Palestine Polytechnic University

Control and monitor IoT devices using EOG and voice commands

Project team

Mohammad Ziada **Lubna Awawdeh** **Mutaz Tahboub**

Supervisor:

Eng. Ayman Wazwaz

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الإهداء

إلى معلمنا وقائدنا وقدوتنا وحبيبنا وشفيعنا محمد صلى الله عليه وسلم.
إلى من رسموا بدمائهم خارطة الوطن وطريق المستقبل وهندسوا بأجسادهم معاقل العزة والكرامة .
إلى من هم أكرم منا جميعا إلى شهداء الوطن الحبيب .
إلى الذين عشقوا الحرية التي تفوح منها رائحة الياسمين وتوارو خلف القضبان ليفسحوا لنا النور إلى أسرانا الأبطال.
إلى التي رآنا قلبها قبل عينيها واحتضنتنا أحشائها قبل يديها إلى التي تعجز الكلمات عن شكرها
إلى منبع الحنان وتاج الرأس ومن تنحني لها جباهنا، كيف لا والجنة تحت إقدامها، أمهاتنا الفضيلات.
إلى من وصلو النهار بالليل، و بذلو الغالي و النفيس من أجلنا، إلى مصدر فخرنا و عزنا، آبائنا الكرام
إلى من يحملون في قلوبهم ذكرياتنا ويتقاسمون معنا أفراحنا وهمومنا ومن ساندونا، إخوتنا وأخواتنا الأعزاء.
إلى من ضاقت السطور لذكرهم فوسعتهم قلوبنا، أصدقائنا الأعزاء.
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Abstract

Many people suffer from spinal cord injury, which causes them to lose their ability to control or even to use any of their body movements. Also some normal people may use voice commands to make life easier.

In our project, we used electrooculography system for the patients who have a spinal cord injury to help them controlling household appliances and using the voice system for normal people to control their home devices.

This project use IoT technology for monitoring and controlling home appliances using Wi- Fi as a communication protocol and Arduino as a microcontroller for the eye signal that will be taken from the patients and voice signals that will be compared with pre-recorded voice commands.

The idea of this project could be developed further in the future so that we can use a smartphone and third-generation technology(3G) for controlling and monitoring the smart home remotely.

المُلَخَّصْ

يعاني الكثير من الناس من إصابة في النخاع الشوكي، مما يؤدي إلى فقدانهم لقدرتهم على التحكم في أي من حركات الجسم أو استخدامها مثل حركة أيديهم أو أرجلهم. أيضًا قد يستخدم بعض الأشخاص العاديين الأوامر الصوتية لجعل حياتهم أسهل.

في مشروعنا، استخدمنا تخطيط اشارة العين الكهربائية للمرضى الذين يعانون من إصابة في النخاع الشوكي لمساعدتهم على التحكم في الأجهزة المنزلية وأيضا نظام الصوت للأشخاص العاديين للتحكم في أجهزتهم المنزلي

هذا المشروع يستخدم تقنية إنترنت الأشياء للتحكم ومراقبة الأجهزة المنزلية التي تستخدم الواي فاي كبروتوكول اتصال والاردوينو كوحدة تحكم دقيق لإشارة العين التي ستؤخذ من المرضى والإشارات الصوتية التي سيتم مقارنتها مع الاوامر الصوتية المسجلة مسبقًا.

يمكن تطوير فكرة هذا المشروع بشكل أكبر في المستقبل مما يمكننا من استخدام الهاتف الذكي وتكنولوجيا الجيل الثالث للتحكم في المنزل الذكي ومراقبته عن بُعد.

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List of Abbreviation

Abbreviation	Full Meaning
CPU	Central Processing Unit
ECG	Electrocardiograph
EEG	Electroencephalograph
EOG	Electrooculography
HPF	High Pass Filter
IoT	Internet of Things
LPF	Low Pass Filter
USB	Universal Serial Bus
WLAN	Wireless Local Area Network
Wi-Fi	Wireless Fidelity

Chapter one
Introduction

1.1 Overview

This chapter focused on the main idea of the project about the eyes movement and voice and how can we use them to control some devices in smart home, it had the aims and the previous works related to the project.

1.2 Motivation

Our project of (Controlling smart home by Using Electrical Signal Generated from Eyes Movement or voice) help people who suffer from muscular and neurological disorders such as spinal cord injury and also to assist natural people to communicate with the surrounding environment by using their eyes movement or by their voice to control devices in home to be smart and to have easy life.

In our project, we will use a new technology, IoT or IoE, a shortcut to the Internet of thing or everything, which aims to connect everything in everywhere and communicate with it over the Internet either wired or wireless, and in our project, we will use Wi-Fi to communicate with anything at home.

1.3 Objectives

The goal of this project is to control home in unusual way to become a smart using the eye movement (electrooculography system) or voice to provide the amenities for the target group of this project also natural persons can use it.

We achieved several objectives in our project:

1. Design and implementation of (EOG) system for eye method.
2. Analysis and recording voice for the voice method.
3. Develop an algorithm for controlling a smart home using Arduino controller with relative to the selected mode.
4. We have used the IoT for making a communication between the client and the server in order to control home devices through home network.
5. We have conducted an experiment that investigated the effect of the surrounding environment on the EOG signal

1.4 Methodology

The Block Diagram in **figure 1.1** allows users to interact with a smart home environment through vertical and horizontal eye movement or by using our voice to give command to Arduino, whereas the Arduino will Communicate with the appropriate relay to control its device.

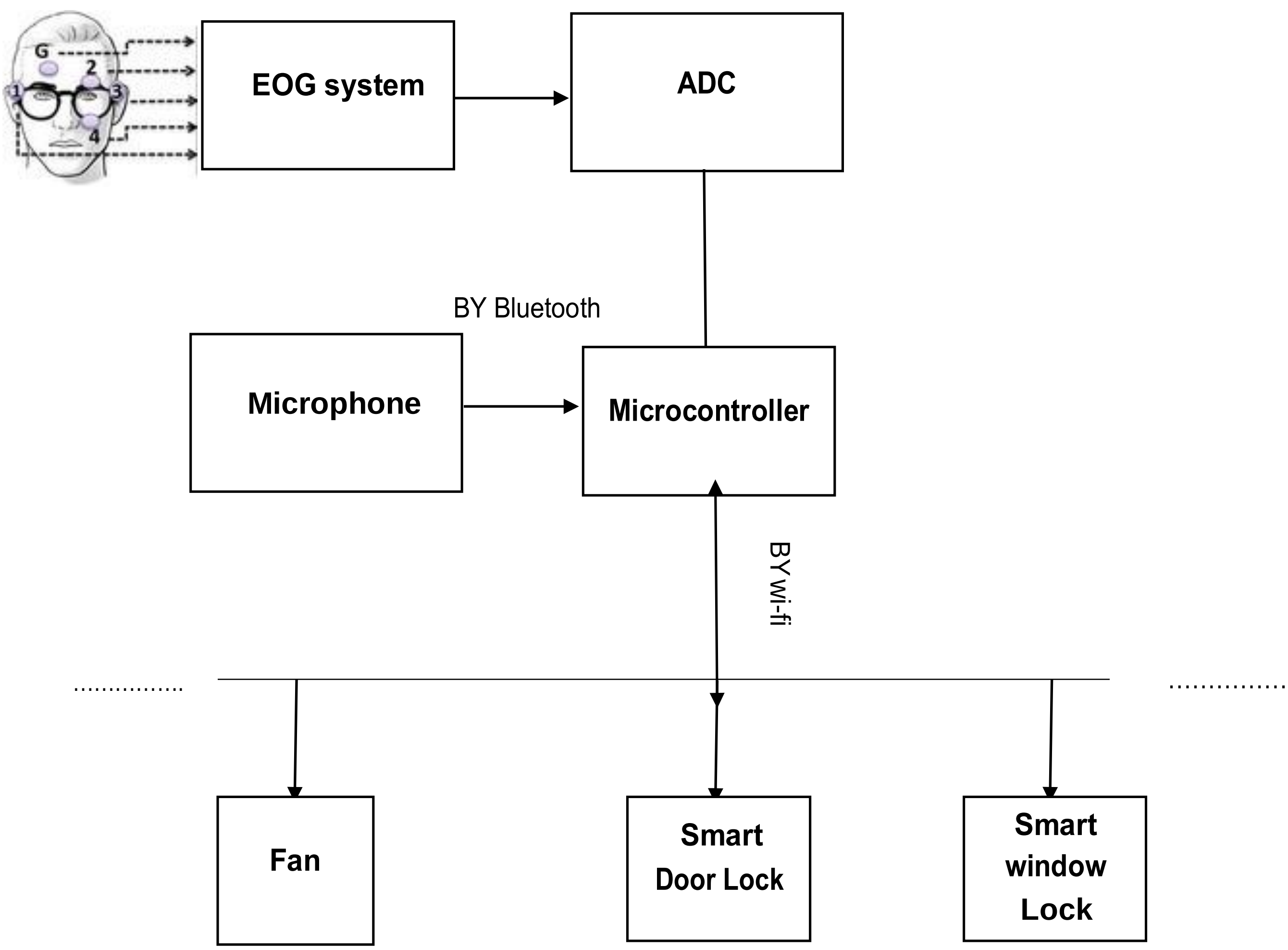

Figure 1. 1: the main block diagram of the system.

The following steps explain how our project works in general:

1. Decide which way to control home either by EOG or voice.

2. In the case of EOG connect electrodes to the eye muscles to get reactions then make conversions and send it to the microcontroller.

3. In the case of voice, input your voice to the microcontroller by using microphone.

4. Microcontroller will select device according to the previous command and send the new state of device to the relay over Wi-Fi.

1.5 Related work

We found many publications and product similar to our project so we choose some published scientific articles as shown below that help us in our project:

- **"Sensing and Processing of EOG Signals to Control Human Machine Interface System"** .[1]

  This paper discussed Human Machine Interface (HMI) to control electromechanical rehabilitation techniques using bio-signals such as EEG, EOG and EMG etc. When patients become completely or partially paralyzed, the only source or a resource offered to them are bio-signals. This work has been focused on controlling Human-machine interface (HMI) system that is based on Electrooculography (EOG) signals for guiding wheelchair motion manually. The user looks up, down, left, right and blink to guide the wheelchair to move forward, backward, left, right and stop respectively. A New Algorithm named as "Navigation point Algorithm" has been designed to navigate the wheelchair and finds a direct path from the origin to the goal point in a single head movement. Also detection sensor is used to find the best path.

- **"Wireless and Portable EOG Based Interface for Controlling Wheelchair"** [2]

  In this paper, they proposed an eye-movement tracking system. Based on Electro-Oculography (E.O.G) technology to detect the signal with different directions in eye-movements and then analyzed to understand horizontal direction or vertical direction. This enables people to control applications using bio-electric signals recorded from the body. In an Electrooculogram (EOG) based, signals during various eye (cornea) movements are employed to generate control signals. Moreover, Electrooculography is a technique for measuring the resting potential of the retina. The resulting signal is called the electrooculogram.

- **“A Method of EOG Signal Processing to Detect the Direction of Eye Movements”** [3]

  In this paper, a signal processing algorithm to detect eye movements is developed. The algorithm works with two kinds of inputs: derivative and amplitude level of electrooculographic signal. Derivative is used to detect signal edges and the amplitude level is used to filter noise. Depending of movement direction, different kinds of events are generated. Events are associated with a movement and its route. A hit rate equal to 94% is reached. This algorithm has been used to implement an application that allows computer control using ocular movement.

- **“IOT Based Monitoring and Control System for Home Automation”** [4]

  In This project an efficient implementation for IoT (Internet of Things) used for monitoring and controlling the home appliances via World Wide Web. Home automation system uses the portable devices as a user interface. They can communicate with home automation network through an Internet gateway, by means of low power communication protocols like Zigbee, Wi-Fi etc. The aim is to controlling home appliances via Smartphone using Wi-Fi as communication protocol and Arduino as server system. By this climbable and price effective Home Automation system will be provided.

our system features are to be able control home with several ways and It can be developed to include a sufficient number of devices not for single device.

1.6 Estimated cost and budget

The initial cost of this project is about, distributed as follows in the **table 1.1**:

Table 1. 1: Estimated cost

Component	Quantity	Price for each component	Price $
Electrodes	5	4	20
IC’s (AD620 &AD820)	2	6	12
Resistors and capacitors	10	0.1	1
Microphone	1	7	7
Arduino	1	25	25
NodeMcu ESP8266	2	10	20
Batteries	2	10	20
4-Channel relay module	1	15	15
Home devices	4	5	20
Bluetooth	1	8	8
Total cost	-	-	148

1.7 Time plane

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

Table 1. 2: timing plane for the first semester

Weeks / Task	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Select the idea																
Gathering information																
System analysis																
System Design																
Writing Documentation																

table 1. 3: timing plane for the second semester

Weeks / Task	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Implementation																
Testing																
Documentation																

1.8 Report Contents

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

Chapter One: Introduction

This chapter was focused on the main idea of the project about the eyes movement and voice and how can we use them to control some devices in smart home, it was state the aims and the previous works related to the project.

Chapter Two: Theoretical background

In this chapter, we discussed a set of concepts that we have used in our project. A short explanation have been provided for each concept. We talked about the electrooculography technique (EOG), Arduino, IoT and the smart home system and their usage in real life.

Chapter Three: System Design

In this chapter, we discussed and explained the main block diagram and the flow chart of whole system, and show the connection between sub systems in our project.

Chapter Four: implementation

After viewing the general system, in this chapter we decided to make our design and calculation in the EOG department and showing a software design in packet tracer program to simulate the technology of IoT.

Chapter Five: Testing and Results

In this chapter we show all testing needed to evaluate the performance of our system to achieve results and many calculations to enhance the percentage of error of the system was used. we were tested EOG technology and voice recognition application that needed and made many experiments in wireless network.

Chapter Two
Theoretical background

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2.1 Overview

In this chapter, we discussed a set of concepts that we have been used in our project. A short explanation has been provided for each concept. We have talking about the electrooculography technique (EOG), Arduino, IoT and the smart home system and their usage in real life.

2.2 Electrooculograph

2.2.1 Definition

Electrooculography is a technique for measuring the resting potential of the retina. The resulting signal is called the electrooculogram. An electrooculography is a device that is use for measuring the voltage between two electrodes placed near eyes so it can detect eye movement. [5]

2.2.2 Physiological Background

The eye movements are controlled by three separate pairs of muscles, including the medial and lateral recti and the superior and inferior recti and oblique as shown in **figure 2.1**:

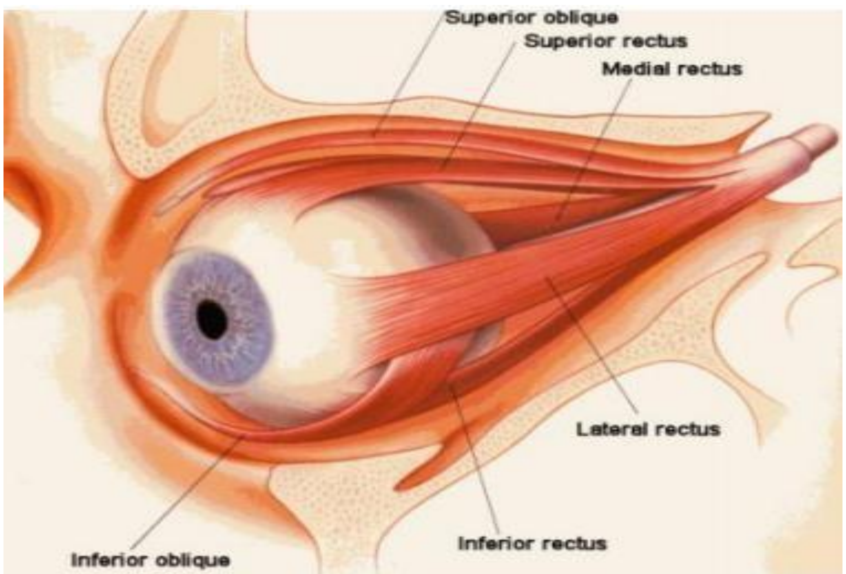


Figure 2. 1: Lateral view of extraocular eye muscles[4]

The function of these muscles is to stabilize and move eye in different direction, distribution of the muscles is symmetrical. Each of the three sets of muscles to each eye is reciprocally innervated so that one muscle of the pair relaxes while the other contracts. **Table 2.1** show the location and action of each muscle.

Table 2. 1: muscles, location and action of the eye [6]

Muscles	Location	Action
Superior rectus	Superior and central part of eyeballs.	Moves eyeballs superiorly (elevation) and medially (adduction), and rotates them medially.
Inferior Rectus	Inferior and central part of eyeballs.	Moves eyeballs inferiorly (depression) and medially (adduction), and rotates them medially.
Lateral Rectus	Lateral side of eyeballs.	Moves eyeballs laterally (abduction).
Medial Rectus	Medial side of eyeballs.	Moves eyeballs medially (adduction).
Superior Oblique	Eyeball between superior and lateral recti.	Moves eyeballs inferiorly (depression) and laterally (abduction), and rotates them medially.
Inferior Oblique	Eyeballs between inferior and lateral recti.	Moves eyeballs superiorly (elevation) and laterally (abduction) and rotates them laterally

2.2.3 Electrooculogram

Electrooculogram (EOG) is a graphic record of the electric activity of eye ball movements. The electrical signal is generated due to the potential difference between retina and cornea of the eye. The voltage for the horizontal eye movement is up to 16µV whereas it is 14µV for the vertical movement of the eye per 1° .[7]

The main application of the EOG is in the measurement of eye movement, by attaching skin electrodes on both sides of an eye the potential can be measured by having the subject move his eyes horizontally and vertically a set distance as shown in **figure 2.2**. every movement of the eye will produce a different signal with different amplitude, **figure 2.3** shows different EOG signal that produced by different eye movement.

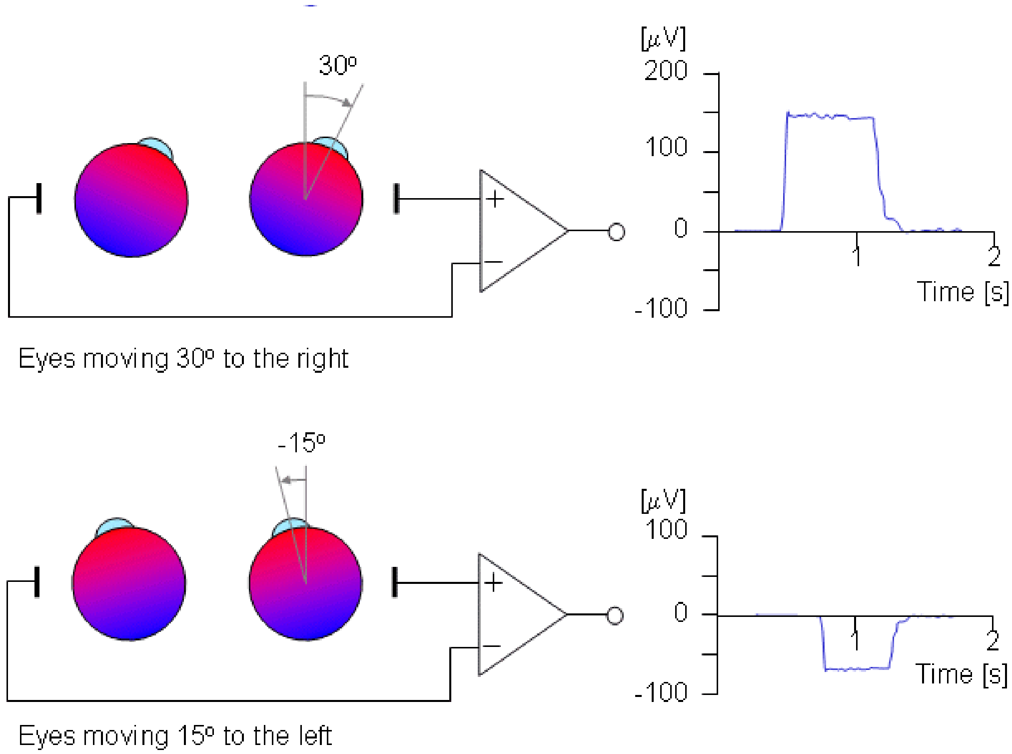


Figure 2. 2: signal generated from horizontal movement of eye [8]

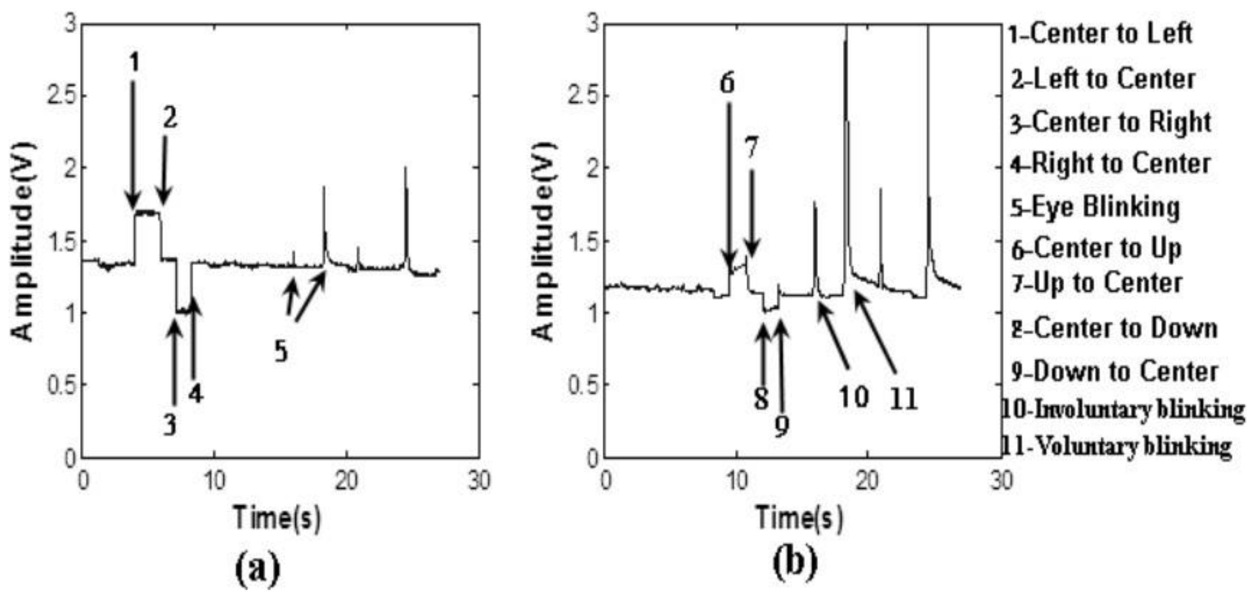


Figure 2. 3: signal generated from all movement directions of eye.[14]

2.2.4 Advantages and disadvantages of EOG signal

EOG approach has both advantages and disadvantages when compared to other methods for determining eye movement.

Advantages of EOG signal:

I. EOG based recording techniques are simple than other methods.
II. Inexpensive
III. Recording with minimal interference and minimal discomfort.
IV. Electrodes did not touch the surface of the eye.

Disadvantages of EOG signal:

I. The corneoretinal potential is not fixed but has been found to vary diurnally, and to be affected by light, fatigue, and other qualities. Consequently, there is a need for frequent calibration and recalibration.
II. EOG signal amplitude is of microvolt range and highly susceptible to noise.
III. EOG signals are very much sensitive and therefore fluctuate with head movements.[4]

2.2.5 EOG System component

The basic components of an EOG system are:

A – surface electrodes

B – amplifiers

C- filters

A- Surface electrodes:

EOG electrodes should be relatively non-polarizable such as standard medical electroencephalograph (EEG) or electrocardiograph (ECG) electrodes, of a size appropriate for attachment to the side of the nose. Four electrodes are placed at the upper, lower, right and left areas of the eye, respectively, and the reference electrode at the frontal lobe or earlobe as shown in **figure 2.4**:

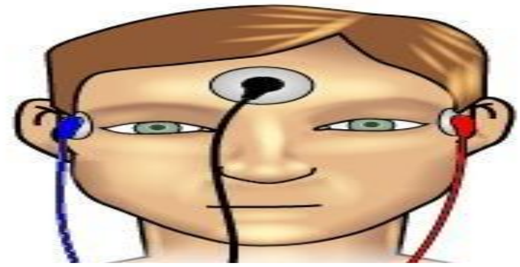


Figure 2. 4: location of EOG electrodes [8]

B- Amplifier: Some of amplification process must perform to obtain electrooculogram in suitable form.

C- Filter: An electronic filter is an arrangement of electronic components used in a circuit to transmit signals within a given frequency range, rejecting others.

2.3 Arduino

2.3.1 Arduino principle

figure 2. 5: Arduino Uno[7]

Arduino is a single-board microcontroller meant to make the application more accessible which are interactive objects and its surroundings.

it is an open-source platform used for building electronics projects. Arduino consists of both a physical programmable circuit board (often referred to as a microcontroller) and a piece of software, or IDE (Integrated Development Environment) that runs on your computer, used to write and upload computer code to the physical board.

The Arduino platform has become quite popular with people just starting out with electronics, and for good reason. Unlike most previous programmable circuit boards, the Arduino does not need a separate piece of hardware (called a programmer) in order to load new code onto the board -- you can simply use a USB cable. Additionally, the Arduino IDE uses a simplified version of C++, making it easier to learn to program. Finally, Arduino provides a standard form factor that breaks out the functions of the micro-controller into a more accessible package.

[7] see appendix C.

2.3.2 Comparison between different versions of Arduino

There are different versions of Arduino available which are: Arduino MEGA 2560, Arduino UNO, Arduino MINI, Arduino NANO.

Out of the above versions of Arduino, more prominently use Arduino and their features are as follows in **table 2.2**:

Table 2. 2: Comparison of different versions of Arduino [9]

Name of Arduino	**MEGA 2560**	**UNO**	**MINI**	**NANO**
processor	ATmega2560	ATmega328P	ATmega328P	ATmega168 ATmega328P
CPU Speed	16 MHz	16 MHz	16 MHz	16 MHz
Analog In/Out	16 / 0	6 / 0	8 / 0	8 / 0
Digital IO/PWM	54 / 15	14 / 6	14 / 6	14 / 6
Flash [KB]	256	32	32	16 32
USB	Regular	Regular	_	Mini

With relative to the above comparison The latest and the most powerful version is called Arduino MEGA 2560.

2.3.3 Why Arduino?

There are many key reasons that we have to choose Arduino to do our project because the Arduino have advantages over the others:

V. It was easy to use than other microcontroller.

VI. The other devices are much more expensive than the Arduino.

VII. Have many pins that can used.

And there is a disadvantages:

I. It doesn’t replace your computer.
II. Big structures of Arduino have to stick with big sized PCB’s.

2.4 Voice recognition

Voice recognition is commonly used in the automotive industry for various manufacturing and inspection applications. It is also used in warehousing and distribution to track material movement in real time, in the transportation industry for receiving and transporting shipments, in laboratory work, and in inspection and quality control applications across all industries.

Voice recognition technology converts human speech into electrical signals and transforms these signals into coding patterns with assigned meanings. It is also the only technology that is generally trained to the way a human works rather than requiring the human to learn the machine's way of doing things. And because speaking doesn't require the use of hands it is ideal for jobs requiring the worker's hands to be free. Inspection and baggage handling are two common applications. Voice terminals shine as automated input devices in applications where an operator's hands and eyes are occupied, enabling source data capture in real time.

Workers typically wear a speaker headset connected to a unit that recognizes spoken words and converts them into analog electrical signals. The analog signals are converted to digital patterns, which are decoded or "recognized" by template-matching or feature analysis. The data output may be entered into a program or it may activate a range of computer-based equipment such as scales, programmable logic controllers, or printers. In dialog voice recognition systems, the unit recognizes human speech and then synthesizes a spoken response (or plays back a digitized response) to verify input and/or prompt the operator through a series of tasks.[11]

2.5 The Internet of Things (IoT)

2.5.1 Introduction

Today the Internet exists for more than twenty years and over 2 billion people are connected to it using computers, smartphones and tablets.

The Internet currently connects people to people (P2P) and is now being called Internet Phase 1. The next Phase of the Internet is just beginning and will connect people to everyday devices (M2P), and everyday devices to each other (M2M).

Now everyday devices like thermostats, lights, cars, TVs and etc are being made smart by connecting them together over networks and to the Internet.

These devices will not only be able to send data to the Internet but they will also be controlled over the Internet.

These devices will become "**things**" on the "**Internet of things**". As shown in **figure 2.6**:

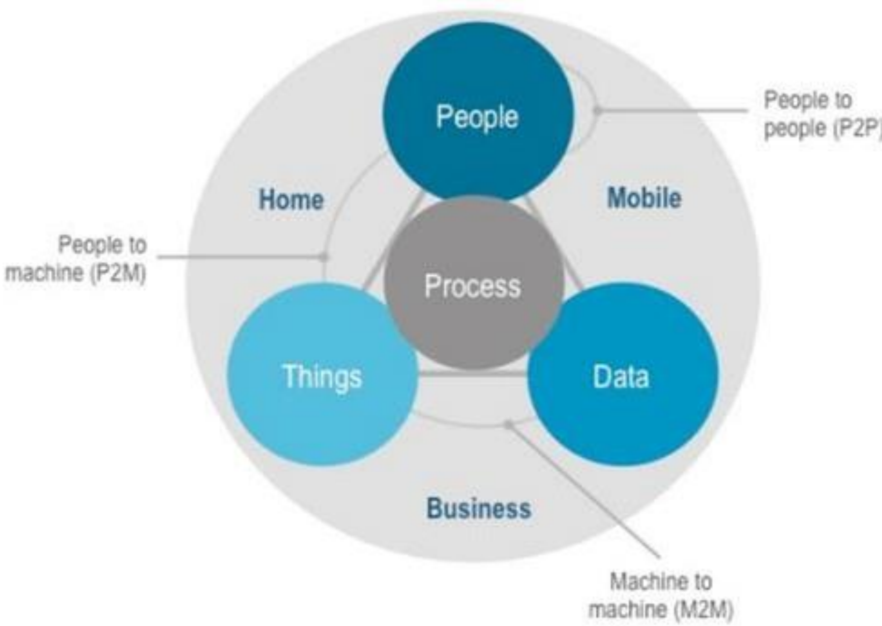


Figure 2. 6: IoT Phases[12]

2.5.2 What is The Internet of Things?

Imagine a world where billions of objects can sense, communicate and share information, all interconnected over public or private Internet Protocol (IP) networks. These interconnected objects have data regularly collected, analyzed and used to initiate action, providing a wealth of intelligence for planning, management and decision making. This is the world of the Internet of Things (IoT).

Internet of things common definition is defining as: Internet of things (IoT) is a network of physical objects. The internet is not only a network of computers, but it has evolved into a network of device of all type and sizes , vehicles, smart phones, home appliances, toys, cameras, medical instruments and industrial systems, animals, people, buildings, all connected ,all communicating & sharing information based on stipulated protocols in order to achieve smart reorganizations, positioning, tracing, safe & control & even personal real time online monitoring , online upgrade, process control & administration.

The goal of the Internet of Things is to enable things to be connected anytime, anyplace, with anything and anyone ideally using any path/network and any service. As shown in **figure 2.7**:

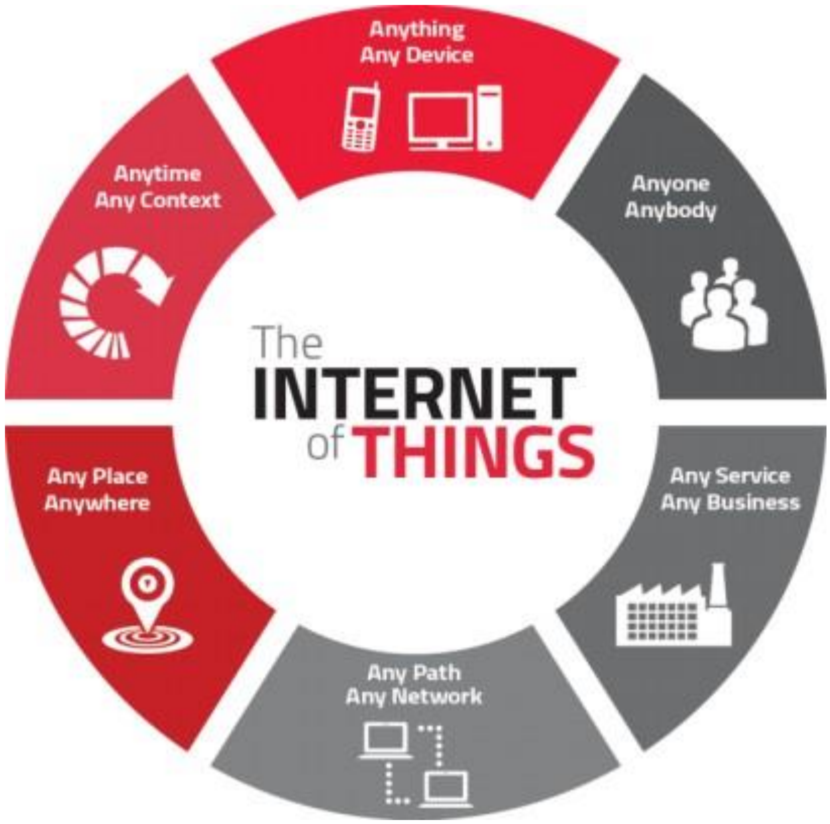


Figure 2. 7: The Internet of Things[13]

2.5.3 History of the Internet of Things

The idea of adding sensor and intelligence to basic objects was discussed throughout the 1980s and 1990s progress was slow simply because the technology wasn't ready.

- The first telemetry system was rolled out in Chicago in 1912. It is said to have used telephone lines to monitor data from power plants.
- Telemetry expanded to weather monitoring in the 1930s.
- Broad adoption of M2M technology began in the 1980s with wired connections for SCADA.
- In the 1990s, M2M began moving toward wireless technologies.
- in 2005: The IOT hit another level when the UN's published its first report on the topic: "A new dimension has been added to the world of information and communication technologies (ICTs) we will now have connectivity for anything."
- In 2011 IPv6 was launched.
- predictions state that by 2022 there will be 18 billion IoT-related connected devices.

- Bain & Company expects annual IoT revenue of hardware and software to exceed $450 billion by 2020. As shown in **figure 2.8**: [13]

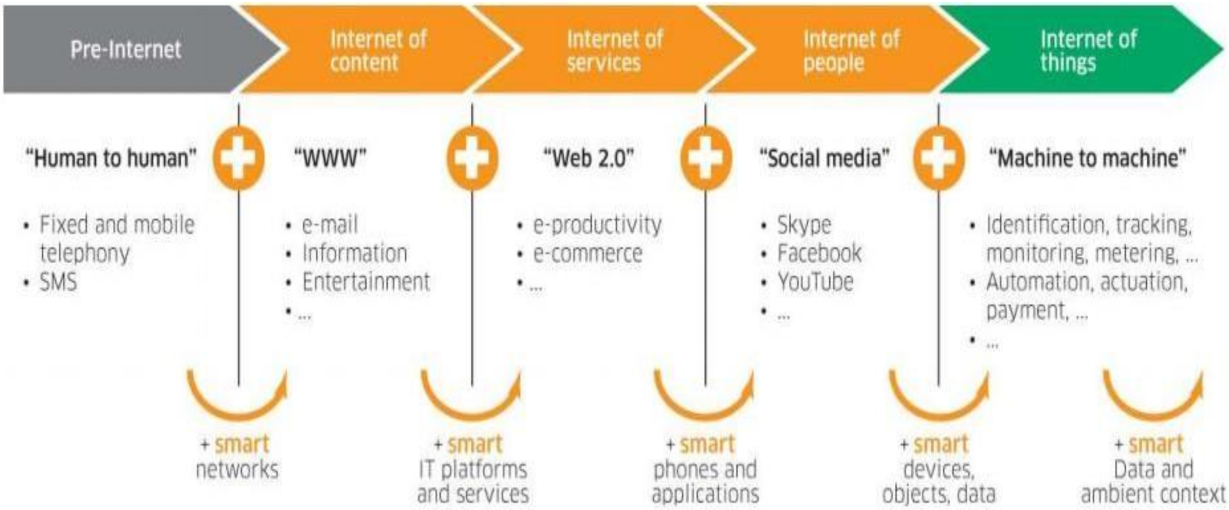


Figure 2. 8: History of IoT[14]

2.5.4 IoT Components

An IoT system comprises three basic Components:

- The things -sensors actuators etc.
- The Network.
- The Platforms, Apps and services. As shown in **figure 2.9**:

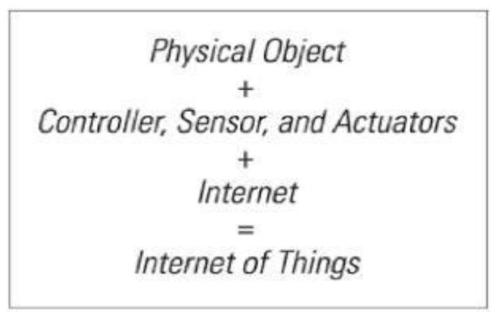


Figure 2. 9: IoT Components[15]

1. The Things:

To turn an everyday object like a house or a car into a smart object will require that the object has:

- A unique address – IP address.
- A way to connect to a network – Wireless.
- sensors like temperature, light, speed etc.

2. IoT Networks:

Wi-Fi and Bluetooth are being actively developed for low powered applications and there are new connection technologies like LPWAN, ZigBee, 6LoWpan and Thread.

At the networking level IPv6 is set to become the standard, but in the intermediate time frame IPv4 will also be used.

At the application level there are a host of new protocols. like HTTP, whereas others have been developed especially for the IoT e.g. COAP.

3. IoT Platforms, Apps and Services:

An IoT platform combines several IoT functions It can collect and distribute data, convert data between protocols, store and analyze data.

They are available as cloud-based and standalone platforms and are available from many companies. Examples:

- Amazon Web services (AWS)
- IBM Watson Bluemix
- Microsoft Azure

2.5.5 IoT − Technology and Protocols

IoT primarily uses standard protocols and networking technologies. However, the major technologies and protocols of IoT are RFID, NFC, Bluetooth, wireless, radio protocols, LTE-A, and Wi-Fi Direct. These technologies support the specific networking functionality needed in an IoT system.

2.5.6 Wi-Fi Technology

Wireless Fidelity, more known by its short form Wi-Fi, is a digital communications protocol, through which gadgets can communicate with each other in a unicast or a broadcasting manner without using any wires. the IEEE committee for 802 standards which manages networking protocols among electronic devices, formed an extension 802.11 which would work on the wireless mode, being a wireless protocol, Wi-Fi standard uses the ISM (Industrial, Scientific, and Medical) band of frequency which is free to use and require no licensing. Launched in 2.4GHz with transmission rates of 1-2mbps, Wi-Fi now works at 5GHz frequency also with astounding data transmission rates reaching up to 54mbps at both frequencies.

Wi-Fi is using for all the standards that fall under 802.11 category of Wireless LAN. So, Wi-Fi defines 802.11 x standards where x is the respective Wi-Fi version. Popular Wi-Fi version are a, b, g and n.

Wi-Fi is based on OSI Model and uses the physical layer and MAC sub-layer of the Data Link Layer.

In this project we will use **ESP-01 WIFI Wireless Transceiver Module:**

ESP-01 ESP-8266 is an ideal choice for hobbyist to start experimenting with IOT. The dimension of this module is 25mm x 15mm, with simple pin connections (standard 2×4 pin headers), using serial TX/RX to send and receive Ethernet buffers, and similarly, using serial commands to query and change configurations of the Wi-
Fi module. As shown in **figure 2.10, 2.11**:

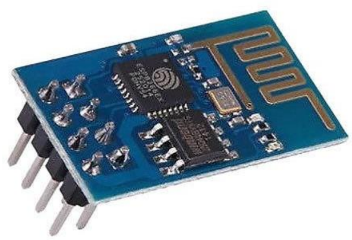


Figure 2. 10: ESP-01 Module

Figure 2. 11: ESP- 01 Relay module

2.5.7 IoT Application

There are numerous real-world applications of the internet of things such as:

- IOSI (Internet of smart industry).
- IOSH (Internet of smart health).
- IOSC (Internet of smart cities).
- IOSE (Internet of smart environment).
- IOSA (internet of smart agriculture).

- IOSL (Internet of smart living). As shown in **figure 2.12**:

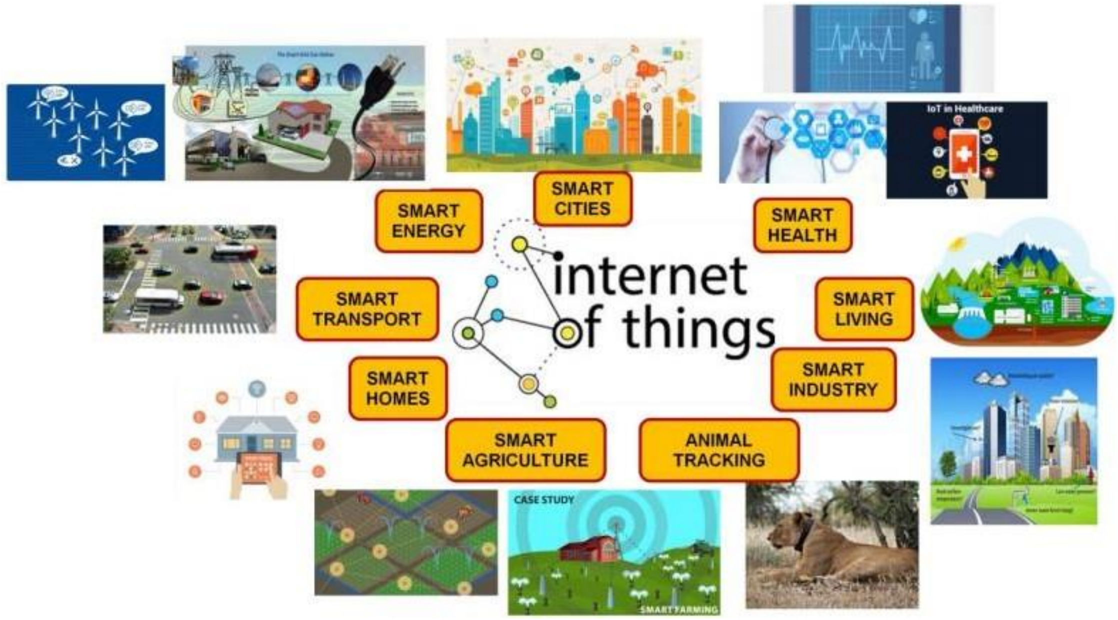


Figure 2. 12: Application of IoT[13]

2.5.8 IoT of Smart Home

For consumers, the smart home is probably where they are likely to come into contact with Internet-enabled things, and it's one area where the big tech companies are competing hard.

there are smart plugs, lightbulbs, cameras, thermostats, doors, fan, and smart fridge. But there's a more serious side to smart home applications. They may be able to help keep older people lying in their own homes longer and Provide care for them and communicate with them.

Chapter Three
System Design

3.1 Overview

In this chapter, we discussed and explained the main block diagram and the flow chart of whole system, and the connection was shown between sub systems in our project.

3.2 System Tools

We used Arduino mega and LCD Display in transmitter circuit and used 4-Channel relay module in receiver circuit. As shown in next figures:

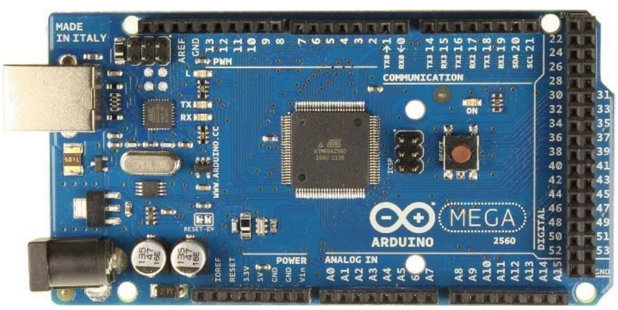


Figure 3. 1: Arduino mega

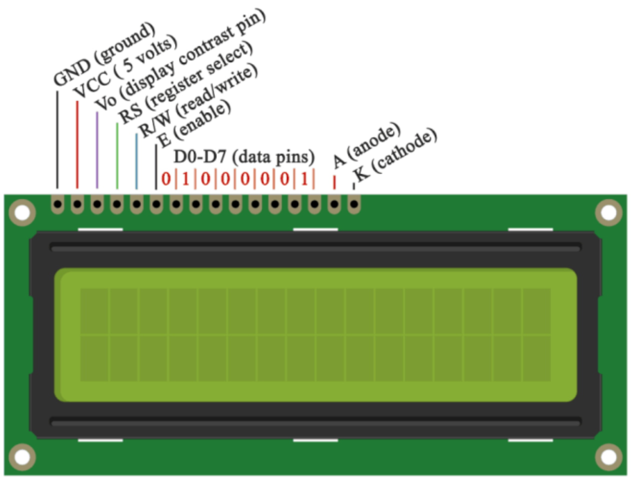


Figure 3. 2 : 16*2 LCD Display

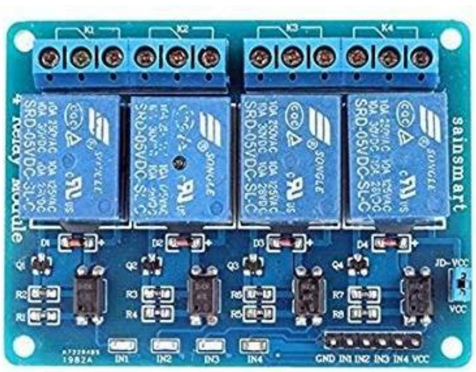


Figure 3. 3: 5V 4-Channel Relay module

3.2.1 EOG Tools

3.2.1.1 Electrodes

Ag/Ag Cl electrode was used to detect signal from eye muscles, electrodes is shown in figure 3.4, We started to test each component of the project to ensure its functionality. 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.

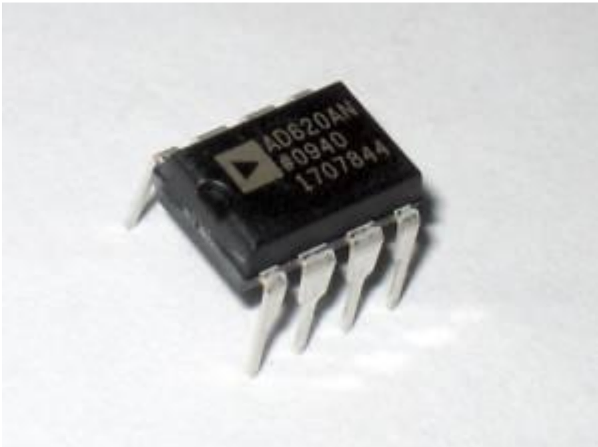
Figure 3. 4: Ag/Ag cl electrode

3.2.1.2 EOG Power Supply

We tested the battery supply first without connecting to horizontal circuits. In this case, battery was successful and gave the required results, It provides positive volts and others negative needed to IC's work.

3.2.1.3 Pre-Amplifier

the AD620 IC was used as instrumentation amplifier, figure 3.4 show AD620 IC, The AD620 IC was connected with potentiometer RG, and then we control the gain of IC by this potentiometer, as shown in figure 3.5.



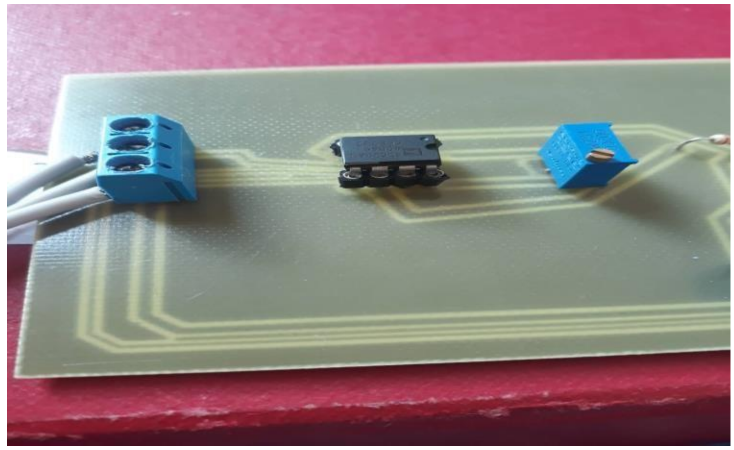


figure 3. 5: AD620 IC

figure 3.6: AD620 IC with potentiometer

3.2.1.4 filter and non-inverting amplifier

AD822 IC was used for design filter and gain amplifier, the circuit of filter and gain amplifier is shown below.

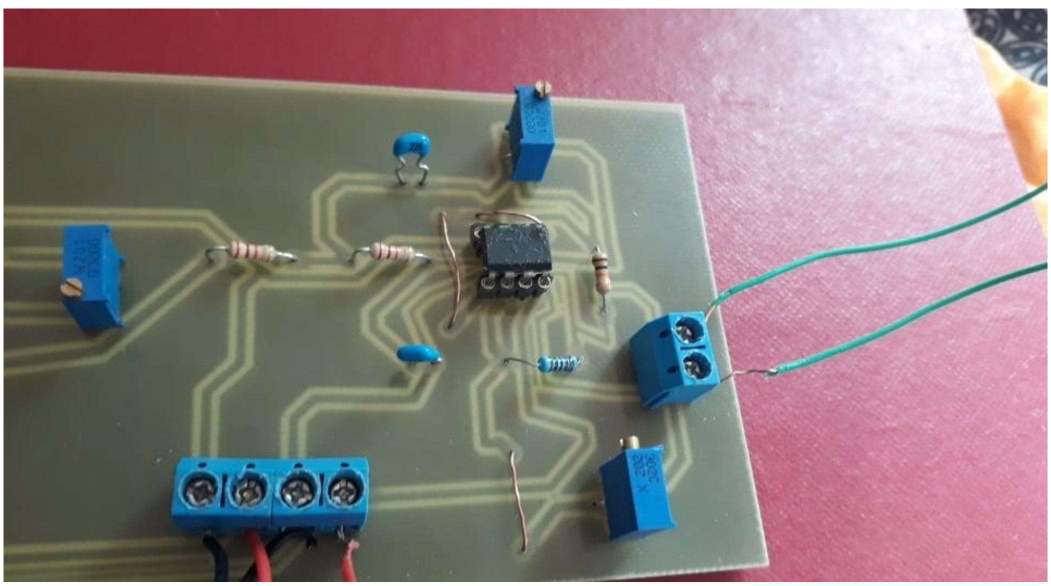


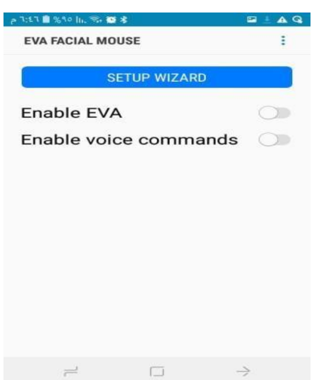
figure 3. 6: filter and non-inverting circuit

3.2.3 Voice Tools

In this section the online voice recognition application was used to send voice to the Bluetooth module which connected with Arduino Mega. As shown in **Figure 3.7** the application with list of Bluetooth connections which our Bluetooth connected with HC-05.

figure 3. 7:voice recognition application.

And for more fixable we decided to use EVA mouse application to allow our patients to use the system without any effort just by their head movement. firstly, they click the mouse to enable the EVA mouse application and then connect the mobile voice recognition application with the HC-05 Bluetooth module.as shown in **figure 3.8** the enabling of EVA mouse and then opining of voice recognition application by head movement in the camera of application.



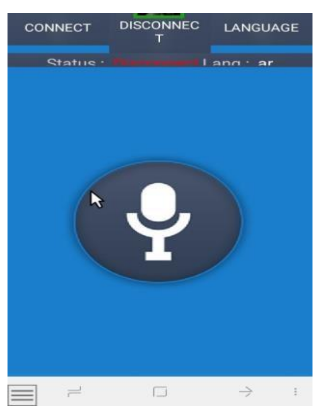


Figure 3. 8:EVA mouse with voice recognition.

Module of Bluetooth HC-05 with 2.45GHz frequency band and 10 m range was used, connected to Arduino to collect signals from voice recognition mobile application and through the algorithm the Arduino done its work to turn “ON” or “OFF” the desired device. **Figure 3.9** show the Bluetooth module with six pins with connect Vcc to +5 volt and ground and pins for receiving (Rx) and transmitting(Tx).

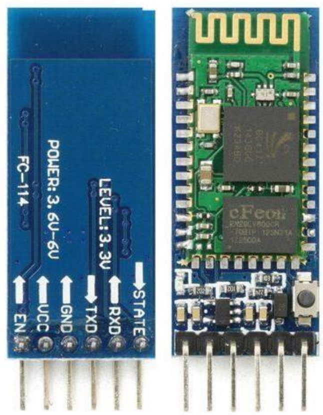


Figure 3. 9:Bluetooth HC-05 module .

3.2.3 Wi-Fi Tools

We used two ESP8266 Wi-Fi module NodeMcu as client in transmitter with Arduino and server in receiver with relays, and use two Bi-Directional Logic Level Converter to convert 5V from/to Arduino into 3.3V to/from Wi-Fi module. As shown in next figures:

Figure 3. 10: ESP8266 Wi-Fi module NodeMcu (see appendix D).

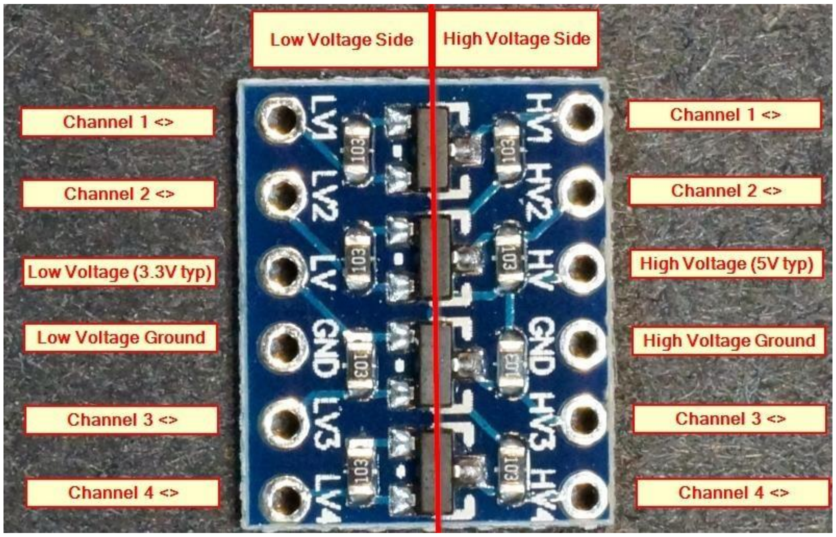


Figure 3. 11: Bi-Directional Logic Level Converter

3.3 Block Diagram and flow chart of the system

The block diagram below represents the whole system of our project, **figure 3.12** shows how our project work in general and components that used.

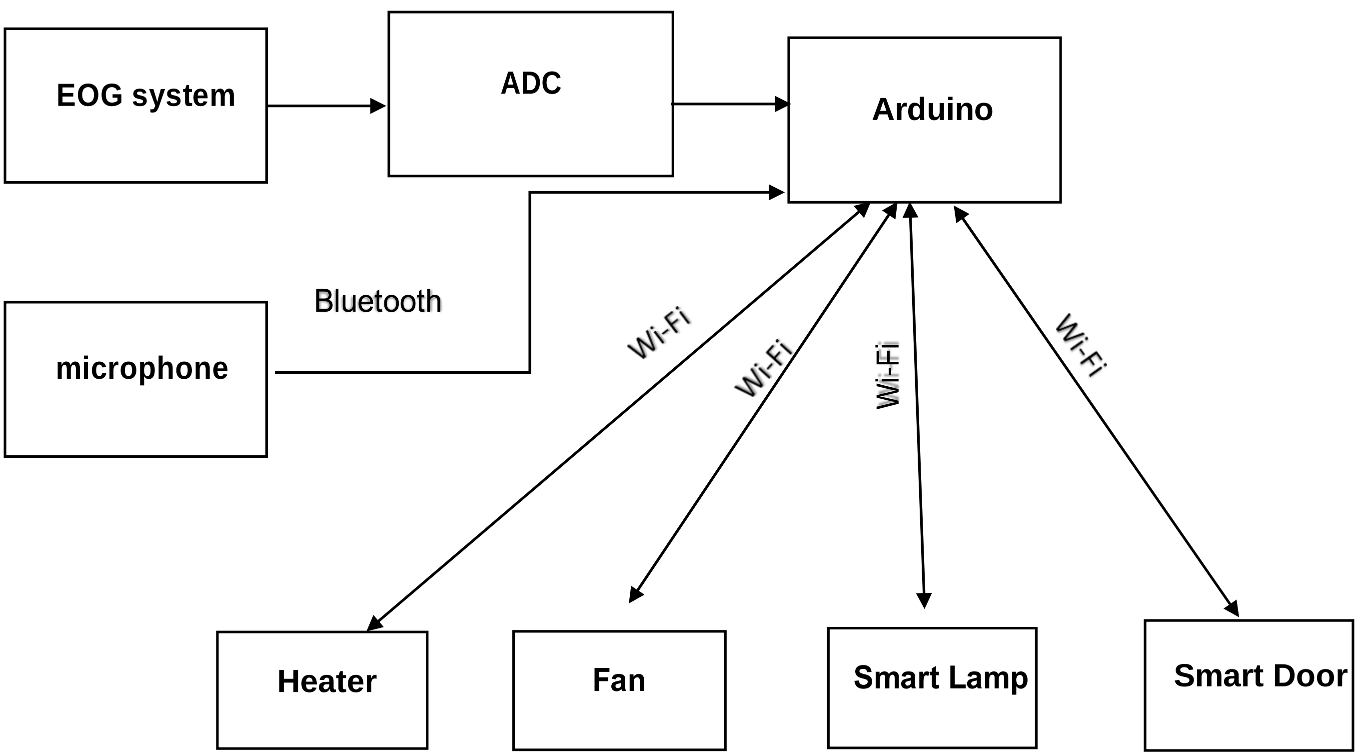


Figure 3. 12: Block diagram of whole system.

The flow chart below represents the whole system of our project, **figure 3.13** shows brief description about how our project worked.

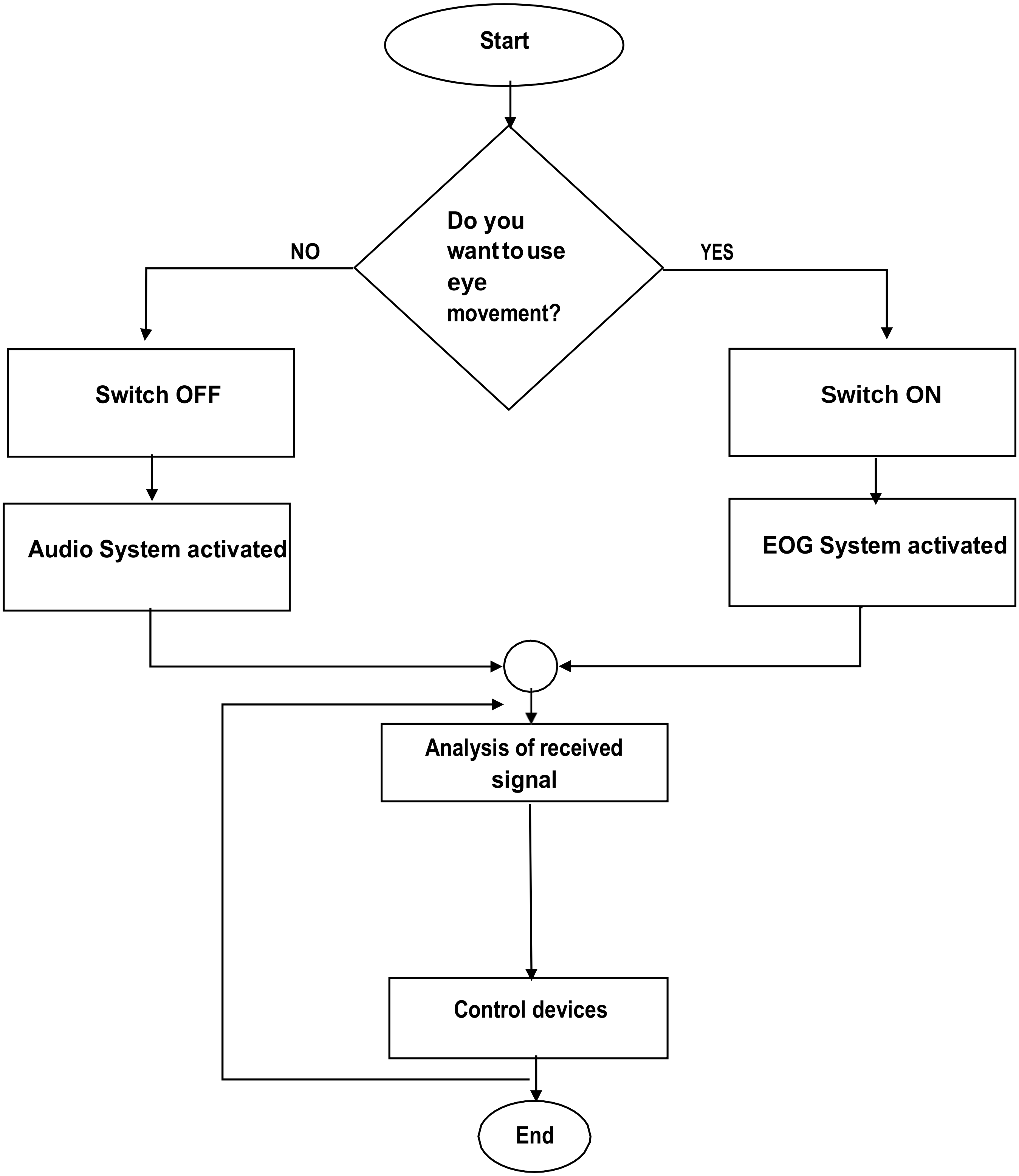


Figure 3. 13: flow chart of whole system

3.4 EOG block diagram

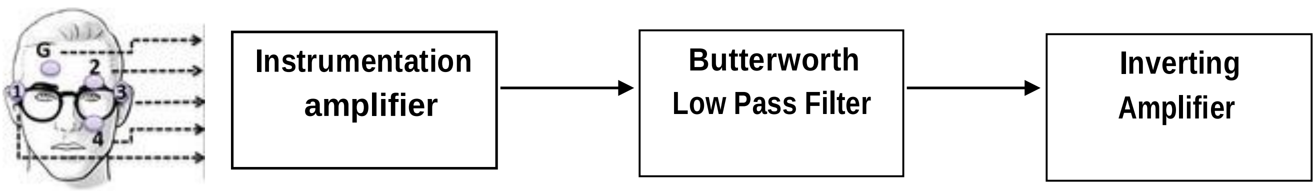


Figure 3. 14: EOG Block diagram

3.4.1 Surface Electrode

In our design of the EOG circuit , we used one type of many types of electrode, this type is called (Ag-AgCl) electrode, the reason for using this type that their performance such as high sensitivity and high accuracy of detecting signal .In this project the electrodes will be put in fifth 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 be put it in the left and on the right around the eye. the fifth electrode will be used as reference.

Biologic systems frequently have electric activity associated with them. This activity can be a constant dc electric field, a constant flux of charge-carrying particles or current, or a time-varying electric field or current associated with some time- dependent biologic or biochemical phenomenon. Bioelectric phenomena are associated with the distribution of ions or charged molecules in a biologic structure and the changes in this distribution resulting from specific processes. These changes can occur as a result of biochemical reactions, or they can emanate from phenomena that alter local anatomy. [16]

The mechanism of electric conductivity in the body involves ions as charges. Picking up bioelectric signals involves interacting with these ionic charges and transuding ionic currents into electric currents required by wires. This transuding function is carried out by electrodes that consist of electrical conductors in contact with the aqueous ionic solutions.

Electrodes are made from noble metals such as platinum are often highly polarizable. A charge distribution different from that of the bulk electrolytic solution 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 solution adjacent to the electrode surface will change, and this will induce a voltage change in the electrode that will appear as motion artifact in the measurement. Then for most biomedical measurements, non-polarizable electrodes are preferred to those that are polarizable. [16]

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 (**fig 3.15**) consists 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 solutions; 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.

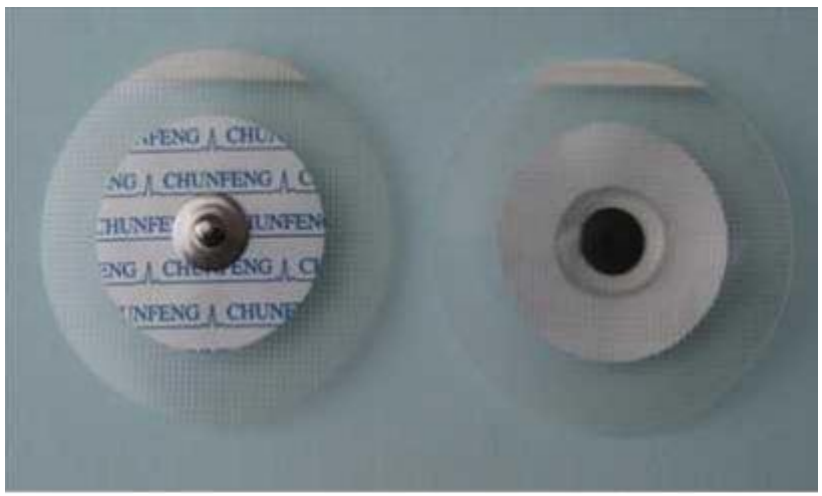


Figure 3. 15: Silver–silver chloride electrode

3.4.2 Electrodes lead wires

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

3.5 Instrumentation Amplifier

Eyes signals such as all bio potential signal, when we detect these signals, we needed to take the difference between the electrodes, to extract this signal we connected the electrode to special circuit, it's the preamplifier. This preamplifier or instrumentation amplifier consist of three amplifiers, two non-inverting and the third is difference amplifier. The eyes signal. 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 takes the difference between two electrodes 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.

Instrumentation amplifier is a differential input single-ended output amplifier, this amplifier is one of 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 bio potential signal and amplified it without noise, and it have been commercial part, on the other hand the AD620 have detected and amplified the signal from the source without any change in the shape of the signal.

This (AD620) are connected as non-inverting amplifier and it has many properties noticed when we have used it as an instrumentation amplifier such as:

1) Low cost.

2) High accuracy that requires only external resistor to set the gain of circuit.

3) High common mode rejection ratio (CMMR), at remove the small voltage noise, it is passed by electrodes.

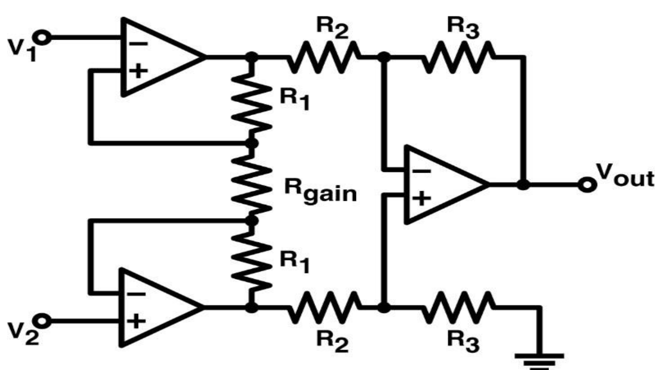


Figure 3. 16: Instrumentation Amplifier[17]

3.6 Butterworth Low Pass Filter

The Low-pass filter passes low-frequencies signals but it attenuates signals with frequencies that are higher than the cut frequency. The concept of a low-pass filter exists in many different forms. In our project we used the second order low pass filter or 2-pole sallen key low pass filter, **figure 3.17** show the circuit diagram of low pass filter.

Were R_1 &R_2 &C_1&C_2 &R_A&R_B are components of low pass circuit,

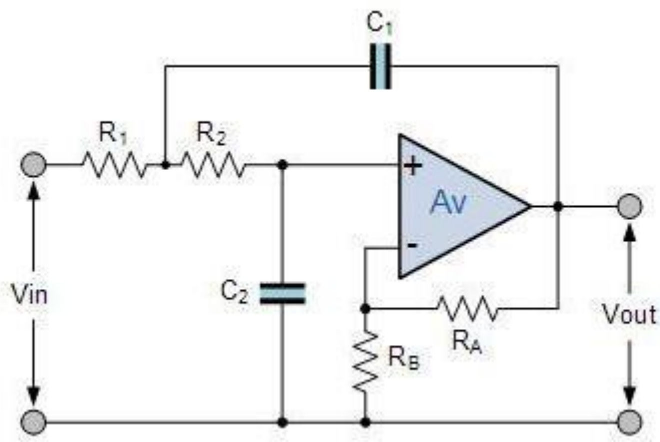


Figure 3. 17: Sallen key 2nd order low pass filter circuit[18]

3.7 Non-Inverting Amplifier

Non-Inverting amplifier is the most basic op-amp circuit. It uses negative feedback to stabilize the overall voltage gain. The reason we needed to stabilize the overall voltage feedback, Non-inverting amplifier configuration has an input impedance approximately equal to the input resistor Ri and output impedance approximately equal to the output impedance of the op amp itself. **figure 3.18** show the circuit diagram of inverting amplifier.

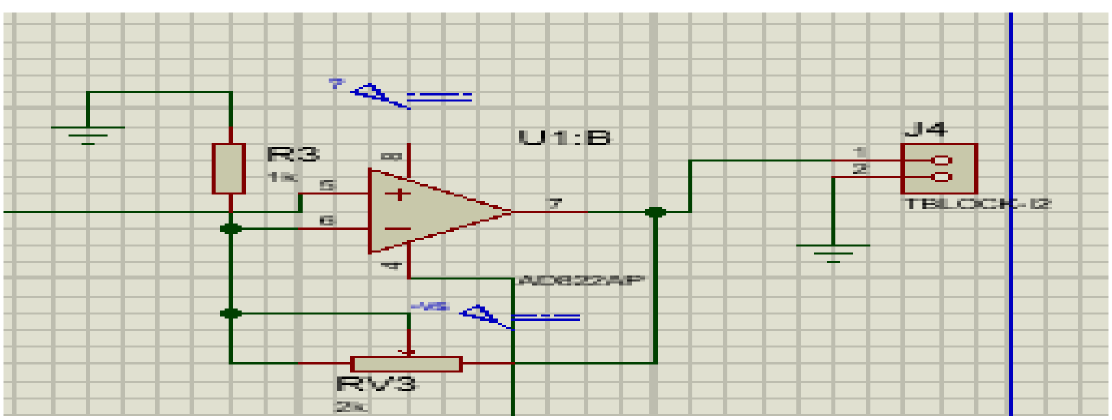


Figure 3. 18: Non-Inverting Amplifier[18]

Two 9-volt battery have been used as a power supply to supply the electrical component with their needed.

2.8 EOG Flow charts

Flow chart in **figure 3.19** represents the methodology of EOG with Arduino in horizontal EOG state (Right and Left) to select devices and control them.

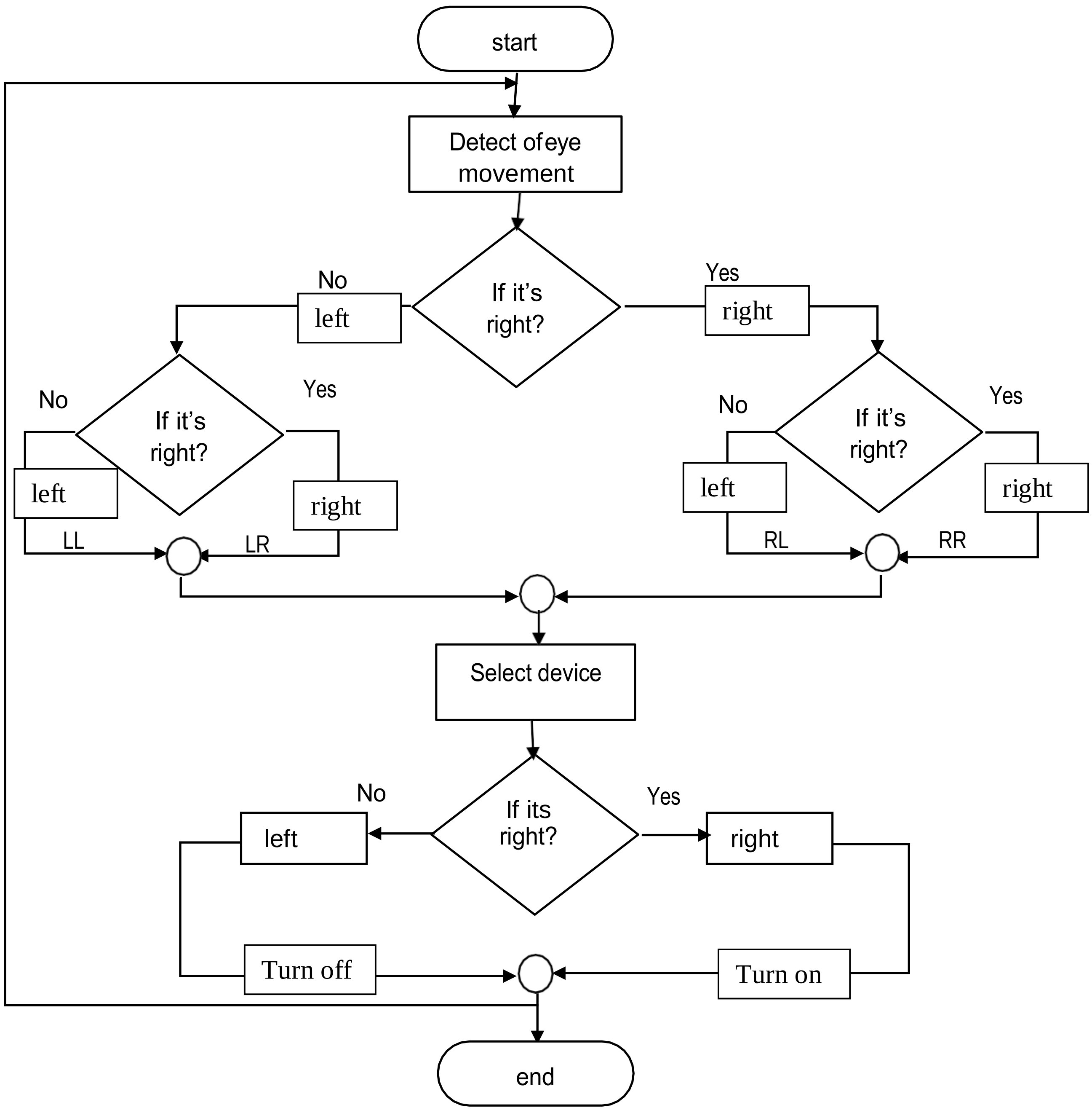


Figure 3. 19: Horizontal EOG flow chart

The following flow chart in **figure 3.20** illustrates the methodology of EOG with Arduino in Vertical EOG flow chart (Up and Down).

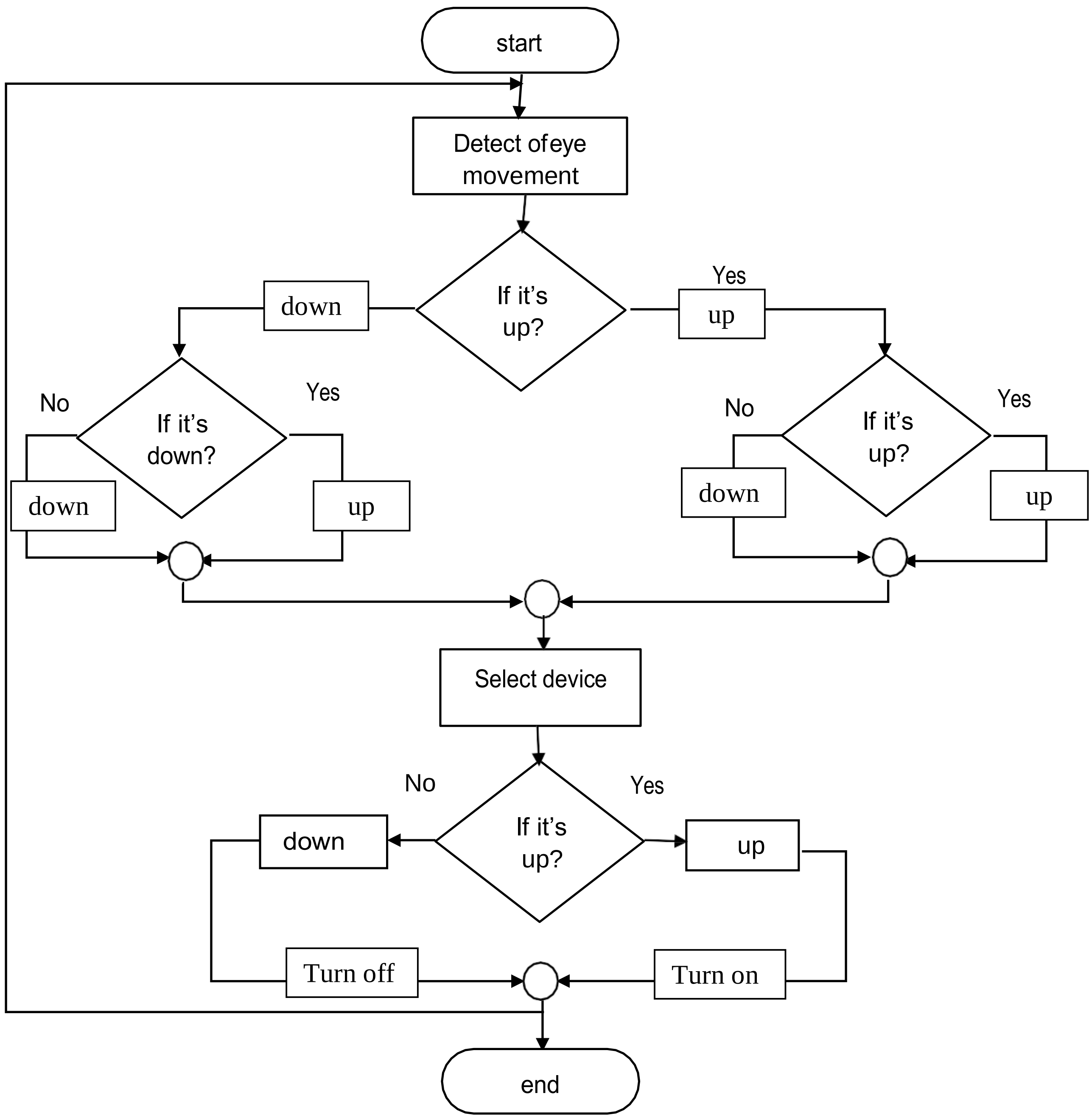


Figure 3. 20: Vertical EOG flow chart

In the future, we can improve the system by make a combination between vertical and horizontal eye movements to expand the range of devices that is possible to control it, for example we can use up then right movement to select the device and up movement for turn on device and left for turn it off.

Table3.1 illustrate samples of sample space (S) which containing eight probabilities (2^3) for both horizontal and vertical eye movements. Each sample selected a Specific device by the first three movements, then the fourth movement will control state of selected device.

$S_{Horizontal}$ **={RRR,RRL,LLR,LLL,RLR,RLL,LRR,LRL}**

$S_{Vertical}$ **={UUU,UUD,DDU,DDD,UDU,UDD,DUU,DUD}**

Table 3.1: Examples of devices selected by eye movements.

Samples	Selected device	State of device
RRRR	TV	Open
LLLL	Lamp	Close
RLLL	Air Conditioner	Close
LRRR	Fan	Open
UUUU	Door lock	Open
DDDD	Heater	Close
UDUU	Microwave oven	Open
DUDD	Boiler	Close

3.9 Voice recognition

In our project we used online voice recognition software to perform the tasks required from Arduino Mega 2560.

We needed a power supply with the Arduino. Firstly, by connect Bluetooth module to Arduino to detect Bluetooth signal from voice recognition application, then the application is able to listen in real time to microphone input or speaker in smart phone and recognize the input words to send it to Arduino and start comparing it with the code to reach the desired aim by connected with relay to have smart home.

EVA Mouse Application was used to allow the patient using his smart phone without touch the screen and that's by using a phone camera to detect head movement, so patient was become able to control devices only by his voice. The **figure 3.21** show the connection between Arduino and microphone:

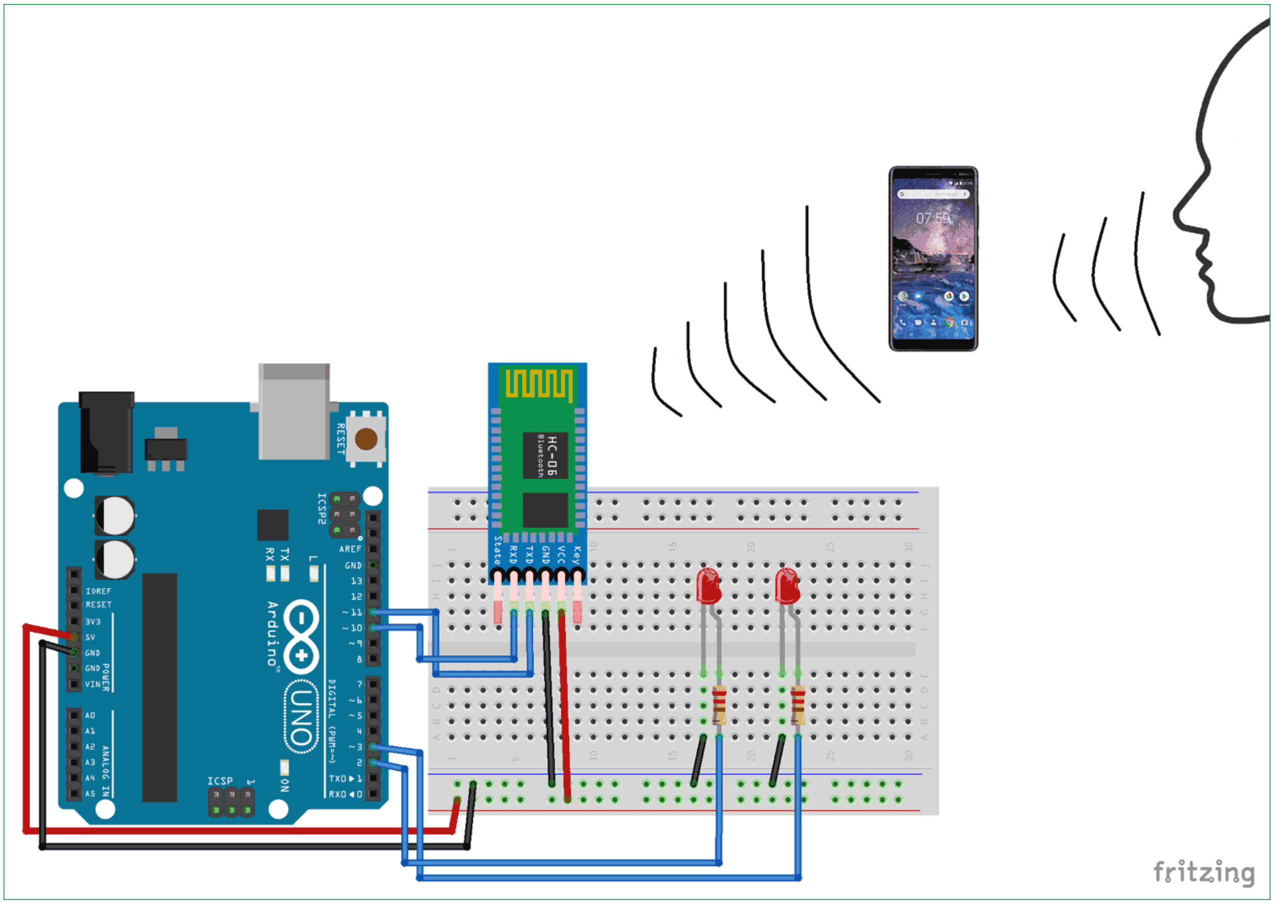


Figure 3. 21: Arduino with Bluetooth connection

In the voice recognition, we have the state of devices in 10 words (commands) and as shown in table 3.2 the relation between the voice command and the state of device.

Table 3.2: voice command and the device state.

The Command	State of device
Light one OFF	OFF
Light one ON	ON
Door open	OPEN
Door closed	CLOSED
Light two OFF	OFF
Light two ON	ON
Fan ON	ON
Fan OFF	OFF
All devices OFF	OFF
All devices ON	ON

3.9.1 Voice recognition flow chart

As shown in **figure 3.22** the flow chart for voice recognition.

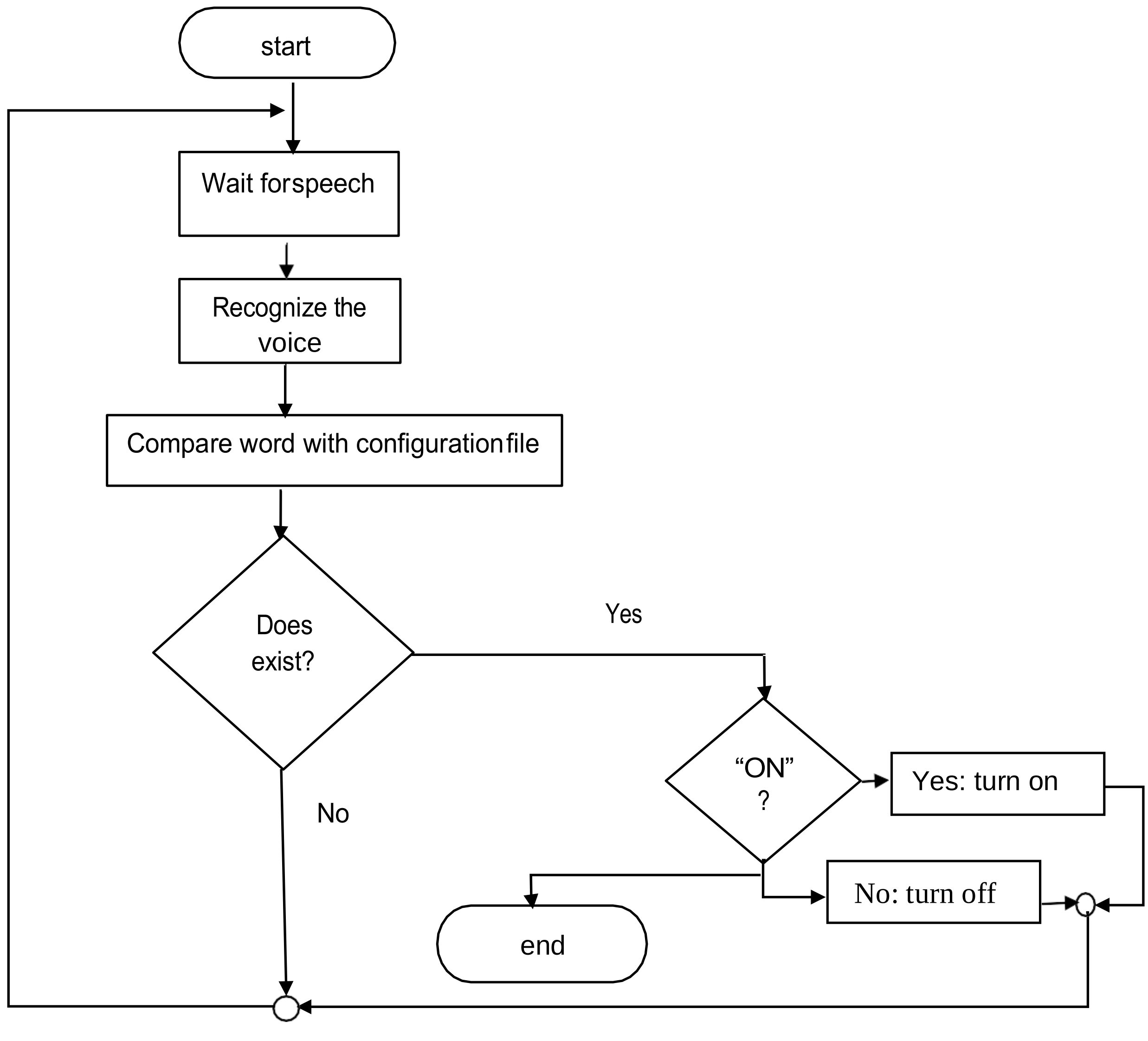


Figure 3. 22: Voice recognition flow chart.

3.10 The Arduino and Smart Home

In this section, an explanation regarding the Arduino and communication with smart home by using Wi-Fi.

Initially, the Arduino was selected the device depending on input signal whether from EOG or the voice, and then this device has been controlled by the relay using Wi-Fi communication.

3.10.1 General Block Diagram

The block diagram in **figure 3.23** Illustrates how to connect the Arduino with Smart Home and select one of the relays based on the selected device and thus continue to Wi-Fi with each other via the IP of this selected relay and control of home appliance.

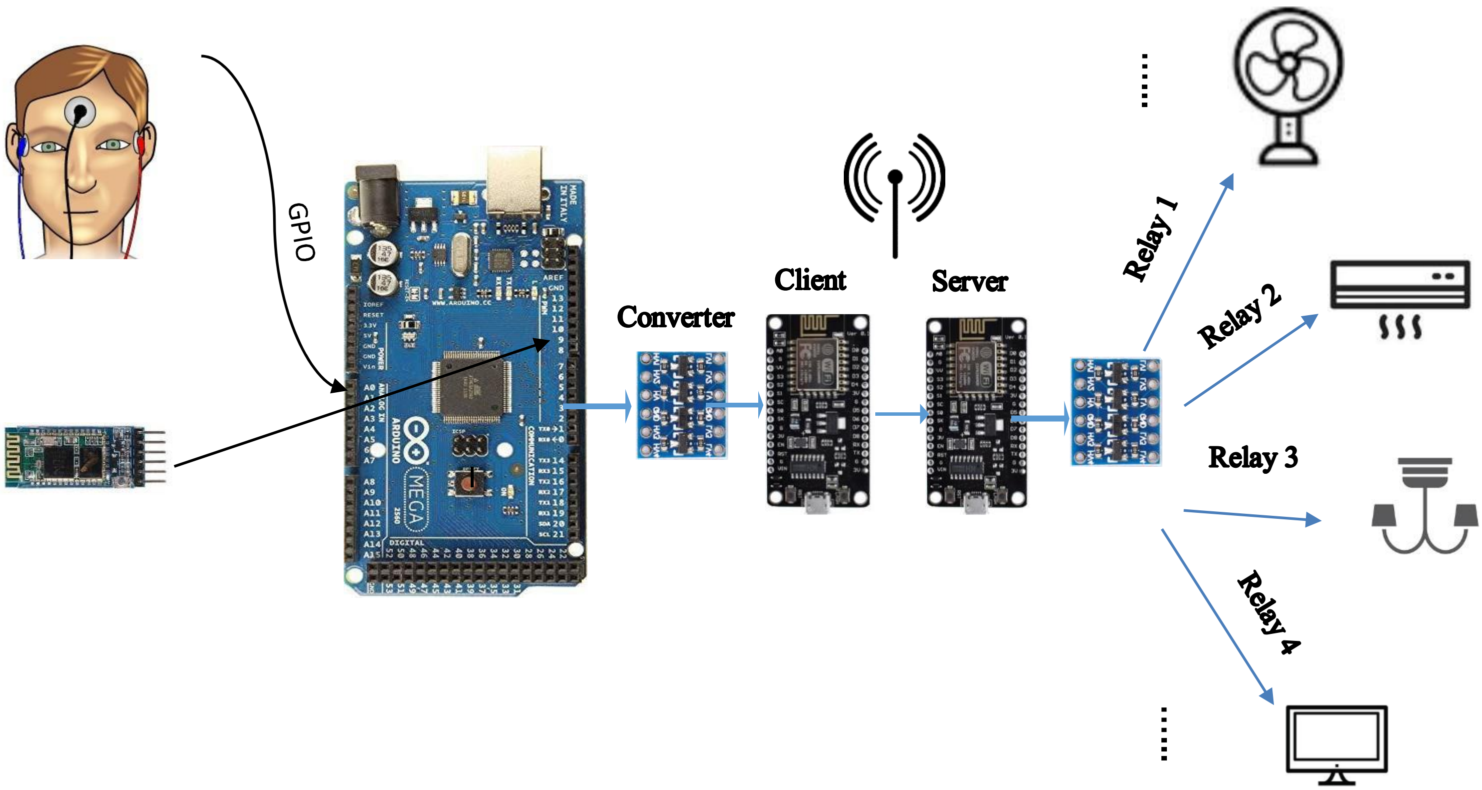


Figure 3. 23: Block diagram illustrating connection between Arduino Mega and Smart home.

3.10.2 Flow chart

Flow chart in **figure 3.24** Starts when Arduino receives the input signal then select the device and using Wi-Fi to connect with the relay and switch the device ON or OFF.

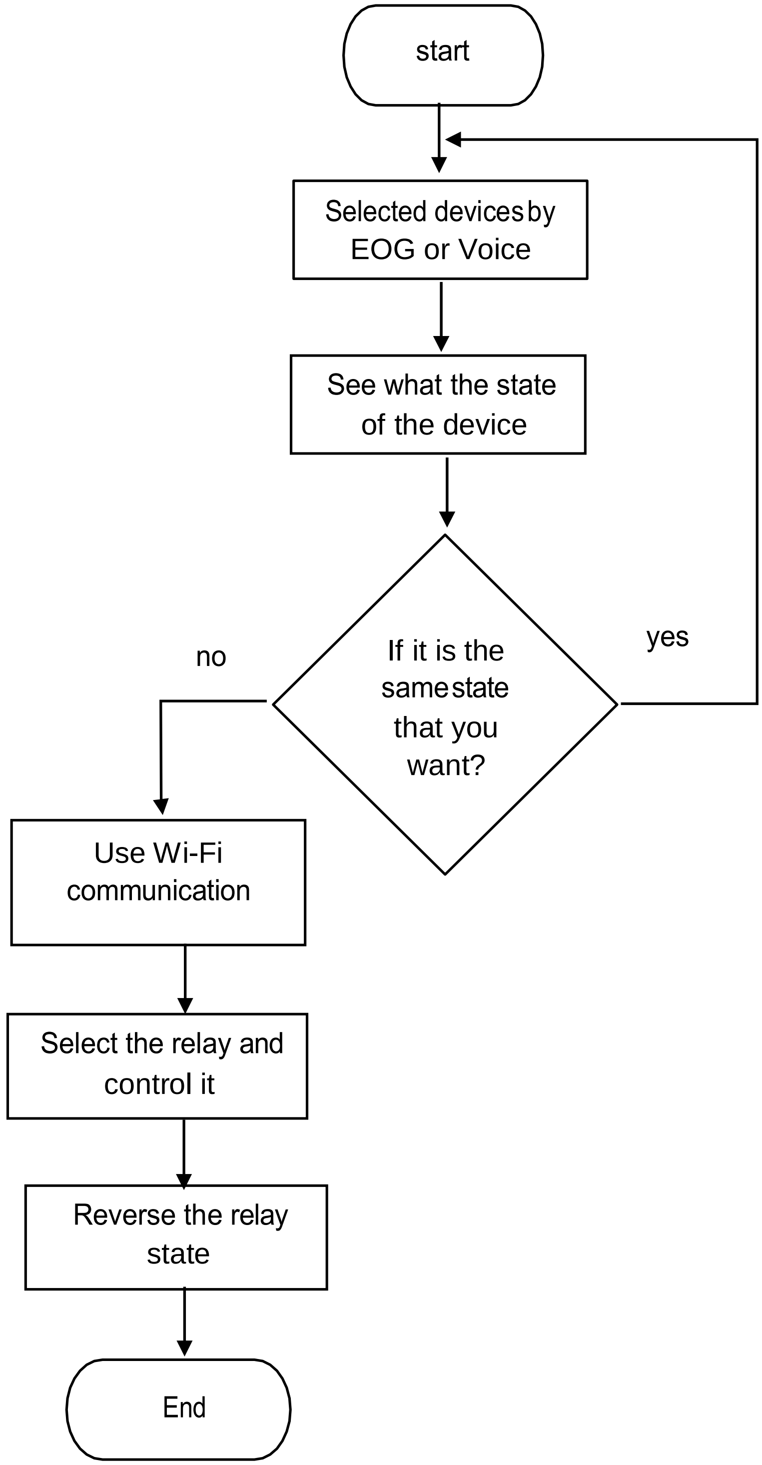


figure 3. 24: General System Block Diagram

3.11 Training

The patient who have used this device have to perform a special training, this training consists of special eye movements testing that used for turn on or off home devices, the aim of this training is to build a data base that will be stored in the Arduino, it is worth mentioning that the more the patient repeat the test the more accurate the results will be.

There is another training should be performed by the person willing to use the device in order for him /her to learn how will use the voice mode, these trainings aim to decrease of error possibility.

3.12 General System

The next simplified steps illustrated how general system work:

1- Select the suitable mode whether voice or EOG.

2- According to the selected mode, the device to be used will be selected.

3-For EOG mode the suitable eye movement will be used to select the device.

4-For voice mode appropriate word will be spoken to determine the device.

5- The data will be sent from EOG or voice into Arduino to analyze it according to the previous algorithms.

6- The device status will be determined and then the decision will be made to turn the device on or off.

7- According to all decision and received data, the Arduino will transmit the command byusing Wi-Fi to control the special relay of the selected device previously.

Chapter Four

System Implementation

4.1 Overview

4.2 EOG design and calculation

4.2.1 current consumption of EOG system
4.2.2 instrumentation amplifier
4.2.3 Butterworth Low pass filter
4.2.4 Non inverting amplifier
4.2.5 General EOG system
4.2.6 Low pass filter testing

4.3 IoT Design and Code

4.3.1 IoT Simulation
4.3.2 IoT Code

4.1 Overview

After viewing the general system, In this chapter we decided to make our design and calculation in the EOG department and a software design in packet tracer program to simulate the technology of IoT was showed.

4.2 EOG design and calculation

4.2.1 Current consumption of EOG system

Every electronic component consumed some of current to operate correctly, **table 4.1** show electronic components of EOG system and their current consumption.

Table 4. 1: electronic component current consumption

Name of electronic Component	**Number of electronic Components**	**Current consumption**
AD620	1	0.9 mA
AD822	1	620 uA
Total	2	1.52 mA

According to 9-volt battery specification it will give 180 mAH, so by using equation 4.1:

mA of battery = mA * Hours--------180 m= 1.52m *hours, Hours =118 hours.

4.2.2 instrumentation amplifier

The instrumentation amplifier circuit in this project connected our input directly to the electrode, this circuit well take the difference between their input and amplify the difference, this difference between the electrode is the electrical signal generated from eyes movement. The instrumentation circuit contain two stages we see it in **figure 3.5**.

We used the instrumentation amplifier AD620 with suitable RG. With gain equal to 50, The resistor RG using to determine the gain of the amplifier according to the equation 4.2 the schematic of amplifier is shown in **Figure 4.1**.

$$R_{v1}= \frac{49.4\square\Omega}{\square-1} \qquad 4.2\ [18]$$

$$R_{v1}= \frac{49.4\square\Omega}{50-1} = 1k\Omega$$

See Appendix A.

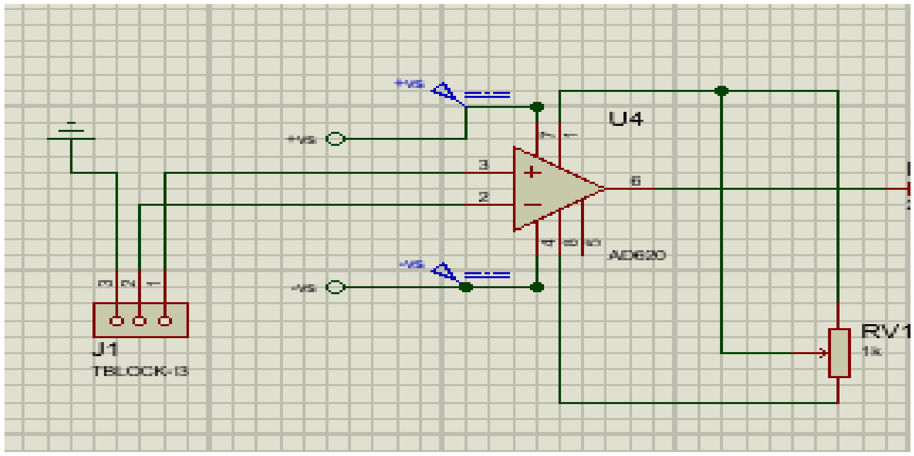


Figure 4. 1: instrumentation amplifier[18]

4.2.3 Butterworth Low pass filter

The **figure 4.2** shows sallen key second-order low pass filter circuit, equation 4.4 for determine the value of resistance.

$$R=\frac{\sqrt{b_1}}{2\pi f_c * C} \qquad 4.4[18]$$

From Butterworth table b_1=1 , Let C1=C2=220 nf ,Fc=30 HZ

$$R1=R6=R = \frac{1}{2\pi * 30 * 220n} = 24\ k\Omega$$

For Butterworth response $R_3/R_4 = 0.568$

Let $R_3 = 5K\Omega$

$R_4 = 5K\Omega/0.568 = 10\ K\Omega$.

See Appendix B .

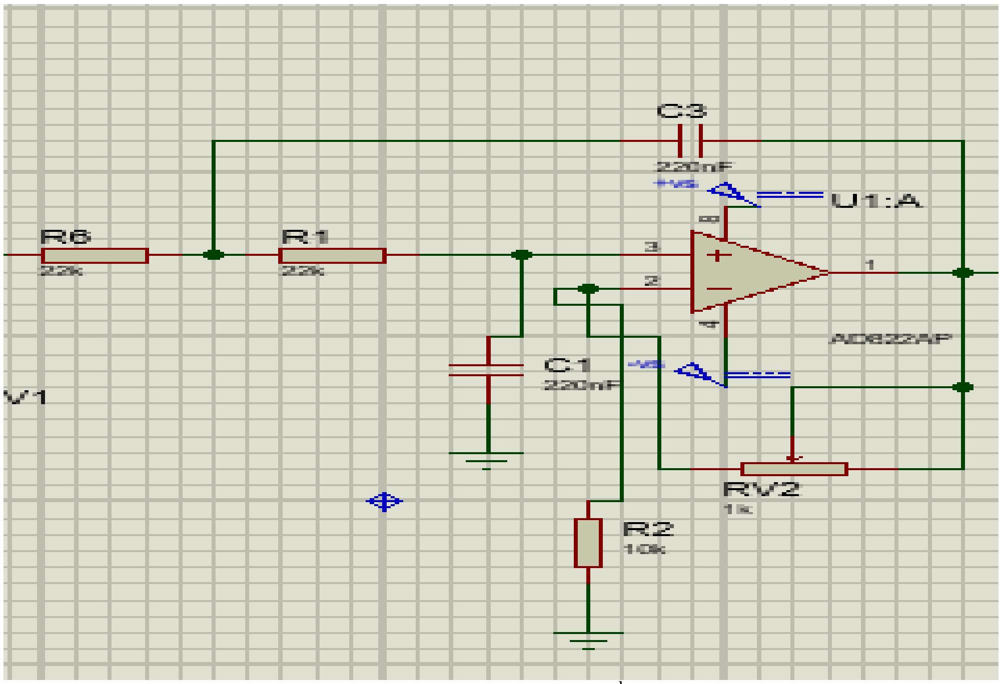


Figure 4. 2: sallen key 2nd order LPF[18]

4.2.4 Non inverting amplifier

In **figure 4.3** shows inverting amplifier circuit, in this stage we will make amplification with value 45, equation 4.5 for determine voltage gain.

$$G = 1 + \frac{\square 2}{\square 1} \qquad 4.5[18]$$

$3=1+(R_2/R_1)$

$R_1=1k\Omega$

$R_2=2k\Omega$

See Appendix B.

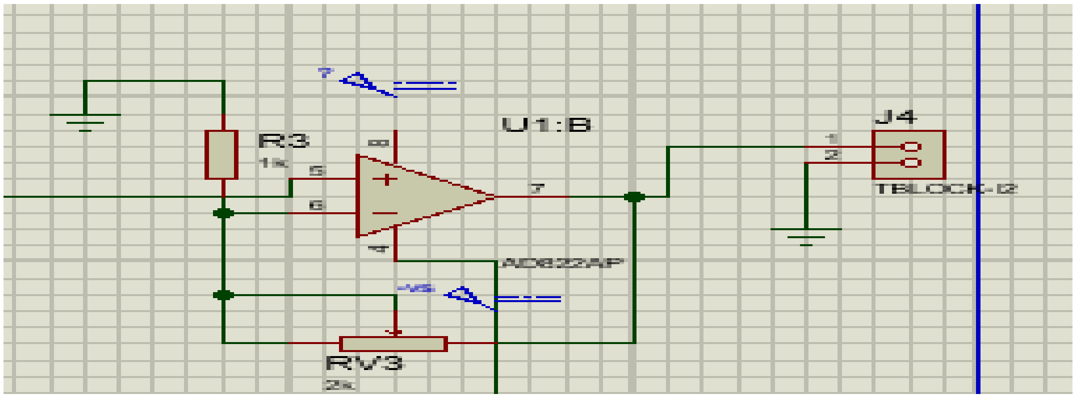


Figure 4. 3: non-inverting amplifier

4.2.5 General EOG system

The final design for horizontal EOG system is shown below in **Figure 4.4**

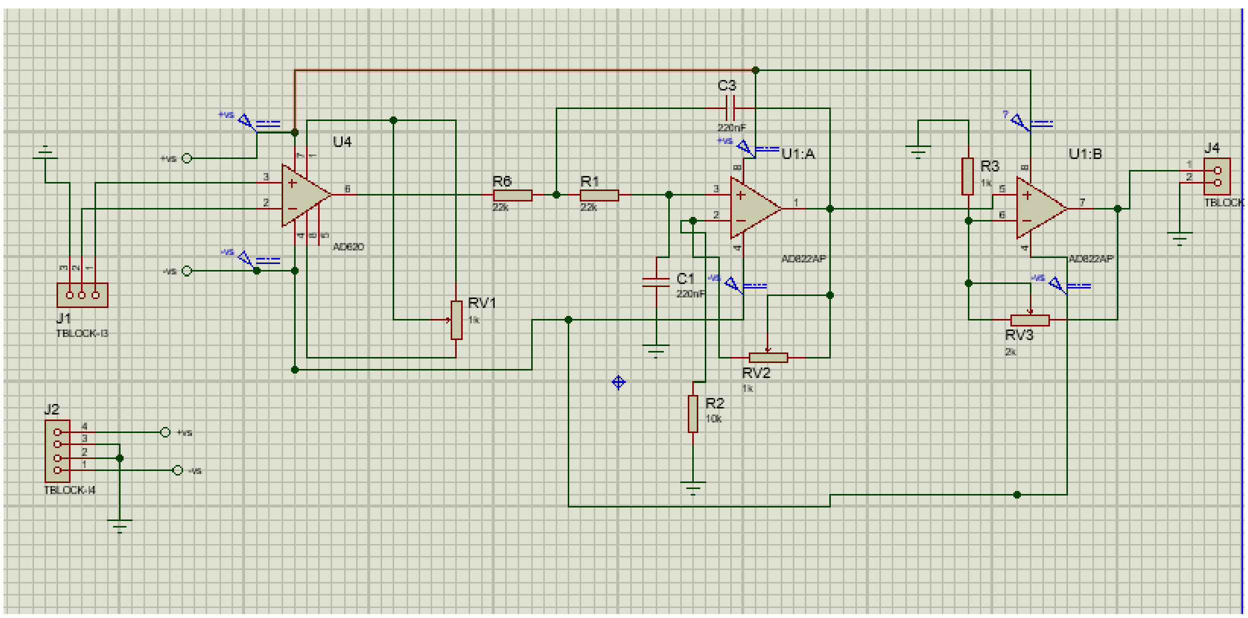


Figure 4. 4: general EOG system[18]

4.2.6 Low pass filter testing

In this section we have made test for EOG filter that used in our project using multisim program.

By apply 1Vpp sine signal input in low pass filter circuit that designed in figure 4.3 we get result as shown in **table 4.3**, **figure 4.5** show the characteristic curve of low pass filter according to its table.

table 4. 2: Measured output amplitude of LPF

Frequency(HZ)	1	10	20	25	30	35	40	50	100
output (Vpp)	1.57	1.55	1.42	1.27	1.1	0.911	0.756	0.522	0.139

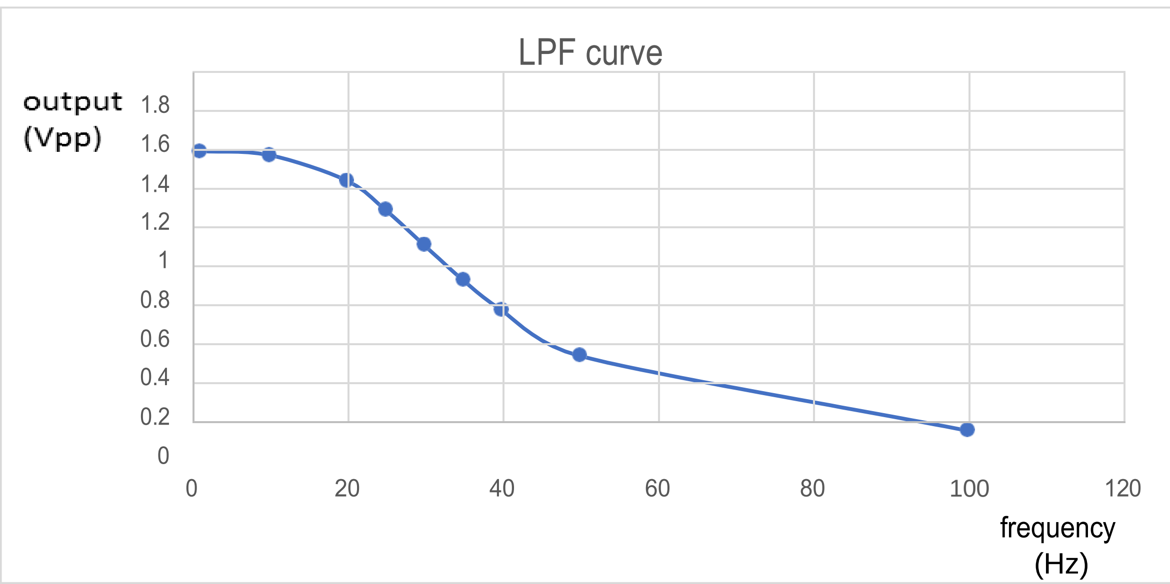


Figure 4. 5: characteristic curve of LPF

This filter was designed in critical frequency equal to 30 Hz, we can also measure the value of output voltage in critical frequency by using previous **equation 4.7**.

V_{out} = 0.707*Gain*vpp 4.7[18]

Vout = 0.707*1.568*1= 1.1 v

4.3 IoT Design and Code

4.3.1 IoT Simulation

In this section, we used Packet tracer to simulate the IoT in general by using microcontroller and we used the smartphone to see the state of devices. See **figure 4.6.**

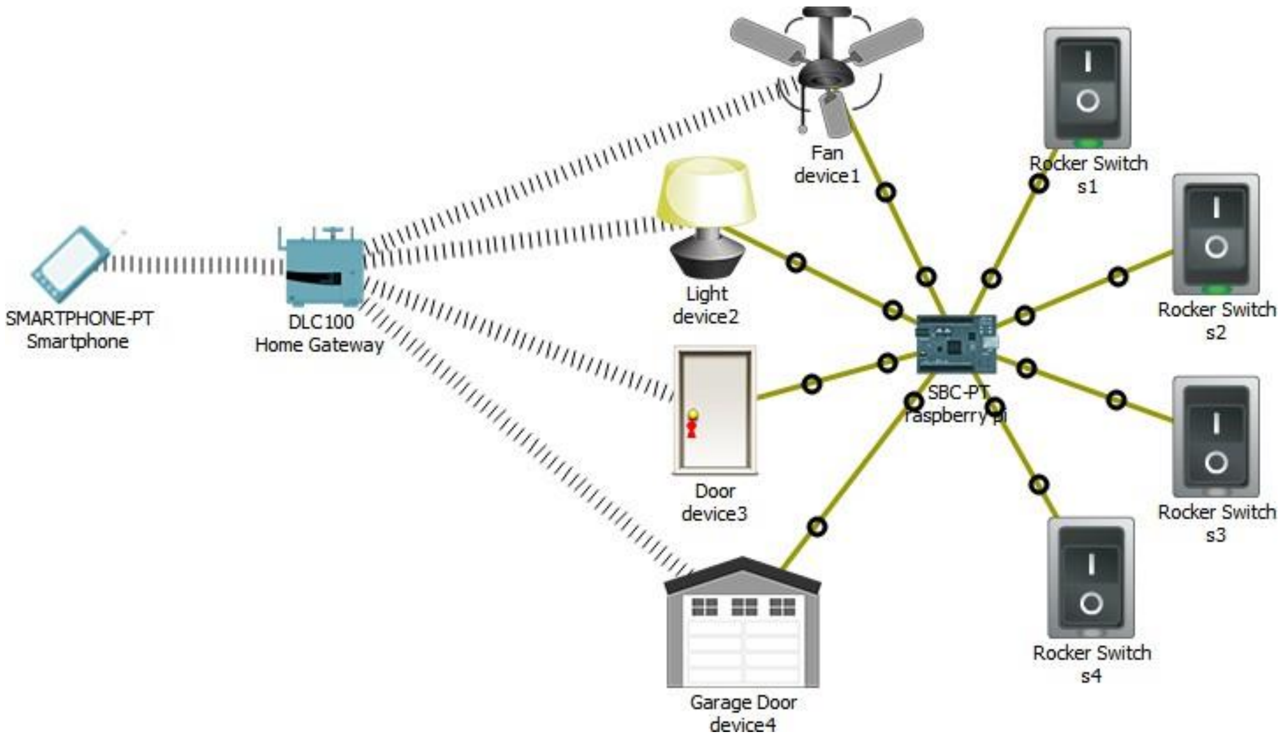


Figure 4. 6: IoT Simulation (packet tracer).

In this project, we use wireless (Wi-Fi) with Arduino instead of wire and use a relay with WiFi instead of switches.

4.3.2 IoT Code

As in in **figure 4.7** below where the code we use to control 4 devices by IoT.

```python
from gpio import *
from time import *
def main():
    pinMode(7,OUT)
    pinMode(6,IN)
    pinMode(4,OUT)
    pinMode(1,IN)
    pinMode(3,OUT)
    pinMode(5,IN)
    pinMode(0,OUT)
    pinMode(2,IN)
    while True:
        customWrite(0,"0,1");
        if digitalRead(2) == HIGH:
            customWrite(0,"0,0");
            if digitalRead(2) == HIGH:
                customWrite(0,"1,0");
            else:
                    customWrite(0,"0,0");
        else:
            customWrite(0,"1,1");
            if digitalRead(5) == HIGH:
                customWrite(3,1);
            else:
                    customWrite(3,0);
            if digitalRead(1) == HIGH:
                customWrite(4,1);
            else:
                    customWrite(4,0);
            if digitalRead(6) == HIGH:
                customWrite(7,1);
            else:
                    customWrite(7,0);
if __name__ == "__main__":
    main()
```

Figure 4. 7: code of simulation (packet tracer).

Chapter Five
Testing and Results

5.1 Overview

In this chapter we show all testing needed to evaluate the performance of our system to achieve results and many calculations to enhance the percentage of error of the system was used. we were tested EOG technology and voice recognition application that needed and made many experiment in wireless network.

5.2 Testing and Result

Testing the system were done in this section including the testing result.

5.2.1 EOG Testing and accuracy

Three designs for EOG was made , the first design used has some problem such as its need continuous calibration ,and when patient move their eye from right direction to center it considered as a left movement , so making a wrong result ,low efficiency performance and long delay between each movement , so we used another design ,the second design correct the direction problem ,delay problem , and efficiency increased but still low because the range for amplitude was still small ,the first and second design was shown in figure 5.1 and 5.2

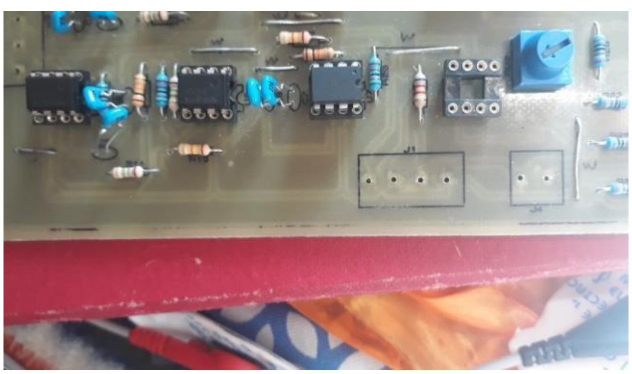


Figure 5. 1: First stage EOG design

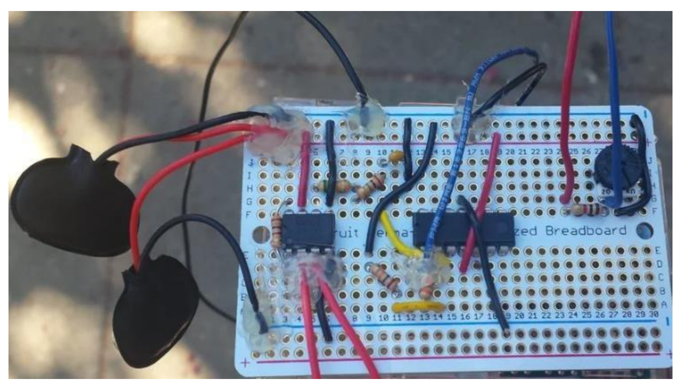


Figure 5. 2: Second stage EOG design

The final design for EOG circuit increased efficiency and solve problem that was mentioned above, the final design is shown below

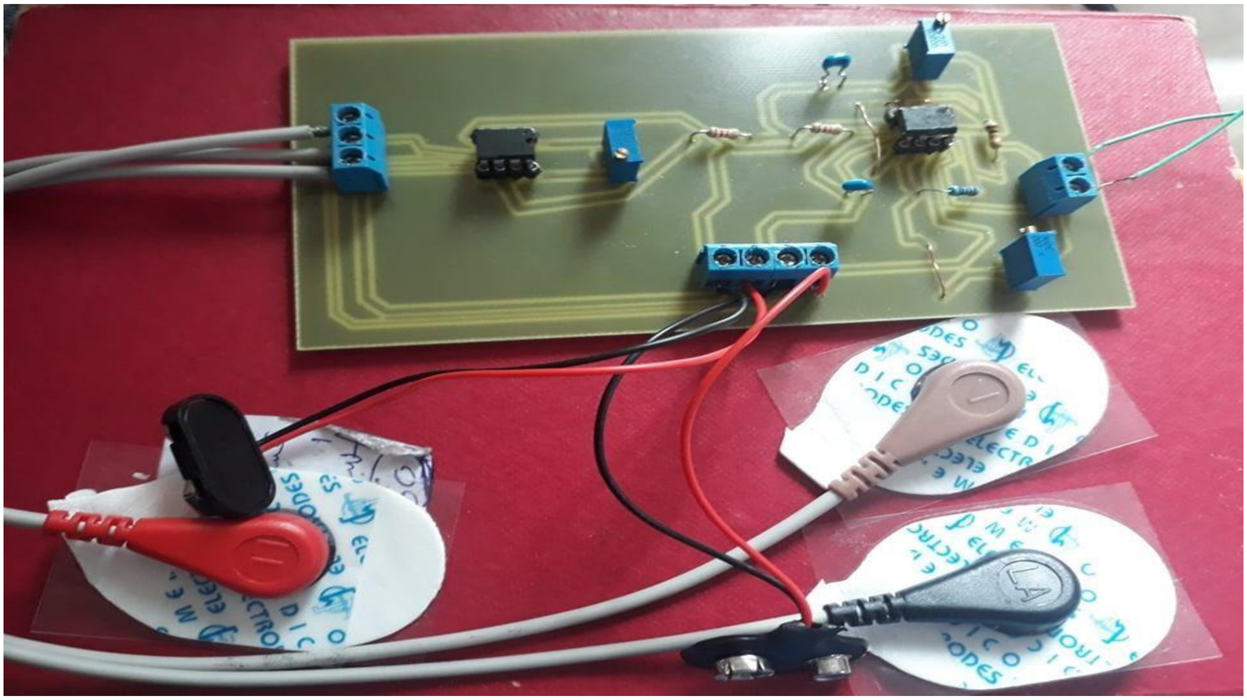


Figure 5.3: final stage EOG design

Then EOG design is used for control led using one movement (1 bit) as shown below:

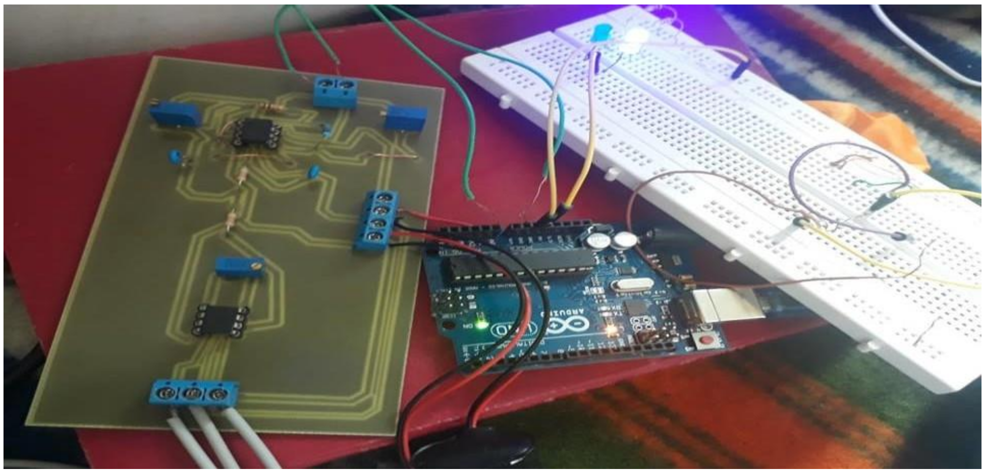


Figure 5. 4: Control led using eye movement

We decided to test EOG circuit with weird connection with a relay to have the light turn ON or OFF .and we have a response where the light was ON when the four bit RRLR from eye movement is recorded, figure5.5 show EOG circuit with light.

Figure 5 5: EOG circuit with light.

Finally, we decided to test EOG circuit with Wi-Fi to turn light ON or OFF .and we have a response where the light was ON when the four bit RRLR from eye movement is recorded, figure5.6 show EOG circuit control light using Wi-Fi.

Figure 5 6: EOG circuit control light using Wi-Fi.

We made a tests for EOG circuit in different conditions, the first test was described the condition of EOG circuit without using any calibration, we obtained results as shown in table 5.1, as we see when patient was tired, we have the maximum delay for turned light on and then turned off and we have the lowest accuracy, we also noticed that intense light causes more wrongs than when patient in dark. figure 5.7 show the effect of conditions on the percentage of error.

Table 5. 1: percentage of error and efficiency of final EOG design without calibration.

Condition	percentage of error	Accuracy	Delay for eights movements
patient tired	17.5%	Low	52 sec
Intense light	12.5%	Medium	43sec
Normal	7.5%	High	39sec
Dark	15%	Low	46 sec

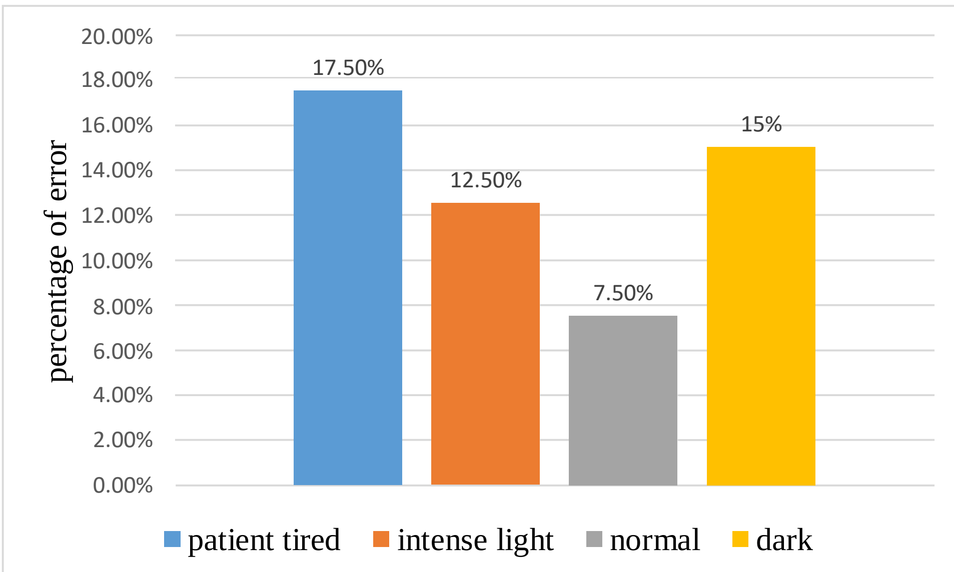


Figure 5 7: chart representing relation between patient state and the percentage of error where the EOG design without calibration.

The second test for the EOG circuit was done using calibration while the patient was relaxing. It can be noted that the maximum delay of turning the light on and off occurred in dark mode. More errors were noticed in the intense light mode than in the dark one. But wrongs are less than previous test, figure 5.8 show the effect of conditions on the percentage of error.

Table 5 2: percentage of error and efficiency of final EOG design with calibration (patient relax).

Condition	percentage of error	Accuracy	Delay for eights movements
Intense light	10%	Medium	41sec
Normal	2.5%	High	36sec
Dark	5%	High	48 sec

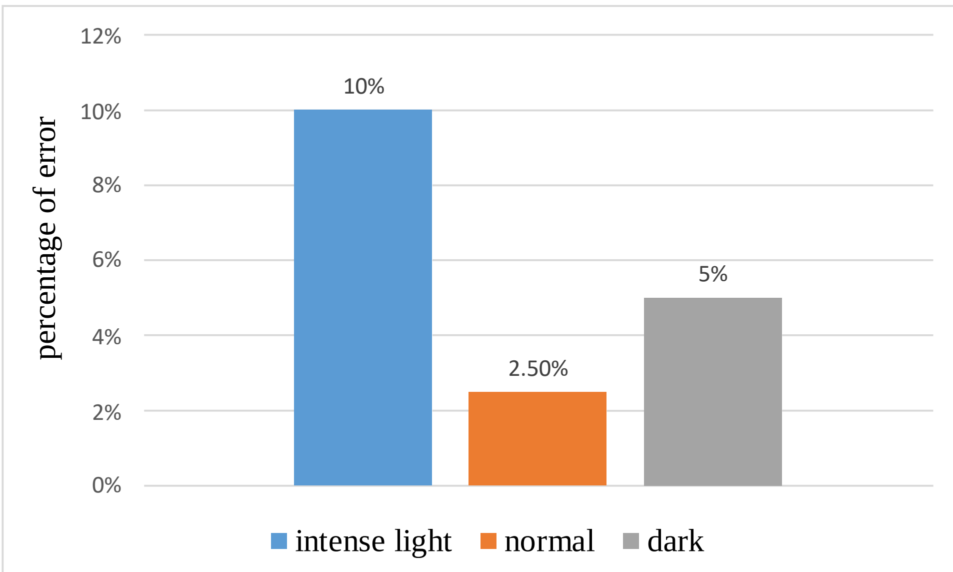


Figure 5 8: chart representing relation between patient state and the percentage of error where the EOG design without calibration where the patient was relaxing.

The final test for the EOG circuit was done using calibration while the patient was tired. The results were obtained as shown in table 5.3. By looking at the table, it can be noted that the maximum delay of turning the light on and off occurred in dark mode. More errors were noticed in the intense light mode than in the dark one. Figure 5.9 shows the effect of these conditions on the margin of error percentage when the patient is tired.

Table 5. 3: percentage of error and efficiency of final EOG design with calibration (patient tired).

Condition	percentage of error	Accuracy	Delay for eights movements
Intense light	12.5%	Medium	43sec
Normal	5%	High	34sec
Dark	7.5%	High	50 sec

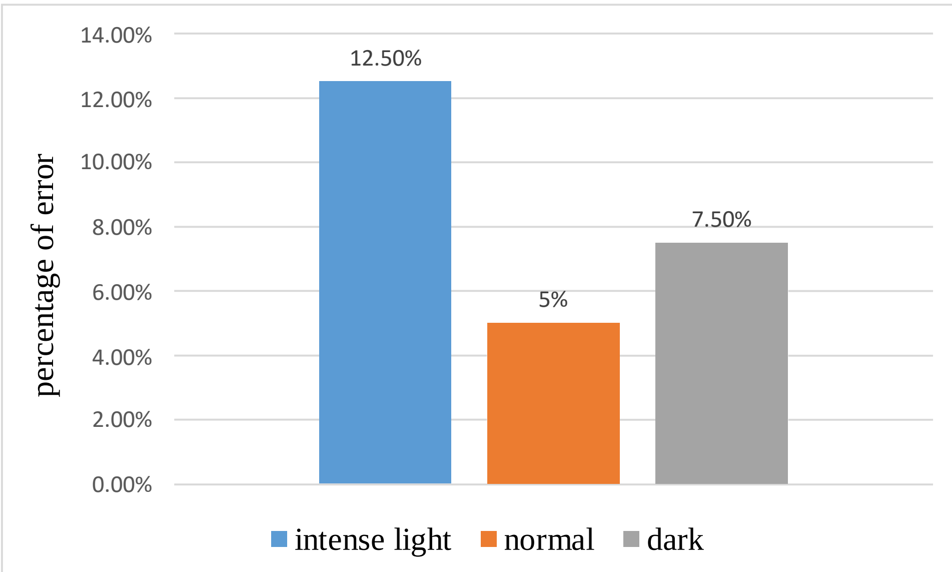


Figure 5 9: chart representing relation between patient state and the percentage of error where the EOG design without calibration where the patient was tired.

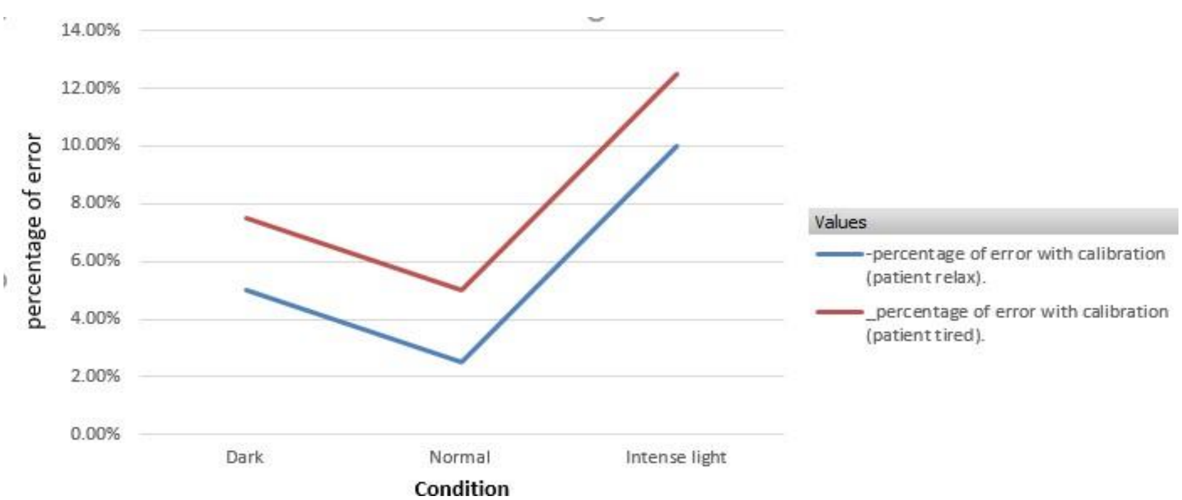


Figure 5 10: chart representing relation between patient and light state with the percentage of error where the EOG design with calibration

The EOG is used to assess the function of the pigment epithelium. During dark adaptation, resting potential decreases slightly and reaches a minimum ("dark trough") after several minutes. When light is switched on, a substantial increase of the resting potential occurs ("light peak"), which drops off after a few minutes when the retina adapts to the light, these conditions used for diagnostic, but in our project, these conditions effect on the accuracy.

5.2.2 voice recognition testing and accuracy

In this section the online application has to lesson to the human voice command and do what was needed. firstly, they click the mouse to connect the mobile voice recognition application with the HC-05 Bluetooth module and then the application is ready.

In this section we tested the online application voice recognition with EVA mouse and as shown in **figure 5.11** where the connection of Bluetooth with Arduino

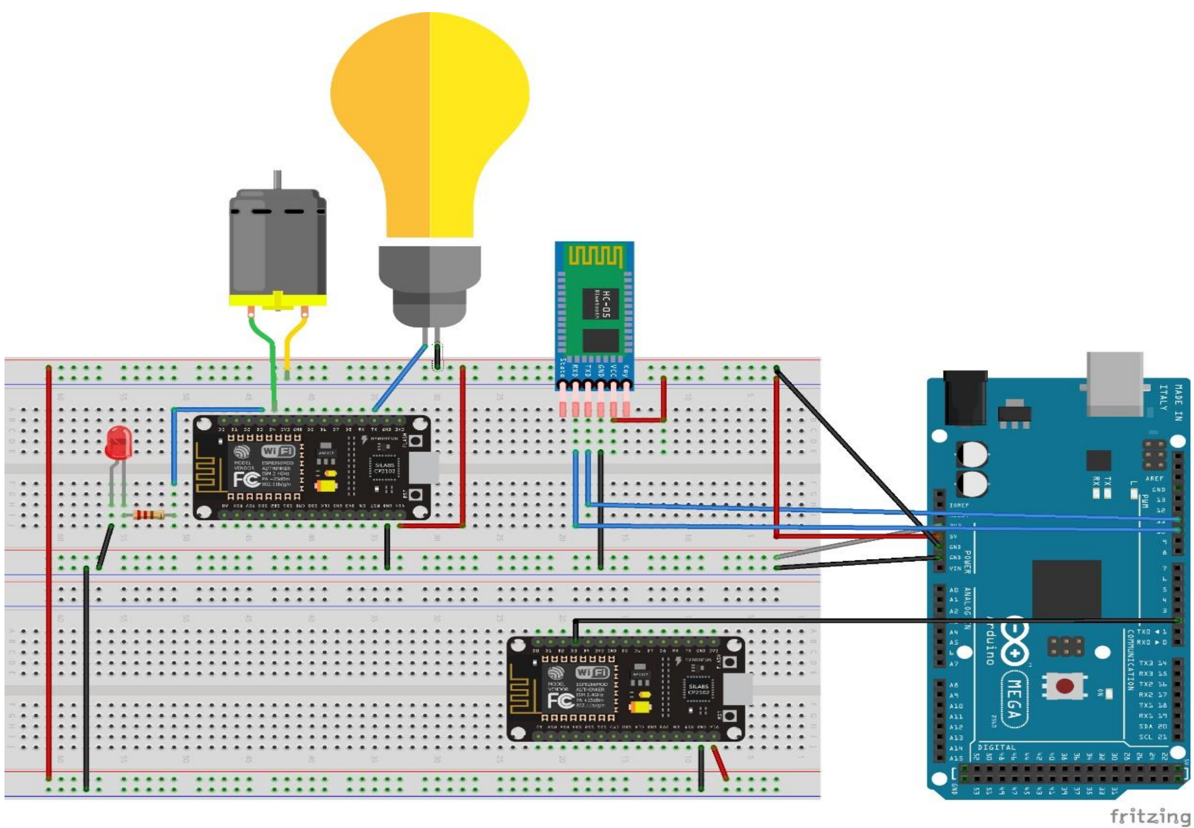


Figure 5 .11: wireless connection with Voice by Bluetooth.

And the result was to turn the light ON or OFF through “light one ON” command. as shown in **figure 5.12.**

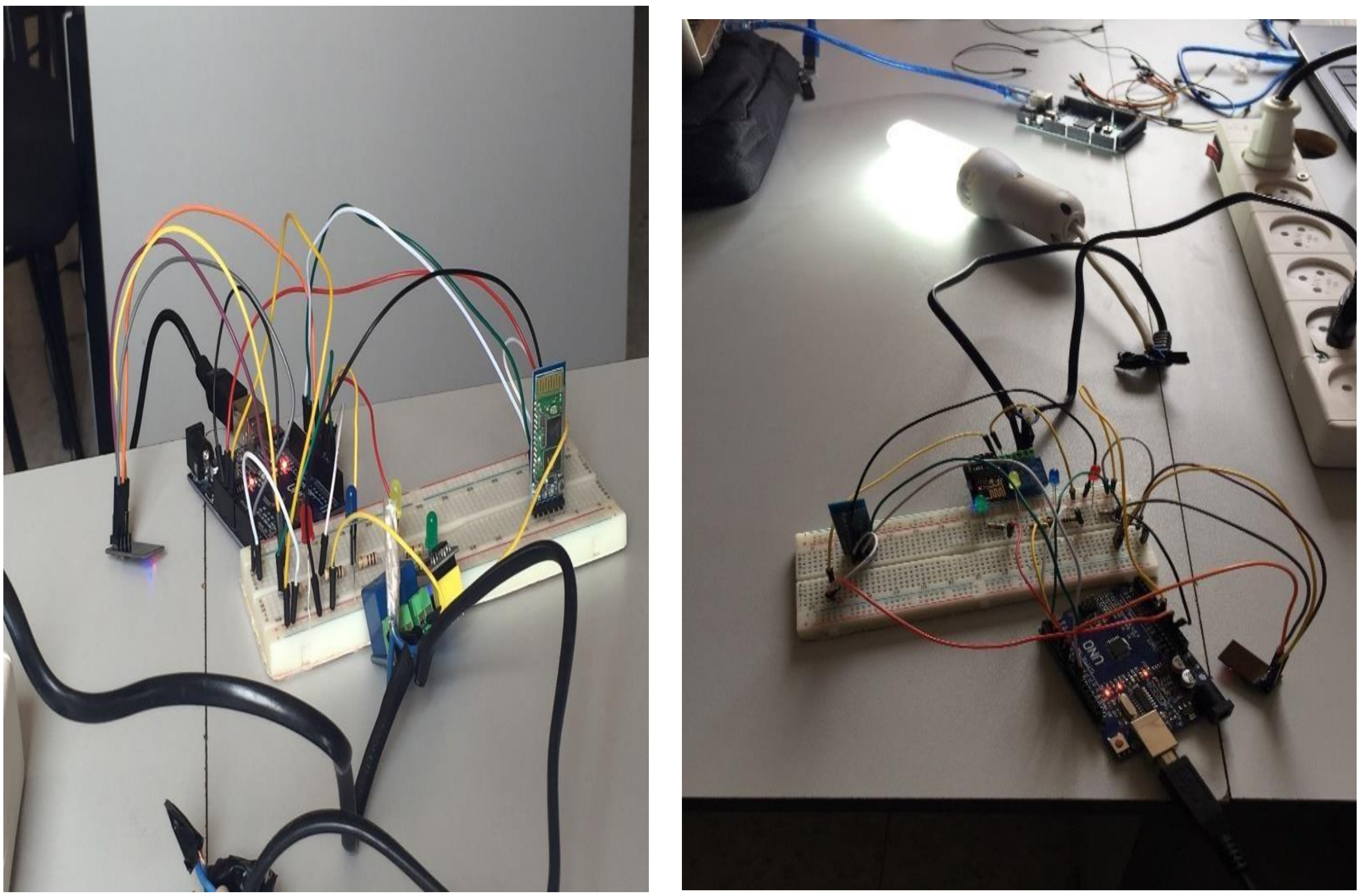


Figure 5 12: wireless connection with light

In this section we tested the online application voice recognition to reduce the error. For this aim we use four to five sentences for each state of device, and this is some samples of sentences. For the fan which state is “OFF” it had four similar words:

value == "fan of"

value == "send off"

value == "fan off"

value == "fa off"

these sentences for the same object which was to turn fan off.

After many trial, by more similar words were taken in consideration, we made accuracy for the percentage of error so, it was reduced to 3%.

Table 5 4: percentage of error of Voice depend on accuracy in case of Fan device.

No. of similar word for the device state	percentage of error with outer voices	percentage of error without outer voices	Average percentage of error
1	30%	20%	25%
3	10%	5%	7.5%
4	5%	1%	3%

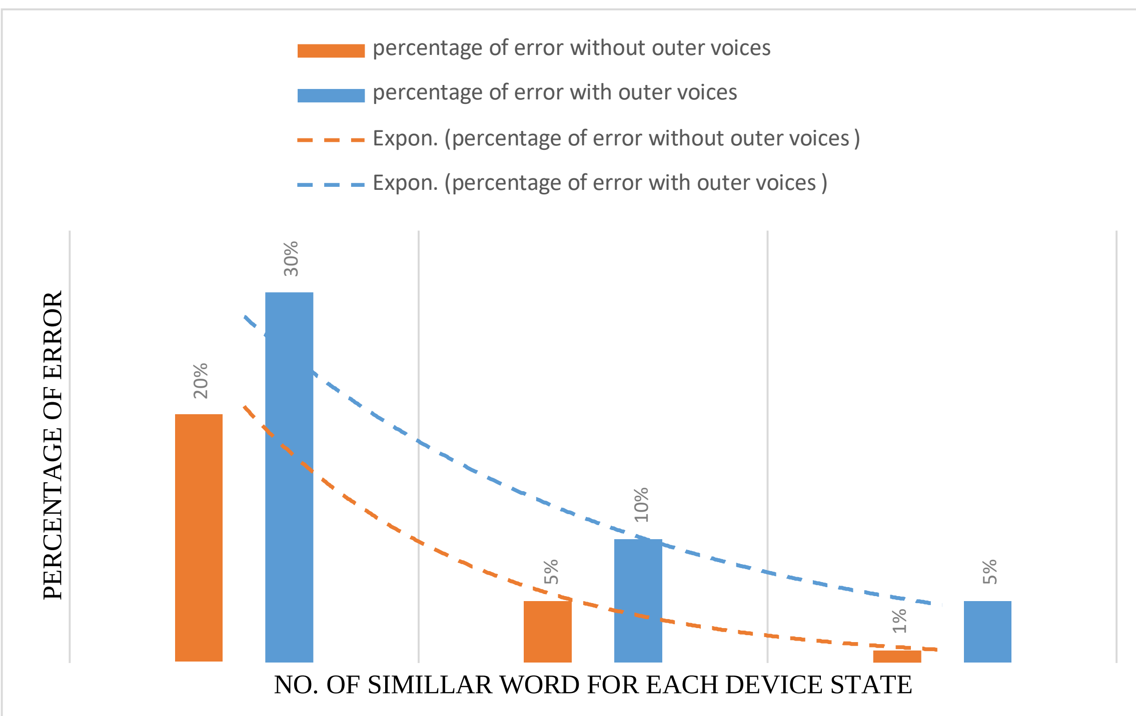


Figure 5 13: chart representing relation between probability of error with number of similar

Words in case of fan.

For OFF state of the light one we increase no. of words to five to have more reliability.

value == "light one-off"

value == "light one of"

value == "light one off"

value == "light win off"

value == "lights one off"

so the accuracy increase and the error reduced from 45 % to 3%.

Table 5 5: percentage of error of Voice depend on accuracy in case of light one device.

No. of similar word for the device state	percentage of error with outer voices	percentage of error without outer voices	Average percentage of error
1	50%	40%	45%
3	30%	20%	25%
4	10%	5%	7.5%
5	5%	1%	3%

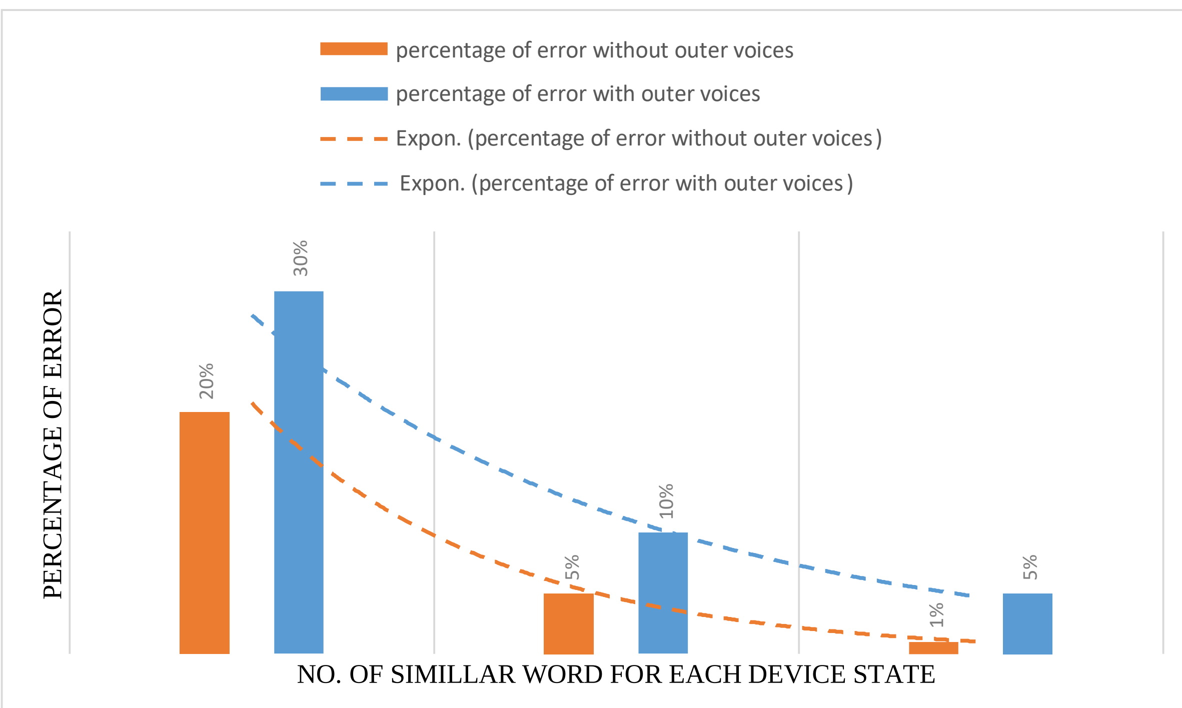


Figure 5 14: chart representing relation between probability of error with number of similar Words in case of light one.

5.2.3 Wi-Fi testing and accuracy

Firstly, we used esp-01 Wi-Fi module as client and server and we made a simple experiment to control a LED with a potentiometer.as shown in next figure:

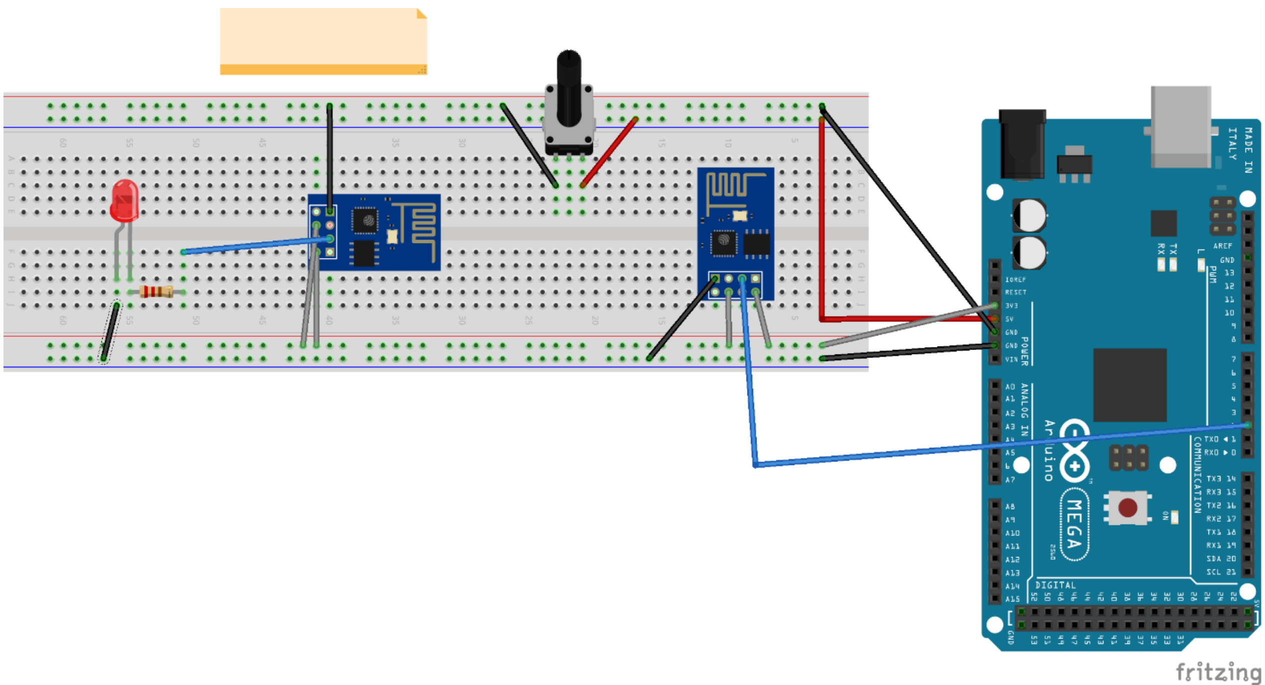


Figure 5.15: Test esp-01 by control LED using potentiometer

But the esp-01 module become disconnected a lot especially when the temperature of it rises and has low efficiency, so we replaced it in transmitter (client) with NodeMcu Wi-Fi module to improve the efficiency of wireless network and tested it by controlling LEDs as shown in next figures:

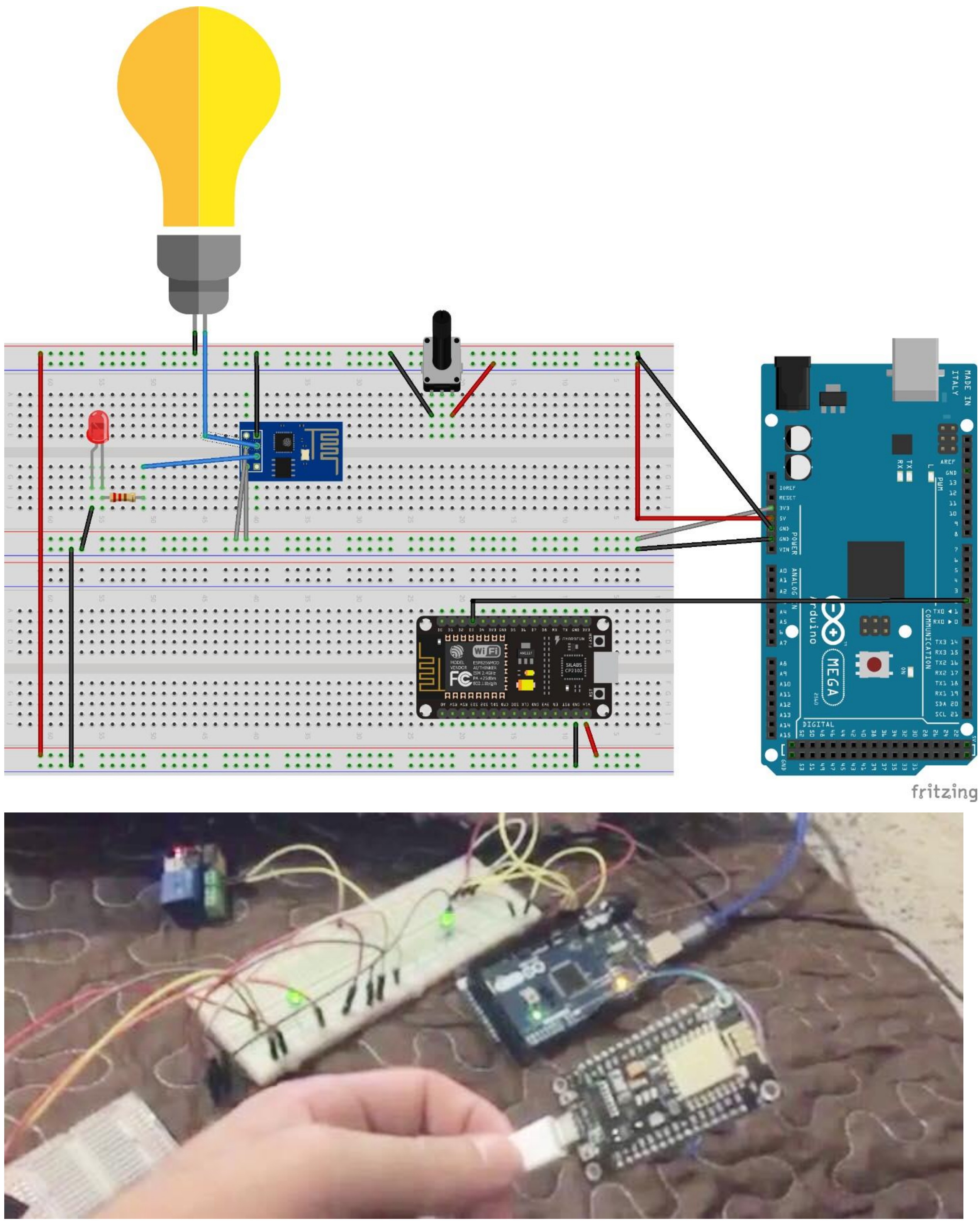


Figure 5.16: Test esp-01 by control LED using potentiometer

But after that, the relay Wi-Fi module is becoming disconnected a lot so, we decided to replace all esp-01 relay Wi-Fi modules by one NodeMcu Wi-Fi module in receiver circuit. The final design of wireless network is shown in next figures:

Figure 5.17: Final design circuit of Wi-Fi network.

Table 5 6: percentage of error and efficiency of Wi-Fi network.

Type of design	Percentage of error	Efficiency
First design	50%	Low
Second design	30%	Medium
Final design	1%	High

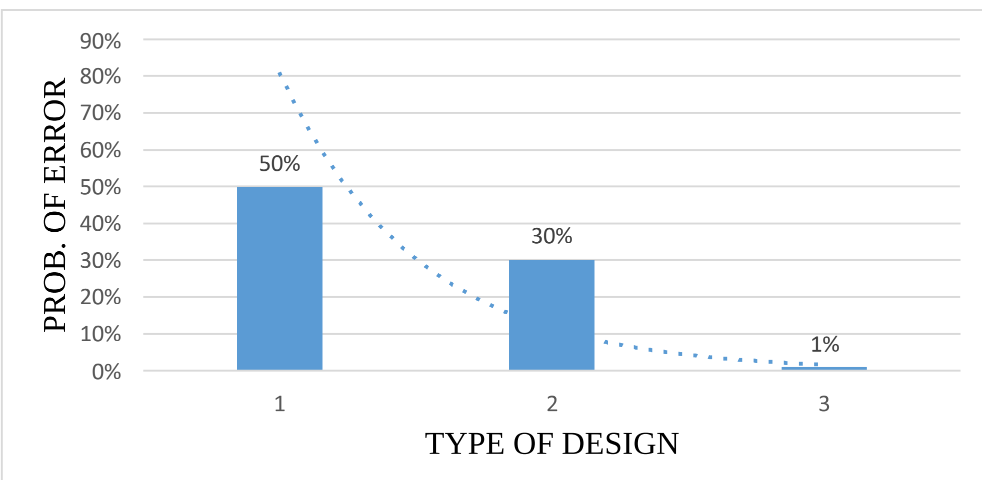


Figure 5.18: chart representing relation between order of design and the percentage of error.

5.3 Whole System result

The final result was obtained by connecting four devices to the four-channel relay in order to have wireless connection.

Firstly, the patient or the ordinary people decide which mode of operation he wants to use, In the mode of EOG, the patient moves his eye with spatial movement to select the device to be used. In case of voice recognition, the application of voice records the voice of the patient in order for him/her to select the device. Then, the command is analyzed in Arduino to send the signal to client before the signal reaches to the client, it passes through a Logical converter in the transmitter side for converting 5V from Arduino into 3V to NodeMcu Wi-Fi client.

After that, a request is sent to a NodeMcu server to control the relay of the device after converting 3V from sever into 5V to relay channel by the Logical converter on the receiver side. this is the mechanism by which the system works. And as shown in figure 5.15 the finishing of the project.

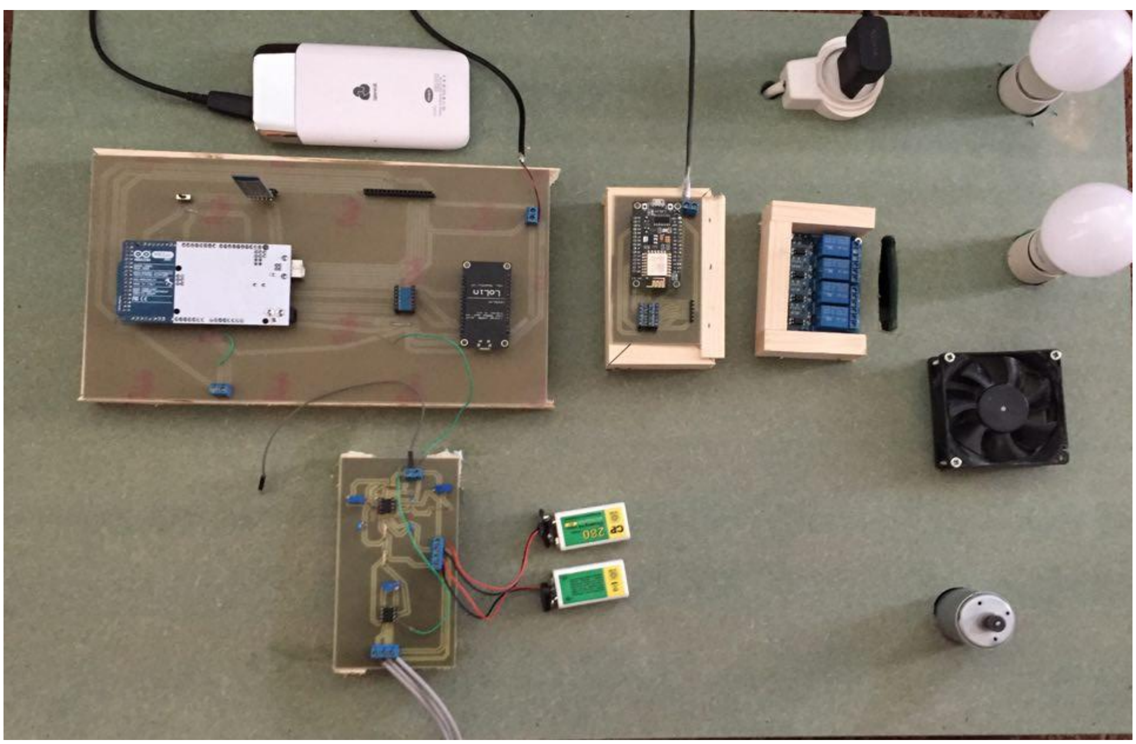


Figure 5 15:the final connection of the project.

5.4 Future work

Our suggestions and recommendation for the project

1. adding more than eight devices to be under serves.

2. build Database for the system to provide machine learning algorithms and artificial intelligence.

3. using 3G technology to control and monitoring the devices remotely.

4. improve our system by using EOG to do many tasks such as writing in google to control devices.

5. we can add sensors to the devices to prevent any suddenly revers state

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APPENDiX A

Voice code

```
#include <SoftwareSerial.h>
String value;
int TxD = 11;
int RxD = 10;
int servoposition;
SoftwareSerial bluetooth(TxD, RxD);
void setup() {
  pinMode(2, OUTPUT);
pinMode(3, OUTPUT);
  pinMode(4, OUTPUT);
  pinMode(8, OUTPUT);
   pinMode(5, OUTPUT);
    pinMode(7, INPUT);
  Serial.begin(9600);
  bluetooth.begin(9600);}
void loop() {
  Serial.println(value);
    if (bluetooth.available())
   {
    value = bluetooth.readString();
    if (value == "fan on"){
      digitalWrite(4, LOW); }
       if (value == "send on"){
      digitalWrite(4, LOW); }
      if (value == "fan o"){
      digitalWrite(4, LOW); }
    if (value == "fa on"){
      digitalWrite(4, LOW); }
    if (value == "fan of"){
     digitalWrite(4, HIGH);}
      if (value == "send off"){
     digitalWrite(4, HIGH);}
    if (value == "fan off"){
     digitalWrite(4, HIGH);}
      if (value == "fa off"){
     digitalWrite(4, HIGH);}

     if (value == "door open"){
     digitalWrite(5, LOW);     }
    if (value == "door opin"){
     digitalWrite(5, LOW); }
       if (value == "do open"){
     digitalWrite(5, LOW); }
   if (value == "door close"){
     digitalWrite(5, HIGH); }
     if (value == "Dora clothes"){
     digitalWrite(5, HIGH); }
      if (value == "door closed"){
     digitalWrite(5, HIGH); }

      if (value == "ALL ON"){
     digitalWrite(2, LOW);
     digitalWrite(3, LOW);
     digitalWrite(4, LOW);
     digitalWrite(5, LOW); }
    if (value == "all on"){
    digitalWrite(2, LOW);
     digitalWrite(3, LOW);
```

```
digitalWrite(4, LOW);
digitalWrite(5, LOW); }
  if (value == "all devices on"){
digitalWrite(2, LOW);
digitalWrite(3, LOW);
digitalWrite(4, LOW);
digitalWrite(5, LOW); }
if (value == "ALL OFF"){
digitalWrite(2, HIGH);
digitalWrite(3, HIGH);
digitalWrite(4, HIGH);
digitalWrite(5, HIGH);}
if (value == "ALL OF"){
digitalWrite(2, HIGH);
digitalWrite(3, HIGH);
digitalWrite(4, HIGH);
digitalWrite(5, HIGH); }
 if (value == "all of"){
digitalWrite(2, HIGH);
digitalWrite(3, HIGH);
digitalWrite(4, HIGH);
digitalWrite(5, HIGH); }
if (value == "all off"){
digitalWrite(2, HIGH);
digitalWrite(3, HIGH);
digitalWrite(4, HIGH);
digitalWrite(5, HIGH); }
if (value == "all devices off"){
digitalWrite(2, HIGH);
digitalWrite(3, HIGH);
digitalWrite(4, HIGH);
digitalWrite(5, HIGH); }


if (value == "light two on"){
  digitalWrite(3, LOW);    }
if (value == "light two-off"){
  digitalWrite(3, HIGH);}
if (value == "light two of"){
  digitalWrite(3, HIGH); }
if (value == "light two off"){
  digitalWrite(3, HIGH); }
if (value == "lights two on"){
  digitalWrite(3, LOW);  }
if (value == "lights two off"){
  digitalWrite(3, HIGH); }

  if (value == "light to on"){
  digitalWrite(3, LOW);    }
if (value == "light to-off"){
  digitalWrite(3, HIGH);}
if (value == "light to of"){
  digitalWrite(3, HIGH); }
if (value == "light to off"){
  digitalWrite(3, HIGH); }
if (value == "lights to on"){
  digitalWrite(3, LOW);  }
if (value == "lights to off"){
```

```
    digitalWrite(3, HIGH); }

    if (value == "light 2 on"){
    digitalWrite(3, LOW);    }
  if (value == "light 2-off"){
    digitalWrite(3, HIGH);}
  if (value == "light 2 of"){
    digitalWrite(3, HIGH); }
  if (value == "light 2 off"){
    digitalWrite(3, HIGH); }
  if (value == "lights 2 on"){
    digitalWrite(3, LOW);  }
  if (value == "lights 2 off"){
    digitalWrite(3, HIGH); }

     if (value == "Light 2 on"){
    digitalWrite(3, LOW);    }
  if (value == "Light 2-off"){
    digitalWrite(3, HIGH);}
  if (value == "Light 2 of"){
    digitalWrite(3, HIGH); }
  if (value == "Light 2 off"){
    digitalWrite(3, HIGH); }
  if (value == "Lights 2 on"){
    digitalWrite(3, LOW);  }
  if (value == "Lights 2 off"){
    digitalWrite(3, HIGH); }
    digitalWrite(3, HIGH);}
  if (value == "Light 2 of"){
    digitalWrite(3, HIGH); }
  if (value == "Light 2 off"){
    digitalWrite(3, HIGH); }
  if (value == "Lights 2 on"){
    digitalWrite(3, LOW);  }
  if (value == "Lights 2 off"){
    digitalWrite(3, HIGH); }


   if (value == "light one on"){
    digitalWrite(2, LOW);    }
     if (value == "light win on"){
    digitalWrite(2, LOW);    }
  if (value == "light one-off"){
    digitalWrite(2, HIGH);}
  if (value == "light one of"){
    digitalWrite(2, HIGH); }
  if (value == "light one off"){
    digitalWrite(2, HIGH); }
     if (value == "light win off"){
    digitalWrite(2, HIGH); }
  if (value == "lights one on"){
    digitalWrite(2, LOW);  }
  if (value == "lights one off"){
    digitalWrite(2, HIGH); }

}}
```

APPENDiX B

EOG code

```
int EOG ; int EOGvalue=450;int x=0;int k=0;int c=0;int w=0;int z =0 ;int m=0;int a=0;int s=0;int
void setup()
{Serial.begin(9600);

}
void loop()
{EOG = analogRead(A0);
Serial.println(EOGvalue);
//RIGHT CONTROL
if(EOGvalue>450&&z==0){EOGvalue=450;Serial.println("R1");z=1;x=4;k=4;c=4;w=4;delay(1500);}
if(EOGvalue>450&&z==1&&x==4&& k==4&&c==4&&w==4){EOGvalue=450;Serial.println("R2");z=2;x=4;k=4;c=4;w=4;delay(1500);}
if(EOGvalue<450&&z==1&&x==4&& k==4&&c==4&&w==4){EOGvalue=450;Serial.println("L2");z=4;m=4;a=1;x=4;k=4;c=4;w=4;delay(1500);}
if(EOGvalue>450&&z==2){EOG = analogRead(A0);EOGvalue=450;Serial.println("R3");z=3;x=4;k=4;c=4;w=4;delay(1500);}
if(EOGvalue<450&z==2&&x==4&& k==4&&c==4&&w==4){EOGvalue=450;Serial.println("L3");m=1;z=4;x=4;k=4;c=4;w=4;delay(1500);}
if(EOGvalue>450&&a==1&&z==4&&m==4&& k==4&&c==4&&w==4){EOGvalue=450;Serial.println("R33");a=2;x=4;k=4;c=4;w=4;delay(1500);}
if(EOGvalue<450&&a==1&&z==4&&m==4&& k==4&&c==4&&w==4){EOGvalue=450;Serial.println("L33");s=1;a=4;x=4;k=4;c=4;w=4;delay(1500);}
//Device control:
if(EOGvalue>450&&z==3&&x==4&&k==4&&c==4&&w==4){EOGvalue=450;Serial.println("Light 1 ON(RRRR)");z=0;x=0;k=0;c=0;w=0;delay(1500);}
if(EOGvalue<450&&z==3&&x==4&&k==4&&c==4&&w==4){EOGvalue=450;Serial.println("Light 1 OFF(RRRL)");z=0;x=0;k=0;c=0;w=0;delay(1500);}
if(EOGvalue>450&&m==1&&z==4&&x==4&&k==4&&c==4&&w==4){EOGvalue=450;Serial.println("light 2 ON(RRLR)");m=0;z=0;x=0;k=0;c=0;w=0;delay(1500);}
if(EOGvalue<450&&m==1&&z==4&&x==4&&k==4&&c==4&&w==4){EOGvalue=450;Serial.println("light 2 OFF(RRLL)");m=0;z=0;x=0;k=0;c=0;w=0;delay(1500);}
if(EOGvalue>450&&a==2&&x==4&&k==4&&c==4&&w==4){EOGvalue=450;Serial.println("light 3 ON(RLRR)");m=0;z=0;a=0;x=0;k=0;c=0;w=0;delay(1500);}
if(EOGvalue<450&&a==2&&x==4&&k==4&&c==4&&w==4){EOGvalue=450;Serial.println("light 3 OFF(RLRL)");m=0;z=0;a=0;x=0;k=0;c=0;w=0;delay(1500);}
if(EOGvalue>450&&s==1&&a==4&&x==4&&k==4&&c==4&&w==4){EOGvalue=450;Serial.println("Light 4 ON(RLLR)");m=0;z=0;a=0;s=0;x=0;k=0;c=0;w=0;delay(1500);}
if(EOGvalue<450&&a==4&&x==4&&k==4&&c==4&&w==4){EOGvalue=450;Serial.println("Light 4 OFF(RLLL)");m=0;z=0;a=0;s=0;x=0;k=0;c=0;w=0;delay(1500);}

}
```

APPENDiX C

Client code

Client §

```
#include <ESP8266WiFi.h>

int stat=0;
int stat1=0;
int stat2=0;
int stat3=0;

const char* ssid ="ziada";
const char* password ="retal@2019";

void setup() {

    Serial.begin(115200);
    WiFi.begin(ssid,password);
    while (WiFi.status() != WL_CONNECTED) {
    delay(500);
    Serial.print(".");
    delay(15000);
    Serial.println("Connected");


  }
 void loop() {
     // wait for WiFi connection

     if((WiFi.status() == WL_CONNECTED)) {



      if(digitalRead(0) == HIGH)
          {
            if (stat!=0) ;
            {

          Serial.print("[HTTP] begin...\n");
          // requesting required link
          http.begin("http://192.168.0.5/Light1=ON"); //HTTP

          Serial.print("[HTTP] GET...\n");
          // start connection and send HTTP header


          http.end();
          stat=1;
          if(digitalRead(0) == LOW)
          {
          if (stat!= 1) ;
          {

          Serial.print("[HTTP] begin...\n");
          // requesting required link
          http.begin("http://192.168.0.5/Light=OFF"); //HTTP

          Serial.print("[HTTP] GET...\n");
          // start connection and send HTTP header


          http.end();
          stat=0;
          }
          }
```

Server code

```
server §
//SERVER

#include <ESP8266WiFi.h>

const char* ssid = "ziada";
const char* password = "retal@2019";

int Light1 = 0; // led connected to D0

WiFiServer server(80);

void setup()
{
 Serial.begin(115200);
 pinMode(Light1, OUTPUT);
 digitalWrite(Light1, LOW);
 Serial.print("Connecting to the Newtork");
 WiFi.begin(ssid, password);
IPAddress ip(192,168,0,5);
IPAddress gateway(192,168,0,1);
IPAddress subnet(255,255,255,0);
WiFi.config(ip, gateway, subnet);

 while (WiFi.status() != WL_CONNECTED)
 {
   delay(500);
   Serial.print(".");
 }
void loop()
{
 WiFiClient client = server.available();
 if (!client)
 {
   return;
 }
 Serial.println("Waiting for new client");
 while(!client.available())
 {
   delay(1);
 }
 int value = LOW;
 if(request.indexOf("/Ligthl=ON") != -1)
 {
   digitalWrite(Light1, HIGH); // Turn ON LED
   value = HIGH;
 }
 if(request.indexOf("/Light1=OFF") != -1)
 {
   digitalWrite(Light1, LOW); // Turn OFF LED
   value = LOW;
 }
  client.println("<br><br>");
  client.println("<a href=\"/light1=ON\"\"><button>ON</button></a>");
  client.println("<a href=\"/light1=OFF\"\"><button>OFF</button></a><br />");
  client.println("</html>");


  delay(1);
  Serial.println("Client disonnected");
  Serial.println("");
 }
```

APPENDiX D

Datasheet for "AD620A"

FEATURES

Easy to use
- Gain set with one external resistor
  - (Gain range 1 to 10,000)
- Wide power supply range (±2.3 V to ±18 V)
- Higher performance than 3 op amp IA designs
- Available in 8-lead DIP and SOIC packaging
- Low power, 1.3 mA max supply current

Excellent dc performance (B grade)
- 50 μV max, input offset voltage
- 0.6 μV/°C max, input offset drift
- 1.0 nA max, input bias current
- 100 dB min common-mode rejection ratio (G = 10)

Low noise
- 9 nV/√Hz @ 1 kHz, input voltage noise
- 0.28 μV p-p noise (0.1 Hz to 10 Hz)

Excellent ac specifications
- 120 kHz bandwidth (G = 100)
- 15 μs settling time to 0.01%

APPLICATIONS

Weigh scales

ECG and medical instrumentation

Transducer interface

Data acquisition systems

CONNECTION DIAGRAM

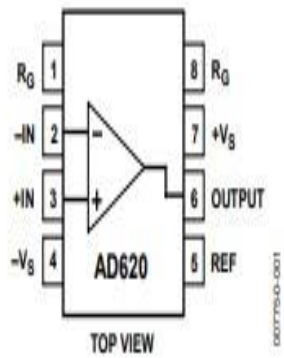


Figure 1. 8-Lead PDIP (N), CERDIP (Q), and SOIC (R) Packages

PRODUCT DESCRIPTION

The AD620 is a low cost, high accuracy instrumentation amplifier that requires only one external resistor to set gains of 1 to 10,000. Furthermore, the AD620 features 8-lead SOIC and DIP packaging that is smaller than discrete designs and offers lower power (only 1.3 mA max supply current), making it a good fit for battery-powered, portable (or remote) applications.

The AD620, with its high accuracy of 40 ppm maximum nonlinearity, low offset voltage of 50 μV max, and offset drift of 0.6 μV/°C max, is ideal for use in precision data acquisition systems, such as weigh scales and transducer interfaces. Furthermore, the low noise, low input bias current, and low power of the AD620 make it well suited for medical applications, such as ECG and noninvasive blood pressure monitors.

Parameter	Conditions	AD620A			AD620B			AD620S[1]			
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	Unit
Common-Mode Rejection											
Ratio DC to 60 Hz with											
1 kΩ Source Imbalance	V_{CM} = 0 V to ± 10 V										
G = 1		73	90		80	90		73	90		dB
G = 10		93	110		100	110		93	110		dB
G = 100		110	130		120	130		110	130		dB
G = 1000		110	130		120	130		110	130		dB
OUTPUT											
Output Swing	R_L = 10 kΩ										
	V_S = ±2.3 V to ± 5 V	$-V_S$ + 1.1		$+V_S$ − 1.2	$-V_S$ + 1.1		$+V_S$ − 1.2	$-V_S$ + 1.1		$+V_S$ − 1.2	V
Overtemperature		$-V_S$ + 1.4		$+V_S$ − 1.3	$-V_S$ + 1.4		$+V_S$ − 1.3	$-V_S$ + 1.6		$+V_S$ − 1.3	V
	V_S = ±5 V to ± 18 V	$-V_S$ + 1.2		$+V_S$ − 1.4	$-V_S$ + 1.2		$+V_S$ − 1.4	$-V_S$ + 1.2		$+V_S$ − 1.4	V
Overtemperature		$-V_S$ + 1.6		$+V_S$ − 1.5	$-V_S$ + 1.6		$+V_S$ − 1.5	$-V_S$ + 2.3		$+V_S$ − 1.5	V
Short Circuit Current			±18			±18			±18		mA
DYNAMIC RESPONSE											
Small Signal −3 dB Bandwidth											
G = 1			1000			1000			1000		kHz
G = 10			800			800			800		kHz
G = 100			120			120			120		kHz
G = 1000			12			12			12		kHz
Slew Rate		0.75	1.2		0.75	1.2		0.75	1.2		V/µs
Settling Time to 0.01%	10 V Step										
G = 1–100			15			15			15		µs
G = 1000			150			150			150		µs
NOISE											
Voltage Noise, 1 kHz	$Total\ RTI\ Noise = \sqrt{(e^2_{ni}) + (e_{no}/G)^2}$										
Input, Voltage Noise, e_{ni}			9	13		9	13		9	13	nV/√Hz
Output, Voltage Noise, e_{no}			72	100		72	100		72	100	nV/√Hz
RTI, 0.1 Hz to 10 Hz											
G = 1			3.0			3.0	6.0		3.0	6.0	µV p-p
G = 10			0.55			0.55	0.8		0.55	0.8	µV p-p
G = 100–1000			0.28			0.28	0.4		0.28	0.4	µV p-p
Current Noise	f = 1 kHz		100			100			100		fA/√Hz
0.1 Hz to 10 Hz			10			10			10		pA p-p
REFERENCE INPUT											
R_{IN}			20			20			20		kΩ
I_{IN}	V_{IN+}, V_{REF} = 0		50	60		50	60		50	60	µA
Voltage Range		$-V_S$ + 1.6		$+V_S$ − 1.6	$-V_S$ + 1.6		$+V_S$ − 1.6	$-V_S$ + 1.6		$+V_S$ − 1.6	V
Gain to Output		1 ± 0.0001			1 ± 0.0001			1 ± 0.0001			
POWER SUPPLY											
Operating Range[4]		±2.3		±18	±2.3		±18	±2.3		±18	V
Quiescent Current	V_S = ±2.3 V to ±18 V		0.9	1.3		0.9	1.3		0.9	1.3	mA
Overtemperature			1.1	1.6		1.1	1.6		1.1	1.6	mA
TEMPERATURE RANGE											
For Specified Performance		−40 to +85			−40 to +85			−55 to +125			°C

APPENDiX E

Datasheet for “AD822A”

ANALOG DEVICES

Single-Supply, Rail-to-Rail Low Power FET-Input Op Amp

Data Sheet **AD822**

FEATURES

True single-supply operation
- **Output swings rail-to-rail**
- **Input voltage range extends below ground**
- **Single-supply capability from 5 V to 30 V**
- **Dual-supply capability from ±2.5 V to ±15 V**

High load drive
- **Capacitive load drive of 350 pF, G = +1**
- **Minimum output current of 15 mA**

Excellent ac performance for low power
- **800 μA maximum quiescent current per amplifier**
- **Unity-gain bandwidth: 1.8 MHz**
- **Slew rate of 3 V/μs**

Good dc performance
- **800 μV maximum input offset voltage**
- **2 μV/°C typical offset voltage drift**
- **25 pA maximum input bias current**

Low noise
- **13 nV/√Hz at 10 kHz**
- **No phase inversion**

APPLICATIONS

Battery-powered precision instrumentation
Photodiode preamps
Active filters
12-bit to 14-bit data acquisition systems
Medical instrumentation
Low power references and regulators

CONNECTION DIAGRAM

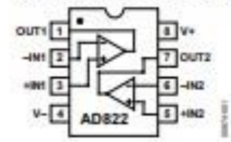


Figure 1. 8-Lead PDIP (N Suffix); 8-Lead MSOP (RM Suffix); and 8-Lead SOIC_N (R Suffix)

GENERAL DESCRIPTION

The AD822 is a dual precision, low power FET input op amp that can operate from a single supply of 5 V to 30 V or from dual supplies of ±2.5 V to ±15 V. It has true single-supply capability with an input voltage range extending below the negative rail, allowing the AD822 to accommodate input signals below ground while in the single-supply mode. Output voltage swing extends to within 10 mV of each rail, providing the maximum output dynamic range.

Offset voltage of 800 μV maximum, offset voltage drift of 2 μV/°C, input bias currents below 25 pA, and low input voltage noise provide dc precision with source impedances up to a gigaohm. The 1.8 MHz unity-gain bandwidth, −93 dB total harmonic distortion (THD) at 10 kHz, and 3 V/μs slew rate are provided with a low supply current of 800 μA per amplifier.

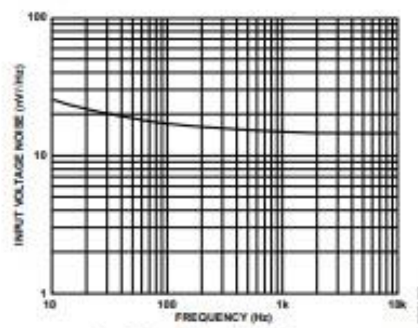


Table 1.

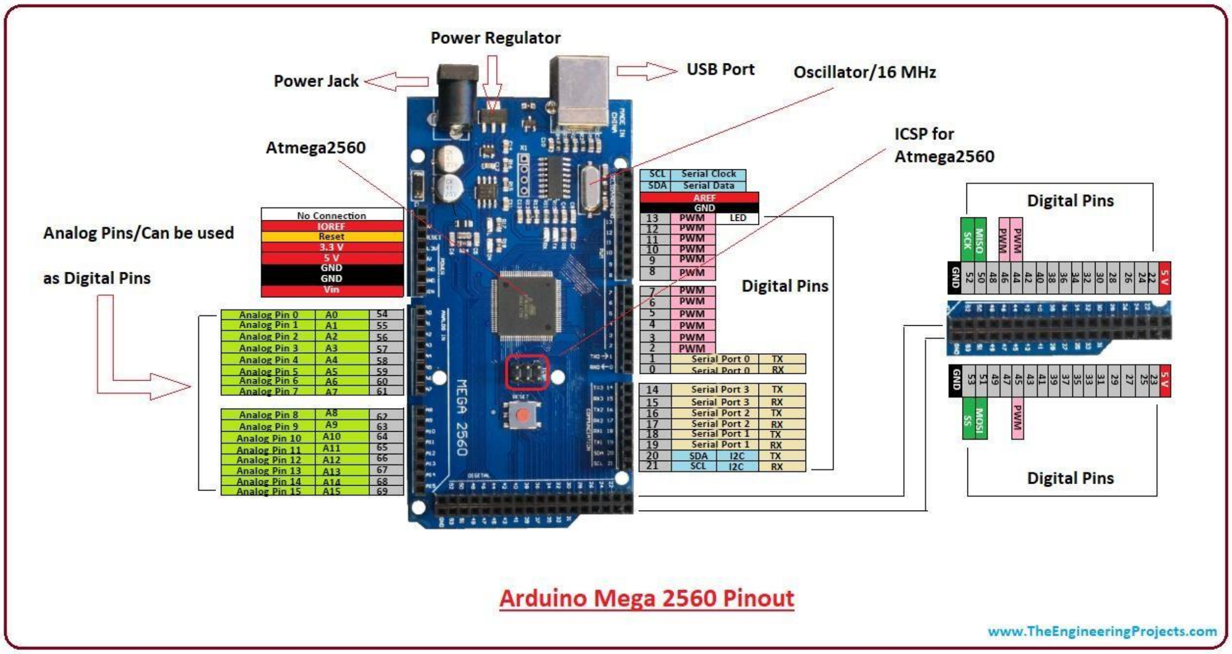
Parameter	Test Conditions/Comments	A Grade Min	A Grade Typ	A Grade Max	B Grade Min	B Grade Typ	B Grade Max	Unit
DC PERFORMANCE								
Initial Offset			0.1	0.8		0.1	0.4	mV
Maximum Offset Over Temperature			0.5	1.2		0.5	0.9	mV
Offset Drift			2			2		µV/°C
Input Bias Current	V_{CM} = 0 V to 4 V		2	25		2	10	pA
At T_{MAX}			0.5	5		0.5	2.5	nA
Input Offset Current			2	20		2	10	pA
At T_{MAX}			0.5			0.5		nA
Open-Loop Gain	V_{OUT} = 0.2 V to 4 V							
	R_L = 100 kΩ	500	1000		500	1000		V/mV
T_{MIN} to T_{MAX}		400			400			V/mV
	R_L = 10 kΩ	80	150		80	150		V/mV
T_{MIN} to T_{MAX}		80			80			V/mV
	R_L = 1 kΩ	15	30		15	30		V/mV
T_{MIN} to T_{MAX}		10			10			V/mV
NOISE/HARMONIC PERFORMANCE								
Input Voltage Noise								
f = 0.1 Hz to 10 Hz			2			2		µV p-p
f = 10 Hz			25			25		nV/√Hz
f = 100 Hz			21			21		nV/√Hz
f = 1 kHz			16			16		nV/√Hz
f = 10 kHz			13			13		nV/√Hz
Input Current Noise								
f = 0.1 Hz to 10 Hz			18			18		fA p-p
f = 1 kHz			0.8			0.8		fA/√Hz
Harmonic Distortion	R_L = 10 kΩ to 2.5 V							
f = 10 kHz	V_{OUT} = 0.25 V to 4.75 V		−93			−93		dB
DYNAMIC PERFORMANCE								
Unity-Gain Frequency			1.8			1.8		MHz
Full Power Response	V_{OUT} p-p = 4.5 V		210			210		kHz
Slew Rate			3			3		V/µs
Settling Time								
To 0.1%	V_{OUT} = 0.2 V to 4.5 V		1.4			1.4		µs
To 0.01%	V_{OUT} = 0.2 V to 4.5 V		1.8			1.8		µs
MATCHING CHARACTERISTICS								
Initial Offset				1.0			0.5	mV
Maximum Offset Over Temperature				1.6			1.3	mV
Offset Drift			3			3		µV/°C
Input Bias Current				20			10	pA
Crosstalk @ f = 1 kHz	R_L = 5 kΩ		−130			−130		dB
Crosstalk @ f = 100 kHz	R_L = 5 kΩ		−93			−93		dB

Parameter	Test Conditions/Comments	A Grade Min	A Grade Typ	A Grade Max	B Grade Min	B Grade Typ	B Grade Max	Unit
INPUT CHARACTERISTICS								
Input Voltage Range[1], T_{MIN} to T_{MAX}		−0.2		+4	−0.2		+4	V
Common-Mode Rejection Ratio (CMRR)	V_{CM} = 0 V to 2 V	66	80		69	80		dB
T_{MIN} to T_{MAX}	V_{CM} = 0 V to 2 V	66			66			dB
Input Impedance								
Differential			10^{13}||0.5			10^{13}||0.5		Ω||pF
Common Mode			10^{13}||2.8			10^{13}||2.8		Ω||pF
OUTPUT CHARACTERISTICS								
Output Saturation Voltage[2]								
$V_{OL} - V_{EE}$	I_{SINK} = 20 μA		5	7		5	7	mV
T_{MIN} to T_{MAX}				10			10	mV
$V_{CC} - V_{OH}$	I_{SOURCE} = 20 μA		10	14		10	14	mV
T_{MIN} to T_{MAX}				20			20	mV
$V_{OL} - V_{EE}$	I_{SINK} = 2 mA		40	55		40	55	mV
T_{MIN} to T_{MAX}				80			80	mV
$V_{CC} - V_{OH}$	I_{SOURCE} = 2 mA		80	110		80	110	mV
T_{MIN} to T_{MAX}				160			160	mV
$V_{OL} - V_{EE}$	I_{SINK} = 15 mA		300	500		300	500	mV
T_{MIN} to T_{MAX}				1000			1000	mV
$V_{CC} - V_{OH}$	I_{SOURCE} = 15 mA		800	1500		800	1500	mV
T_{MIN} to T_{MAX}				1900			1900	mV
Operating Output Current		15			15			mA
T_{MIN} to T_{MAX}		12			12			mA
Capacitive Load Drive			350			350		pF
POWER SUPPLY								
Quiescent Current, T_{MIN} to T_{MAX}			1.24	1.6		1.24	1.6	mA
Power Supply Rejection	V+ = 5 V to 15 V	66	80		70	80		dB
T_{MIN} to T_{MAX}		66			70			dB

[1] This is a functional specification. Amplifier bandwidth decreases when the input common-mode voltage is driven in the range (V+ − 1 V) to V+. Common-mode error voltage is typically less than 5 mV with the common-mode voltage set at 1 V below the positive supply.
[2] $V_{OL} - V_{EE}$ is defined as the difference between the lowest possible output voltage (V_{OL}) and the negative voltage supply rail (V_{EE}). $V_{CC} - V_{OH}$ is defined as the difference between the highest possible output voltage (V_{OH}) and the positive supply voltage (V_{CC}).

APPINDIX F

arduino 3 mod B+ pin specification



APPINDIX G

Node MCU pin specification