to as “hyper scanning” to record data from multiple people at once, allowing them to gain deeper insights into leadership and team interactions.

* **Psychology and Neuroscience:**

Most generally, psychological studies utilize EEG to study the brain processes underlying attention, learning and memory. How do we perceive the world? How do our expectations shape the way we see our surroundings? Based on massive trial repetition, event-related potentials (ERPs) are extracted from the continuous stream of EEG data, which allows to characterize brain processes triggered by the events on a very detailed time scale (tens of milliseconds). ERPs can be characterized by their amplitude (in millivolts, with positive and negative going waves labelled “P” and “N”, respectively), timing (in ms relative to event onset), and voltage distribution across all electrodes (topography). Specific ERPs have been identified for the processing of faces (N170), words and meaning (N400), surprise (P300), or memory recall (P600).

* **Clinical and Psychiatric Studies:**

Whenever brain processes are impaired (e.g., lesions, genetic dysfunctions, diseases), deficits in behavioural, attentional and cognitive processing can be observed. Clinical and psychiatric fields use EEG to evaluate the patients’ cognitive states, determine lesion sites, and classify symptoms. Also, EEG is heavily used to evaluate the effect of medical and psychological treatment (e.g., in cognitive-behavioural therapy). More and more therapies utilize virtual reality technology and record EEG data to monitor how the patients’ brains improve over time.

* **Brain Computer Interfaces (BCI):**

A relatively new but emergent field for EEG is brain computer interfaces. Today we know in much more detail which brain areas are active when we perceive stimuli, when we prepare and execute bodily movements or learn and memorize things. This gives rise to very powerful and targeted EEG applications to steer devices using brain activity. This can, for instance, help paralyzed patients steer their wheelchairs or move a cursor on a screen, but BCI technology is also used for military scenarios where soldiers are equipped with an exoskeleton and [EEG cap](https://imotions.com/blog/eeg-cap/), allowing them to move, lift and carry very heavy items simply based on brain activity.

If you would like to know more about EEG and its applications as well as anything else regarding biometric research please [contact](https://imotions.com/contactus/?_ga=1.36318501.428381221.1422438189) the team at [iMotions](https://imotions.com/blog/exponential-growth-in-academic-eye-tracking-papers-over-the-last-40-years/) or [request a demo](https://imotions.com/requestdemo/?_ga=1.36318501.428381221.1422438189) [9].

CHAPTER 2

BRAIN COMPUTER INTERFACE

CONTENTS

* 1. Introduction to BCI
  2. Modelling of Brain Computer Interface (BCI)
  3. EEG (Electroencephalography)

**2.1 Introduction to BCI (Brain Computer Interface)**

A **brain–computer interface** (**BCI**), sometimes called a **mind-machine interface** (**MMI**), **direct neural interface** (**DNI**), or **brain–machine interface** (**BMI**), is a direct communication pathway between an enhanced or wired [brain](https://en.wikipedia.org/wiki/Brain) and an external device. BCIs are often directed at researching, mapping, assisting, augmenting, or repairing human cognitive or sensory-motor functions.[10] [11]

Brain Computer interface is the discipline of neuroscience in which a communication path is devised between brain and some external device using a machine like personal computer. BCI is also known as “A direct neural interface” or “Brain machine interface” [12]

Research on BCIs began in the 1970s at the [University of California, Los Angeles](https://en.wikipedia.org/wiki/University_of_California,_Los_Angeles) (UCLA) under a grant from the [National Science Foundation](https://en.wikipedia.org/wiki/National_Science_Foundation), followed by a contract from [DARPA](https://en.wikipedia.org/wiki/DARPA) [10] [11]

* **TYPES**

1. **Invasive BCI**

A BCI in which electrodes are implanted in to the brain or head of the object. [13]

1. **Partially Invasive BCI**

IN this method of BCI brain’s signal sensing devices are partially implanted into the person head while other parts of the device are exposed. [13]

The most important type of type of BCI is the third type which is the non-invasive one on which our project and focus is based on.

1. **Non-invasive BCI**

There have also been experiments in humans using [non-invasive](https://en.wikipedia.org/wiki/Non-invasive_(medical)) [neuroimaging](https://en.wikipedia.org/wiki/Neuroimaging) technologies as interfaces. The substantial majority of published BCI work involves noninvasive EEG-based BCIs. Noninvasive EEG-based technologies and interfaces have been used for a much broader variety of applications. Although EEG-based interfaces are easy to wear and do not require surgery, they have relatively poor spatial resolution and cannot effectively use higher-frequency signals because the skull dampens signals, dispersing and blurring the electromagnetic waves created by the neurons. EEG-based interfaces also require some time and effort prior to each usage session, whereas non-EEG-based ones, as well as invasive ones require no prior-usage training. Overall, the best BCI for each user depends on numerous factors. [14]

**2.2 Modeling of Brain Computer Interface (BCI)**

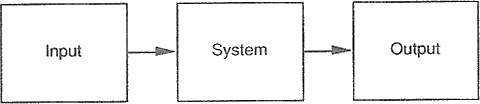
Brain Computer interface can be modeled as in electrical system which requires some input/excitation (usually of small electrical magnitude) then by processing this input/excitation it performs certain certain pre-defined tasks. It can be schematically represented by simple signal approach as shown in figure.

Figure 2.2.0 Basic Process of Recieving Information

The BCI system depends upon following considerations:

1. Nature of input/Excitation and its recording techniques.
2. Synthesis of processing module that is an interconnection of other sub-systems or sub-modules.
3. Nature of the output/Response or controlling device.[15]

**2.3 EEG (Electroencephalography)**

Electroencephalography, or EEG, is a neurological test that uses an electronic monitoring device to measure and record electrical activity in the brain. [16]

In the early days of BCI research, another substantial barrier to using EEG as a brain–computer

interface was the extensive training required before users can work the technology. For example, in experiments beginning in the mid-1990s, Niels Birbaumer at the University of Tübingen in [Germany](https://en.wikipedia.org/wiki/Germany) trained severely paralysed people to

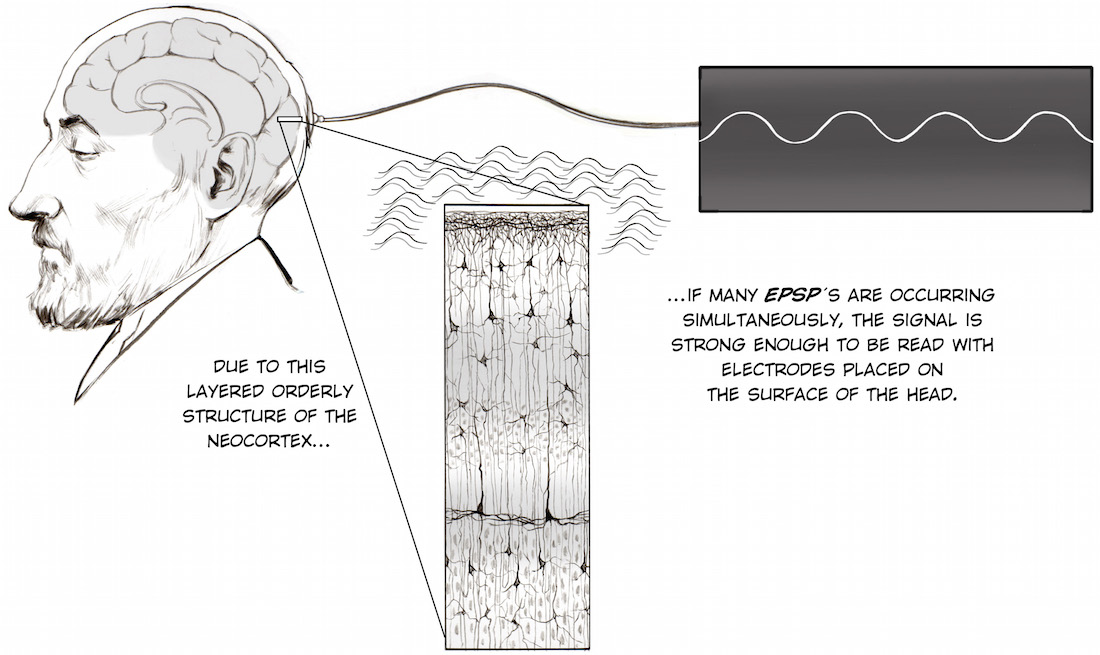
self-regulate the *slow cortical potentials* in their EEG to such an extent that these signals could be used as a binary signal to control a computer cursor.[[17]](https://en.wikipedia.org/wiki/Brain%E2%80%93computer_interface#cite_note-47) (Birbaumer had earlier trained [epileptics](https://en.wikipedia.org/wiki/Epilepsy) to prevent impending fits by controlling this

Figure 2.3.0 Electrodes Reading Electrical Signals

low voltage wave.) The experiment saw ten patients trained to move a computer cursor by controlling their brainwaves. The process was slow, requiring more than an hour for patients to write 100 characters with the cursor, while training often took many months. However, the slow cortical potential approach to BCIs has not been used in several years, since other approaches require little or no training, are faster and more accurate, and work for a greater proportion of users.

Another research parameter is the type of [oscillatory activity](https://en.wikipedia.org/wiki/Neural_oscillation) that is measured. Birbaumer's later research with Jonathan Wolpaw at [New York State University](https://en.wikipedia.org/wiki/New_York_State_University) has focused on developing technology that would allow users to choose the brain signals they found easiest to operate a BCI, including [*mu*](https://en.wikipedia.org/wiki/Mu_wave) and [*beta*](https://en.wikipedia.org/wiki/Beta_wave) rhythms.

A further parameter is the method of feedback used and this is shown in studies of [P300](https://en.wikipedia.org/wiki/P300_(Neuroscience)) signals. Patterns of P300 waves are generated involuntarily ([stimulus-feedback](https://en.wikipedia.org/wiki/Event-related_potential)) when people see something they recognize and may allow BCIs to decode categories of thoughts without training patients first. By contrast, the [biofeedback](https://en.wikipedia.org/wiki/Biofeedback) methods described above require learning to control brainwaves so the resulting brain activity can be detected.

While an EEG based brain-computer interface has been pursued extensively by a number of research labs, recent advancements made by [Bin He](https://en.wikipedia.org/wiki/Bin_He) and his team at the [University of Minnesota](https://en.wikipedia.org/wiki/University_of_Minnesota) suggest the potential of an EEG based brain-computer interface to accomplish tasks close to invasive brain-computer interface. Using advanced functional neuroimaging including BOLD functional [MRI](https://en.wikipedia.org/wiki/MRI) and [EEG](https://en.wikipedia.org/wiki/EEG) source imaging, Bin He and co-workers identified the co-variation and co-localization of electrophysiological and hemodynamic signals induced by motor imagination.[[18]](https://en.wikipedia.org/wiki/Brain%E2%80%93computer_interface#cite_note-48) Refined by a neuroimaging approach and by a training protocol, Bin He and co-workers demonstrated the ability of a non-invasive EEG based brain-computer interface to control the flight of a virtual helicopter in 3-dimensional space, based upon motor imagination.[[18]](https://en.wikipedia.org/wiki/Brain%E2%80%93computer_interface#cite_note-49) In June 2013 it was announced that Bin He had developed the technique to enable a remote-control helicopter to be guided through an obstacle course.[[19]](https://en.wikipedia.org/wiki/Brain%E2%80%93computer_interface#cite_note-50)

CHAPTER 3

EEG(ELECTROENCE-PHALOGRAPHY)

CONTENTS

* 1. Introduction to EEG
  2. EEG Brain Waves
  3. EEG-based BCI

**3.1 Introduction to EEG**

Electroencephalography (EEG) is an [electrophysiological](https://en.wikipedia.org/wiki/Electrophysiology) monitoring method to record electrical activity of the [brain](https://en.wikipedia.org/wiki/Brain). It is typically noninvasive, with the [electrodes](https://en.wikipedia.org/wiki/Electrode) placed along the [scalp](https://en.wikipedia.org/wiki/Scalp), although invasive electrodes are sometimes used in specific applications. EEG measures voltage fluctuations resulting from [ionic current](https://en.wikipedia.org/wiki/Ion_current) within the [neurons](https://en.wikipedia.org/wiki/Neurons) of the [brain](https://en.wikipedia.org/wiki/Brain).[[20]](https://en.wikipedia.org/wiki/Electroencephalography#cite_note-Niedermeyer-1)

 In clinical contexts, EEG refers to the recording of the brain's spontaneous electrical activity over a period of time,[[20]](https://en.wikipedia.org/wiki/Electroencephalography#cite_note-Niedermeyer-1) as recorded from multiple [electrodes](https://en.wikipedia.org/wiki/Electrode) placed on the scalp.

Diagnostic applications generally focus on the [spectral content](https://en.wikipedia.org/wiki/Frequency_spectrum) of EEG, that is, the type of [neural oscillations](https://en.wikipedia.org/wiki/Neural_oscillation) (popularly called "brain waves") that can be observed in EEG signals.

EEG is most often used to diagnose [epilepsy](https://en.wikipedia.org/wiki/Epilepsy), which causes abnormalities in EEG readings.[[21]](https://en.wikipedia.org/wiki/Electroencephalography#cite_note-2)

* **Digital Analysis Of EEG Brain Signal**

Electroencephalography is a medical imaging technique that reads scalp electrical activity generated by brain structures. The electroencephalogram (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. The EEG measured directly from the cortical surface is called electrocortiogram while when using depth probes it is called electrogram. Thus electroencephalographic reading is a completely non-invasive procedure that can be applied repeatedly to patients, normal adults, and children with virtually no risk or limitation. When brain cells 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. 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. 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 the detailed microscopic picture is more sophisticated, including different types of synapses involving variety of neurotransmitters. 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. Due to capability to reflect both the normal and abnormal electrical activity of the brain, EEG has been found to be a very powerful tool in the field of neurology and clinical neurophysiology. The electrical signals generated by the brain represent not only the brain function but also the status of the whole body. The electrical nature of the human nervous system has been recognized for more than a century. It is well known that the variation of the surface potential distribution on the scalp reflects functional activities emerging from the underlying brain .This surface potential variation can be recorded by affixing an array of electrodes to the scalp, and measuring the voltage between pairs of these electrodes, which are then filtered, amplified and recorded[22]

Evoked potentials or event-related potentials (ERPs) are significant voltage fluctuations resulting from evoked neural activity. Evoked potential is initiated by an external or internal stimulus [23]

**3.2 EEG Brain Waves**

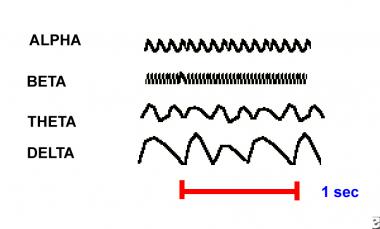
***[](javascript:refImgShow(1))***EEG waveforms are generally classified according to their frequency, amplitude, and shape, as well as the sites on the scalp at which they are recorded. The most familiar classification uses EEG waveform frequency (eg, alpha, beta, theta, and delta).[24][25][26]

Figure 3.2.0 Different Waveforms

Normal EEG waveforms, like many kinds of waveforms, are defined and described by their frequency, amplitude, and location.[27]

* **EEG FREQUENCY**

1. Frequency (Hertz, Hz) is a key characteristic used to define normal or abnormal EEG rhythms.
2. Most waves of 8 Hz and higher frequencies are normal findings in the EEG of an awake adult. Waves with a frequency of 7 Hz or less often are classified as abnormal in awake adults, although they normally can be seen in children or in adults who are asleep.

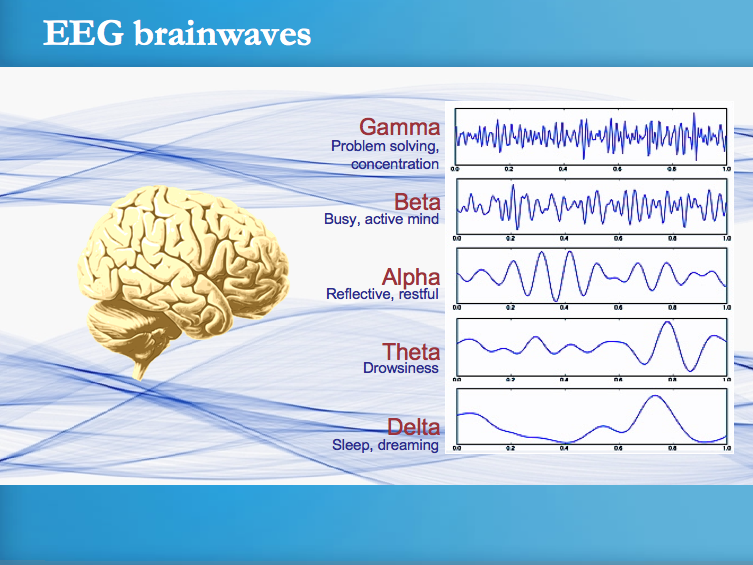
 In certain situations, EEG waveforms of an appropriate frequency for age and state of alertness are considered abnormal because they occur at an inappropriate scalp location or demonstrate irregularities in rhythmicity or amplitude. [28]

Figure 3.2.1 EEG brainwaves

1. Some waves are recognized by their shape, scalp location or distribution, and symmetry. Certain patterns are normal at specific ages or states of alertness and sleep.
2. The morphology of a wave may resemble specific shapes, such as vertex (V) waves seen over the vertex of the scalp in stage 2 sleep or triphasic waves that occur in the setting of various encephalopathies.

* **Frequency**

The frequencies most brain waves range from are 0.5-500 Hz. However, the following categories of frequencies are the most clinically relevant:

* Alpha waves - 8-13 Hz
* Beta waves - Greater than 13 Hz
* Theta waves - 3.5-7.5 Hz
* Delta waves - 3 Hz or less
* **Alpha waves**

1. Alpha waves generally are seen in all age groups but are most common in adults. They occur rhythmically on both sides of the head but are often slightly higher in amplitude on the non dominant side, especially in right-handed individuals. A normal alpha variant is noted when a harmonic of alpha frequency occurs in the posterior head regions. They tend to be present posteriorly more than anteriorly and are especially prominent with closed eyes and with relaxation.
2. Alpha activity disappears normally with attention (eg, mental arithmetic, stress, opening eyes). In most instances, it is regarded as a normal waveform.
3. An abnormal exception is alpha coma, most often caused by hypoxic-ischemic encephalopathy of destructive processes in the pons (eg, intracerebral hemorrhage). In alpha coma, alpha waves are distributed uniformly both anteriorly and posteriorly in patients who are unresponsive to stimuli.

* **Beta waves**

1. Beta waves are observed in all age groups.
2. They tend to be small in amplitude and usually are symmetric and more evident anteriorly.
3. Drugs, such as barbiturates and benzodiazepines, augment beta waves.

* **Theta waves**

1. Theta waves normally are seen in sleep at any age. In awake adults, these waves are abnormal if they occur in excess.
2. Theta and delta waves are known collectively as slow waves.

* **Delta waves**

1. These slow waves have a frequency of 3 Hz or less.
2. They normally are seen in deep sleep in adults as well as in infants and children.
3. Delta waves are abnormal in the awake adult.
4. Often, they have the largest amplitude of all waves.
5. Delta waves can be focal (local pathology) or diffuse (generalized dysfunction).[29]

**3.3** [**EEG-based BCI**](http://en.wikipedia.org/wiki/Brain%E2%80%93computer_interface)

Figure 3.3.0 EEG-based BCI

**EEG BASED BCI** is the most studied and perhaps the most clinically promising BCI technology.

* **Advantages**

1. non-invasive
2. superior temporal resolution
3. ease of use
4. portability
5. low set-up cost.

* **Disadvantages**

1. susceptibility to noise,
2. Extensive user training is required.

Other BCI signals that were employed include evoked potentials, MEG, and MRI.

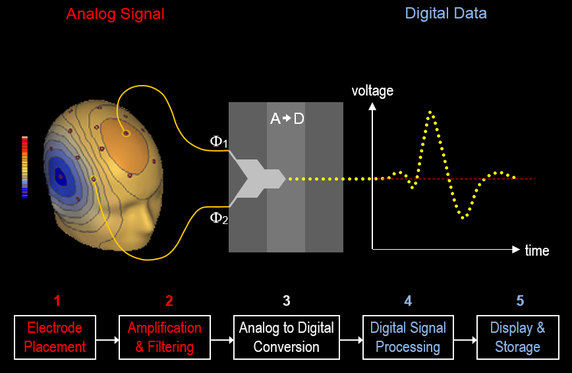
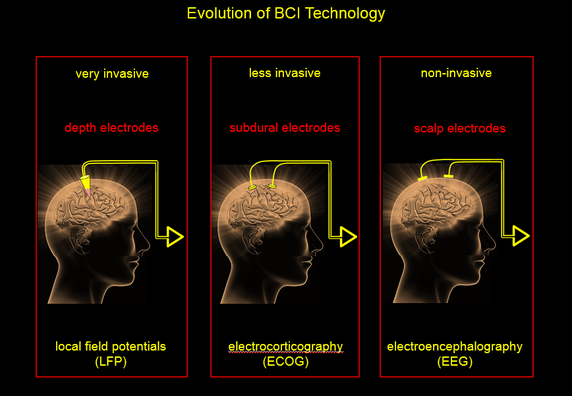
Brain waves are tiny analog signals (electrical potentials) that are usually recorded on the scalp with electrodes. These tiny signals induce tiny [electronic](http://s.igmhb.com/click?v=UEs6MTMwMDUxOjIxOTIyOmVsZWN0cm9uaWNzOjdhNWFkZWE4MDIzZjI1N2YzYjFhZWIxZDQ3ZmQ5Nzc5OnotMjQ0OS04ODQzNTU5MTp3d3cucXVvcmEuY29tOjM3OTU5ODowOmM0MTE2NDEzZWM5NjQ3ODJhYTA0YTNhMzkyNDI2NTY2OjA6ZGF0YV9zcyw3Mjh4MTM2NjtkYXRhX3JjLDI7ZGF0YV9mYix5ZXM7OjEwNTg6OjowLjAx&subid=g-88435591-14f316c18eeb4fccbd6b40e2bb34b33d-&data_ss=728x1366&data_rc=2&data_fb=yes&data_tagname=A&data_ct=link_only&data_clickel=link&data_sid=5ee2adb2d7dc3cfdaf8b2beed97344ae) currents in the wires that connect to the EEG machine. From the wires, the tiny signals go through an amplifier where the difference between the two input signals is amplified. The amplified signal is then passed through a filter to remove unwanted

Figure 3.3.1 Analog signals being converted into Digital signals

signal components (noise). The next step involves converting the analog signal to digital signal with an analog-to-digital converter (ADC). The digital

[Finally, the digital signal is stored in a media [hard disk](https://www.quora.com/What-is-EEG-based-brain-computer-interface#37573945), SSD, CD, DVD, etc). There is also an option to transport it remotely so you don't have to drive to the hospital and so you can read it while watching football (source: my Quora answer)

* **BCI EVOLUTION**

Non-invasive electroencephalography (EEG) based brain-

computer interface (BCI) is able to provide an alternative means of communication with and control over external assistive devices. In general, EEG is insufficient to obtain detailed information about many degrees of freedom (DOF) for arm movements.

Figure 3.3.2 Evolution of BCI Technology

The main objectives are to design a non-invasive BCI and create a signal decoding strategy that allows people with limited motor control to have more command over potential prosthetic devices.

* **PROCESSING OF RAW DATA**

Raw data or primary data is the data collected from source. In EEG the scalp potentials acquired.

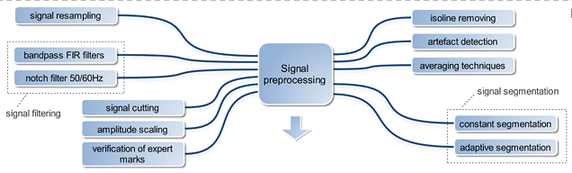


Figure 3.3.3 Signal Processing

Like any kid, the story of raw data processing happens before its birth. There are some hardware level processing like frequency band-pass filtering, killing the age old villain 50/60 Hz.[30]

Now we have other small but very gory villains to slain. let me introduce them one by one:

* **Blinking artifact**

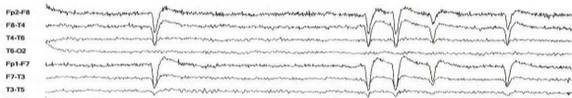
  
Humans are supposed to close their eyes or never close their eyes. The blinking of eye creates a spike in EEG signal. And no one should swallow or grin their teeth thinking is the researcher doing. There are plenty of eye-blink removal filters available in market. Use them thrice a day.

Figure 3.3.4 Different EEG Signals

CHAPTER 4

TOOLS REQUIRED IN EEG BASED SMART HOMES

CONTENTS

4.1 EEG Headset

4.2 Working

4.3 Softwares and Apps for EEG Headsets

4.4 Mobile Apps

4.5 What is Arduino UNO?

4.6 BCI based controlled system

4.7 How Arduino works?

4.8 How Arduino amplifies signals?

**4.1 EEG Headset**

* **INTRODUCTION:**

The headset used for our design of EEG based smart home is EMOTIVE INSIGHTTM

These **headsets** sense the electrical activity inside a person's brain using a technique known as electroencephalography, or **EEG**

****There are many headsets based on performing specific functions.

The Emotiv team are veterans when it comes to brainwave-reading headsets.

Back in 2010, the company presented a rough version of what would later transform into the Insight, demonstrating with a [TED talk](http://www.ted.com/talks/tan_le_a_headset_that_reads_your_brainwaves.html) the possibilities of the technology.

Figure 4.1.0 An EEG EMOTIV Headset

But how does it work, and what can it do?

The Insight is a sleeker, more advanced version of the headset presented at the TED conference. Utilizing five sensors that attach to your head, the Insight monitors the electrical impulses that your brain releases, turning this information into usable data.

For example, if you were playing a video game and wanted to map a brain command to make your character run forward, you could hypothetically record yourself visualizing the 'forward' command.

Once the Insight headset can recognize your 'forward' thought, it could be taught to move your game character forward each time you think it.

Besides being able to recognize up to four mental commands, the Insight can also turn facial expressions such as winking, smiling, and blinking into commands.

Gaming is only one aspect of what the Insight is capable of — the company is billing the Insight as a device to "optimize your brain fitness & performance, measure and monitor your own or your family’s cognitive health & wellbeing, and develop amazing new applications."

And while applications implementing direct integration with the Insight are scarce, Emotiv is hoping that a successful Kickstarter will put enough developer units in people's hands early enough to have a solid app selection upon launch. [31]



* **DESCRIPTION:**

Emotiv Insight is a 5-channel mobile EEG headset that records your brainwaves and translates them into meaningful

Figure 4.1.1 EMOTIV Insight

data you can understand. Designed for extended use in field research, BCI and advanced self-assessment use-cases, Insight boasts advanced electronics that are fully optimized to produce clean, robust signals anytime, anywhere.

Emotiv Insight is the only device in its category that offers 5 EEG sensors + 2 reference sensors.  This high spatial resolution provides in-depth information on your brain activity.  Leveraging years of science-backed research and experience to create the next generation brainwear®, the

Insight features an elegant, lightweight and user-friendly design

* **SIGNALS:**

1. 5 channels: AF3, AF4, T7, T8, Pz
2. 2 references: In the CMS/DRL noise cancellation configuration

* **SIGNAL RESOLUTION:**

1. Data transmission rate: 128 samples per second per channel
2. Minimum voltage resolution: 0.51μV least significant bit

* **FREQUENCY RESPONSE: 1-43HZ**

1. Connectivity
2. Wireless: Bluetooth 4.0 LE
3. Proprietary wireless: 2.4GHz band

* **POWER:**

1. Battery: Internal Lithium Polymer battery 480mAh
2. Battery life: 4 hours minimum run time

* **USB RECIEVER UNIVERSAL MODEL (ADDITIONAL):**

The Universal USB Receiver is required for use with devices which do not support the Bluetooth SMART protocol and is strongly recommended for all purchasers who plan to use Insight with a PC running Mac OSX, Windows 7+ or Linux (Ubuntu or Fedora)[32]

Figure 4.1.1 USB for devices that do not support bluetooth protocol

* **FEATURES:**

1. Elegant, lightweight, intuitive, ergonomic design
2. Provides high spatial resolution ensuring ‘whole brain’ measurement
3. Hydrophilic Polymer Sensor technology – No preparation, safe and no sticky gels!
4. Wireless connectivity to phone, tablet and PC
5. 4 hrs minimum battery run time, freeing you to maintain continual performance in almost any activity
6. 9 axis motion sensors for precision measurement of head position and movement
7. Windows, OSX, Linux, Android, and iOS compatible
8. Provides access to raw EEG data with software subscription
9. Leverage Performance Metrics, Mental Commands and Facial Expressions

* **COMPATIBILITY:**

The EMOTIV INSIGHT neuroheadset connects wirelessly to PCs, tablets, and smart phones running Windows, Linux, MAC OSX, Android, or iOS.

Windows system requirements

* GHz Intel Pentium 4 processor (or equivalent)
* Microsoft Windows XP with Service Pack 2, Windows Vista, Windows 7, or Windows 8
* 2GB RAM
* 200MB available disk space.

Mac system requirements

* MAC OS X (10.5.x, 10.6.x, 10.7.x, 10.8.x, 10.9.x )
* Intel-based Macintosh
* 2GB RAM
* Hard disk with 500Mb available

Linux system requirements

* 2.4 GHz Intel Pentium 4 processor (or equivalent)
* Ubuntu version 12.04 or above, Fedora stable version 20
* 2GB RAM
* 200MB available disk space
* **Android system requirements**

1. A device that has Bluetooth Low Energy (Bluetooth 4.0) functionality. Most modern high-end devices have this ability. Check the documentation and specification of your device (this functionality is usually called Bluetooth LE or Bluetooth 4.0).
2. OS: Android 4.4.3+
3. Sample Devices: Samsung Galaxy S3, Samsung Galaxy S4, Sony Xperia SP, Sony Experia Z

IOS system requirements

* iOS 6, 7, and 9+

Compatible with iPhone 4s or later, iPad 3 or later, iPod touch generation 5 and iPad mini.

**4.2 Working**

Brainwear that allows you to monitor your cognitive health and wellbeing and optimize your performance.The EMOTIV Insight uses a proprietary polymer sensor that is safe to use and offers great electrical conductivity with the convenience of a dry sensor.

A new kind of hydrophilic polymer biosensor system eliminates the need for extensive preparation and conductive materials like gels or saline solution, by absorbing moisture from the environment. [33]A VIDEO THAT GIVES A COMLETE DESCRIPTION OF WORKING ON INSIGHT CAN ALSO BE VIEWED AT <https://www.emotiv.com/insight/>

“EMOTIV Insight introduction Video”

[](http://blog.visual.ly/emotiv-insight-measures-and-visualizes-brain-data/emotivinsight_mediaimage3/)The Emotiv Insight is not just a brain computer interface, a lot of new detections and software that provides feedback to allow users to optimize their cognitive performance. We are moving into the wearable devices space with this product but instead of tracking the number of steps you've taken, it tracks your cognitive performance.

Figure 4.2.0 EMOTIV Insight and EMOTIV EPOC Headsets

At launch, consumers can download a free mobile app (Android/iOS) that measures, tracks and helps them improve their Attention, Focus, Engagement, Interest, Excitement, Affinity, Relaxation and reduce Stress levels.

You will get a much better idea of your productivity profile. When you're paying attention, the time of day and how long you can sustain your attention, your interest levels, your bursts of focus. How well you can relax, your stress levels. How attracted you are to new or old experiences. How well you relate to others and how you react to new situations. Emotiv Insight offers you the tools you need to monitor your performance across a range of different situations and to optimize the way you go about your work and play. Discover if classical music sharpens your performance, distracts you from your work or sends you to sleep. Learn how to approach business meetings to enhance your productivity. Set the thermostat so your creative juices can flow freely. Pick the best time of day for exercising, working, meditating or chilling out.

Research has shown that when you are made aware of all of these indicators, people are better informed and empowered to make decisions to optimize and improve their cognitive fitness and performance. Recent studies of brain plasticity and epigenetics provide strong evidence that you can rewire your brain and even overcome genetic predispositions by the activities you undertake and the way you respond to new experiences. Neurofeedback – a fancy name for modifying your behaviour to achieve desirable goals in your ability to perform well and respond more positively to your environment – is becoming well established as a way to improve your learning, improve concentration and develop your potential more effectively. Emotiv Insight will provide reports, graphs, hints and suggestions allowing you to decide which factors most influence your performance in your chosen activities. [34]

The brain is an incredibly complex organ. It is made up over around 100 billion nerve cells, which can be measured through electroencephalography (also known as EEG). Emotive Insight records EEG data in real time and in a variety of different forms, such as through Alpha, Beta, and Gamma waves. Emotiv Insight then translates this EEG data into easily understood and actionable forms. “Emotiv Insight provides metrics for desirable and undesirable characteristics which are familiar to the users,” said Kim Du, Emotiv’s Vice President for Corporate Development. “The recorded levels of these metrics during different sessions of similar activity can be used to reveal details about how the user can improve their performance or mental attitudes based on the differences between specific sessions. For

example, does playing classical music allow you to focus more or less when you are studying? Do you study better late at night or early in the morning?”[35]

* **EMOTIV INSIGHT-QUICK START GUIDE**

1. Attach the rear arm connector to the headset body. The connector should slide fully into the slot and the arm should be flush with the body
2. Attach a sensor to the end of each arm with the sensor pads facing inward. The sensor should snap in place and be flush with the arm.
3. Charge the Insight with the included cable. The Insight will attain full charge at about 2 hours.
4. The Insight’s ON/OFF button is above the charging port.
5. Position the reference sensors to touch the skin behind the ear. It is critical that the reference sensors make contact behind the ear.
6. Frontal sensors should align above each eye and should be positioned about the finger widths above the eyebrows.
7. If necessary remoisten the pads with rehydration solution.[36]

* **OTHER HEADSETS:**

There are also many other headsets like:

1. Neurosky Mindwave EEG
2. Emotiv Epoc
3. Melon
4. Muse
5. Emotiv EEG
6. 3D DIY EEG Headsets[37]

**4.3 Softwares and Apps for EEG Headsets**

There are many PC softwares and mobile apps for training with headsets. The softwares supporting EMOTIV Insight are:

* **PC SOFTWARES:**

These are the softwares that are run on our PC. They play an important role in enhancing and brain ability and our capability to control various devices merely through our thoughts.

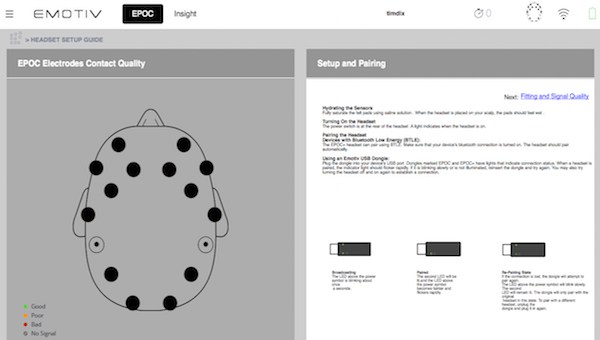
These softwares actually enhance our brain skills.

Following are such softwares:

1. **EMOTIV SDK COMMUNITY:**

Build neurofeedback applications, control your avatar, fly a drone or connect your smart home by translating your thoughts into actions.  Our community SDK is free and provides API access to the following:

* Facial Expressions
* Mental Commands
* 9 Axis Inertial Sensors
* FFT (Frequency Bands)

1. **EMOTIV SDK PREMIUM:**

Leverage the latest advancements in neuroscience to understand cognitive performance, emotional experiences

Figure 4.3.0 EMOTIV's software that enhances the brain activity

and preferences to create commercial applications that open new market opportunities.

Access is available to our scientifically validated metrics:

* Performance Metrics
* Raw EEG

**Versions available for the following platforms:**   
Windows, Mac, Linux, iOS, Android, Arduino, and Raspberry Pi. [38]

* **EMOTIV CONTROL PANEL:**

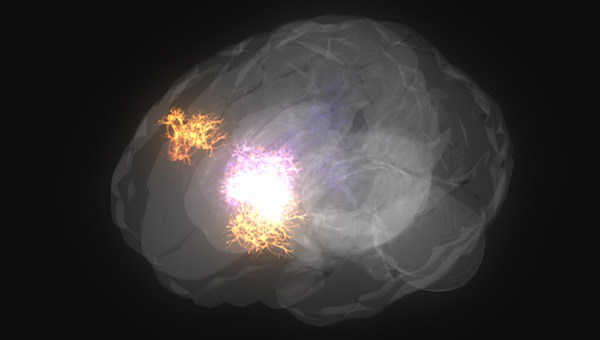
EMOTIV Control Panel: the latest EMOTIV Wireless EEG companion software. For use with both the EMOTIV [EPOC+](http://emotiv.com/product/emotiv-epoc-14-channel-mobile-eeg/) and [Insight](http://emotiv.com/product/emotiv-insight-5-channel-mobile-eeg/) headsets. Get acquainted with EEG and brain monitoring and learn how to use your

Figure 4.3.1 A SDK Software

EMOTIV wireless EEG headsets and their features. Fit and connect your EEG headset, set base lines (eyes open/eyes closed), monitor and record performance metrics, facial expressions and practice mental commands. Begin self-assessment via this easy to use desktop application.

\*\*A new feature of the Xavier is that it can be used as a mouse (input device) emulator using the built in inertial sensors.

* **EMOTIV BRAIN VISUALIZER:**

Displays a real-time 3D visualization of brain activity across the four major brainwave frequency bands (Delta, Theta,

Alpha, Beta). Auto-intensity and adjustable intensity sliders

Figure 4.3.2 Software visualizing the brain

allows you to see detailed information and relative strengths between different brain regions. Please note that an Emotiv headset enabled for raw EEG data is required.

* **EMOTIV PURE EEG:**

Pure•EEG provides real-time display of the EPOC/+ & Insight headset data stream, including raw EEG data from 14 channels, FFT, gyro, wireless packet acquisition/loss display, marker events, headset battery level. Record and replay files in binary EEGLAB format. Command line file converter included to produce .csv format.

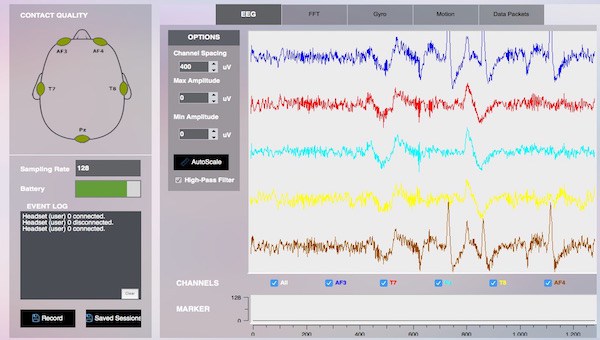
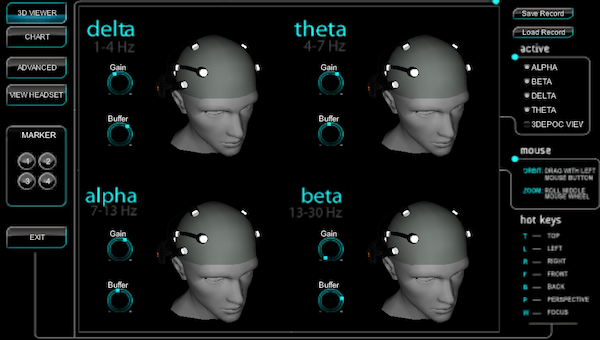
Define and insert timed markers into the data stream, including on-screen buttons and defined serial port events. Markers are stored in EEG data files. Marker definitions can be saved and reloaded. Markers are displayed in real time and playback modes.

Figure 4.3.3 collecting EEG Sigals

Pure EEG is provided in monthly, annual pre-paid, and multi-year plans to allow for better budget planning and lower upfront cost. So whether you’re a student, a citizen hacker, a small start-up team, or a large corporation, you’ll have the ability to pay for tools for the amount of time that is right for you.

Discover Pure.EEG™

* 5 second rolling time window (chart recorder mode)
* ALL or selected channels can be displayed
* Synchronized marker window.
* Automatic or manual scaling (individual channel display mode)
* Adjustable channel offset (multichannel display mode)
* **EMOTIV 3D BRAIN MAP:**

This application displays a real-time 3D Brain visualizer of

Figure 4.3.4 Emotive 3D Brain Maps

your brain activity in four significant brainwave frequency bands. Auto-intensity and adjustable intensity sliders allows you to see detailed information and relative strengths between different brain regions. A headset with access to raw EEG data is required.

**Note:** Insight support requires an Universal USB dongle.

**IMPORTANT:** To install on Windows 7, Vista & 8, Right click the installer and select “Run As Administrator”. Please pick your preferred platform for this app, OSX or Windows, by choosing from the drop down menu... [39][40]

**4.4 Mobile Apps**

Following are some frequently used mobile apps for Emotive Insight.

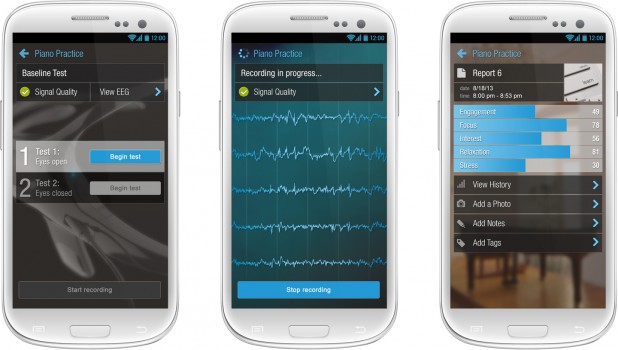
* [](http://blog.visual.ly/emotiv-insight-measures-and-visualizes-brain-data/mobile-update-pane2/)**EMOTIV Insight:**

Figure 4.4.0 EMOTIV Mobile Apps for EMOTIV Insight

[](http://blog.visual.ly/emotiv-insight-measures-and-visualizes-brain-data/mobile-update-pane1-1/)The main visual dashboard for Emotiv Insight is a mobile app for Android and iOS devices. The app doesn’t reveal raw brainwave data, but instead real-life cognitive performance feedback across areas such as attention, focus, engagement, interest, excitement, affinity, relaxation, stress. Emotiv links brain data and areas of cognitive performance using complex algorithms based on a combination of accepted measures (for example, “frontal asymmetry is linked to feelings of attraction or repulsion, positive or negative feelings,” Du said) and learned patterns based on controlled experiments. All Emotiv Insight data will be uploaded to a cloud server where it can be further analyzed and compared against similar demographic

Figure 4.4.1 Mobile Apps for EMOTIV Headset

groups or the larger Emotiv Insight wearing population. Du stressed that while Emotiv Insight measures EEG brain data, it is not targeted to the EEG research community. Instead, she said, “it is designed to empower more people to understand their brain and provide the research community with an easy to use, wearable EEG for everyday use.” “There are significant benefits to having a multi-channel system with spatial resolution of key EEG sites around the cerebral cortex,” she added. “We’ve spent a lot time building new detections and software that provides feedback to allow users to optimize their cognitive performance. Research has shown that when you are made aware of all of these indicators, people are better informed and empowered to make decisions to optimize and improve their cognitive fitness and performance.”[35]

* **MYEMOTIV:**

It is the companion app for EMOTIV INSIGHT and EPOC+ wearable EEG headsets



Figure 4.4.2 MYEMOTIV Mobile App

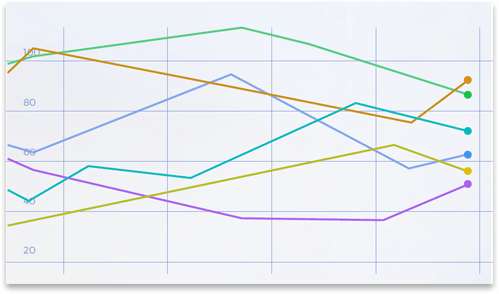
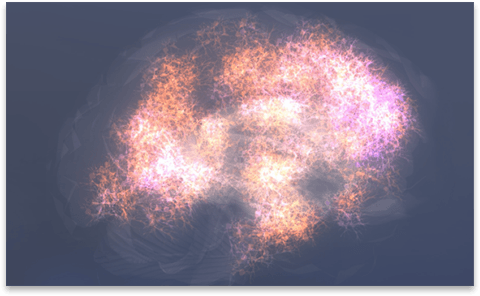
Don’t just look at your brain, look after it MyEMOTIV takes the complexity out of reading and interpreting your brain waves, so you can easily measure your mental performance and fitness. Our Performance Metrics provide real time detection of cognitive and emotional states,

Figure 4.4.3 Mobile Apps visualise brain's activity

so you can get valuable insights from your EEG right away.

* **Track and Optimize your Brain Performance**

Icon 1Capture, save and playback recordings of your brain activity

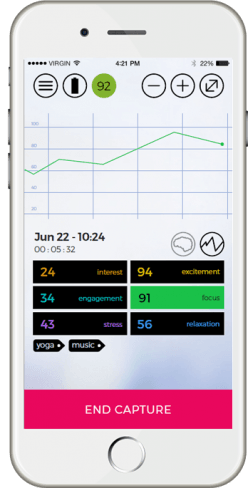
https://i2.wp.com/dev.emotiv.com/wp-content/uploads/2016/11/Icon-2.png?resize=60%2C60Measure six key cognitive and emotional metrics: focus, stress, excitement, relaxation, interest and engagement

https://i1.wp.com/dev.emotiv.com/wp-content/uploads/2016/11/Icon-3.png?resize=60%2C60Explore your brain’s activity patterns in real time with our popular 3D BrainViz viewer

https://i1.wp.com/dev.emotiv.com/wp-content/uploads/2016/11/Icon-4.png?resize=60%2C60Compare your results to previous sessions and the Emotiv community

https://i1.wp.com/dev.emotiv.com/wp-content/uploads/2016/11/icon-5.png?resize=60%2C60Get recommendations on activities you can do in daily life to improve your focus and manage your stress.

**Get to know your Brain**

MyEMOTIV allows you to capture brain activity over 6 Key Cognitive and Emotional Metrics

**Interest** measures how much you like or dislike something.

**Excitement** captures your level of emotional arousal.

**Engagement** measures how immersed you are in what you are doing or experiencing.

**Focus** is your ability to concentrate on one task and ignore distractions.

**Stress** measures how comfortable you are with the current challenge you are facing.

Figure 4.4.4 Mobile App showing Brain’s details

**Relaxation** is your ability to switch off and reach a calm mental state.

**Improve your Brain Fitness**

Understanding how your brain responds to everyday activities is the first step in optimizing

your brain’s performance and well-being.Learn what time of day you aremost focused or what activities make you the most relaxed. Or try one of our recommended strategies for managing stress or improving focus and see how it works for you. [41]

**4.5 What is Arduino UNO?**

Arduino is an open-source electronics platform based on easy-to-use hardware and software. Arduino UNO are able to read inputs - light on a sensor, a finger on a button, or a Twitter message - and turn it into an output - activating a motor, turning on an LED, publishing something online. You can tell your board what to do by sending a set of instructions to the microcontroller on the board. To do so you use the [Arduino programming language](https://www.arduino.cc/en/Reference/HomePage) (based on [Wiring](http://wiring.org.co/)), and [the Arduino Software (IDE)](https://www.arduino.cc/en/Main/Software), based on [Processing](https://processing.org/).

Over the years Arduino has been the brain of thousands of projects, from everyday objects to complex scientific instruments. A worldwide community of makers - students, hobbyists, artists, programmers, and professionals - has gathered around this open-source platform, their contributions have added up to an incredible amount of [accessible knowledge](http://forum.arduino.cc/) that can be of great help to novices and experts alike.

Arduino was born at the Ivrea Interaction Design Institute as an easy tool for fast prototyping, aimed at students without a background in electronics and programming. As soon as it reached a wider community, the Arduino board started changing to adapt to new needs and challenges, differentiating its offer from simple 8-bit boards to products for IoT applications, wearable, 3D printing, and embedded environments. All Arduino boards are completely open-source, empowering users to build them independently and eventually adapt them to their particular needs. The [software](https://www.arduino.cc/en/Main/Software), too, is open-source, and it is growing through the contributions of users worldwide.

* **Why Arduino?**

Thanks to its simple and accessible user experience, Arduino has been used in sharing ideas online with other members of the Arduino community. The Arduino software is easy-to-use for beginners, yet flexible enough for advanced users. It runs on Mac, Windows, and Linux. Teachers and students use it to build low cost scientific instruments, to prove chemistry and physics principles, or to get started with programming and robotics. Designers and architects build or interactive prototypes, musicians and artists use it for installations and to experiment with new musical instruments. Makers, of course, use it to build many of the projects exhibited at the Maker Faire, for example. Arduino is a key tool to learn new things. Anyone - children, hobbyists, artists, programmers - can start tinkering just following the step by step instructions of a kit, or sharing ideas online with other members of the Arduino community.[43]

**4.6 BCI based controlled system**

The Electroencephalogram (EEG) pulses that are sensed by the brain computer interface have to be processed by the physiological signal acquisition module. The processed signal is transmitted via Bluetooth to an embedded processing module. A simple control protocol is to be created such that the home network is controlled based on the processed signal inputs. A smart home network is to be designed based on the cognitive nature of an individual that is sensed using a Brain Computer Interface. The block diagram of the model is represented as shown in Fig.1. The system architecture of the proposed model mainly consists of four parts:

1) wireless physiological signal acquisition module

2) embedded signal processing module and

3) host system

Here, the wireless physiological signal acquisition module is designed to acquire and transmit an EEG signal to the embedded signal processing module wirelessly via Bluetooth . Bluetooth provides a short range wireless and secure communication between

devices to eliminate the need for messy cables.By using the encryption function in the security procedures of Bluetooth, it will translate the transmitted data into secret code to avoid the contents being eavesdropped.

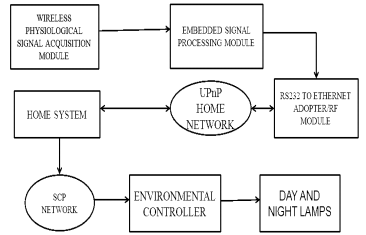


Figure 4.6.0 Setup of BCI based home

The embedded signal processing module is designed to estimate the user’s cognitive state from his or her EEG, and provides the estimated cognitive state to the host system. The host system is designed for data storage/display, and is also served as an UPnP control point to manage the request from UPnP control device as well as the SCP/PLC environmental controller, which is used to control electric home appliances, such as day and night lamps, air conditioners, and others.

* **Wireless Physiological Signal Acquisition Module**

The block diagram of the proposed wireless physiological acquisition module is shown in Fig.2. It mainly consists of a front end amplifier unit, a microprocessor unit, and a wireless transmission unit. Here, the front end amplifier unit contains a preamplifier, a band-pass filter, and a 12-bit analog to digital converter (ADC). The gain of the front end amplifier unit is set to 5040 times with a passing frequency band of 0.1– 100 Hz. EEG data digitized by ADC with the sampling rate of 512 Hz will be stored into the memory of the microprocessor unit, and then be processed to pass through a moving average filter in the microprocessor unit to remove power-line interference before being sent to the wireless transmission unit.

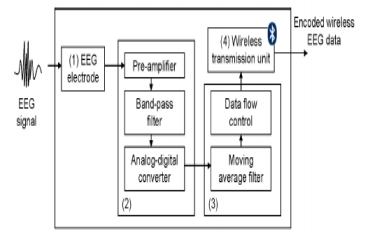
The wireless transmission unit consists of a printed circuit board antenna and a Bluetooth module, which is fully compliant with the Bluetooth v2.0+ EDR specification. This module operates at 31mA with 3.7 V DC power supply, and

Figure 4.6.1 Journey of EEG Signals

can continuously operate over 33 h with a commercial 1100 mAh Li-ion battery. The volume of the proposed wireless physiological signal acquisition module is about 4 cm × 2.5 cm × 0.6 cm, which is small enough to be embedded into a headband as a wearable device.

* **B. Embedded Signal Processing Module**

The proposed embedded signal processing module that contains a powerful computation capability and can support various peripheral interfaces is developed to perform the real time cognitive state detection algorithm, and is also evaluated as the UPnP control device to send out the estimated cognitive state and EEG signal to host system to drive environmental controller via UPnP home networking. Here, the Arduino embedded processor is used in the embedded signal processing unit. The operating clock frequency of central processing unit can run at up to 16 MHz It contains two 16-bit multiply-and-accumulate to execute 1200 lines addition and multiplication functions and also has four independent direct memory access mechanisms to effectively reduce the processing time of core. A memory-mapped thin film transistor liquid crystal display, which shares the same memory bus with synchronous dynamic random access memory, is used in this module. Here, serial peripheral interface Flash is used to replace the parallel NOR flash to reduce the module size. Furthermore, this module also contains power management circuits. The embedded processor communicates with wireless transmission unit via universal asynchronous receiver/transmitter interface. This module can be operated with a 5 V DC power supply, and it can continuously operate for more than 45 h operations. The volume of the embedded signal processing module is about 2.4 inches × 2.1 inches × 0.5 inch. The cognitive state detection algorithm was implemented as a multithreaded application on operation system. The received EEG data will be real-time processed, analysed and displayed by the embedded signal processing module. When the change of cognitive state of the user is detected, the corresponding command will be transmitted either by radio frequency (RF) module or by Ethernet (a RS232-to-Ethernet adopter module is required) through UPnP protocol to the host system.

* **C. Host System and Environmental Controller**

The host system is an UPnP/SCP bridge and is also served as the home gateway to internet network. With UPnP/SCP techniques, the system is realized to simply plug-and play IP/non-IP consumer equipment in home networking without any complicated settings. In the host system computer, Windows XP was used as the operation system, and the host system program, developed on Microsoft Visual C#, was designed to provide following functions: data storage and display, UPnP control point to receive and reply the request from UPnP control device and SCP host to transmit control commands to environmental controller for operations. A SCP-based environmental controller with four channel AC/DC power line control outputs is used to control home equipment in this paper. All settings and control commands are accomplished with writing/reading three continuous registers. Two or more kinds of commands can be sent from the host system to environmental controller to control the endpoints according to user’s cognitive state. In this paper, the SCP based environmental controller is used to control the day and night lamps in the showroom. The adjustable DC outputs of environmental controller can be also employed if adjustable illumination of lights is required.

**4.7 How Arduino works?**

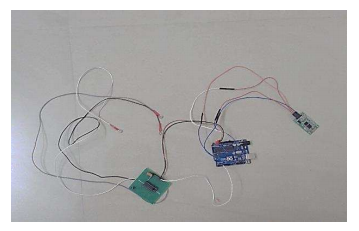
The EEG electrodes are connected to the Arduino Uno board. The electrodes are used to measure the alpha, beta and gamma values of EEG pulse signal. These electrodes are placed around the forehead of a person. The EEG values are sensed and sent through a motor driver

Figure 4.7.0(a) ARDUINO UNO

unit. The values are passed to the Arduino Uno board. The transmitter side and the receiver side setup are shown in EEG shown in Fig.5.3.0 (a) and Fig.5.3.0 (b). The Arduino software version 1.0.3 is used program the Arduino Uno board. The board has to be selected in the software. The board is uploaded with the program to read the EEG values.

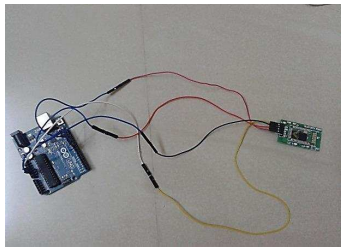


Figure 4.7.0(b) ARDUINO UNO

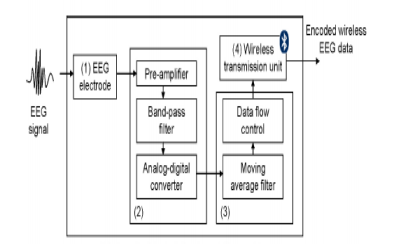
The block diagram of the proposed wireless physiological acquisition module is shown in Fig. It mainly consists of a front end amplifier unit, a microprocessor unit, and a wireless transmission unit. Here, the front end amplifier unit contains a preamplifier, a band-pass filter, and a 12-bit analog to digital converter (ADC). The gain of the front-end amplifier unit is set to 5040 times with a passing frequency band of 0.1– 100 Hz. EEG data digitized by ADC with the sampling rate of 512 Hz will be stored into the memory of the microprocessor unit, and then be processed to pass through a moving average filter in the microprocessor unit to remove power-line interference before being sent to the wireless transmission unit. The wireless transmission unit consists of a printed circuit board antenna and a Bluetooth module, which is fully compliant with the Bluetooth v2.0+ EDR specification. This module operates at 31mA with 3.7 V DC power supply, and can continuously operate over 33 h with a commercial 1100 mAh Li-ion battery. The volume of the proposed wireless physiological signal acquisition module is about 4 cm × 2.5 cm × 0.6 cm, which is small enough to be embedded into a headband as a wearable devices.[42]

Figure 4.7.1 Journey of EEG Signals in ARDUINO UNO

* **How Arduino converts analogue signals to digital signals?**

In our device we need to convert brain signals (analogue signals) into digital signals which electronic devices can understand. Arduino ADC (Analogue to Digital Converter) do this job. Following discussion explains how Arduino acts as ADC:

Analog-to-digital converters are everywhere — every smartphone, tablet, notebook and PC has at least one because they all convert audio (voice or music) into digital data. But audio is just the tip of the iceberg when it comes to analog-to-digital converter applications. Digital storage oscilloscopes (DSOs) turn analog voltages into digital data displayed on an LCD panel in real time; electronic thermometers turn analog temperature readings into digital data shown on 7-segment displays; digital cameras use ADCs to turn light into digital images; CPUs use them to measure core temperature etc. The real world is analog — and analog-to-digital converters are the link between the real world and our digital approximation of it.

Every microcontroller chip worth its silicon comes with at least one analog-to-digital converter and Arduino is no different. But at this point, we need to get geeky and talk about the specific microcontroller chip rather than using the generic Arduino term. The Arduino Uno R3 board we’ve used in this series is powered by Atmel’s ATMEGA328P 16MHz/8-bit microcontroller chip.

But once the analog input is routed to the analog-to-digital converter, what happens next? There are a number of different techniques engineers can use to build an analog-to-digital converter. The simplest and least efficient is the ‘ramp ADC’. Here’s how it works — the analog input is fed into what’s called a ‘sample-and-hold comparator’ while the outputs of a binary counter are fed into a digital-to-analog converter (DAC), whose output is fed back into the comparator. A comparator is a simple circuit element that compares two analog inputs — if one input designated the ‘non-inverting’ input has a higher voltage than the other ‘inverting’ input, the output is digital 1, otherwise, it’s digital 0. It’s the electronic equivalent of an ‘if..then..else’ command in a programming language. IFTTT ([ifttt.com](http://ifttt.com/)) is a simpler example.

The binary counter increments on each clock cycle until the DAC voltage is greater than the analog input, triggering the comparator to stop the clock and the binary counter now holds the digital conversion value. The problem with ramp ADCs, however, is they can take many clock cycles to complete that conversion — imagine a 16-bit counter having to reach 65,535 to finish a conversion. That’s 65,535 clock cycles spent. The other end of the extreme is the ‘flash ADC’ — no

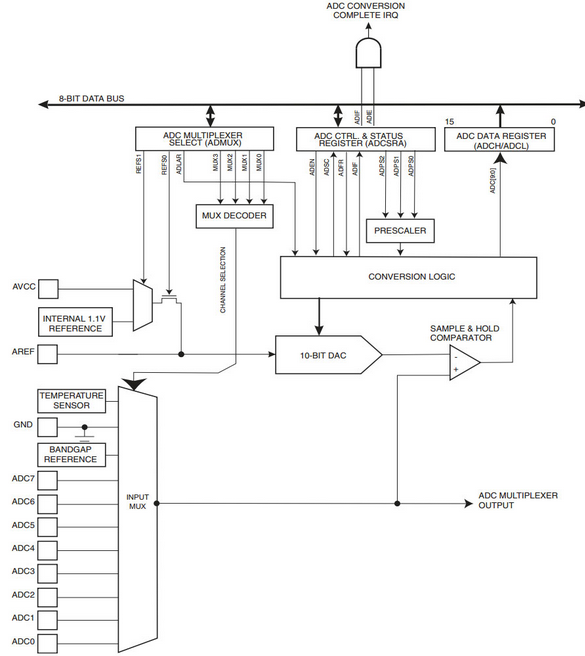
matter what the bit size, it theoretically takes just one clock

Figure 4.7.2 Flowchart of Conversion Analog to Digital Signals

cycle to convert. Instead of using a binary counter, a flash ADC uses a series of comparators that all look at the same analog input, each one comparing the input to a slightly different voltage through what’s called a ‘linear voltage ladder’. The comparator outputs are fed into digital logic elements to create the digital conversion number instantly. The problem is that even with just an 8-bit ADC, you need 255 comparators; a 16-bit ADC needs 65,535 comparators — the precision required makes these expensive.

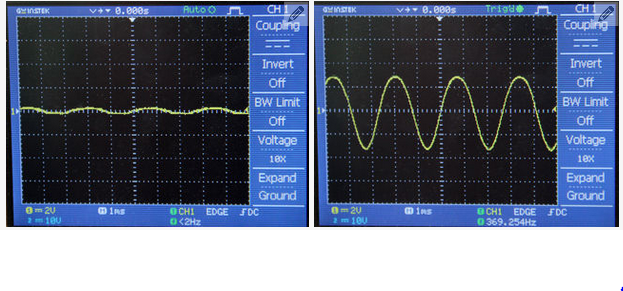
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**4.8** **How Arduino amplifies signals?**

Signals sent by brain to headset are very low so Arduino first amplifies these signals and then manipulate them.

The amplifier is the first step in the circuit, it increases of the signal

from around + or - 200mV to + or - 2.5V (ideally).Above diagram shows how a simple amplifier enhances amplitude of a signal.

Figure 4.8.0 ARDUINO amplifying signals

# Very Basic Op Amp Functionality

## Two Inputs and One Output

Simply put…

* It accepts **two inputs**
* It provides a single output

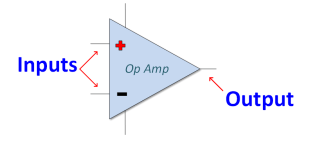


Figure 4.8.1 OP Amplifier

## What the output does?

The output responds to an input by raising or lowering its voltage **until the voltage at the inputs are equal**.

This is done by connecting the op amp in such a way that feedback is provided to one of the inputs.  You’ll see some circuits with feedback a little further on.

In a sense, the device works to create a balance.

## Inverting and Non-Inverting Inputs

The two inputs to the Op Amp each will affect the output differently.  Their names derive from how they affect the output.

The input with minus sign is known as the **Inverting Input**. When it increases (or goes more positive), the output decreases (or goes more negative).  Conversely, if the inverting input goes more negative, the output will go more positive.

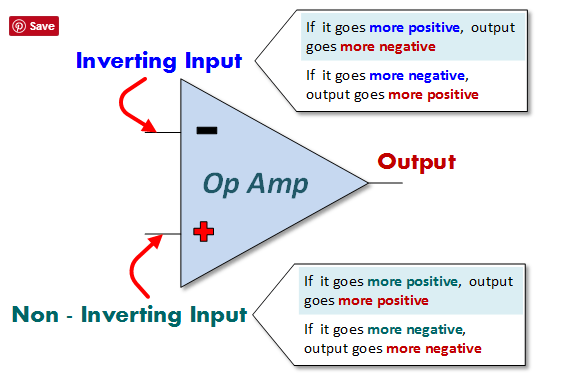
The input with the plus sign is known as the **Non-Inverting Input**.   It causes to output to behave exactly the opposite of the inverting input.   If it goes more positive, the output will go more positive.   If it goes more negative, the output will go more negative.

Figure 4.8.2 Non-Inverting Amplifier

Op Amp circuits on the internet don’t always include a thorough functional explanation.  For you to make use of these circuits, you will want to thoroughly grasp how these inputs affect the output.

* **Bi-Polar and Uni-Polar Op Amps**

The op amp comes in a variety of packages that include DIP, Surface Mount, Cans and others.   Regardless of the package, the Op Amp will at least five pins.

The inputs and outputs have been sufficiently discussed for now.  That said, it is useful to discuss the pins used to provide power.

While we apply to those pins clearly depends on the specs, it is important to know that there are a couple basic flavours available.

One is known as a **bi-polar op amp**.   The other is known as a **uni-polar op amp**.

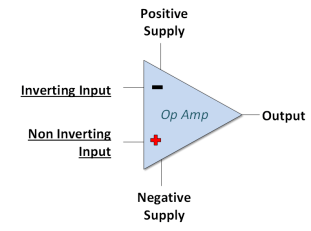
Both can be used with an Arduino, but uni-polar variety is preferred. It is a little less complex to use.

Figure 4.8.3 OP Amplifier

* **Bipolar OP Amplifier**

The Bi-Polar Op Amp is the style that is the most commonly featured in various sample schematics found on the internet.   For power, it is designed to receive both a positive and negative voltage.

It is extremely useful if you need to provide an output that indicates a difference that is less than zero volts.

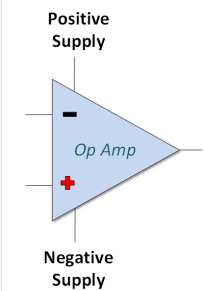
With some thought, it is possible to design a circuit that grounds the negative terminal.  In fact, there are tons out there that do just that.   However, its not how it best operates.

Figure 4.8.4 OP Amplifier

* **Uni-Polar OP Amplifier**

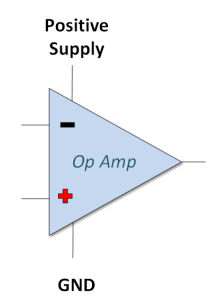
The uni-polar op amp is one where there is a power input and a ground connection.   The power supply will be positive in

Figure 4.8.5 Symbol of Amplifier

most cases.LM358 is a unipolar op amp.

# Common Op Amp Circuit Configurations

Each of the circuits shown uses feedback.   Remember,  the op amp will work raise or lower its output until both inputs are equal.

## The Op Amp Voltage Follower

The illustration below shows a voltage follower.   In this circuit, the output voltage will equal the input voltage.

The benefit here has to do with the input impedance of the op amp.  It has a very high input impedance and will not likely drag the output of the micro-controller (or other device down).

More, depending on the Op Amp selected, the output of the Op Amp can have a much higher current handling capacity than the Arduino Output.

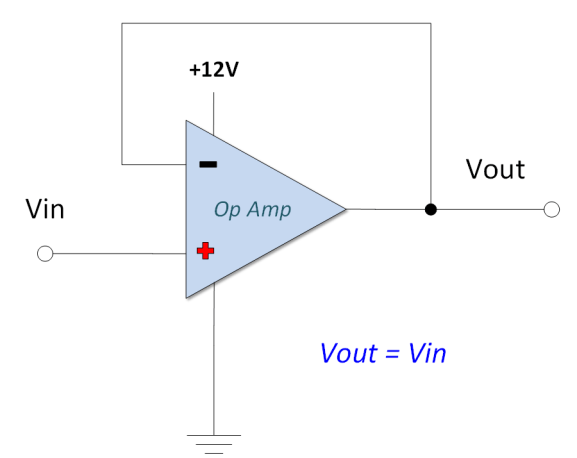
Notice how the output is connected to inverting input.   Thus, the output will respond to change in voltage at the non-inverting input by raising or lowering the voltage until both inputs are equal. Five volts in, gets you five volts out.

Figure 4.8.6 OP Amplifier

## The Op Amp Non Inverting Amplifier

With the non-inverting amplifier we introduce the gain and feedback resistors.   These resistors together determine the amount of amplification or attenuation we see at the output.

The image below is a non-inverting amplifier.  In this circuit,  the output is going to raise or lower its voltage until the inverting input is equal to the value present at **Vin**.

How much it has to raises or lower its voltage is determined by the voltage divider formed by **RF** and **RG**.

**RF** is referred to as a feedback resistor.  **RG** is the gain resistor.

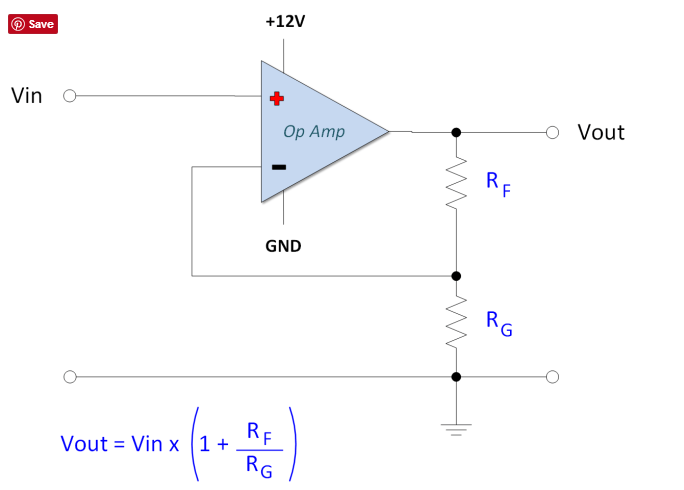
When solving for this circuit, you’re asking yourself what value at the output will cause the voltage at the inverting input to equal **Vin**.

Figure 4.8.7 OP Amplifier Circuit Diagram

The equation is:  **Vout = Vin (1+ RF/RG)**

## The Op Amp Inverting Amplifier

As the name suggests, the inverting amplifier will provide an output that decreases when Vin goes more positive.

Conversely, the output will decrease as the input goes more positive.

The inverting amplifier also introduces us to gain and feedback resistors.   In the drawing below, the gain resistor is identified as **Rg** and the feedback resistor is identified as **Rf**.

The values of these resistors set up circuit behavior.  In fact, these resistors set up a direct ratio.   Specifically:  **-1 x**(**Rf/Rg) = Vout/Vin**

Or put another way:  **Vout = -1 x Vin x (Rf/Rg). [45][46][47]**

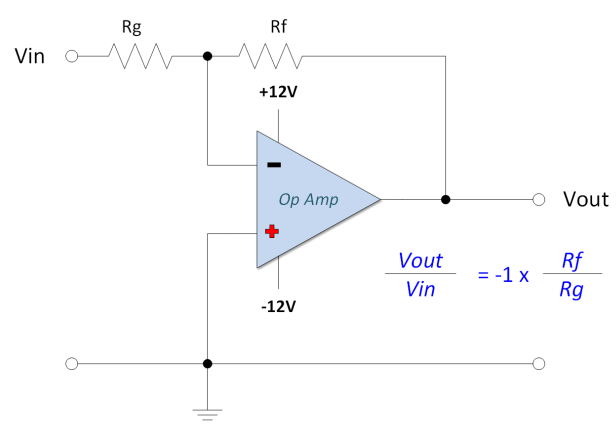


Figure 4.8.8 Circuit Diagram OP Amplifier

CHAPTER 5

Home Smart Home: Brain-computer Interface Control for real Smart Homes Environment

CONTENTS

* 1. INTRODUCTION
  2. BCI based Smart Homes
  3. System architecture
  4. Multi-task management
  5. Monitoring Host system platform
  6. Results
  7. Environment Controller

**5.1 INTRODUCTION**

The kernel feature of Brain-Computer Interface (hereafter

BCI) systems is the exploitation of brain signal modifications

arising from the execution of a cognitive task assigned

to the BCI user.

The final goal is to translate these modifications

to commands enabling both interaction with other people

and operations on devices (ranging from simple switches

to wheelchairs), without requiring muscular activations from

the BCI user.

Thus, whatever the signal acquisition approach,

BCI systems are gifted with a close relation to neural

plasticity and therefore can be considered as neurorehabilitation tools from both assistive technology and strictly clinical neurorehabilitation point of view [1].

In particular,BCI based on Electroencephalography (EEG) are non invasive interfaces that use brain signals acquired from the scalp, exploiting EEG changes related to event-related potentials

(like visual P300, hereafter P300) or to voluntary control

(like Motor Imagery, MI). For assistive technology applications,

MI-based BCI systems present some shortcomings

with respect to P300-based BCI.

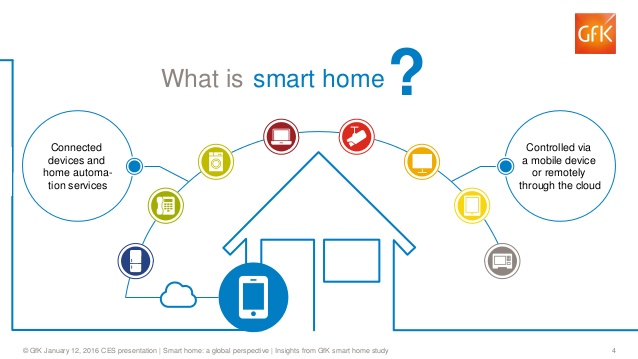


Figure 5.1.0 Smart Home setup

From a neurophysiological point of view, the latter is an event-related potential elicited using an oddball approach, thus naturally allowing

a multiple choice scenario which is difficult to achieve by

using a MI approach. Moreover, the selection of a P300 approach instead of a MI one, shifts the control strategy from process-control to goal-selection [6], thus making the use of a BCI more natural. Finally, experimental results indicate that P300-based BCI requires shorter training and that, for two different samples of healthy subjects with no previous experience in BCI, 81% of was able to use a P300-based

BCI with a classifier accuracy ranging from 80% to 100%,

whereas only 19% was able to reach the same accuracy range

using a MI-based BCI system [3,4].

**5.2 BCI based Smart Homes**

An elective environment for BCI use is the smart home,

which can be defined as “a residence equipped with computing

and information technology, which anticipates and

responds to the needs of the occupants. [5]

In recent years, instead of applying BCIs in real smart homes

and in accordance to a cost-effective investigation strategy,

P300-based BCIs were applied in virtual apartments, experienced watching a monitor or using an immersive approach [9, 8].

Experimental results confirm the feasibility of the P300

approach for healthy subjects in controlling virtual environments.

Moreover, results were obtained using flashing objects

[9] or icons [10], instead of characters in the P300 speller

matrix, as is typical in most applications.

Our main purpose is to think that what we are doing and we what we want to do then by only thinking the head set can detect through EEG and then amplifier emplify it and then send it to the arduino and then it connect with the computer and process and then complete the command with the help of computer. [2]

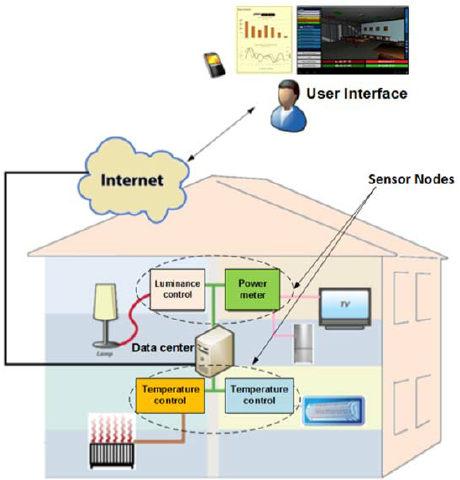


Figure 5.2.0 Smart Home system

A rapid growth of research on smart houses is proposed and

developed to provide various kinds of environmental control

systems. Some environmental control systems in a smart

house employed radio frequency identification (RFID),

external sensor modules, and voice recognition as the

controlled signals.

RFID tag or external sensors are usually installed in different areas in advance for automatic detection of users’ motions. By combining with universal plug and play (UPnP) home networks [7], the users could send out service requests from their personal digital assistant, mobile phones, a wearable appliance, or external sensors to home server either

with voice, graphic user interface, or motion. Moreover, with

the development of brain computer interface (BCI), it is an

extremely new option to apply the physiological signals as the

stimulus of environmental control system in a smart house.

But in the existing brain computer interface-based

environmental control systems the user’s active mental

command is required to control external devices. Hence, these

systems lack the capability to control devices automatically

and adaptively according to the user’s current cognitive state.

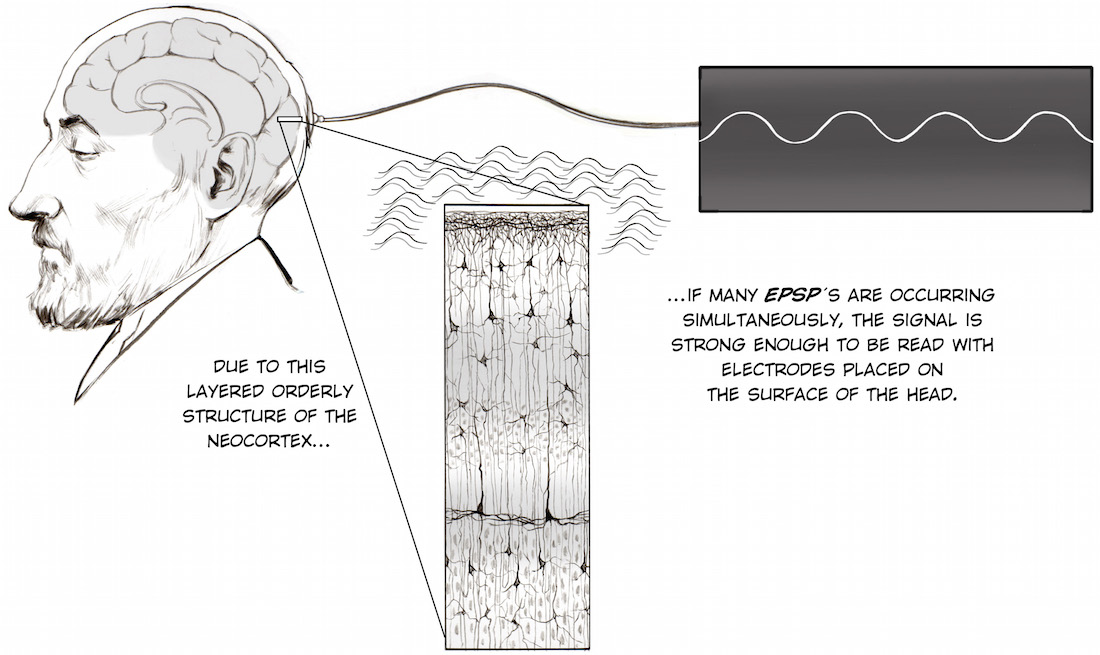


Figure 5.2.1 EEG signal

Also, most of current BCI-based environmental control

systems are very inconvenient because bulky and expensive electroencephalogram (EEG) machines and personal

computers are both required for physiological signals

acquisition and backend analysis, which will limit the

flexibility, portability, and practicability of these systems.

Therefore, the proposed model is a cost effective, simply

extendable and easy-to-use brain computer interface-based

smart auto-adjustment control system to control electric home

appliances based on the change of user’s cognitive state

(drowsiness or alertness). In this model a wireless

physiological signal acquisition module and an embedded

signal processing module were also proposed. Different from

other BCI systems, which are usually bulky and have to

transmit an EEG signal to a backend personal computer to

process the EEG signal, this wireless physiological signal

acquisition module and embedded signal processing module

contain the advantages of small volume and low power

consumption, and are more suitable for practical application.

The UPnP home networking can easily be integrated with

electric home appliances for other applications.

The wearable middleware framework consists of various

components. The bridge system architecture proposed in this

section works as one of the components [10][11]. It is mainly

composed of Device Discovery Module, UPnP Virtual Agent

and Profile Manager. The bridge is a typical example of an

interworking device. Device Discovery Module and Virtual

UPnP Agent work together to bridge the Bluetooth device to

the UPnP environment, and in the meanwhile an UPnP

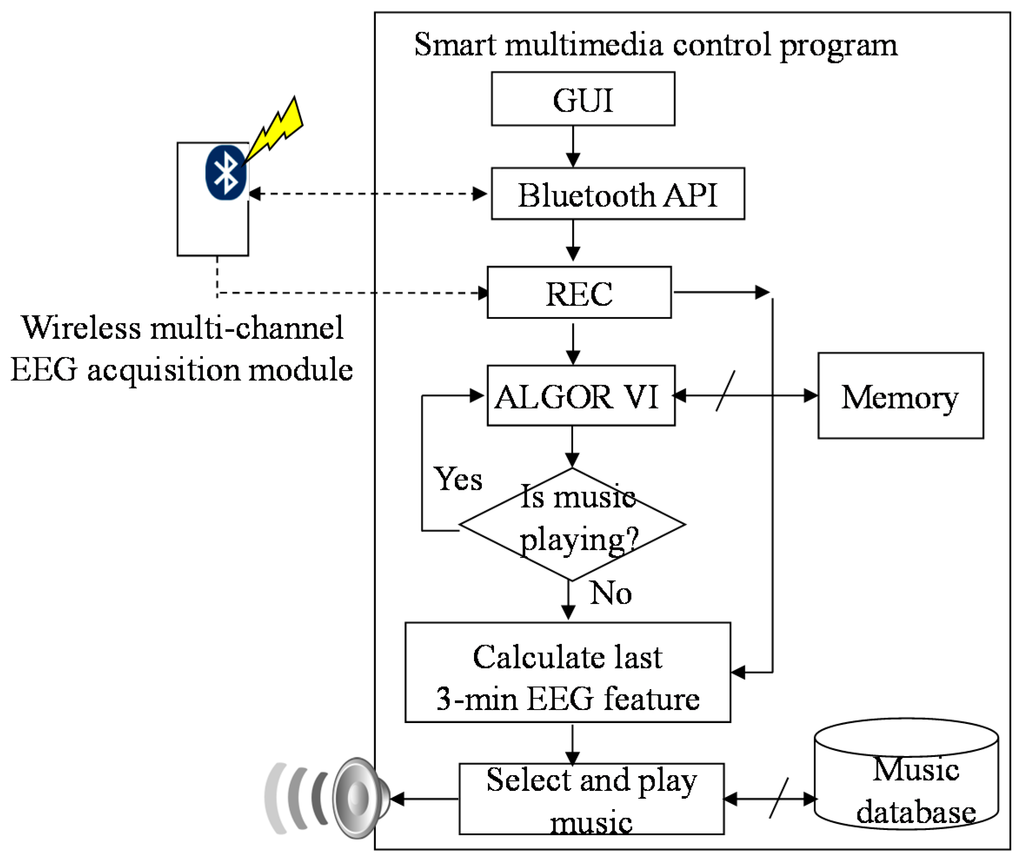
description file [12] is created by interworking with the Profile Manager.

Figure 5.2.3 : Signal processing

The lower-layer interface of the bridge refers to the

Application Program Interface (API) of the System

Adaptation Layer (SAL). It is used to provide transparency to

the subordinate OS and enhance scalability with other media.

The underlying OS can be replaced without changing the

internal implementation of the bridge components. Likewise,

the bridge component can be extended to support another

protocol rather than Bluetooth by revising the lower-layer

interface.

The higher-layer interface refers to the API that can be used

when the application accesses the bridge. The application can

use all the functions of the bridge simply through the higher

layer interface API without having to access the inner

modules of the bridge. The higher-layer interface allows any

application to use the bridging function easily. The Device

Discovery Module plays the role of detecting a Bluetooth

device in run time and extracting information from it. The

information of the Bluetooth device generally consists of the

Bluetooth Generic Access Profile (GAP) and Service

Discovery Protocol (SDP) information. The extracted

information is transmitted to the Profile Manager component,

where the UPnP description-type profile is created. The list

on detected Bluetooth devices is also maintained and each

device is identified as a currently activated UPnP device.

**5.3 System architecture**

On-line independent component analysis (ICA), which was proven an effective technique to remove various types of inevitable EEG artifacts, but was most performed offline on a personal computer, was implemented in the embedded signal processing unit for the physiological state estimation.

As shown the block diagram of the developed EEG-based BCI smart living environmental control system includes five units:

(1) Wireless EEG acquisition circuit unit

(2) Interactive flow control unit

(3) Real-time physiological signal processing unit

(4) Environment controller unit

(5) Monitoring host system for DSP development, data storage and status watchdog.

The three-layer sensing module in our previous developed BCI system for real-time driver drowsiness detection and warning [13] was re-designed and implemented with two stackable PCBs to reduce PCB size in this system. Such Lego-like design can also improve the hardware flexibility for future applications.

The complex programmable logic device (CPLD) module, which is designed and implemented to control the data flow and format exchange between A/D converter and wireless module, is implemented as the downside PCB, while the analog acquisition module and Bluetooth module are integrated as the upside PCB. The new sensing module can therefore provide 4-channel biomedical signal acquisition, amplification, data flow control and wireless transmission functions. For wireless transmission module, the RF3100 in our previous research [13] can be also used in this sensing module. The size of the sensing module is 4.5 cm × 6.5 cm, and the weight of the module with a Li-ion battery is less than 39 g. The sensing module (including signal acquisition, amplification and wireless units) was designed to operate at 400 mA with 3.7-V DC power supply, and its power consumption is about 1.11 W. The module can be operated continuously for more than 45 hours with a commercial 16,000-mAh Li-ion battery. Also, the embedded signal processing platform (OMAP1510) and the PC host system are powered by AC.

* **Hardware Components**

As shown in Fig. , the structure of our system

consists mainly of commercial off-the-shelf components shows the EMOTIV EPOC headset that is used to record raw EEG signals and transmits that data to the computer via a Bluetooth module. The headset has 14 saline sensors to tune into subject’s brain electric signals, and two axis gyroscope for head movements. It has the capability to detect a wide range of thoughts and emotions such as excitement, engagement, meditation, and frustration. Further, left, right, up, down, push, pull movements, and facial actions like individual’s smiling, laughing, clenching, and smirking can be detected. All the data coming out from the headset is encrypted and passed to the computer. Emotiv software like (edk.dll) is used to decrypt this data and makes it available to the researchers who have an educational license.

Figure 5.3.0 Emotiv Head Set

* **Wireless EEG acquisition circuit unit**

As shown in Figure, the detailed architecture of the wireless EEG acquisition circuit unit consists of two major modules:

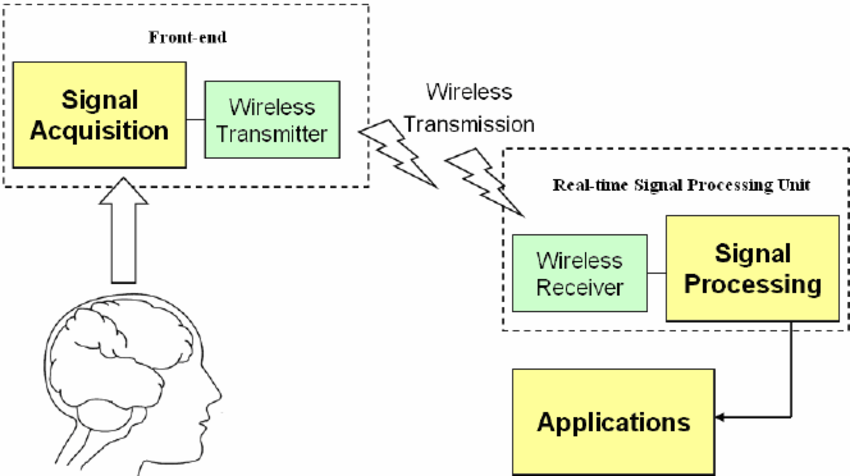
* 1. A signal acquisition and amplification unit that includes MEMS EEG signal acquisition sensors, amplifier and filters.
  2. A wireless data transmission unit that includes an A/D converter and CPLD, that is designed and implemented for data flow control and format exchange between the A/D converter and the wireless data transmission module.

Figure 5.3.1 Real-Time signal processing

* **Signal acquisition and amplification unit**

The amplitude of the EEG signal is as small as 1 μV-150 μV, which is quite noise-sensitive during acquisition. Enhanced sensor technology, higher signal to noise ratio (SNR) and sufficient gains of filter and amplifier are all important and necessary for EEG signal acquisition. In this study, the dry electrodes [14,15] based on MEMS technologies were placed on the subject’s forehead to acquire the EEG signal because such electrodes can maintain the signal quality for long-term physiological monitoring, and overcome the uncomfortableness and inconvenience of traditional EEG sensors (e.g., using electrolytic gel). After signal is acquired, the amplification unit is applied to filter out the artifacts.

The EEG amplifying circuit consists of a differential pre-amplifier with a gain of 99, an isolated amplifier to protect the subject, a band-pass filter that is composed of a low-pass filter and a high-pass filter to preserve 1-100 Hz signals, a differential amplifier with a gain of 51, and a 60-Hz notch filter to eliminate power line noise. The capacitors in the band-pass filter can also compensate the DC-offset. The sensing module carried by the subject is designed to operate with a 3.7-V DC power supply.

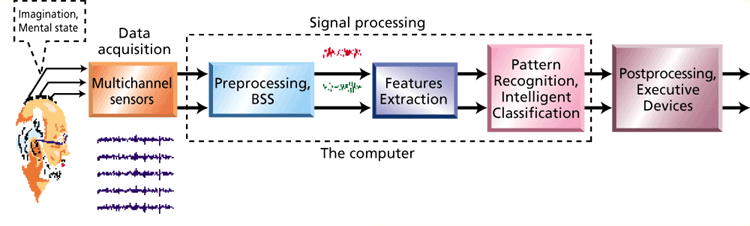


Figure 5.3.2 EEG signal processing

* **Wireless data transmission unit**

Figure shows the wireless data transmission unit that includes 8-b A/D converters (parallel output, sampling rate = 768 Hz, AD-7575, Analog Device, Inc.), a CPLD (ALTERA FLEX10K EPM 7128STC100-7), and wireless modules. The preprocessed analog EEG signals after 60-Hz notch filter were first converted to digital, and then transmitted through the wireless modules. The CPLD is designed to control the A/D converter and encode the data for the wireless modules. Two different transmission approaches, RF3100/RF3105 (Ancher Technology, Inc.) and Bluetooth, were both available in this study. The transmission rate is set as 19,200 b/s only in our final design to prevent transmission error, and it can still provide 295 Hz sampling rate for 4-channel signal transmission.

**5.4 Multi-task management**

Since the proposed BCI system is designed to work in real time, the signal-receiving task should continue when the EEG signal is going through process. An embedded task management algorithm, also called the multi-task scheduling mechanism, is well defined to manage these tasks and to ensure the accurate sampling rate for EEG signal acquisition and data process/ analysis are in real time. The tasks are divided into four types according to their execution period:

(1) Task A – wireless device and data recovery control

(2) Task B – call DSP task and transmit EEG data to memory unit

(3) Task C – receiving data from memory unit for further processing

(4) Task D – Network control and send command with TCP/IP envelope.

**5.5 Monitoring Host system platform**

The monitoring host system has two functions, which include:

(1) Data storage and real-time status watchdog, such as physiological states and EEG signals display.

(2) DSP processing implementation and uClinux OS development platform.

The data size of continuous EEG recordings is beyond the storage capacity of the embedded system. Thus, we have implemented a network file system to store EEG signals. In addition, we built a graphic user interface (GUI) to show the biomedical signals for monitoring. The connection between the host system and the embedded signal processing system is the TCP/IP protocol. [13]

**5.6 Results**

Demonstrations system of the proposed BCI system is constructed in which includes:

(a) A monitoring host PC for DSP procedure implementation and uCLinux OS development, data storage and real-time status display/watchdog,

(b) The environment controller, and

(c) A demo room with two fans to evaluate as the air conditioner, two LEDs to evaluate as the day lights, and one LED to evaluate as the night lamp in the real world.



Figure 5.6.0 Environmental controller diagram

To verify that the proposed BCI system, we firstly tested the modules of biomedical signal amplification/acquisition and wireless transmission in this system with the basic functions. Secondly, the embedded multi-task scheduling mechanism was then tested and compared with the system without scheduling. Finally, to evaluate the performance of the proposed cognitive-state estimation method, the driving performances of six subjects participated in the VR-based highway-driving experiments in different days were compared.

**5.7 Environment Controller**

When a different physiological state is detected, the corresponding package will be delivered with the TCP/IP envelope to the environment controller. Then, the command decoder will send out the control commands to the endpoints to drive and control the equipment in the demo room. The related control commands for these three control endpoints are well defined as the following:

(1)When we think about on of the Led light then the IP/TCP control detect the brain waves and then process the signal and complete the command.

(2) It do multi tasking also that we think about the different devices that they on and off then the EMOTIV HEADSET works and process and then proceed.

Most often in the real-world application, the control endpoint may far away from the command decoder. To overcome this problem, a remote command decoder and control end point (RCEP), such as wireless or wired Ethernet, are practicable and workable. In our experiment, the wired connection between command decoder and control endpoints are implemented.

**CONCLUSION**

The document presented the Smart Home Control System based on BCI using EEG signals. The system used EEG sensors (ARDUINO) for acquiring brain signals. User can control devices only by thinking to do specific task. In this system, user is not required to perform any physical activity. BCI based system can facilitate the disabled person and can take the drastic change in their lives.

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| **UNIVERSITY OF ENGINEERING AND TECHNOLOGY** | | | | |
| **Department of Computer Science** | | | | |
| **EEG (Electroencephalography) Based Smart Homes** | | | | |
| This is where I describe the study that their participation is voluntary and their data are anonymous and confidential | | | | |
| According to your views tick the most suitable option in the following questions. | | | | |
| **S.#** | **QUESTIONS** | **OPTIONS** | | **Tick here** |
| 1 | What is the most important aspect of a BCI (Brain Computer interface) based device? | i | Time saving |  |
| ii | Ease in communication |  |
| iii | Easy access |  |
| iv | Aesthetics or style |  |
| 2 | Are you excited that every appliance is just a thought away with BCI? | i | Yes |  |
| ii | No |  |
| 3 | Which is more preferable? | i | Invasive BCI |  |
| ii | Non-invasive BCI |  |
| iii | Partially invasive BCI |  |
| iv | All the above options |  |
| 4 | Are you ready to use it in spite that through BCI someone could effectively “see how you feel” | i | Yes |  |
| ii | Probably |  |
| iii | May be |  |
| iv | No |  |
| 5 | In your opinion which device is more convenient? | i | Thought controlled |  |
| ii | Blinking controlled |  |
| iii | Both of them |  |
| 6 | Is it only useful for | i | Disabled people |  |
| ii | Normal people |  |
| iii | Every one |  |
| 7 | Do you think mind controlled devices are future of technology? | i | Yes |  |
| ii | No |  |
| iii | Not sure |  |
| 8 | Do you think brain controlled homes will become reality? | i | Definitely |  |
| ii | Probably |  |
| iii | May be |  |
| 9 | Can a company be established on EEG based Smart Homes? | i | Yes |  |
| ii | No |  |
| 10 | Will it be a huge success in business market? | i | Definitely |  |
| ii | Probably |  |
| iii | Maybe |  |