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Design and Implementation of EEG Signal Analysis on FPGA

تصميم وتطبيق لتحليل اشارة رسم الدماغ باستعمال FPGA

A thesis submitted in partial fulfillment of the requirements for the degree of BSc,(Honors) in Biomedical Engineering

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الإستــهـلال

﴿وَيَسأَلونَكَ عَنِ الرّوحِ قُلِ الرّوحُ مِن أَمرِ رَبّي وَما أوتيتُم مِنَ العِلمِ إِلّا قَليلًا﴾

[الإسراء: ٨٥]

Dedication

It is our genuine gratefulness and warmest regard that we dedicate this dissertation work to our families and many friends. A special feelingof gratitude to Dr.Fragoon Mohammed, whose words of encouragement and push for tenacity ring in our ears.

Acknowledgment

We would like to express our thanks to our supervisors, Dr. Fragoon Mohammed and Ustz.Montasir Mohamed Munsor for their guidance, patience, support and valuable supervision of this work. Thanks Saddam for technical support and helping to getting the suitable program used in this project. Thanks Ustz.Rania for valuable advice and helping to get required EEG data for this work.

Finally we would like to thank our parents for their support and encouragement.

Abstract

EEG signals is complex and non-stationary signal so that requires real time processing. This processing of digital signal (DSP) algorithms requires running them with minimal delay device; one of these devices is FPGA which present low cost and high speed implementation.

This project presents the hardware implementation of BCI system which aims to make communication between brain and external device. The technique of EEG signal processing using FPGA architecture by generating VHDL code from Xilinx MATLAB SIMULINK blocks into ISE is proposed in this work. The band pass filter was designed using FDATool to achieve the wanted range of whole the signal in order to signal segmentation, and then the 2 levels DWT system was designed using high and low pass filters to extract the features of the input signal. This work faced several challenges in designing filters with Xilinx blocks.

المستخلص

إشارات EEGهي إشارات معقدة ومتغيرة لذلك تتطلب معالجة في الزمن الحالي. حساب هذه المعالجة للإشارات الرقمية(DSP) تتطلب تشغيلها مع أجهزة الحد الأدنى للتأخير،و من هذه الأجهزة ال(FPGA) التى تعطي تنفيذ منخفض التكلفة و بسرعة عالية.

هذا المشروع يعرض التنفيذ العملي لنظام ال(BCI) الذي يهدف إلي عمل تواصل بين المخ و الجهاز الخارجي. تعرض في هذا العمل التقنية المستخدمة لمعالجة إشارات ال(EEG) باستخدام هيكلة (FPGA) بواسطة إنشاء (VHDL Code)في برنامج (ISE) من Xilinx) MATLAB SIMULINK blocks) . في المرحلة الأولى صمم مرشح لإشارة الدخلبإستخدام(FDATool)لكي تُجزّأ الاشارة ذلك للحصول علي المدى المطلوب من الإشارة الكاملة, ثم صمم نظام لتحديد مواصفات الإشارة من مرحلتين باستخدام (DWT).

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TABLE OF ABBREVIATION:

EEG	Electroencephalography
BCI	Brain computer interface
SoC	System on Chip
WT	Wavelet Transform
DWT	Discrete Wavelet Transform
FPGA	Field Programmable Gate Array
ANN	Artificial Neural Network
SVM	Support vector machines
FIR	Finite impulse response
ISE	Integrated Synthesis Environment
SASI	A spectral asymmetry index
LLE	Largest Lyapunov Exponent
Isim	ISE simulation
MMI	Mind-Machine Interface
BMI	Brain–Machine Interface
DSP	Digital Signal Processing
STFT	the Short-Time Fourier Transform
PROM	Programmable Read Only Memory
LEs	Logic Elements
CLBs	Configurable Logic Blocks
CAD	Computer Aided Design
HCI	Human Computer Interface
EOG	Electrooculography
EMG	Electromyography
ASIC	Application Specific Integrated Circuit

1 Chapter One

Introduction

1.1 General review

Handicapped people with locomotive disabilities need some devices or tools to help them to perform functions that require them to move around. They can do so manually by pushing the wheelchair with their hands. However, many individuals have weak upper limbs or find the manual mode of operating too tiring. Hence, it is desirable to provide them with a motorized smart wheelchair that can be controlled by bio-signal & non bio-signal approach .Today with the availability of low cost electronic systems and powerful processing tools has eased the bio-signal processing. These factors currently opened up the possibility of developing a system that allows restoration of person's capabilities with severe neuromuscular disorders and also makes their easier. A system which allows interfacing brain signals with computers is known as Brain computer interface (BCI).(1)

Brain Computer Interface (BCI) is a direct connection between computer(s) and human brain (2), this work aims to develop a System on Chip (SoC) technology which can be used for controlling electronic devices using EEG signals under various mind set of people with disabilities. (1)

In general, signals in their raw form are time-amplitude representations. These time-domain signals are often needed to be transformed into other domains like frequency domain, time-frequency domain, etc., for analysis and processing. Transformation of signals helps in identifying distinct information which might otherwise be hidden in the original signal. Depending on the application. (3)

In order to extract features from EEG signals, the wavelet transform (WT) has been widely applied which results in the representation of the wavelet coefficients in the time- frequency plane. By performing this operation on the EEG signals, the doctor would be able to better analyze the EEG signals. This process, when done in software, requires a great deal of computational resources and so it is not practical to implement such a method for real time analysis of the EEG signals. As a result by placing such an operation in the hardware domain with the use of FPGAs, it would ease the processing power required for a system that is required to analyse EEG signals through the use of the WT transform. (4)

1.2 Problem statement

BCI system somehow is complex; because it dealing with EEG signals.we need to make it simpler.

1.3 Proposed solution

There are many techniques can be programmed to implement BCI system that helps disable, one of the modern and new techniques is FPGA approach that can be configured for a wide variety of applications.

1.4 Objectives

General objective is:

To Design and implementation of EEG signal analysis on FPGA

Specific objectives are to:

1. Help disable people to move more easily.
2. Reduce the complexity of BCI system.
3. Implement the methods of signals extraction on FPGA with highly speed and accuracy.

1.5 Methodology

EEG data four imaginary motor well be got and processed using MATLAB, then the data will be entered into DWT system to extract the required features, the output feature extraction will be entered into classification system that will be designed using ANN. Final output will be converted into command to generate the application.

1.6 Thesis layout

This research consists of six chapters:

Chapter one is an introduction. The literature review is represented chapter two. Chapter three is representing the theoretical background. The proposed system is described in chapter four. Chapter five present the results and discussion. Finally, chapter six illustrates the conclusion and recommendation

2 Chapter Two

Literature Review

M, Aravind and Babu, Dr. S. Suresh implemented BrainComputer Interface (BCI) concept using FPGA(5) , aimed to build a direct communication pathway between brain and external device , The signal acquisition is carried out by the EEG recorder , the data set were filtered using FIR filter, as it is simpler and more convenient for programming on dedicated digital signal processing platform ,then the required features are extracted using feature extraction process from the obtained signals by using wavelet analysis, discrete wavelet analysis (DWT). Then the data is classified based on the features using Support Vector Machine (SVM) and is used to control devices. The SVM provide facility for huge data space to incorporate the collected data.

The proposed system is designed using Xilinx ISE Design suite. The input EEG signal form the BCI competition is scaled to suitable form for the easiness of implementation. Unwanted noises are removed using FIR filter. The implementation of FIR filter is carried out using direct form 64 order filters, and then 8-level DWT is used for detailed analysis of EEG signals. Features such as variance, standard deviation, frequency, mean, large and small amplitude are calculated. The SVM will classify the desired action using the best feature.

Gorev, Maksim, et al. calculated asymmetry a spectral index (SASI) (6) as relative differences in power of two EEG special frequency bands selected higher and lower of the EEG spectrum maximum. The EEG central frequency band around the spectrum maximum (alpha band) is excluded from the calculations. The input data for the calculation, stored on SD-card, is the EEG signal recorded for 20 minutes from 2 electrodes.

Carballo, Walther, et al presented in this work an integration of different mathematical and technological tools(7) in order to automatically classify through software a sort of preprocessed time series from electroencephalograms (EEG) obtained from healthy patients and patients suffering epilepsy. Time series are analyzed using different chaotic descriptors like the Largest Lyapunov Exponent (LLE) and the Correlation Dimension (Dg). These descriptors are used to describe the different patterns in EEG for a diagnosis of the current status patients. Once the descriptors are obtained these descriptive algorithms are embedded into a multicore Field Programmable Gate Array (FPGA)Zynq ZC702® from Xilinx®, once the algorithm is tested in software .

Singh, Thingujam Churchil, et al implemented project that is related to the design of home diagnostic system based upon the brain signal (electro encephalogram) (8) , which helps in detecting the abnormality condition of a person after analyzing the brain signal of that particular person and finding a solution to the problem in the nearest future. In this project, the main idea was to capture a set of normal brain signals and a set of brain signals of patients with different diseases and comparing the brain signal condition of a person whose condition is to be checked. FPGA implementation will be used for the comparison purpose and for detecting abnormal conditions, the signal was acquired and converted to its equivalent ASIC value and the code for the signal had been written and the acquired signal had been compared to that of the reference signal to detect the particular disease.

Raj, Sreethu and George, Anuja described an automated classification of EEG signals for the detection of seizures using wavelet transform and support vector machines (9). The decision making process consisted of three main stages: (a) filtering operation by FIR filter, (b) feature extraction based on discrete wavelet transform (DWT) and (c) classification by support vector machines (SVM) classifiers. The proposed methodology was applied on EEG data sets that belong to two subject groups: a) healthy subjects and b) seizure subjects. Based on the data sets the boundaries of all the features were identified for the proper detection of the test signal. After processing all the data sets, the test signal was given to the system. Decision was made by comparing the features of the test signal with the maximum and minimum values of all the features of data sets. The EEG feature extraction and seizure detection system was verified by Verilog in ISim simulator and implemented on Xilinx Spartan6.

3 Chapter Three

Theoretical Background

3.1 Brain Computer Interface (BCI)

A Brain–Computer Interface (BCI), often called a Mind-Machine Interface (MMI), or sometimes called a direct neural interface or a Brain–Machine Interface (BMI), is a direct communication channel between the brain and an external device. Brain-computer interface (BCI) is an upcoming technology which aims to convey people's intentions to the outside world directly from their thoughts, enhancing cognitive capabilities. BCIs are often directed at assisting, augmenting, or repairing human cognitive or sensory-motor functions. The BCI can be used for people who are unable to express through speech. Normally these people are "locked in" meaning they can't move their face or any of their appendages. The field of BCI research and development has been focused on neuroprosthetics applications. This aims at restoring damaged hearing, sight and movement. (10).

BCI provides a new communication channel between the human brain and the computer. Mental activity leads to changes of electrophysiological signals like the EEG. The BCI system detects such changes and transforms it into a control signal which can be used in various applications like video game, motion of a wheel chair etc. One of the main goals is to enable completely paralyzed patient to communicate with their environment. The machine should be able to learn to discriminate between different patterns of brain activity as accurate as possible and the user of the BCI should learn to perform different mental tasks in order to produce distinct brain signals. A BCI is a communication and control system that does not depend in any way on the brain's normal neuromuscular output channels. The user's intent is conveyed by brain signals (such as EEG) rather than by peripheral nerves and muscles, and these brain signals do not depend for their generation on neuromuscular activity. Furthermore, as a communication and control system, a BCI establishes a real-time interaction between the user and the outside world. The user receives feedback reflecting the outcome of the BCI's operation, and that feedback can affect the user's subsequent intent and its expression in brain signals.(10)

3.2 Brain anatomy

The brain receives information through different sensors such as sight, smell, touch, taste, and hearing. The brain constructs the received data from the different sensors and forms a meaningful message. The brain controls our body movement of the arms and legs, thoughts, memory and speech. It also determines how a human respond to different situations such as stress by regulating our heart and breathing rate. (11)

Anatomically the brain can be divided into three major parts; cerebrum, cerebellum and brainstem as illustrated in Figure3.1 Below is a brief explanation of the three aforementioned parts of the brain.

1. Cerebrum: The cerebrum is the largest and most important part of the human brain and is generally associated with brain functions related to thoughts, movements, emotions and motor functions. The outermost layer of the cerebrum is made up of neural tissues known as the cerebral cortex. The cerebrum consists of two hemispheres, such as right and left

hemispheres. Each hemisphere can be divided into four lobes: frontal, parietal, occipital and temporal .These lobes are responsible for a variety of bodily functions.

- Frontal Lobe is involved with personality, emotions, problem solving, motor development, reasoning, planning, parts of speech and movement.
- Parietal Lobe is responsible for sensation (e.g. pain, touch), sensory comprehension, recognition, perception of stimuli, orientation and movement.
- Occipital Lobe is responsible for visual processing.
- Temporal Lobe is involved in dealing with the recognition of auditory stimuli, speech, perception and memory.

2. Cerebellum: The cerebellum is located at the lower back of the head and is also divided into two hemispheres. It is the second largest structure of the brain and contains more than half of the brain neurons. The cerebellum is one of the sensory areas of the brain that is responsible for motor control, sensory perception and co-ordination. The cerebellum is also associated with voluntary muscle movements, fine motor skills, and posture and balance regulation.
3. Brainstem: The brainstem is located at the bottom of the brain and connects the cerebrum to the spinal cord. The brainstem is like a hard drive of a computer and it is the main control panel of the body. It controls vital functions of the body, including breathing, consciousness, movements of the eyes and mouth, and the relaying of sensory messages (pain, heat, noise etc), heartbeat, blood pressure and hunger. (11)

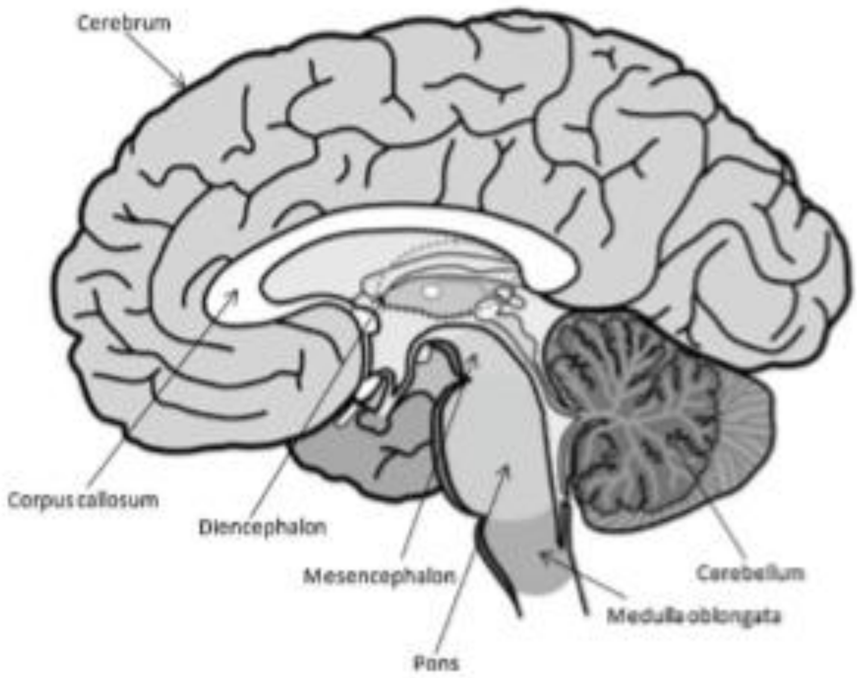

Figure 0.1 Brain anatomy (2)

3.3 Human brains' neurophysiology

The human brain consists of about 100 billion nerve cells called neurons and the electrical charge of the brain is maintained by these neurons. Neurons share the same characteristics and have the same parts as other cells, but the electrochemical aspect lets them transmit electrical signals and pass messages to each other over long distances. Neurons have three basic parts: cell body (soma), axon and dendrites.

The cell nucleus is the heart of the cell, providing it with instructions on what to do. The axon is a long, slender portion of the neuron that connects the nucleus of its own neuron to the dendrite of another. The dendrite is a short section of the neuron with many receptor sites for neurotransmitters that may be sent by a paired axon. Dendrites can be located on one or both ends of the cell. Through the axon-dendrite link, neurons can communicate between each other. This communication is made possible through the action potential.

The action potential is an event where the ion pumps along the outside of an axon rapidly changing the ionic makeup of the axon, allowing an electrical signal to travel quickly through the axon to the next dendrite. As a result of this rapid change in ionic charge, a voltage is generated both on the inside and the outside of the cell membrane of the neuron. These neurons emit a chemical which is sent to another neuron through the synapse, i.e. the gap between the neurons, in order to trigger an activity. The chemicals sent from one neuron to another to trigger it are known as neurotransmitters. The inter-neuron communication system is depicted in Figure 3,2. (11)

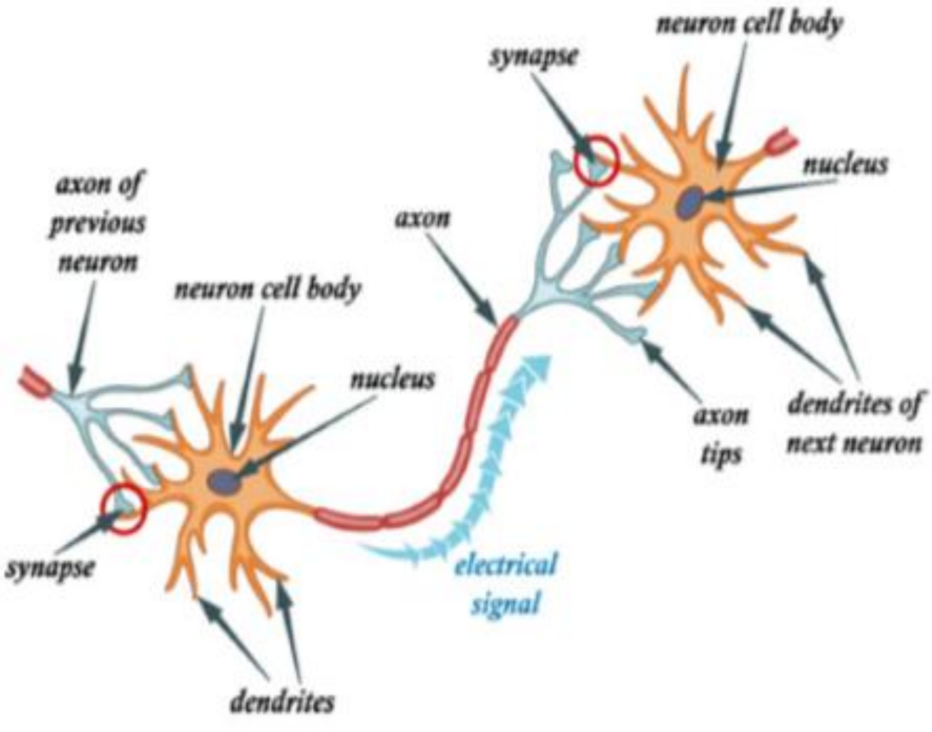

Figure 0.2 A simple structure of neuron (9)

3.4 Electroencephalography (EEG)

Electroencephalography (EEG) is a measurement of potentials that reflect the electrical activity of the human brain. It is a readily available test that provides evidence of how the brain functions over time. The EEG is widely used by physicians and scientists to study brain functions and to diagnose neurological disorders. The study of the brain electrical activity, through the EEG records, is one of the most important tools for the diagnoses of neurological diseases, such as epilepsy, brain tumor, head injury, sleep disorder, dementia and monitoring depth of anesthesia during surgery etc. It may also be recommended for the treatment of abnormalities, behavioral disturbances (e.g. Autism), attention disorders, learning problems, language delay etc. (11)

3.5 Brain Wave Patterns

The EEG is typically described as rhythmic activity and is divided into bands by frequency, they are called wave patterns and these patterns within a certain frequency range were noted to have a certain biological significance or a certain distribution over the head. Different types of wave patterns are indicatedin Figure3.3. (1)

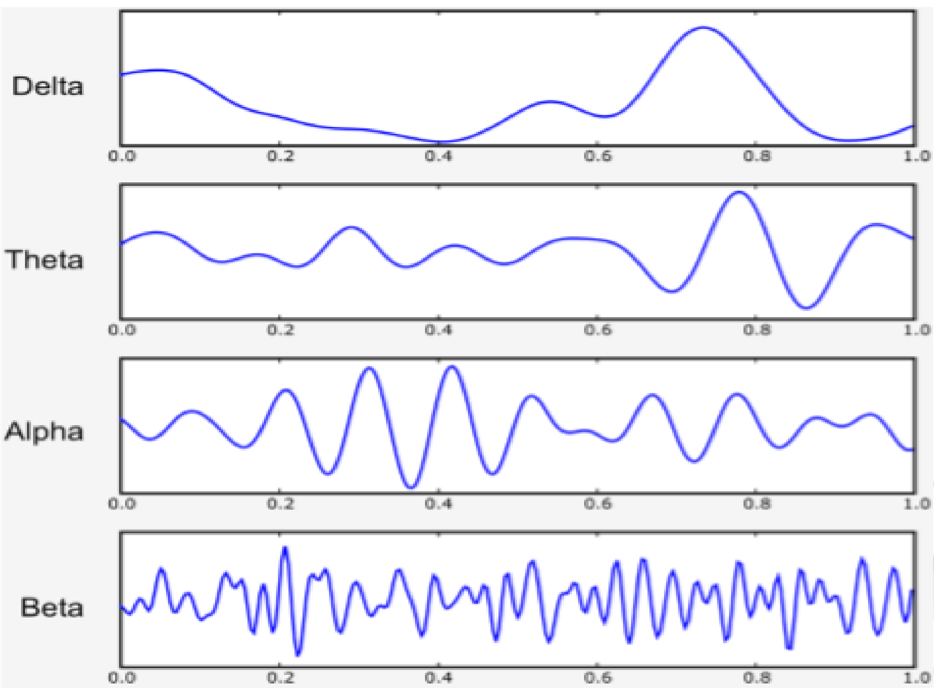

Figure 0.3 EEG wave patterns (1)

3.5.1 Delta Waves

Delta is the frequency range up to 4 Hz depicted in Figure 3.3. It is known as slowest waves and its amplitude is the highest among other waves. It may occur in general distribution with deep mid line lesions, diffuse lesions and focally with sub cortical lesions.(1)

3.5.2 Theta Waves

Theta is the frequency range from 4 Hz to 7 Hz depicted in Figure3.3 Normally it is seen in young children, in meditation, may be seen in arousal in older children and adults, and in drowsiness. It can be seen as a focal disturbance in focal sub cortical lesions, also it is formed in person of relaxed, meditative, and creative states. It may be seen in diffuse disorder or deep midline disorders or metabolic encephalopathy or some instances of hydrocephalus. Excess theta for age shows abnormal activity. (1)

3.5.3 Alpha Waves

Alpha is the frequency range from 8 Hz to 12 Hz depicted in Figure 3.3. Hans Berger who initiated the study of rhythmic activity and he named it as "alpha wave". This is EEG activity in the 8–12 Hz frequency range seen in the posterior regions of the scalp on both sides of the brain and higher in amplitude on the dominant side. Closing the eyes and relaxation are the main situation of this activity and this rhythm is actually slower than 8 Hz in young children(1).

3.5.4 Beta Waves

Beta is the frequency range from 12 Hz to 30 Hz depicted in Figure 3.3. It is seen mainly on both sides and is most evident frontally. This activity is mostly happening during motor behavior and is attenuated due to active movements. Active, busy or anxious thinking and active concentration are the main reasons for this activity and it is low amplitude with multiple and varying frequencies. Sometimes rhythmic beta is associated with drug effects and various pathologies, especially benzodiazepines. Beta is the dominant rhythm in patients who are anxious or alert or who have their eyes open and may be reduced or even absent in areas of cortical damage**.**(1)

3.5.5 Mu rhythms

Mu rhythm is alpha frequency range activity that is normally seen over the sensor motor cortex is depicted in Figure 3.4. It attenuates with movement of the arm or motor imagination of movement of the arm. (1)

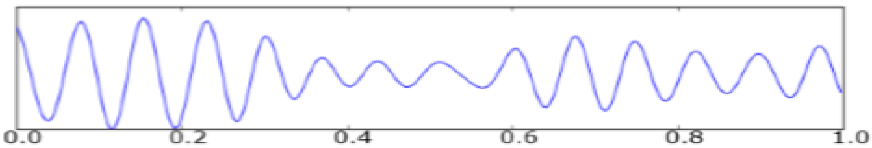

Figure 0.4 Mu rhythm wave pattern (1)

3.5.6 Gamma Waves

Gamma is the frequency range approximately 30–100 Hz is depicted in Figure3.5. Gamma rhythms are thought to attenuate with sudden motor sensory stimuli.

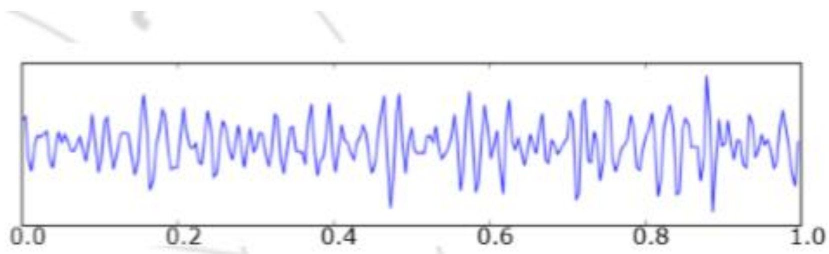

Figure 0.5 Gamma wave pattern (1)

Out of these wave patterns, we use the beta and Mu rhythms in the proposed system. Because these signals are produced in brain while thinking of movement actions such as left, right hand movements or movement of tongue and legs etc.(1)

3.6 BCI types

3.6.1 Invasive BCI Acquisition Techniques

In invasive BCI techniques, special devices have to be used to capture the brain signals. Such devices are called Invasive BCI devices; devices that are based on detecting from single area of brain cells is called single unit while the detection from multiple areas is called multi-units. Invasive BCI devices are inserted directly into the human brain by a critical surgery. (2)

3.6.2 Partially Invasive Brain Computer Interfaces

Partially invasive BCI devices are implanted inside the skull but rest outside the brain rather than within the grey matter. Signal strength using this type of BCI is bit weaker when it compares to Invasive BCI. (10)

3.6.3 Non Invasive Brain Computer Interfaces

Noninvasive brain computer interface has the least signal clarity when it comes to communicating with the brain (skull distorts signal) but it is considered to be very safest when compared to other types. This type of device has been found to be successful in giving a patient the ability to move muscle implants and restore partial movement. Non-Invasive technique is one in which medical scanning devices or sensors are mounted on caps or headbands read brain signals. (10)

3.7 BCI System

BCI system built up from sequence processes that contain six levels: signal acquisition, preprocessing, feature extraction, classification, translation into a command and feedback.

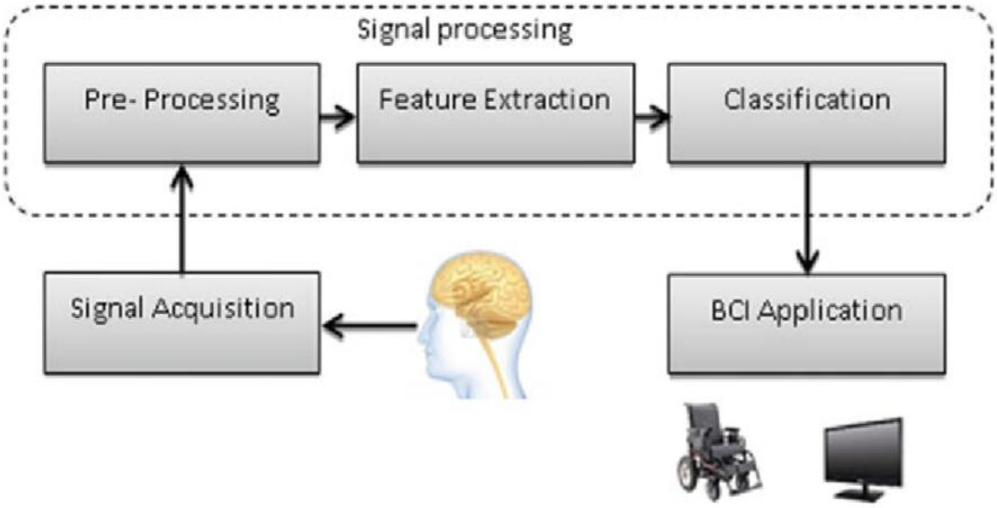

Figure 0.6 BCI signal processing (2)

3.7.1 Signal acquisition

Measuring brain activity effectively is a critical step for BCI communications. Human intentions modulate the electrical signals which are measured using various types of electrodes and then these signals are digitized, we use EEGs as the measurement of brain activities. (11)

3.7.2 Feature extraction

The original EEG signal is time domain signal and the signal energy distribution is scattered. The signal features are buried away in the noise. In order to extract the features, the EEG signal is analyzed to give a description of the signal energy as a function of time or/and frequency. Features are extracted from signals using several methods: Time Analysis, Frequency Analysis, Time- Frequency Analysis and Time Frequency-Space Analysis. Based on previous studies, features extracted in frequency domain are one of the best to recognize the mental tasks based on EEG signals. (12)

3.7.2.1 Wavelet transform

In most Digital Signal Processing (DSP) applications, the frequency content of the signal is very important. The Fourier Transform is probably the most popular transform used to obtain the frequency spectrum of a signal. But the Fourier Transform is only suitable for stationary signals, i.e., signals whose frequency content does not change with time. The Fourier Transform, while it tells how much of each frequency exists in the signal, it does not tell at which time these frequency components occur.

Signals such as image and speech have different characteristics at different time or space, i.e., they are non-stationary. Most of the biological signals too, such as, Electrocardiogram, Electromyography, etc., are non-stationary. To analyze these signals, both frequency and time information are needed simultaneously, i.e., a time-frequency representation of the signal is needed.

To solve this problem, the Short-Time Fourier Transform (STFT) was introduced. The major drawback of the STFT is that it uses a fixed window width. The Wavelet Transform, which was developed in the last two decades, provides a better time-frequency representation of the signal than any other existing transforms. (3)

3.7.2.2 DWT

The wavelet transform has achieved widespread acceptance in signal processing and image processing. The discrete wavelet transform (DWT) has been established as a highly flexible and efficient method for subband decomposition of signals. At present, DWT considered as a key operation in EEG signal processing. DWT of an EEG signal are calculated by passing it through a series of filters. The EEG samples are passed through a low pass and a high pass filter simultaneously, giving detail coefficients and approximation coefficients as outputs. According to Nyquist's rule half the samples can be discarded because half the frequencies of the signal have been removed in the above process. (1)

Discrete wavelet transform can be implemented as a set of filter banks comprising a high-pass and a low- pass filters, each followed by down sampling by two. The low-pass filtered and decimated output is recursively passed through similar filter banks to add the dimension of varying resolution at every stage. This is mathematically expressed:

$$DWDT_{x(n)} = \begin{cases} d_{j,k} = \sum x(n) h_j^*\left(n - 2^j k\right) \\ a_{j,k} = \sum x(n) g_j^*\left(n - 2^j k\right) \end{cases}$$

The coefficients aj,k and dj,k refer to the approximation and detail components in the signal, respectively. The functions h(n) and g(n) in this equation represent the coefficients of the high-pass and the low-pass filters. (13)shown in Figure 3.7.

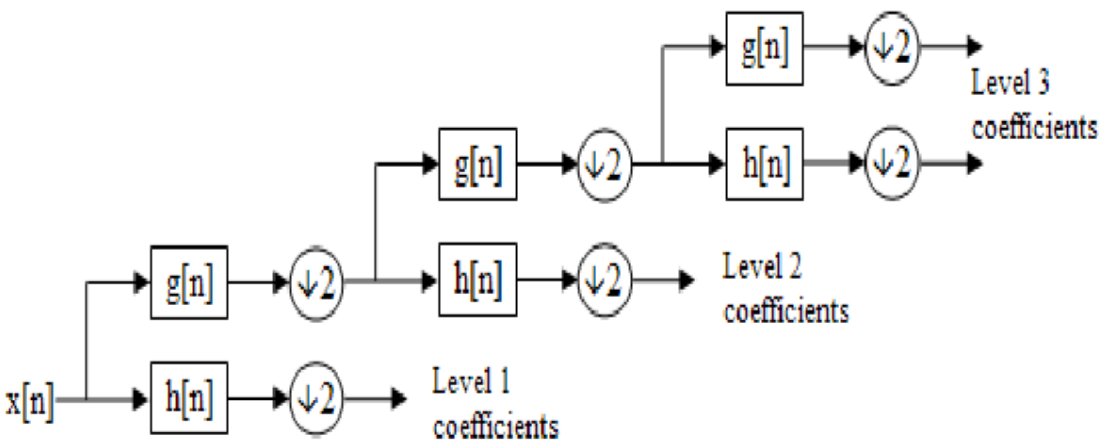

Figure 0.7 Block diagram of DWT (9)

3.7.3 Classification

It translates the extracted signal features into device commands orders that carry out the user's intent. The signals are classified on both frequency and on their shape; the classification algorithm might use linear methods or nonlinear methods

3.8 FPGA (field programmable gate array)

FPGA provide the next generation in the programmable logic devices. The word Field in the name refers to the ability of the gate arrays to be programmed for a specific function by the user instead of by the manufacturer of the device. The word Array is used to indicate a series of columns and rows of gates that can be programmed by the end user.

As compared to standard gate arrays, the field programmable gate arrays are larger devices. The basic cell structure for FPGA is somewhat complicated than the basic cell structure of standard gate array.

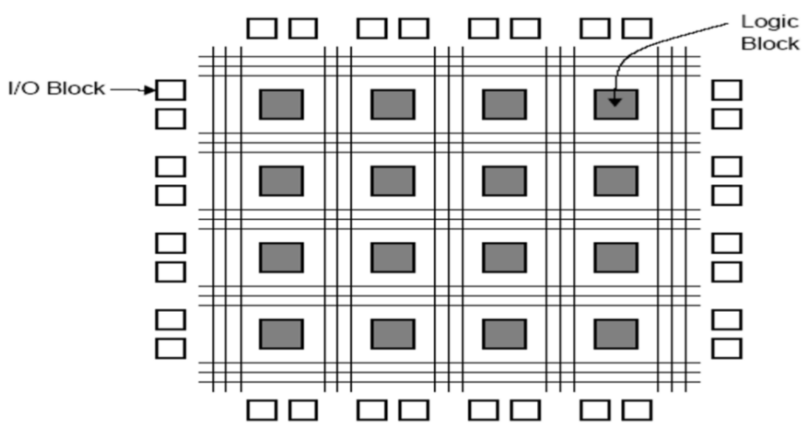

Figure 0.8 FPGA internal structure (14)

The FPGA devices are customized by loading configuration data into internal memory cells. The FPGA device can either actively read its configuration data out of an external serial or byte-wide parallel PROM (master modes), or the configuration data can be written to the FPGA devices (slave and peripheral modes).

FPGAs are programmable logic devices made up of arrays of logic cells and routing channels. They have ASIC characteristics such as reduced size and power dissipation, high throughput, etc., with the added advantage that they are reprogrammable. Therefore, new features can be easily added and they can be used as a tool for comparing different architectures. Currently, Altera Corporation and Xilinx Corporation are the leading vendors of programmable devices. The architecture of the FPGAs is vendor specific. Among the mid-density programmable devices, Altera's FLEX 10K and Xilinx XC4000 series of FPGAs are the most popular ones. They have attractive features which make them suitable for many DSP applications. FPGAs contain groups of programmable logic elements or basic cells. The programmable cells found in Altera's devices are called Logic Elements (LEs) while the programmable cells used in Xilinx's devices are called the Configurable Logic Blocks (CLBs). The typical design cycle for FPGAs using Computer Aided Design (CAD) tools is shown in figure 4.1.

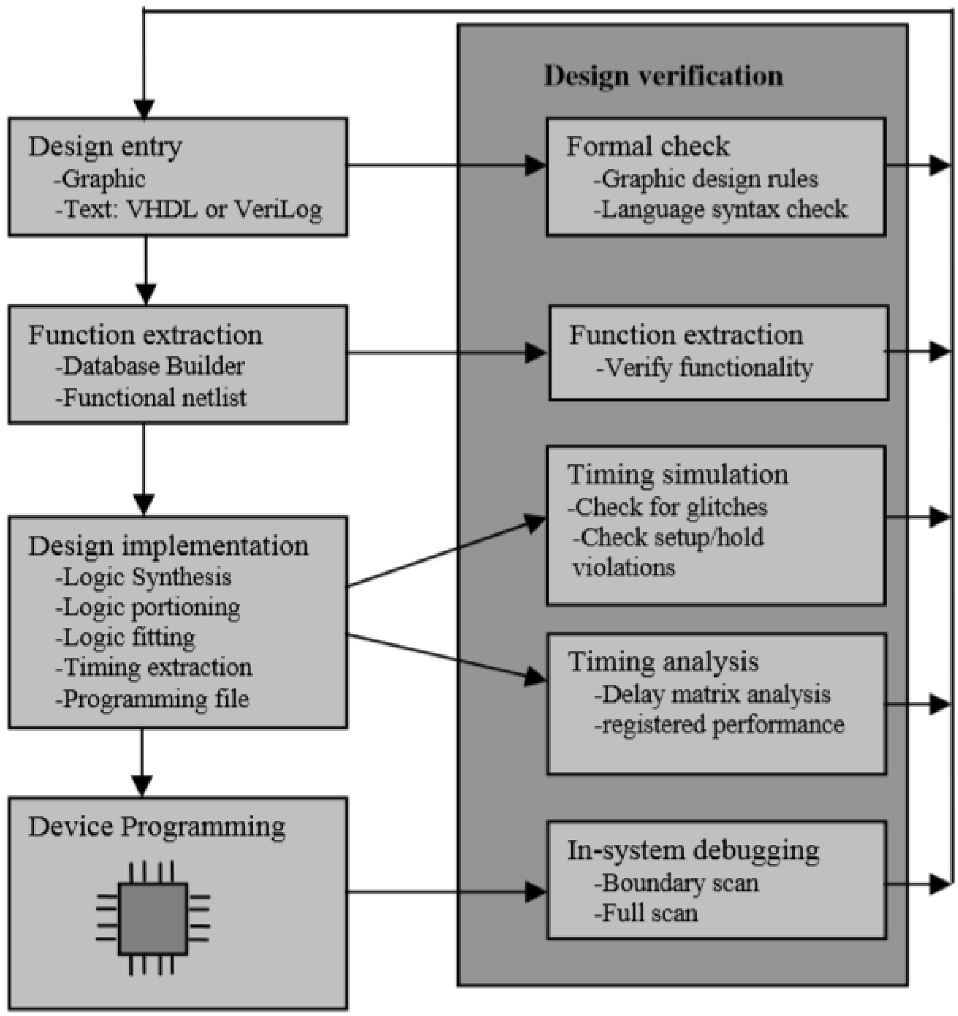

Figure 0.9 CAD design cycle (10)

The design is first entered using graphic entry or text entry. In the next stage the functionality of the design is extracted. Then the design is targeted on a selected device and its timing is extracted. Finally the actual hardware device is programmed. At every stage the appropriate verification is done to check the working of the design. For design entry, text is preferred as it allows more control over the design compared to graphic design entry. (3)

3.9 SPARTAN-3E:

The S3Kit is a stand-alone board for experimenting and developing prototypes withFPGAs using Xilinx FPGA architecture. The S3Kit has many features that facilitate experimentation in reconfigurable logic design as well as the general rapid prototyping of digital logic (15)

The Spartan 3 Development Kit provides a platform for engineers designing with the Xilinx Spartan3 FPGA. The board provides the necessary hardware to not only evaluate the features of the Spartan 3 but also to implement complete user applications (16).

3.10Xilinx ISE simulation design suite

Xilinx ISE (Integrated Synthesis Environment) is a software tool produced by Xilinx for synthesis and analysis of HDL designs, enabling the developer to synthesize ("compile") their designs, perform timing analysis, examine RTL diagrams, simulate a design's reaction to different stimuli, and configure the target device with the programmer.

Xilinx ISE is a design environment for FPGA products from Xilinx, and is tightly-coupled to the architecture of such chips, and cannot be used with FPGA products from other vendors (17)

3.11MATLAB

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming environment. Furthermore, MATLAB is a modern programming language environment: it has sophisticated data structures, contains built-in editing and debugging tools, and supports object-oriented programming. These factors make MATLAB an excellent tool for teaching and research. MATLAB has many advantages compared to conventional computer languages (e.g., C, FORTRAN) for solving technical problems. MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. The software package has been commercially available since 1984 and is now considered as a standard tool at most universities and industries worldwide. It has powerful built-in routines that enable a very wide variety of computations. It also has easy to use graphics commands that make the visualization of results immediately available. Specific applications are collected in packages referred to as toolbox. There are toolboxes for signal processing, symbolic computation, control theory, simulation, optimization, and several other fields of applied science and engineering. (18)

3.12SIMULINK

SIMULINK is an environment for simulation and model-based design for dynamic and embedded systems. It provides an interactive graphical environment and a customizable set of block libraries that let you design, simulate, implement, and test a variety of time-varying systems, including communications, controls, signal processing, video processing, and image processing. (19)

3.13Wheelchair

There is a vast development in the field of wheelchairs. Out of all the methodologies, HCI (Human Computer Interface) and HMI (Human Machine Interface) are the latest and most effective techniques. In user interface systems both bio-signals and non bio-signals are used as a medium of control. Bio-signal based devices mainly use bio-signals like EEG, EOG or EMG as control signals. The bio-signal based approach is used for completely paralyzed patients who can only use their bio-signals as the only resource to control. (20)

3.13.1 EEG based

The Electroencephalography (EEG) records electrical brain signals from the scalp, where the brain signal originates from post-synaptic potentials, aggregates at the cortex, and transfers through the skull to the scalp. BCI is a device that extracts EEG data from brain and converts it into device control commands using signal processing techniques. EEG techniques are non-invasive and low cost. However, it brings great challenges to signal processing and pattern recognition, since it has relatively poor signal-to-noise ratio and limited topographical resolution and frequency range (20)

4 Chapter four

Methodology

This system is proposed to connect brain with electronic device. It consists of three levels between the input signal and output command as shown in Figure 4.1.

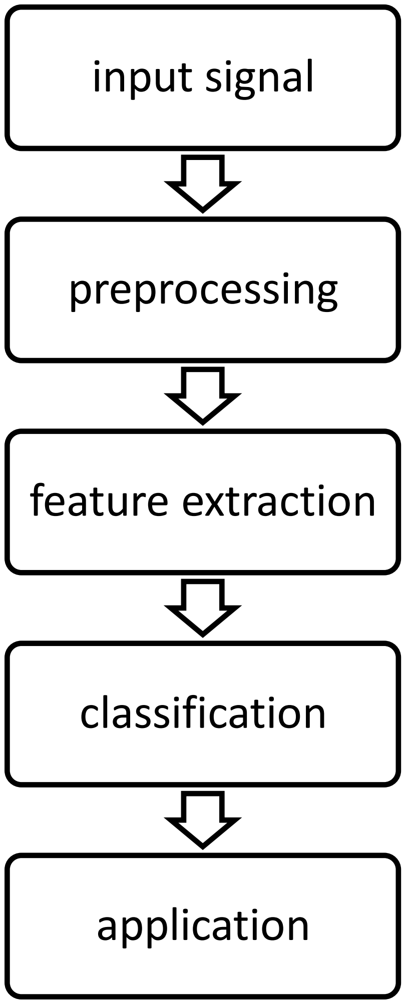

Figure 0.1 proposed system

Before starting of designing the system; MATLAB should connected with ISE application, then the suitable version of MATLAB was installed to match the available version of ISE.

We found that only MATLAB (R2010a) and (R2011a) could connected to ISE14.7

In MATLAB, there are the customizable block libraries and solvers for modeling and simulating dynamic systems. It can make the blocks and exports simulation results to MATLAB for the further analysis. (21)The blocks which are required are discussed below.

1. The 'Xilinx system generator' is a high level tool for designing high-performance DSP systems using FPGAs. The system generator tool enables us to integrate Xilinx with Simulink; it creates an .ISE file which is used in Xilinx using the model file of Simulink. (21)

2. Xilinx block sets works only in the gateway blocks, i.e. gateway-in and gateway-out. Any sample based input is given to the gateway-in block; the output can be seen on the scope by passing through the gateway out block. (21)

3. FDA Tool is the important tool of MATLAB which is used to design the filter of required specification. There are different responses (i.e. High pass, Low pass, Band pass, Band stop, Differentiator, Integrator, etc) and Design method (i.e. IIR, FIR) for implementing the filter. By placing the filter order, frequency specifications and magnitude specifications, windows can be customized. Tools create coefficients in the MATLAB workspace in matrix form through the specifications provided. (21)

4.1 Input signal

Firs level is input signal; the input signal that is used in the system is from BCI COMPETITION IV. Have this description:

This data set consists of EEG data from 9 subjects. The cue-based BCI paradigm consisted of four different motor imagery tasks, namely the imagination of movement of the left hand (class 1), right hand (class 2), both feet (class 3), and tongue (class 4).Two sessions on different days were recorded for each subject. Each session is comprised of 6 runs separated by short breaks. One run consists of 48 trials (12 for each of the four possible classes), yielding a total of 288 trials per session. At the beginning of each session, a recording of approximately 5 minutes was performed to estimate the EOG influence. The subjects were sitting in a comfortable armchair in front of a computer screen. At the beginning of a trial (t = 0s), a fixation cross appeared on the black screen. In addition, a short acoustic warning tone was presented. After two seconds (t = 2s), a cue in the form of an arrow pointing either to the left, right, down or up (corresponding to one of the four classes left hand, right hand, foot or tongue) appeared and stayed on the screen for 1.25s. This prompted the subjects to perform the desired motor imagery task. No feedback was provided. The subjects were ask to carry out the motor imagery task until the fixation cross disappeared from the screen at t = 6s. A short break followed where the screen was black again. The paradigm is illustrated in Figure 4.2.

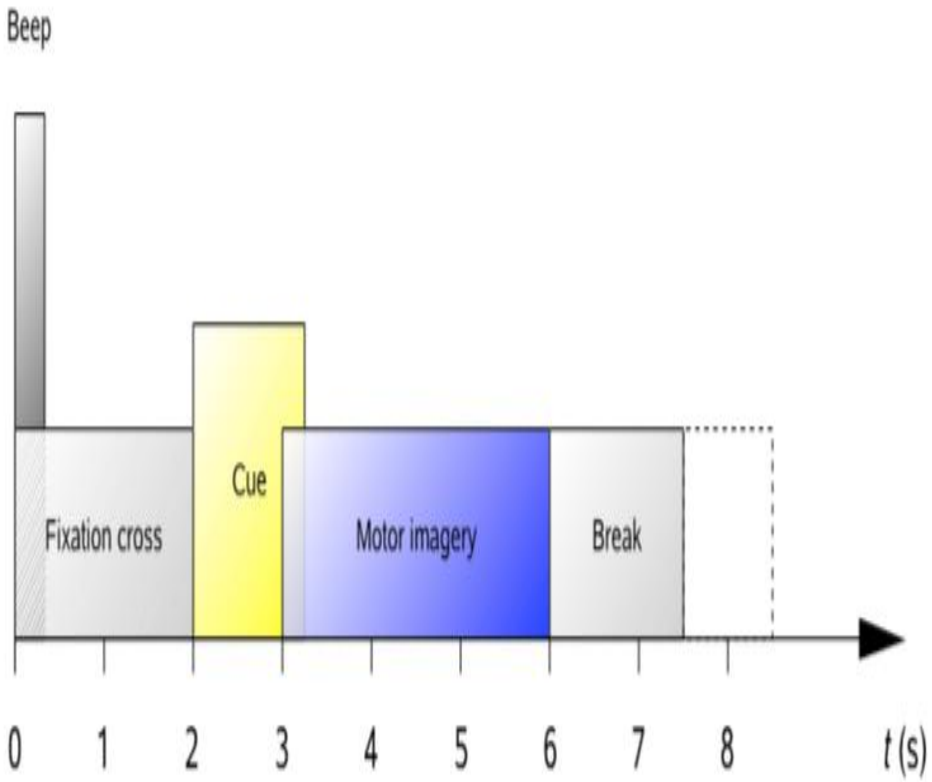

Figure 0.2 Timing scheme of the paradigm

The data set have been filtered to remove the noise using FIR filter. (22)

One of these data has been chosen randomly to apply it in the system; here A01E has been chosen. The code that loads the signal into MATLAB has been generated; as shown below as Figure 4.3.

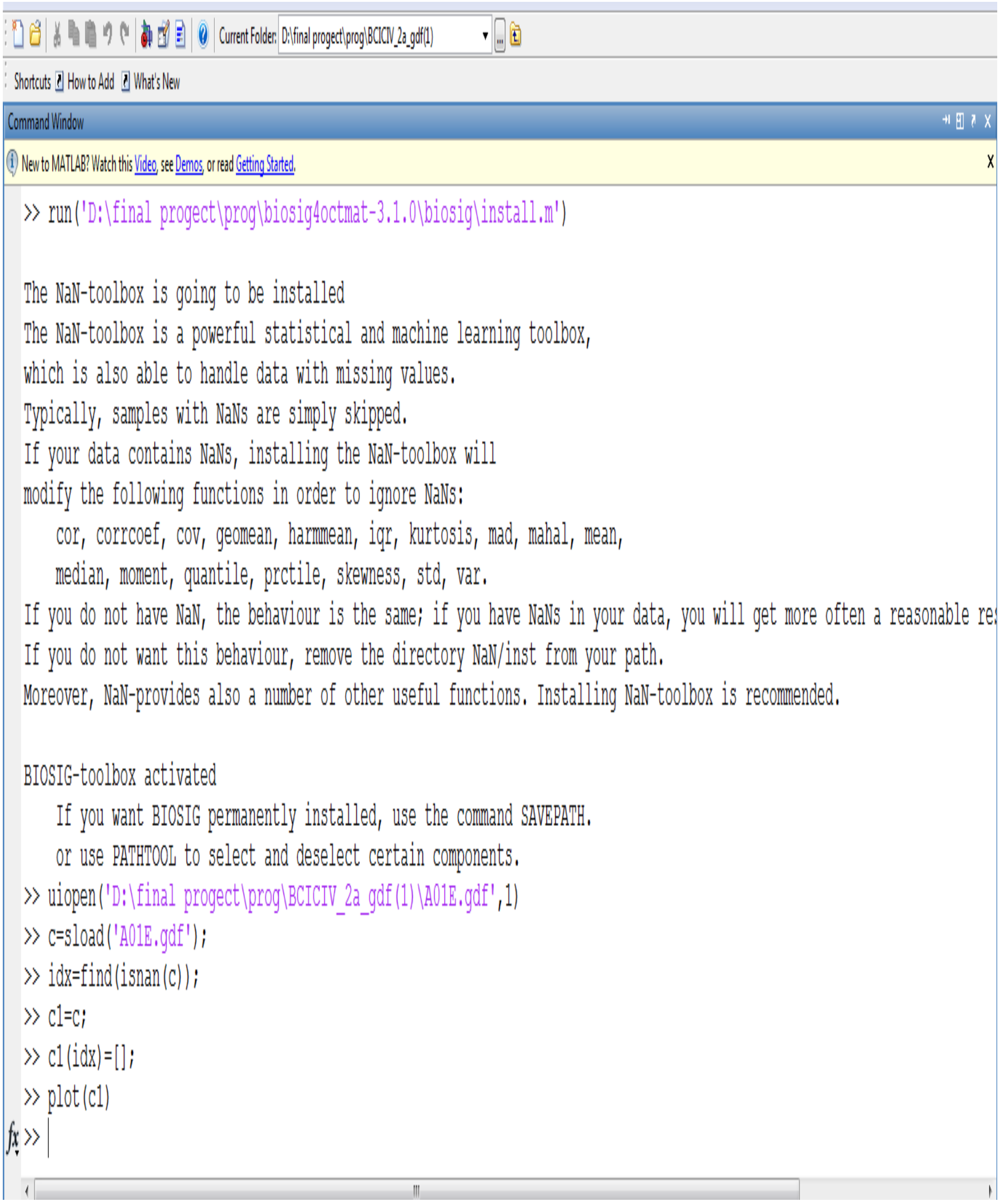

Figure 0.3 MATLAB loading signal code

4.2 preprocessing

In this level the signal was filtered by band pass FIR filter to obtain Beta range (12Hz-30Hz). Beta range is mostly happening during motor behavior. This level was designed as shown as Figure 4.4.

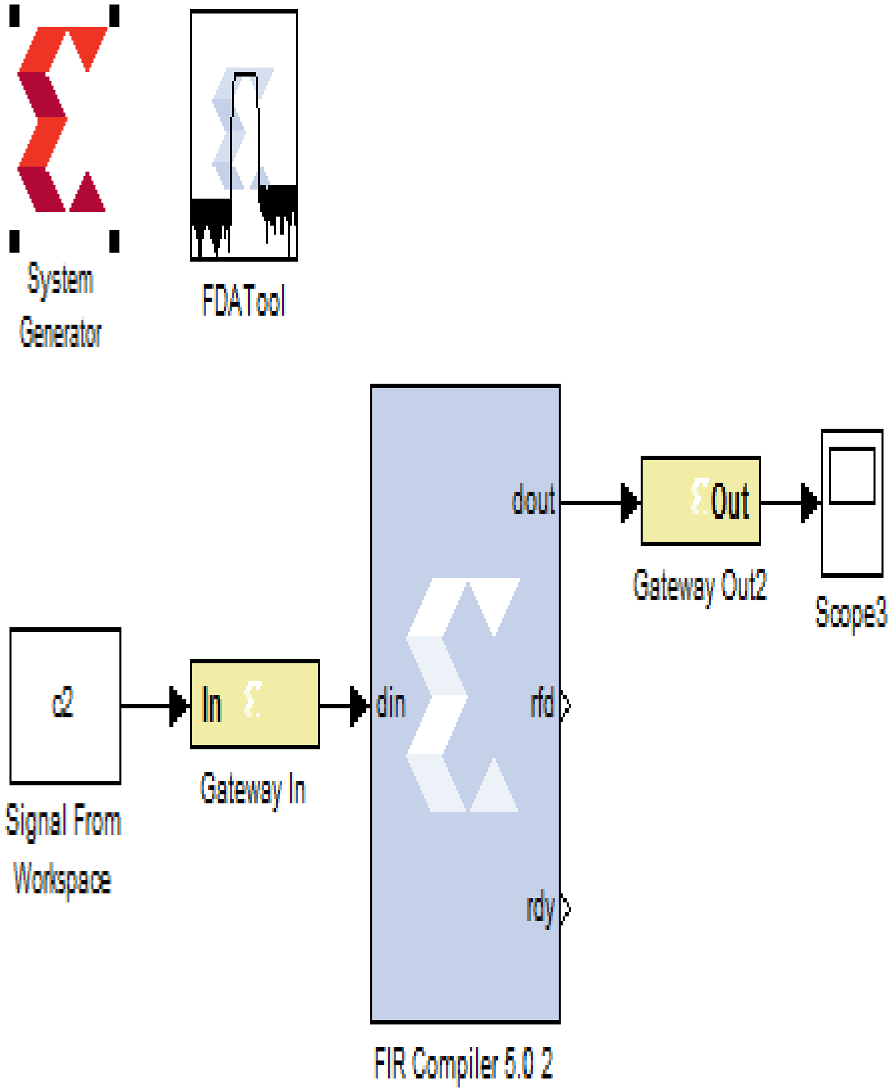

Figure 0.4 SIMUINK scheme of band pass filter

4.3 Feature extraction

The third level is feature extraction process, the system was designed to obtain the required feature from the signal using DWT,The discrete wavelet transform (DWT) has been established as a highly flexible and efficient method for sub-band decomposition of signals.2 level DWT was designed as shown in Figure 4.5 below

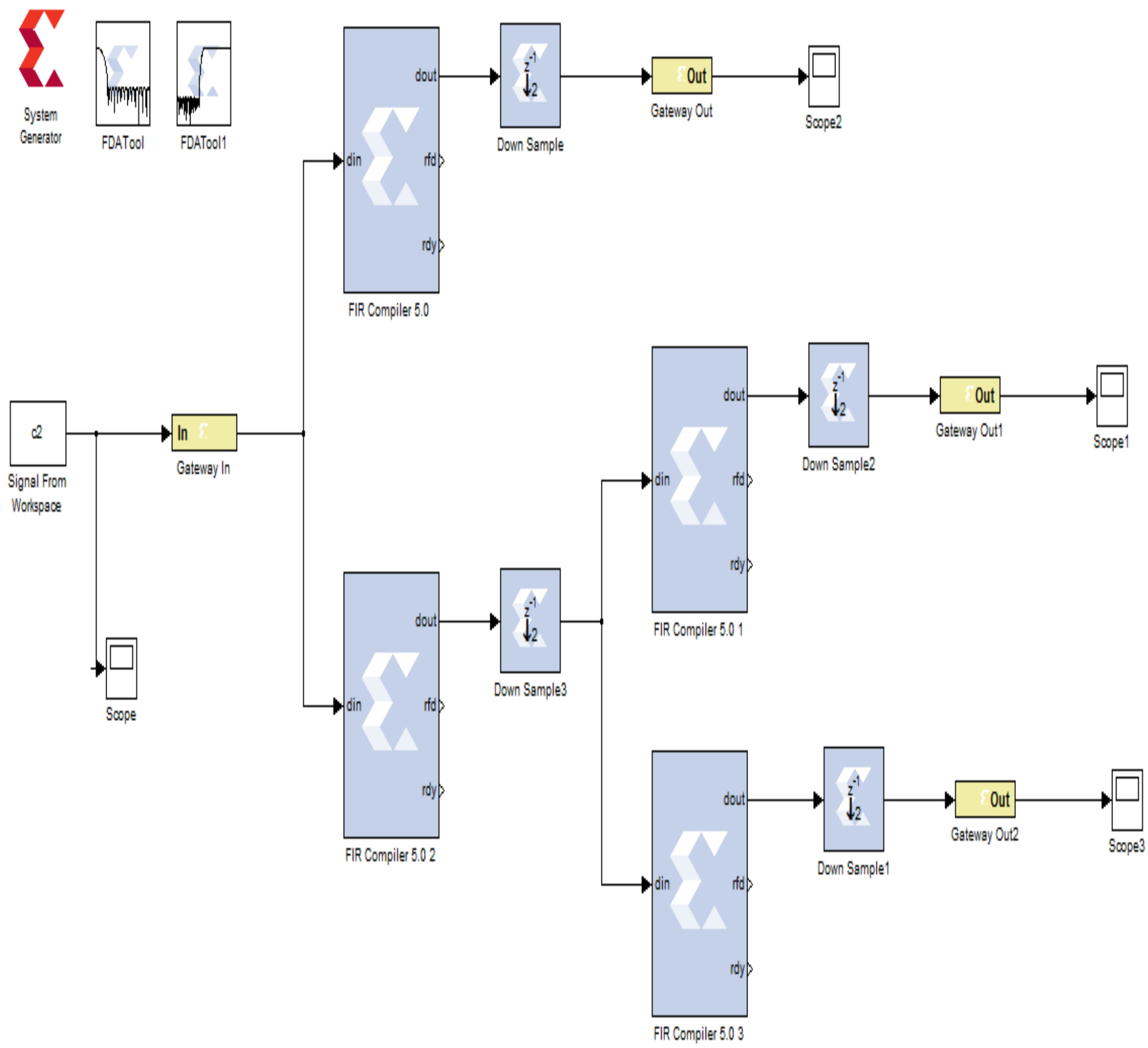

Figure 0.5 SIMUINK scheme of two levels DWT

5 Chapter five:

Results

EEG signal (A01E) is plotted:

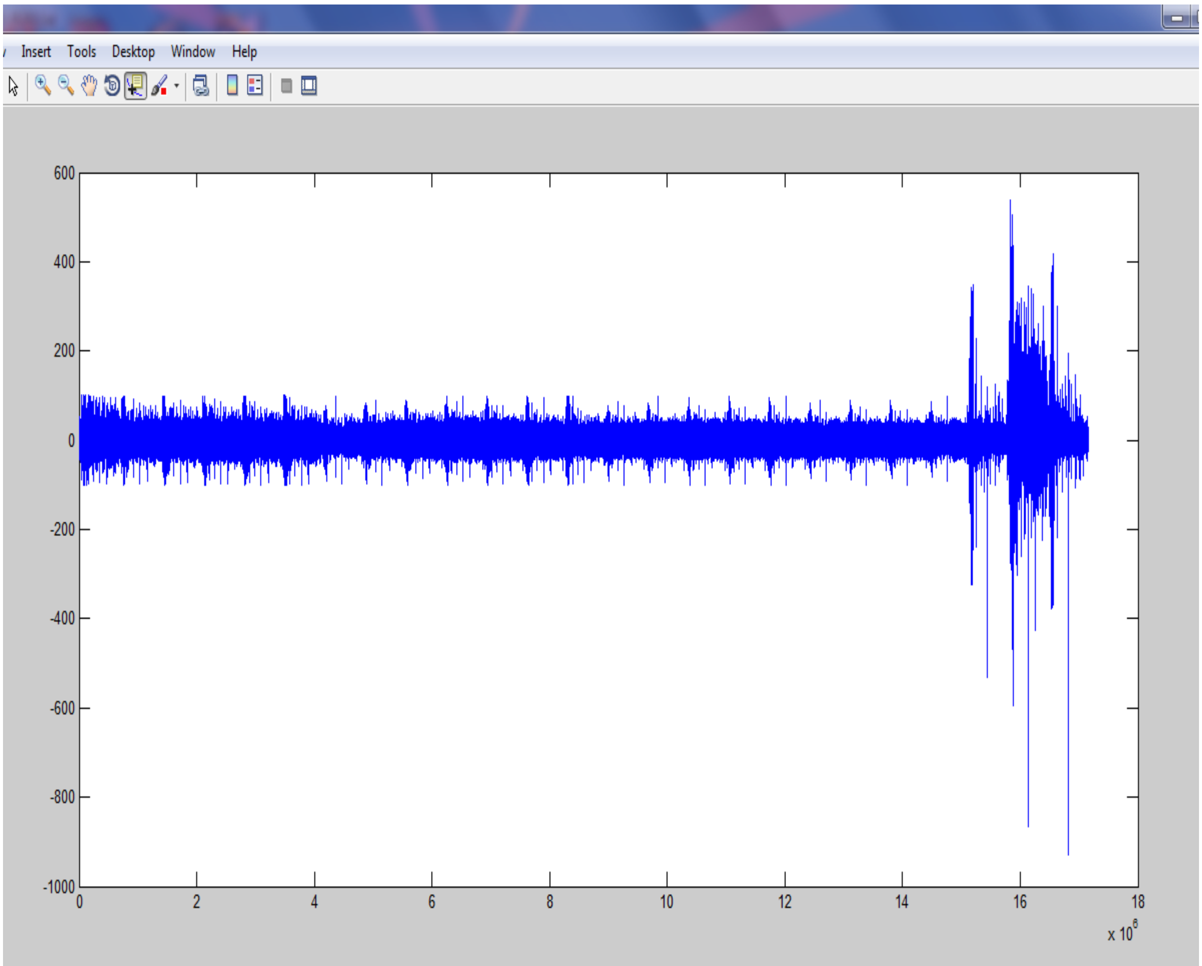

Figure 0.1plotting of A01E Signal

The result after preprocessing:

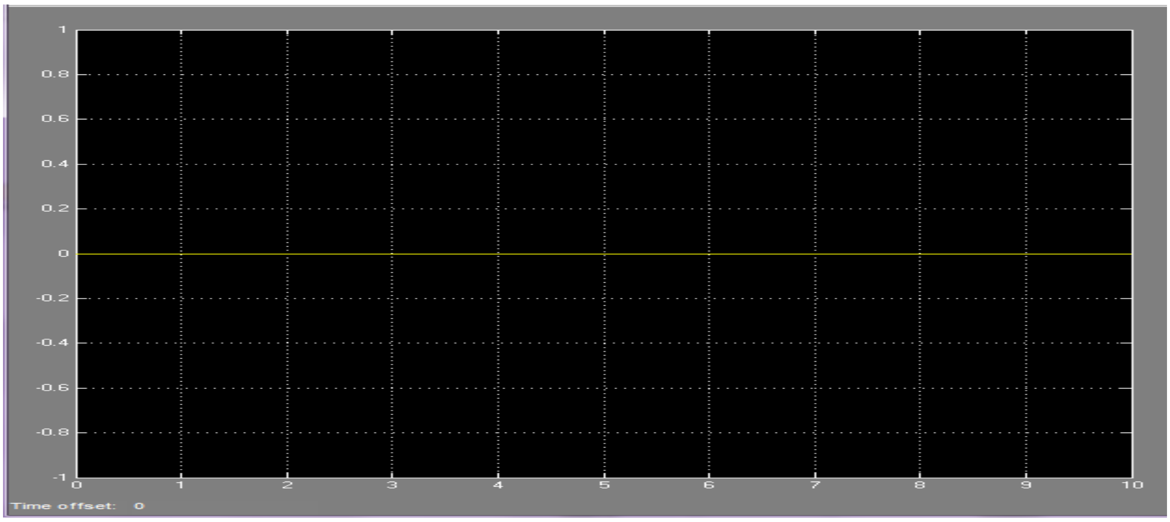

Figure 0.2 the output of preprocessing

Unfortunately the result that was got from the preprocessing is zero value; that's because of FIR filter coefficients; they are needed to adjusted with suitable values. So the other results will be zero.

6 Chapter six

Conclusion and Recommendation

6.1 Conclusion

This work faced a number of challenges some of which are mentioned below; getting and connecting ISE program with suitable version of MATLAB, SIMULINK blocks are inflexible to compatible with EEG signal and the complexity of EEG signal.

This work can be extended to analyze the EEG signal that leads to control some devices like wheelchair video games,and Rehabilitation parts.

6.2 Recommendations

- FIR filter block needs to adjust accurately to get desired output that should be entered to DWT feature extraction system.
- Design classification system totranslate the extracted signal features into device commands orders that carry out the user’s intent.
- After completing of whole design; the blocks should be converted into VHDL code which will program the FPGA chip.

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