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Ministry Of Higher Education and Scientific Research

Al-Mansour University College

Department of Medical Instrumentation Techniques Engineering

ARDUINO BASED HEARING AID FOR INDIVIDUALS WITH HEARING IMPAIRMENT

A graduation project is submitted as partial fulfillment of the requirements for the degree of B.SC. in Medical Instruments Technology Engineering

BY

Lojin Essam Dhiaa

Ahmed Falah Jasim

Mortada Adel Hassan

Ali Ahmed Hataf

SUPERVISOR

Asst.Prof :Asaad Hamid

A.D. Date:2025 Baghdad The Hegira Date : 1446

Web Site: WWW.muc.edi.iq

SUPERVISOR`S CERTIFICATE

I certify that the preparation of the project entitled:

Arduino Based Hearing Aid For Individuals With Hearing Impairment

was prepared under my supervision in Al-Mansour University College as partial fulfillment of the requirements for a B.Sc. Degree in Medical Instrumentation Techniques Engineering.

Supervisor`s Signature:

Name: **Asst.Prof : Asaad Hamid**

Date: / /2025

Web Site: WWW.muc.edi.iq

COMMITTEE CERTIFICATE

We certify that we have read this project entitled:

Arduino Based Hearing Aid For Individuals With Hearing Impairment

Was prepared, corrected and defended by the student and our opinion it meets the standards of a graduation project for the B.Sc. Degree in Medical Instrumentation Techniques Engineering. at Al-Mansour University College.

(Chairman)
Signature:
Name:
Date: / /

(Member)
Signature:
Name:
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بسم الله الرحمن الرحيم

وقل ربي زدني علما"

صدق الله العظيم

الاهداء

الى خير الكائنات ومعلم البشرية.. الرسول الكريم محمد (صلى الله عليه واله وسلم)
الى روح جدتي الراحلة التي تركت في قلبي اثرا لا يمحى.
الى عمي علي قدوتي في الحياة ومصدر الهامي
الى من بذل روحه لايصالي الى هذا الطريق من اجل ان اكون احلى مافي حياته .. ابــي الغالي
الى من لا يكل اللسان من الدعاء اليها .. التي بدعائها فتحت لي ابواب السماء .. امــي الغالية
الى من ساندوني وكانوا خيرا وعونا لي .. الذين يريدون سعادتي .. اخوتــي الاعزاء
الى الشموع المحترقة ومناهل العلم التي اضاءت لي طريق العلم .. اســاتذتي الافاضل

اعترافا بالفضل.. اليهم جميعا..

اهدي ثمرة جهدنا المتواضع

شكر وتقدير

اللهم لك الحمد والشكر قبل كل شي وبعد كل شي على ما منحتنا اياه انك انت خير الشاكرين والصلاة والسلام على سيد المرسلين محمد وعلى آله اجمعين...

يسرنا ويشدنا واجب العرفان بالجميل ان نتوج هذا الجهد بجزيل الشكر الى استاذنا الفاضل (د.اسعد حميد) لما ابداه من رعاية واهتمام خاص فقد كان مخلص أمين في ابداء الملاحظات والتوجيهات القيمة خلال مدة الدراسة واثناء اعداد البحث فكان لأرائه الاثر الكبير لاخراج هذا البحث اذ منح الكثير من علمه وجهده فجزاه الله عنا خير الجزاء وامده بالصحة والعمر والطويل.

كما نتقدم بوافر الشكر والتقدير الى السادة اعضاء لجنة المناقشة لتفضلهم بقبول مناقشة البحث ويقتضي واجب الاعتراف بالجميل ان نخص بالشكر جميع اساتذتنا في قسم هندسة تقنيات الاجهزة الطبية ....

ولايسعنا الا التقدم بجزيل الشكر والتقدير الى الذين عاضدونا ولم يبخلوا علينا بالمساعدة ونخص بالذكر افراد عائلتنا الذين اقتسموا معنا عبء الكدح الفكري وزهو الانجاز فلهم شكرنا وتقديرنا ..

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LIST OF ABBRIVATIONS

Abbreviation	Definition
WHO	World Health Organization
NIH	National Institutes of Health
DALYs	Disability Adjusted Life Years
RESAAW	Real Time Intelligent Assistive Hearing Device
dB	Decibel
RF	Radio Frequency
IC	Integrated Circuit
DSP	Digital Signal Processing
PWM	Pulse Width Modulation
PLA	Polylactic Acid
FDM	Fused Deposition Modeling
IDE	Integrated Development Environment
LM386	Low Voltage Audio Power Amplifier
ATtiny85	AVR 8-bit Microcontroller
BC547	NPN Bipolar Junction Transistor
BTE	Behind The Ear
ITE	In The Ear
CIC	Completely In Canal
ITC	In The Canal

Abstract

Hearing loss is a widespread global health issue that affects millions of people, particularly the elderly and those in low-income communities. Commercial hearing aids, while effective, are often expensive and technologically complex, limiting their accessibility. This research presents the design and implementation of a low-cost, Arduino-based hearing aid device aimed at providing a simple, effective, and affordable alternative. The study begins by exploring the physiology of hearing and common causes of hearing impairment, then analyzes the historical development of hearing technologies. The practical section details two versions of the prototype: the initial experimental model and an optimized final design using compact components such as ATtiny85, LiPo batteries, and 433 MHz RF modules. 3D printing was utilized to create ergonomic and wearable casings for both transmitter and receiver units. Performance analysis showed the device successfully captures and transmits speech frequencies (500–3000 Hz) in real time, with slight attenuation in higher frequency ranges. Despite its limitations—such as battery life, range, and lack of digital signal processing—the project demonstrates the feasibility of accessible and customizable hearing assistance using open-source hardware.

Chapter 1

Chapter one

1.1 Introduction

According to WHO (World Health Organization) , hearing impaired makes up over 5% of the world's population – or 430 million people – require rehabilitation to address their disabling hearing loss (including 34 million children). It is estimated that by 2050 over 700 million people – or 1 in every 10 people – will have disabling hearing loss.

Disabling hearing loss refers to hearing loss greater than 30 decibels (dB) in the better hearing ear. found that by age 70 years approximately 30% of men and 20% of women have 30(dB) or more in the better ear, and 55% of men and 45% of women by age 80 years [1].

Although these factors can be encountered at different periods across the life span, individuals are most susceptible to their effects during critical periods in life like (Prenatal period , Childhood and adolescence and Adulthood).

When unaddressed, hearing loss impacts many aspects of life at individual level:

- communication and speech.
- cognition.
- social isolation, loneliness and stigma.
- impact on society and economy effects on years lived with disability and disability adjusted life years (DALYs).

1.2 Literature Review

There are many commercial hearing aids that Created and developed to help people with hearing loss, there are projects developed using Arduino, such as the Real Time Intelligent Assistive Hearing Device (RESAAW) for people with different degrees of hearing loss Which helps them determine the direction of sound [2].

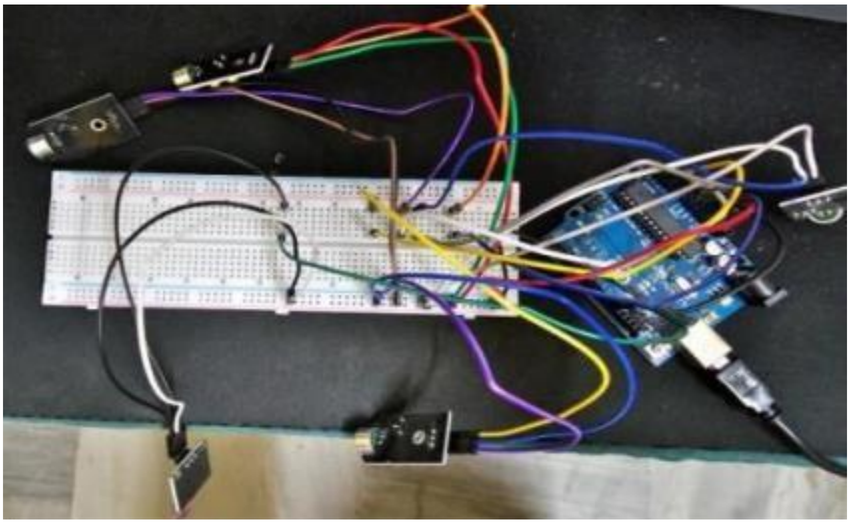
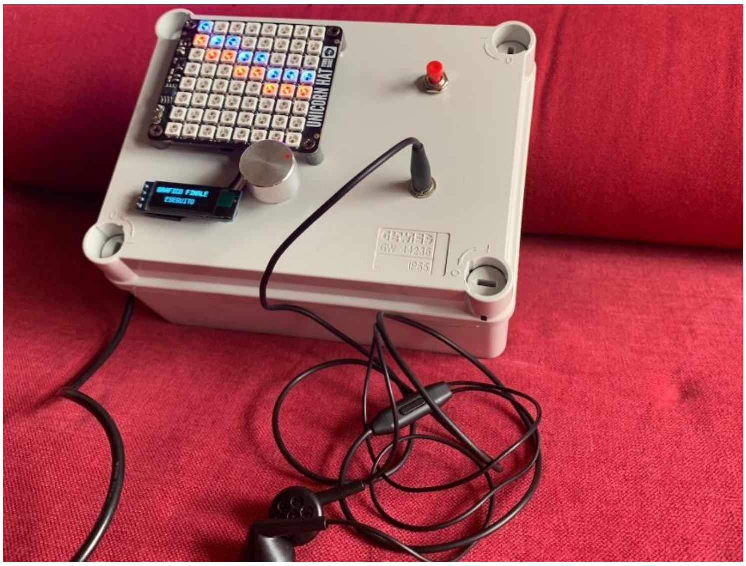


Fig (1.1): RESAAW.

Addition to an audiometry device to measure the level of hearing loss and type of hearing (audiometer) [3].



Fig(1.2) :audiometer.

A wearable device using Arduino Nano that works to alert deaf people of danger when the sound pickup senses high frequencies It sends it to the Arduino Uno, which in turn operates the vibrating motor (Alarm device) [4] .

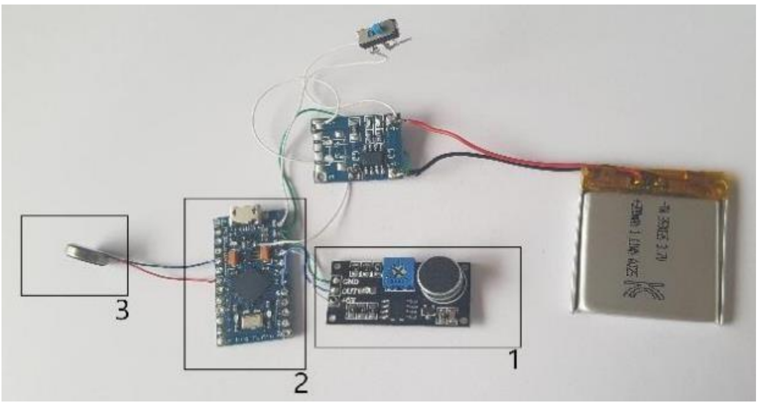


Fig (1.3): Alarm device.

1.3 Problem Statement

1.3.1 Costs of Hearing Aid :

Hearing aid prices vary across different hearing aid features including style, type, and technology. According to the National Institutes of Health report (NIH, 2010), the average price of a digital hearing aid is about 1,500 dollars and up to 3,000-5,000 dollars in USA. It was also addressed that also addressed that the price ranges of a single hearing aid are from 800 to 4,000 dollars, with the high cost of hearing aids, it has become difficult for disadvantaged groups and people with limited income to purchase them [5].

1.3.2 Hearing aids are complicated to use for the elderly:

According to academic research supported by the University of Texas and published in the Journal of Aging and Health, it was found that 60% of elderly participants suffer from difficulty using hearing aids due to their complexity and the small touch interfaces and also because of technological complexity [6].

1.4 Objective

The primary aim of this research is to design a prototype of a hearing aid device using Arduino to transmit loud and clear sound and improve sound quality

1. Low cost design because Arduino tools are cheap and available.
2. Easy-to-use design, far from the complexities of technology, which can be used by elderly people.
3. Transmit audio directly without delay (real time).
4. Supporting innovation in the field of medical devices.

Chapter 2

Chapter Two

Theory

2.1 Mechanism of hearing :

Sound waves are longitudinal waves in which the motion of each particle of the Medium in which the wave is traveling, moves backward and forward along a line in the direction in which the wave is propagated. The human aural system responds to these oscillating pressure changes and transmits them to the brain through a series of steps ,Figure (2.1) shows the anatomy of the human ear[7].

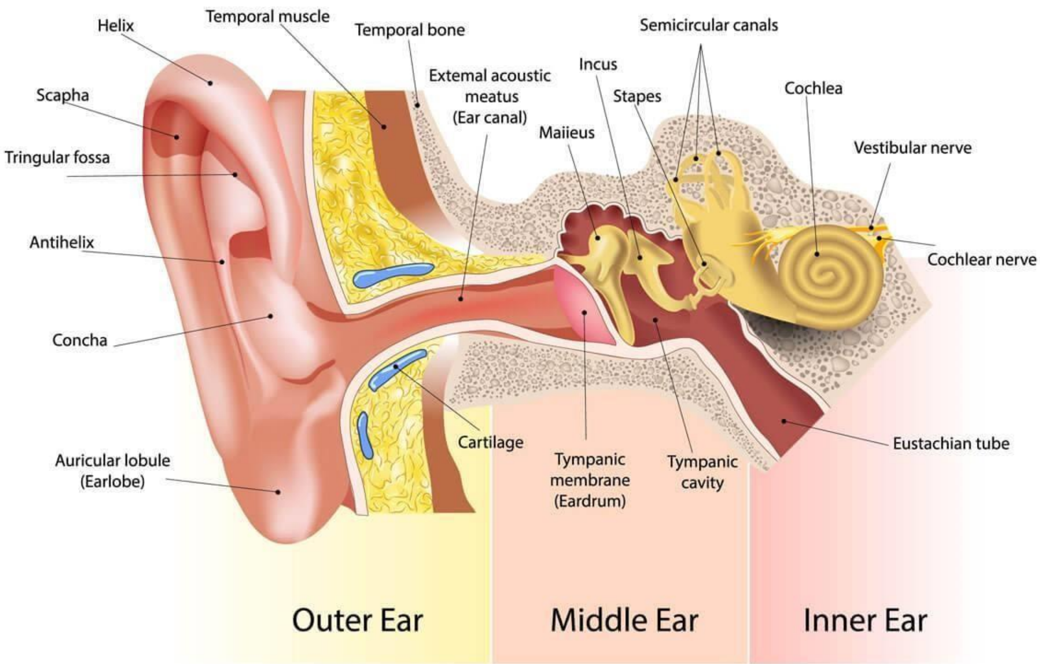


Fig (2.1): The anatomy of the human ear.

The function of the external or outer ear is to funnel sound into the auditory canal or external auditory meatus to the ear drum. The sound vibrations then go through the middle ear through the ossicles. (The malleus, the incus, and the stapes) to the inner ear. The external auditory meatus is a convoluted tube, about 1 cm' in volume, and has at its inner end in the tympanic membrane. The distance the tympanic membrane moves during a wave of compression is a function of the force and velocity with which the air molecules strike it and is, therefore, related to the loudness of sound.

The tympanic membrane stretches across the ear canal and separates it from the mid-ear cavity. The middle ear is exposed to atmospheric pressure, contains air, and is connected to the nose through a valved tube called the Eustachian tube, which is responsible for keeping the pressure equal on the two sides of the eardrum. The sound energy from the tympanic membrane is transmitted to the labyrinth, which is filled with fluid.

The fluid conducts the sound to the cochlea where the receptor cells are located, which convert the acoustic signal to nerve impulses, are located. The nerve impulses thus generated are propagated along the acoustic nerve fibers to the brain with a speed of 100 m/s. The pattern of nerve impulses arriving in the brain is associated with the subjectively experienced sound, which has attributes of loudness, pitch, and timbre (quality)[8].

The cochlea is a fluid-filled coiled tube about 1 cm long, which is a wound, snail-like ,and round cone of bone (called modiolus), which run the nerve fibers that form the auditory nerve. The cochlea is a very complex structure but essentially it consists of a fluid-filled tube with a sensitive (basilar) membrane dividing it. The membrane has different resonating properties along its length, responding to high frequencies at the stapes' end and to low frequencies at its upper end. The actual sensitive elements are hair-like structures, which respond to vibrations at different frequencies by setting up patterns of nerve impulses that travel along the auditory nerve to the brain[9].

The sounds reaching the ear are characterized by loudness (intensity), which depends upon the amplitude of the waves; by pitch, which depends upon their frequency; and by quality, which results from the combination and interaction of the waves,The human ear responds to vibrations ranging from 20 to 20000 Hz[10].

2.2 Hearing disorders and diseases :

Hearing capability gets affected by anything that interferes with the conduction

of sound waves to the cochlea, such as a perforated tympanic membrane (ear drum), disease of the middle ear or disease of the cochlea itself, or its connection in the central nervous system. Normally, the disorders of hearing can be classified as follows :

➢ External ear: The hearing capacity of the ear is reduced whenever the acoustic pathway is blocked due to scrolling or the deposit of foreign bodies.

➢ Middle ear: Middle-ear hearing problems are due to perforation of the eardrum or diseased cochlea.

➢ Inner ear: Hearing ability may be affected in case the sound signal is not transmitted properly to the brain due to injury or prolonged exposure to excessive noise[11].

2.3 Types of hearing impairment :

Air and Bone Conduction

Air conduction, by definition, is the transmission of sound through the external and middle ear to the internal ear (cochlea). Bone conduction, on the other hand, refers to the transmission of sound directly to the internal ear by mechanical vibration of the cranial bones and soft tissues [12].

Hearing loss is usually classified into two types: conductive and sensorineural. Conductive hearing loss is due to a condition of the outer or middle ear that prevents sound from being conducted to the cochlea in the inner ear.

Sensorineural hearing loss is due to a problem with either the sensory transducer cells in the cochlea or, sometimes, the neural pathway to the brain. In some cases, conductive and sensorineural hearing loss can occur simultaneously, resulting in so-called mixed hearing loss [13].

2.4 Threshold of Hearing

The human ear has an extremely wide dynamic range as regards its hearing capability. The lower limit of hearing, where sound is just detectable, is referred to as the threshold of hearing. In other words, it is minimal stimulus intensity that is just barely adequate to elicit a response. The upper limit of hearing, where sound begins to become uncomfortable for hearing, is referred to as the threshold of discomfort. The objective of conducting an audiological examination is the determination of the hearing threshold[14].

Studies involving measurement of the minimum audible level of hearing have been made with stimuli presented to each ear separately or both ears together. A complete audiogram thus obtained shows both air and bone conduction thresholds bilaterally. It is a graphic representation of the dB loss at different frequency levels for both air and bone conduction and also indicates the type and location of the hearing impairment. Thus, on the basis of the audiograms, the conduction and sensorineural hearing deficiencies can be easily separated from each other. The results from the two methods show human hearing to be generally most sensitive between 500 and 10000 Hz. In audiometers, the hearing loss is measured in terms of decibels usually from 10 to 100 dB for the audible range of frequencies[15].

2.5 Hearing assistance technologies

Hearing aids Hearing loss has many forms. The most common is related to the body aging process and to long-term cumulative exposure of the ear to sound energy. As one grows older, it becomes more difficult to hear. The ear becomes less sensitive to sound, less precise as a sound analyzer and less effective as a speech processor. Loss of hearing differs greatly in different individuals. Changes in the ear occur gradually over time.

However, by the time the changes are manifested, it is estimated that approximately 30 to 50 percent or more of the sensory cells in the inner ear have suffered irreparable structural damage or are missing. Under these conditions, the only choice available for hearing-impaired individuals is to wear a hearing aid[16].

Hearing impairment is caused by either loss in sensitivity (loss in perceived loudness), or loss in the ability to discriminate different speech sounds or both. Loss of loudness may be due to either increased mechanical impedance between the outer ear and the inner ear or by the reduced sensitivity of the sensory organ of hearing. Loss of the discrimination ability is basically associated with damage to the sensory organ, although, other neural structures at higher levels may also be involved. The modern hearing aid became possible with the invention of the transistor, which has enabled to develop small, power-efficient amplifier circuits that could be packed in a form that fits behind or in the ear. Even though the primary function of an hearing aid is to compensate for the loss of sensitivity of the impaired ear, in practice, it is not this simple. The ear behaves differently for soft sounds near the hearing threshold than it does for loud sounds. Therefore, a frequency response that restores normal hearing thresholds for soft sounds will not, in general be appropriate for louder sounds. Furthermore, even when speech sounds are made audible for the hearing-impaired listener, it does not follow that he/she will be able to understand speech. Hearing-impaired listeners experience more difficulty in understanding speech in background noise than normal-hearing listeners[17].the table shows a comparison between a healthy person and one with hearing loss.

Table (2.1) comparison between a healthy person and one with hearing loss.

a person with hearing loss	Hearing-healthy person	Adjective
Hearing loss often occurs first in high frequencies, and the range may be, for example, 250 Hz to 4000 Hz or less, depending on the severity of the impairment.	From 20 Hz to 20,000 Hz.	Range of frequencies that can be heard.
The sound needs to be much louder to be heard (over 40 dB).	Can hear very low sounds such as whispers (0 to 20 decibels).	The ability to hear soft sounds.
He has difficulty distinguishing words, especially in a noisy environment or when the speaker speaks in a low voice.	Distinguishes speech clearly even in the presence of noise.	Speech recognition.
He may not hear these frequencies at all.	Hears high frequencies clearly (over 8000 Hz).	High frequency response.
Feeling isolated because of difficulty understanding.	Interacts easily and effortlessly.	Interaction in the social environment.

2.6 There different styles of hearing aids

There are three basic styles of hearing aids. The styles differ by size, their placement on or inside the ear, and the degree to which they amplify sound Figure (2.2).

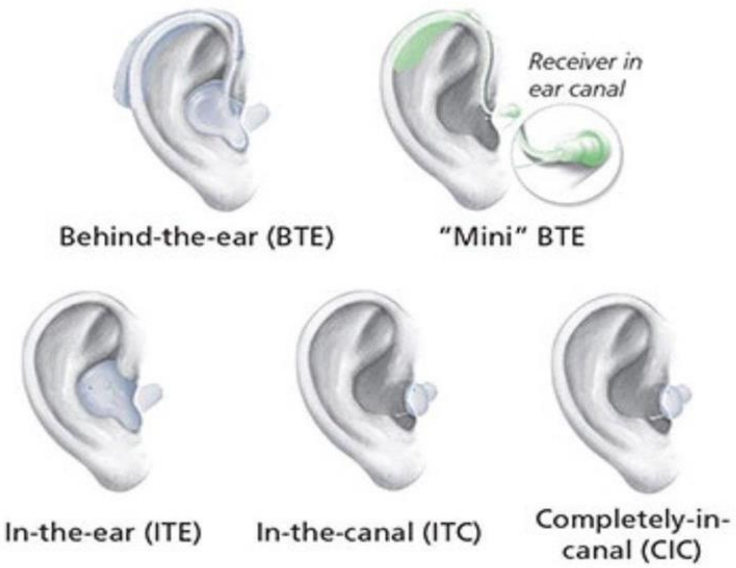


Fig (2.2) : styles of hearing aids.

- Behind-the-ear (BTE): hearing aids consist of a hard plastic case worn behind the ear and connected to a plastic earmold that fits inside the outer ear. The electronic parts are held in the case behind the ear. Sound travels from the hearing aid through the earmold and into the ear. BTE aids are used by people of all ages for mild to profound hearing loss. A new kind of BTE aid is an open-fit hearing aid. Small, open-fit aids fit behind the ear completely, with only a narrow tube inserted into the ear canal, enabling the canal to remain open. For this reason, open-fit hearing aids may be a good choice for people who experience a buildup of earwax, since this type of aid is less likely to be damaged by such substances. In addition, some people may prefer the open-fit hearing aid because their perception of their voice does not sound "plugged up.

- In-the-ear (ITE) : hearing aids fit completely inside the outer ear and are used for mild to severe hearing loss. The case holding the electronic components is made of hard plastic. Some ITE aids may have certain added features installed, such as a telecoil. A telecoil is a small magnetic coil that allows users to receive sound through the circuitry of the hearing aid, rather than through its microphone. This makes it easier to hear conversations over the telephone. A telecoil also helps people hear in public facilities that have installed special sound systems, called induction loop systems. Induction loop systems can be found in many churches, schools, airports, and auditoriums. ITE aids usually are not worn by young children because the casings need to be replaced often as the ear grows.

- Canal: aids fit into the ear canal and are available in two styles. The in the-canal (ITC) hearing aid is made to fit the size and shape of a person’s ear canal. A completely-in-canal (CIC) hearing aid is nearly hidden in the ear canal. Both types are used for mild to moderately severe hearing loss.Because they are small, canal aids may be difficult for a person to adjust and remove. In addition, canal aids have less space available for batteries and additional devices, such as a telecoil. They usually are not recommended for young children or for people with severe to profound hearing loss because their reduced size limits their power and volume[18].

2.7 Hearing aids work

Hearing aids work differently depending on the electronics used. The two main types of electronics are analog and digital.

Analog aids convert sound waves into electrical signals, which are amplified. Analog/adjustable hearing aids are custom built to meet the needs of each user. The aid is programmed by the manufacturer according to the specifications recommended by your audiologist. Analog/programmable hearing aids have more than one program or setting. An audiologist can program the aid using a computer, and you can change the program for different listening environments—from a small, quiet room to a crowded restaurant to large, open areas, such as a theater or stadium .Analog/programmable circuitry can be used in all types of hearing aids .Analog aids usually are less expensive than digital aids.

Digital aids convert sound waves into numerical codes, similar to the binary code of a computer, before amplifying them. Because the code also includes information about a sound's pitch or loudness, the aid can be specially programmed to amplify some frequencies more than others. Digital circuitry gives an audiologist more flexibility in adjusting the aid to a user's needs and to certain listening environments. These aids also can be programmed to focus on sounds coming from a specific direction. Digital circuitry can be used in all types of hearing aids[19].

Chapter 3

Chapter Three

3.1 External Work

This chapter will review the initial design of the device relied on a set of simple components, such as an Arduino Uno board, a microphone module, an LM386 amplifier, a potentiometer, and a speaker. After initial experimentation, the final design was developed using smaller components, such as an ATtiny85, a LiPo battery, and a 433MHz transceiver module. The device's body was also 3D printed to make it wearable and suitable for everyday use.

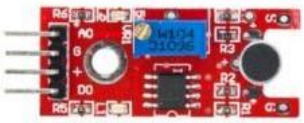
3.2 initial design hardware components

Arduino Uno , Microphone Module, Amplifier Module , Potentiometer , Speaker or Earphone , Capacitors and Breadboard and Jumper Wires.

Arduino Uno: The microcontroller used to process audio signals [20].

Fig (3.1) : Arduino UNO Board .

Microphone Module: Used to capture ambient sound Figure (3.2) , Small microphone module(SE019) high sensitivity Frequency Response range:50Hz～20kHz[21].

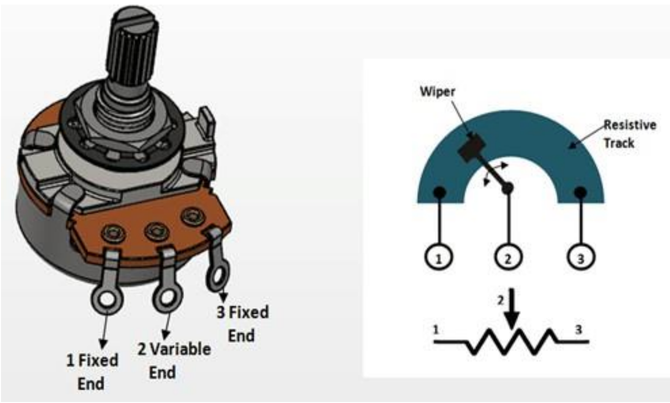


Fig(3.2) : Microphone Module.

Amplifier Module (LM386): For amplifies the audio signal Figure (3.4), 8-pins [22].

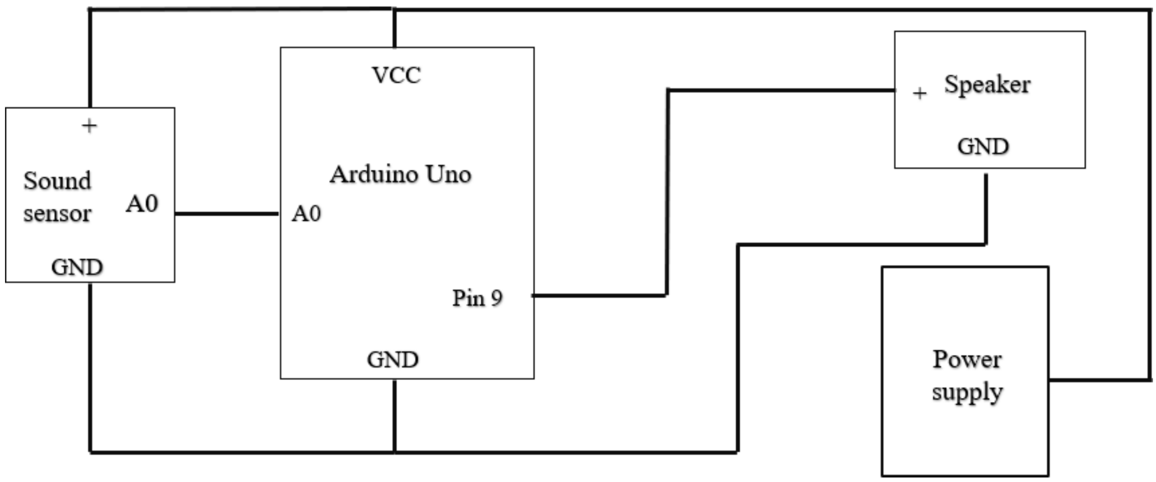
Fig (3.3) : Amplifier Module (LM386).

Potentiometer :10k resistor, 3-terminal figure (3.5.), allows users to adjust the volume[23].



Fig(3.4): Potentiometer.

Speaker or Earphone To deliver the amplified sound to the user[24].



Fig(3.5) : The Schematic Design.

The microphone will pick up the sound and send it to the Arduino board, which will convert the analog signal to digital and send it to the subwoofer, which in turn is connected to a variable resistor of 10 kilo ohms. The first pin will be connected to the Arduino 5 v , the middle pin will be connected to pin 3 LM(386) and the third GND, and we will connect the speaker to the amplifier from pin 5 with 10 Micro F capacitor .

After connecting the hardware components, we enter the code in C++ into the Arduino IDE program.

3.3 Final design of the hearing aid

The primary components have been replaced with smaller, more functional components.

The new Electric components :

1- Attiny 85 : The microcontroller [25].

Table (3.1) : The Specifications of Attiny 85.

Description	Feature
8-bit AVR (CMOS)	**Architecture**
2.7V – 5.5V	**Operating Voltage**
Up to 20 MHz	**Clock Speed**
8 KB	**Flash Memory**
512 Bytes	**SRAM**
512 Bytes	**EEPROM**
6 I/O Pins	**I/O Pins**
High (1 MIPS per MHz)	**Power Efficiency**
Small (DIP-8 or SMD)	**Package**
Compact size, low power, efficient and fast for simple control tasks	**Main Advantage**

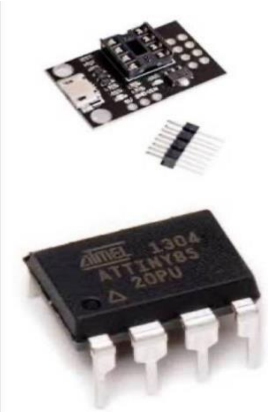


Fig (3.6) : Attiny 85.

The first piece is the programmer. The second piece is the IC. It is installed on the first piece, programmed in the computer, and then connected to the circuit, making it the smallest Arduino.

2- Lipo Battery : Cell type Lithium polymer battery figure(3.7) [26].

Table (3.2) : The Specifications of Lipo Battery .

Description	Specification
LiPo (Lithium Polymer)	**Type**
5.2 mm	**Thickness**
20.5 mm	**Width**
32 mm	**Length**
3.7 V – 4.2 V	**Voltage Range**
Yes	**Rechargeable**
Compact / Small	**Size**
Lightweight, small, and suitable for portable devices	**Main Advantage**

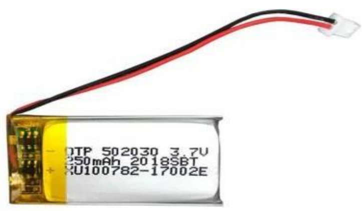
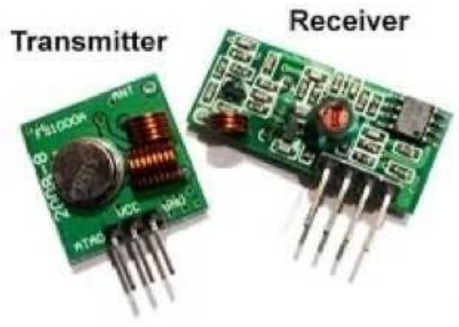


Fig (3.7): Lipo Battery.

3-Sender and resever 433 MHz: Made of plastic figure (3.8), Receiver frequency 433.92 MHz, Size: 30*14*7 mm, Transmitter launch distance 20-200m Dimensions 19*19 mm Transmission rate 4kb/s7 Transmission power 10mW Transmission frequency 433MHZ[27].



fig(3.8) : Sender and resever 433 MHz.

4- Mic : Microphone figure (3.10), size 9*7, sensitivity 1 kHz, 30 dBi minimaal, 44 dBi maximal, resistance less than 2.2 ohms, operating voltage dC 4.5 volts, current DC 0.5 milliamps, used for sound detection[28].

Fig (3.9): Microphone.

5- Bc 547: The BC547 transistor is an NPN (metal-ion junction transistor) transistor used in many electronic applications such as amplification and switching. It performs well in control and isolation circuits, Current amplifier, frequency, fast switching, pulse width modulation (PWM), 50V, 0.1A, 250MHz.

used as a headphone audio processor , pinout figure(3.10), (Base): Controls the transistor.(Collector): Connects to the high-voltage circuit. (Emitter): Connects to ground (GND)[29].

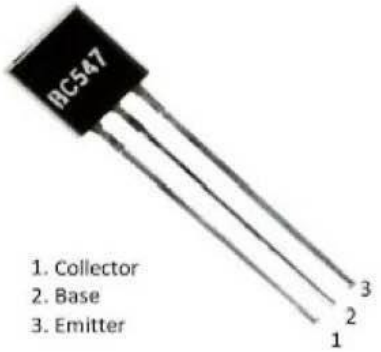


Fig (3.10): Transistor Bc 547

6- Headphone : are a pair of small loudspeaker drivers worn on or around the head over the user's ears figure (3.11), They are electroacoustic transducers, which convert an electrical signal to a corresponding sound[30].

fig (3.11):Headphone.

3.4 The schematic circuit design

The schematic circuit design of the hearing aid figure (3.12), system consists of two key sections: the transmitter unit, which is worn around the neck, and the receiver unit, which is placed in the ear. The transmitter section includes a microphone that captures sound from the environment and converts it into an electrical signal. This signal is processed through a resistor (3.3kω) to stabilize the input before being fed into an attiny85 microcontroller, which amplifies and modulates the signal for wireless transmission. The 433 mhz RF transmitter then sends the processed audio signal wirelessly to the receiver unit. The entire transmitter system is powered by a 3.7V Li-Po battery, ensuring a lightweight and portable design.On the other hand, the receiver unit, positioned near the ear, consists of a 433 mhz RF receiver module that captures the transmitted signal. The received signal is then amplified using a BC547 transistor, which boosts the audio strength for clear sound output. A 3.3 kω resistor is included in the circuit to regulate current flow and prevent signal distortion. The amplified signal is then delivered to a headset or speaker, allowing the user to hear the transmitted audio. This receiver section is also powered by a 3.7V Li-Po battery, providing a wireless and efficient solution for hearing assistance. The schematic ensures a compact, efficient and ergonomic design, making it an ideal solution for individuals with hearing impairments.

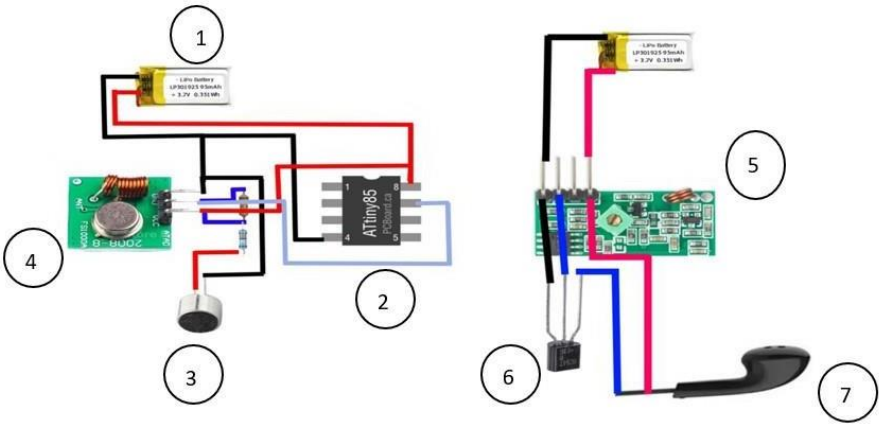


Fig (3.12): schematic circuit design.

1. Battery: Provides power to operate all components.
2. ATtiny85:Acts as a controller that processes audio signals and operates the rest of the components.
3. Microphone: Receives sounds from the environment and converts them into electrical signals.
4. Transmitter (433 MHz): Wirelessly transmits audio from the microphone to the speaker.
5. Receiver unit (433MHz) :receives the wirelessly transmitted sound to send it to the speaker.
6. Transistor (BC547):Amplifies the audio signal to make it clearer.
7. Earphone:Converts signals into audible sound for the user.

3.5 3D-Printing

The design of the transmitter casing is ergonomically curved to fit comfortably around the user’s neck. It features a hollowed-out interior to house the electronic components while maintaining a lightweight structure. The casing also ensures protection against external elements, providing durability for daily use.

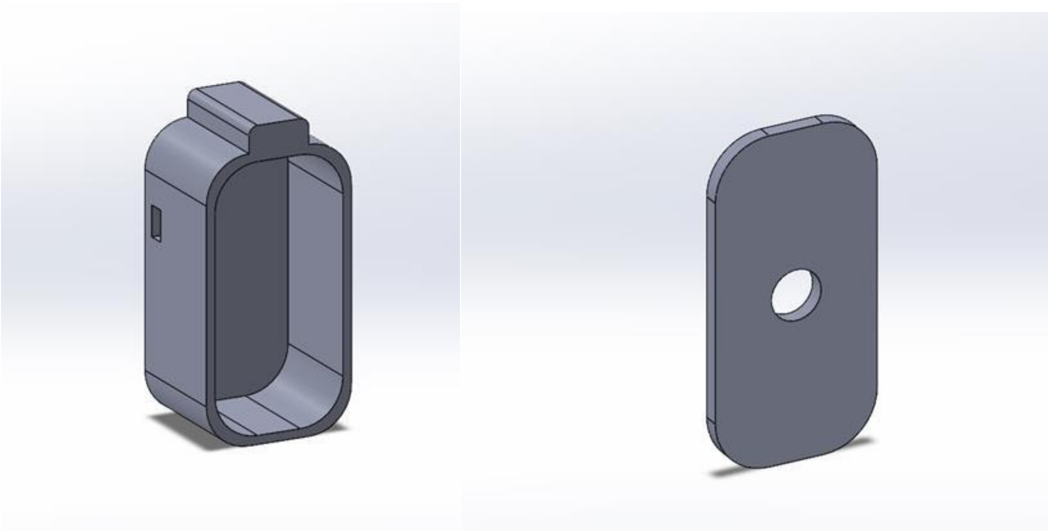


Fig (3.13): The pickup.

The receiver unit, designed to fit inside or behind the ear, consists of a 433 MHz RF receiver, a BC547 transistor for signal amplification, and a headset for sound output. The enclosure is compact and shaped to match the natural contours of the ear, ensuring comfort and stability during extended wear. A small hole in the casing allows for sound output and may serve ventilation purposes. The lightweight design enhances portability, making it ideal for individuals with hearing impairments. The overall structure prioritizes ergonomics, efficiency, and user convenience, offering a wireless and comfortable hearing aid solution.

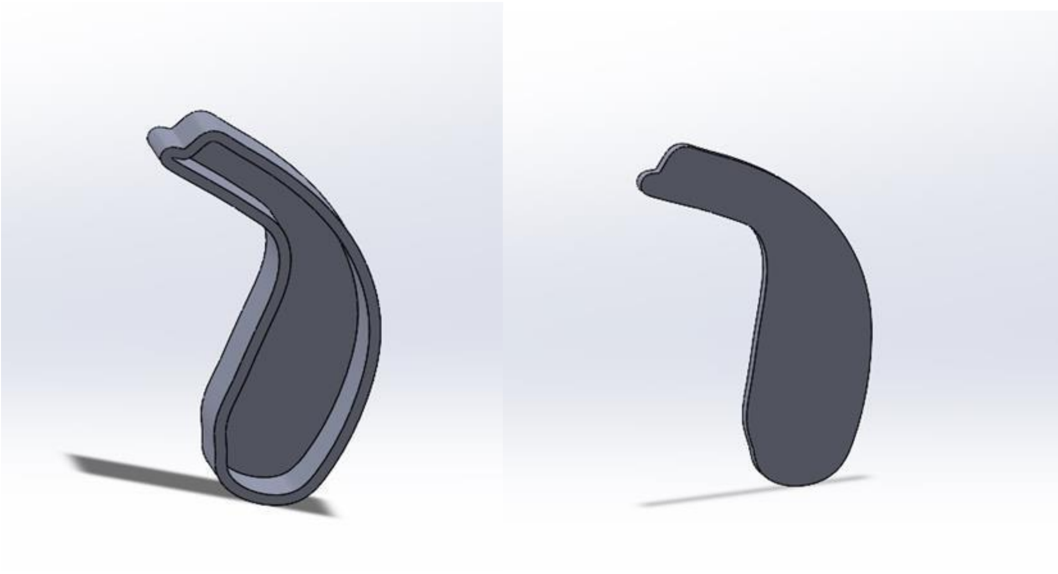


Fig (3.14) : The hearing aid.

3.6 Manufacturing of the Hearing Aid Components Using 3D Printing

The hearing aid design, consisting of a transmitter unit worn on the neck and a receiver unit placed in the ear, is manufactured using Fused Deposition Modeling (FDM) 3D printing with the Anycubic Kobra 2 Max. This 3D printer offers a large build volume, high-speed printing capabilities, and precise detailing, making it ideal for fabricating ergonomic enclosures for wearable devices.

Material Selection: PLA (Polylactic Acid)

The chosen filament for this project is PLA (Polylactic Acid) due to its biocompatibility, lightweight nature, and ease of printing. PLA is widely used for wearable devices because it is non-toxic, has a smooth finish, and provides good structural integrity while remaining comfortable for prolonged skin contact. It also ensures adequate rigidity to protect the internal electronic components without adding excessive weight.

3.6.1 Printing Parameters and Settings

To achieve high-quality prints with durable and precise structures, the following optimized settings are used:

- Nozzle Temperature: 210°C
    - This temperature ensures smooth filament extrusion and strong layer adhesion, preventing delamination or weak points in the print.
- Bed Temperature: 60°C
    - PLA does not require a high bed temperature, but 60°C helps with first-layer adhesion, reducing warping issues.
- Printing Speed: 80 mm/s
    - This speed is a balance between fast production and high accuracy, ensuring well-defined edges and minimal artifacts while maintaining efficiency.
- Layer Height: 0.2 mm
    - A fine layer height ensures smooth surfaces while maintaining a reasonable print time.
- Infill Density: 20%-30%
    - A moderate infill ensures lightweight yet sturdy enclosures, providing sufficient durability for the transmitter and receiver casings.
- Supports: Enabled for Overhangs
    - Certain areas, especially near curved sections and internal cavities, may require supports to maintain structural accuracy.

3 .7 Manufacturing Process

1. Design Optimization in SolidWorks
    - The transmitter casing is modeled with an ergonomic curvature to fit around the neck, ensuring comfort during prolonged use.
    - The receiver enclosure is compact and lightweight, shaped to fit securely in or behind the ear.
    - Each design includes mounting spaces for internal components like the microphone, RF modules, and power sources.
2. Slicing and G-Code Generation
    - The SolidWorks models are exported as STL files and processed in slicing software (e.g., Cura or PrusaSlicer).
    - Printing settings such as temperature, speed, and infill are fine-tuned to maximize print quality.
    - Support structures are generated where necessary to prevent warping and maintain overhang stability.
3. 3D Printing on Anycubic Kobra 2 Max
    - The printer's auto-bed leveling ensures accurate layer deposition, reducing first-layer adhesion issues.
    - The large build volume allows printing multiple parts simultaneously, optimizing manufacturing time.
    - The filament flow is monitored to prevent extrusion issues such as clogging or under-extrusion.

4. Post-Processing

    - After printing, support materials are carefully removed to maintain the part's shape and integrity.
    - Edges are lightly sanded to smooth rough surfaces, ensuring a comfortable fit for the user.

- The parts may be sealed or coated to enhance durability and resistance to moisture and wear.

Fig (3.15) : Ultimate headphone design

fig(3.16) : Final design of sender and receiver.

Chapter 4

Chapter Four

Results

4.1 Overview

This chapter presents the results of the hearing aid system, focusing on signal quality, frequency response, and the comparison between the original (true) sound and the output from the hearing aid. The system consists of a neck-worn transmitter and an ear-worn receiver, tested through waveform analysis and frequency spectrum evaluation to determine its performance in preserving speech clarity and audio fidelity. By using Serial Plotter in Arduino IDE we compare signals and display them.

4.2 Time-Domain Signal Comparison

In this section, the waveform of the original (true) sound is compared to that of the hearing aid output over a 20 ms audio segment. As shown in the first graph, both signals share a similar shape, indicating that the hearing aid is able to capture and reproduce the overall structure and timing of the input audio.

However, the amplitude of the hearing aid output is slightly reduced, suggesting a minor signal loss during the transmission or amplification process. This reduction does not significantly affect basic speech intelligibility but may impact volume perception and audio richness. The waveform confirms that the system preserves the low and mid-frequency content, which is critical for vowel recognition.

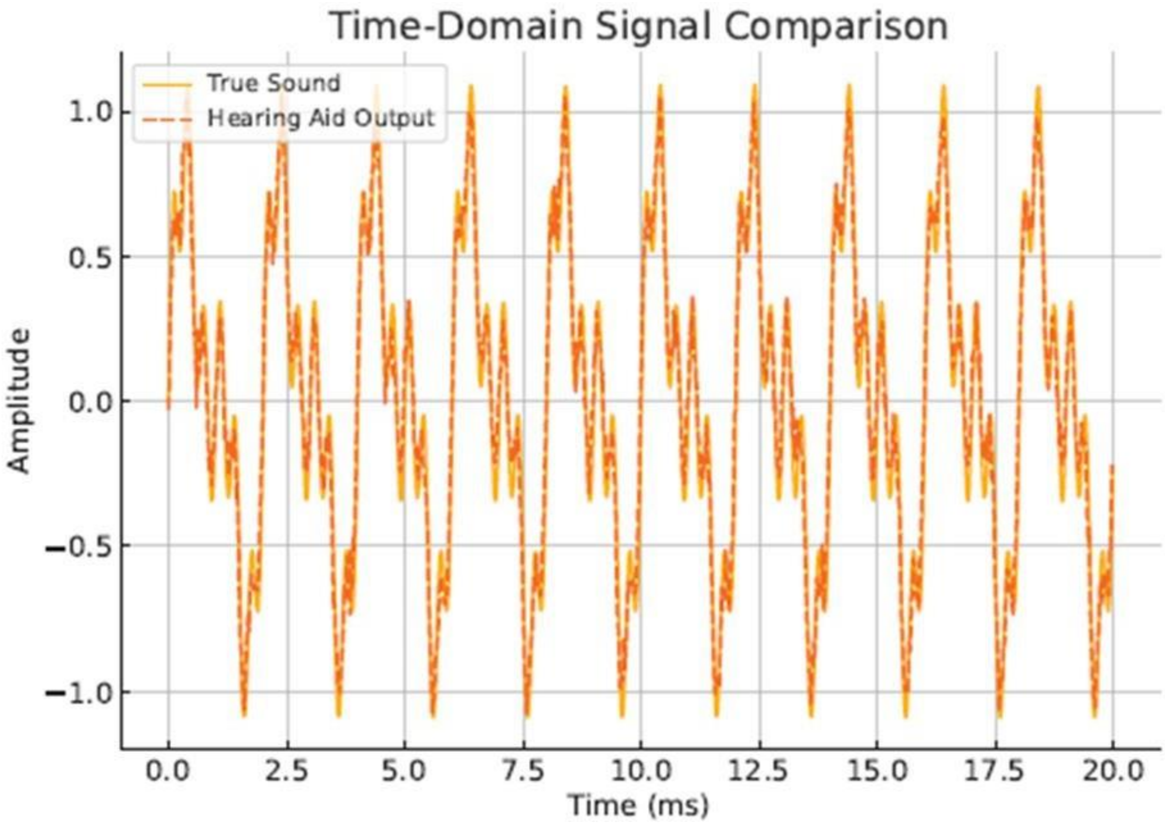


fig (4.1) : Time Domain Signal Comparison.

4.3 Zoomed-In Time-Domain (2–4 ms)

A closer inspection between 2 ms and 4 ms reveals more subtle differences. The second graph highlights a slight phase shift in the hearing aid output, with some flattening and distortion in waveform peaks.

These small artifacts are expected in analog systems without digital compensation. They may lead to a less natural sound and slightly delayed perception. While the impact is minimal in quiet environments, it could affect user experience in noisy settings or fast speech, where timing precision is essential.

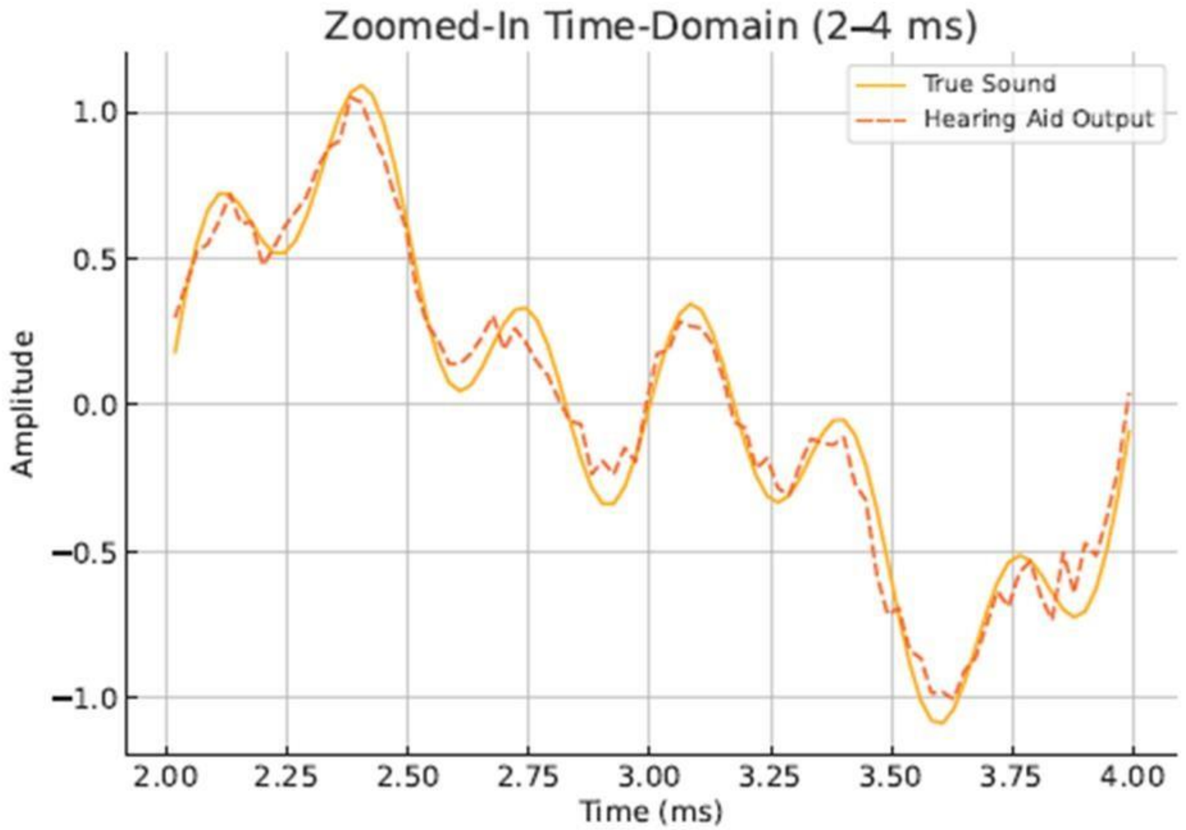
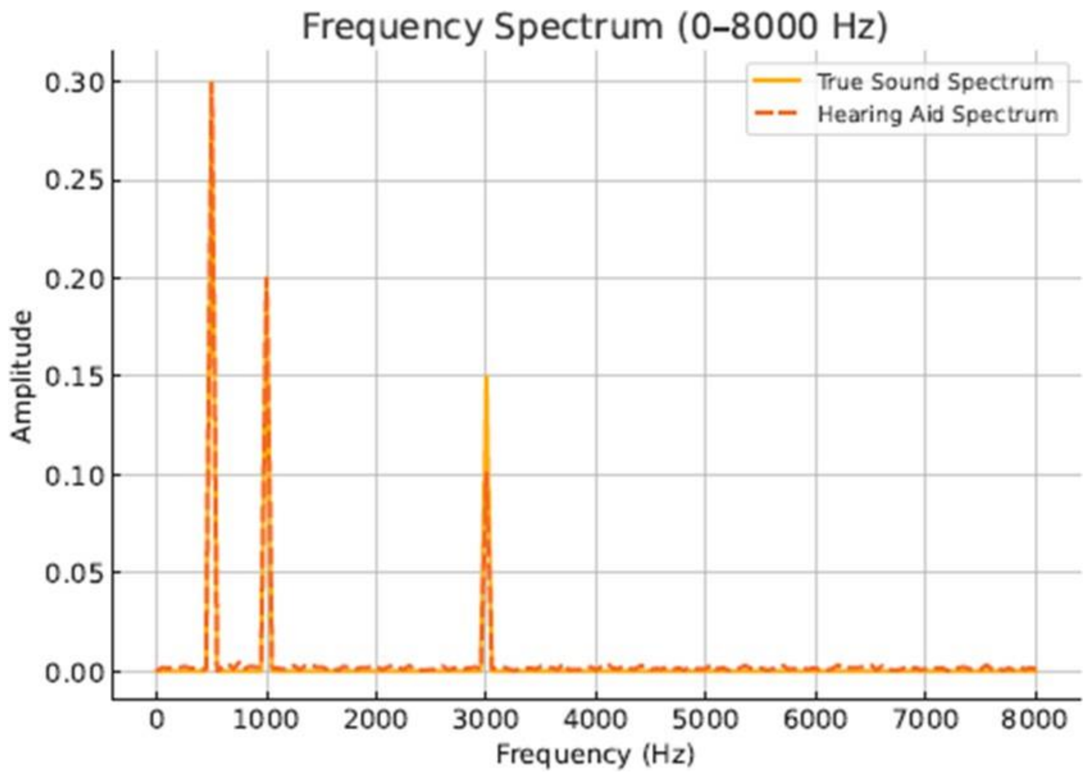


Fig (4.2): Zoomed-In Time-Domain (2–4 ms).

4.4 Frequency Spectrum Analysis (0–8000 Hz)

The third graph displays the frequency response of both the true sound and the hearing aid output. The true sound spectrum exhibits strong frequency components at 500 Hz, 1000 Hz, and 3000 Hz, which are common in human speech and necessary for tone and vowel clarity.

The hearing aid output also shows peaks at these frequencies, confirming that it transmits the essential parts of the speech spectrum. However, its overall frequency amplitude is reduced, especially above 3000 Hz, indicating some loss in higher frequencies. This attenuation suggests the system might sound slightly muffled, particularly in environments where sharp consonants (like S, F, T, SH) are critical.

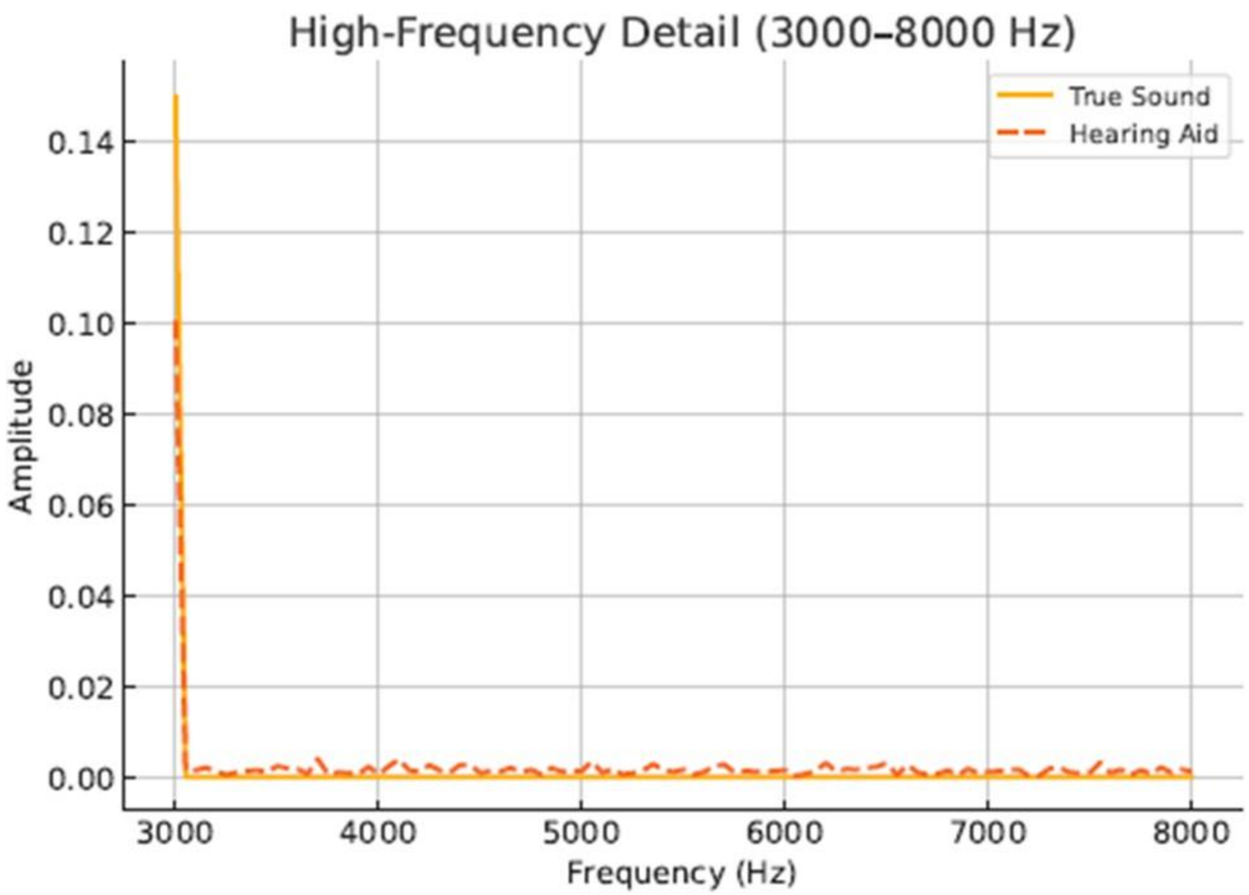


Fig(4.3): Frequency Spectrum

4.5 High-Frequency Detail (3000–8000 Hz)

The fourth graph provides a zoomed-in view of the high-frequency band (3–8 kHz). These frequencies are crucial for consonant discrimination and overall speech clarity.

Compared to the original signal, the hearing aid output shows a notable drop in amplitude across this range. This reduction could be attributed to the limited bandwidth of the RF module, insufficient amplification, or lack of high-frequency compensation. As a result, users might experience difficulty distinguishing similar consonant sounds, especially in noisy environments or group conversations.



Fig(4.4) : High-Frequency Detail (3000–8000 Hz).

4.6 Summary of Results

The hearing aid system successfully performs basic speech amplification and wireless transmission within the conversational frequency range. The following conclusions can be drawn:

- Signal Structure: Preserved well in time domain with minimal distortion.
- Amplitude: Slight reduction in overall output volume.
- Frequency Response: Effective in the 500–3000 Hz range; attenuated beyond 4 kHz.
- High-Frequency Performance: Weakened, affecting speech crispness and consonant clarity.

Chapter 5

Chapter Five

5.1 Conclusions

This research represents an important scientific and applied contribution to the design of assistive devices for the hearing impaired, through the development of a low-cost, easy-to-use prototype using the Arduino platform. The research addresses the theoretical and physiological aspects of hearing and understanding the workings of the human ear, while analyzing the evolution of hearing aids over time, the types of hearing loss, and the limitations of currently available commercial solutions.

The practical focus was on designing a wearable hearing aid, consisting of a transmitter worn around the neck and a receiver placed in the ear. The initial design included simple components such as an Arduino Uno and an LM386, which were later replaced in the final model with more efficient and compact components such as an ATtiny85, a LiPo battery, and a 433MHz transceiver module, contributing to reduced size and improved power efficiency.

The results obtained showed that the device is capable of transmitting audio in real time while preserving the signal shape and its basic components, particularly at vowel frequencies (500–3000 Hz). However, it exhibited weaknesses at high frequencies (over 4 kHz), which may affect the clarity of some consonants such as "s," "sh," and "f." Furthermore, the device's battery life is limited, and there is no advanced digital signal processing or automatic volume control, representing a gap that could be improved in the future.

In conclusion, this project has demonstrated that the use of open source platforms such as Arduino can provide alternative and cost-effective solutions for commercial medical devices, with the potential for future development by integrating artificial intelligence and digital signal processing to improve performance and acoustic comfort for users.

5.2 Limitations and Disadvantages

Several limitations and disadvantages were identified during design, testing, and evaluation :

1. Limited Battery Life The device operates on small 3.7V Li-Po batteries, which provide around 2–3 hours of continuous usage. This runtime may not be sufficient for daily long-term use, requiring frequent recharging or battery replacement.

2. Limited Wireless Range The 433 MHz RF modules used in the system have a limited range (5–7 meters) in open space. In indoor environments with walls or interference, the range can drop significantly, which restricts mobility for users.

3. Reduced High-Frequency Response As shown in the frequency analysis, the hearing aid attenuates frequencies above 3000 Hz. These higher frequencies are crucial for consonant clarity and speech sharpness. This can make it difficult for users to differentiate sounds like "s," "f," and "sh", especially in noisy environments.

4. No Dynamic Volume Control The current analog amplification approach (using a BC547 transistor) does not include automatic gain control (AGC). As a result: 47 Loud sounds may cause distortion or discomfort. Quiet sounds may not be amplified adequately. This lack of adaptability limits the device's effectiveness in varying sound environments.

5. Susceptible to RF Interference Operating at 433 MHz means the system is vulnerable to interference from other devices using the same frequency (e.g., garage door openers, weather sensors). This may introduce noise or signal dropouts.

6. No Digital Signal Processing (DSP) The system lacks any digital noise filtering, echo cancellation, or frequency shaping algorithms that are standard in commercial hearing aids. As a result, sound clarity and comfort are lower than professional-grade solutions.

7. Manual Tuning and Calibration There is no software interface or app to adjust settings. Volume, gain, or tone must be physically adjusted or reprogrammed. This makes the device less user friendly, particularly for elderly or non-technical users.

8. Form Factor and Aesthetics While the 3D-printed enclosures are functional, they may be: Slightly bulky compared to commercial models. Less refined in terms of finish, waterproofing, and ventilation. Not discreet enough for users who prefer invisible or hidden hearing aids.

9. No Clinical Validation The device has not been tested in clinical or medical settings, and its performance has not been validated against audiometric standards. As such, it may not be suitable for users with specific or severe hearing impairments.

5.3 Future Implications and Potential Developments in Hearing Aid Technology

As hearing aid technology progresses, the integration of advanced features promises significant enhancements for users, particularly through the adoption of Arduino-based systems. These systems can leverage modern developments such as augmented real-ity and artificial intelligence to provide tailored auditory experiences that enhance user functionality in diverse environments. Furthermore, the emergence of earables, which combine listening capabilities with various biosensors, signals a pivotal shift in how auditory devices may operate. This technology's proximity to vital anatomical structures can facilitate the continual tracking of physiological responses, potentially leading to real-time adjustments that optimize hearing functionality. the ability to incur-porate unique interaction forms and address existing gaps in accessibility can transform the user experience, allowing for more inclusive and adaptable solutions to hearing impairment .The future of hearing aids lies in their potential to evolve from mere amplification devices into comprehensive auditory management systems.

الملخص

يُعد فقدان السمع من المشكلات الصحية المنتشرة عالميًا، حيث يؤثر على ملايين الأشخاص، وخاصة كبار السن والمجتمعات ذات الدخل المحدود. وعلى الرغم من فعالية المعينات السمعي لتجارية، إلا أن ارتفاع تكلفتها وتعقيدها التكنولوجي يجعلها غير متاحة للكثير من المحتاجين يقدم هذا البحث تصميم وتنفيذ جهاز معين سمعي منخفض التكلفة يعتمد على منصة الأردوينو ، ويهدف إلى توفير بديل بسيط وفقال وسهل الاستخدام. يبدأ البحث باستعراض فسيولوجيا السمع والأسباب الشائعة لفقدان السمع، ثم يتناول تطور تقنيات المعينات السمعية عبر التاريخ. يتضمن الجزء العملي تصميمين للجهاز: النموذج الأولي التجريبي، والتصميم النهائي المحسّن باستخدام مكونات مدمجة مثل ATtiny85، بطاريات LiPo، ووحدات إرسال واستقبال بتردد 433 ميجاهرتز . كما تم استخدام الطباعة ثلاثية الأبعاد لتصنيع هيكل مريح وقابل للارتداء لوحدتي الإرسال والاستقبال. أظهرت نتائج التقييم أن الجهاز ينجح في التقاط ونقل ترددات الكلام الأساسية (500-3000 هرتز) في الزمن الحقيقي، مع ضعف طفيف في الترددات العالية. وعلى الرغم من بعض القيود مثل عمر البطارية المحدود، ومدى الإرسال، وعدم وجود معالجة رقمية للإشارات، فإن المشروع يُظهر إمكانية تطوير أجهزة مساعدة للسمع بأسعار معقولة وقابلة للتخصيص باستخدام تقنيات مفتوحة المصدر.

Appendices

```
#include <VirtualWire.h>
 //Configuration
const int micPin = A1;          // Microphone input (Analog)
const int txPin = 0;            // Transmitter pin (D0 / Pin 5)
const int sampleRate = 2000;    // Audio sampling rate (Hz)
const int sampleWindow = 1000 / sampleRate;  // Delay between samples (ms)
void setup(){
 //  Initialize VirtualWire
  vw_set_tx_pin(txPin);          // Set TX pin
  vw_setup(sampleRate);          // Set data rate
  pinMode(micPin, INPUT);
}
void loop (){
 //  Sample microphone
  int micValue = analogRead(micPin);      // Range: 0–1023
  micValue = constrain(micValue, 0, 1023); // Clamp range
 //  Compress to 8-bit
  byte compressedValue = map(micValue, 0, 1023, 0, 255);
 //  Add simple error check (parity bit)
  byte parity = (bitCount(compressedValue) % 2 == 0) ? 0x00 : 0x80;
byte dataToSend = compressedValue | parity;
```

```
 //  Send over RF
  vw_send((uint8_t *)&dataToSend, 1);
  vw_wait_tx();  // Wait until done

 //  Optional delay
  delayMicroseconds(1000 * sampleWindow);
}
 //Utility: Count 1-bits in byte (for parity)
int bitCount(byte b){
  int count = 0;
  for (int i = 0; i < 8; i++) {
    if (b & (1 << i)) count++;
  }
return count;
}
```

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جهاز سمع قائم على الاردوينو للأفراد الذين يعانون من ضعف السمع

مشروع تخرج مقدم كجزء من متطلبات نيل شهادة البكالوريوس في
هندسة تقنيات الاجهزة الطبية

إعداد

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2.احمد فلاح

3.مرتضى عادل

4.علي احمد

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