بسم الله الرحمن الرحيم

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Wireless Based Portable EOG Monitoring For Real Time Drowsiness Detection

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الاهداء

الى كل من اشعل شمعة في دروب عملنا

والى كل من وقف على المنابر واعطى من حصيلة فكره لينير طريقنا

الى والدي العزيزين الذين لم يبخلا علي بدعائهما الجميل فلولا دعائهما ومساعدتها لما وصلت الى هذه المرحلة

الى زوجي الغالي رفيق دربي والذي كان خير سند لي بكل خطوة اخطوها

الى اخوتي واخواتي

الى الاساتذة الكرام ونتوجه بالشكر الجزيل الى

المهندس

احمد قديمات

الذي تفضل بالاشراف علينا على هذا البحث فجزاه الله عنا كل خير فله منا كل تقدير واحترام

Abstract

Drowsiness is one of the major risk factors causing accidents that result in a large number of damage. Drivers and industrial workers ,who do not take regular breaks when driving or work for long time probably have a large effect on several mishaps occurring from drowsiness.

Therefore, advanced technology to reduce these accidental rates is a very challenging problem.

The purpose of this project is to develop a portable wireless device that can automatically detect the drowsiness in real time by using the electrooculogram (EOG).

These include the mechanism that take the dynamic signal of the eye and turn it into an electrical signal through electrodes placed around the eye to monitor the eye movement. The signal was sent via the wireless communication of zigbee to a standalone microcontroller to analyze drowsiness using Convolutional Neural Networks .The alarm will ring when the drowsiness occurs. Such application is helpful to reduce losses of casualty and property.

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CHAPTER ONE

Introduction

Chapter contents

1.1 Overview

This chapter focuses on the main idea of the project that relate to eyes movements ,drowsiness detection, as well as the aims of the project and the previous work related to the project.

1.2 Motivation

Millions people are killed in road crashes every year, and as many as million are injured, this huge number of losses caused by several reasons, most of them caused by drowsiness during driving

Driver drowsiness detection is a car safety technology which prevents accidents when the driver is getting drowsy. This system based on evaluating Electrooculogram (EOG) signal, in order to prevent such state.

This system consists mainly of two parts, transmitting and receiving. Transmitting part involves acquiring the EOG signal ,amplifying and filtering circuit in order to process this signal, wireless transmitter. However, the receiving one contains wireless receiver ,microcontroller and alarm device.

1.3 Objectives:

The main objective of our project:

1) design and implementation EOG acquisition circuit .
2) Built wireless communication system .
3) extract the drowsiness state from electrooculogram signal Using artificial neural networks .

1.4 Previous Studies

1. **Development of Vehicle Driver Drowsiness Detection System Using Electrooculogram (EOG):**

driver drowsiness detection systems have been designed to detect and warn the driver of impending drowsiness. depending on the eye movements that can be detected through electrooculogram (EOG), which is the electrical signal generated by eye movements, is acquired by a mobile biosignal acquisition module. The recorded data were stored on a Personal Digital Assistant (PDA) connected to the acquisition module. Digital signal differentiation and simple information fusion techniques are used to detect signs of drowsiness in the EOG signal.[1]

2. EOG Based Low Cost Device for Controlling Home Appliances:

This project depends on the acquisition and analysis of EOG signals for activation of home appliances for paralysis patients. The method here uses a minimum number of electrodes for signal acquisition thereby reducing the occurrence of artifacts, further following a simple circuitry for implementation of signal conditioning.

The standing potentials in the eye can be estimated by measuring the voltage induced across a system of electrodes placed around the eyes as the eye-gaze changes, thus obtaining the EOG. And this EOG signal can be used as an input for a microcontroller in order to control home appliances[3].

3. Microcontroller Based EOG Guided Wheelchair

This project depends on eye controlled method to guide and control a wheel chair for disable people, based on Electrooculography (EOG).Which is sensing the eye signals for eye movements and these signals are captured using electrodes, signal processed such as amplification, noise filtering, and then given to microcontroller which drives the motors attached with wheel chair for propulsion.

a. Estimated cost and budget:

The initial cost of this project is about, distributed as follow:

Table 1.1:initial cost

Component	Required number	Price$
Electrodes	5	300
ICs	8	50
Resistors and capacitors		20
Microcontroller	2	150
Bluetooth	2	40

1.5 Time Table:

The project schedule will be divided into the following table (1.2) :

Table 1.1: project schedule

Week / Task	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Select the idea	■	■													
Preparing for the project and collecting information			■	■	■	■	■	■	■	■	■	■	■		
Project analysis				■	■	■									
Basic Design						■	■	■	■	■	■	■			
Writing documentation												■	■	■	■

1.6 Report contents:

The documentation of this project is divided into four chapters, each chapter describe a specific points in the project ,and these chapters are divided as follows:

chapter one : Introduction

This chapter focuses on the main idea of the project that relate to eyes movements ,drowsiness detection, as well as the aims of the project and the previous work related to the project.

chapter two: Background

This chapter contain the idea of our project which is analysis the EOG signal and detect the drowsiness, including the anatomy and the theory that require to realize the project.

Chapter Three : Project Design

This chapter include block diagram of the project ,explain each part in block diagram.

Chapter four : Implementation and Testing

This chapter discuss project hardware, processing and interfacing designed, each stage was explained and the calculation of these stage.

CHAPTER TWO

Back ground

Chapter contents

2.1 overview

To drive safely, it is necessary for the driver to handle the information from the surrounding traffic environment appropriately. This ability to perform correctly is deteriorated by drowsiness. for this reason we offer such application to decrease these number of accidents.

To recognize the concept of this we introduces in this chapter a detailed description of the Drowsiness, Possible Measures , Physiology and Anatomy of human eye, electrodes.

muscular movement noise, wireless communication and finally Convolutional neural networks (CNN).

2.2 Drowsiness

Drowsiness is a state of decreased awareness or alertness associated with a desire or tendency to fall in a sleep. Drowsiness is therefore the brain`s last step before falling asleep[4]. It is a normal and natural companion of fatigue but it does appear alone. Experts say, drowsiness during the day, even during boring activities, indicates a sleeping disorder.

Drowsiness very often leads to sleep. Five different stages of sleep can be identified, which all have their own characteristics. A drowsy driver is most certainly in the state of wakefulness or in the first stage of sleep. Wakefulness is characterized by a high tonic Electromyogram (EMG) in the facial muscles. Rapid eye movements (REM) and eye blinks are present. The sleep onset occurs between wakefulness and sleep. During a few minutes the sleep is characterized by very light sleep with slow eye movements (SEM) that can last several seconds.

According to several researchers SEM are characteristic indicators of the transition from wakefulness to sleep. Since SEM are easily distinguished they could in fact be a distinctive sign of drowsiness.

Categorization of drowsiness is difficult. Both a driver and an observer are able to rate the drowsiness from experienced and observed behavior. But this judgment is subjective and not an absolute method and the ratings can therefore not be put on a nominal scale. For absolute methods physiological measurements like for example Electroencephalogram (EEG), EMG or EOG are necessary.

2.3 Possible Measures

There are generally four different methods used to measure drowsiness: Physiological measures, behavioral measures, performance measures and self-report. As the names indicate, the methods are of different character and their validity differs according to their subjective or objective nature. This article concentrate on Physiological method by using self-report .

2.2.3 Self-report

one can ask a subject to self evaluate his/her levels of drowsiness. today there are many subjective sleepiness scales used today to describe the states of sleepiness . as an example of this scales is Karolinska Sleepiness Scale (KSS), Stanford Sleepiness Scale, and Visual Analog Scales

The main differences between these scales are the number of stages and how the level

of sleepiness is described in the stages, here KSS will be used

Karolinska Sleepiness Scale:

Karolinska Sleepiness Scale (KSS) is a subjective sleepiness scale used to describe the states of sleepiness, which focuses on detection of absolute levels of drowsiness. The scale contains nine levels from extremely alert to extremely sleepy. The KSS levels are shown in table (2,1) .

Table (2.1): Karolinska Sleepiness Scale

Levels	**Descriptions**
1	extremely alert
2	very alert
3	Alert
4	Rather alert
5	neither alert nor sleepy
6	some signs of sleepiness
7	sleepy, but no effort to keep alert
8	sleepy, some effort to keep alert
9	very sleepy, great effort to keep alert, fighting sleep

2.3.1 Physiological method For Drowsiness Detection

In several tests, electroencephalogram (EEG) has been shown a good measure of drowsiness. By fixing electrodes to the scalp, alpha, beta and theta brain waves can be examined and the brain status from fully alert to falling asleep can be recognized. But the cost is still high when using EEG and uncomfortable in long-term monitoring, so EEG is unpractical to measure in the car and therefore more useful to use it as a reference, when calibrating other measures.

Other physiological measures are for example EOG and EMG. It seems natural to believe that sleep onset, the moment when a person falls asleep, is related to certain muscle activities. But muscles activities offer no predictive information to sleep onset. Sometimes muscle activities do not change until after several minutes of sleep So as a result it seem that the eye movements and the electrooculogram physiology are appropriate methods for detecting driver drowsiness since EOG signal's easiness to collect and immunization to slight noise, EOG based methods are considered as a compromise between accuracy and facility[4].

In order to realize what is the basis of electrooculogram physiology, we should be more contact with the Physiological structure of the human eye.

2.4 Physiology and Anatomy of human eye:

2.4.1 eyes muscles

The eye movements are controlled by three separate pairs of muscles , including the medial and lateral rectuc (it enables the eyeball to move from side to side) , the superior and Inferior rectus (it enables the eyeball to move upward or downward) and oplique muscles (operate mainly to rotate the eyeballs). Distribution of the muscles for controlling the two eyes is symmetrical.[3]

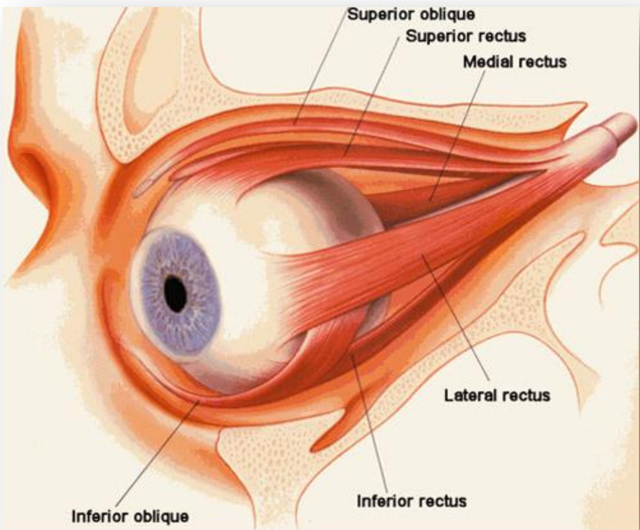

Figure 2.1 eye muscles[5]

Each of the three sets of muscles to each eye is reciprocally innervated, so that one muscle of the general , two types of the pair relaxes while the other contracts.

In general , two types of storied muscles are distinguished in the skeletal system

- red or dark muscles compared of fibers of small diameter and rich in sarcoplasm.
- pale or white muscles with fibers of greater diameter and scanty sarcoplasm.

Red muscles will contract more slowly and are kept in a state of tonic contraction by fewer Impulses per second than are white muscles, and their metabolism increases much less during contraction than that of white muscles . consequently , red muscles do not tire as easily as white muscles but red are more continuously active and serve the function of postural activity rather than the white muscles are muscles of that will be in the locomotion and quick activity.

2.4.2 Electrooculogram (EOG)

EOG has been found as a possible measure method for all different types of eyeball movements except for intra ocular movements.

EOG is an electrical signal generated by polarization of the eyeball ,The basis is the electrical potential difference between the front and back of the eye and can be measured on skin around the eyes by equipment commonly used in psychophysiological laboratories.

Its magnitude varies in accordance to the displacement of the eye ball from its resting location. EOG is a suitable tool for objective characterization of drowsiness. One advantage of EOG in comparison to other methods is the possibility to use a sufficiently high scan rate which is necessary for reliable recording of lid closure. Another advantage is the correspondence between EOG and the saccadic eye movements, which are the conjugate fast eye movements from one fixation point to the other.

2.4.3 Generation of the EOG Signal

The cornea in the front of the eye is electrically positive and the retina in the back is negative. This makes the eyeball a dipole. When electrodes are placed on the skin, any movement makes the poles come nearer to or farther away from those electrodes. If a person looks straight forward, a stable baseline potential is recorded. When the eyes move, potential changes are detected depending on the direction of the movements. EOG can be used to detect eye movements up to 70 degrees from central fixation and the accuracy is better than two degrees.

2.4.4 Measurement of EOG

EOG signal is measured by placing electrophysiology electrodes around the eyes. Two channel of bipolar EOG signal are acquired for analysis, which are the horizontal channel and vertical channel. The horizontal channel EOG reflects horizontal eyeball movements while the vertical channel EOG reflects vertical eyeball movements, but more importantly, vertical channel also records the eyelid movements (e.g. blinks). Two electrodes were placed above and below the right eye to measure vertical EOG while two other such electrodes were placed at the outer canthi to measure horizontal EOG. A fifth silver plated electrode was clipped on forehead, acting as a reference point, as shown in figure 2.2.

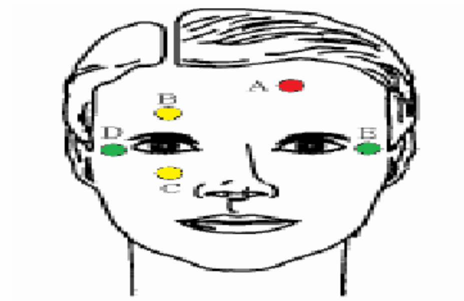

Figure 2.2 The electrodes placement

It can be seen in figure 2.3 that, if the electrical dipole orientation constituted by corneo retinal potential is perpendicular to the connection line of two EOG electrodes, the differential voltage between the electrodes would be zero and it will increase with the rotation of the eye. The

EOG may vary from µ100V to 500 µV for eye movements up to 70 degrees. However, when the eyes are moving, the potentials at the electrodes vary proportionally to the sine of eye's rotation angle, it can be as small as just some microvolt , the linearity becomes progressively worse for angles beyond 30 degree. When the muscles of the eyelids are moving, there will be a large change in the potentials around the eye.[5]

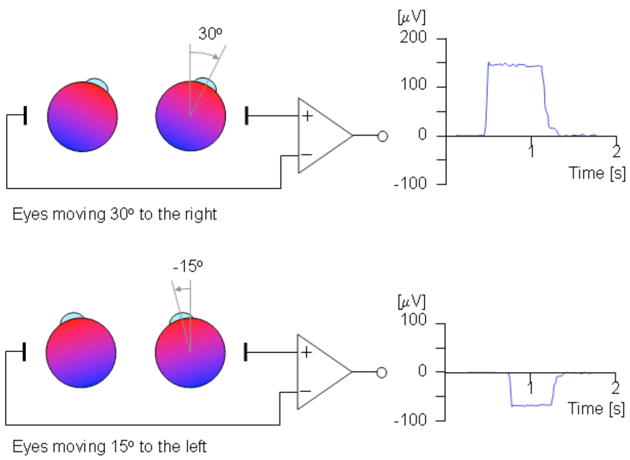

Figure 2.3: An illustration of EOG signal generated by horizontal movement of eyes.[5]

2.5 Electrodes

There are many types of electrode that will be used to detect the bio potential signal . This project will use the skin surface electrode. This type of electrode is defined as a bipolar electrode ,the surface electrode are not expensive . The problem with skin surface electrodes is that they create sometimes an unstable contact. An unstable contact causes potential artifacts, it could also add thermal noise to an EOG signal and we will correct these problems by using a high impedance electrode that helps prevent thermal noise problem. To avoid unstable skin contact the electrode must be placed firmly to the skin. To secure the electrode contact, the electrode that has an adhesive surface is selected for this EOG amplifier.

these electrode will be put as shown in figure 2.4.

Figure 2.4: Displacement of EOG electrodes

The description above only considers the ideal situation, in practice more realistic factors affects on EOG recording need to be considered, such as facial muscles, head movement and other activities like speaking.

Other Type of Electrode

One type of electrode is the metal plate form. The basic metal plate electrode consists of a metallic conductor in contact with a thin layer of an electrolyte gel between the metal and the skin to establish this contact as we show in (fig 2.5).

The other electrode is suction electrode as we show in (fig 2.6) to make it easier to attach the electrode to the skin to make a measurement and then move it to another point to repeat the measurement. These types of electrodes are used primarily for diagnostic recordings of biopotential such as the electrocardiogram(ECG) or the electroencephalogram(EEG).[6]

Metal disk electrodes with a gold surface in a conical shape are frequently used for EEG recordings. The apex of the cone is open so that electrolyte gel or paste can be introduced to both make good contact between the electrode and the head and to allow this contact medium to be replaced should it dry out during its use.

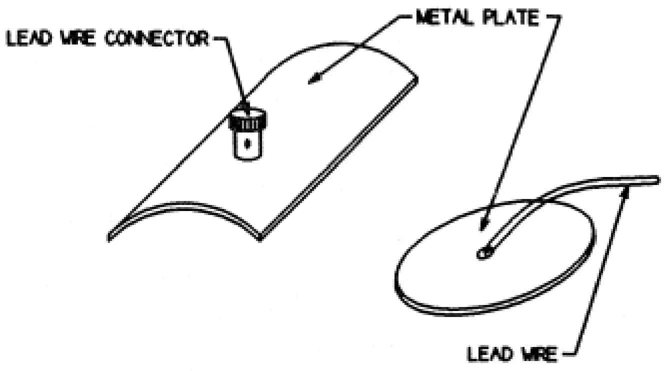

Figure 2.5: Metal plate electrode

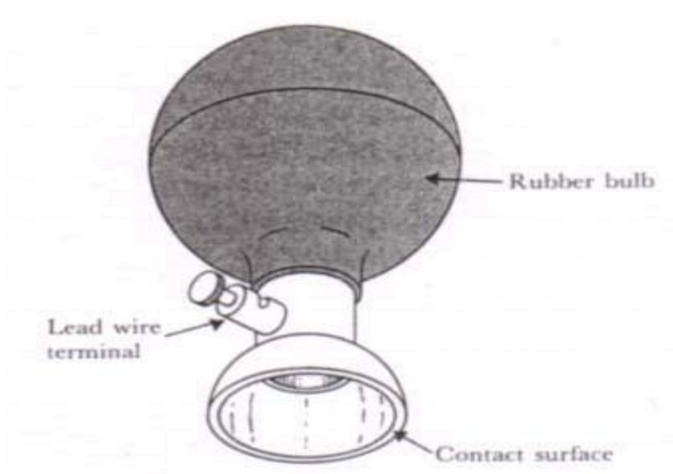

Figure 2.6: Suction electrode

2.6 Muscular Movement Noise

EOG measure the electrical potential difference between the retina and the cornea by placing electrodes in vertical or horizontal positions on the skin surface. Therefore during the whole driver session, the electrodes not only record the useful signal from the eye movements, but it also interferes by the muscular electrical signal of the driver's face. Such muscular noises can be violent in the EOG data and result in huge amplitudes and low frequency noise.[4] some of this activities introduced here.

2.6.1 Yawning

During the night driving test session, yawning can be found continues appears. It is a signal that indicates the driver is becoming drowsy. The driver open the mouth widely with some face muscle stretched tight. Yawn mainly affects the vertical channel of EOG signal.

2.6.2 Talking

During the driving test session, the participants sometimes need to talk with the researchers. The talking effect on the EOG signal is similar to the yawning effect. In the vertical channel, the signal baseline wander from the original level during the driver's talking action. It is also a low frequency wave and the amplitude is much smaller than yawning.

2.6.3 Head Movement

During driving, the driver sometimes needs to check the traffic situation behind the vehicle where the rearview mirror cannot reach. At this time, the driver needs to turn his/her head to left or right in a comparatively large range. This kind of movement also produces noise in EOG signal. horizontal channel signal's amplitude increases during this movement.

This kind of EOG signal can be distinguished from yawning by checking the horizontal channel. The yawning mainly affect vertical channel, but when the driver turn his/her head to one side, the horizontal channel signal will definitely change.

In order to extract essential features from the EOG signal in absence of noise, EOG processing circuit should be need it. This will be describe in more details in next chapter.

After acquire the EOG signal using the proposed electrode and transform it to process in order to eliminate noise,EOG will standalone as input to the microcontroller to start analysis process in order to get the main result that this article aimed to ,which is drowsiness detection. This analysis will describe with details in next section.

2. 7Drowsiness Detection Model

Most attempts at drowsiness detection based on EOG involve a feature extraction step, which is difficult to extract effective features, since the electrooculogram signal differ from one person to another and has a very small values in addition it highly affected by noise.

This system based on regression models of drowsiness detection by incorporating Artificial neural network ANN based on electrooculogram [10].

Artificial neural networks (ANN)

Today's real-time systems have an ever-increasingly challenging task. process all the data and make intelligent decisions about what to do next. Artificial neural networks (ANN) are the key to processing all of this data very quickly.

Definition:

An Artificial Neural Network (ANN) is a computational model that is inspired by the way biological neural networks in the human brain process information. which can be computerized to perform a specific task such as learning things, recognize patterns, and make decisions in a humanlike.

The importance of the ANN's is mainly recognized in the fact that it can be learned by the observed data .It takes samples of observed data , and deal with those data as training and testing tools.

The amazing thing about a neural network is that you don't have to program it to learn explicitly: it learns all by itself, just like a brain!

Components of the Neural Networks :

The basic unit of computation in a neural network is the neuron. It receives input from some other nodes, or from an external source and computes an output. Each input has an associated weight (w), which is assigned on the basis of its relative importance to other inputs. Additionally, there is another input 1 with weight b (called the Bias) associated with it.

The node applies non-linear Activation Function *F* to the weighted sum of its inputs. .as Sigmoid or tanh or ReLU function .as shown in figure 2.9.

Generally ,In classification tasks a SoftMax function(sigmoid) is used as the Activation Function in the Output layer of the ANN to ensure that the outputs are probabilities and they add up to 1.

$$\mathrm{sig}(x) = \frac{1}{(1 + \exp(-x))} \qquad (2.1)$$

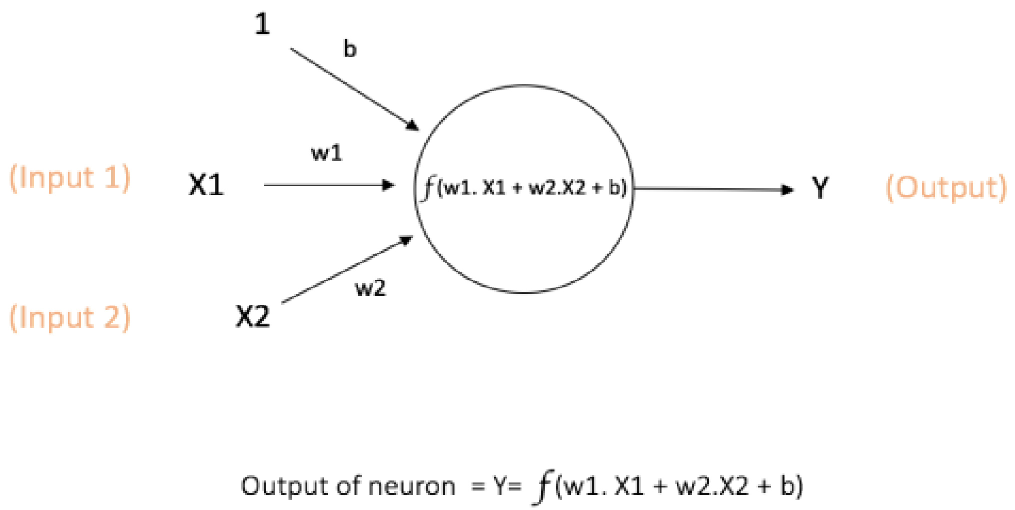

Figure 2.7: a single neuron

The output Y from the neuron is computed as :

$$Y = F\left[\sum_{i=1}^{n}\left(X_i\, w_{im}\right) + b\right] \qquad (2.2)$$

where ;
Y= output
X= input
w= The weight of connection between the input and the next layer .
θ= The bias value .
F= The activation function.
n=number of input variables.

ANN contains multiple neurons arranged in layers. Nodes from adjacent layers have connections or edges between them. All these connections have weights associated with them. ANN has three types of layers input ,hidden and output layer.as shown in figure 2.10.

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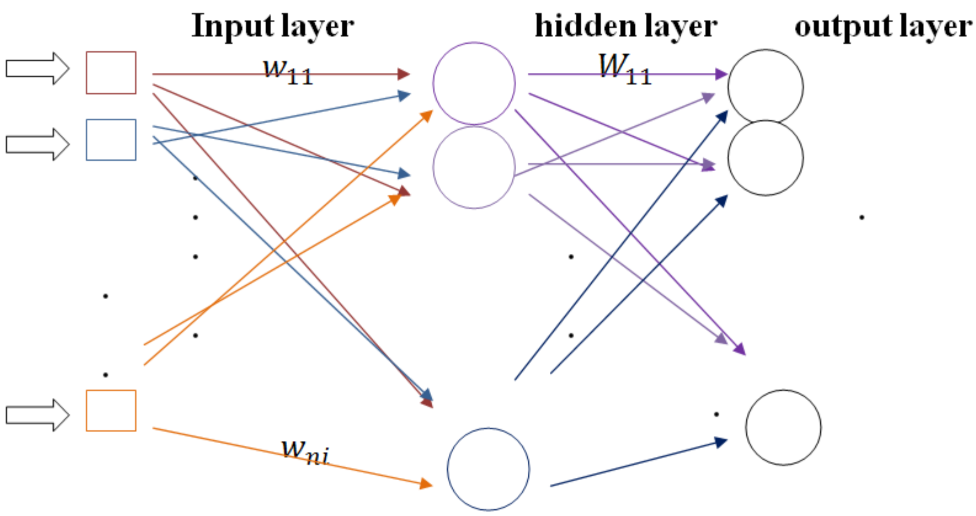


Figure 2.8 : ANN algorithm

working algorithm of ANN's:

The neural network receives the inputs from the outside world . After that each input is multiplied by its connection weight .Where the weight of each connection gives an indication of the strength of interconnection between neurons .Then The weighted inputs are all summed up inside computing unit , and a bias is added to make the output not- zero , in case the input was zero or to scale up the system response. The activation function is set of the transfer function used to get desired output.

Artificial neural network work in two step:

1) Feedforward Neural Network

In a feedforward network, the information moves in only one direction – forward – from the input nodes, through the hidden nodes and to the output nodes.

can learn from the given examples (training data) and make an informed prediction given a new data point.

2) Back-Propagation Algorithm

The process by which ANN learns is called the Backpropagation algorithm. it learns from labeled training data. This means, for some given inputs, we know the desired/expected output (label).

Initially all the edge weights are randomly assigned. For every input in the training dataset, the ANN is activated and its output is observed. After determining the error (the difference between desired and target), and the error is propagated back from output layer to the input layer via hidden layer. in order to calculate the *gradients*. Then we use an optimization method such as *gradient descent* to ‘adjust’ all weights in the network. This process is repeated until the output error is below a predetermined threshold.

We repeat this algorithm with all training examples in our dataset. Then, our network is said to have *learnt* those examples

We repeat this algorithm with all training examples in our dataset. Then, our network is said to have *learnt* those examples. at this instant the ANN is ready to work with “new” inputs.

Back Propagation algorithm equations:

$$Y = sig\left[\sum_{i=1}^{n}(X_i\, w_{im}\Big) - \theta\right]$$

$$e_j = y_d - y_a \qquad (2.4)$$

$$\delta_j = dy\left[sig(y_j)\right] - e_j \qquad (2.5)$$

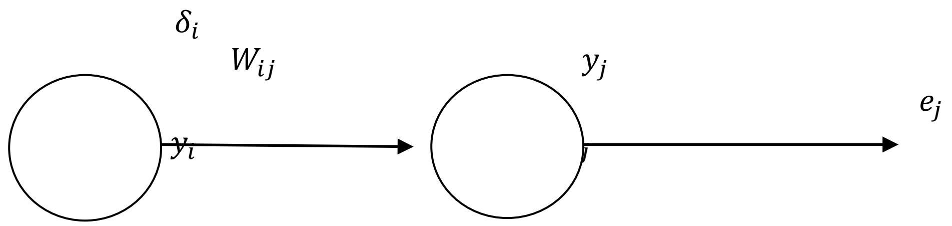
$$\delta_i = dy\left[sig(y_i)\right].\left(\delta_j - W_{ij}\right) \qquad (2.6)$$

$$\Delta W_{ij} = \propto y_i \delta_j \qquad (2.7)$$

$$\Delta\theta_j = \alpha(\theta)\delta_j \qquad (2.8)$$

$$W_{newij} = \Delta W_{ij} + W_{oldij} \qquad (2.9)$$

$$\theta_{newij} = \Delta\theta_{ij} + \theta_{oldij} \qquad (2.10)$$



where:
sig is the sigmoid function , which is the activation function .
e_j is the error of neuron j , (the difference between the actual output data and the desired data).
δ is the error gradient .
α is the learning rate .

The main object of deep learning as artificial neural network is to extract the common feature from the dataset for classification or pattern recognition tasks .But what about if there a features with the similar priorities or some unimportant features?

At this instance it is great to think about algorithms that able to reduce the number of features by choosing the most important ones that still represent the entire dataset . One of the most common is principal component analysis PCA.

The idea behind PCA is simply to find a low-dimension set of axes that summarize data.

The main concept for this algorithm is to looking for some properties in features that strongly differ across the classes. some properties that present low variance are not useful, it will make the examples look the same. On the other hand, PCA looks for properties that show as much variation across classes as possible to build the principal component space. The algorithm use the concepts of variance matrix, covariance matrix, eigenvector and eigenvalues pairs to perform PCA, providing a set of eigenvectors and its respectively eigenvalues as a result.

So, in order to reduce the dimension of the dataset we are going to choose those eigenvectors that have more variance and discard those with less variance.

Eigenvectors and Eigenvalues

When we get a set of data points, every eigenvector has a corresponding eigenvalue. An eigenvector represents a new set of axes. An eigenvalue is a number, telling us how much variance there is in the data. The eigenvector with the highest eigenvalue is the principal component. So, in order to reduce the dimension of the dataset we are going to choose those eigenvectors that have more variance and discard those with less variance.

The *principal components* now are the new set of variables. All the principal components are orthogonal to each other, so there is no redundant information.

The general PCA steps:

1) The observations should normalized by the calculated mean.

2) Projecting the observations on the principle component matrix to generates the new variables.

Until now there is no sound to alert the driver from the drowsiness so transmitting the classification result to microcontroller using wireless communication device should be taking into account.

2.8 Wireless communication

Wireless is a term that refers to any type of electrical connection that is achieved without using hard wired connection. Wireless communication is the transfer of data or information between electrical or electronic components over a distance without using electrical wires. Distances can vary from very short distances (few meters like TV remote control)to very long distances (thousands of kilometers for radio waves) wireless communication is considered to be a branch of telecommunication, it is used in large number of applications including, cellular telephones networks, satellite television, GPS unit, wireless computer keyboard and mouse, and many other applications.

There are many different types of wireless communication which is IR wireless communication, satellite communication, broadcast radio, Microwave radio, Bluetooth, Zigbee etc. Normally, all types of wireless technologies use a transmitter and a receiver.

2.8.1The transceiver

The word transceiver consists of two words (transmitter, receiver). The block diagram of the transceivers is shown in figure() It is comprised of the following component:

- The transmitter basic function is to take the information signal produced by the source of information and modify it into a form suitable for transmission over the channel.
- The channel provides the physical means for transporting the signal produced by the transmitter and delivering it to the receiver.
- The receiver operates on the received signal to produce an estimate of the
  original information

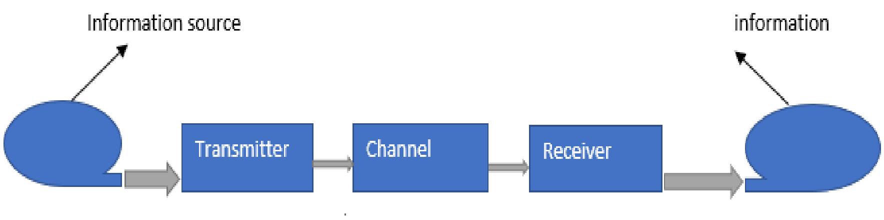


Figure 2.9 : The transceiver

Chapter Three

Project design

Chapter content

3.1 Overview

As the purpose of this article indicate**,** Signal acquisition and processing is an important step to measure drowsiness phenomenon. According to Figure 3.1,which is observe the whole components that the system contain. It has two main units including unit and receive unit. The transmission unit include signal acquisition tools , signal processing circuit and wireless transmitter. However, The receive unit is composed of wireless receiver, microcontroller and alarm device.

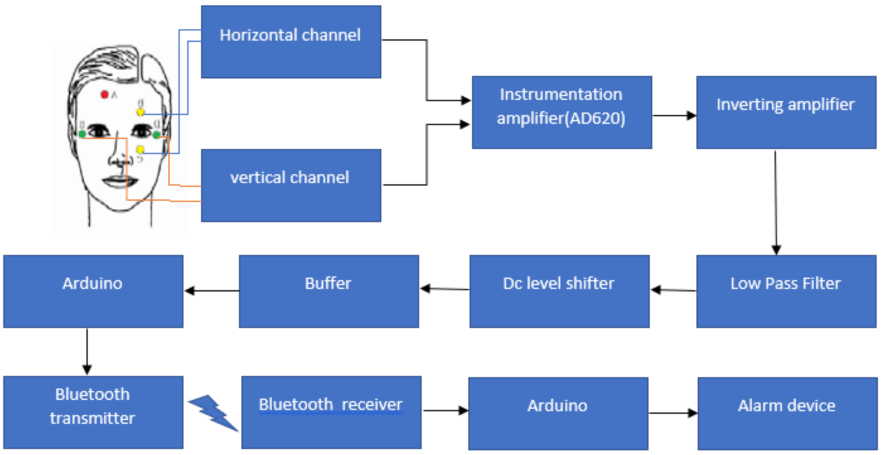


Figure 3.1: Simple block diagram show all stages that require for this project.

3.2 Acquiring system

As we mention in the previous chapter EOG signal is measured by placing electrophysiology electrodes around the eyes. Designing acquiring EOG circuit require to use one type of electrodes from several one.

When eyeballs move to different directions, the corresponding ocular muscles will be stimulated, the vertical and horizontal components of the eye movements can be observed simultaneously, to detect the electrical signal from eyes muscle we use electrodes.

3.2.1 (Ag/AgCl) electrodes

The reason for using this type of surface electrode that their performance such as high sensitivity and high accuracy of detecting signal. In this project the electrodes will be put in five different places to detect the electrical signal from eyes muscle. One of these electrodes are put above the eye and the other under the eye, the other two electrode will put it in the left and on the right around the eye, and one electrode will be put in the forehead as reference.

Electrodes are made from noble metals such as platinum are often highly polarizable. A charge distribution from that of the bulk electrolytic is found in the solution close to the electrode surface. Such a distribution can create serious limitations when movement is present and the measurement involves low frequency or even dc signals. If the electrode moves with respect to the electrolytic solution, the charge distribution in the electrode that will appear as motion artifact in the measurement. Then for most biomedical measurement, non polarizable electrodes are preferred to these that are polarizable.

The silver-silver chloride electrode is one that has characteristics similar to a perfectly non polarizable electrode and is practical for use in many biomedical applications. The electrode show (fig 3.2) consist of a silver base structure that is coated with a layer of the ionic compound silver chloride. Some of the silver chloride when exposed to light is reduced to metallic silver, so a typical silver-silver chloride electrode has finely divided metallic silver within a matrix of silver chloride on its surface.

The silver chloride is relatively insoluble in aqueous solution, this surface remains stable. Because there is minimal polarization associated with this electrode, motion artifact is reduced compared to polarizable electrodes such as the platinum electrode. And due to the reduction in polarization, there is also a smaller effect of frequency on electrode impedance, especially at low frequencies.

Figure 3.2 Silver-silver chloride electrode.

3.2.2 Electrode lead wires

Wires with specific shape will be used to carry the electrode, and to make interface between electrode and EOG system.

3.3 Processing EOG signal

Due to the noise that the EOG signal affected by, Processing circuit ,which filtered and amplified the EOG signal, are needed. As shown in figure 3.3 Processing circuit include multiple stage. Each one will describe next in details.

Figure 3.3 processing EOG signal

3.3.1 Instrumentation Amplifier (AD620):

Eyes signals such as all biopoteitial signal, when we detect these signal we will need to take the difference between the electrodes, to extract this signal we will connect the electrode to special circuit, it's the preamplifier. This preamplifier or instrumentation amplifier will consist of three amplifier ,tow non-inverting and the third is inverting . The eyes signals.

It is very small in amplitude and needs to amplify to be suitable to use ,this amplification is done on multi stages , in our design we will use an instrumentation amplifier that will connect directly to the electrodes, this instrumentation amplifier take the difference as we mentioned above and take this difference and amplify it to be an electrical signal that will be developed and generated from contraction muscle.

The differential input single-ended output instrumentation amplifier is one the most versatile signal processing amplifiers available. It is used for precision amplification of differential dc or ac signals while rejecting large values of common mode noise. By using integrated circuits, a high level of performance is obtained at minimum cost.

The instrumentation amplifier circuit contains two stages, we find these two stage in one IC that used in our project this IC is (AD620), because the most of amplifier can’t detect the biopotential signal and amplified it without noise, and it will be commercial part, on the otherwise the AD620 will detect and amplify the signal from the source without any change in the shape of the signal.

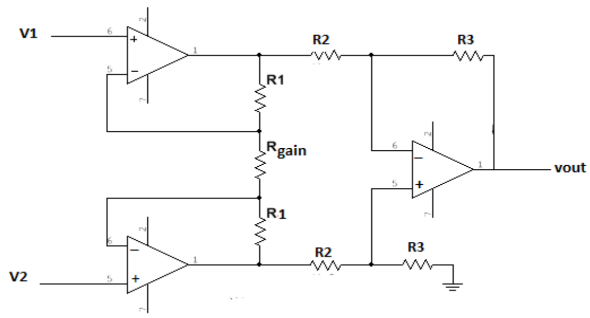


Figure 3.4: instrumentation amplifier

This (AD620)are connected as non-inverting amplifier and it has many properties noticed when we see it as an instrumentation amplifier such as :[from datasheet]

- Easy to use.
- High common mode rejection ratio.
- Low power consumption.
- Low internal noise.
- High input impedance.

The common-mode rejection ratio (CMRR) is simply the ratio of the differential gain, to the common-mode gain.

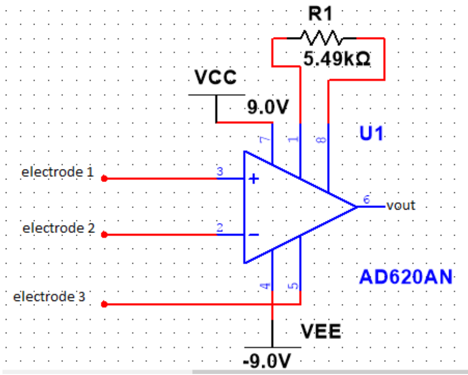


Figure 3.5: AD620 INE

From datasheet of AD620, the gain is illustrated in Eq(3.1):

$$A = \frac{49.9K\Omega}{R_{gain}} + 1 \qquad (3.1)$$

Where:

A : INA voltage gain.

R_{gain} : External resistance added to achieve a determined voltage gain.

So, the gain that need in this stage is 10, by using Eq(3.1) the value of R_{gain} is approximately 5.49kΩ.

3.3.2Inverting Amplifier

After filtration the signal from common mode voltage , now we can amplify this signal since it is very small signal in (microvolt). Inverting amplifier will be use for this purpose as shown in fig(3.8),Eq(3.8) illustrated the gain of this filter .

$$A = -\frac{R_2}{R_1} \qquad (3.8)$$

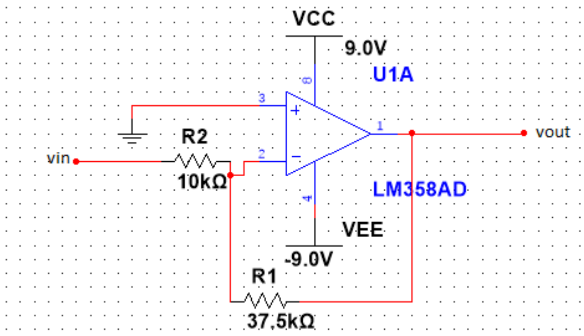


Figure3.6 : inverting amplifier

Since the gain of this stage equal -3.75, by using Eq(3.8) let $R_1 = 10k\Omega, so\ R_5 = 37.5k\Omega$

3.3.3Low Pass Filter

An optimum low-pass filter (LPF) will be designed to passes low frequency signals but attenuate the signal that have frequencies higher than low cutoff frequency(F_l). Since this signals far exceed the size of the EOG voltages. We used first order low-pass filter, Figure(3.6)shown LPF circuit.

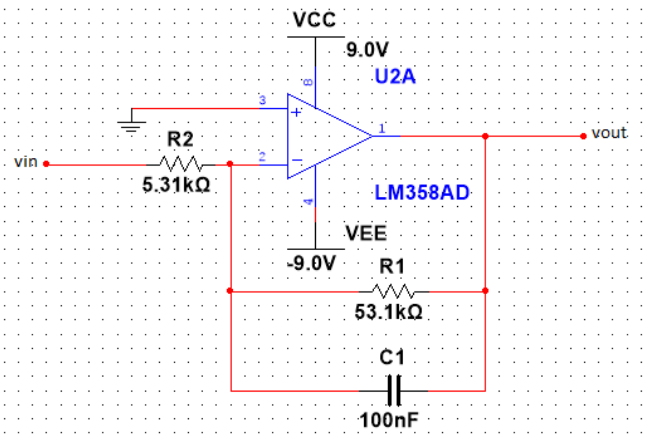


Figure 3.7: LPF circuit

Eq(1.6)illustrated low critical frequency :

$$F_l = \frac{1}{2\pi\sqrt{R_1R_2C_1C_2}} \qquad (3.6)$$

The low cutoff frequency that required in this project is 30Hz

Let $C_1 = 100nF$

By using Eq(3.6):

$R_1 = 5.3k\Omega$

$R_2 = 53k\Omega$

3.4 DC level shifter

The EOG signal obtained after acquisition circuit has positive and negative peaks corresponding to the eyeball movements. However, in order to use the signal further into microcontroller we require to level shift the signal in such a way that no negative peaks are present in the signal.

For this reason a DC level shifter is used This ensures the EOG signal have both the peaks above zero line. shown figure(3.6).Such that Rth >0.1Xc.

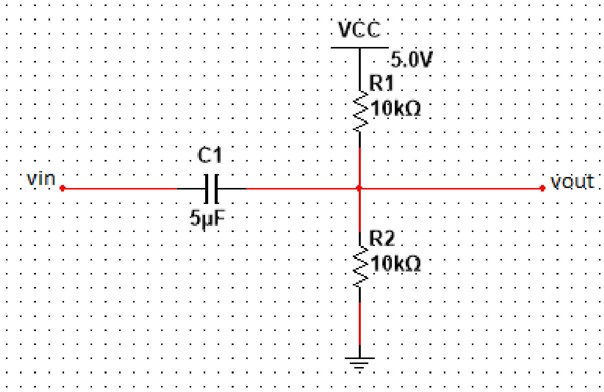


Figure 3.8: DC level shifter

3.5 Buffer amplifier

buffer amplifier is used to transfer a voltage from a first circuit, having a high output impedance level, to a second circuit with a low input impedance level. As shown figure(3.7)

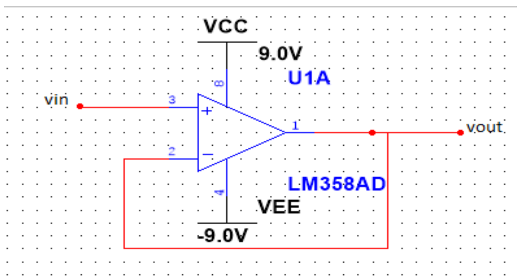


Figure 3.9 :buffer amplifier

As shown in Figure 3.8 describe the all the previous component as a whole block.

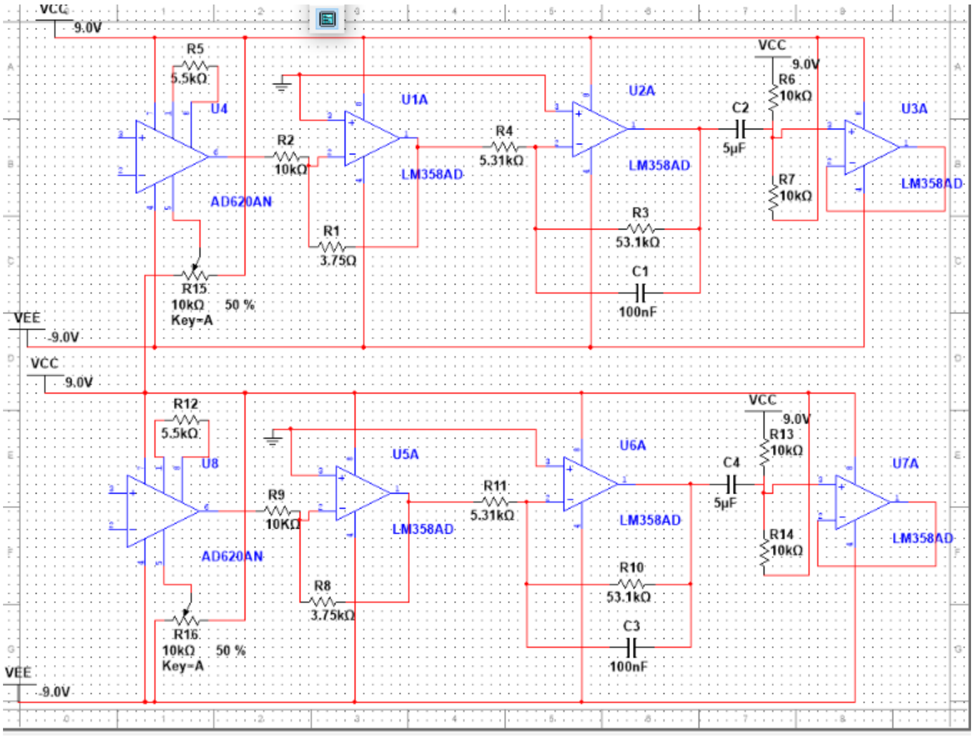


Figure 3.10 :EOG acquitting circuit with dc level shifter and buffer

3.6Microcontroller

a microcontroller is a device used for controlling hardware components by programming it . It consists from physical programmable circuit board and a piece of software, that used to write and upload computer code to the physical board. There are many types of microcontrollers and many languages to program it. In this paper an Arduino microcontroller is a good choice, since the Arduino uses a simplified version of C++ in which programming becoming easier. In addition , Arduino can supported MATLAB which we use it for training ANN.

There are many type Arduino such as Uno, Due ,mega and others. In this article an Arduino Due will be the interface between the EOG system and Bluetooth at transmitter side. Arduino Due opening the door to processing EOG signal since and apply the artificial neural network without any obstacles since it has12 analog inputs(ADC)with 12-bit resolution, large memory and high speed ,so it can accommodate the large data that will testing using ANN at the transmitter circuit.

In contract an Arduino Uno will be used as interface between the Bluetooth and alarm device at the receiver side. to receive the output result from the transmitter and in turn activate the connected alarm device in case the driver become drowsy.

Bluetooth will be used to send signal from transmitter to on or off the alarm device at the receiver.

3.7 Bluetooth technique

Bluetooth is a wireless technology used to transfer data between different electronic devices. The distance of data transmission is small in comparison to other modes of wireless communication. This technology eradicates the use of cords, cables, adapters and permits the electronic devices to communicate wirelessly among each other.

The features of Bluetooth technology:

- Less complication
- Less power consumption
- Inexpensive
- Robustness

Bluetooth is managed by the Bluetooth Special Interest Group (SIG),operates at frequencies between 2.402 and 2.480 GHz, or 2.400 and 2.4835 GHz including guard bands 2 MHz wide at the bottom end and 3.5 MHz wide at the top. it uses a radio technology called frequency-hopping spread spectrum, which is used in spread spectrum signal transmission.

Bluetooth is a packet-based protocol with a master/slave architecture. One master may communicate with up to seven slaves in a piconet.

Bluetooth divides transmitted data into packets, and transmits each packet on one of 79 designated Bluetooth channels. Each channel has a bandwidth of 1 MHz.

There are two technologies for Bluetooth, Basic Rate/Enhanced Data Rate (BR/EDR) and Low Energy (LE).

- **Basic Rate/Enhanced Data Rate (BR/EDR)**

Bluetooth BR/EDR enables continuous wireless connections and uses a point-to-point network topology to establish one-to-one device communications. Bluetooth BR/EDR audio streaming is ideal for wireless speakers, headsets and hands-free in-car systems.

- **Low Energy (LE)**

Bluetooth LE enables short-burst wireless connections and uses multiple network topologies, including point-to-point, broadcast and mesh.

HC-05 Serial port Bluetooth module with V2.0+EDR (Enhanced Data Rate) technology will be used as wireless transmitter and receiver as receiving unit in figure 3.9 and3.10 , Respectively.

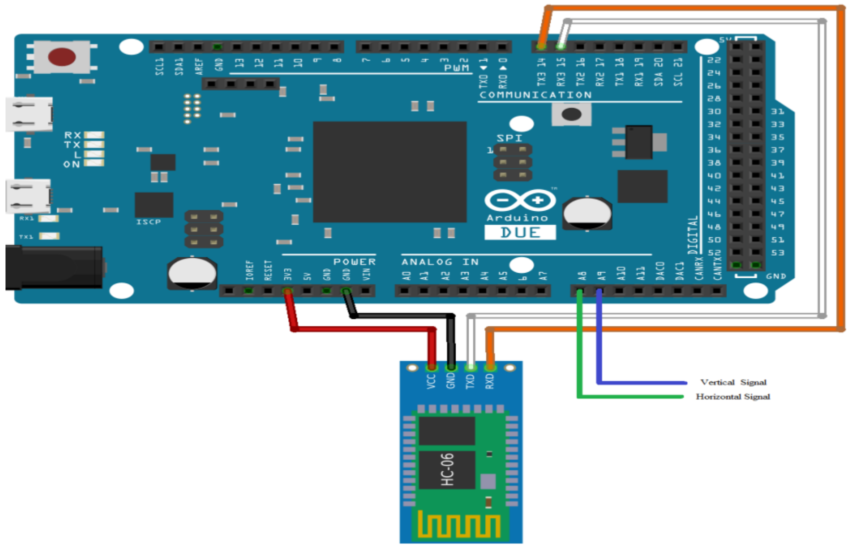


figure 3.11: Transmitting unit

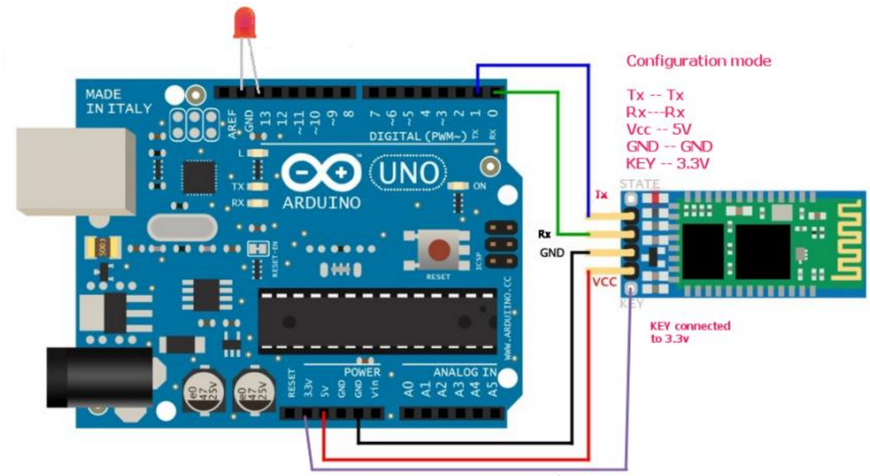


Figure3.12: receiving unit

3.8 Alarm Device

An alarm device gives an audible, visual or other form of alarm signal about a problem or condition. Audible alarm will be used in this system to wake up the driver.

3.9 Power Supply

A 9 volt battery will be used as a power supply to supply the electrical component with their needed .

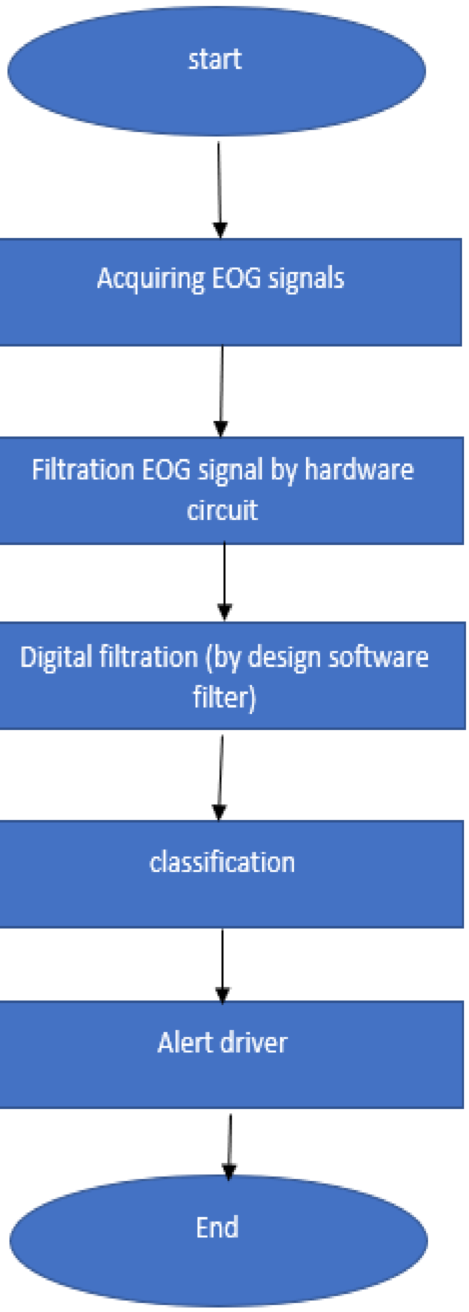


Figure 3.13: flow chart of whole system

Chapter Four

implementation and the testing

4.1 Overview

This chapter covers the implementation and the testing for all the stages of this project including acquiring EOG signal, the communication system and the classification process using Artificial neural network .

4.2 Testing Component

EOG acquiring system for vertical and horizontal signals have the same components ,we started to test each component of this system to ensure its functionality as follow:

4.2.1 Ag/AgCl Electrodes

Electrode lead testing was done by connecting each branch to each pin in electrode cable by using Digital Multimeter (DMM) and get sound mean that's no short and it's working.

4.2.2 power supply Testing

we tested the batteries first without connecting to horizontal and vertical circuits In this case, battery was successful and gave the required results, it provides positive volts and negative one, which are needed for IC's work.

4.2.3 Pre-Amplifier Testing

The AD620 IC was connected with Rg and then we control the gain of IC by potentiometer, as shown in figure4.1.

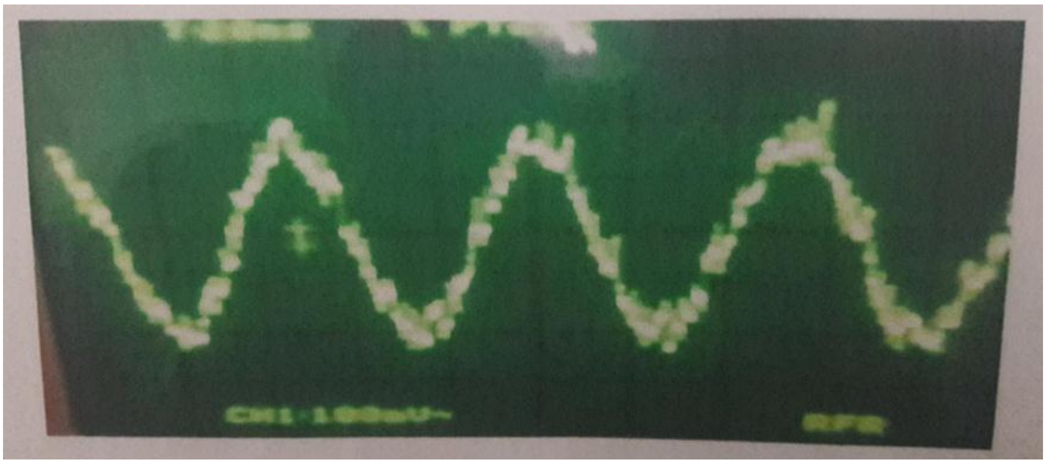


figure4.1: output signal after AD620

Then applied sine signal from function generator to the circuit in order to test it and observed the result on the oscilloscope as shown figure(4.2).

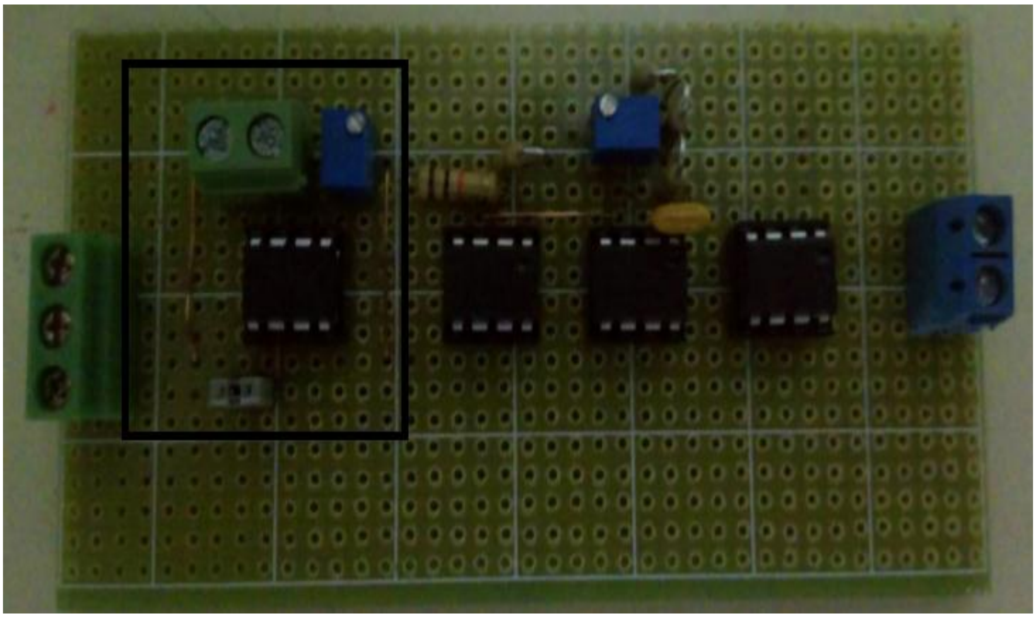


Figure 4.2:AD620 circuit

4.2.3 Inverting Amplifier Testing

The inverting amplifier was connected with potentiometer to get a gain between 3.75. It also constructed by using LM358 IC. And the recorded signal as shown in figure 4.5

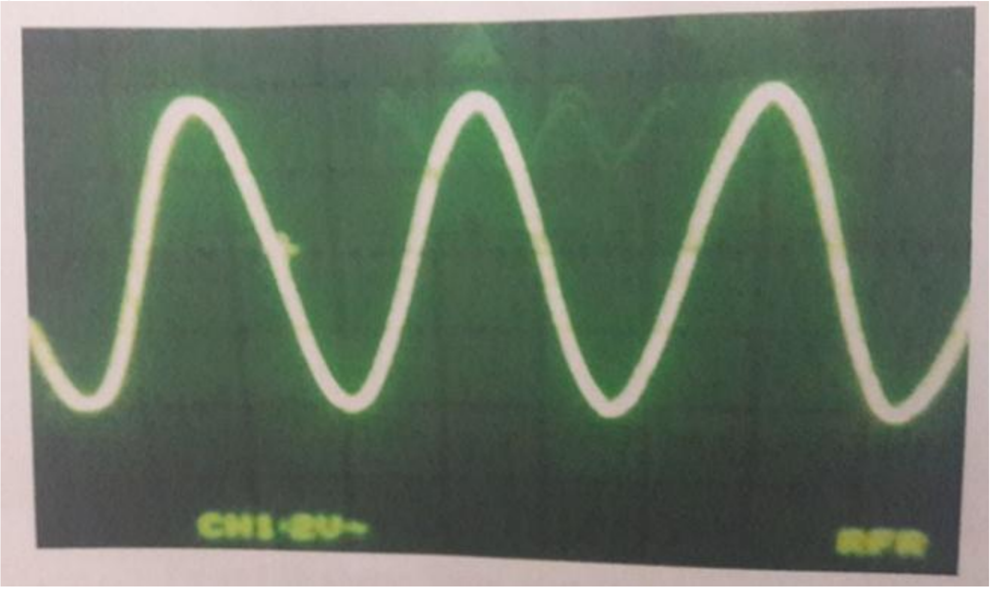


Figure 4.3: output signal after inverting amplifier

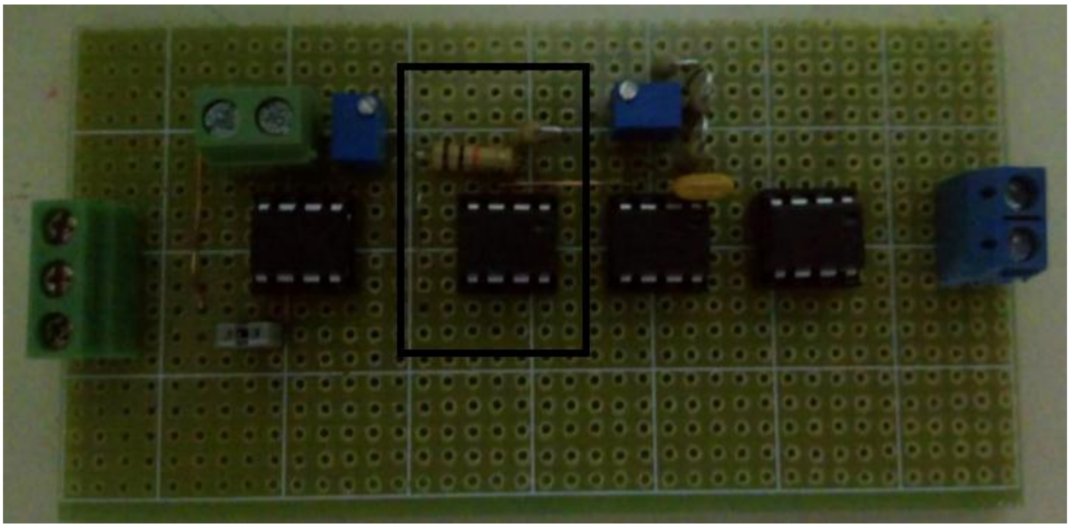


Figure 4.4:inverting amplifier

4.2.4 low Pass Filter

The low pass filter was constructed by using LM358 IC with suitable resistances and capacitors as shown in figure 4.5. LPF was used to pass low frequency which less than 30Hz. Figure 4.6 shows the output signal from low pass filter.

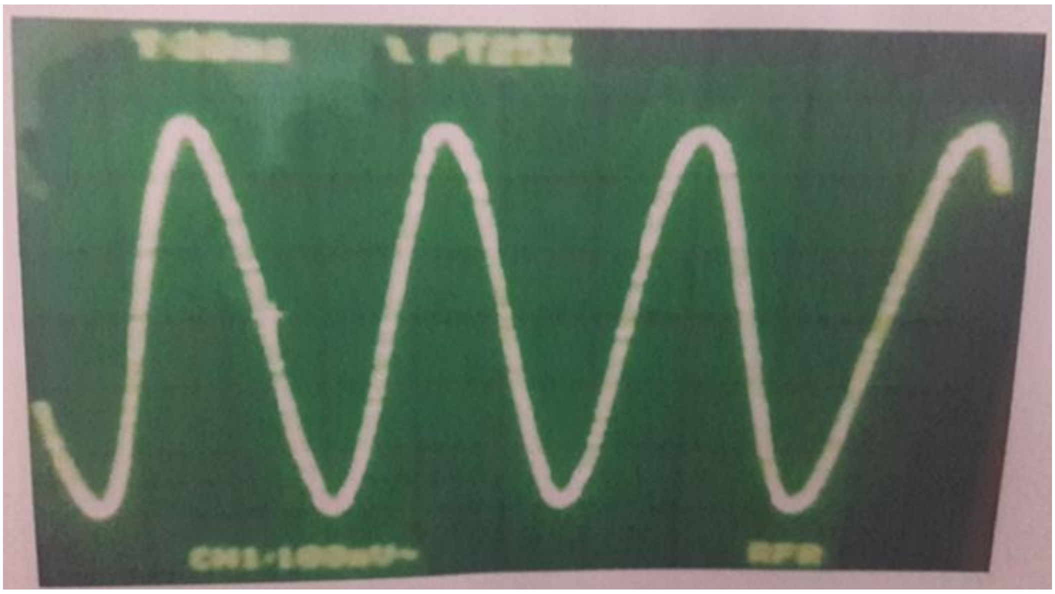


Figure 4.5: output signal after low pass filter

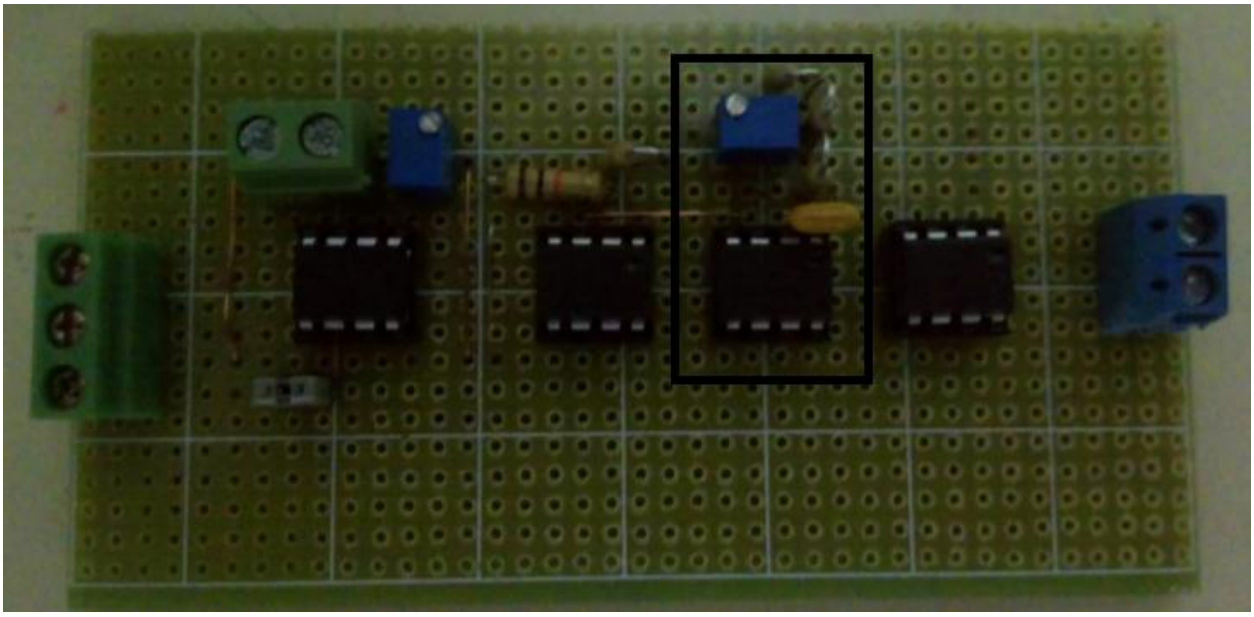


Figure 4.6: Low Pass filter

4.3 acceptance testing

In this section, the system will be tested to see if it meets the requirement were the system was built for, and as this point the system did meet the needed tasks in the system.

Unit	function	Expected result	Actual result	Verification
Electrodes	Detect electrical signal from eye movement	Connect between the human body and EOG system	Connected between the human body and EOG system	Pass
AD620	Take the difference from two electrodes	Amplify the difference		Pass
Bluetooth	Used for sending and receiving the data	Receive and send the data	It received and sent data	Pass
Arduino	Interfacing and controlling	Interface between EOG system and Bluetooth, interfacing between Bluetooth and switches	It interfaced between EOG system and Bluetooth, interfacing between Bluetooth and switches	Pass

Table 4.1: white Box Testing

4.4 Communication system

The transmitter unit and the receiver one are shown in figure 4.7 and 4.8 respectively.

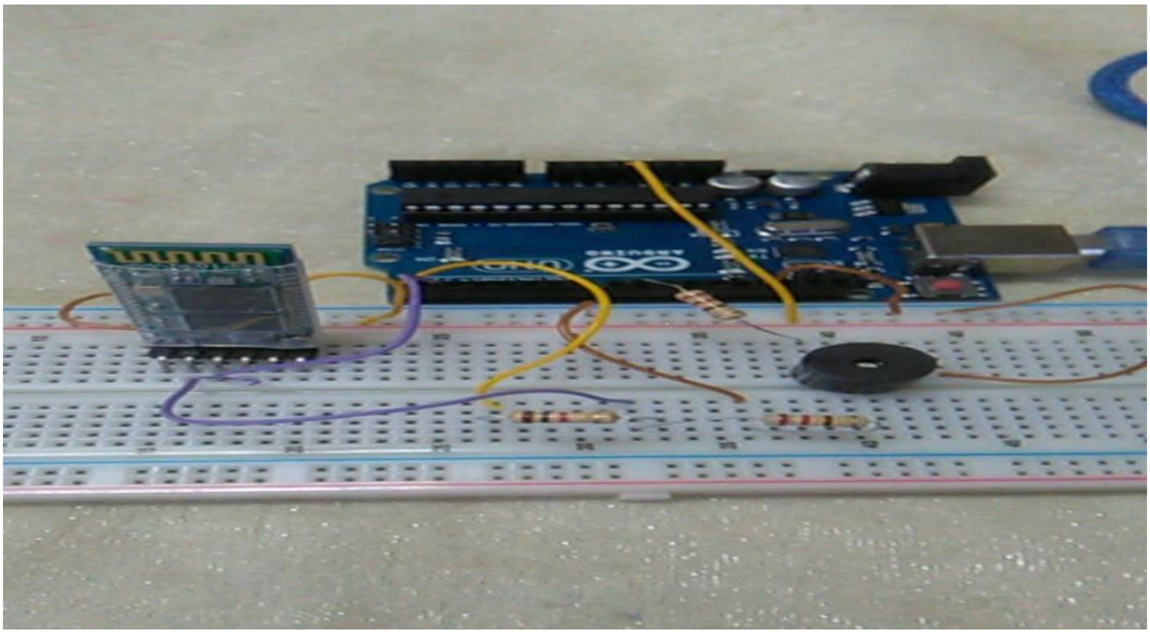


Figure4.7: the transmitter circuit

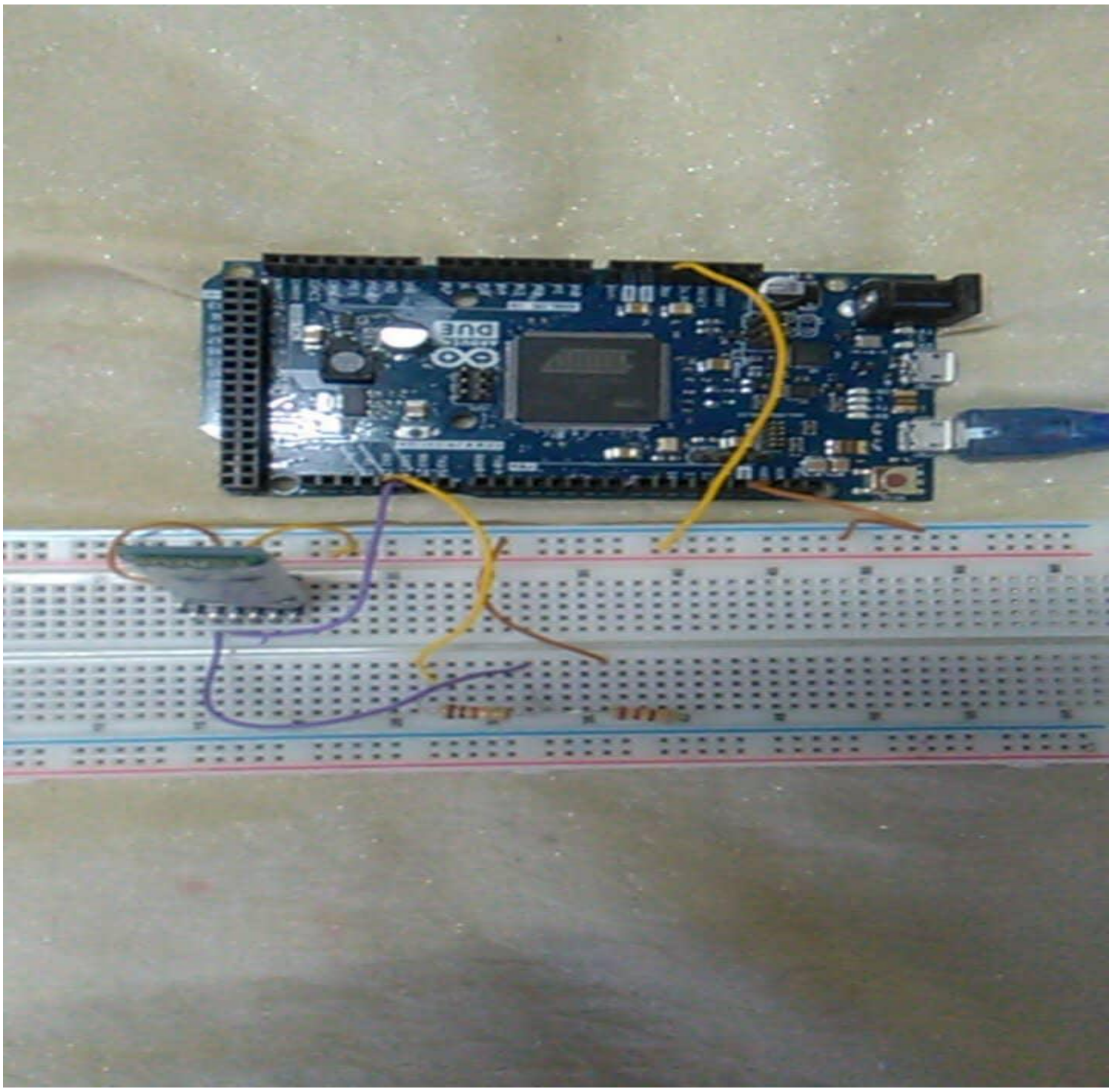


Figure 4.8: the receiver circuit

4.5 Classification Process Using ANN

4.5.1Training Artificial neural network

Artificial neural network was used in order to classify the EOG signal to drowsy and wakeful state.

In order to achieve this classification a dataset of multiple samples will need it so we use

the "ULg Multimodality Drowsiness Database", also called DROZY, is a database containing various types of drowsiness-related data (signals, images, etc.) and intended to help researchers to carry out experiments, and to develop and evaluate systems (i.e. algorithms), in the area of drowsiness monitoring.

The (multimodality) data were collected by the Laboratory for Signal and Image Exploitation (INTELSIG), which is part of the Department of Electrical Engineering and Computer Science of the University of Liège (ULg), Liège, Belgium. This laboratory is denoted here by "ULg-INTELSIG".

Content

The data in the DROZY database contains different type of data , however we use the following perfectly time-synchronized data:

- Karolinska Sleepiness Scale (KSS) scores: subjective, self-evaluated levels of drowsiness according to the KSS, thus from 1 (Extremely alert) to 9 (Very sleepy, great effort to keep awake, fighting sleep), at the beginning of each PVT.
- Polysomnography (PSG) signals: 5 EEG channels (Fz, Cz, Pz, C3, and C4, all referenced to A1), 2 EOG channels (horizontal and vertical), ECG, and EMG, all sampled at 512 Hz.

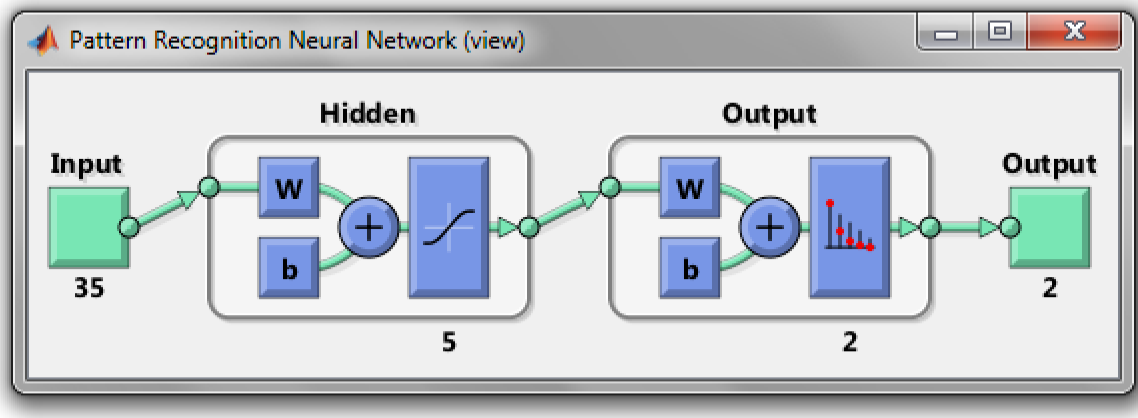
A database from 14 subjects (3 males, 11 females) were used as reference to train the artificial neural network , in which those subjects performed three 10-min tests in conditions of increasing sleep deprivation induced by acute, prolonged waking.

The total number of the dataset were thirty six vertical and horizontal signals, there were some missing tests ,Each signal recorded with sampling frequency 512Hz , a 307200 variables for each sample, by rearrangement the signal as a vectors of vertical and horizontal sample ,the training inputs become a matrix with dimension(36x614400) and this is a huge number of variables , so it should be reduced in order to be train by ANN, so by applying principle component analysis technique on the data we get (36x35) as a total input matrix.

The target or the desired output for each sample were classified by subjective, self-evaluated levels of drowsiness according to the KSS with matrix (2x36). After all this preparations the ANN become ready to train using Pattern Recognition Neural Network MATLAB Application.

The maximum error that we get it from the MATLAB application by using fifth neurons for hidden layer and two neurons for output layer (figure 4.8), with adjusted weights is 0.030869 at epoch 22 shown in figure 4.9.

figure 4.8



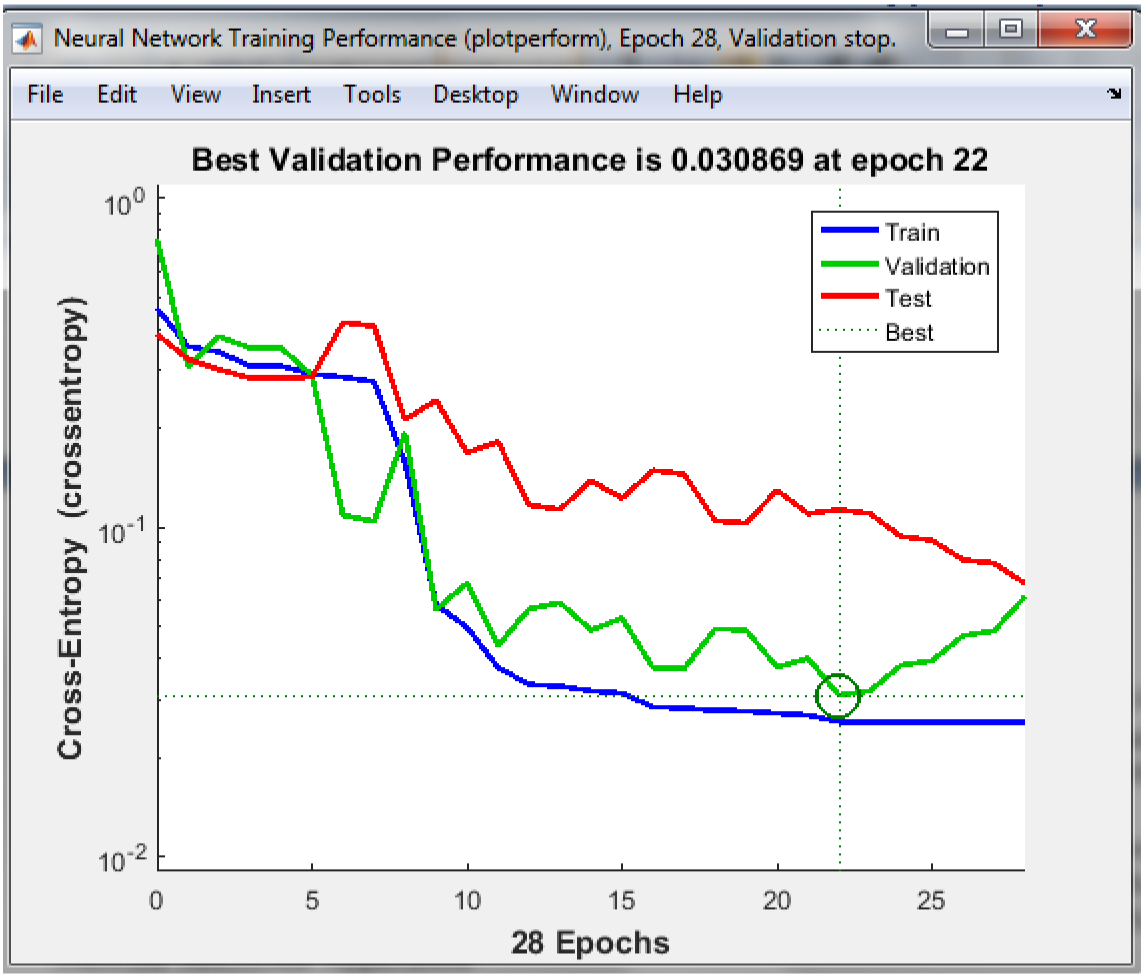


Figure 4.9: output layer

The next figure 4.9 shows the confusion matrices for training, testing, and validation. The number of correct response in the green squares and numbers of incorrect response in red squares. The blue squares illustrate the overall accuracies.

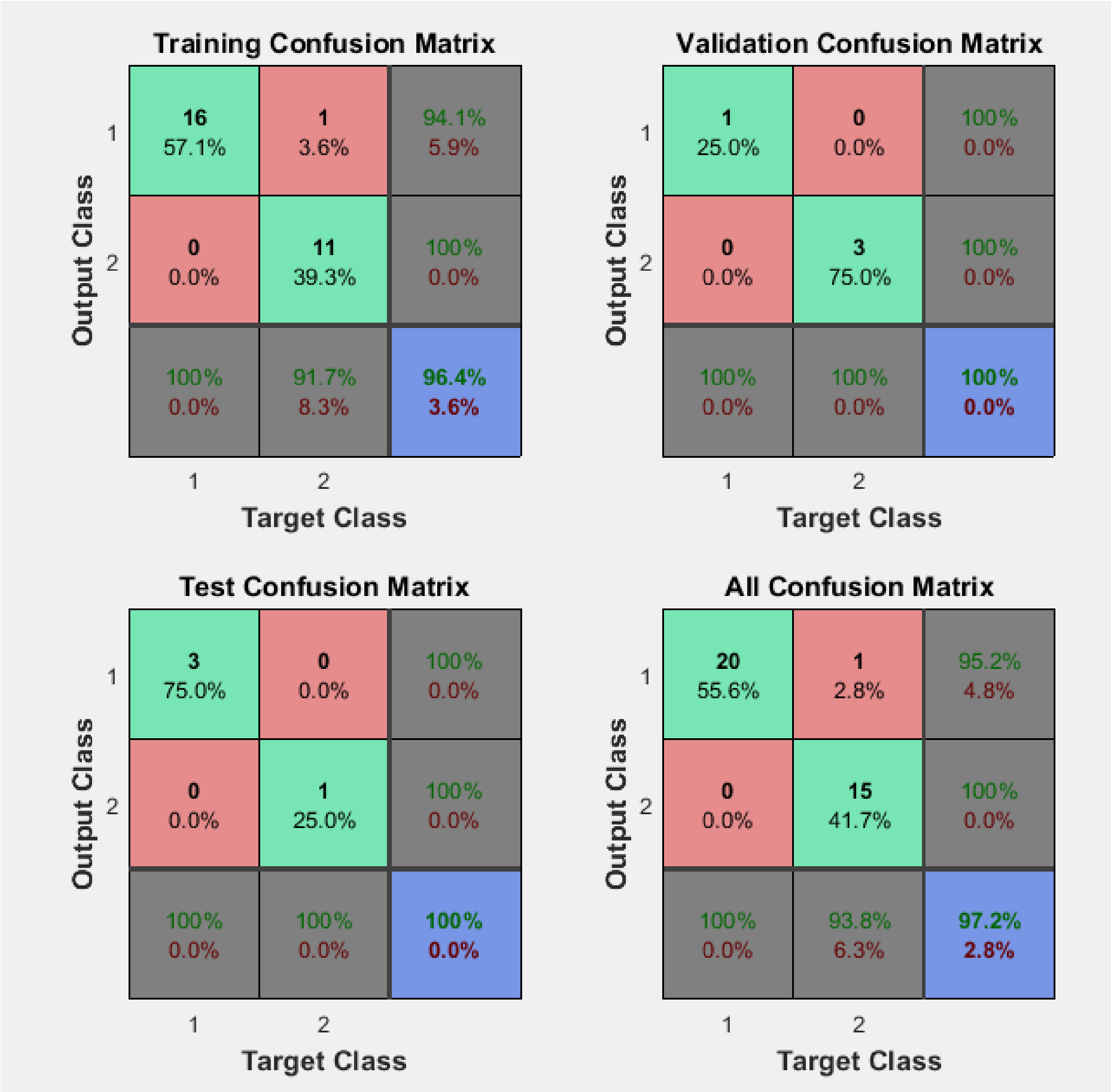


Figure 4.10 confusion matrices

4.5.2Testing Artificial neural network

ANN was tested by using a samples with 10 minutes as a time window and with a time step of 2 minutes.

This samples with labeled outputs undergo to the principle component analysis before testing it, to become a vector with 35 variables and it is classified by ANN in the next step to get the desired output.

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```
#include "Timer.h"
Timer t;
#include "AltSoftSerial.h"
AltSoftSerial BTserial  ;
boolean DEBUG = true;
float Result=0.0;
long i =0;
int sensorH=0;
int sensorV=0;
float H=0.0;
float V=0.0;
float ArrH[307200;[
float arrV[307200;[
     void setup}  ()
     if (DEBUG (
}

        Serial.begin(9600;(

        Serial.println(Result;(
{

    BTserial.begin(9600  ;(
    if (DEBUG)  {  Serial.println(Result{       ;(


            analogReadResolution(12;(
            t.every(1.953125,takeReading;(
{

void loop}  ()
 t.update;()
{
void takeReading()
}
        if(i<307200(
}
          sensorH=analogRead(A0;(
          H =sensorH*(5.0/4096;(
          sensorV=analogRead(A1;(
          V =sensorV*(5.0/4096;(
          arrH[i]=H;
          arrV[i]=V;
          i=i+1;
{
  else
}
   proccesing;
   for(int j=0;j<306600;j(++
}
        arrH[j]=arrH[j+1;[
        arrV[j]=arrV[j+1;[
 {
   i=306600;
{

{

  {
void proccesing()
}
```

```
//{end takeReading Function
```