“Development and Simulation of a Brainwave Controlled Prosthesis Environment”

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DECLARATION

We, Prathibha R, Swetha L, and Vaishnavi S, students of B.E., Telecommunication Engineering, M.S. Ramaiah Institute of Technology, Bangalore, hereby declare that the Project entitled “Development and Simulation of a Brainwave Controlled Prosthesis Environment” has been carried out in dependently by us in M.S.Ramaiah Institute of Technology, Bangalore-560054, under the guidance of Dr.Shobha K R, Associate Professor, Department of Telecommunication Engg, MSRIT, Bangalore.

We declare that the work submitted in this report is our own, except where acknowledged in the text, and has not been previously submitted for the partial fulfilment of the degree at the Visvesvaraya Technological University, Belgaum or and other Institution/University.

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"Remember to look up at the stars and not down at your feet. Try to make sense of what you see and wonder about what makes the universe exist. Be curious. And however difficult life may seem, there is always something you can do and succeed at. It just matters that you don't give up." - Stephen Hawking

ABSTRACT

A brain–computer interface (BCI) or brain–machine interface (BMI), is a direct communication pathway between an enhanced or wired brain and an external device. People who suffer from motor neuron diseases face many problems, primarily to communicate with others in their daily life. The field of BCI research and development has thus focused primarily on neuro-prosthetics applications.

The major goal of this project is to develop a system that allows disabled people or ALS (Amyotrophic Laterals Sclerosis) to communicate with other people and thus help them to interact with the external environments. For this purpose, there are invasive and non-invasive types of EEG sensors.

In our system, we have implemented a BCI system using a non-invasive type of EEG sensor, known as NeuroskyMindwave Mobile. This is single channel electrode which has a ThinkGearchip inside and uses a TGAM module (ThinkGear Application specific IC) that measures and analyses the EEG signals. It detects raw brainwaves and outputs processed EEG signals such as eSense parameters like Attention, Meditation, Blink Strength values along with Alpha, Beta, Gamma, Theta and Delta waves.These brain waves are further used to control and actuate a moving robotic gripper. These parameters are parsed using Bluetooth communication.

The initial stages of collecting and analysing the brain waves was done using the a BCI platform known as OpenVibe. The processed data from this platform was further collected in Matlab to reduce the noise. The second stage of the system aims at controlling the above-mentioned application. Here a Python Interface is established to collect the eSense parameters and transmit it to the microcontroller. This is done by establishing a Telnet communication using the ThinkGear socket protocol. The eSense values are thus transmitted to microcontroller. Thus, the different movements of the moving robotic gripper are controlled which aims at picking and placing an object.

The advantages of the project as listed as follows:

- Real time collection of brainwave data.
- Continuous automatic measurement of parameters.
- Feature extraction/Control commands to develop a prosthesis environment

THIS WORK IS DEDICATED TO RESEARCHERS, TEACHERS, OPENSOURCE COMMUNITY, TO OUR PARENTS AND FRIENDS.

ACKNOWLEDGEMENTS

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LIST OF ACRONYMNS

BCI	Brain Computer Interface
MMI	Mind Machine Interface
LFP	Local Field Potential
EEG	ElectroEncephaloGram
fMRI	functional Magnetic Resonance Imaging
fNIRS	functional Near Infrared Spectrsoscope
MEG	MagnetoEncephloGraphy
ALS	Amyotrophic Lateral Sclerosis
VR	Virtual Reality
VEP	Visual Evoked Potential
LIS	Locked -In State
ABCI	Augmented BCI
AAC	Augmentative and Alternative Communication
TMS	Trascranial Magnetic Stimulation
TES	Transcranial Electrical Stimulation
tDCS	Transcranial Direct Current Stimulation
SNR	Signal to Noise Ratio
SVM	Support Vector Machine
LDA	Linear Discriminant Analysis
NBC	Naive Bayes Classifier
KNN	K Nearest Neighbour Classifier
HMM	Hidden Markov Model
MI	Motor Imagery

DOF	Degrees of Freedom
VRPN	Virtual Reality Peripheral Network
JSON	Java Script Object Notion
ERP	Event Related Potential
TGAM	ThinkGear Application specific Module
ASIC	Application Specific Integrated Circuit
EMG	ElectroMyoGraphy
SPP	Serial Peripheral Protocol
TGSP	ThinkGear Socket Protocol
AP	Application Program Interface
LSL	LSL – Lab Streaming Layer
CSV	Comma Separated Value

CHAPTER 1

CHAPTER 1

INTRODUCTION

In this chapter the different areas of BCI are introduced. Further the project definition, statement and objective of the project are discussed, implying the need for BCI research.

1.1 Overview

The human brain consists of 86 billion neurons that communicate information through electro-chemical action potential, an endogenic bioelectric phenomenon, and preserves this information in synapses.Action potential of a single unit (neuron) has an electrical discharge characteristic that can be recorded by intracellular electrodes. Activities of a collection of neurons at a proximal location can be recorded through extracellular electrodes as Local Field Potential (LFP) or as neural firing. LFP is recorded by filtering the electrode signals through a low pass filter (1-100 Hz), while the neuron firings are detected through a spike discriminator. Such endogenic electrical activities are recorded through microelectrodes placed inside the brain cortex or at the surface of the brain cortex (invasive). The electrode converts the ionic current of neurons to electronic current, which can be recorded through a high impedance electrical sensing circuit.

A Brain–Computer Interface (BCI), often called a Mind-Machine Interface (MMI), is a direct communication pathway between the brain and an external device. BCIs are often directed at assisting, augmenting, repairing human cognitive or sensory-motor functions. BCI systems measure specific features of brain activity and translate them into control signals that drive an output. BCIs can be used for communication, computer access, or control of devices such as a wheelchair or prosthetic arm, among other applications. Virtually anything that can be controlled by a computer could potentially be controlled by a BCI. BCI is being examined as a rehabilitation device to help people re-gain motor skills that are lost from stroke, as well as a prosthetic device to replace or compensate for motor skills that will never return.

There are basically two types of BCI systems: invasive and non-invasive. Invasive systems require surgery to implant electrodes on or near the surface of the brain. Most non-invasive systems use electrodes placed on the scalp. Non-invasive systems cause little or no discomfort, although most currently require the use of conductive gel which must be wiped or washed out of the hair after use. The electrodes, whether invasive or non-invasive, are connected to a computer (usually through an additional hardware component about the size of an external hard drive). The brain signals that are picked up by the electrodes are sent to the computer, which uses sophisticated software to translate the brain signals into computer commands. In this project, we are making use of Neurosky Mindwave Mobile Headset, which is a non-invasive dry electrode, Electroencephalogram (EEG) sensor.

Brain-computer interface technology allows software to read and interpret signals directly from the brain. This is possible because our brain is filled with neurons that move when we think, feel, or remember something. When the neurons move, they are carried by small electric signals that move from neuron to neuron and scientists can detect those paths and signals to interpret what they mean. This new technology is the next step in healthcare.More simply, a BCI can be defined as a system that translates "brain signals into new kinds of outputs".After brain signal acquisition, the BCI evaluates the brain signal and extracts signal features that have proven useful for task performance.

BCI technology involves monitoring conscious brain electrical activity via EEG signals and detecting characteristics of EEG patterns via digital signal processing algorithms that the user generates to communicate. It has the potential to enable the physically disabled to perform many activities, thus improving their quality of life and productivity, allowing them more independence and reducing social costs.

BCI performs four distinct tasks: translating neurological input signals into electrical signals, extracting features from the signals, deriving meaningful information, and aggregating knowledge for useful purposes. The challenge with BCI, however, is to extract the relevant patterns from the EEG signals produced by the brain each second. Recently, there has been a great progress in the development of novel paradigms for EEG signal recording, advanced methods for processing them, new applications for BCI systems and complete software and hardware packages used for BCI applications.

Brain signals can be acquired in several forms, including electrical (e.g., (EEG)) or magnetic fields (e.g., Functional Magnetic Resonance Imaging (fMRI)) or Functional Near Infrared Spectroscopy (fNIRS). Most studies use EEG and Magneto Encephalography (MEG) to record all electrical and magnetic activities respectively, occurring with the ionic current that flows within the neurons of the brain. **(**Figure 1.1**)**Each of the brain's hemispheres is segmented into four lobes with different functions. These lobes are separated by fissures (sulcus). Signal generation initially occurs at the outer surface containing Grey Cortex (Grey Matter). The Primary Somatic Sensory Cortex (Parietal Lobe) and the primary Motor Cortex (Temporal Lobe) are the most important regions for BCI research.

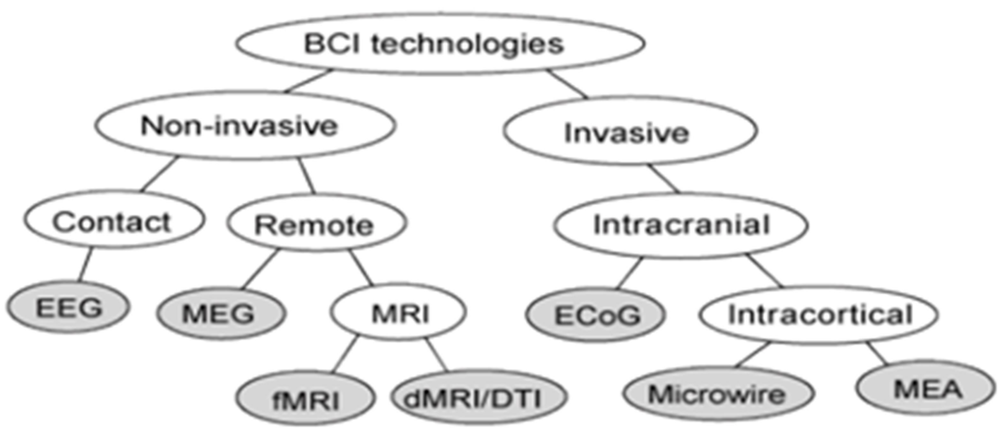

Fig 1.1. General classification of currently available BCI technologies. EEG, MEG. MRI, fMRI, dMRI (Diffusion MRI)DTI (Diffusion Tensor Imaging ECoG (Electrocorticography) MEA (Multiple Electrode Array)

Quadriplegics,Amyotrophic lateral sclerosis (ALS) patients or people who have suffered from a stroke and are paralyzed, have had success with this new technology. Recent studies have shown many successful stories of quadriplegics using brain-computer interfaces to control a robotic arm with their brain waves and even drink coffee from a cup. Brain-computer interface also shows promising signs in both preventing and delaying the onset of dementia, Alzheimer’s and Parkinson’s disease in the elderly.

Other opportunities are abundant, such as using virtual reality (VR) to enhance the experience of neurofeedback, design new brain activity visualization tools and embed the participant in a rich multi-sensory context, or enhancing VR experiences with so-called passive BCIs, such that the VR content adapts to the participants' cognitive and emotional state, as extracted from their brainwaves. BCI technologies can also be used to assess the ergonomic qualities of a VR environment or of a human-robot interaction.

The field of brain computer interfaces (BCI) is making fast progress. Research is mostly aimed at providing disabled patients some levels of communication, control of external devices, and mobility, but there is also interest in real-world applications for the healthy population. A unique scenario is controlling such a representation by 'thought' alone; in this setup, the virtual or robotic body becomes a replacement of the participant's body. Brain signals and BCI can also be a complementary mean of interaction to control a virtual environment or a robot, together with traditional inputs.

In recent years, BCI based on non-invasive scalp EEG have become an increasingly active research area. Event-related potentials, mu and beta rhythms, event-related synchronization and desynchronization, slow cortical potentials, and Visual Evoked Potentials (VEP) are commonly used signals in EEG-based BCIs. Different from other systems, the VEP-based BCI is considered a dependent BCI because the generation of the VEP depends on the control of eye movements via the output pathways of cranial nerves and extra ocular muscles. Therefore, for the people with severe neuromuscular disabilities, who may even lack the output channel of extra ocular muscle control, this BCI is inapplicable.

BCI represents a highly growing field of research with application systems.More recent studies have targeted normal individuals by exploring the use of BCIs as a novel input device and investigating the generation of hands-free applications. Applications of Brain Computer

Interface base its functionality on either observing the user state or allowing the user to deliver his/her ideas. BCI system records the brain waves and sends them to the computer system to complete the intended task. The transmitted waves are therefor used to express an idea or control an object.Healthcare field has a variety of applications that could take advantage of brain signals in all associated phases including prevention, detection, diagnosis, rehabilitation and restoration.

1.1.1 Basic Principle and Technology

Many people imagine that BCI will allow them to simply think of a word or phrase and have it appear on the screen, or control a wheelchair by thinking about where they want to go. Unfortunately, this is not the case with current BCI technology. There are a variety of types of BCI systems, and each one works a little differently. Most BCI spelling systems display a series of letters, either one at a time or by highlighting letters in a grid. When the letter you want lights up, your brain wave changes. The computer looks for that change and interprets it as a 'keystroke'. For example, if you wanted to type the letter A, you would focus on the A and count each time it flashed, or think “Yes!” when you saw it appear on the screen. Recognizing the A would trigger a spike in your brain signals, which would be detected by the BCI system. Usually, each letter must be ‘selected’ multiple times, so typing with a BCI is quite slow. Systems designed to control a computer cursor often rely on movement imagery. You would imagine squeezing your right hand to move the cursor to the right, and your left hand to move the cursor to the left.

All BCI systems require conscious effort from the user to type a message or move a computer cursor. BCI technology will not read your mind or share your private thoughts with others. In addition, BCI cannot be used for mind control. The electrodes are simply sensors that detect brain activity, and cannot send thoughts or commands into the brain. The user controls the computer, not the other way around. BCIs will be most beneficial for people who have little or no reliable muscle movement, including some people with advanced ALS

1.1.2 Applications

BCI research has experienced a recent exponential growth, which can be attributed to several factors, as follows:

1. Availability of rapid, real-time sophisticated signal processing methods.
2. A greater understanding of the characteristics and uses of brain signals.
3. An appreciation of the phenomenon of activity-dependent brain plasticity.
4. A growing dissatisfaction with current rehabilitation methods and the need for improved methods for recovery of function for those with persistent motor impairment.

Few applications in real lifeincludes:

1. Mental state monitoring function of BCI systems has also contributed in forecasting and detecting health issues such as abnormal brain structure (such as brain tumour), Seizure disorder (such as epilepsy), Sleep disorder (such as narcolepsy), and brain swelling (such as encephalitis). Tumour, which is generated from uncontrolled self-dividing of cells, could be discovered using EEG as a cheap secondary alternative for MRI and CT-SCAN.
2. Dyslexia, one of the brain disorders, can be diagnosed by measuring brain behaviour. Sleep disorders can also be detected with BCI assistance. They demonstrate some methods for deploying EEG signals in noticing idiopathic Rapid Eye-Movement sleep behaviour disorder .This has been found to be a strong early predictor for Parkinson's disease .
3. Brain signals also assist in improving workplace conditions by assessment of an operator's cognitive state. They also analyse the impact of workload mental fatigue and task time on EEG features. Operating room as well represents a candidate place for smart workplace BCI-based application.
4. Car manufacturers are exploring technologies that can detect when people are falling asleep while driving and will rattle the steering wheel to awaken the drivers. The field of intelligent transportation has also been benefitted from the cognitive state monitoring BCI function. Also, Driver's behaviour has been studied in numerous

studies. It has been found that distraction and fatigue are two main sources for driver's inattention, which is considered as a strong cause for most traffic accidents.

5. Brain-Computer Interface also helps in predicting diseases such as dyskinesia, peripheral neuropathy, and musculoskeletal disease.
6. Other than healthcare, many other companies have started taking advantage of this new technology. Ex: OpenBCI, Emotiv, NeuroSky.
7. BCIs have the potential to provide an array of leisure pursuits, useful computer access, control functions, such as TV control. BCIs based on sensorimotor brain activity have used games as part of user training protocols.

Research has even proved the possibility of using brain-computer interfaces to connect different brains together. Researchers at Duke University last year reported the brains connection of two mice over the internet, where mice in different countries could cooperate to perform simple tasks together to obtain a reward.Over the next decades, brain-based technologies will allow computers, for the first time, to leverage sophisticated analyses of the emotional and cognitive states and processes of the people using them, revolutionizing it.
Current BCI systems are challenging to use, and require expensive equipment and time-consuming setup.

Areas of Research:

- BCI for robotic control or control of prosthetic limbs
- Neuroergonomics, Neurofeedback of virtual reality (VR) or human-robot interaction
- Real-time neurophysiological loops in VR and robotics
- BCI and augmented reality
- Multimodal control (Hybrid BCI) of VR and robots

BCI applications should be differentiated from a BCI system definition. Indeed, BCI is a system to capture, analyse, and transform the brain signals to control devices. On the other hand, BCI application is developed utilizing the output as commands to implement specific purposes using devices of interests. According to this, the main target populations for BCI applications fall into three classes.

i. Complete locked-in state patients lacking any motor control.

ii. Locked-in state (LIS) patients who barely have voluntary movements and almost completely paralyzed. Sometimes they can move and blink their eyes, or twitches with the lip.

iii. Substantial neuromuscular control, particularly speech and/or hand control.

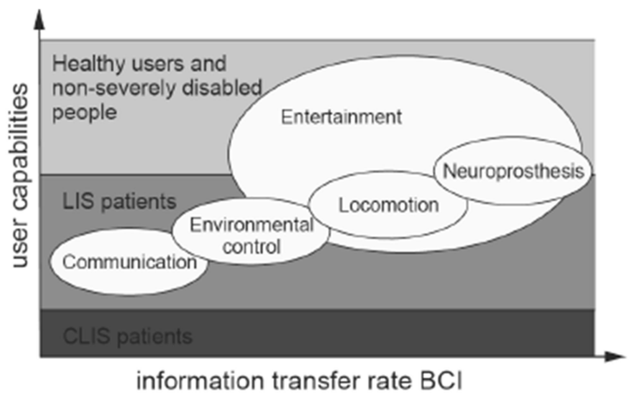

Fig 1.2. Relationship between BCI Application areas and BCI information transfer rates and user capabilities.

Eventually, effect of different type of disorders can be addressed applying specific BCI systems. In addition, the potential clinical use of BCIs are: communication, movement control, environmental control, locomotion, and neuro-rehabilitation. The relationship between BCI application areas and BCI information transfer rates depends on the user capabilities and is presentedin Fig. 1.2.

1.1.3 Role of BCIs in Rehabilitation

In contrast to most available augmentative and alternative communication (AAC) devices, BCIs can be controlled through the direct use of brain signal, bypassing the need for volitional muscle activity as a control paradigm. For several years, potential BCI users and caregivers have expressed the importance of BCIs for communication.

BCIs are most appropriate and most needed by people with few other options for control of assistive technology. These include people with late-stage ALS, people with disorders of consciousness who show signs of cognitive awareness but lack other means of communication, and other populations of people who cannot reliably operate physical interfaces or eye gaze systems to access assistive technology.

For patients diagnosed with disorders of consciousness, BCI may offer the only opportunity of demonstrating awareness. A recent review showed that 4 of 24 patients (17%) who had been diagnosed as being in a vegetative state were not only consciously aware but could

answer yes or no questions. BCI use for disorders of consciousness is an emerging field of great importance. Studies in this area include BCIs using auditory, tactile- and motor imagery-based designs.

BCI technology is constantly changing. Hardware will improve with wireless electrode connections. Software will provide new options for typing and speaking messages; using the internet, email, and social media; creating artwork; safely driving a wheelchair; controlling door locks, light switches, entertainment systems, and other features of the home; and much more. It is hoped that the cost of BCI will decline as it becomes more widely used, and that insurance carriers will eventually cover it as an assistive technology. Since this technology is being developed for a much larger market than those with neurological disease, in the future we will see BCI devices available for many computer functions.

1.2 Problem Definition

BCIs are increasingly being integrated with other commercial assistive technology on an experimental basis and can form an interface that is based on brain signal and incorporated within the framework of other existing assistive technology, increasing the accessibility of such devices. There is a growing awareness that BCIs can be used in combination with physical input signals if the patient has such signals available, a concept described as a hybrid BCI design.

1.3 Problem Statement

The ultimate purpose of a direct brain computer interface (BCI) is to allow an individual with severe motor disabilities to have effective control over devices. A BCI system detects the presence of specific patterns in a person's ongoing brain activity that relates to the person's intention to initiate control.BCIs offer a method to evaluate awareness and to restore a communication channel. People with ALS, spinal cord injury or brain-stem stroke represent populations for whom BCI is important and useful.Hence there arises a need for faster, more reliable BCI systems that work for more potential users.

1.4 Problem Objective

EEG devices used to be prohibitively expensive and time consuming to connect, and the data required expert knowledge to interpret. They required conductive gel to connect with very clean hair and skin. We hence chose NeuroSky'sMindwave Mobile headset, which is the cheapest option for a dry EEG sensor available in the market. The headset is easy to wear and works on dry skin without any gels. It only needs electrical contact on forehead and earlobe. This measures attention and meditation as well as the raw brainwave data. The main aim of this project is to create an interface between brain and the computer that will allow an individual with severe motor disabilities to have effective control over external devices and perform some work independently.

The objectives of our project are:

- Design a method for real time collection of different types of data from the headset.
- To develop a prosthesis environment consisting of a robotic gripper controlled by the brainwaves.
- To design an efficient and a reliable method for the ALS patients and severely paralyzed to communicate and lead a self-reliant life

1.5 Motivation

Advances in the cognitive neuroscience and human machine interaction technologies have evoked to provide the ability to interact with human brain. People who suffer from motor disabilities face many problems in their daily life. Most of them have more struggles to communicate with others. Increased interest in the application ofEEG signals have more efficiency than other bio medical signals. This can be done by using BCI technique which facilitates direct communication between human brain and physical device (Fig. 1.3). Employing BCI technique, the users significantly betray their brain activity to accomplish brain signals.

This is the motivation to execute the prosthesis environment by utilizing human brain signals as an input command. The proposed system consists of single channel prototype Mind Wave sensor to acquire the EEG signals. Feature extraction process is carried out by employing two human mental fatigues: eye blink strength and attention level. Based on these brain activities

the prosthetic grippe is controlled, and different real time conditions are implemented to direct the arm such as right, left, forward and backward.

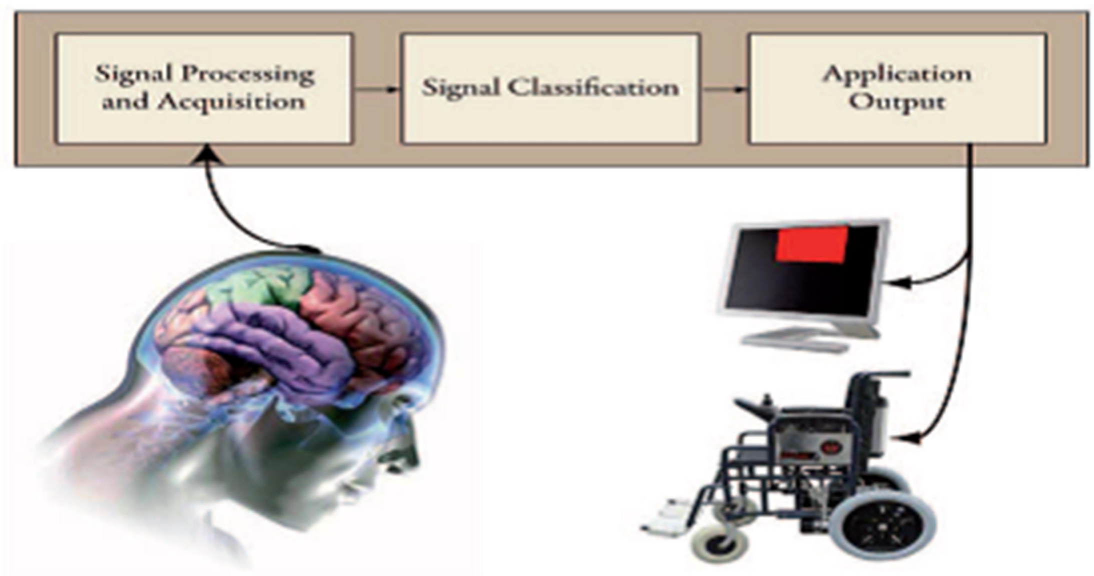

Fig. 1.3 General overall system

CHAPTER 2

CHAPTER 2

BACKGROUND

In this chapter,the need for a BCI system along with different approaches in this field are discussed. The recent advances along with challenges faced in Neurotechnology are discussed here.

2.1 Introduction

Computers touch almost every aspect of our lives, performing critical functions in diverse areas including education and training, home and entertainment, medicine and work. The importance of computers in our lives makes human-computer interaction one of the most criticalfactors in systems design. One fundamental issue in human-computer interaction is that limitations exist on the communication between human and computer. That is, human-system interaction is still fundamentally bounded by the inherent capabilities of humans to absorb, analyse, store, and interpret information to create behaviour; and by limitations in the ability of computers to predict human intentions, action, and communications. Over the past decades, tremendous advancements have pushed the bounds on these limitations, including thedevelopment of novel devices for improving information flow into the computer via multi-modal devices,collaborative performance among groups of people, eye trackers, speech and language, touch screens, gesture, motion capture and facial expression recognition. It can also be used for allowing the computer to provide more useful, relevant, or realistic information back to the user through improved visual displays and graphics, tactile and haptic feedback, 3D audio, and virtual reality (VR) environments.

In addition, improved algorithmic approaches for predicting human behaviour and intention, such as collaborative filtering, physiological computing, affective computing, user modelling, and player modelling open the possibility of adapting devices to users and their needs. These steps have increased the quantity, quality and interpretation ofinformation transferred between the human and the system; however, as computational capabilities and complexity increase, the limited bandwidth between human and machine will become increasingly constraining. The tremendous growth of research in the field of neuroscience over the past several decades offers an approach to address these limitations. This basic research offers many potential insights into the brain state and mental processes of thehuman; insights that could potentially expand the current fundamental bounds on human computer communications and open the door to completely novel approaches to both human computerand human-human interaction.

Major forerunners of these future brain-based technologies are early BCIs, which were intended to provide a direct communication pathway between the human brain and an external device. First developed in the 1970s, but largely unexplored until the past decades, earlyBCIs predominately focused on improving the quality of life of selectedclinical populations.

There are two major ways in which BCIs can be employed. The first is straightforward and has been studied for more than 25 years; in this case, the BCI system acquires brain signal and allows the user, to engage the BCI output for control of the environment (light switch, temperature control) or communication devices through feedback. A second and newly emerging BCI application involves using the system as a motor learning-assist device. In this case, the BCI may enhance motor control recovery by demanding more focused attention or guiding activation or deactivation of brain signals.

2.2 Need for the System

Disability touches every aspect of human life, and therefore assistive technology is needed to provide access to all types of activities that contribute to quality of life.BCIs have the potential to enhance rehabilitation methods. Even though early work on brain activity recording was performed in 1940s, before pacemaker or defibrillators were developed, recent advancements in low-power, wearable embedded systems technology and cyber physical systems have demonstrated the promise of real-time brain activity monitoring for patient centric diagnostics, therapy, and even preventative, proactive monitoring for well-being. Understanding this critical connectivity, activations, and mechanism are necessary for developing strategies and rehabilitation therapies to aid in various treatments for the severely paralyzed. However, understanding brain functions is based on two critical factors - the correct identification of the active brain regions and determination of the functional interactions among the neural assemblies across various brain regions.

2.2.1Early Approaches to BCI

The technologies can be broadly classified into non-invasive (EEG, MEG, MRI) and invasive (Microelectrode, ECoG, MEA). Challenges to resolve include neuronal damage, neurotrophic, usability and comfort.

Two methodological constraints defined the nature and the scope of early BCI applications. The first constraint was to require users to focus on a task. For example, a typical application for spelling and writing had users focus on a single letter while watching streams ofletters presented by the computer. These letters induce event-related potentials (ERPs) such as P300s, which can be detected from the EEG signals and indicatewhich letter the user was focusing upon. An alternative method to spelling and writing applications leveraged motor imagery (e.g., users imagining a part of the body moving) which induces changes in EEG spectral power (often in the mu rhythm band) that are utilized to select a letter from a series of options. In such a system, an array of letters is presented to the user andthe computer uses EEG signals arising from the brain's perceptual-motor system to rotate an arrow through the letter options based on which body part the user was imagining moving. Despite the differences in these approaches, what existing BCI approaches have in common is that they are inseparable from the task being performed; however, the performance of these applications is dramatically outperformed by healthy populations using typical alternatives (i.e., a mouse for cursor control, speech for communications). In part, the reason for this is that early applications attempted to utilize the higher cortical function as a moment-to-moment control signal, thereby circumventing the highly evolved and efficient system between the brain and muscles that healthy humans normally rely upon to perform motor movements.

Early BCI applications have targeted disabled users who have mobility or speaking issues. Their aim was to provide an alternative communication channel for those users. But later, BCI entered the world of healthy people as well. It works as a physiological measuring tool that retrieves and uses information about an individual's emotional, cognitive state. The target of brain signals utilization has been extended beyond controlling some object or offering a substitution for specific functions in what is called passive BCI.

Currently, researchers are realizing the benefit of developing applications that use neural signals in ways that are more consistent with the natural neural processing for clinical populations. As researchers continue to extend BCI technologies to healthy populations, many current applications are still just extensions of the original clinical applications; however, several promising new types of applications are being developed, including attempts to integrate emotion into video games (Fig. 2.1), toys, advertising and music. Attempts to merge human pattern recognition with computer processing power for joint human-computer object detection.

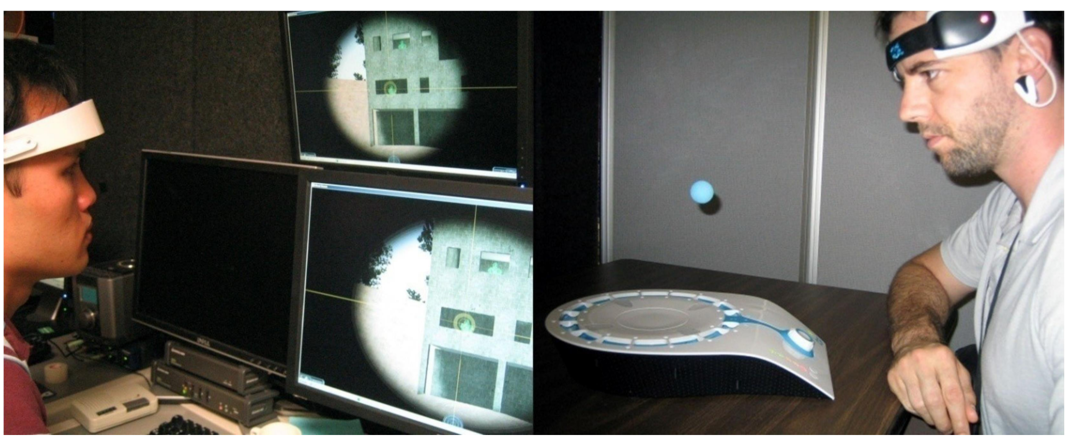

Fig 2.1. Brain-Computer Interfaces for Gaming. On the left a gamer uses a BCI to toggle zooming in a first-person shooter game, on the right, tests out his ability to use a BCI to adjust the speed of the system's fans to control the height of a ball floating on air above a platform.

Significant strides have been made since 1940s for monitoring brain activities and utilizing the information for diagnosis, therapy and control of robotic instruments including prosthetics. Monitoring brain activities with BCI technologies are of recent interest to due to the immense potential for various medical applications, particularly for many neurological disorder patients and the emergence of technologies suitable for long duration BCI applications. Recent initiatives are geared towards transforming these clinic centric technologies to patient centric technologies by monitoring brain activities in practical settings.

2.2.2 Recent Advancements in Neurotechnology

Over the past five years, the bridging of technological gaps in brain imaging and sensing have led to the development of the new augmented BCI (ABCI) concepts, that can be used by individuals in everyday life. Thus, ABCIs must function while people move and interact with their environment; allow non- intrusive and rapid-setup EEG solutions that require minimal training and provide stability, robustness, comfort, and longevity for accurate long-term data collection.

Technological improvements have also led to advanced algorithmic approaches to analysing and interpreting brain data gathered under noisy, real-world environments enabling an explosion of BCI research and technology development even to the point of the commercialization of the first neurally-based toys, such as the Star Wars Force Trainer™ by Uncle Milton or the Mindflex™ by Mattel (Fig. 2.1).

The application of brain stimulation and the use of brain neural feedback training both depend upon our knowledge of motor skill acquisition, the function of the neural centres involved, the mechanisms of the interventions and the mechanisms of neural recovery of motor control. The synthesis of these discoveries will provide the platform for future BCIs.
Over the next decades, neurotechnology's will increase or create a new sensing capabilities and the ability for sensors to be seamlessly be integrated with our everyday life. These projected developments will move brain-based neurotechnology's from toys and prototype

interfaces for specialized populations to a core technology that has the potential to revolutionize human-system interactions across all aspects of everyday life.

2.3 Challenges

The primary concern for BCIs as an Augmentative and Alternative Communication (AAC) is the reliance of most BCIs on visual presentation of options, with an associated concern about possible reliance on eye gaze. Indeed, some people with ALS have trouble not only controlling eye gaze, but also with keeping their eyes open, which poses potential problems in using a visual display to view options and feedback results. To address this problem, BCIs operated with covert attention have been developed, proving that eye gaze control is not required for BCI use. However covert attention is associated with lower accuracy of BCI performance. A BCI with a visual display has even been designed for use in an eyes-closed condition by using lights that are visible through the eyelids. Alternative BCI designs using auditory and even tactiledisplays of information are under development.

It is important to develop innovative methods, such as BCI neural feedback systems, to restore motor function to those with neural injury or disease, because current standard care and research approaches do not restore normal function. Generally, there are two research approaches currently studied for treating motor impairment after neurological injury or disease: peripherally directed treatments such as exercise or exercise-assisted technologies or centrally directed treatments involving brain stimulation methods such as Transcranial Magnetic Stimulation (TMS), Transcranial Electrical Stimulation (TES), or Transcranial Direct Current Stimulation (tDCS).

Brain stimulation methods hold some promise. But, as applied to the problem of motor re-learning after neural injury or disease, results are currently mixed. In the study of stroke treatment, scientists are reporting transient (days to a few weeks) motor gains in response to the application of TMS, but it is difficult to evaluate the body of literature due to heterogeneity of both subject and intervention variables. These include time since stroke (acute/chronic), treatment duration variability; and measures of motor function for which the value is unknown regarding the minimally clinically significant improvement.tDCS application for those with Parkinson's disease ranges from mixed to no response on most motor measures. Some have proposed that the problem arises from the variability of neural networks across individuals, leading to a lack of certainty as to whether the applied stimulus did not work well in general or only for a given individual.

Another challenge is communication as for those with neuromuscular impairments have difficulty with writing or speaking. Augmentative and alternative communication (AAC) .

devices can compensate and provide device-assisted communication. But AAC devices can have task complexity and some individuals may not possess the required physical capability to control an AAC device, Thus BCI comes into picture. BCI can enable participation in sport and leisure activity, providing connection to others as well as improvements in self-esteem and self-confidence.

BCIs are emerging as interventions to restore function through assistive technology and to promote recovery. Success in these applications has been observed in the laboratory and in limited in-home studies for communication applications. However, BCI technology is still clinically immature and further development is needed before the full potential of BCIs for rehabilitation can be realized. Overall, BCIs for communication have been successful in the laboratory, and for long-term functional use.

CHAPTER 3

CHAPTER 3

LITERATURE SURVEY

In this chapter,the different papers,journals,technical articles in the field of BCI are referred and addressed here. Hence this forms a solid platform to understand the role played by BCI in recent innovation and technology.

3.1 IEEE/International/National/Journal Papers Referred

1. Brain-computer interface (BCI) systems provide a device for communication that does not depend on the brain's normal output and peripheral nerves. Recently, BCIs have attracted massive attention, triggered by new scientific progress in understanding brain function and by impressive applications. The paper [1] referred studies the steps in the regular BCI system, methods used in processing signals, applications, improvements, and current challenges. Finally, BCI possible future trends are discussed.

BCI Framework: - The BCI framework is described in several building blocks that need to interact properly. Different BCIs rely on different mental activities and corresponding EEG patterns. There are three dominant approaches to BCI systems, categorized according to the type of mental activity and corresponding brain activity used for control. Three existing types of BCIs are Steady State Visual Evoked Potential (SSVEP), P300, and event related desynchronization and synchronization (ERD/S) or Motor Imagery (MI).

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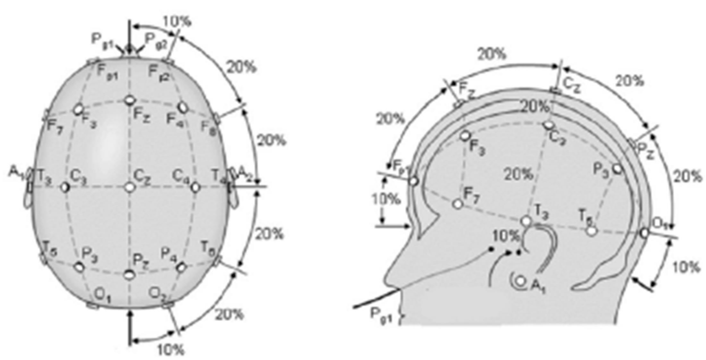

Fig 3.1: Arrangement of electrodes according to 10-20 system

Data Collection: -The human being often referred as subject is the source of the brain signals and the measurement of the neurophysiologic state of the brain is called signal acquisition. EEG, ECoG, local field potentials (LFPs), and neural action potentials are the most popular electrophysiological signals applied for BCI systems. ECoG collected by electrodes placed underneath the skull and over the cortical surface, EEG recorded by electrodes on the scalp, local field potentials (LFPs), and neuronal action potentials (spikes) collected by microelectrodes within brain tissue. Fig. 3.1 shows the position of electrodes based on international 10-20 system for electrical signals acquisition across the surface of the scalp.

Pre-Processing:- In order to increase the SNR (signal to noise ratio) of thebrain signal a pre-processing methodology must be appliedon the acquired signal. This stage will ensure a reliable brainstate discrimination. This optimization procedure relies onboth the knowledge of the signal, and the type of measurement technology.

Feature Generation: -The feature generation is an important task to predictoutcomes from the raw signal. Feature generationcharacterize the pre-processed brain signals, mainly byemploying temporal or spectral features. These features arederived directly from the signal and include the averagedtime-course. Collectingfeatures has several benefits, which can be listed as follows:

(a) Increasing the effectiveness of classification
(b) Reducing computational effort
(c) Reducing the amount of stored data
(d) Reducing data redundancy

Classification methods:-Features selected in feature generation section are thenused in the classification process. There are manyalgorithms able to perform features classification. Popularclassifiers in BCI tasks are: linear Support Vector Machine(SVM), Linear Discriminant Analysis (LDA), Naive Bayes Classifier (NBC), K-Nearest Neighbor Classifier (KNN), Hidden Markov Models (HMM), and Multilayer Perceptron [1].

2. Brain-computer interface (BCI) provides a novel communication channel between human and external devices, which translates the brain activities directly to the computer commands. In this paper, an event-related potential (P300) based BCI paradigm was constructed to control a real humanoid robot. First, the images of the robot and the environment were integrated with the P300 graphic stimulation interface. Then the subjects could obtain all the necessary feedback information in one computer screen. Second, a variable space mechanism was designed for human-robot cooperating in different situations. Third, an on/off button based on two layer P300 decision was devised, allowing the subject to turn on/off the system. Three subjects participated in this study, and the accuracy in offline test was above 90.0%. Furthermore, all the subjects successfully controlled the humanoid robot to accomplish a walk task with our BCI paradigm. The results prove the effectiveness of our improved BCI paradigm to control a humanoid robot [2]. In the meanwhile, this study also demonstrates that it can be used as a potential technology applied to rehabilitation, aerospace and other related applications.

Overall System Description: -This study designs a P300-based humanoid robot controlsystem. Fig 3.2 illustrates thesystem structure. A computerscreen contains all the feedback information for subjects tooperate the robot. Subjects stare on the stimulus target afterobserving robot states and take control decision. BCIsystem synchronously record and analyse EEG and finallyrecognize the command which the subject expected. Afterthe human intent was recognized, the command is then sendto Nao(robot) to execute the corresponding movement immediately. After the command is accomplished, a feedback sign is sent back to the system to start the next working trial. During the experiment, subjects were able to turn off/on the system by using the SW command at any time.

Graphical User Interface Design: -In the graphical user interface designing, mainlyconsiders to decrease the negative effect of attention switchbetween stimulus GUI and the controlled object. For this reason,design of a multi-information GUI, in which all the informationnecessary for controlling the robot are included.The GUI is as shown in the Fig 3.3, This consists of robot monitor, system-states recorder and P300 stimulus icons.

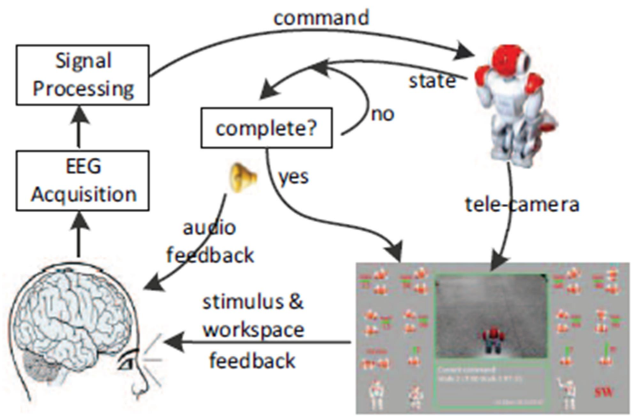

Fig 3.2 Overall System StructureFig 3.3: Graphical User Interface

Offline Training and Result:-Offline training is aimed to make subjects adapt to thesystem and accumulate standard signal samples.

Here SWLDA is adopted to obtain parameters of classification for online control. The offline training includes four sessions. In each session, twenty tasks are randomly chosen and combined.

subjects	trial1	trial2	trial3
sub1	100.0%	100.0%	95.0%
sub2	90.0%	95.0%	95.0%
sub3	95.0%	95.0%	100.0%

Table 3.1: The testing accuracy of each trial

Subjects	trial 1		trial 2		trial 3	
	turn on	turn off	turn on	turn off	turn on	turn off
sub1	2/2	1/1	2/2	1/1	2/2	1/1
sub2	3/2	1/1	2/2	1/1	2/2	1/1
sub3	2/2	1/1	2/2	1/1	2/2	1/1

Table 3.2 The number of runs of each trial for turning on/off the system. The former number is the actual number of turning system on/off, the latter is the least runs.

After each session is accomplished, the parameters are trained by SWLDA and tested in the next session. This accuracy rate is the evaluation of the corresponding parameters. The Table 3.1 records the tested accuracy of former three trials. The accuracy in each trial is 90%.

3. This paper [3] illustrates a motor imagery BCI-based robotic arm system. To control a robot arm with multiple freedoms, BCI system should provide multi-commands. Herea novel MI-based BCI protocol, which applies three mode of MI to output eight commands is constructed. A control strategy is used to simplify the movement control of robot arm. The validity of this system is verified by experiments in real and virtual environment [3].Motor imagery (MI)-based BCI translates subject's suppositional activities into real instructions using mu and beta rhythms. In general, MI-based BCI system only can provide three or four commands, which is a strong restriction for multiple instructions application. However, with increasing number of mental task, the accuracy of the system will decrease. Considering trade-off between accuracy and multimode, three-mode is the best choice in MI-based BCI system. To obtain a multi-command BCI system, which keep high accuracy, we introduce a grouping protocol to apply three MI modes to output eight instructions. And then, thisprotocol is used to control a robot arm consists of five degrees of freedom (DoF).MI-based BCI subsystem In this part, we present a novel protocol for a three-modeMI-based BCI, in which left/right hand and foot motorimageries are adopted. In view of the special application of thiswork, eight instructions are used in the protocol. They are"Left", "Right", "Up", "Down", "Ahead", "Aback", "Hold", and "Put". We divide eight instructions into four groups. As shown in Fig 3.4, two commands in horizontal line form a command group.

Left	**Right**
Up	**Down**
Ahead	**Aback**
Hold	**Put**

Figure 3.4.Grouping method of eight commands

To drive the eight commands, one motor imagery mode (foot) is specified as a switcher and the others (left and right hand) are assigned as executive orders. Switcher is used to highlight a command group from up to down. When a command group is highlighted, the left (right) command is executed by left (right) hand motor imagery.Fig.3.6. shows how to output "UP". In the initial state, the default selected is the first group. "Up" locates in the second group. Subject should select objective command group using switcher order. After the objective group is highlighted, subject can use left executive order (left hand motor imagery) to output "Up" command. When the arm control system receives "UP", arm will move up one step. In this example, two steps are used. In above example, if next command is also "Up", it still needs two steps. To reduce average steps, a new rule is set which keeps the highlight line in current command group. Only one step is needed to output second continuous "Up".

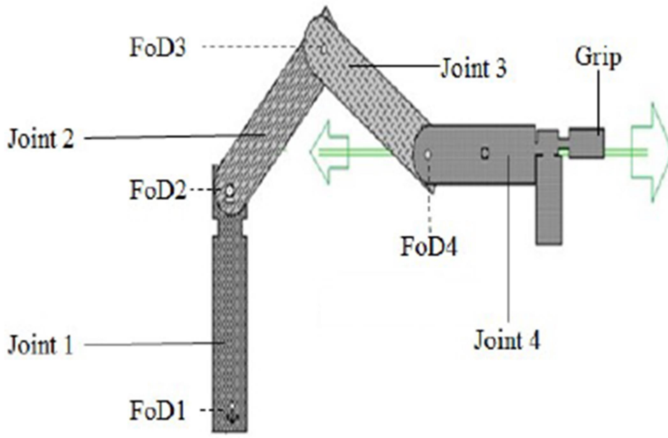

Fig 3.5. The illustration of the robotic arm structure

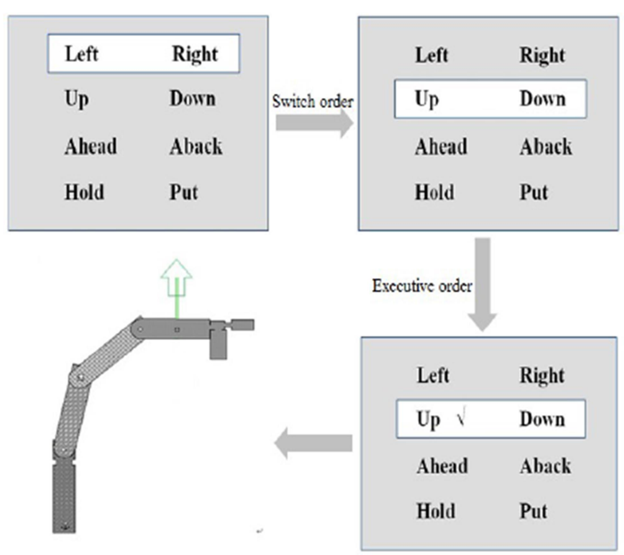

Figure 3.6. Controlling sketch map using eight commands

4. In recent years, a vast research is concentrated towards the development of EEG based human computer interface in arrangement to enhancing the quality of life for medical as well as non-medical applications. Industry and community of research has been attracted by wireless EEG devices and they are easily available in the market. Such technology can be incorporated to psychology, anaesthesiology, and for real-time patients monitoring. The Neurosky Mind wave headset device is generally utilized to detect and measure electrical activity of the user's forehead and transmits the collected data wirelessly, to a computer for further processing. After processing data base, the signals are categorized into various frequency bands for feature extraction. In this paper [4], the characteristics and specification of EEG based human computer interfaces for real-time applications are specified. Furthermore, here the mental or behaviour state of the person (Eye Blink, Meditation, Attention levels) through the NeuroSkyMindwave (MW001) device using Openvibe are discussed.

EEG is the measurement of electrical activity in the brain from the scalp. The first neural activity of the human brain published in Hans Berger (1924) using a simple galvanometer. EEG is generally described in frequency band vary of amplitude and frequency of the wave represent various brain states it's depend on internal brain behaviour state and external simulation. In recent years, clinical use of EEG 2 electrodes are used to identify 5 fundamental waves. Generally brainwaves are differentiated in five frequency bands they are Delta, Theta, Alpha, Beta and Gamma, Delta (0.1- 3.5Hz) is associated with deep sleep condition, Theta (4- 8Hz) is associated with dreams, imaginary, idling, drowsiness, Alpha (8-12Hz) Relaxed, Reflection and pattern appears in wakefulness, Beta(13 to 30Hz)alert, working active, busy, thinking and concentration and Gamma(30 to 100Hz) is associated with the rhythms for high level information processing in the shown table 3.3.

Frequency Bands (Hz)	Frequency Range
43.4-86.8	External Noise
30-43	Gamma
14-30	Beta
8.-13	Alpha
4-8	Theta
0.1-4	Delta

TABLE 3.3. Frequencies generated by different types of activities in the Brain

A.Wired EEG Device: -Wired EEG device system shown in Fig 3.7 shows the conventional EEG based BCI system. Using EEG signals as an input to the system, the BCI system extracts feature signals from the EEG signals. Feature signals are the components of EEG signals which reflect subject's intention. Because these feature signals are often corrupted by noise or contaminated by an interfering signal, the informative signal features are hidden. To extract these feature signals and translate the command for external device, signal processing methods are applied such as feature extraction and classification.

B. Wireless EEG Device: -Now a day's researchers are using wireless devices becausein wired devices system are complex rather than wirelessdevices. Here data transfer uses Bluetooth and differenttypes of communication protocols, wireless devices and are used for mainly gaming, healthcare and other applications normallywireless device system can be shown in the below Fig 3.8.

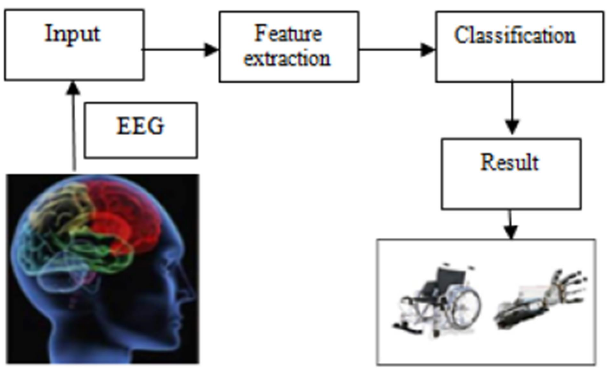

Fig 3.7 Wired BCI

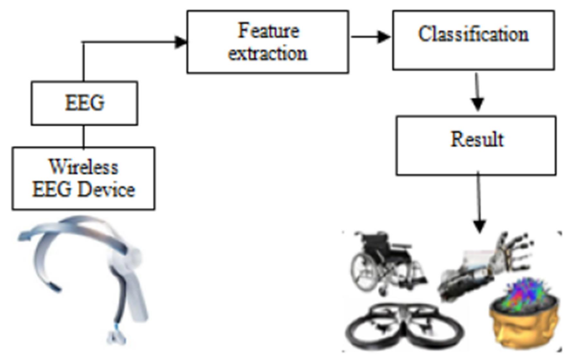

Fig 3.8 Wireless BCI

Software:-Openvibe allows 2D and 3D visualization of data through the topology. Normally EEG machines electrodes placed on the head of the subject and transmits data to computers. These signals have huge external noise, artifacts and interference, these issues are easily tackled by Openvibe software. Here the headest device is setup to the computer for acquiring brain signal. In the next step connection between Openvibe with headset is setup. By pairing with Bluetooth of the system/laptop, it allows the Bluetooth connection and sends the data through the packets of raw data. In the next step an algorithm in Openvibedesigner is used for behaviorstate/mental state of the user.

5. EEG-based brain controlled prosthetic arm is a non-invasive technique that can serve as a powerful aid for severely disabled people in their daily life, especially to help them move their arm voluntarily [5]. In this paper, EEG-based brain controlled prosthetic arm is developed using BCI with the help of Neurosky Mindwave headset to yield the two main movements of fingers in the arm: Flexion and Extension. BCI system consists of an EEG sensor to capture the brain signal, which will process using ThinkGear module in MATLAB. The extracted brain signals act as command signals that are transmitted to the Microcontroller via RF medium. The prosthetic arm module designed consists of Arduino coupled with servo motors to perform the command. The flexion and extension of finger can be successfully controlled with an accuracy of 80 per cent. The low cost wireless BCI system could allow the disabled people to control their prosthetic arm to lead a self-reliant life with the help of their brain signals.

6. Electroencephalogram (EEG) application taken by the means of the NeuroSky neuroheadset is considered [6]. This headset has one dry electrode and transmits the digital signal via Bluetooth as an input for the OpenViBE software. Neurocomputer Interface (NCI), all components of which are combined into one system is proposed. This system includes the determination of the brain rhythm's frequency range and their implementation for the education of the psychic state's identification classifiers. The proposed NCI allows the creation of the interaction scenarios with a computer based on the mental event control.OpenViBe architecture is built based on the kernelthat is used by the plugin manager and provides functionalexpandability. Plugin manager can dynamically loadconnected modules (such as DLL in Windows or ".so" files in Linux) and get their extensions. This allows to add functions and algorithms fast and effectively as shown in Fig 3.9.

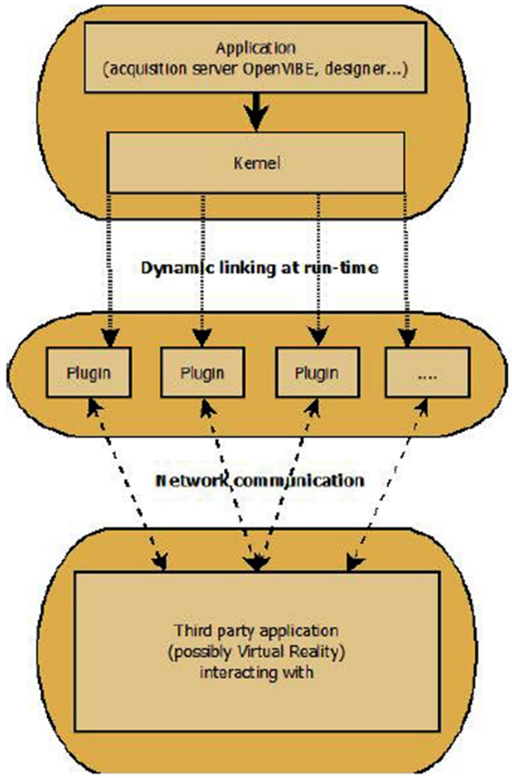

Fig 3.9 :OpenVibe Architecture

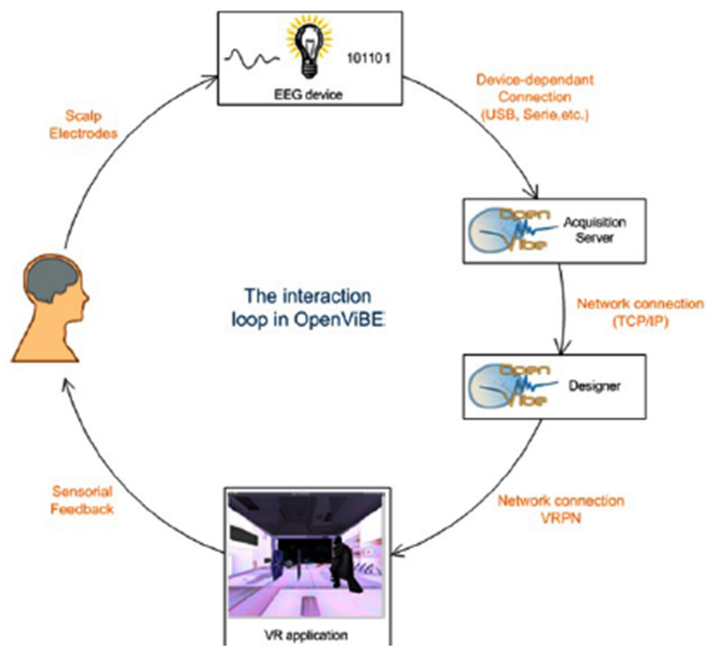

Fig 3.10: The connection between OpenViBE and the VR application

OpenViBE platform can be used as the peripheral interaction for each general application in real and virtual environments. One of the interaction ways is to use the module which can transmit the parameters in the standardized form to the virtual reality application. The platform includes “VRPN” module, which acts as a server (Button & Analog Server) sending commands to the virtual reality applications with the values that provide feedback in relation to any interaction.

7. The BCI is a captivating application which could be used in various fields like Gaming, Education, Industrial and Medical areas. In this paper [7], EEG-based Brain Controlled Wheelchair is developed using BCI with the help of Neurosky technology. The Event-Related Potential (ERP) is offered by the Neurosignal information with the help of P300 component. BCI system consists of a Biosensor to capture the EEG/EMG signals. The signals will be processed by the ThinkGear module in MATLAB. The Level Analyzer Technique is performed on all the training signals and Alpha and Beta waves are extracted for controlling the wheelchair. The command signals are transmitted to the Microprocessor via RF medium. The robotic module designed consists of ARM 7 Microprocessor coupled with DC motor to perform the command. The Eye blinking strength and attention level were used to control the direction of the wheelchair. The wireless BCI system could allow the paralyzed people to control their wheelchair without any complexity, provided it is more enhanced, portable and wearable. A

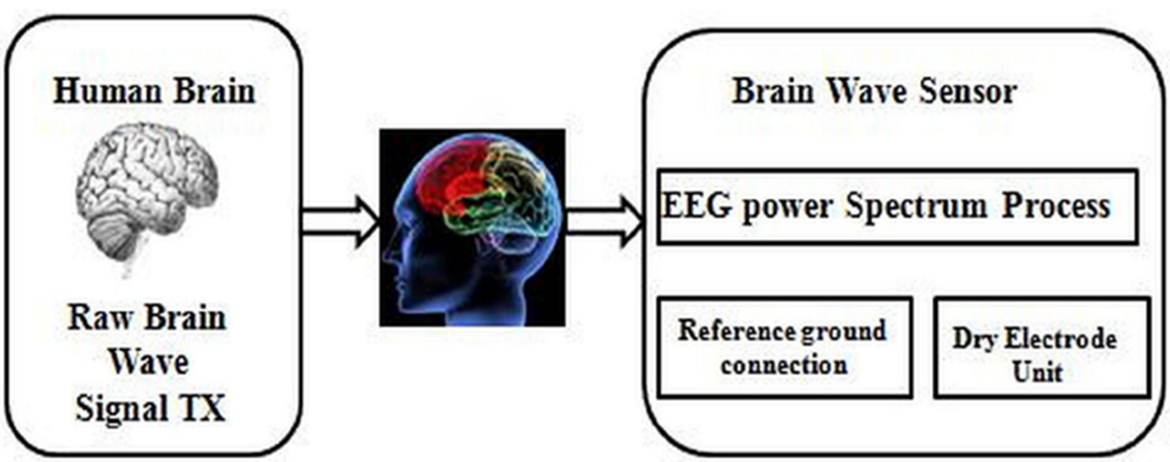

Fig 3.11 BCI System

wireless Single-channel EEG bio-sensor is used to capture the electrical signals in the brain, which is located on the frontal lobe (FP1). The other ground and reference electrodes are placed on the earlobe. Figure 3.12 shows the location of an EEG sensor for recording the Neurosignal. An event-related potential offered by a sensory information about the brain response at a specific latency time and P300 is evoked at every 300ms after the specific event occurs.

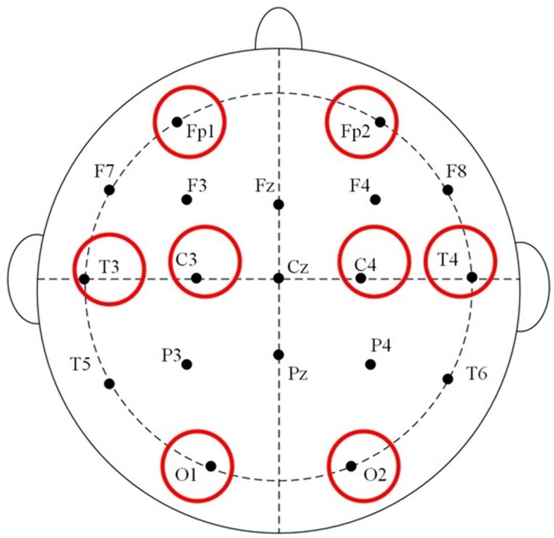

Fig 3.12: Biosensor placed in the position of FP1 on frontal lobe for EEG recordings

P300 is widely used in the BCI world for the performance of detecting the target. Here EEG and EMG were used for acquiring signals. EEG focused on obtaining the brain electrical activities and EMG more concentrated on capturing the muscle activities like Eye blink. Generally, EEG signals are characterized by rhythmic activity.

8.Independent mobility is the core perform activities of daily living by oneself. However, powered wheelchairs are not an option for many people who are unable to use conventional interfaces, due to severe motor–disabilities. For some of these people, non–invasive brain–computer interfaces (BCIs) offer a promising solution to this interaction problem and in this article a shared control architecture that couples the intelligence and desires of the user with the precision of a powered wheelchair is presented. Here four healthy subjects are able to master control of the wheelchair using an asynchronous motor–imagery based BCI protocol and how these results in a higher overall task performance, compared with alternative synchronous P300–based approaches.

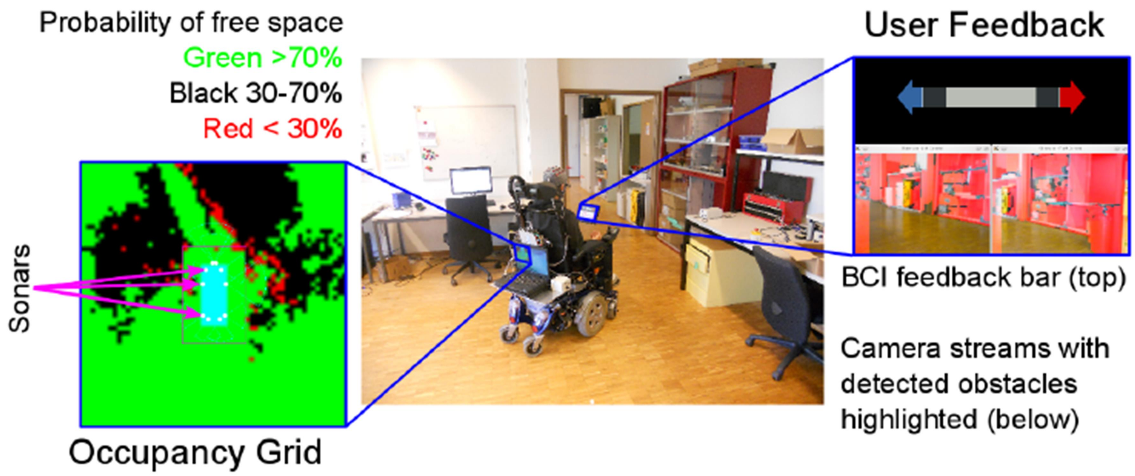

Fig. 3.13: The complete brain–actuated wheelchair. The wheelchair's knowledge of the environment is acquired by the fusion of complementary sensors and is represented as a probabilistic occupancy grid. The user is given feedback about the status of the BCI and about the wheelchair's knowledge of the environment.

3.2 HISTORY OF INTERNATIONAL BCI SOCIETY MEETINGS

The International BCI Meeting Series (1999, 2002, 2005, 2010, 2013, and 2016) brings together a wide range of research groups and disciplines vital to BCI research, and triggers many productive interactions and collaborations. The impact of these meetings on BCI

research is illustrated by the striking fact that over half the BCI articles ever published include at least one author who attended the BCI Meeting Series.

The Sixth International BCI Meeting: *"BCI Past, Present, and Future"*, which was held during May 30 – June 3, 2016 at the Asilomar Conference Center in Pacific Grove, California, USA, will be the first in the BCI Meeting Series organized under the leadership of a Program Committee appointed by the newly formed BCI Society.

The first four meetings of the International BCI Meeting Series were organized by the organization by the Wadsworth Center, Albany, NY. The First International Meeting, “Brain-Computer Interface Technology: Theory and Practice” was held in 1999, in Rensselaerville, NY. Fifty scientists and engineers from the 24 then-active BCI research labs came from the US, Canada, Great Britain, Germany, Austria, and Italy. In 2002 the Second

International Meeting, “Brain-Computer Interface Technology: Moving Beyond Demonstrations,” was held in Rensselaerville, NY. Ninety representatives from 38 labs participated. The Third International Meeting, “Brain-Computer Interface Technology: Making a Difference,” was held in 2005, in Rensselaerville, NY. The 160 participants represented 53 labs from throughout the world. The Fourth International BCI Meeting was held in 2010 in Pacific Grove, CA. The 283 participants represented 136 BCI labs from throughout the world.

The Fifth International BCI Meeting marked the transition of the BCI Meeting Series to organization by a committee encompassing the complex multidisciplinary breadth and international nature of BCI research. The Fifth International BCI Meeting: “Defining the Future” was held in Pacific Grove, CA June 3-7th, 2013. The 315 registrants represented 164 labs from 29 countries.

The Sixth International BCI Meeting: “BCI: Past, Present, and Future” was held in Pacific Grove, CA May 30th-June 3rd, 2016. The 407 registrants represented 188 labs from 26 countries.

The 7th International Brain Computer Interface Conference 2017 will be held on September 18th – 22nd, 2017, in Graz, Austria.

CHAPTER 4

CHAPTER 4

PROPOSED SYSTEM AND METHODOLOGY

In this chapter the methodology of the entire system is discussed. The block diagram, system architecture and the circuit diagram of the setup are discussed in detail .This chapter also covers brief explanation of different components and parameters used.

4.1 BLOCK DIAGRAM

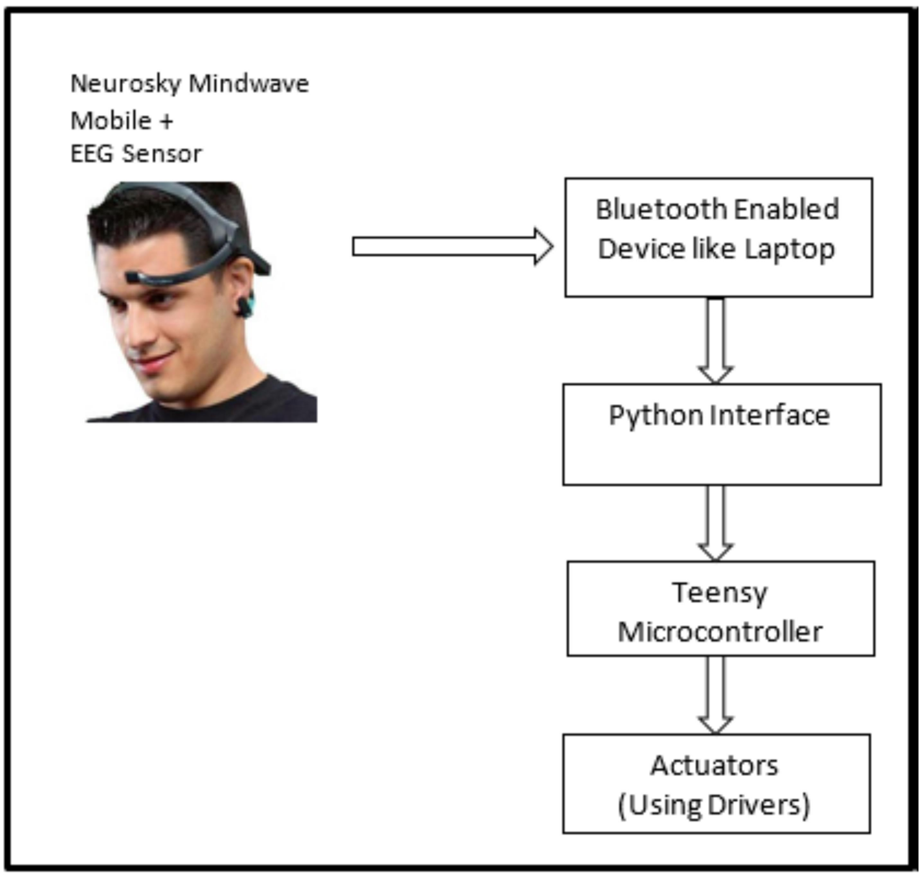

Fig 4.1 : Block Diagram

The most fundamental idea of BCI is to convert the brain patterns or the cerebral activity into respective scenarios which can be used for various control applications. In this project, we are using a non-invasive environment to develop a Brainwave Controlled Prosthesis gripper. Neurosky Mindwave Mobile headset is used to detect the brain waves in real time.

The block diagram is as shown in fig 4.1.The headset transfers data using Bluetooth communication. A python interface is created to obtain the values on the Python Shell.This is established using Telnet communication to the headset.A local host (13854) is used to establish connection between python shell and the headset .These values are sent to the microcontroller through serial communication. An interface with the Dual H-Bridge and the microcontroller is created. Based on the different actuation commands obtained from the microcontroller the moving gripper is controlled.

1. **Neurosky Mindwave mobile Headset**

The Neurosky Mindwave headset, as shown in Fig. 2, is powered by AAA battery and communicates via Bluetooth. It has a Think Gear chip inside and uses a TGAM module (Think Gear Application specific IC). It detects raw brainwaves and outputs processed EEG signals consisting of Alpha, Beta, Delta, Theta and eSense parameters like Attention, Meditation, Blink strength. The blink values range from 0-255 and attention values ranges from 0-100. The frequency range of the headset is typically between frequency 2.42 – 2.472 GHz. Sampling rate of EEG signal is done at 512Hz and its maximum power is found to be 50mw.

2. **Think Gear**

Think Gear technology [19] is a patented NeuroSky's technology which measures and analyses the EEG signals.The TGAM (Think Gear) module consists of an inbuilt small chip which helps in filtering the electrical noise. The headset can measure the wearer's state of mind. The processed signal is made available for applications. Further, mapping of different brain signals is performed to achieve various control activities

3. **Signal Detection**

The different states of the brain corresponds to different patterns of the cerebral activity. These patterns give rise to waves which are distinguished with the help of amplitudes and frequency pattern generated. The interaction occurring between the neurons produce a microscopic electrical discharge These patterns lead to waves characterized by different amplitudes and frequencies. These processed signals are then transmitted via Bluetooth communication to various applications.

4. **Python interface- Telnet communication**

A python module establishes connection between NeuroSky headset and Laptop using Telnet communication. Telnet is a protocol used on local area networks to provide a bidirectional communication facility. In general, the Telnet protocol establishes a TCP connection using which a program on one host (refers to Telnet client) may gain accessibility of the resources of another host (refers to Telnet server).

5. **Signal Acquisition**

The headset captured the EEG signals and are transmitted to the Laptop with the help of Bluetooth communication. The headset performs detection, analysis and processing of the signal and transmits the processed data to laptop.

6. **Pyserial**

Pyserial module encapsulates the access for the serial port. It provides an access to the communication port of Teensy microcontroller. Different commands like read and write are used to establish this communication.

7. **Teensy**

Teensy 3.0 is a 32-bit ARM Cortex-M4 development board running at 48MHz. It has 34 Digital I/O Pins out of which 10 pins are shared with analog and 3 UARTs (serial ports) and 10 PWM outputs. It has 128K Flash Memory, 16K RAM and 2K EEPROM.. It supports a USB host mode, an I2S audio interface (for high quality audio interface), SPI and I2C. The serial ports of Teensy is set to a baud rate in accordance with the Pyserial command. Thus, data is transmitted from the python module to Teensy using the digital pins, with the help of the Arduino IDE (Teensyduino).

8. Actuators

The data obtained from the Teensy microcontroller is used to drive the motors using L293D motor drivers. These motors perform action as per the data obtained and processed from Neurosky and Python interface. Thus, real time brain waves are used to control the prosthetic mobile robotic gripper.

4.2DETECTION OF EYE BLINK SIGNAL

The most common and widely used system is one consisting of multiple channels, which are located on the corresponding regions of the brain. these electrodes. In this system we are adopting a single electrode to measure the EEG signals.

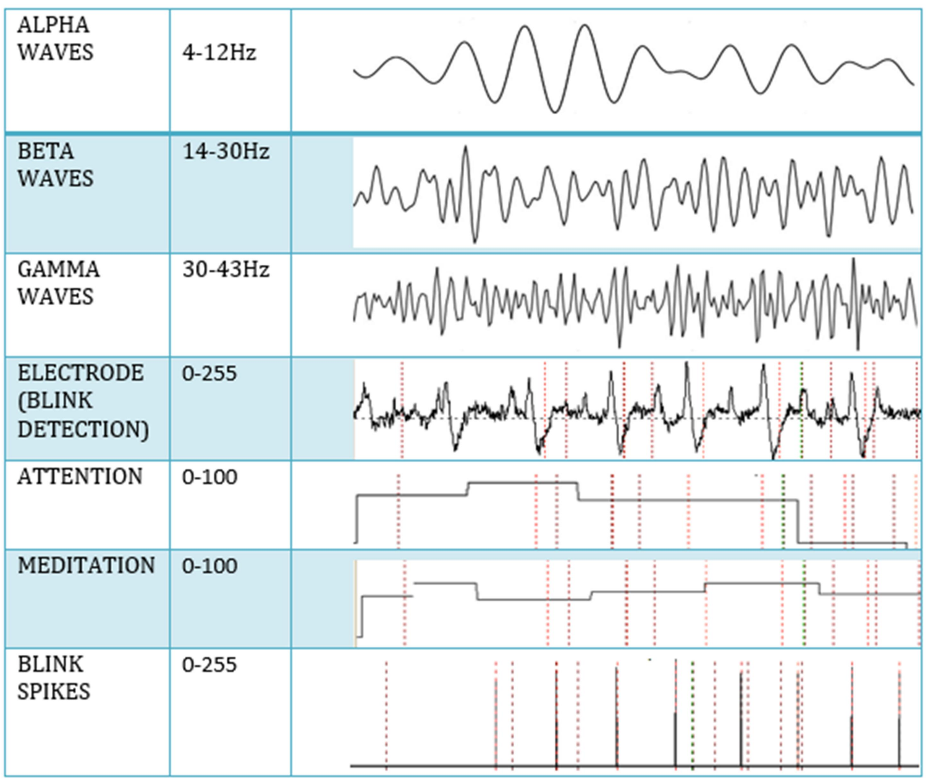

Fig. 4.2 Plot of real time brain waves

The brain signals detected from the headset is as shown in Fig.4.2. The signals measured from the sensor are decomposed and recorded. The blink spikes, was plotted to filter the noise in the blink signal using OpenVibe Platform. The EEG signal was acquired in real time using an acquisition server which connects with the Neurosky headset by enabling the local host address. An OpenVibe design scenario was created using a simple temporal filter of an order N. Thus, distinct blink signals were captured and classified.

.

Action	Range	Actuation
Long Blink	40-60	Forward
Quick Blink	Normal Blink	Backward
Stress Blink	>100	Stop
Blink (twice)	40-70	Move Left
Stress Blink (twice)	90-255	Move Right
Attention 1	40-60	Pick
Attention 2	70-100	Place

Fig 4.3 . Blink and Attention status to perform control application

The blink strength values range from 0-255. A higher number indicates a strong blink while a smaller number indicates regular/lighter blink. The frequency of blinking is often correlated with nervousness. Based on these values, it is coded to perform the control applications as shown in Fig 4.3.

4.3 SYSTEM ARCHITECTURE

The architecture flow is as shown in Fig 4.4. The brain waves detected and processed by the Neurosky EEG sensor, are transmitted via Bluetooth communication to Laptop. The platform used to extract real-time data is Python. A Telnet communication is established between Neurosky and Python to collect and parse the data. The values of the different mind-states and mind-waves corresponding to a frequency and activity are extracted. The signal flow of the system is as follows: if the Telnet communication isn’t established as shown in Fig 6, the connection is retried. Once the connection is established the brain waves are continuously collected. The parsed data are read and forwarded to the Teensy microcontroller which drives the actuators based on these values.

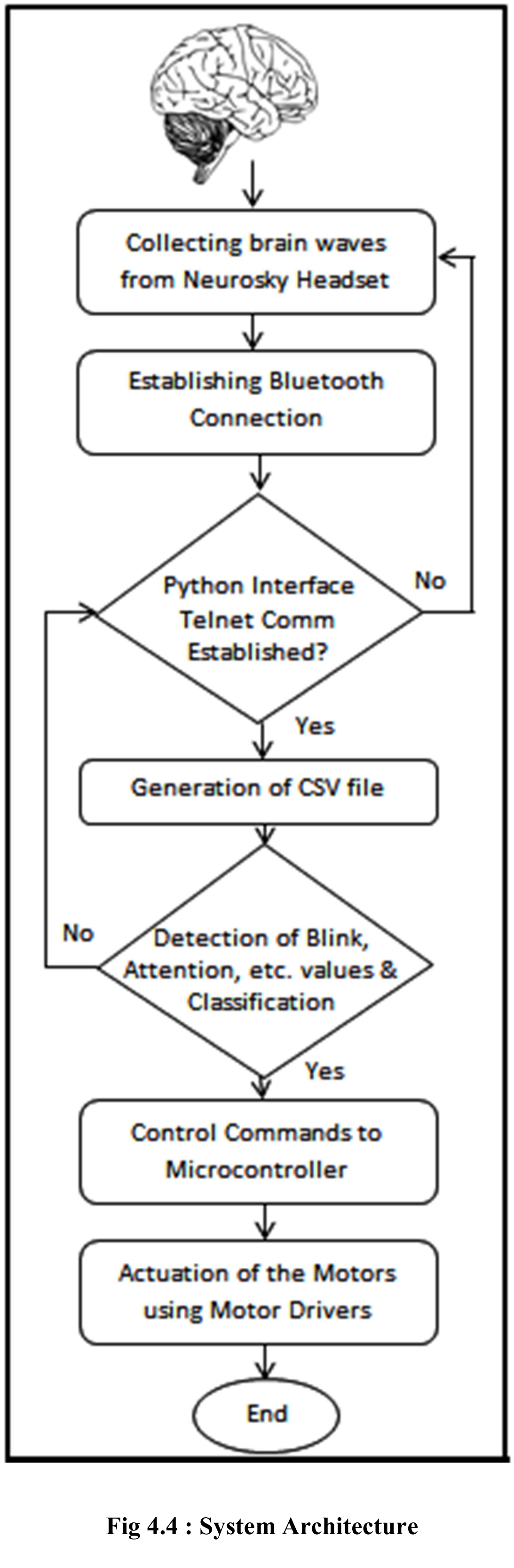

Fig 4.4 : System Architecture

Algorithm

Step 1: Establish serial communication between the laptop and microcontroller.

Step 2: Establish telnet communication to Neurosky headset (local host: 13854) and enable Think Gear Socket Protocol.

Step 3: Read and parse relevant eSense parameters like attention and blink strength values.

Step 4: Enable pyserial communication.

Step 5: Transmit the parsed control parameters from the program module to the microcontroller.

Step 6: Using the received parameters in microcontroller perform the corresponding actions.

4.4 CIRCUIT DIAGRAM

The circuit diagram of the system is as shown in Fig 4.5. The eSense parameters which are transferred to the laptop/desktop are further interfaced with the python program to parse the necessary data using Pyserial communication. This data is further transferred to the Teensy microcontroller. The circuit connections are as described. The eight digital pins of the microcontroller(Pin no 2,3.,4,5,14,15,16,17) are connected to the input pins of the L293D i.e (2,7,10,15) of both the motor drivers. These pins are used to drive the dual H-bridge in both the directions (i.e. clockwise and anticlockwise).The enable pins of the drivers (i.e. Pin no 1,9) are connected to 5V.Further the L293D is powered by connecting it to 12V supply. There are four grounds available on a single L293D IC (Pin no 4,5,12,13).The four motors used to actuate the moving robotic gripper are connected to pins 3,6 and pins 11,14.Thus each motor driver can drive two motors.

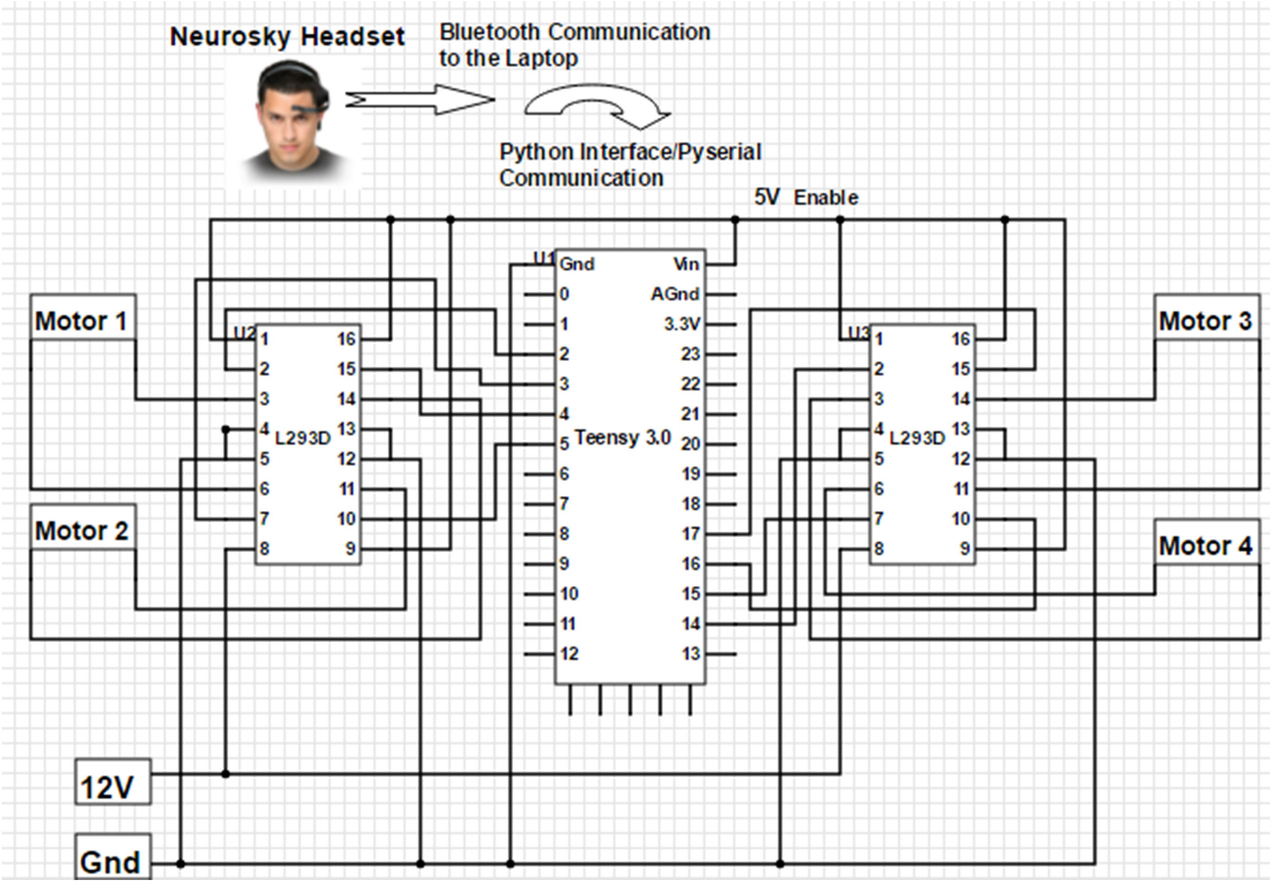

Fig 4.5 Circuit Diagram of the Proposed System

CHAPTER 5

CHAPTER 5

SIGNAL DETECTION AND FEATURE EXTRACTION

In this chapter an introduction to Neurosky Headset along with TGAM module are discussed which forms the basis of understanding this chapter. The methods involved in signal acquisition and detection are discussed. Also the feature extraction different eSense Parameters along with the different brain signals are discussed.

5.1 MIND WAVES and EEG

The human brain is made up of billions of interconnected neurons; the patterns of interaction between these neurons are represented as thoughts and emotional states. Every interaction between neurons creates a minuscule electrical discharge; alone these charges are impossible to measure from outside the skull. However, the activity created by hundreds of thousands of neurons concurrently, aggregates into waves which can be measured.

Different brain states are the result of different patterns of neural interaction. These patterns lead to waves characterized by different amplitudes and frequencies; for example, waves between 12 and 36 hertz, Beta Waves, are associated with concentration while waves between 8 and 12 hertz, Alpha Waves, are associated with relaxation and a state of mental calm.

EEG is an electrophysiological monitoring method to record electrical activity of the brain. It is typically non-invasive, with the electrodes placed along the scalp, although invasive electrodes are sometimes used in specific applications. It approximates the cumulative electrical activity of neurons.EEG measures voltage fluctuations resulting from ionic current within the neurons of the brain. In clinical contexts, EEG refers to the recording of the brain's spontaneous electrical activity over a period, as recorded from multipleelectrodes placed on the scalp. Diagnostic applications generally focus on the spectral content of EEG, that is, the type of neural oscillations (popularly called "brain waves") that can be observed in EEG signals. All electrical activity produces these waves (even light bulbs), thus all electrical devices create some level of ambient “noise”; this “noise” interferes with the waves emanating from the brain, therefore most EEG devices will

pick up readings even if they are not on a person's head. Measuring mental activity through these waves is like trying to eavesdrop on a conversation at a loud concert. In the past, EEG devices circumvented this problem by measuring these signals in environments where electrical
activity is strictly controlled and increasing the signal strength of the data coming from the brain.

5.1.1 Types of BCI Signal

The brain generates an amount of neural activity. There are a plethora of signals,which can be used for BCI. These signals are divided into two classes: spikes andfield potentials. Spikes reflect the action potentials of individual neurons andacquired through microelectrodes implanted by invasive techniques. Field potentialsare a measure of combined synaptic, neuronal, and axonal activity of groups ofneurons and can be measured by EEG or implanted electrodes.

The following is theclassification of EEG signals based on their frequencies/bands.

• **Delta Signal:**It is captured within the frequency range of 0.5–3.5 Hz. It tends to be the highest in amplitude and the slowest waves. It is seen normally in adults in slow wave sleep as well as in babies. Seen during deep, dreamless sleep, non-REM sleep, unconscious

• **Theta:**The frequency of this signals ranges from 3.5 to 7.5 Hz. Theta is linked to inefficiency and daydreaming. In fact, the very lowest waves of theta represent the fine line between being awake or in a sleep. However, high levels of theta are considered abnormal in adults. Seen during intuitive,creative,recall, fantasy, imaginary, dream.

Type	Frequency	Location	Use
Delta	<4 Hz	everywhere	occur during sleep, coma
Theta	4-7 Hz	temporal and parietal	correlated with emotional stress (frustration & disappointment)
Alpha	8-12 Hz	occipital and parietal	reduce amplitude with sensory stimulation or **mental imagery**
Beta	12-36 Hz	parietal and frontal	can increase amplitude during intense **mental activity**
Mu	9-11 Hz	frontal (motor cortex)	diminishes with movement or **intention of movement**
Lambda	sharp, jagged	occipital	correlated with visual attention

Fig 5.1 Different brain waves and their ranges

• **Alpha:** This signal frequency ranges from 7.5 to 12 Hz.This is seen in the posterior regions of the head on both sides, being higher in amplitude on the dominant side. It is brought out by closing the eyes and by relaxation but not drowsy, tranquil, conscious

• **Beta:** Beta is another brain signal in which its frequency ranges from 12 Hz to about 36 Hz. It is seen usually on both sides in a symmetrical distribution and itis most evident frontally. Beta waves are often divided into β1 and β2 to get more specific range. The waves are small and fast when resisting or suppressing movement, or solving a math task. It has been noticed in these cases that there isan increase of beta activity. Low Beta (12-15 Hz) Is seen during relaxed yet focused state;Midrange Beta (16 to 20 Hz) aware of self and surroundings; High Beta (21 Hz to 30 Hz) Alertness, agitation

•**Gamma.**: It is a signal with frequency range of 31 Hz and up. It reflects the mechanism of consciousness.

BCI is a hardware and software communications system that permits cerebral activity alone to control computers or external devices. The immediate goal of BCI research is to provide communications capabilities to severely disabled people who are totally paralyzed or 'locked in' by neurological neuromuscular disorders, such as ALS, brain stem stroke, or spinal cord injury.

A BCI is an artificial intelligence system that can recognize a certain set of patterns in brain signals following five consecutive stages:

1. **Signal acquisition** - The signal acquisition stage captures the brain signals and may also perform noise reduction and artefact processing.
2. **Pre-processing** - The pre-processing stage prepares the signals in a suitable form for further processing.
3. **Signal enhancement**
4. **Feature extraction, classification** - The feature extraction stage identifies discriminative information in the brain signals that have been recorded. The feature vector must also be of a low dimension, to reduce feature extraction stage complexity, but without relevant information loss. The classification stage classifies the signals

taking the feature vectors into account. The choice of good discriminative features is therefore essential to achieve effective pattern recognition, to decipher the user's intentions. Once measured, the signal is mapped onto a vector containing effective and discriminant features from the observed signals. The extraction of this interesting information is a very challenging task.

5. **The control interface** - Finally the control interface stage translates the classified signals into meaningful commands for any connected device, such as a wheelchair or a computer.

5.2 NeuroSky Technology Overview

The last century of neuroscience research has greatly increased our knowledge about the brain and particularly, the electrical signals emitted by neurons firing in the brain. The patterns and frequencies of these electrical signals can be measured by placing a sensor on the scalp. An example for one such EEG sensor is Neurosky Mindwave Mobile Headset.

NeuroSky, Inc. is a manufacturer of (BCI) technologies for consumer product applications, which was founded in 2004 in Silicon Valley, California. The company adapts EEG and Electromyography (EMG) technology to fit a consumer market within a number of fields such as entertainment (toys and games), education, automotive, health and research.

NeuroSky technology allows for low-cost EEG-linked research and products by using inexpensive dry sensors; older EEGs require the application of a conductive gel between the sensors and the head. The systems also include built-in electrical "noise" reduction software/hardware, and utilizes embedded (chip level) solutions for signal processing and output.

The headset contains NeuroSkyThinkGear™ technology, measures the analog electrical signals, commonly referred to as brainwaves, and processes them into digital signals to make the measurements available for various applications. Itoutputs the EEG power spectrums (alpha waves, beta waves, etc.), NeuroSkyeSense meters (attention and meditation) and eye blinks.

The device consists of a headset, an ear-clip, and a sensor arm. The headset's reference and ground electrodes are on the ear clip and the EEG electrode is on the sensor arm, resting on the forehead above the eye (FP1 position). It uses a single AAA battery with 8 hours of battery life.

5.2.1 Key features:

- Uses the ThinkGear Application specific Module(TGAM), Headset is rated at 60 Hz
- Automatic wireless pairing (Bluetooth v2.1 Class 2 (10 meters range)
- Outputs 12 bit raw brainwaves (3 - 100Hz) with Sampling rate at 512Hz, 1Hz eSense sampling calculation.
- Processing and output of EEG power spectrums (Alpha, Beta, etc.) and output of NeuroSky proprietary eSense parameters- Attention, Meditation and Blink Strength.
- Single AAA Battery, 8-hours battery run time
- Static Headset ID (headsets have a unique ID for pairing purposes)
- UART Baud rate: 57,600 Baud, 1mV pk-pk maximum
- Supported platforms: Windows (XP/7/8/8.1/10), Mac (OSX 10.7.5 or later), iOS (iOS 8 or later) and Android (Android 2.3 or later), MATLAB.
- 30mW power; 50mW max power
- 2.420-2.471GHz RF frequency; 6dBm RF max power; 250kbit /s RF data rate; 5% loss of bytes packets via wireless medium.
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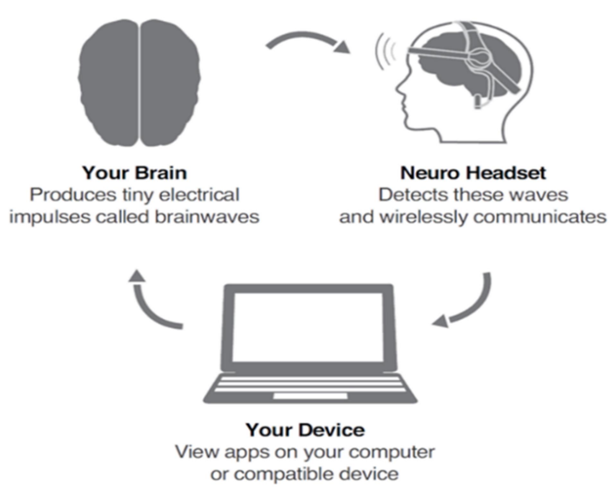


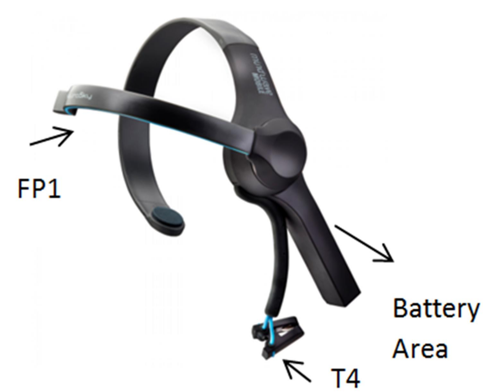


Fig 5.2: Overall System

FlowFig 5.3: Neurosky Headset

Fig 5.4 Neurosky Headset

5.3 ThinkGear:

ThinkGear™ is the technology inside every NeuroSky product or partner product that enables a device to interface with the wearers' brainwaves. It includes - the sensor that touches the forehead, the contact and reference points located on the ear pad, and the on-board chip that processes all the data. Both the raw brainwaves and the eSense Meters (Attention and Meditation) are calculated on the ThinkGear chip.

NeuroSkyThinkGearApplication Specific IC(ASIC) module (TGAM**)** is the world's most popular EEG technology. Together with a dry electrode, it senses the faint signal from the human brain, filters out extraneous noise and electrical interference and converts to digital signals to use in games, apps, toys, and research.

The amplitude of the EEG is ~ 100 µV when measured on the scalp, and about 1-2 mV when measured on the surface of the brain. The bandwidth of this signal is from under 1 Hz to about 50 Hz. The analog brainwaves enter a processing ASIC chip and have digital values that are communicated over Bluetooth to any computer that can receive a Bluetooth serial stream (SPP).

Embedded within the TGAM, is the TGAT chip, a powerful, fully integrated single chip EEG sensor. The chip comes programmed with NeuroSkyeSense, A/D, amplification off head detection, and noise filtering for EMG and 50/60Hz AC powerline interference.

There are three levels of signal coming from Neurosky'sThinkGear chip – the top-level, most-highly-processed signal is eSense, it sends in a packet once a second, calculated on-chip using a proprietary closed algorithm, the details of which not shared. This gives you two values called ‘Attention’ and ‘Meditation’, plus other processed quality-of-signal. The least-processed and most-frequent (512 samples/second) data is a raw wave power reading from

the contact. Everything else that comes from the headset has its origins in this raw wave.But the evidence that it’s clearly not merely a random number generator comes most clearly when you blink – the electricity involved in the muscle twitch close to the contact completely swamps the feeble signal from the brainwaves and creates a characteristic pattern in the wave signal, will be a big spike high followed quickly by a big spike low followed by returning to normal, reliably, every time.

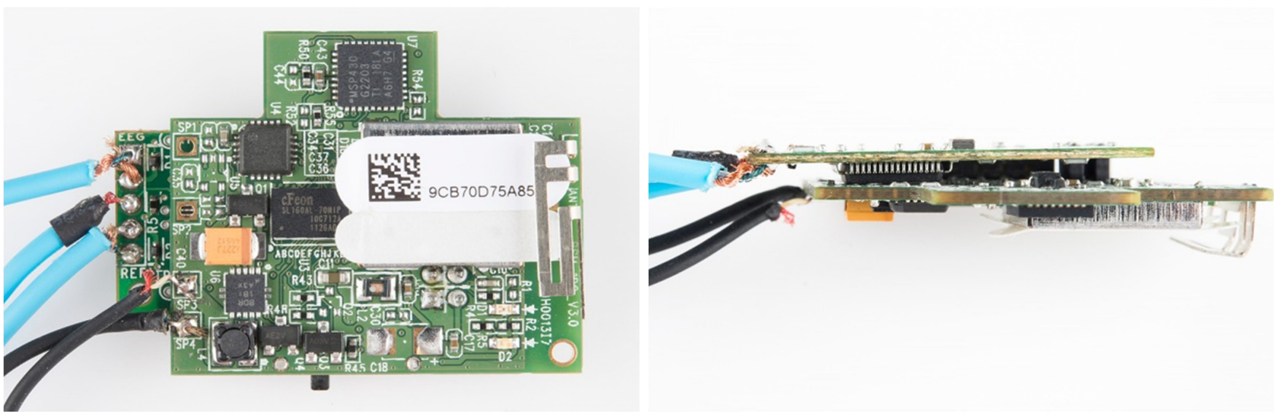


Fig5.5 : Closer look at the TGAM module

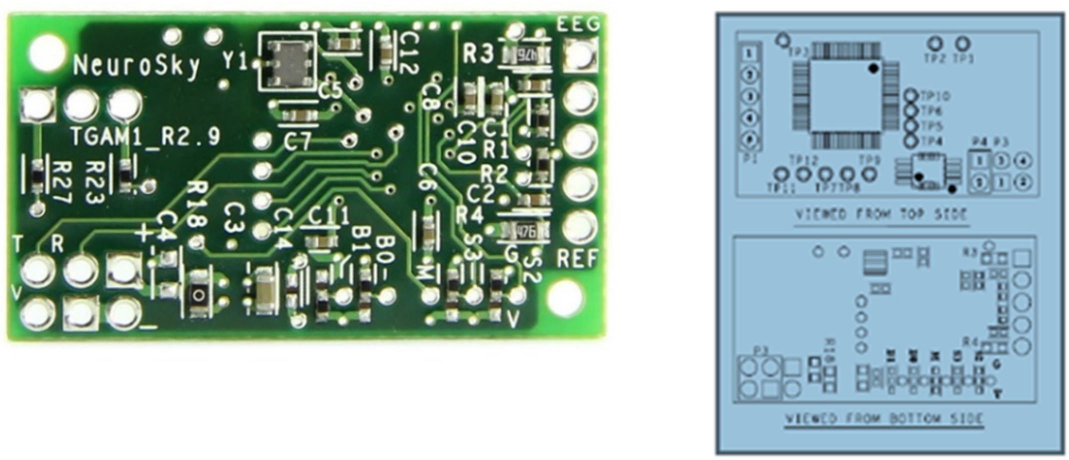
5.3.1 Features, Specifications

Features

- Direct connect to dry electrode.
- One EEG channel + Reference + Ground
- Extremely low-level signal detection
- Advanced filter with high noise immunity
- Raw sampledEEGvalues at 512Hz
- eSense Brainwave Patterns (Attention, Meditation Eye Blink)
- EEG band power values for delta, theta, alpha,low alpha, beta, low beta, and gamma

Specifications

- 512Hz sampling rate
- 3-100Hz frequency range
- Electro Static Discharge (ESD) Protection: 4kV Contact Discharge; 8kV Air
- Max Power Consumption: 15mA at 3.3V;Operating voltage 2.97 ~3.63V
- UART (Serial): - 1200, 9600, 57600 baud- 8-bits- No parity
- 1 stop bit



Header P1 (Electrode)
Pin1: EEG Electrode "EEG"
Pin2: EEG Shield
Pin3: Ground Electrode
Pin4: Reference Shield
Pin5: Reference Electrode "REF"

Header P4 (Power)
Pin1: VCC "+"
Pin2: GND "-"

Header P3 (UART/Serial)
Pin1: GND "-"
Pin2: VCC "+"
Pin3: RXD "R"
Pin4: TXD "T"

Fig 5.6 Pin Diagram of TGAM Module

Mindwave headset has five essential parts:

1. The arm going on the front sensor

2. The main body of the headphones, including the AAA battery cables

3. The ear loop and clip

4. The TGAM board. # 1 and # 3 are connected on the TGAM board directly. This is the rectangular table

5. The Bluetooth board. This joint sits atop the TGAM Board. It also receives power wiring. This is the T-shaped table. The switch incorporated into this board into account

.

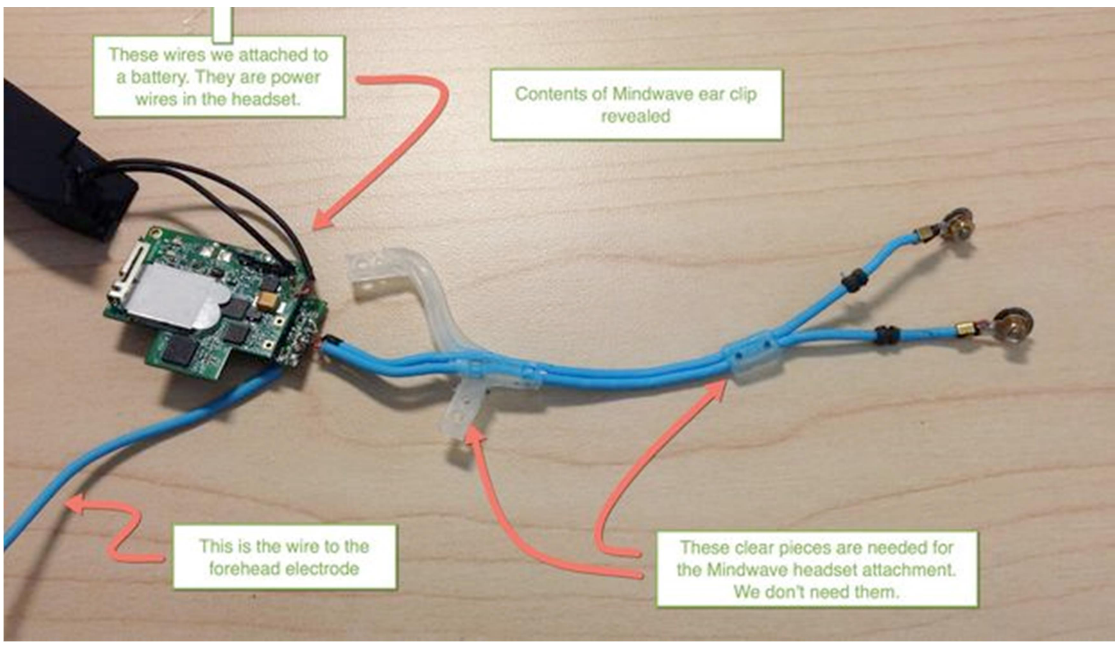


Fig 5.7 : Inner View

The single dry sensor and reference pick up potential differences (voltages) on the skin at the forehead and the ear. The two are subtracted through common mode rejection to serve as a single EEG channel, and amplified 8000x to enhance the faint EEG signals. The signals are passed through analog and digital low and high pass filters to retain signals generally in the 1-50Hz range. After correcting for possible aliasing, these signals are ultimately sampled at 512Hz.

Each second, the signal is analyzed in the time domain to detect and correct noise artifacts as much as possible, while retaining as much of the original signal as possible, using NeuroSky's proprietary algorithms. A standard FFT is performed on the filtered signal, and finally the signal is rechecked for noise and artifacts in the frequency domain, again using NeuroSky's proprietary algorithms.

In between the two boards is an ASIC. The ASIC on the Neurosky calculates a value for Attention and Meditation. It also processes five types of brainwaves and sends out unitless values for each one.

Fig 5.8 : Overview

5.3.2 eSense:

eSense™ is a NeuroSky's proprietary algorithm for characterizing mental states. To calculate eSense, the NeuroSkyThinkGear technology amplifies the raw brainwave signal and removes the ambient noise and muscle movement. The eSense algorithm is then applied to the remaining signal, resulting in the interpreted eSense meter values. eSense meter values do not describe an exact number, but instead describe ranges of activity.

Each thinkGear model reports its raw wave information in only certain areas of the full -32768 to 32767 range. For example, MindSet reports raw waves that fall between approximately -2048 to 2047.

5.3.2.1 eSense Meter

The eSense meters are a way to show how effectively the user is engaging Attention (like concentration) or Meditation (similar to relaxation). Like exercising an unfamiliar muscle, it may take some time to gain full proficiency with each of the eSense™ meters. In many cases, people tend to be better at one eSense than the other when they first begin. With practice data, can be got with much accuracy and consistency.

Generally, Attention can be controlled through a visual focus. Focus on a singular idea.Try to "funnel" your concentration and focus your train of thought towards pushing up the meter. Or we could pick a point on the screen to stare at or imagine the action you are trying to accomplish happening.

For Meditation, it typically helps to try to relax yourself. Connect to a sense of peace and calm by clearing your mind of thoughts and distractions. If you are having difficulty engaging Meditation, close your eyes, wait several seconds, and then open your eyes to see how the meter has responded.

For each different type of eSense (i.e. Attention, Meditation), the meter value is reported on a relative eSense scale of 1 to 100. On this scale, a value between 40 to 60 at any given moment in time is considered "neutral" and is similar in notion to "baselines" that are established in conventional brainwave measurement techniques.

A value from 60 to 80 is considered "slightly elevated", and may be interpreted as levels tending to be higher than normal (levels of Attention or Meditation may be higher than normal for a given person). Values from 80 to 100 are considered "elevated", they are strongly indicative of heightened levels of that eSense.

Similarly, on the other end of the scale, a value between 20 to 40 indicates "reduced" levels of the eSense, while a value between 1 to 20 indicates "strongly lowered" levels of the eSense. These levels may indicate states of distraction, agitation, or abnormality, according to the opposite of each eSense.

The reason for the somewhat wide ranges for each interpretation is that some parts of the eSense algorithm are dynamically learning and at times employ some “slow-adaptive” algorithms to adjust to natural fluctuations and trends of each user, accounting for and compensating for the fact that brainwaves in the human brain are subject to normal ranges of variance and fluctuation. This is part of the reason why ThinkGear sensors are able to operate on a wide range of individuals under an extremely wide range of personal and environmental conditions, while still giving good accuracy and reliability.

5.3.3.ThinkGear Data Values:

The ThinkGear Socket Protocol (TGSP) is a JSON-based protocol for the transmission and receipt of ThinkGear brainwave data between a client and a server. TGSP was designed to allow languages and/or frameworks without a standard serial port API (e.g. Flash and most scripting languages) to easily integrate brainwave-sensing functionality through socket APIs.

The TGSP involves the following parameters:

- A ***server***is a device or application that implements TGSP, and is responsible, amongst other things, for responding to authorization requests and broadcasting headset data. the ThinkGear Connector is an example of a "server".
- A ***client*** is a device or application that connects to a server.
- ***Headset data***refers to the data returned by a headset containing a ThinkGear module.

a) POOR_SIGNAL Quality:

This unsigned one-byte integer value describes how poor the signal measured by the ThinkGear is. It ranges in value from 0 to 200. Any non-zero value indicates that some sort of noise contamination is detected. The higher the number, the more noise is detected. A value of 200 has a special meaning, specifically that the ThinkGear contacts are not touching the user's skin. This value is typically output every second, and indicates the poorness of the most recent measurements. Poor signal may be caused by a number of different things.In order of severity, they are:

- Sensor, ground, or reference contacts not being on a person's head (i.e. when nobody is wearing the ThinkGear).
- Poor contact of the sensor, ground, or reference contacts to a person's skin (i.e. hair in the way, or headset which does not properly fit a person's head, or headset not properly placed on the head).
- Excessive motion of the wearer (i.e. moving head or body excessively, jostling the headset).
- Excessive environmental electrostatic noise (some environments have strong electric signals or static electricity buildup in the person wearing the sensor).
- Excessive non-EEG biometric noise (i.e. EMG, EKG/ECG, EOG, etc).A certain amount of noise is unavoidable in normal usage and both NeuroSky's filtering technology and eSense™ algorithm have been designed to detect, correct, compensate for, account for, and tolerate many types of non-EEG noise.

b) ASIC_EEG_POWER:

This Data Value represents the current magnitude of 8 commonly-recognized types of EEG (brainwaves). This outputs a series of eight 3-byte unsigned integers in Little-Endian format. The eight EEG powers are obtained in the following order: delta (0.5 - 2.75Hz), theta (3.5 - 6.75Hz), low-alpha (7.5 - 9.25Hz), high-alpha (10 - 11.75Hz), low-beta (13 - 16.75Hz), high-beta (18 - 29.75Hz), low-gamma (31 - 39.75Hz), and mid-gamma (41 - 49.75Hz). These values have no units and therefore are only meaningful compared to eachother and to themselves, to consider relative quantity and temporal fluctuations. By default, output of this Data Value is enabled, and typically outputs once a second.

c) ATENTION sense:

The eSense Attention meter indicates the intensity of a user's level of mental “focus” or “attention”, such as that which occurs during intense concentration and directed (but stable) mental activity. Its value ranges from 0 to 100. Distractions, wandering thoughts, lack of focus, or anxiety may lower the Attention meter level.

d) MEDITATION eSense :

The eSense Meditation meter indicates the level of a user's mental “calmness” or “relaxation”. Its value ranges from 0 to 100.Meditation is a measure of a person's mental state, not physical level, so simply relaxing all the muscles of the body may not immediately result in a heightened Meditation level. However, for most people in most normal circumstances, relaxing the body often helps the mind to relax as well. Meditation is related to reduced activity by the active mental processes in the brain.

It has long been an observed effect that closing one's eyes turns off the mental activities which process images from the eyes. So, closing the eyes is often an effective method for increasing the Meditation meter level. Distractions, wandering thoughts, anxiety, agitation, and sensory stimuli may lower the Meditation meter levels.

e) BLINK STRENGTH:

This unsigned one byte value reports the intensity of the user's most recent eye blink. Its value ranges from 1 to 255 and it is reported whenever an eye blink is detected. The value indicates the relative intensity of the blink, and has no units.

Except forrawEEg and blinkStrength, the headset components are transmitted at a rate of 1Hz. rawEeg, if enabled, is transmitted at a rate no higher than 512Hz. blinkStrengthis transmitted whenever a blink is detected by the headset.

5.3.4 ThinkGear Packets:

ThinkGear components deliver their digital data as an asynchronous serial stream of bytes. the serial stream must be parsed and interpreted as ThinkGear Packets in order to properly extract and interpret the thinkGear Data Values described in the chapter above.

A thinkGear Packet is a packet format consisting of 3 parts:

1. Packet Header
2. Packet Payload
3. Payload Checksum

ThinkGear Packets are used to deliver Data Values from a ThinkGearmodule to an arbitrary receiver (a PC, another microprocessor, or any other device that can receive a serial stream of bytes). Since serial I/O programming Application Program Interfaces (API) are different on every platform, operating system, and language, it is outside the scope to explain in detail.
The Packet format is designed primarily to be robust and flexible: Combined, the Header and Checksum provide data stream synchronization and data integrity checks, while the format of the Data Payload ensures that new data fields can be added to (or existing data fields removed from) the Packet in the future without breaking any packet parsers in any existing applications/devices. This means that any application that implements a ThinkGear Packet parser properly will be able to use newer models of ThinkGear most likely without having to change their parsers or application at all, even if the newer ThinkGear hardware includes new data fields or rearranges the order of the data fields.

5.4 ThinkGearSystem Overview:

Headset Data Transmission

Data transmission from the server is done using a streaming model; the client does not issue any explicit requests to the server for brainwave data. Because there is no mechanism in JSON to handle streaming (i.e. continuously appended) data, TGSP delimits individual JSON objects with carriage return characters (\r), so each JSON object will occupy its own line.

Recording

If the server supports brainwave and event recording, the client can enable recording by sending the following commands:

{"startRecording":{"rawEeg":true,"poorSignalLevel":true,"eSense":true, "eegPower":true,"blinkStrength":true},"applicationName":"ExampleApp"}

Parsing

Clients will first have to tokenize the stream using the carriage return (\r) delimiter, then parse each token individually as a JSON object. This is demonstrated by the following pseudocode:

while there is still data in the stream
read the line
parse the line as JSON

When using the JSON output format and tokenizing a packet stream using a \r delimiter, be careful about parsing the last token as a JSON object. Thee packet stream will end in a \r character, meaning that the tokenizer will likely return an empty string as the last token. Also, your parsing code should be tolerant of incomplete packet strings, in the event that the stream is parsed mid-transfer. Once a JSON object has been extracted out of the stream, it can be parsed using any of a number of readily-available JSON parsing libraries.

5.5 Blink Detection System

Eye blink is powerful component in various control applications. Especially, people with motor disabilities can only use their eyes to exercise their will power. Human eye blink detection supports these paralyzed people in an effective way to communicate with physical devices without depending on others. An eye blink characteristic includes the measures of parameters such as frequency, amplitude and time duration for closing and opening of the eye lids.

Here, the Mind Wave sensor detects the user's eye blink strength and other mental fatigues. Several processing steps need to be performed in order to recognize the blink strength.
Three different types of blinks are detected and each type of blinkis made to correspond todifferent activity of the module after cancellation of noise. In this way ,different blink states can be mapped accordingly to the prosthesis environment.

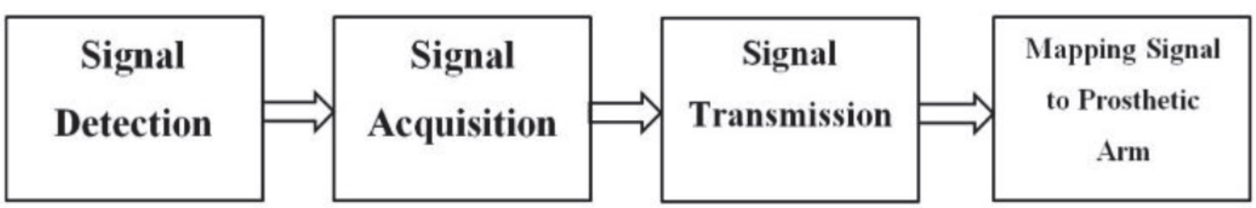


Fig : 5.9 System design

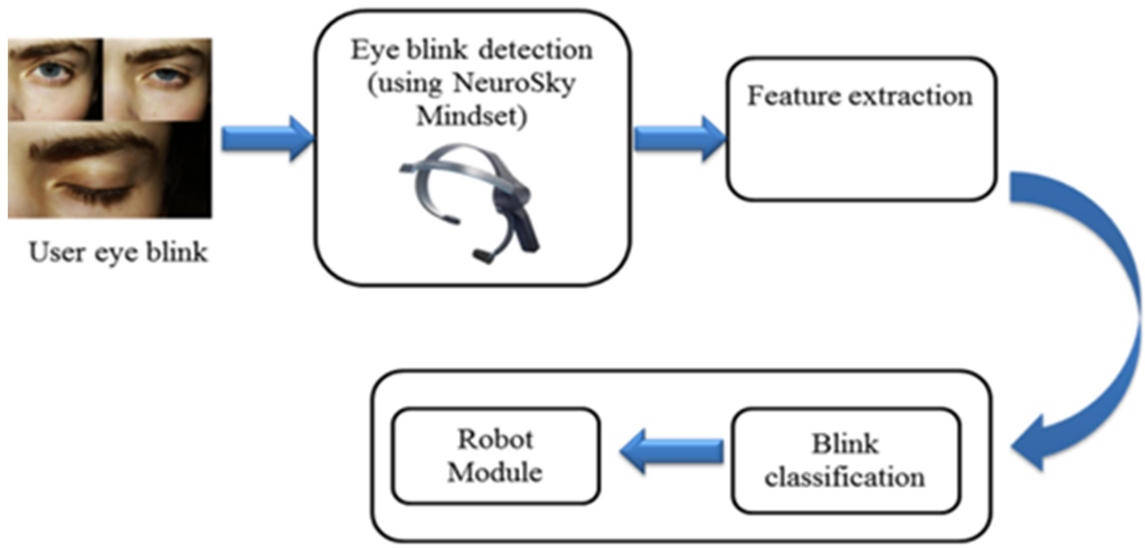


Fig : 5.10 System flow

5.5.1 Feature Extraction of Eye Blink Signal

Distinguishing eye flicker rate and consideration level of user was taken into account of the EEG signal. We are using the blink strength values gathered from the processed signal from the NeuroSkyMindset headset.

Typically, electrodes set on the frontal, focus and parietal segment of cerebrum are chosen to concentrate on mind signals. The universal standard 10-20 electrode framework comprises of 16 channels, for example, FP2, T4, T6, FP1, F7, T3, F3, F4, C3, C4, P3, P4, O2, F8, O1, T5 which are placed on its corresponding location. As opposed to utilizing these electrodes framework, here we make use of NeuroSkyheadset, which has a single channel. The channel A1 corresponds with sensor ear clip, FP1 relates to Brain Sensor and T4 corresponds to the headset reference point as shown in Fig: 5.3

The blink strength values range from 0-255. A higher number indicates a strong blink while a smaller number indicates regular/lighter blink. The frequency of blinking is often correlated with nervousness. Based on these values, it is coded to perform the control applications as shown in Fig 5.12

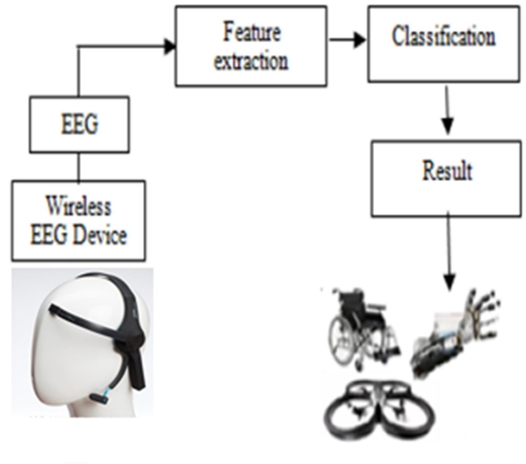


Fig 5.11: Types of Blink

Fig 5.12: Control application

5.6 WORK ON SSVEP/P300

Principle- Steady-State Visual-Evoked Potential is a brain response induced by a visual stimulus, flickering at a constant frequency between approximatively 6 and 100Hz. The response manifests itself as an increase in amplitude of the stimulated frequency. The scenarios in BCI-examplesillustrate a typical SSVEP experiment. In a few steps, you will be able to test a SSVEP-based BCI. These steps are:

- Experiment configuration
- Training data acquisition
- Classifier training

After intense analysis and experimentations on the device and mapping of the signals with different cortex of the brain, depending on the various scenarios mentioned above, we concluded that Neurosky being a single channel sensor could not capture the change in the brain waves when exposed to visual stimulus.

This is due to the fact that the position of the sensor in NeuroskyMindawave Headset is at FP1, which is near the forehead, rather than in the middle cortex Cz, which taps the visual stimulus.This led us to use the signals from the forehead itself and hence use blinking, attention and meditation values being recorded.

CHAPTER 6

CHAPTER 6

LEARNING PLATFORMSFORBCI

In this chapter the different learning tools and platforms which marks a major part in the research are discussed. The platforms discussed here helps us in understanding the various ways to collect the brain waves and process them for further applications. Thus the software requirements are discussed in this chapter.

6.1 NeuroExperimenter

NeuroExperimenter(NEx) is a BCI based software platform which helps in viewing andlistening to the brainwave output. It helps in discovering which combination of brainwaves characterize a mind state. The purpose of NEx is to explore brainwave output to attempt different "mind states", such as meditation, relaxation, concentration, etc. We can also train ourselves to generate that state via visual and audio feedback.

Here we select the necessary brainwaves to view and thus can specify any combination using a "formula". The following functions can be performed using NEx:

- View the last "n" seconds in a line graph or the last sample in a bar graph in real time
- Compare a "base line" session to a "performance" session via a box plot.
- Create a log and run it through the application to view different graphical outputs.
- Submit the log to statistical programs such as "R".

Headset Tester

This is used to validate the headset. The connection status of the headset can be determined using this tool. The COM ports to which the headset is connected is validated and selected. Once a good signal is established the SUCCESS message is retrieved. The window displayed is as shown in Fig 6.1.

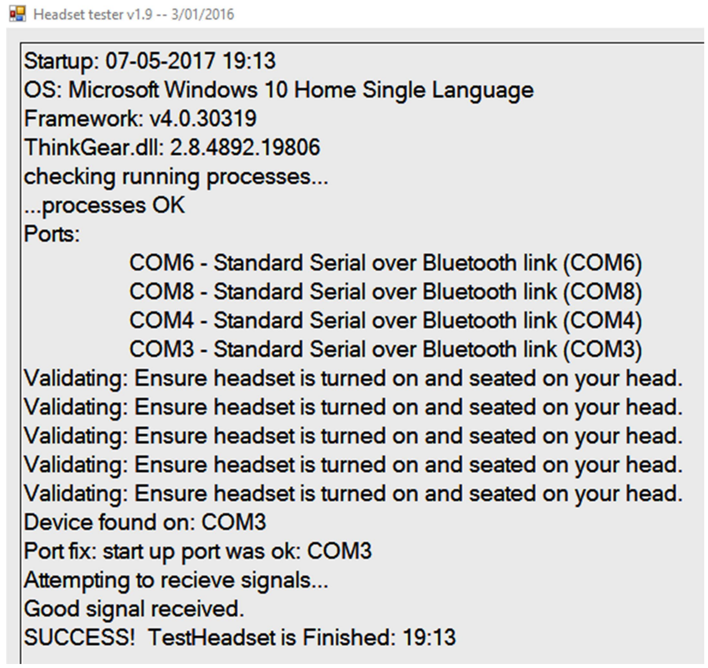


Fig 6.1 Headset Tester

Software details Regarding NEx software

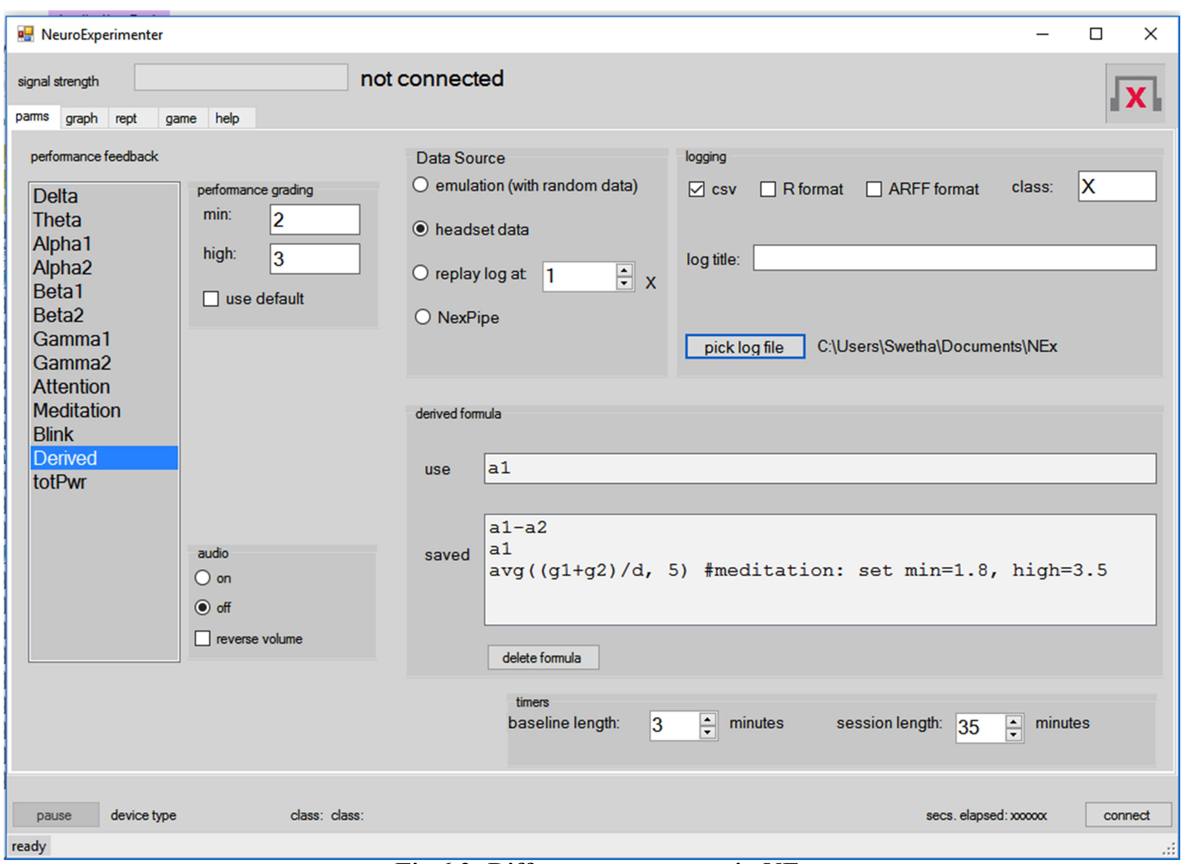


Fig 6.2: Different parameters in NEx

6.1.1 Data Source

The headset data option should be selected to acquire data from the headset.An existing log via the pick log file button is specified. The log can be played back at higher speeds by increasing the X multiplier. The overview of the session can be obtained by increasing the replay time and increasing the number of seconds (on the graph page). By clicking the pause button, the replay speed (on the parameterspage) can be reset; the log continues at the new speed when you click the button again. This is useful to get to a certain point in the log quickly, then slow the replay so that examining the session slowly from that point becomes easier.The selection of the performance wave type, the derived formula, and the grading logic can be chosen before starting the log. This allows us to perform different experiments against the same log. The timers are not used during the log replay: the baseline and session split are that of the original session.

6.1.2 Logging

The sample data can be saved up to 3 logs (except when replaying an existing log). R format is suitable for input to R(a free statistical system) and the NEx software. A "csv" log with "comma separated variables" can also be generated. This can be read into most spreadsheet programs and applications . Python has many capabilities for analysing a csv log.

6.1.3 Class box

Log entries are tagged with the "class". An '*' is appended for samples taken during the baseline. Furthermore, the class can be changed (to a single, printable character) by pressing a key on the keyboard while NEx is connected to the headset. All subsequent samples are tagged with this class until a different key is pressed. In this way one can mark samples with various external events (e.g. music starts to play, subject starts to answer a question, etc.). A program/spreadsheet can be written to analyse the log based on these events.

6.1.4 Log file

The filename entered should not have extensions. NEx will remove all extensions and add new ones for each log selected. So, for the selected "/C:/my Logs/relax.Rdata.txt", or input "relax", NEx would output a file "/C:/myLogs/relax.Rdata.txt" for the R-formatted log, and a file "/C:/myLogs/relax.ARFFdata.txt" for the ARFF formatted log.

6.1.5 Derived Formula

This allows us to create a new kind of waveform by combining other ones. The formula works on the normalized values of a data sample (wherein sample data is converted to values between 0 and 1). An existing formula from the "saved" box can be selected. A new formula can be selected by typing it in the "use" box. A formula can be deleted using the "delete" button.

6.1.6 Timers

The session can be divided into 2 parts: baseline and performance. The time for the whole session is specified by the session timer. Chimes are sounded at the end of the baseline and at the end of the session. When the session ends, the headset is automatically disconnected. The session can be ended at any time by clicking on the connect/disconnect button. The baseline timer ends the first part of the session and starts the second part (the "performance" part). The timers cannot be changed until the headset is disconnected.

6.1.7 Performance Feedback

One of the wave types is selected to measure for "performance". The performance of different waves like alpha, beta, gamma, theta, blink, etc. can be observed.

6.1.8 Audio

It is selected to generate a steady tone output for the last sample for the selected wave type. The volume (or silence) and pitch reflect the intensity (power output) of the wave selected in the feedback box.

6.1.9 Audio output

Once the session starts, if a performance wave type is selected and turned the audio on, you will receive audio feedback. The tone's frequency and volume will increase based on your performance. The "reverse volume" box when selected, the tone will get softer and lower as the signal strength increases.

6.1.10 Graphical output

The graph type are as follows: either the last n seconds of output, the last sample, a summary for the whole session and performance data are available. Selections can be changed even while samples are being generated or a log replayed.

6.1.11 Result / Recordings of the Output Simulated

The graphical representations are recorded in order to analyse and understand the different brain waves such as Delta, Theta, Alpha1, Beta1, Gamma1 and eSense parameters such as attention, meditation and blinkStrength.

Graphical Results:

1. Graphical Results of Different Brain Waves and eSense Parameters

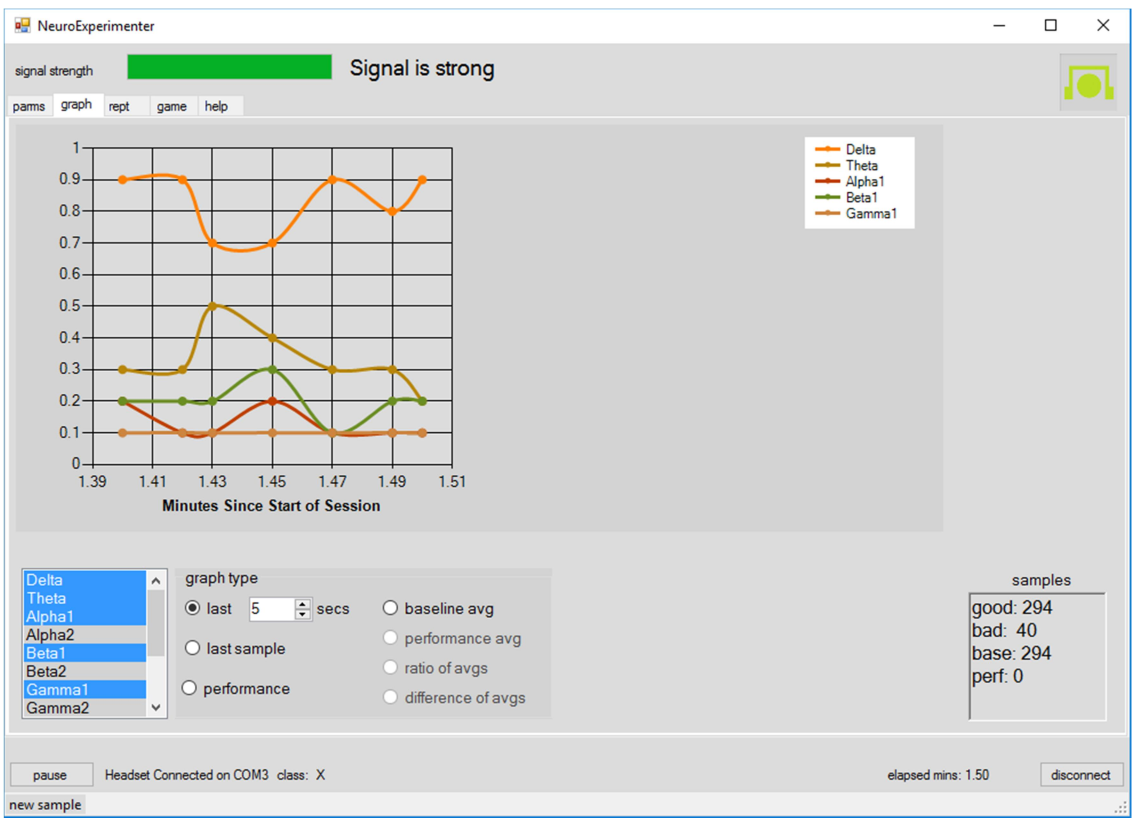


Fig 6.3: Graphical representation of Delta, Theta, Alpha1, Beta1, Gamma1 brain waves

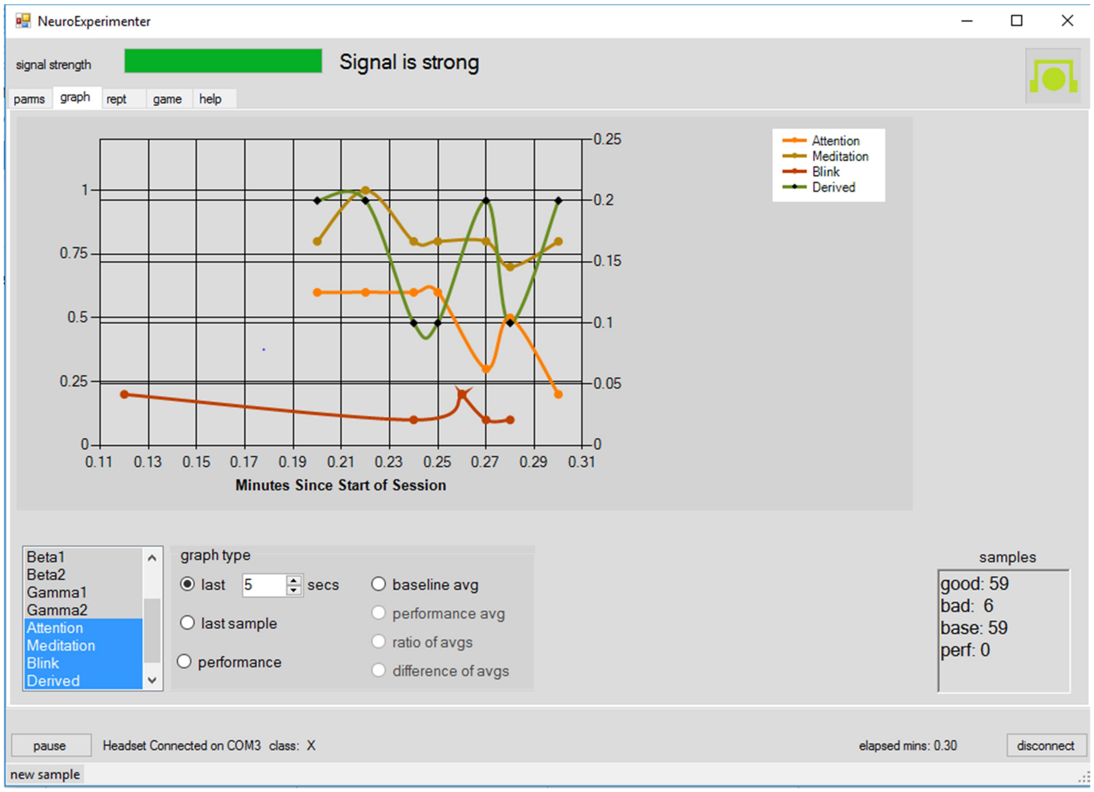


Fig 6.4: Graphical representation of Attention, Meditation, Blink, Derived Power

2. Bar Graph Representation of the Different Brain Waves and eSense Parameters

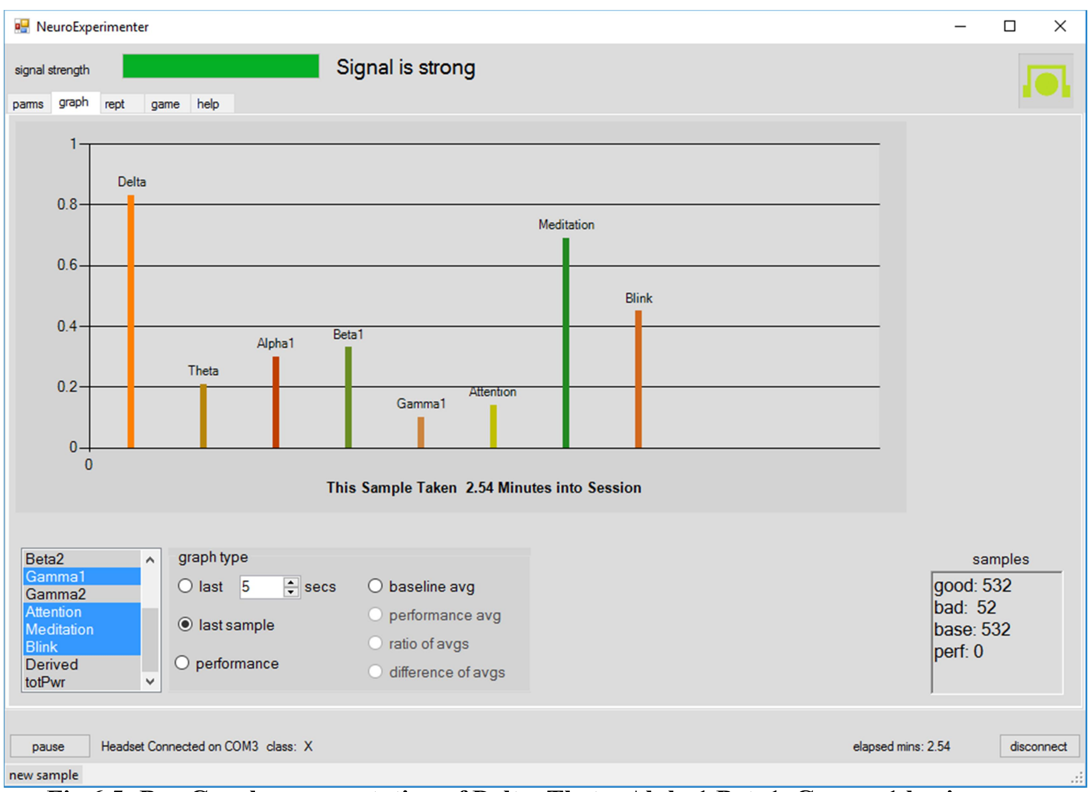


Fig 6.5: Bar Graph representation of Delta, Theta, Alpha1,Beta1, Gamma1 brain waves

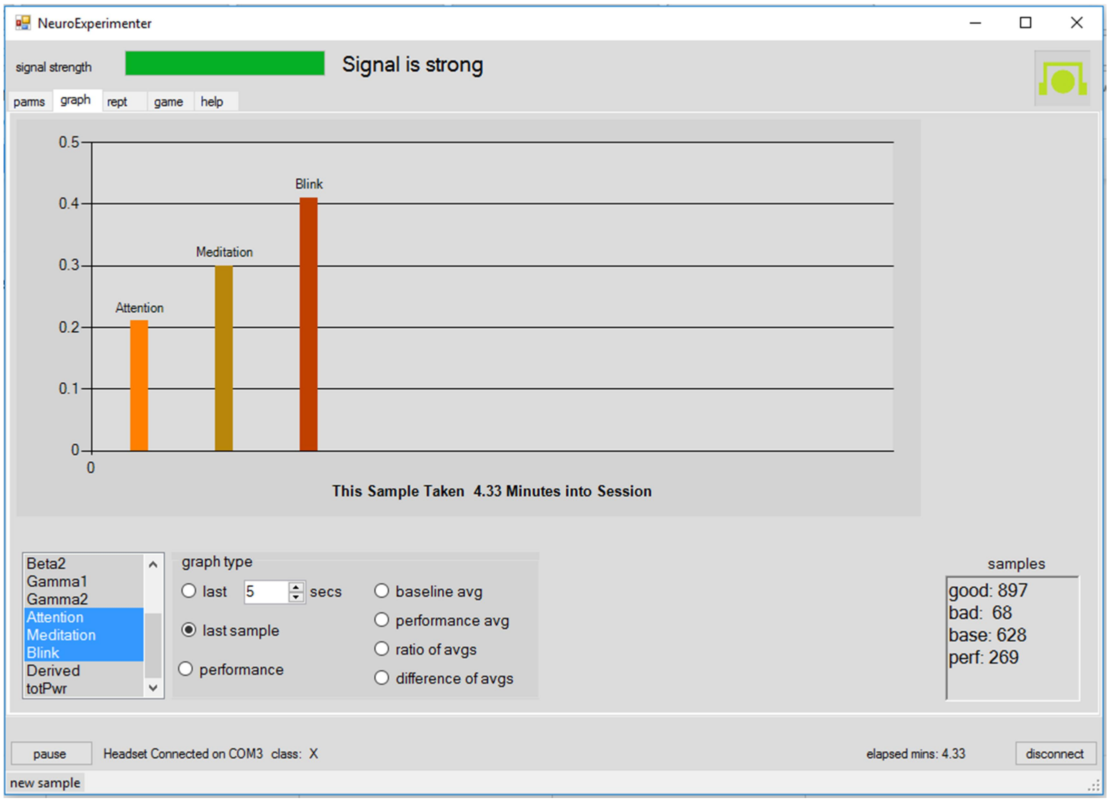


Fig 6.6: Bar Graph representation of Attention, Meditation, Blink, Derived Power

3.Performance / Baseline Characteristics

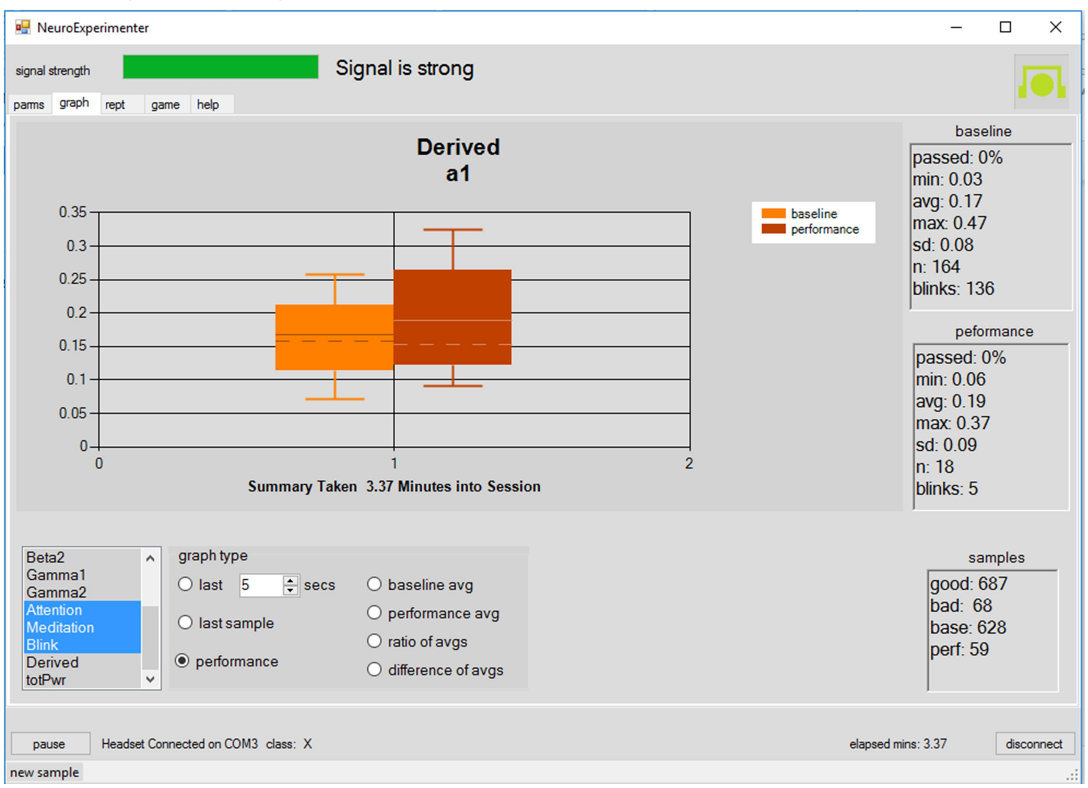


Fig 6.7: Complete Performance Monitoring

4.CSV File Generated / Log File

obs	time	Delta	Theta	Alpha1	Alpha2	Beta1	Beta2	Gamma1	Gamma2	Attention	Meditatic	Blink	Derived	totPwr	class
1	2.2	1813912	67667	11409	8428	23565	34266	3522	1040	0	0	52	0.08	1963809	X*
2	3.3	95423	9751	1818	1314	10875	6587	1153	146	0	0	76	0.12	127067	X*
3	4.2	725906	58926	29062	25874	36096	29301	5599	2611	0	0	NA	0.18	913375	X*
4	5.2	1537476	106988	9959	29342	49929	137925	17837	6435	53	35	56	0.07	1895891	X*
5	6.2	970731	517322	21899	38351	306714	169715	18600	6240	47	16	63	0.1	2049572	X*
6	7.2	1310690	462773	68478	70226	167006	107706	23463	11974	30	16	46	0.18	2222316	X*
7	8.2	680199	163670	74046	59452	89786	117648	7697	3355	29	27	55	0.25	1195853	X*
8	9.2	247619	94844	37721	23143	31875	12917	3559	3667	1	47	NA	0.29	455345	X*
9	10.2	1834559	1045309	30347	49255	156243	126946	26427	3839	1	47	71	0.1	3272925	X*
10	11.2	2061420	239670	32499	15676	93409	143411	17872	5750	11	37	73	0.11	2609707	X*
11	12.2	122774	21686	18882	25021	50510	64416	4538	694	26	30	73	0.25	308521	X*
12	13.2	1732872	138314	12391	27720	49408	41684	4674	1919	41	16	NA	0.08	2008982	X*
13	14	130570	12878	7513	4537	35980	25063	8783	1201	69	30	71	0.18	226525	X*
14	14.5	421146	279677	18180	31725	44099	40992	6332	910	51	38	70	0.15	843061	X*
15	15	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	74	NA	NA	X*
16	15.4	474408	746613	205578	67478	182698	111141	19487	9020	23	37	71	0.34	1816423	X*
17	16.1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	63	NA	NA	X*
18	16.5	1176097	40796	12945	7072	39508	27789	5409	2902	30	38	71	0.1	1312518	X*
19	17.2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	62	NA	NA	X*
20	17.5	189640	93535	27092	14694	65969	37273	2291	2423	13	43	68	0.25	432917	X*
21	17.7	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	34	NA	NA	X*
22	18.5	435591	150282	15268	58437	65761	33079	6594	1817	16	54	71	0.14	766829	X*
23	18.9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	66	NA	NA	X*
24	19.4	565918	197892	20537	21058	65128	26997	3457	2169	17	44	75	0.15	903156	X*

logFile

Fig 6.8: CSV file

6.2 OpenVibe

OpenViBE is a software platform dedicated to designing, testing and using brain-computer interfaces.OpenViBE is a software for real-time neurosciences (that is, for real-time processing of brain signals). It can be used to acquire, filter, process, classify and visualize brain signals in real time.OpenVibe is free and open source software which works on Windows and Linux operating systems.

There are various ways to stream data and events (stimulations) between OpenViBE and external applications in real time. For example, classification results can be sent from Designer to control a game, or a robotic arm, and processed data can be forwarded to show custom visualizations, etc. Whatever technique is chosen, a corresponding receiving or sending capability is added into the application or device.

6.2.1 EEG markers

One of the most common requirements in EEG and BCI experiments is to have the EEG recording annotated with a marker timeline describing the time course of the experiment. For

example, flashes in P300 and the starts and stops of motor imagery trials fall into this category. In OpenViBE, such timeline defining markers are called *stimulations*. It is usually important to get these markers as accurately aligned to the EEG data as possible, regarding the time the event occurred. Rendering component directly to the amplifier or Acquisition Server is used for this purpose. A software solution to this in OpenViBE is called the TCP Tagging technique. The received markers will be appended to the EEG stream by the Acquisition Server as stimulations.

6.2.2 Data and stimulations

The commonly used techniques to transmit information from/to the OpenViBE Designer in real time are the following:

- **VRPN**

  The classic OpenViBE way to send stimulations and data to external applications is the VRPN protocol.VRPN can also receive stimulations and small-scale numeric data into OpenViBE.

- **TCP/IP**

  Data and stimulations can also be sent using the TCP/IP protocol, if no 'exotic' dependencies are wanted. The TCP/IP can also be more efficient if large amounts of data are to be sent. The corresponding box is called the TCP Writer. In Acquisition Server, the Generic Telnet Reader driver can receive signal data over TCP/IP. The telnet driver can be configured to accept the TCP Writer box stream format.

- **Lab Streaming Layer (LSL)**

  Lab Streaming Layer is another protocol for exchanging data and stimulations between streaming applications. It can be used with a corresponding box.

OpenViBEAcquisition Server also has LSL plugins both to receive and send numeric data and stimulations.

- **OpenSoundControl**

  Open Sound Control is usually used to control synthetizers, but can also be used as a general output channel from OpenViBE Designer to anything that can receive data from an OSC controller.

- **Python and Matlab**

  Using either the Python box or the Matlab box, it is possible to stream data and stimulations to/from an application using some further communication mechanism that has been implemented in these languages. There can be some overhead from the run-time interpretation of the scripts, and in general from having this kind of 'middle layer'.

6.2.3 Acquisition Server

OpenViBE Acquisition Server is a tool designed to communicate with various hardware signal acquisition devices (list here). The task of the server is to forward the acquired signals and other experiment information to OpenViBE applications in a standardized and generic OpenViBE format.

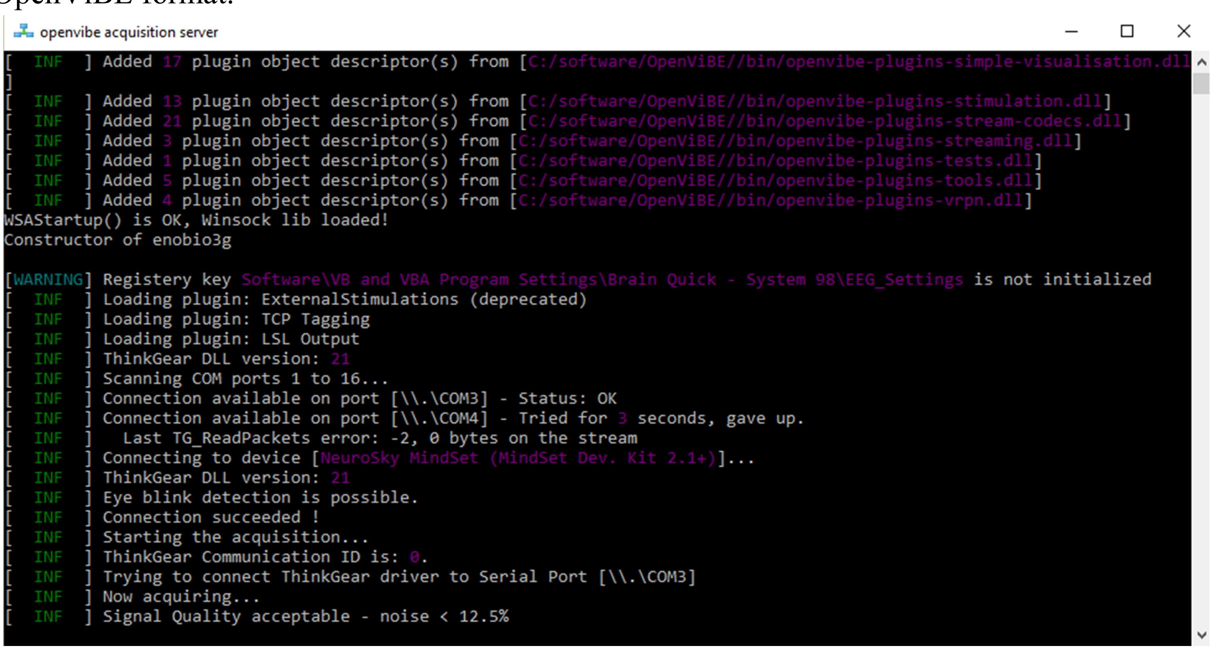


Fig 6.9 Acquisition Server Initialization

The acquisition server doesn’t communicate directly with acquisition devices. Instead, it provides the user with a set of drivers to choose from, each one being dedicated to specific devices. Support for new devices can added to the server by developing new drivers.

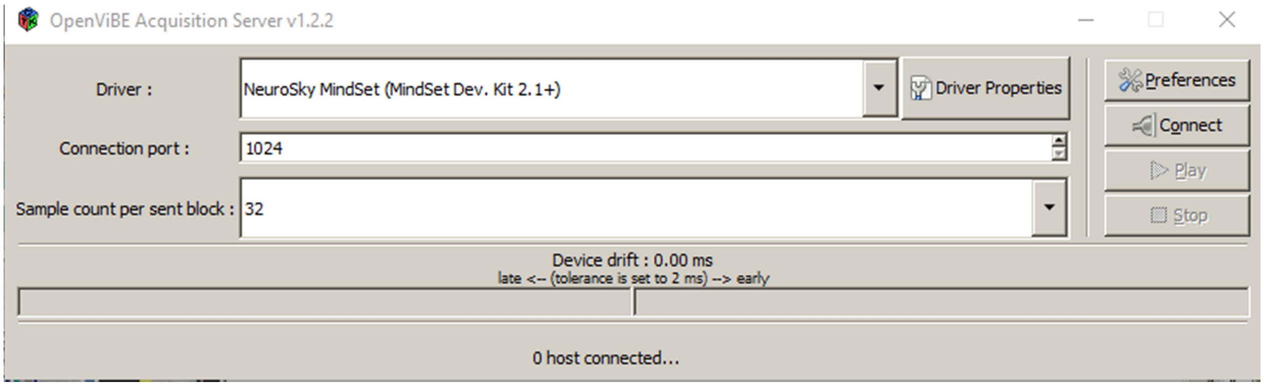


Fig 6.10 Acquisition Server

6.2.4 Acquisition Device Drivers

A list of available drivers is accessible under ‘**driver**‘. Depending on your distribution of OpenViBE, a number of drivers are usually available. It is appropriate for testing purposes

6.2.5 Connection Settings

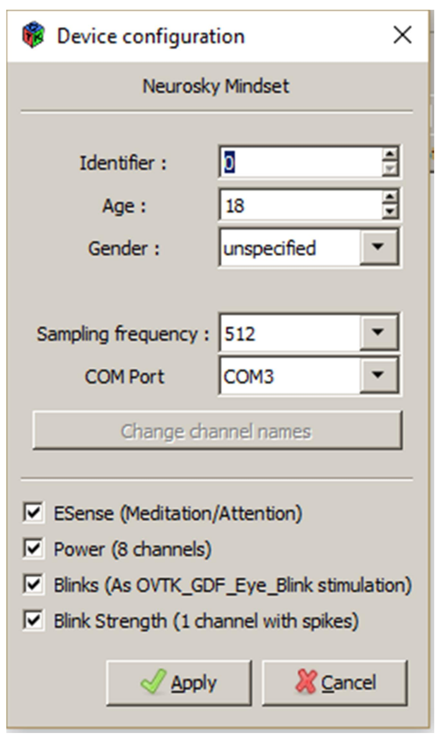


Fig 6.11:Device Driver Settings

In order to use a driver, connection details should be set so that the server communicates with connected OpenViBE applications as desired. The port to which to send data can be changed under 'Connection Port' (e.g. 1024 is a standard default setting).

An OpenViBE application will then have to fetch data from this port once an experiment is started. Also, the size of the buffers sent to connected applications may be configured under '**Sample count per sent block**'.This defines how many samples should be sent per acquired channel in a single buffer. Valid values are powers-of-two and 32 is the default. The duration or 'epoch' of a buffer depends on the sampling frequency, which may be set in the Driver Properties dialog.

6.2.6 Driver Properties

Once a driver is selected from the drop-down list and before it can be used, its settings should be configured appropriately. Settings provide information about the experiment being conducted and the subject undergoing the experiment. Additionally, these settings include configurable device parameters. The 'Driver Properties' button opens up the settings dialog of the currently selected driver. It displays settings that are available for the hardware and that can be changed by the user. They may vary between drivers.

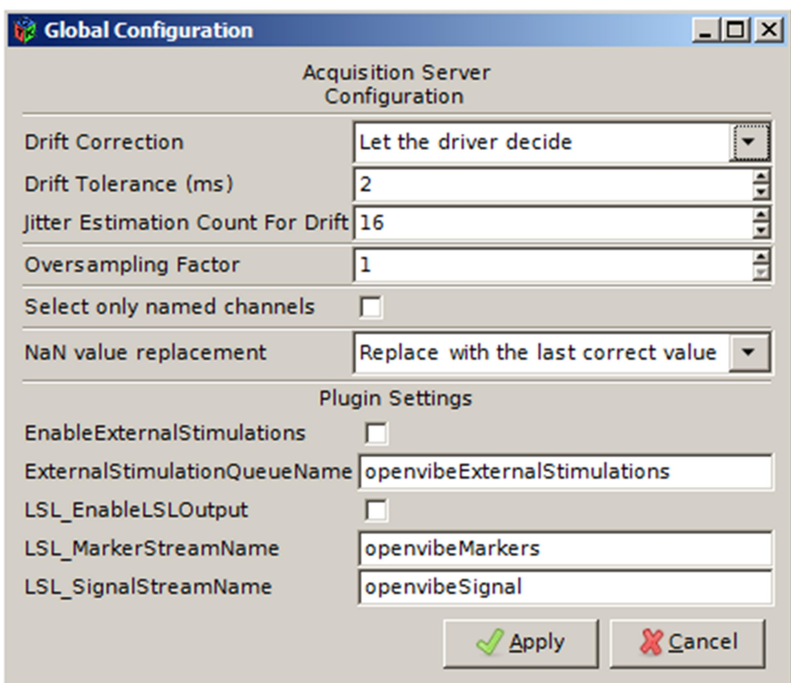


Fig 6.12: Acquisition Server Configuration

For example, the Generic Oscillator settings include information about the subject (identifier, age, gender) and the experiment (number of channels to be acquired, sampling frequency, channel names). Some hardware may also provide different operating modes, such as the impedance checking mode. Changing the channel names can be done easily, by specifying a label for each channel index. The possible labels must be chosen in a list that includes all the extended 10-20 system labels. The list can then be saved in a file for later use. The format of the file produced is very simple: a text file with one name per line.

6.2.7 Acquisition Server Preferences

Various global settings can be accessed through the '**Preferences** 'button. The contents of these settings may depend a little on the plugins that have been loaded.

6.2.8 Drift Correction

The Acquisition Server monitors the behaviour of the driver in order to ensure that it actually sends the number of samples it should, based on the theoretical sampling frequency of the device.When a drift is detected, you will see a progress bar moving on the left or right (not enough or too many samples). When the drift reaches a threshold, an automatic correction is done: the Acquisition Server removes or duplicates some samples, and sends stimulation(s) to any acquisition client connected, indicating that the signal correction just occurred.

If samples have been added, the portion of signal is delimited by the stimulations **OVTK_GDF_Correct** and **OVTK_GDF_Incorrect**. If samples have been removed, **OVTK_GDF_Incorrect** tags the corresponding moment.

Here are the parameters you can set for the Drift Correction:

- **Drift correction**: either Forced, Disabled, or driver dependant.
- **Drift Tolerance** (ms) : when reaching a drift duration of that value, a correction is triggered.
- **Jitter Estimation Count for Drift**: the window in number of "blocks" used to compute the drift.

6.2.9 Usage

Once a device driver has been selected and relevant settings configured, data acquisition can start. The server should first connect to the acquisition device, which is done by clicking the '**Connect** 'button. A label will inform the user whether the connection is successful.

If the connection was established and the device(s) successfully connected, data sampling can be started/stopped by clicking '**Play** '/'**Stop**'.

Once a driver is 'connected' and 'playing', the clients (e.g. acquisition client boxes in a Designer scenario) may be started: press 'play' in the designer. Data should be received, decoded and sent through the openvibe pipeline you designed. In the acquisition server window, you should see the number of clients connected to your server (e.g. '2 hosts connected').

6.2.10 Box Documentation

- **Acquistion Client**

Fig 6.13 Acquisition Client Box

This algorithm as shown in fig 6.13 waits for EEG data from the network and distributes it into the scenario. Opens a socket to read experiment information, signal, stimulations and channel localization data sent across the network.

Settings

1. Acquisition server hostname
   EEG server hostname
   Type identifier: *String (0x79a9edeb, 0x245d83fc)*
   Default value:[*${AcquisitionServer_HostName}*]
2. Acquisition server port
   EEG server port
   Type identifier: *Integer (0x007deef9, 0x2f3e95c6)*Default value: [*1024*]

➢ **Time Signal**

This box as shown in fig 6.14 ,generates a linear signal on a single channel. The box can be used in order to test some processing on a specific signal when no data is available. Each sample value of the generated signal exactly equals to time in second.

Fig 6.14: Time Signal Box

Settings

1. Sampling frequency

   The first setting indicates the sampling frequency of the produced signal in Hz.

   Type identifier: *Integer (0x007deef9, 0x2f3e95c6)*

   Default value: [*512*]

2. Generated epoch sample count

   The last setting indicates how many sample will be sent for each output chunk.

   Type identifier: *Integer (0x007deef9, 0x2f3e95c6)*

   Default value:[*32*]

➢ **CSV file reader**

This box as shown in fig 6.15 ,allows to read some of the OpenViBE streams from a text file that is easy to read both by machines and humans. CSV files are text files with different values separated by a special character such as a colon, a semicolon or a tabulation. This basic syntax makes it very easy to parse. The purpose of this box is to quickly import some data from other software.

Fig 6.15 CSV File Reader Box

➢ CSV file writer

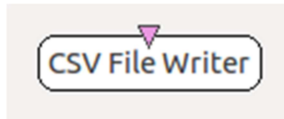


Fig 6.16: CSV File Writer Box

Inputs

1. Input stream

   This is input is used to know what data to dump in the considered file. The type of this input can be modified by the user and the format of the output will be adapted depending on this type. Supported inputs are: Signal, Spectrum, Streamed Matrix, Feature Vector, and Stimulations.

   Type identifier: Signal *(0x5ba36127, 0x195feae1)*

   Settings

   1. Filename

      This setting contains the file where to store the data.

      Type identifier: *Filename (0x330306dd, 0x74a95f98)*

      Default value: [*record-[$core{date}-$core{time}].csv*]

   2. Column separator

      This setting contains the special character to use as a separation for the different fields. Typical examples are colon, semi colon and tabulations.

      Type identifier: *String (0x79a9edeb, 0x245d83fc)*

      Default value:[*;*]

   3. Precision

      This allows you to set std: precision, i.e. how many digits are used to represent each input value in the output.

      Type identifier: *Integer (0x007deef9, 0x2f3e95c6)*

      Default value: [*10*]

- **Signal Average**

  This plugin as shown in fig 6.17, computes the average of each incoming sample buffer and outputs the resulting signal.

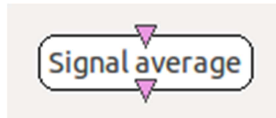


Fig 6.17: Signal Average Box

- **Python scripting**

  This box as shown in fig 6.18, can process data from and to OpenViBE using Python script. Available IO types are Streamed Matrix, Signal and Stimulations. The user

  Python Script must define a new class that inherits from OVBox, and implements the initialize, process and uninitialized methods.
  User script must end with: box = MyOVBox() where MyOVBox is the new class.

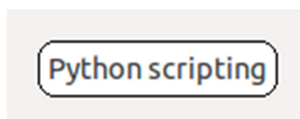


Fig 6.18: Python Scripting Box

- **Run Command**

  This box as shown in fig 6.19, allows to launch a command on specific stimulation reception. The goal of this is to trigger an external process on specific events, for example launch an external process on a given stimulation.

Fig 6.19: Run Command Box

- **Signal Display**

This boxas shown in fig 6.20, can be used to visualize signal and matrix streams. This plugin displays incoming signals. It plots values on the vertical axis while the horizontal axis represents time.

Fig 6.20: Signal Display Box

Settings

1. **Display Mode**

   Type of display, can be either Scan mode or Scroll mode. In Scan mode, the new data arrives from left to right and the displayed data does not move. In Scroll mode, the new data always arrives on the right and all displayed data moves right to left.

   Type identifier: *Signal display mode (0x5de046a6, 0x086340aa)*

   Default value: [*Scan*]

2. **Auto vertical scale**

   Automatic vertical (y) scaling mode: Per channel, Global, or None.

   Type identifier: *Signal display y scaling (0x33a30739, 0x00d5299b)*

   Default value: [*Per channel*]

3. **Scale refresh interval (secs)**

   Only used when automatic vertical scaling mode is not None.

   Type identifier: *Float (0x512a166f, 0x5c3ef83f)*

   Default value: [*5*]

4. **Vertical Scale**

   Vertical (y) scale for each channel when automatic vertical scaling mode is None.

   Type identifier: *Float (0x512a166f, 0x5c3ef83f)*

   Default value: [*100*]

5. **Vertical Offset**

   Vertical (y) offset for each channel when automatic vertical scaling mode is None.

Type identifier: *Float (0x512a166f, 0x5c3ef83f)*

Default value: [*0*]

6. **Time Scale**

Size of time window to display, in seconds.

Type identifier: *Float (0x512a166f, 0x5c3ef83f)*

Default value: [*10*]

7. **Multiview**

This mode displays several signals on top of each other. It is sometimes called a 'butterfly plot'.

Type identifier: *Boolean (0x2cdb2f0b, 0x12f231ea)*Default value: [*false*]

- **Temporal filter**

The user can choose among a variety of filter types to process the signalThis plugin as shown in fig 6.21, is used to filter the input signal. This plugin allows the selection of the kind of filter (Butterworth or Chebyshev), the kind of filter (low pass, high pass, band pass, band stop), the low or/and the high passband edge and the passband ripple for the Chebyshev filter.

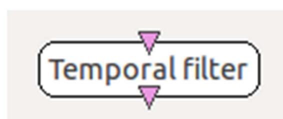


Fig 6.21: CSV File Writer Box

- **Matrix display**

The streamed matrix can be visualized using a table of values and/or a colourgradient. This box displays an input matrix in a table of gradient-coloured squares. The colour gradient is centered (50%) at the value 0. The limits of colours match the minimum and maximum values, ever received or in real time if the corresponding setting is set. These values can evolve symmetrically, using the maximum absolute value.

Fig 6.22: CSV File Writer Box

6.2.11 Scenarios Created in OpenVibe

- Design Algorithm for acquiring real time EEG waves from Neurosky headset

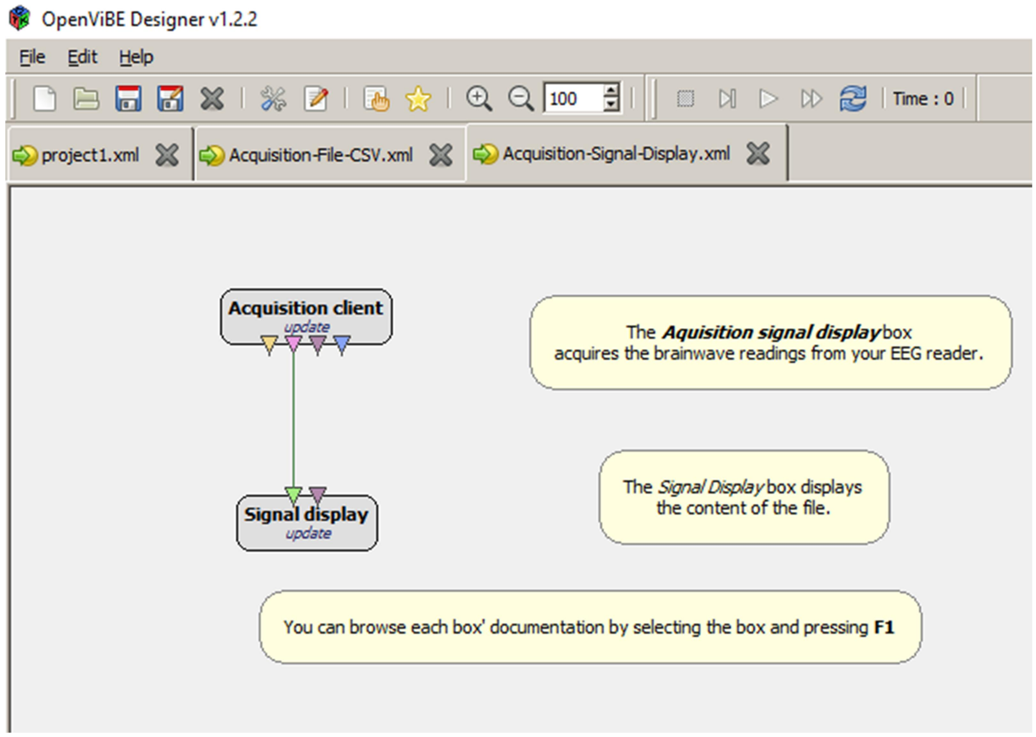


Fig 6.23 The Acquisition Client box from where the signals are displayed using Signal Display Box Documentation

- Design algorithm for generating a .csv file from the above available real time data.

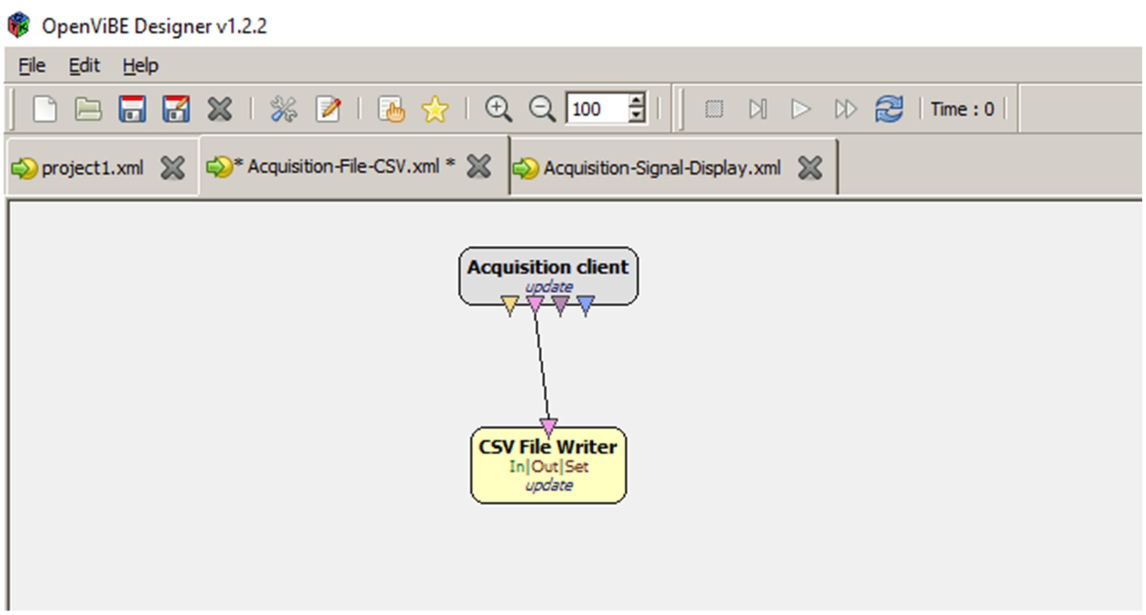


Fig 6.24: Design algorithm for generating a .csv file from the above available real time data.

➤ Design algorithm for generating a .csv file from the above available real time data.

- Simple DSP block as shown in fig 6.25 computes the unfiltered signal to produce a filtered signal. This plugin is used to apply a mathematical formula to each sample of an incoming signal and output the resulting signal. It thus acts as a simple DSP.

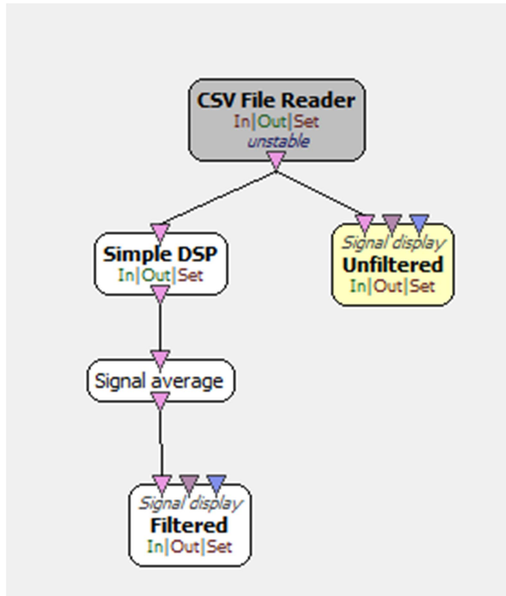


Fig 6.25: Scenario created on OpenVibe to filter the noise from the signal using a simple DSP box documentation.

- Simulation Result Obtained using a simple DSP scenario

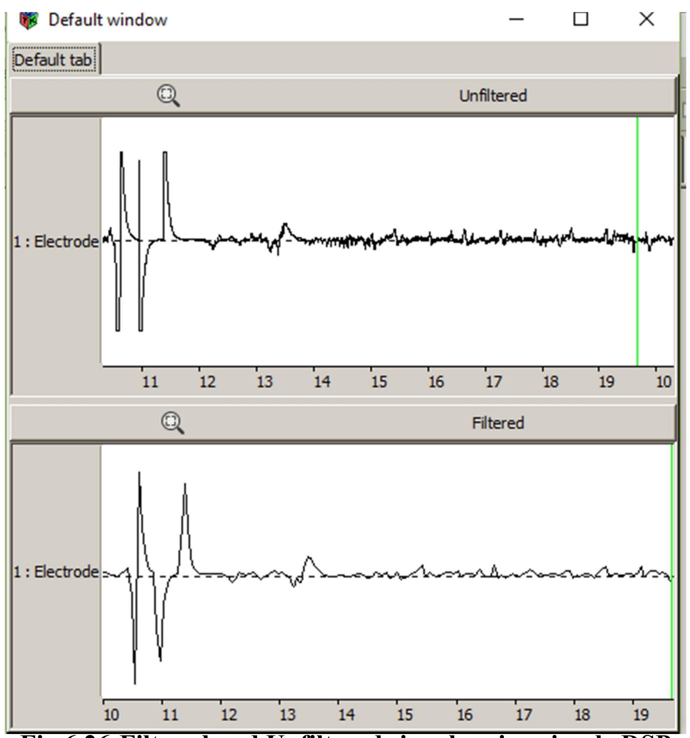


Fig 6.26:Filtered and Unfiltered signals using simple DSP

* Temporal filter plugin as shown in fig 6.27 is used to filter the input signal.

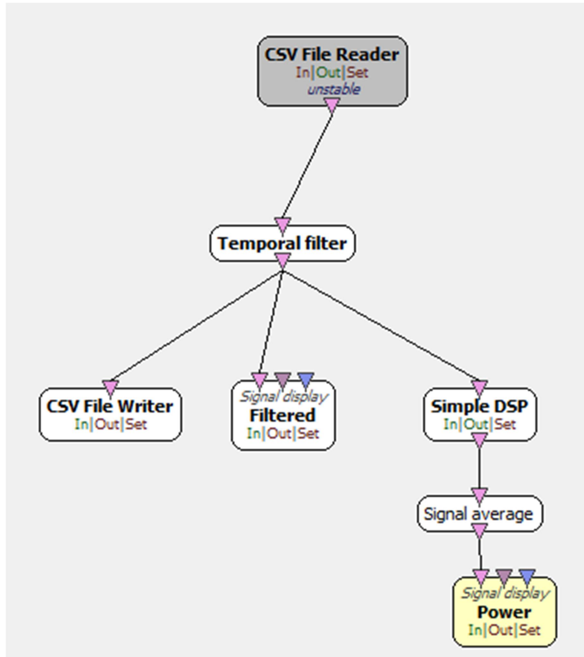


Fig 6.27 : Scenario created on OpenVibe to filter the noise from the signal using the temporal filter by defining the filter order N.

This plugin allows the selection of the kind of filter (Butterworth or Chebychev), the kind of filter (low pass, high pass, band pass, band stop), the low or/and the high passband edge and the passband ripple for the Chebychev filter.

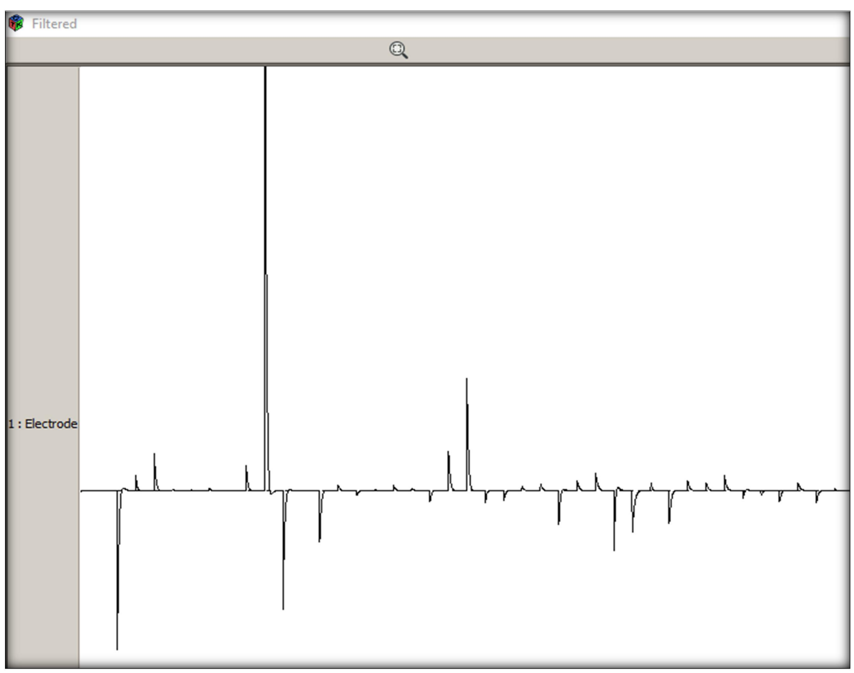


Fig 6.28: Blink Spikes obtained using temporal filter

Simulation Result Obtained using a temporal filter scenario

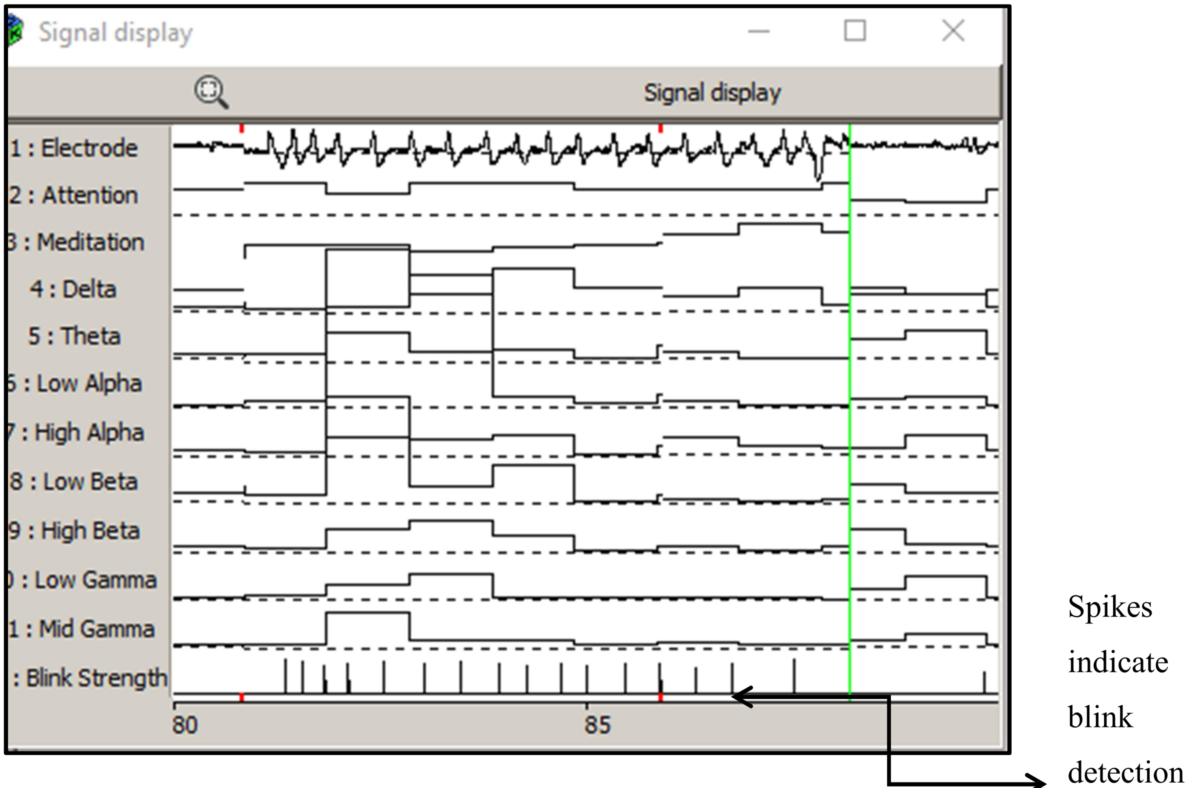


Fig 6.29 Signal Display

6.3PySerial COMMUNICATION

Fig 6.30 Pyserial Communication

PySerial module encapsulates the access for the serial port. It provides back ends for Python running on Windows, OSX, Linux, BSD (possibly any POSIX compliant system) and Iron Python. The module named “serial” automatically selects the appropriate backend.

1) Features

- Same class based interface on all supported platforms.
- Access to the port settings through Python properties.
- Support for different byte sizes, stop bits, parity and flow control with RTS/CTS and/or Xon/Xoff.
- Working with or without receive timeout.
- File like API with "read" and "write" ("read line" etc. also supported).
- The files in the pyserial package are 100% pure Python.
- The port is set up for binary transmission. No NULL byte stripping, CR-LF translation etc. (which are many times enabled for POSIX.) This makes this module universally useful.
- Compatible with I/O library
- RFC 2217 client (experimental), server provided in the examples.

2) Requirements

- Python 2.7 or newer, including Python 3.4 and newer
- "Java Communications" (JavaComm) or compatible extension for Java/Python

3) Installation

- This installs a package that can be used from Python (import serial).
  To install for all users on the system, administrator rights (root) may be required.

4) Commands for Installing Pyserial

pySerial can be installed from PyPI, either manually downloading the files and installing as described below or using:

```
pip install pyserial
```

or

```
easy_install -U pyserial
```

5) Opening Serial Ports

Open port at “9600,8,N,1”, no timeout:

```
>>>importserial
>>>ser=serial.Serial('/dev/ttyUSB0')# open serial port
>>>print(ser.name)# check which port was really used
>>>ser.write(b'hello')# write a string
>>>ser.close()# close port
```

Open named port at “19200,8,N,1”, 1s timeout:

```
>>>withserial.Serial('/dev/ttyS1',19200,timeout=1)asser:
      ... x=ser.read()# read one byte
      ... s=ser.read(10)# read up to ten bytes (timeout)
      ... line=ser.readline()# read a '\n' terminated line
```

6) Configuring Ports

Get a Serial instance and configure/open it later:

```
>>>ser=serial.Serial()
>>>ser.baudrate=19200
>>>ser.port='COM1'
>>>ser
>>>ser.open()
>>>ser.is_open
      True
>>>ser.close()
>>>ser.is_open
      False
```

```
Serial<id=0xa81c10, open=False>(port='COM1',
baudrate=19200,bytesize=8, parity='N', stopbits=1, timeout=None,
xonxoff=0, rtscts=0)
```

6.4 Telnet Communication

Telnet and NeuroSky

Mindstream is a simple java-based system tray app that streams EEG brainwave data from NeuroSky devices (MindWave,MindSet). This is being interfaced toNeuroSky devices using theThinkGear Socket protocol (connecting on localhost:13854).Hence this retrieves data in JSON Format, and can "stream" to other applications. The following data can be obtained:

- Focus levels - attention – meditation
- EEG values - delta - theta - low Alpha - high Alpha - low Beta - high Beta - low Gamma - high Gamma -blink Strength
- Headset signal strength - poorSignalLevel Streaming functions
- Saving EEG data to a CSV File
- Listen on a socket and replay data from localhost:13854 - allowing other applications to connect. This localhost establishes connection between Neurosky and Telnet Protocol.
- Broadcast to a URL - supporting POST/M-POST and streaming real-time data.

Using Telnet in Python

To make use of Telnet in Python, we can use the telnetlib module.

This module provides a Telnet class that implements the Telnet protocol.

The Telnet module have several methods such as

tn.write('{"enableRawOutput": true, "format": "Json"}');

JSON Format

JSON (JavaScript Object Notation) is a lightweight format that is used for data interchanging. It is based on a subset of JavaScript language (the way objects are built in JavaScript). The json library can parse JSON from strings or files. The library parses JSON into a Python dictionary or list. It can also convert Python dictionaries or lists into JSON strings.

Format Used

- json loads -> returns an object from a string representing a json object.
- json dumps -> returns a string representing a json object from an object.
- load and dump -> read/write from/to file instead of string

JSON is built on two structures:

- A collection of name/value pairs. In various languages, this is realized as an object, record, struct, dictionary, hash table, keyed list, or associative array
- An ordered list of values. In most languages, this is realized as an array, vector, list, or sequence.

The telnetlib module provides a Telnet class that implements the Telnet protocol. In addition, it provides symbolic constants for the protocol characters and for the telnet options. The symbolic names of the telnet options follow the definitions in arpa/telnet.h, with the leading TELOPT_ removed. For symbolic names of options which are traditionally not included in arpa/telnet.h, see the module source itself.

The symbolic constants for the telnet commands are: IAC, DONT, DO, WONT, WILL, SE (Subnegotiation End), NOP (No Operation), DM (Data Mark), BRK (Break), IP (Interrupt process), AO (Abort output), AYT (Are You There), EC (Erase Character), EL (Erase Line), GA (Go Ahead), SB (Subnegotiation Begin).

class telnetlib.Telnet([host[, port[, timeout]]])

- Telnet represents a connection to a Telnet server. The instance is initially not connected by default; the open () method must be used to establish a connection. Alternatively, the host name and optional port number can be passed to the constructor, to, in which case the connection to the server will be established before the constructor returns. The optional timeout parameter specifies a timeout in seconds for blocking operations like the connection attempt (if not specified, the global default timeout setting will be used).

This class has many read_*() methods. Some of them raise EOFError when the end of the connection is read, because they can return an empty string for other reasons.

CHAPTER 7

CHAPTER 7

ELECTRONIC DESIGN

In this chapter the different hardware components used in the system configuration are discussed. Here the Teensy microcontroller is explained in detail. The commands from the microcontroller which are further passed to the dual H-bridge motor drivers (L293D) are discussed. Also, the concept of DC motor is mentioned here which is used to driver the different the moving robotic gripper according to the DOF.

7.1 TEENSY

Teensy 3.0 is a small, breadboard-friendly development board designed by Paul Stoffregen and PJRC. Teensy 3.0 is low-cost,32-bit ARM Cortex-M4 platform.Teensy 3.0 aims to greatly increase the computing capability and peripheral features, but maintain the same easy-to-use platform.Teensy 3.0 boards have a black solder mask, instead of green. The board size is 1.4 by 0.7 inch (~3.5 by 1.8 cm).

7.1.1 FEATURES

- 32-bit ARM Cortex-M4 48 MHz CPU (M4 = DSP extensions)
- 128K Flash Memory, 16K RAM, 2K EEPROM
- 14 High Resolution Analog Inputs (13 bits usable, 16-bit hardware)
- 34 Digital I/O Pins (10 shared with analog)
- 10 PWM outputs
- 7 Timers for intervals/delays, separate from PWM
- USB with dedicated DMA memory transfers
- 3 UARTs (serial ports)
- SPI, I2C, I2S, IR modulator
- I2S (for high quality audio interface)

- Real Time Clock (with user-added 32.768 crystal and battery)
- 4 general purpose DMA channels (separate from USB)
- Touch Sensor Inputs

The chip has a 16-bit A/D converter, for much better analog input resolution. There is an I2S interface, which can be used to connect CD quality audio input and output. On top of 10 PWM capable pins, the chip features 4 interval timers and 4 delay timers which do not conflict with the PWM channels, which opens the possibility of libraries which achieve their special timing features without disabling the PWM pinsThe USB port features dedicated DMA (direct memory access). There are also 4 other DMA channels which can be used by the other peripherals, to allow fast data transfer without taxing the CPU.

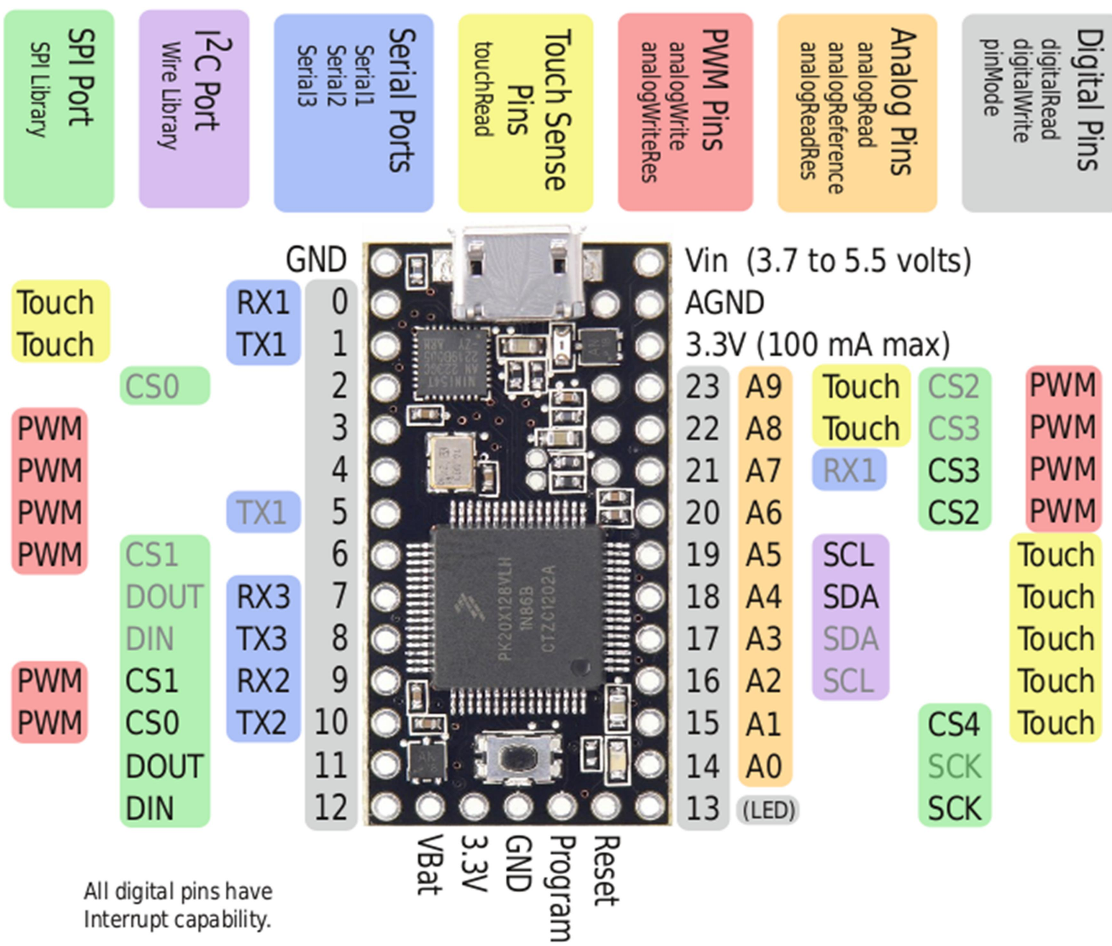


Fig 7.1 Teensy Pinout Diagram-Top View

As a stand-alone platform, or together with a laptop or Raspberry Pi (where Teensy 3.0 handles timing critical I/O and analog signals), Teensy 3.0 is intended to enable all sorts of electronic projects, with exceptional ease-of-use, and at a very affordable price.

Teensyduino is a platform to support on Arduino interface.It supports Windows, Macintosh and Linux. Teensyduino will provide a USB stack which leverages DMA feature to allow better USB utilization.

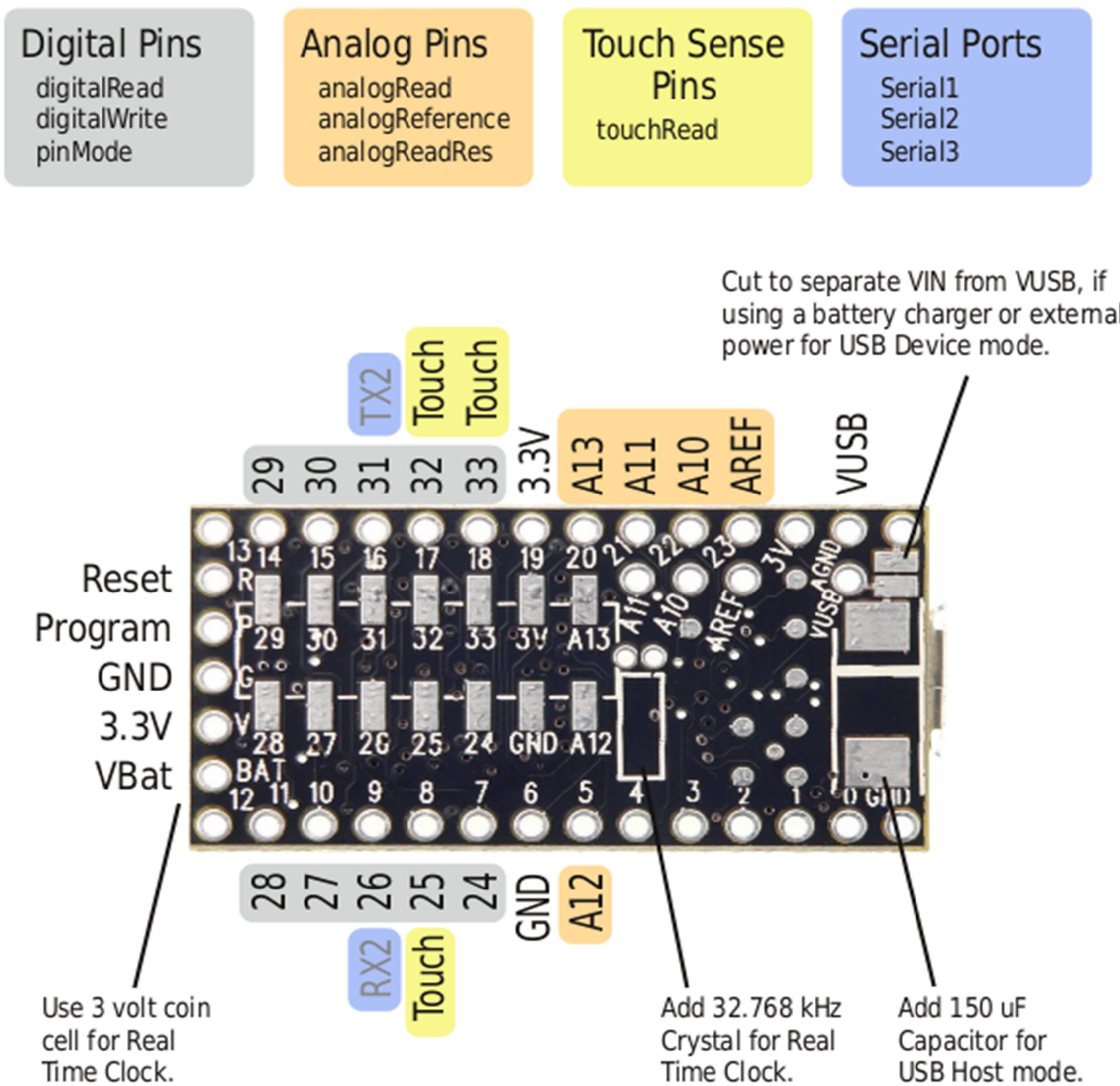


Fig 7.2 Teensy Pinout Diagram-Back View

7.1.2 SCHEMATIC DIAGRAM OF TEENSY3.0

A pair of pads are linked to join VUSB to VIN. For applications where external power is needed, these pads may be cut apart to isolate the board's VIN power from VUSB.

A 32.768 kHz crystal (shown in grey) may be added to support the real-time clock feature. A 100 uF capacitor (shown in grey) may be added for USB host applications, where power applied at VUSB or VIN is not capable of supplying inrush current to USB devices.

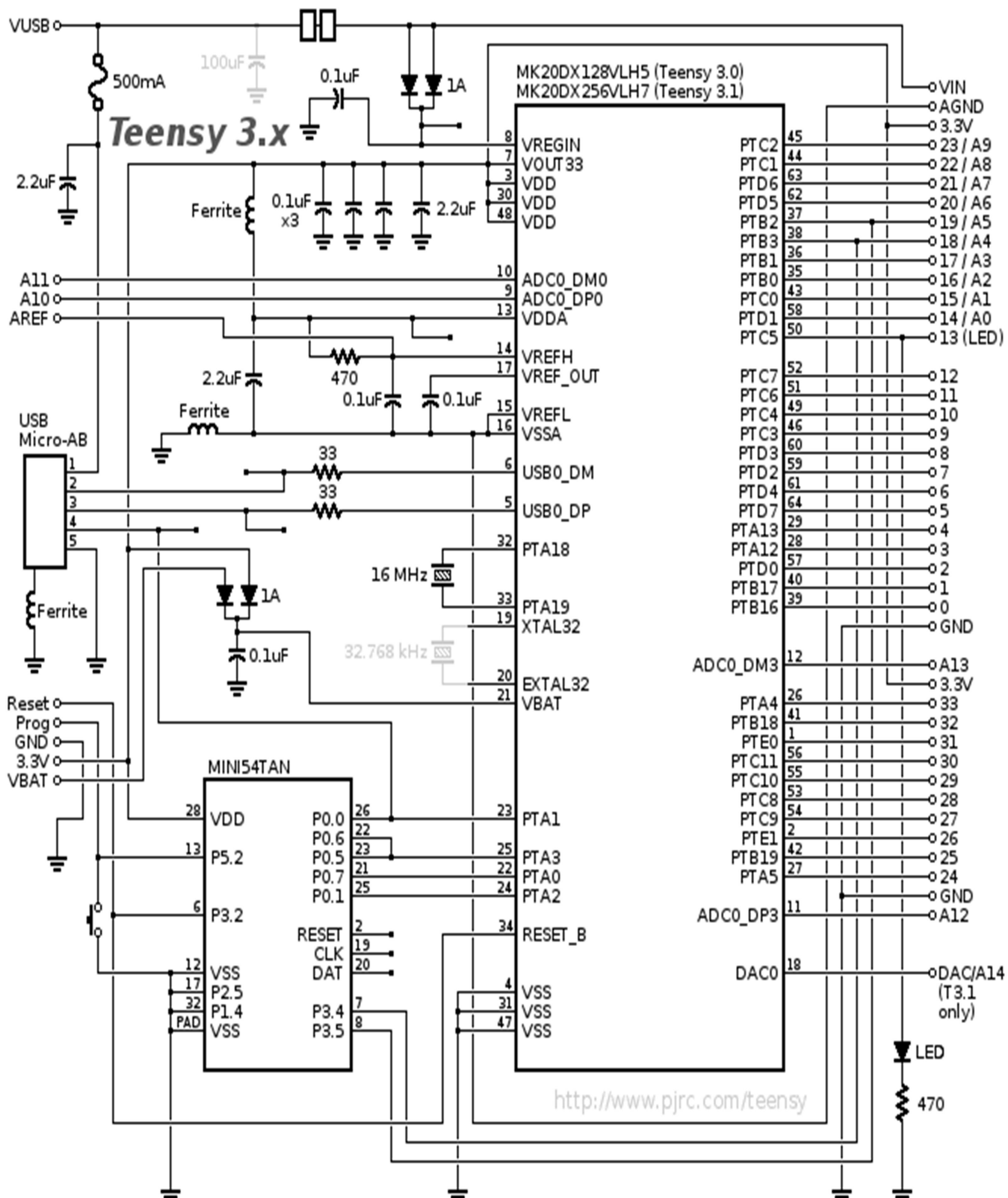


Fig 7.3 Teensy Schematic Diagram

7.1.3 ARM CORTEX M4 CONFIGURATION

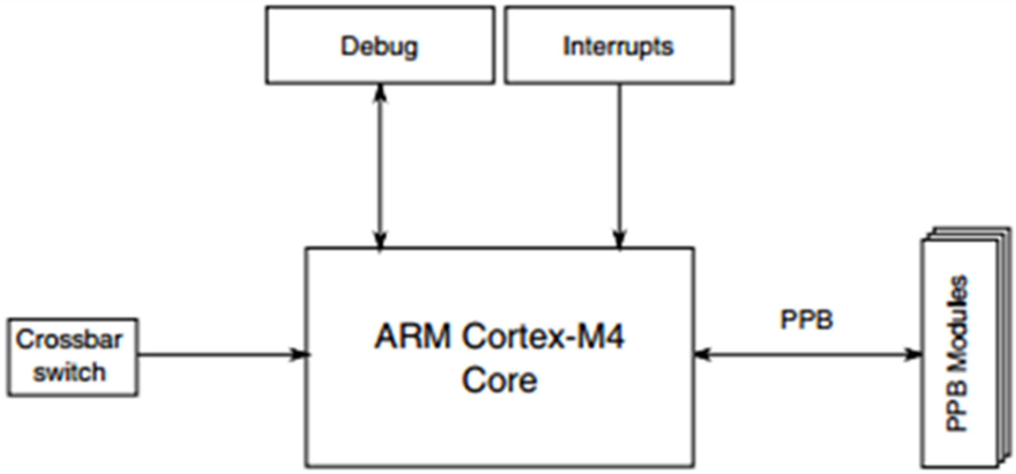


Fig 7.4 Core configuration

- MK20DX128VLH5 is used here.
- Belongs to K20 Sub-Family

7.1.4 BUSES AND SYSTIC TIMER

The ARM Cortex-M4 core has four buses as described in the following table.

Bus name	Description
Instruction code (ICODE) bus	The ICODE and DCODE buses are muxed. This muxed bus is called the CODE bus and is connected to the crossbar switch via a single master port.
Data code (DCODE) bus	
System bus	The system bus is connected to a separate master port on the crossbar.
Private peripheral (PPB) bus	The PPB provides access to these modules: • ARM modules such as the NVIC, ITM, DWT, FBP, and ROM table • Freescale Miscellaneous Control Module (MCM)

Fig 7.5 Types of Buses

System Tick Timer

The System Tick Timer's clock source is always the core clock, FCLK. The CLKSOURCE bit in SysTick Control and Status register is always set to select the core clock. Because the timing reference (FCLK) is a variable frequency, the TENMS bit in the SysTick Calibration

Value Register is always zero.The NOREF bit in SysTick Calibration Value Register is always set, implying that FCLK is the only available source of reference timing.

7.1.5 AVAILABLE PROTOCOLS

Wake-up source	Description
Available system resets	$\overline{\text{RESET}}$ pin and WDOG when LPO is its clock source, and JTAG
Low-voltage detect	Mode Controller
Low-voltage warning	Mode Controller
Pin interrupts	Port Control Module - Any enabled pin interrupt is capable of waking the system
ADCx	The ADC is functional when using internal clock source
CMPx	Since no system clocks are available, functionality is limited
I^2C	Address match wakeup
UART	Active edge on RXD
USB	Wakeup
LPTMR	Functional in Stop/VLPS modes
RTC	Functional in Stop/VLPS modes
I2S	Functional when using an external bit clock or external master clock
TSI	

Fig 7.6 Protocols

7.2 DC Motor

A DC motor is a class of rotary electrical machines that converts Direct Current (DC) i.e. electrical energy into mechanical energy. The most common types rely on the forces produced by magnetic fields. Nearly all types of DC motors have some internal mechanism, either electromechanical or electronic, to periodically change the direction of current flow in part of the motor.

DC motors were the first type widely used, since they could be powered from existing direct-current lighting power distribution systems. A DC motor's speed can be controlled over a wide range, using either a variable supply voltage or by changing the strength of current in its field windings. Small DC motors are used in tools, toys, and appliances. The universal motor can operate on direct current but is a lightweight motor used for portable power tools and appliances. Larger DC motors are used in propulsion of electric vehicles, elevator and hoists,or in drives for steel rolling mills. The advent of power electronics has made replacement of DC motors with AC motors possible in many applications. We are using 4 DC motors in our project to drive the robot

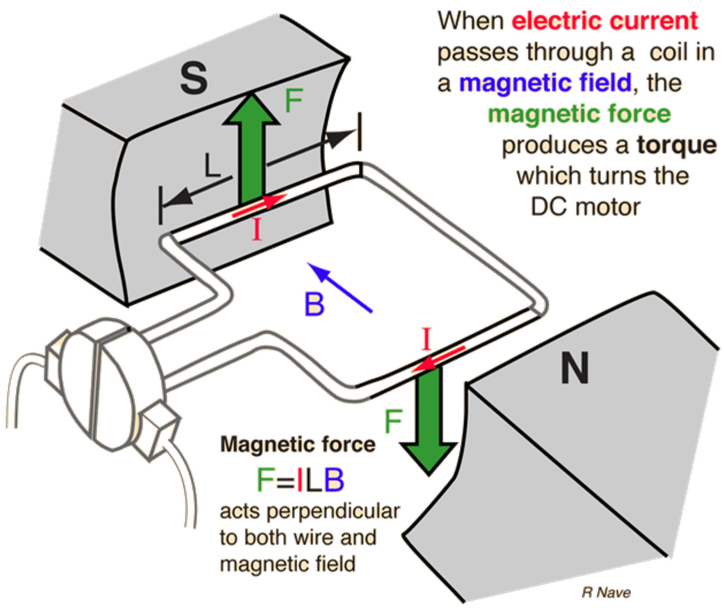


Fig 7.7 Working of DC Motor

7.3 L293D MOTOR DRIVER

L293D chip from Texas Instruments is used to drive inductive loads such as relays, solenoids, DC and bipolar stepping motors, as well as other high-current/high-voltage loads in positive-supply applications. Motor driver ICs act as an interface between microprocessors in robots and the motors in the robot. The most commonly used motor driver IC's are from the L293 series such as L293D, L293NE, etc. These ICs are designed to control 2 DC motors simultaneously. The "D" version is chosen because it has built in fly back diodes to minimize inductive voltage spikes.

Motor Driver ICs are primarily used in autonomous robotics only. Also, most microprocessors operate at low voltages and require a small amount of current to operate while the motors require a relatively higher voltage and current.Thus, current cannot be supplied to the motors from the microprocessor. This is the primary need for the motor driver IC.

L293D is a 16-pin IC which can control a set of two DC motors simultaneously in any direction. It contains two output ports& one 12V input port. This board needs 3 input lines from microcontroller for each DC motor. One line for enable/disable, other 2 lines for set the direction (Clockwise/Anti-clockwise) of motor. These lines relate to microcontroller using jumper wires. This board also provide 5V output. Using L293 Breakout Board, DC motor can be controlled easily.

The L293D can control 4 inductive loads with currents up to 600mA. By connecting the L293D breakout board to a microcontroller and connecting a motor in a bridge configuration (using 2 drivers per motor) we can control motor direction via the chip's driver enable signals and motor speed by applying a PWM signal to the driver inputs.

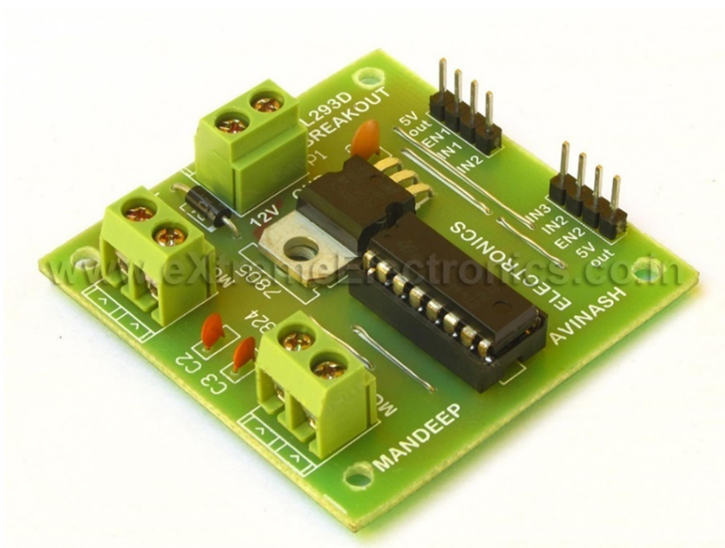


Fig 7.8 L293D Breakout Board

7.3.1. FEATURES

- Screw Connectors for motor interface
- Interface 2 motors
- Compatible with any microcontroller
- Compatible with 28 & 40 pin development board
- 5 V output
- Input 12 V For motor
- Ground Pins – 4 ,Input Pins – 4, Output Pins – 4, Enable pins - 2, Voltage Pins – 2

7.3.2 WORKING

The L293D IC receives signals from the microprocessor and transmits the relative signal to the motors. It has two voltage pins, one of which is used to draw current for the working of the L293D and the other is used to supply voltage to the motors. The L293D switches it output signal perthe input received from the microprocessor.

For Example: If the microprocessor sends a 1(digital high) to the Input Pin of L293D, then the L293D transmits a 1(digital high) to the motor from its Output Pin. An important thing to note is that the L293D simply transmits the signal it receives. It does not change the signal in any case.

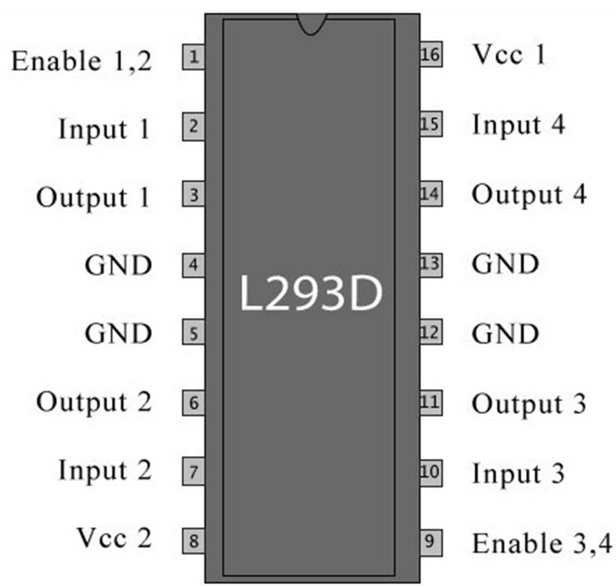


Fig 7.9 L293D Pin diagram

Pin No.	Pin Characteristics
1	Enable 1-2, when this is HIGH the left part of the IC will work and when it is low the left part won't work. So, this is the Master Control pin for the left part of IC
2	INPUT 1, when this pin is HIGH the current will flow though output 1
3	OUTPUT 1, this pin should be connected to one of the terminal of motor
4,5	GND, ground pins
6	OUTPUT 2, this pin should be connected to one of the terminal of motor
7	INPUT 2, when this pin is HIGH the current will flow though output 2
8	VC, this is the voltage which will be supplied to the motor. So, if you are driving 12 V DC motors then make sure that this pin is supplied with 12 V
16	VSS, this is the power source to the IC. So, this pin should be supplied with 5 V
15	INPUT 4, when this pin is HIGH the current will flow though output 4
14	OUTPUT 4, this pin should be connected to one of the terminal of motor
13,12	GND, ground pins
11	OUTPUT 3, this pin should be connected to one of the terminal of motor
10	INPUT 3, when this pin is HIGH the current will flow though output 3
9	Enable 3-4, when this is HIGH the right part of the IC will work and when it is low the right part won't work. So, this is the Master Control pin for the right part of IC

Table 7.1: Pin Specifications

The L293D is a 16 pin IC, with eight pins, on each side, dedicated to the controlling of a motor. There are 2 INPUT pins, 2 OUTPUT pins and 1 ENABLE pin for each motor. L293D consist of two H-bridge, which can rotate two DC motor independently. H-bridge is the simplest circuit for controlling a low current rated motor. It allows the voltage to flow in either direction. The voltage needs to change its direction for being able to rotate the motor in clockwise or anticlockwise direction, Hence H-bridge ICs are ideal for driving a DC motor. Due its size it is very much used in robotic application for controlling DC motors.

Pin 1 and pin 9 are enable pins, and to drive the motorneed to be high. For driving the motor with left H-bridge we need to enable pin 1 to high. And for right H-Bridge we need to make the pin 9 to high. If anyone of the either pin1 or pin9 goes low, then the motor in the corresponding section will suspend working. It acts like a switch.

The DC motor is an inductive load. So, it develops a back EMF when supplied by a voltage. There can be fluctuations of voltage which is quite high and this can damage the IC. Thus, we use four capacitors that help to dampen the extreme variation in current.

There are 4 input pins for L293D, pin 2,7 on the left and pin 15 ,10 on the right. Left input pins will regulate the rotation of motor connected across left side and right input for motor on the right-hand side. The motors are rotated based on the inputs provided across the input pins as LOGIC 0 or LOGIC 1. We need to provide Logic 0 or 1 across the input pins for rotating the motor.

7.3.3 LOGIC TABLE

Considering a Motor connected on left side output pins (pin 3,6). For rotating the motor in clockwise direction the input pins has to be provided with Logic 1 and Logic 0.

Pin 2 = **Logic 1** and **Pin 7** = **Logic 0** | Clockwise Direction

Pin 2 = **Logic 0** and **Pin 7** = **Logic 1** | Anticlockwise Direction

Pin 2 = **Logic 0** and **Pin 7** = **Logic 0** | Idle [No rotation]

Pin 2 = **Logic 1** and **Pin 7** = **Logic 1** | Idle [No rotation]

Similarly, the motor can also operate across input pin 15,10 for motor on the right-hand side.

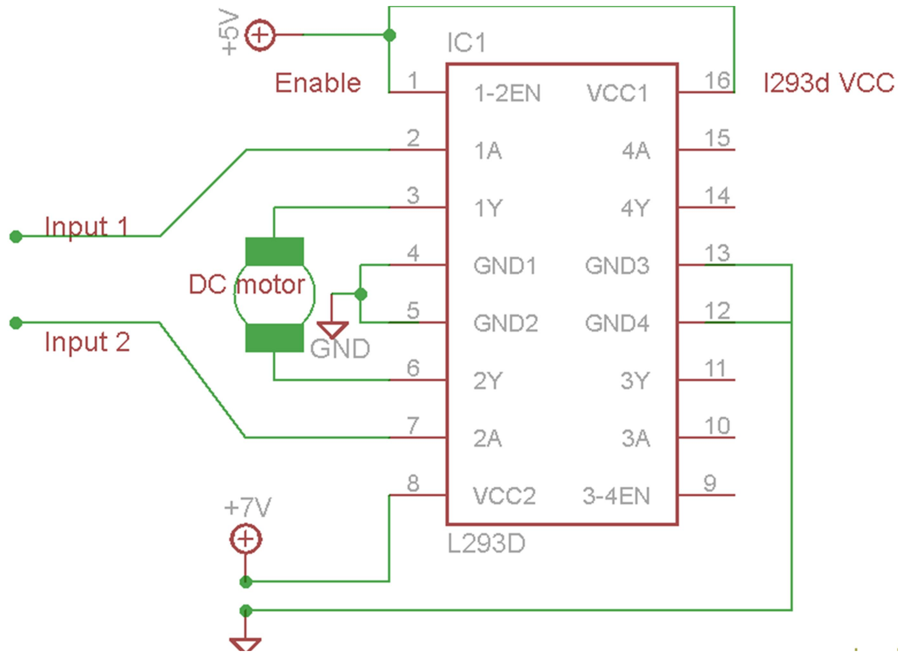


Fig 7.10 Typical connection of Single Motor

Depending upon the values of the Input and Enable the motors will rotate in either clockwise or anticlockwise direction with full speed (when Enable is HIGH) or with less speed (when Enable is provided with PWM). Let us assume for Left Motor when Enable is HIGH and Input 1 and Input 2 are HIGH and LOW respectively then the motor will move in clockwise direction. So, the behaviour of the motor depending on the input conditions will be as follow

INPUT 1	INPUT 2	ENABLE 1,2	Result
0	0	1	Stop
0	1	1	Anti-clockwise rotation
1	0	1	Clockwise rotation
1	1	1	Stop
0	1	50% duty cycle	Anti-clockwise rotation with half speed
1	0	50% duty cycle	Clockwise rotation with half speed

Table 7.2: Logic Level

7.3.4 VOLTAGE SPECIFICATION

L293D will not use VCC voltage for driving the motor. For driving the motors, it has a separate provision to provide motor supply VSS (V supply). L293D will use this to drive the motor. It means that to operate a motor we need to provide a supply of 9V/12V across VSS Motor supply.

The maximum voltage for VSS motor supply is 36V. It can supply a max current of 600mA per channel.Since it can drive motors up to 36V hence we can drive big motors pin 16 is the voltage for its own internal Operation. The maximum voltage ranges from 5V and up to 36V.

7.3.5 WORKING OF A H-BRIDGE

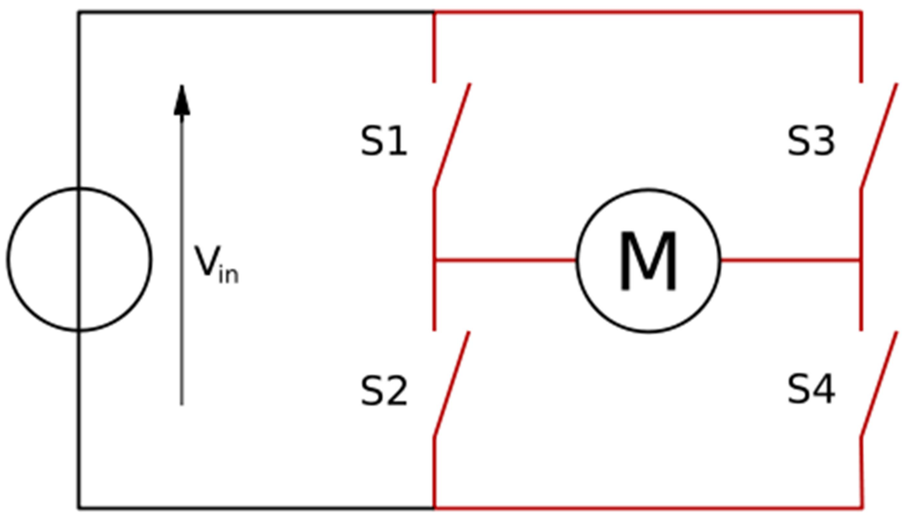


Fig 7.11 Basic Diagram of H-bridge

H-bridges can be built from scratch with bi-polar junction transistors (BJT) or with field effect transistors (FET), or can be purchased as an integrated unit in a single integrated circuit package such as the L293. H-bridge is given this name because it can be modelled as four switches on the corners of 'H'.

In the given diagram, the arrow on the left points to the higher potential side of the input voltage of the circuit. Now if the switches S1 & S4 are kept in a closed position while the switches S2 & S3 are kept in open position meaning that the circuit gets shorted across the switches S1 & S4. This creates a path for the current to flow, starting from the V input to switch S1 to the motor, then to switch S4 and then the exiting from the circuit. This flow of the current would make the motor turn in one direction. The direction of motion of the motor can be clockwise or anti-clockwise, this is because the rotation of the motor depends upon the connection of the terminals of the motor with the switches. For simplicity, let's assume that in this condition the motor rotates in a clockwise direction. Now, when S3 and S2 are closed then and S1 and S4 are kept open then the current flows from the other direction and the motor rotates in counter-clockwise direction When S1 and S3 are closed and S2 and S4 are open then the 'STALL' condition will occur (The motor will break). When the motor is applied positive voltage on both sides then the voltage from both the sides brings the motor shaft to a halt.

7.4PICK AND PLACE SYSTEM

Patients suffering from motor neuron diseases are unable to move and are in "locked-in" state. In such case a pick and place robot comes very handy and helps them to interact with the external world more effectively. Pick and place robots take product from one location to another with high accuracy. It can be a cylindrical robot providing movement in horizontal, vertical and rotational axes, a spherical robot providing two rotational and one linear movement, an articulate robot. These robots can provide increased efficiency and get things done sitting in one place.

7.4 .1 DEGREES OF FREEDOM (DOF)

In general,robotic arms are described by their degrees of freedom. This number typically refers to the number of single-axis rotational joints in the arm, where higher number indicates an increased flexibility in positioning a tool.Degrees of freedom, in a mechanics context, are specific, defined modes in which a mechanical device or a system can move. The number of degrees of freedom is equal to the total number of independent displacements or aspects of motion. The term is widely used to define the motion capabilities of robots.

A degree of freedom also refers to a something's ability to move in a single independent direction of motion. To be able to move in multiple directions means to have multiple degrees of freedom. Moving up & down is one degree of freedom, moving right & left is another; something that can move up/down and left/right has two degrees of freedom. In our project, we are mounting a 2DoF robotic arm on a movable base and this is controlled from the brainwave signals in real time.

The first type of degree of freedom is one in which the robot's arm can rotate about an axis parallel to the arm. This degree of freedom is found in the human wrist. One can imagine someone holding a pencil in his or her fist so it is parallel to the floor (horizontal). Now this same person twists his or her wrist such that the pencil is pointed straight up at the ceiling (vertical). This "twisting" is one degree of freedom. This is shown in Fig 7.9

The second type of degree of freedom is linear movement. In this case, a component on a robot can slide in and out (or up and down, or left and right). An elevator represents this linear degree of freedom (moving up and down), as does a common desk drawer (moving in and out). This is shown in Fig 7.10

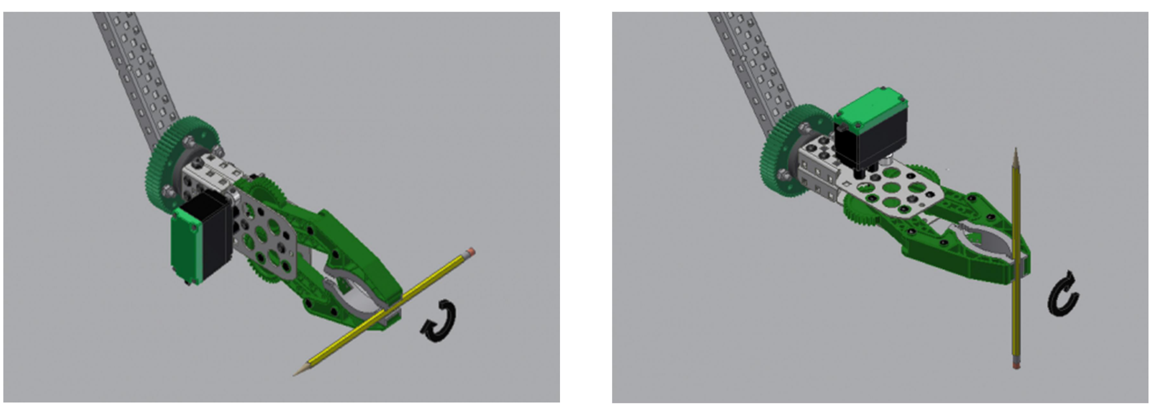


Fig 7.12 Rotation about the axis

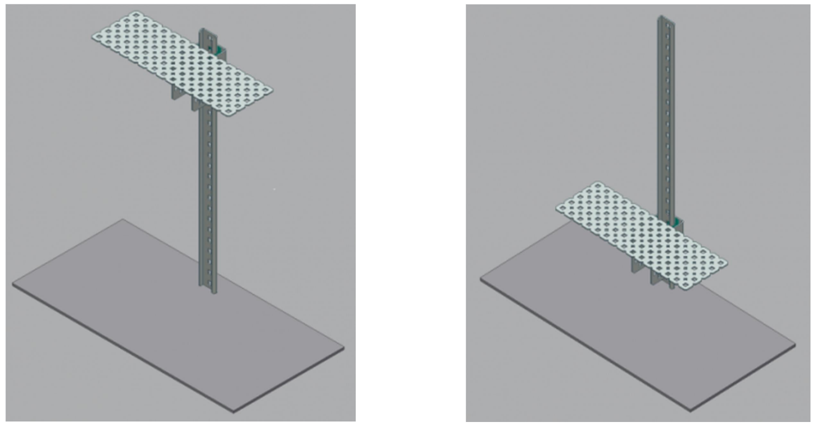


Fig 7.13 Linear Movement

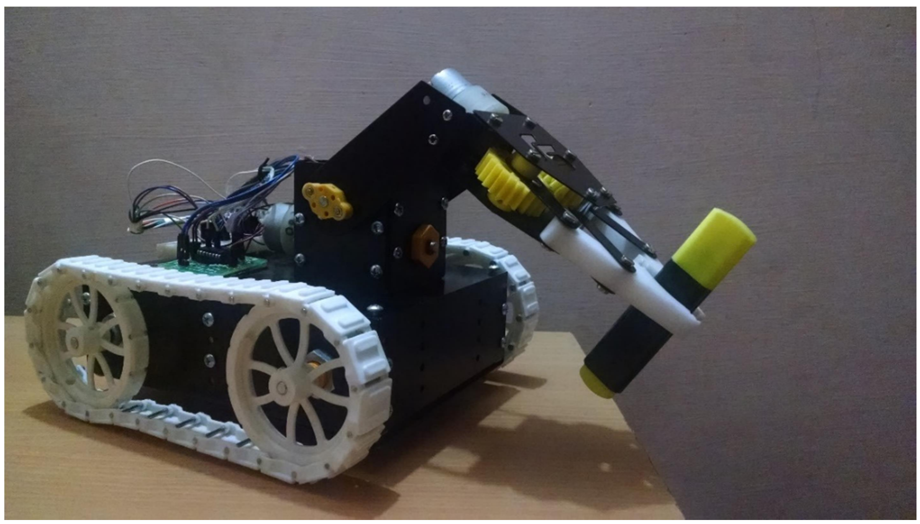


Fig 7.14 Two DoF Pick and Place Robot

Advantages of a pick and place system include:

- They are faster and can get the work done in seconds compared to their human counterparts.
- They are flexible and have the appropriate design and are accurate.

  Practical Applications of Pick and Place Robot:
- Defence Applications: It can be used for surveillance and to pick up harmful objects like bombs and diffuse them safely.
- Industrial Applications: These robots are used in manufacturing, to pick up the required parts and place it in correct position to complete the machinery fixture. It can

be also used to place objects on the conveyer belt as well as pick up defective products from the conveyer belt.

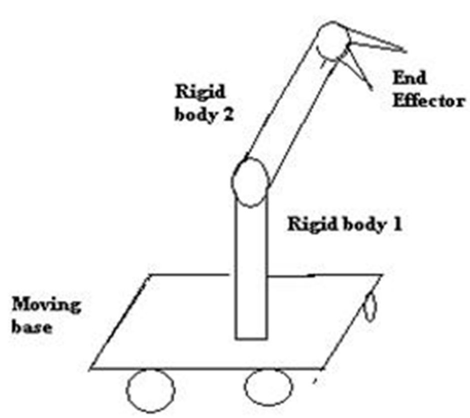
- Medical Applications: These robots can be used in various surgical operations like in joint replacement operations, orthopaedic and internal surgery operations. It performs the operations with more precision and accuracy.

7.4 .2 PARTS OF A PICK AND PLACE ROBOTIC SYSTEM

The basic function of a pick and place robot is done by its joints. Joints are analogous to human joints and are used to join the two consecutive rigid bodies in the robot. They can be rotary joint or linear joint. Degrees of freedom implement the linear and rotational movement of the body which uses 4 wheel all terrain locomotion. This system supports Forward, Reverse, Left and Right Motion. Grippers support Open, Close, Up and Down Movements. Typical parts are:

- **A Rover:** It is the main body of the robot consisting of several rigid bodies like a cylinder or a sphere, joints and links. It is also known as a manipulator.
- **End Effector**: It is the body connected to the last joint of the rover which is used for gripping or handling objects. It can be an analogy to the arm of a human being.
- **Actuators**: They are the drivers of the robot. It actuates the robot. It can be any motor like servo motor, stepper motor or pneumatic or hydraulic cylinders.
- **Sensors**: They are used to sense the internal as well as the external state to make sure the robot functions smoothly as a whole. Sensors involve touch sensors, IR sensor etc.
- **Controller**: It is used to control the actuators based on the sensor feedback and thus control the motion of each joint and eventually the movement of the end effector.

Fig 7.15 Basic Structure



7.4.3 WORKING

A simple pick and place robot consists of two rigid bodies on a moving base, connected with rotary joint and can be controlled by controlling the movement of its end effector. A rotary joint is a one which provides rotation in 360 degrees around any one of the axes. The wheels underneath the base help to move the robot to the desired location. The rigid body supporting the end effector bends or straightens up to reach the position where the object is placed. The end effector picks up the object with a strong grip and places it at the desired position.Although, the appearance and capabilities of robot vary vastly, all robots share the feature of a mechanical, movable structure under some form of control. The control of robot involves three distant phases: perception, processing, action. Generally, the preceptors are sensors mounted on the robot, processing is done by the on-board microcontroller and the task is performed using motors or with some other actuators.Specifications of the system include:

- The bottom or the base is attached with wheels which provide linear movement.
- The 1^{st} rigid body is fixed and supports the second rigid body to which the end effector is provided.
- The 2^{nd} rigid body is provided with movement in all 3 axes and has 3 degrees of freedom. It is connected to the 1^{st}body with a rotational joint.
- The end effector should accommodate all 6 degrees of freedom, to reach all sides of the component, to take up position to any height.

The system consists of two motors for providing motion to the whole robot and two other motors to provide the arm motion. The end effector or the gripper needs to be controlled to apply proper pressure on the object to handle it effectively, to give it a soft grip. This is ensured by controlling the arm motors through proper command. Four high torque DC motors of 12V, 150 rpm rating are used.

At the transmitting end, the brain waves are used to send commands in real time through Python interface, to control the movement of the robot either to move forward, backward and left or right etc. Based on the corresponding blink and attention values, the microcontroller sends the appropriate input signals to the motor drivers to drive the respective motors.

At the receiving end four motors are interfaced to the Teensy microcontroller where two for them are used for arm and gripper movement of the robot while the other two are for the body movement.

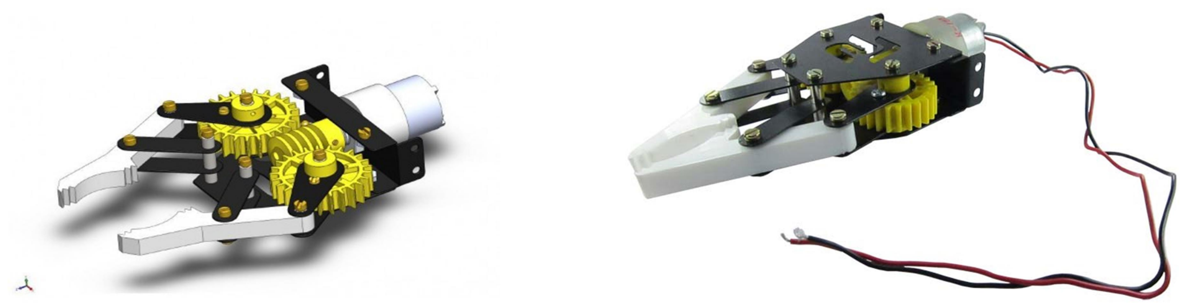


Fig 7.16 Gripper Assembly

The gripper module can be used in various 'pick and place' kind of robots. This is great for "getting a grip" on many robotics projects. The self-locking function of fingers, together with the anti-slippery material added on the inner side of two fingers, protect objects it grips from falling off. It works on DC Motor (9 to 12V DC). Change in rotation direction of the DC Motor, generates Jaw Open & Close Action. The DC motors can be easily be controlled with the help of DPDT Switch (manual mode) or with the help of any microcontroller along with L293D Motor Driver module.Gear box contains a mechanical assembly which uses a worm gear assembly and can lift heavy loads. Implements differential gear mechanism for turning. This system contains an assembly of one worm gear and two spur gears.

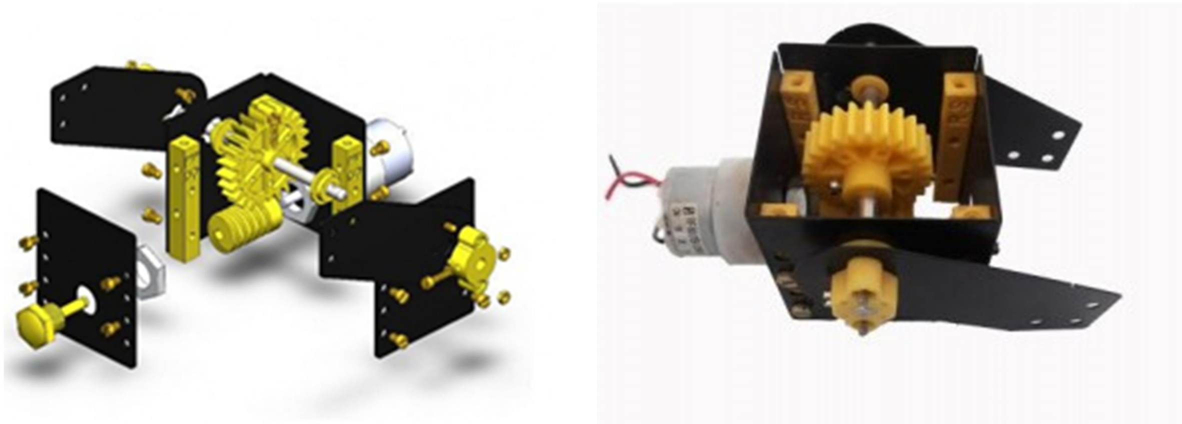


Fig 7.17 Worm and Spur Gear Assembly

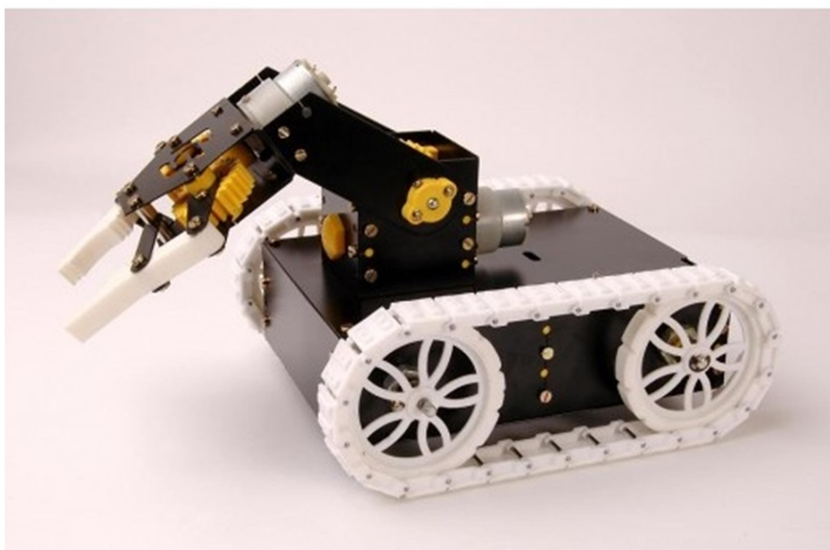


Fig 7.18 Entire Pick and Place Assembly

CHAPTER 8

CHAPTER 8

RESULTS

In this chapter the results obtained are illustrated. The filtering process in MATLAB is also described. The final application, i.e. controlling a prosthetic moving robotic gripper is shown diagrammatically. Further the position of the pick and place robot controlled by the eSense parameters are illustrated in the figures.

8.1 MATLAB Simulation

The CSV file produced from the filtered and unfiltered box scenario are further realized in MATLAB to observe the distinct blink spikes for further processing.

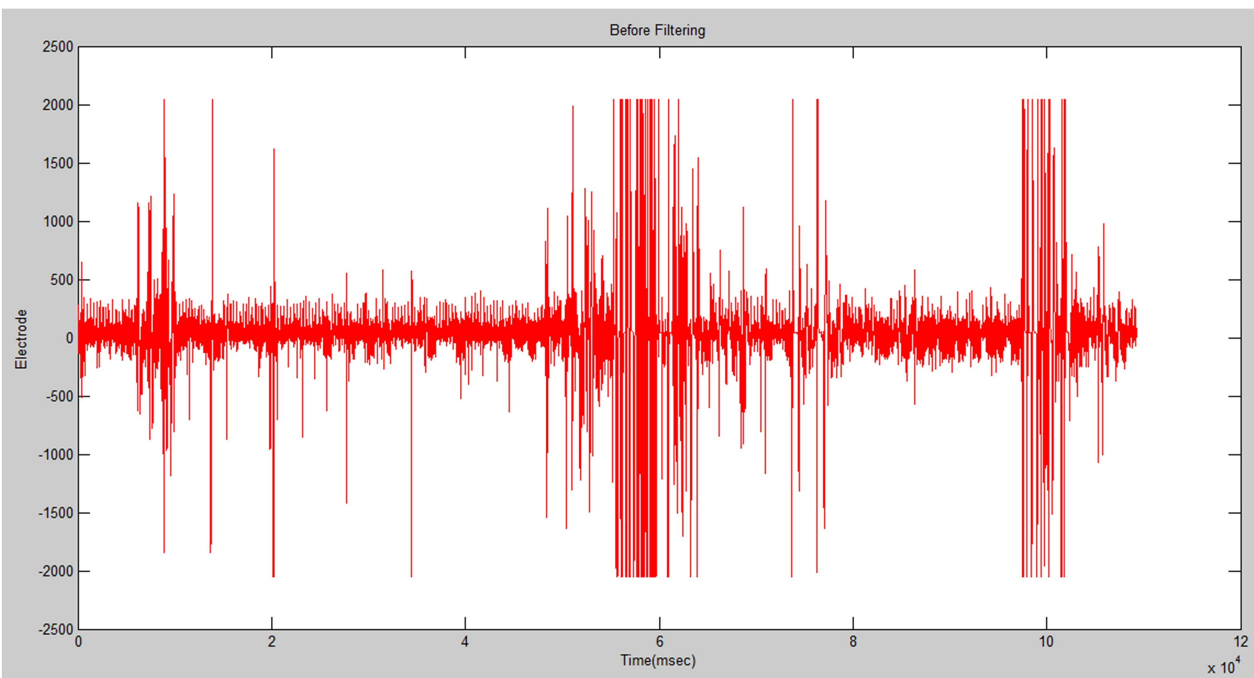


Fig 8.1 Signal generation (distinct blink spikes) obtained before filtering

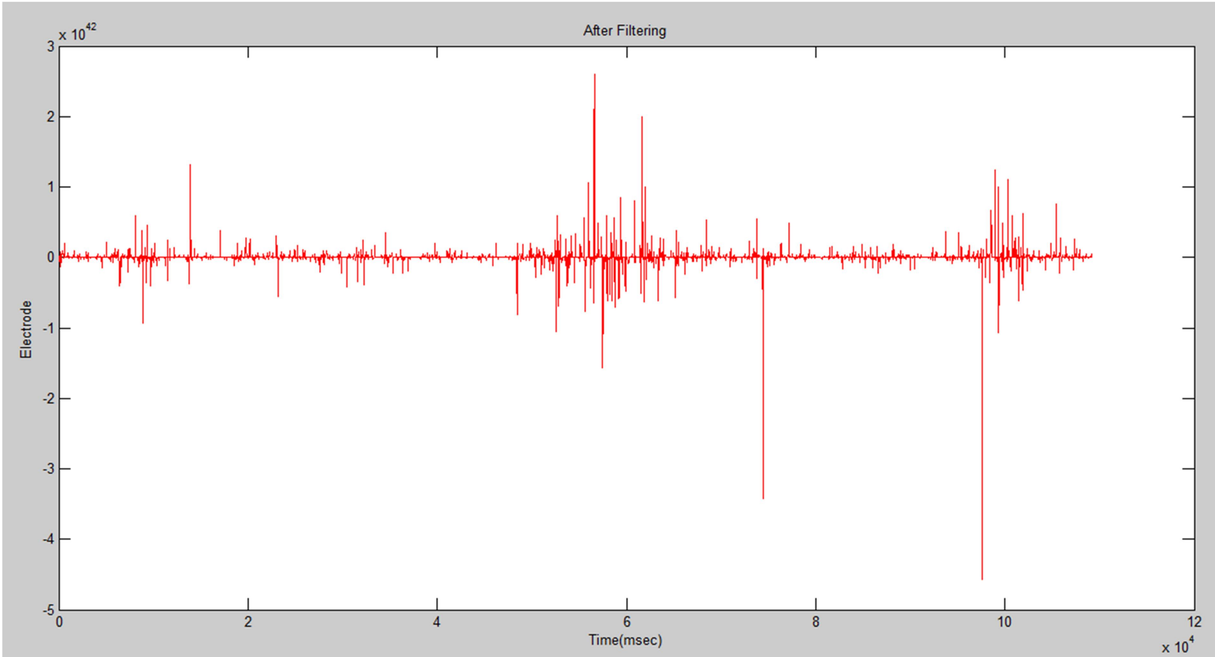


Fig 8.2 Signal generation (distinct blink spikes) obtained after filtering

8.2 Experimental Results

The experimental setup, shown in Fig.8.3 and Fig. 8.4, consists of a cylindrical robotic gripper, providing movement in horizontal and vertical axes. To perform control action, the blink values were acquired and the EEG headset picked up these blinks in real time. A Telnet communication is established between the headset and the python interface; such that data was read in real time on the python shell. The extracted brain signals are recorded in a CSV format and data is exported to python.

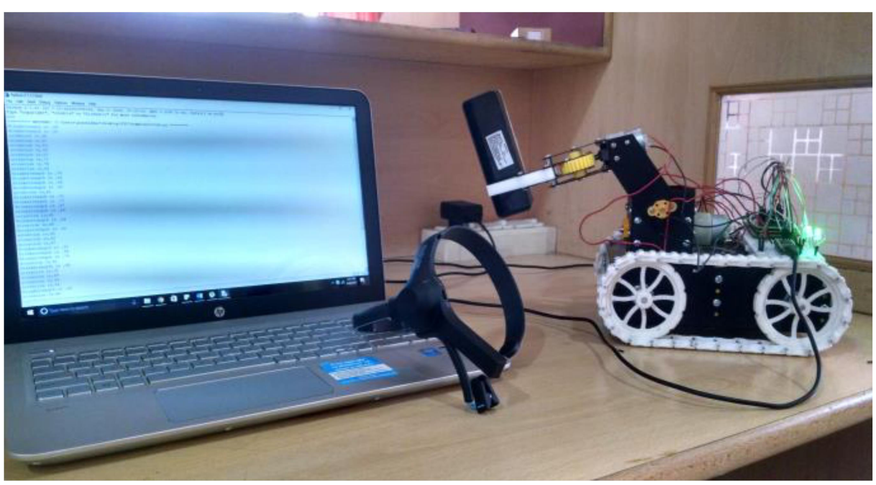


Fig.8.3. Experimental setup showing the robotic gripper picking up the object from position A

These data were further coded in python to drive the motors with the help of Teensy microcontroller and pyserial communication. Depending on the presence of blink values detected, the gripper is observed to perform actions such as picking and placing at the desired location, as guided by the subject using the headset.

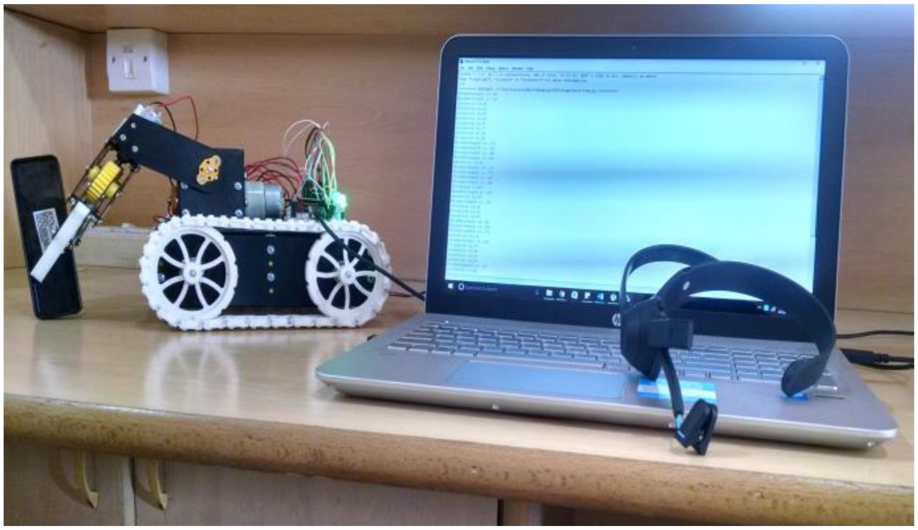


Fig.8.4 Experimental setup showing the robotic gripper moving from position A and placing the object at position B.

CHAPTER 9

CHAPTER 9

CONCLUSION AND FUTURE SCOPE

In this chapter the different challenges encountered during the period of project development are illustrated. Also future work with respect to BCI are incorporated to develop new areas in this domain. Also the different application areas are coverd in this chapter.

9.1 CONCLUSION

This system goes some way towards giving severely paralyzed people some independence. The arm can be controlled intuitively, meaning the person just has to think. Based onattention or blink states the movement of the pick and place system is controlled in real team. Subjects were able to grab objects and place it, using a single channel EEG sensor, at the end of the project. This level of movement was previously only achieved using invasive, multi-channel brain computer interfaces.

The results of controlling robotic arm by brain waves are extremely promising and accurate.It also involves very little risk for people suffering from motor neuron diseases as the technology is non-invasive. Our project blended human motor physiology with engineering to create a BCI guided by attention, meditation and eye movements. The technology also has other potential uses, such as for video games and car safety systems, where it could be used to monitor the driver or provide driver assistance. The project presents a new line of research in robotics and BCI, is not only geared to solve an urgent clinical need, but also opens new possibilities of research into basic questions about motor physiology and brain function and organization.

The main advantage of this robot is its soft catching arm that is designed to avoid extra pressure on the suspected object for safety reasons. Simulation results obtained from Openvibe and Matlab were seen in the first phase of the project. Streaming the real time data in the above mentioned platform was also performed.

We also analysed the different signals like alpha,beta,gamma. Also, the attention and meditation values were plotted and observed in real time Using temporal filtering methods on OpenVibe,noise was reduced to a greater extent.

An interface with python was created to collect and parse the data from the Neurosky headset using Telnet communication. Writing a program to obtain the necessary parameters required in further processing and control, involved varioustrail and error methods. After this process a serial communication using PySerial module between python and microcontroller was created.Later Teensy 3.0 ARMcortex M4 microcontroller interfacing andL293D motor driver was interfaced to perform and control actions in real time.

9.2 CHALLENGES FACED

The Bluetooth transmission rate of the headset is higher when compared to the receiving data rate of the laptop, so there is a delay on the computer while receiving the values from the headset. Eliminating this delay was highly crucial. The brain signals vary from person to person, so initially training of the headset is required. The compatibility of the headset varies from laptop to laptop. The battery consumption is more. The clip which is placed on the ear lobe is considered as a null point as the brain signals are weaker in strength at this position, but in real it is not an ideal ground/null point. Sweating can also alter the impedance at the electrode-scalp interface.

The most important technical challenge was establishing communications with the headset. Brainwaves were plotted and data was recorded on Neuro-Experimenter in real time .UsingOpenViBE different brainwaves, in real time values, like blinking, meditation, attention were plotted and a CSV file was generated which recorded all the brain signal data. Also eliminating as much noise and performing feature extraction of the brain signal with respect to different blink states was another crucial task.

The platform used to extract real time data is Python. This helped to code on the microprocessor according to the brainwave received. ThinkGear Connector being detected on laptop, for the sensor to transmit data was another challenge. Linking the Telnet library to the ThinkGear Socket Protocol to detect the brain waves in real time was another issue.Once the above process was completed,there was a challenge in establishing serial communication with Teensy.Since the real time data obtained is very large , real time data streaming to the microcontroller using pyserial was a tedious process

9.3 FUTURE SCOPE AND APPLICATIONS

Bridging software must be developed to eliminate the delay issues. External filters maybe incorporated to reduce the fluctuations. Transform algorithms can be used to differentiate the artefacts from brain signals. Further the project can be enhanced by interfacing it with a wireless camera so that the person controlling it can view operation of the arm and gripper remotely. Using multiple channels to collect brainwaves gives more distinct and precise signals to control external applications. Here a trade-off must be made between accuracy and filtering process involved to eliminate noise, as brain is an extremely noisy environment.

One of the most exciting area of BCI research is the development of devices that can be controlled by thoughts. Some of the applications of this technology may seem frivolous, such as the ability to control a video game by thought. If you think a remote control is convenient, imagine changing channels with your mind. Wireless or injectable implants in the brain is a future scope. Direct control over the activities of all neurons by means of nanorobots and arbitrary read/write access to the whole brain can also be achieved. Researches are occurring for more direct links into the brain with the ability to read certain thoughts and extract a wide range of data and information for various applications.However, there is a bigger picture, devices that would allow severely disabled people to function independently. Something as basic as manipulating a computer cursor, with the subject thinking about forward, left, right and ack movements of the cursor. With enough practice, users can gain control over a cursor to draw a circle, access computer programs and control a TV. It could theoretically be expanded to allow users to "type" with their thoughts. The usage of a BCI for predicting the driver's movement intention, fatigue etc. can help to trigger well sophisticated drive-dynamic and driver support systems for increasing traffic safety and to avoid fatalities.

Once the basic mechanism of converting thoughts to computerized or robotic action is perfected, the potential use for the technology are almost limitless. Instead of a robotic hand, disabled users could have robotic braces attached to their own limbs, allowing them to move and directly interact with the environment. This could be sent to the appropriate motor control nerves in the hands, bypassing a damaged section of the spinal or and allowing actual movement of the subject's own hands.

9.4 BCI INNOVATIONS

A few companies are pioneers in the field of BCI. Most of them are still in the research stages, though a few products are offered commercially.

- Neural Signals is developing technology to restore speech to disabled people. An implant in an area of the brain associated with speech (Broca's area) would transmit signals to a computer and then to a speaker. With training, the subject could learn to think each of the 39 phonemes in the English language and reconstruct speed through the computer and speaker (source:Neural Signals).
- NASA has researched a similar system, although it reads electric signals from the nerves in the mouth and throat area, rather than directly from the brain. They succeeded in performing a Web search by mentally "typing" the term "NASA" into Google.
- Cyber kinetics Neurotechnology Systems is marketing the Brain Gate, a neural interface system that allows disabled people to control a wheelchair, robotic prosthesis or computer cursor.

Fig 9.1 Various applications of BCI

CHAPTER 10

CHAPTER 10

REFERENCES

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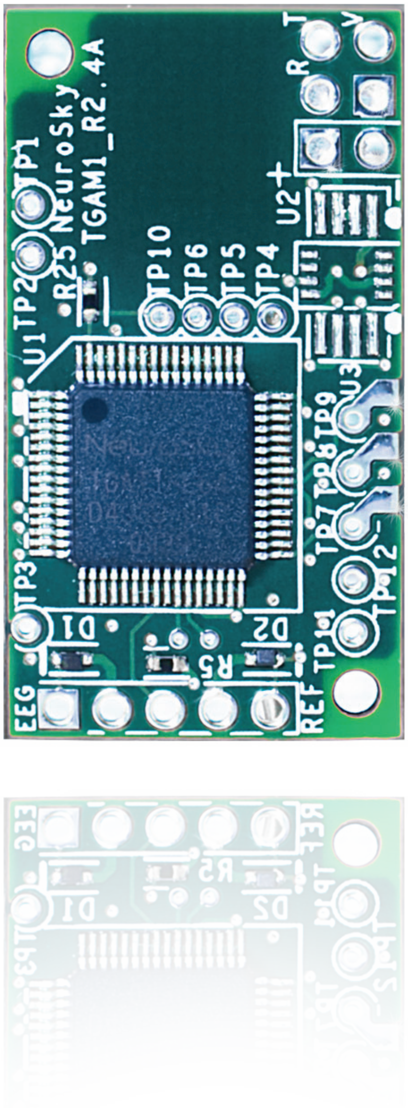
APPENDIX

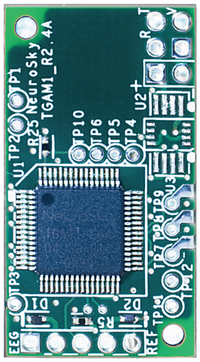
NeuroSky

Brain Wave Sensors for Every Body



TGAM

ThinkGear // Features + Technical Specifications



Main Benefit

The TGAM is NeuroSky's primary brainwave sensor ASIC module designed for mass market applications. The TGAM processes and outputs EEG frequency spectrums, EEG signal quality, raw EEG, and three NeuroSky eSense meters attention; meditation; and eyeblinks. With simple dry electrodes, this module is excellent for use in toys, video games, and wellness devices because of its low power consumption, which is suitable for portable battery-driven applications.

Overview

The TGAM module contains the TGAT, the chip that revolutionized an industry, with the Mattel MindFlex being named to TIME Magazine's 100 Best Toys of All Time. With over one million in circulation, it is the world's first EEG (electroencephalography) sensor designed for consumer use. It connects to dry electrodes needed for mass market needs (as opposed to conventional medical wet sensors). Its advanced filtering technology allows for high noise immunity, making the device usable for almost all individuals and in almost all settings.

TGAM: ThinkGear ASIC Module

- Directly connects to dry electrode (as opposed to conventional medical wet sensors)
- One EEG channel with three contacts: EEG; REF; and GND
- Improper fit detected through "Poor Signal Quality" warning from ASIC to reset if off the head for four consecutive seconds, or if it is receiving a poor signal for seven consecutive seconds
- Advanced filtering technology with high noise immunity
- Low power consumption suitable for portable battery-driven applications
- Max power consumption 15mA @ 3.3 V
- Raw EEG data output at 512 bits per second

Measures

- Raw brainwave signal
- Processing and output of EEG power spectrums (Alpha, Beta, etc.)
- Processing and output of NeuroSky proprietary eSense meter for Attention, Meditation, and other future meters
- EEG/ECG signal quality analysis (can be used to detect poor contact and whether the device is off the head)
- Eyeblink detection

Physical

- Dimensions (Max) 2.79cm x 1.52cm x 0.25cm
- Weight (Max) 130 mg

Specs

- 512 bits per second sampling frequency
- 3-100Hz frequency range
- ESD Protection: 4kV Contact Discharge; 8kV Air Discharge
- Max Power Consumption: 15mA @ 3.3V
- Operating voltage 2.97 ~3.63V

UART (serial) standard output interface

- 1200, 9600, 57600 output baud rate
- 8bits
- Parity: none
- Stop Bit: 1

Configurable Options AC Noise Filter

- 50 Hz
- 60 Hz

Output & Baud Rate:

- 1200 Baud with Attention, Meditation, EEG Powers (alpha, beta, etc) and Poor Signal Quality
- 9600 Baud with Attention, Meditation, EEG Powers (alpha, beta, etc) and Poor Signal Quality
- 57600 Baud with Attention, Meditation, EEG Powers (alpha, beta, etc) and Poor Signal Quality and Raw EEG wave

To be used with:

Electrodes

- Maximum surface area of ~150mm2 (but less surface area is optimal)
- Ag/AgCl, Stainless Steel, Gold, or/and Silver (both solid and plated material works)
- EEG electrode located above the left or right eye on the forehead
- Ground and reference electrodes located behind the ear or at the earlobe
- Have enough pressure to prevent movement, with a minimum of 0.8 PSI

Electrodes

- Length of less than 12 inches, the longer the higher the susceptibility to noise
- Shielding (not necessary for the ground)
- Thinner than AWG28

Mechanical Drawing

The dimensions and major components of the TGAM is shown in the mechanical drawing in *Figure 1*. There are two mounting holes at the upper right and lower left corner. They can be used to secure the TGAM to your system housing.

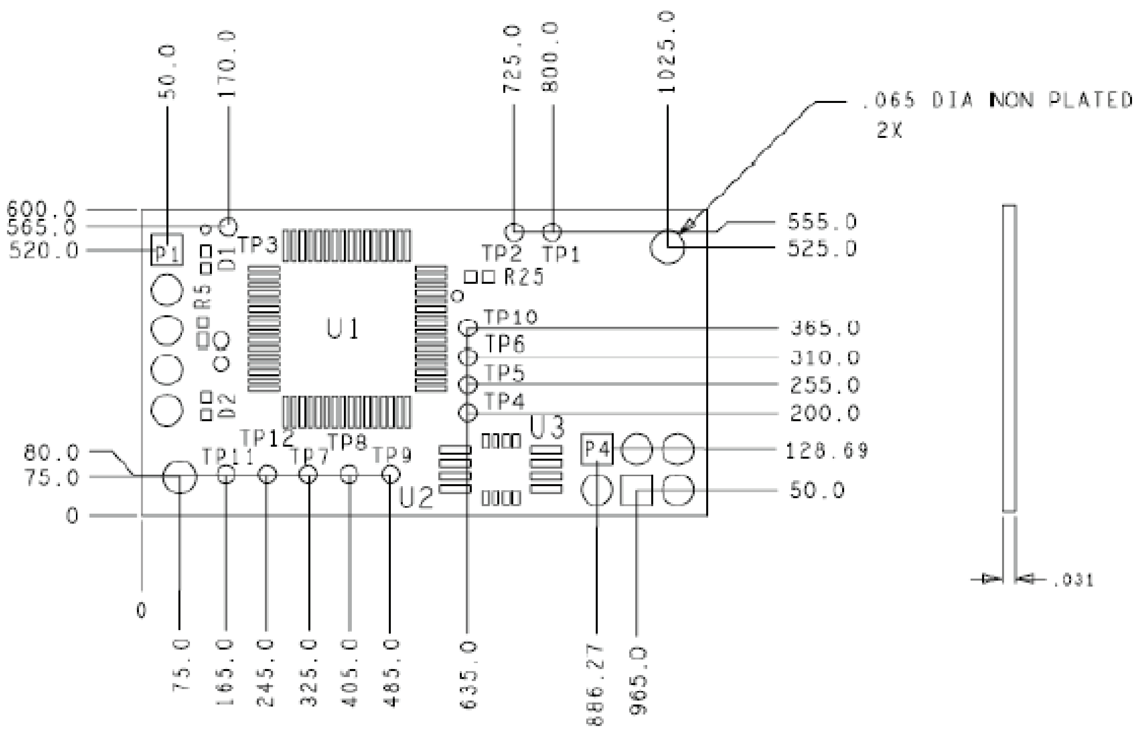
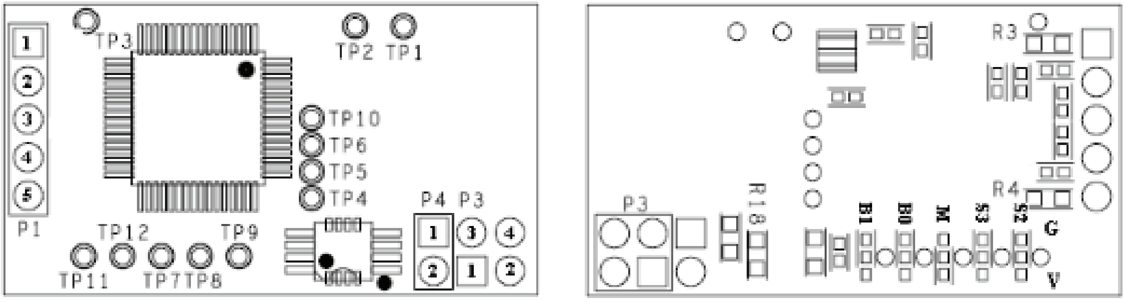


Fig 1 Mechanical Drawing & Board Thickness

Board Layout



View From Top View From Bottom

Fig 2 Board Layout *Note: Labels in "" indicated on PCB for convenience*

Header p1 (Electrode)

Pin 1 - EEG Electrode "EEG"
Pin 2 - EEG Shield
Pin 3 - Ground Electrode
Pin 4 - Reference Shield
Pin 5 - Reference Electrode "REF"

Header p4 (Power)

Pin 1 - VCC "+"
Pin 2 -GND "-"

Header p3 (UART/Serial)

Pin 1 - GND "-"
Pin 2 - VCC "+"
Pin 3 - RXD "R"
Pin 4 -TXD "T"

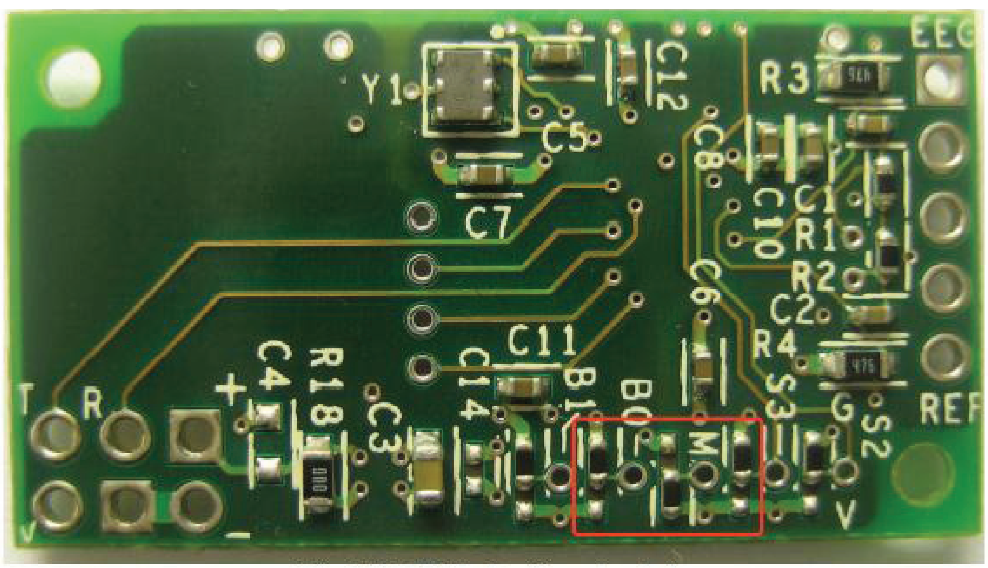


Fig 3 TGAM Configuration Pads ** Normal Output mode includes the following output: poor quality value, EEG value, attention value, and meditation value*

BR1	BR2	Function
GND	GND	9600 Baud with Normal* Output Mode
GND	VCC	1200 Baud with Normal* Output Mode
VCC	GND	57.6k Baud with Normal* + Raw Output Mode
VCC	VCC	N/A

Example Design

This example design uses 2 AAA batteries to power a TGAM module. Both the EEG and REF electrodes are connected with shielded wires to TGAM, and both of the shielded ground wires are connected to the UART ports of a processor.

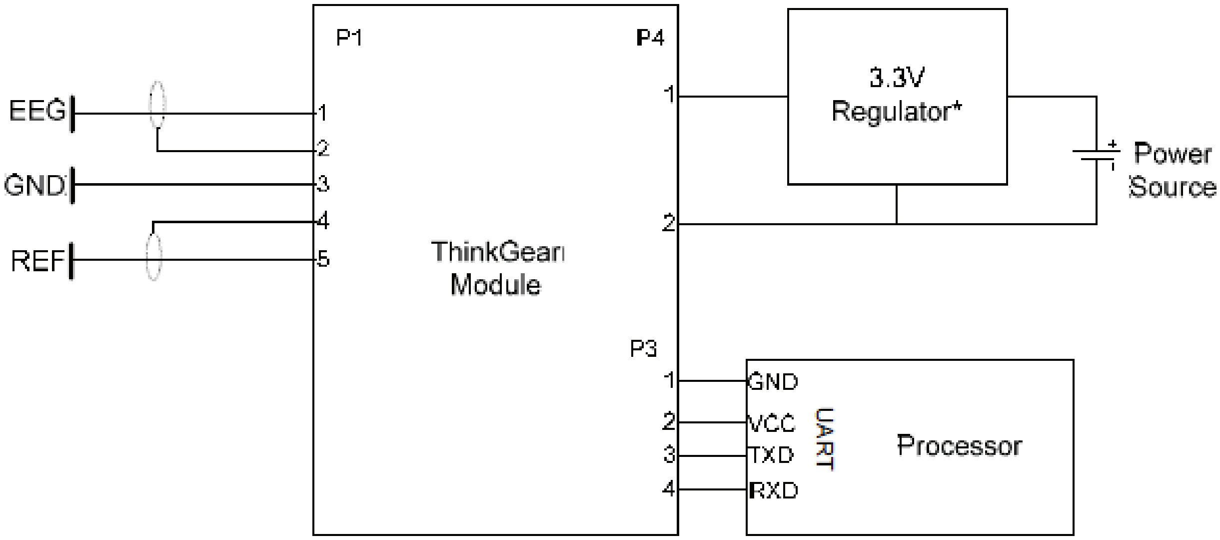


Fig 4 Example Schematic ** Normal Output mode includes the following output: poor quality value, EEG value, attention value, and meditation value*

ThinkGear Packets

ThinkGear components deliver their digital data as an asynchronous serial stream of bytes. The serial stream must be parsed and interpreted as ThinkGear Packets in order to properly extract and interpret the ThinkGear Data Values described in the chapter above.

A ThinkGear Packet is a packet format consisting of 3 parts:

1. Packet Header
2. Packet Payload
3. Payload Checksum

ThinkGear Packets are used to deliver Data Values (described in the previous chapter) from a ThinkGear module to an arbitrary receiver (a PC, another microprocessor, or any other device that can receive a serial stream of bytes). Since serial I/O programming APIs are different on every platform, operating system, and language, it is outside the scope of this document (see your platform's documentation for serial I/O programming). This chapter will only cover how to interpret the serial stream of bytes into ThinkGear Packets, Payloads, and finally into the meaningful Data Values described in the previous chapter.

The Packet format is designed primarily to be robust and flexible: Combined, the Header and Checksum provide data stream synchronization and data integrity checks, while the format of the Data Payload ensures that new data fields can be added to (or existing data fields removed from) the Packet in the future without breaking any Packet parsers in any existing applications/devices. This means that any application that implements a ThinkGear Packet parser properly will be able to use newer models of ThinkGear modules most likely without having to change their parsers or application at all, even if the newer ThinkGear hardware includes new data fields or rearranges the order of the data fields.

Packet Structure

Packets are sent as an asynchronous serial stream of bytes. The transport medium may be UART, serial COM, USB, bluetooth, file, or any other mechanism which can stream bytes.

Each Packet begins with its Header, followed by its Data Payload, and ends with the Payload's Checksum Byte, as follows:

```
[SYNC] [SYNC] [PLENGTH]  [PAYLOAD...]  [CHKSUM]
_______________________  _____________ ____________
^^^^^^^^(Header)^^^^^^^  ^^(Payload)^^ ^(Checksum)^
```

The `[PAYLOAD…]` section is allowed to be up to 169 bytes long, while each of `[SYNC]`, `[PLENGTH]`, and `[CHKSUM]` are a single byte each. This means that a complete, valid Packet is a minimum of 4 bytes long (possible if the Data Payload is zero bytes long, i.e. empty) and a maximum of 173 bytes long (possible if the Data Payload is the maximum 169 bytes long).

A procedure for properly parsing ThinkGear Packets is given below in Step-By-Step Guide to Parsing a Packet.

Packet Header

The Header of a Packet consists of 3 bytes: two synchronization `[SYNC]` bytes (`0xAA 0xAA`), followed by a `[PLENGTH]` (Payload length) byte:

```
[SYNC] [SYNC] [PLENGTH]
_______________________
^^^^^^^^(Header)^^^^^^^
```

The two `[SYNC]` bytes are used to signal the beginning of a new arriving Packet and are bytes with the value `0xAA` (decimal 170). Synchronization is two bytes long, instead of only one, to reduce the chance that `[SYNC]` (`0xAA`) bytes occurring within the Packet could be mistaken for the beginning of a Packet. Although it is still possible for two consecutive `[SYNC]` bytes to appear *within* a Packet (leading to a parser attempting to begin parsing the middle of a Packet as the beginning of a Packet) the `[PLENGTH]` and `[CHKSUM]` combined ensure that such a "mis-sync'd Packet" will never be accidentally interpreted as a valid packet (see Payload Checksum below for more details).

The `[PLENGTH]` byte indicates the length, in bytes, of the Packet's Data Payload `[PAYLOAD...]` section, and may be any value from 0 up to 169. Any higher value indicates an error (`PLENGTH TOO LARGE`). Be sure to note that `[PLENGTH]` is the length of the Packet's **Data Payload**, NOT of the entire Packet. The Packet's complete length will always be `[PLENGTH] + 4`.

Data Payload

The Data Payload of a Packet is simply a series of bytes. The number of Data Payload bytes in the Packet is given by the `[PLENGTH]` byte from the Packet Header. The interpretation of the Data Payload bytes into the ThinkGear Data Values described in Chapter 1 is defined in detail in the Data Payload Structure section below. Note that parsing of the Data Payload **typically should not even be attempted** until **after** the Payload Checksum Byte `[CHKSUM]` is verified as described in the following section.

Payload Checksum

The `[CHKSUM]` Byte must be used to verify the integrity of the Packet's Data Payload. The Payload's Checksum is defined as:

1. summing all the bytes of the Packet's Data Payload
2. taking the lowest 8 bits of the sum
3. performing the bit inverse (one's compliment inverse) on those lowest 8 bits

A receiver receiving a Packet must use those 3 steps to calculate the checksum for the Data Payload they received, and then compare it to the `[CHKSUM]` Checksum Byte received with the Packet. If the calculated payload checksum and received `[CHKSUM]` values do not match, the entire Packet should be discarded as invalid. If they do match, then the receiver may procede to parse the Data Payload as described in the "Data Payload Structure" section below.

Data Payload Structure

Once the Checksum of a Packet has been verified, the bytes of the Data Payload can be parsed. The Data Payload itself consists of a continuous series of Data Values, each contained in a series of bytes called a DataRow. Each DataRow contains information about what the Data Value represents, the length of the Data Value, and the bytes of the Data Value itself. Therefore, to parse a Data Payload, one must parse each DataRow from the Data Payload, until all bytes of the Data Payload have been parsed.

DataRow Format

A DataRow consists of bytes in the following format:

```
([EXCODE]...) [CODE]  ([VLENGTH])  [VALUE...]
____________________ ____________ ___________
^^^^(Value Type)^^^^ ^^(length)^^ ^^(value)^^
```

Note: Bytes in parentheses are conditional, meaning that they only appear in some DataRows, and not in others. See the following description for details.

The DataRow may begin with zero or more `[EXCODE]` (**Ex**tended **Code**) bytes, which are bytes with the value `0x55`. The number of `[EXCODE]` bytes indicates the Extended Code Level. The Extended Code Level, in turn, is used in conjuction with the `[CODE]` byte to determine what type of Data Value this DataRow contains. Parsers should therefore always begin parsing a DataRow by counting the number of `[EXCODE]` (`0x55`) bytes that appear to determine the Extended Code Level of the DataRow's `[CODE]`.

The `[CODE]` byte, in conjunction with the Extended Code Level, indicates the type of Data Value encoded in the DataRow. For example, at Extended Code Level 0, a `[CODE]` of `0x04` indicates that the DataRow contains an eSense Attention value. For a list of defined `[CODE]` meanings, see the CODE Definitions Table below. Note that the `[EXCODE]` byte of `0x55` will never be used as a `[CODE]` (incidentally, the `[SYNC]` byte of `0xAA` will never be used as a `[CODE]` either).

If the `[CODE]` byte is between `0x00` and `0x7F`, then the the `[VALUE...]` is implied to be 1 byte long (referred to as a Single-Byte Value). **In this case, there is no `[VLENGTH]` byte, so the single `[VALUE]` byte will appear immediately after the `[CODE]` byte.**

If, however, the `[CODE]` is greater than `0x7F`, then a `[VLENGTH]` ("Value Length") byte immediately follows the `[CODE]` byte, and this is the number of bytes in `[VALUE...]` (referred to as a Multi-Byte Value). These higher CODEs are useful for transmitting arrays of values, or values that cannot be fit into a single byte.

The DataRow format is defined in this way so that any properly implemented parser will not break in the future if new `CODE`s representing arbitrarily long `DATA...` values are added (they simply ignore unrecognized `CODE`s, but do not break in parsing), the order of `CODE`s is rearranged in the Packet, or if some `CODE`s are not always transmitted in every Packet.

A procedure for properly parsing Packets and DataRows is given below in Step-By-Step Guide to Parsing a Packet and Step-By-Step Guide to Parsing DataRows in a Packet Payload, respectively.

6 Specifications

6.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)(1)

	MIN	MAX	UNIT
Supply voltage, V_{CC1} (2)		36	V
Output supply voltage, V_{CC2}		36	V
Input voltage, V_I		7	V
Output voltage, V_O	–3	V_{CC2} + 3	V
Peak output current, I_O (nonrepetitive, t ≤ 5 ms): L293	–2	2	A
Peak output current, I_O (nonrepetitive, t ≤ 100 µs): L293D	–1.2	1.2	A
Continuous output current, I_O: L293	–1	1	A
Continuous output current, I_O: L293D	–600	600	mA
Maximum junction temperature, T_J		150	°C
Storage temperature, T_{stg}	–65	150	°C

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
(2) All voltage values are with respect to the network ground terminal.

6.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 (1)	±2000	V
		Charged-device model (CDM), per JEDEC specification JESD22-C101 (2)	±1000	

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

6.3 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

			MIN	NOM	MAX	UNIT
	Supply voltage	V_{CC1}	4.5		7	V
		V_{CC2}	V_{CC1}		36	
V_{IH}	High-level input voltage	V_{CC1} ≤ 7 V	2.3		V_{CC1}	V
		V_{CC1} ≥ 7 V	2.3		7	V
V_{IL}	Low-level output voltage		–0.3 (1)		1.5	V
T_A	Operating free-air temperature		0		70	°C

(1) The algebraic convention, in which the least positive (most negative) designated minimum, is used in this data sheet for logic voltage levels.

6.4 Thermal Information

THERMAL METRIC (1)		L293, L293D NE (PDIP) 16 PINS	UNIT
$R_{\theta JA}$	Junction-to-ambient thermal resistance (2)	36.4	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	22.5	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	16.5	°C/W
ψ_{JT}	Junction-to-top characterization parameter	7.1	°C/W
ψ_{JB}	Junction-to-board characterization parameter	16.3	°C/W

(1) For more information about traditional and new thermal metrics, see the *Semiconductor and IC Package Thermal Metrics* application report, SPRA953.
(2) The package thermal impedance is calculated in accordance with JESD 51-7.

6.5 Electrical Characteristics

over operating free-air temperature range (unless otherwise noted)

PARAMETER			TEST CONDITIONS		MIN	TYP	MAX	UNIT
V_{OH}	High-level output voltage		L293: I_{OH} = −1 A		V_{CC2} – 1.8	V_{CC2} – 1.4		V
			L293D: I_{OH} = − 0.6 A					
V_{OL}	Low-level output voltage		L293: I_{OL} = 1 A			1.2	1.8	V
			L293D: I_{OL} = 0.6 A					
V_{OKH}	High-level output clamp voltage		L293D: I_{OK} = –0.6 A			V_{CC2} + 1.3		V
V_{OKL}	Low-level output clamp voltage		L293D: I_{OK} = 0.6 A			1.3		V
I_{IH}	High-level input current	A	V_I = 7 V			0.2	100	µA
		EN				0.2	10	
I_{IL}	Low-level input current	A	V_I = 0			–3	–10	µA
		EN				–2	–100	
I_{CC1}	Logic supply current		I_O = 0	All outputs at high level		13	22	mA
				All outputs at low level		35	60	
				All outputs at high impedance		8	24	
I_{CC2}	Output supply current		I_O = 0	All outputs at high level		14	24	mA
				All outputs at low level		2	6	
				All outputs at high impedance		2	4	

6.6 Switching Characteristics

over operating free-air temperature range (unless otherwise noted) V_{CC1} = 5 V, V_{CC2} = 24 V, T_A = 25°C

PARAMETER			TEST CONDITIONS	MIN	TYP	MAX	UNIT
t_{PLH}	Propagation delay time, low-to-high-level output from A input	L293NE, L293DNE	C_L = 30 pF, See Figure 2		800		ns
		L293DWP, L293N L293DN			750		
t_{PHL}	Propagation delay time, high-to-low-level output from A input	L293NE, L293DNE			400		ns
		L293DWP, L293N L293DN			200		
t_{TLH}	Transition time, low-to-high-level output	L293NE, L293DNE			300		ns
		L293DWP, L293N L293DN			100		
t_{THL}	Transition time, high-to-low-level output	L293NE, L293DNE			300		ns
		L293DWP, L293N L293DN			350		

6.7 Typical Characteristics

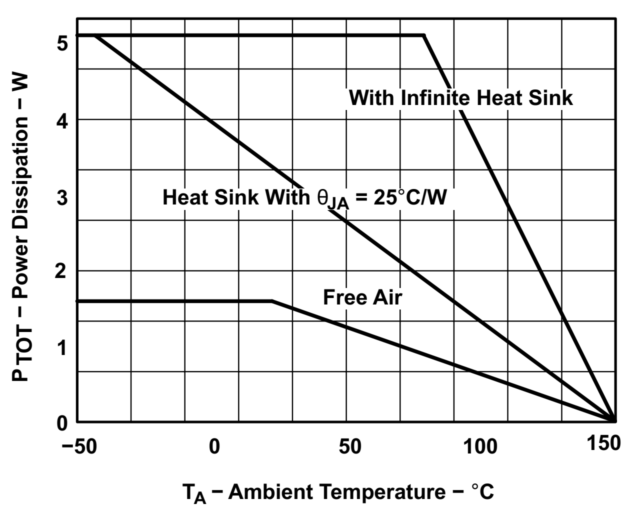
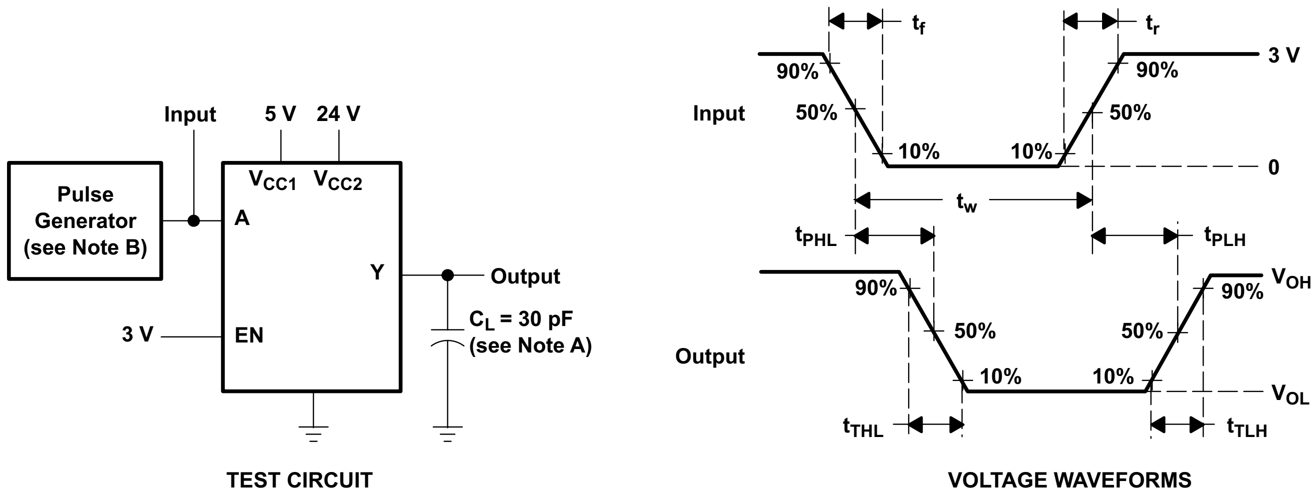


Figure 1. Maximum Power Dissipation vs Ambient Temperature

7 Parameter Measurement Information



NOTES: A. C_L includes probe and jig capacitance.
B. The pulse generator has the following characteristics: $t_r \leq 10$ ns, $t_f \leq 10$ ns, t_w = 10 μs, PRR = 5 kHz, Z_O = 50 Ω.

Figure 2. Test Circuit and Voltage Waveforms

8 Detailed Description

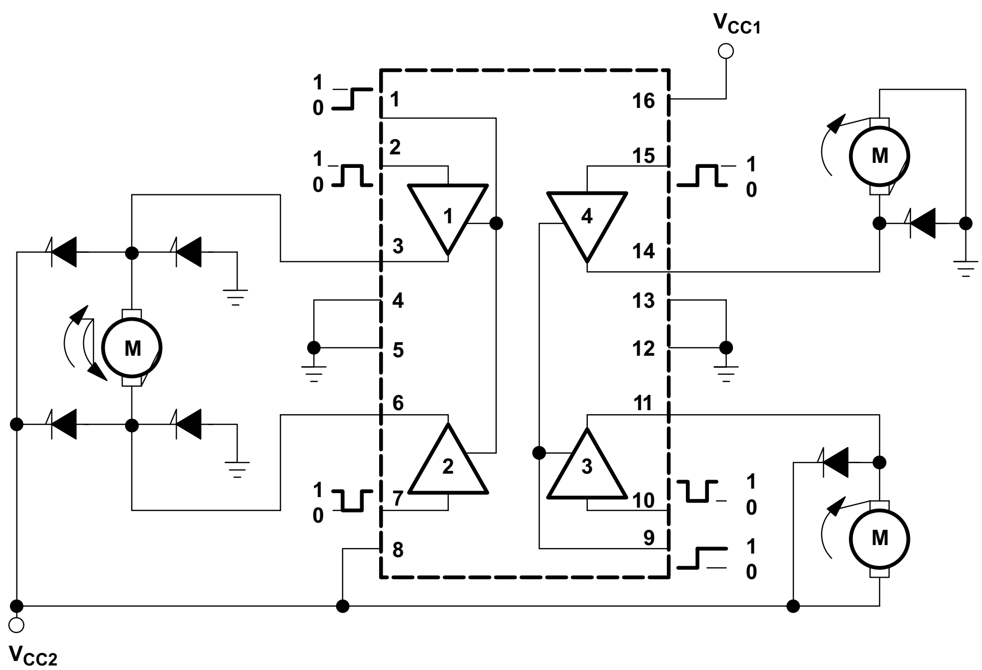
8.1 Overview

The L293 and L293D are quadruple high-current half-H drivers. These devices are designed to drive a wide array of inductive loads such as relays, solenoids, DC and bipolar stepping motors, as well as other high-current and high-voltage loads. All inputs are TTL compatible and tolerant up to 7 V.

Each output is a complete totem-pole drive circuit, with a Darlington transistor sink and a pseudo-Darlington source. Drivers are enabled in pairs, with drivers 1 and 2 enabled by 1,2EN and drivers 3 and 4 enabled by 3,4EN. When an enable input is high, the associated drivers are enabled, and their outputs are active and in phase with their inputs. When the enable input is low, those drivers are disabled, and their outputs are off and in the high-impedance state. With the proper data inputs, each pair of drivers forms a full-H (or bridge) reversible drive suitable for solenoid or motor applications.

On the L293, external high-speed output clamp diodes should be used for inductive transient suppression. On the L293D, these diodes are integrated to reduce system complexity and overall system size. A V_{CC1} terminal, separate from V_{CC2}, is provided for the logic inputs to minimize device power dissipation. The L293 and L293D are characterized for operation from 0°C to 70°C.

8.2 Functional Block Diagram



Output diodes are internal in L293D.

8.3 Feature Description

The L293x has TTL-compatible inputs and high voltage outputs for inductive load driving. Current outputs can get up to 2 A using the L293.

8.4 Device Functional Modes

Table 1 lists the fuctional modes of the L293x.

Table 1. Function Table (Each Driver)(1)

INPUTS (2)		OUTPUT (Y)
A	EN	
H	H	H
L	H	L
X	L	Z

(1) H = high level, L = low level, X = irrelevant, Z = high impedance (off)
(2) In the thermal shutdown mode, the output is in the high-impedance state, regardless of the input levels.

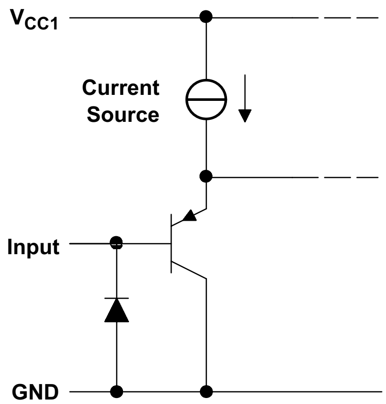


Figure 3. Schematic of Inputs for the L293x

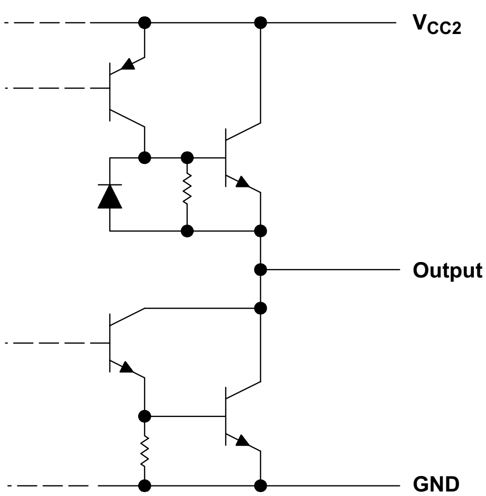


Figure 4. Schematic of Outputs for the L293

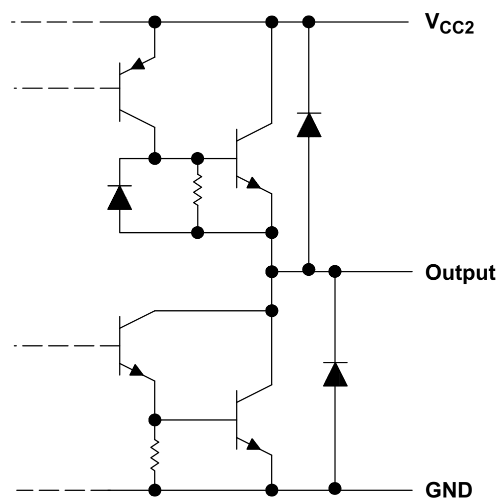


Figure 5. Schematic of Outputs for the L293D