Palestine Polytechnic University

College of Engineering

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Design and Implementation of Hearing Aid with Photovoltaic Charger

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الإهداء :

بسم الله الرحمن الرحيم

اذا كان الإهداء يعبر ولو بجزء من الوفاء فالإهداء

إلى معلم البشرية ومنبع العلم ... نبينا محمد (صلى الله عليه وسلم)

إلى من علمني العطاء بدون انتظار الذي زرع في نفسي الطموح والمثابرة ... والدي العزيز

إلى نبع الحنان الذي لا ينضب ... أمي الغالية

إلى الذين رووا بدمائهم ثرى فلسطين إلى من هم أفضل منا جميعاً إلى الذين ارتقوا إلى السمو ... شهداء فلسطين

إلى أعمدة العلم والمعرفة الذين خطوا لي وللآخرين صفحات الإبداع ... المعلمة والمربية الفاضلة م. فداء الجعافرة

الى من تحلو بالإخاء وتميزوا بالعطاء والوفاء الى من كانوا معي على طريق النجاح والخير ...

صديقاتي جميعا

إلى القلوب الطاهرة الرقيقة والنفوس البريئة إلى رياحين حياتي ... إخوتي

وشكر خاص الى الاستاذ الفاضل رسمي السيد أحمد والمهندس محمد القيسي والمهندس الياس محارمة ...

سمر , أنوار

Abstract

Due to various and increasing human medical needs and requirements in treatment of hearing problems , several techniques and application have been developed to facilitate dealing with different hearing problems.

Hearing aid device is a small electronic gadget that is fit in or behind the ear to improve one's hearing and consequently communication ability .This research work involves the design and development of a hearing aid device with audio-amplifier , an acoustic signal picked-up using a condenser microphone. The audio amplifier is configured to produce an audio amplification which is converted to audio signal through a headphone. Design equations were employed to calculate the physical parameters of the circuit. Hearing aids need for power to run , these power taken from batteries, in this project will be recharged batteries by solar cell.

After the design, the circuit was constructed and tested on 20 people with partial hearing problem. The result showed that there was a significant improvement in the hearing ability of all the patients tested. Recommendations were proposed for further improvement .

Keywords: hearing aid , acoustic signal , pre-amplifier , condenser microphone , solar cell , rechargeable battery.

ملخص المشروع

نتيجة للاحتياجات الطبية البشرية المتزايدة والمختلفة في مشاكل فقدان السمع .هنالك العديد من التطبيقات التي طورت لتسهيل التعامل مع مختلف الحالات المرضية المتعلقة وذات الصلة بمشاكل الاذن والسمع .

السماعة الطبية هي عبارة عن اداة الكترونية صغيرة يتم وضعها داخل او خلف الاذن بشكل مناسب لتحسين مستوى السمع عند الاشخاص ليمكنهم من التواصل بشكل طبيعي .

هذا المشروع ينطوي على تصميم وتطوير سماعة طبية تعمل على استخدام مكبر صوت خاص بالنواحي الطبية , يتم التقاط الاصوات من خلال مايكروفون ثم مرورها الى مكبر الصوت لتضخيمها ثم تحويلها الى اشارات صوتية يتم سماعها من خلال سماعة الرأس , تم عمل جميع الحسابات والمعادلات الرياضية الخاصة بتصميم الدائرة الالكترونية .
تحتاج هذه السماعات الي مصدر تغذية حيث قمنا بتصميمه في هذا المشروع ليتم تغذيته من خلال الخلايا الشمسية وهي مصدر
رخيص وحديث للطاقة المتجددة , باستخدام هذه الخلايا سنقوم بإعادة شحن البطاريات القابلة للشحن.

بعد تصميم الدائرة وتركيبها تم اختبارها على عشرين شخص يعانون من مشاكل مختلفة في السمع وأظهرت النتائج ان هناك تحسن كبير في مستوى السمع .

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List of Abbreviations:

SNHL: Sensorineural Hearing Loss

dB: Decibels

CPS: Cycles Per Second

PV: Photovoltaic`

BTE: Behind The Ear

ITE: In The Ear

ITC: In The Canal

CIC: Completely in the canal

DSP: Digitized Sound Processing

DC: Direct Current

AC: Alternating Current

CE: Common Emitter

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Chapter 1

Introduction

1.1 Introduction:

Hearing is one of the major senses and like vision is important for distant warning and communication. It can be used to alert, to communicate pleasure. One of the problem that may occur in ear is hearing losses, hearing loss is a common health issue that affects nearly 10% [1] of the world population and 4% [2] of Palestinians people There are types of hearing loss Possible to be deep or chronic, the deep can solving by cochlear implants and the chronic by using hearing aids.

In our project we design hearing aid ,is a small electronic device that can wear in or behind the ear. It makes some sounds louder so that a person with hearing loss can listen, communicate, and participate more fully in daily activities. A hearing aid can help people hear more in both quiet and noisy situations.

A hearing aid has three basic parts: a microphone, amplifier, and speaker. The hearing aid receives sound through a microphone, which converts the sound waves to electrical signals and sends them to an amplifier. The amplifier increases the power of the signals and then sends them to the ear through a speaker.

Then we design a charger by using PV cell in order to charge batteries solar cell is one of renewable energy system which uses PV modules to convert sunlight into electricity. The electricity generated can be either stored or used directly, Solar PV system is very reliable and clean source of electricity that can suit a wide range of applications.

1.2 Project Motivations:

1. Increasing the percentage of hearing loss in Palestine about 4%, special due to the nature of the environment (e.g. Quarrying).
2. Relatively high cost of hearing aid.
3. Relatively short life of hearing aid batteries, Constitute a burden on the patient.

1.3 Project Objective:

1. Design and implement hearing aid that has less expensive.
2. Design charger using photovoltaic cell.
3. Offering cheap hearing aid for all persons need it.

1.4 Literature Review:

There are several studies about designing of hearing aids one of them titled Perceptual Consequences of Cochlear Hearing Loss and their Implications for the Design of Hearing Aids , This paper provides an overview of changes in the perception of sound that result from cochlear damage, It is concluded that, for losses up to about 45 dB, audibility is the single most important factor. However, for greater losses, poor discrimination of suprathreshold (audible) stimuli is also of major importance.[3]

Another study titled Noise, Amplification, and Compression: Considerations of Three Main Issues in Hearing Aid Design .This paper deals with the following three topics interfering noise, the amplitude-frequency response of the hearing aid, the benefit of frequency-dependent compression. It concluded that a persons with impaired hearing typically need 3 to 6 dB higher speech-to-noise ratios than do normal-hearing listeners-a technically very difficult problem to solve , within a relatively ample range, the speech-reception threshold in noise is independent of the amplitude-frequency response , and the small time constants of syllabic compression deteriorate the speech signal. Multichannel amplification with automatic gain control for each channel is recommended .[4]

1.5 Time Plan:

The Table 1.1 shows the activities that done in the project, and the time of each one.

Table 1.1: Activities planning

Weeks / Activities	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Obtaining required components	■	■	■	■												
System Design					■	■	■	■								
Recording Results									■	■	■	■	■			
Results analysis and conclusion														■	■	■
Documentation				■	■	■	■	■	■	■	■	■	■	■		

1.6 Project Cost:

The following table shows the cost of all component used in the project.

Table 1.2: Project cost

Component	**Cost €**
condenser microphone	12 €
Medium Power Amplifier (TDA2822 IC)	17 €
Battery	6 €
Photovoltaic module (4v, 80mA)	10 €
Total cost	45 €

Chapter 2

Anatomy and physiology of the ear and hearing

2.1 Introduction

Hearing is one of the major senses and like vision is important for distant warning and communication. It can be used to alert, to communicate pleasure and fear. It is a conscious appreciation of vibration perceived as sound. In order to do this, the appropriate signal must reach the higher parts of the brain. The function of the ear is to convert physical vibration into an encoded nervous impulse. It can be thought of as a biological microphone. Like a microphone the ear is stimulated by vibration: in the microphone the vibration is transduced into an electrical signal, in the ear into a nervous impulse which in turn is then processed by the central auditory pathways of the brain.

2.2 Ear anatomy:

The following figure shows the parts of the air:

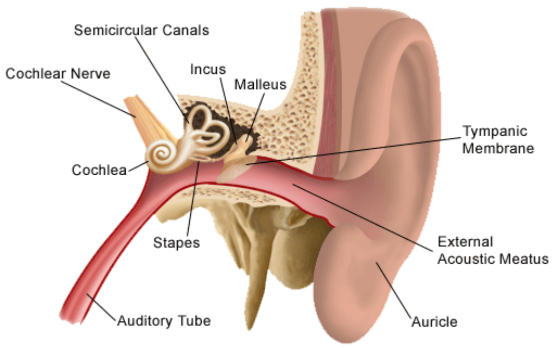


Fig. 2.1: Ear parts[5]

The parts of the ear include:

1. External or outer ear**,** consisting of:

- Pinna or auricle. This is the outside part of the ear.
- External auditory canal or tube. This is the tube that connects the outer ear to the inside or middle ear.

- Tympanic membrane (also called the eardrum). The tympanic membrane divides the external ear from the middle ear.

2. Middle ear (tympanic cavity), consisting of:

- Ossicles. Three small bones that are connected and transmit the sound waves to the inner ear. The bones are called:
- Malleus
- Incus
- Stapes
- Eustachian tube. A canal that links the middle ear with the back of the nose. The Eustachian tube helps to equalize the pressure in the middle ear. Equalized pressure is needed for the proper transfer of sound waves. The Eustachian tube is lined with mucous, just like the inside of the nose and throat.

3. Inner ear, consisting of:

- Cochlea (contains the nerves for hearing)
- Vestibule (contains receptors for balance)
- Semicircular canals (contain receptors for balance)

2.3 Hearing physiology:

Hearing is one of the five senses. It is a complex process of picking up sound and attaching meaning to it. The ability to hear is critical to understanding the world around us.

The human ear is a fully developed part of our bodies at birth and responds to sounds that are very faint as well as sounds that are very loud. Even before birth, infants respond to sound.

So, how do we hear?

The ear can be divided into three parts leading up to the brain – the outer ear, middle ear and the inner ear , The outer ear consists of the ear canal and eardrum. Sound travels down the ear canal, striking the eardrum and causing it to move or vibrate. The middle ear is a space behind the eardrum that contains three small bones called ossicles , This chain of tiny bones is connected to the eardrum at one end and to an opening to the inner ear at the other end. Vibrations from the eardrum cause the ossicles vibrate which, in turn, creates movement of the fluid in the inner ear.

Movement of the fluid in the inner ear, or cochlea, causes changes in tiny structures called hair cells. This movement of the hair cells sends electric signals from the inner ear up the auditory nerve (also known as the hearing nerve) to the brain, the brain then interprets these electrical signals as sound.

2.4 Hearing loss:

Hearing loss is a sudden or gradual decrease in how well you can hear. Depending on the cause, it can be mild or severe, temporary or permanent.

2.5 Symptoms of hearing losses.

- Trouble understanding phone conversations
- Trouble hearing above background noise
- Trouble following a conversation when more than one person speaks at once
- Perception that people are not speaking clearly or mumbling
- Often misunderstanding what people say and responding inappropriately
- Often having to ask people to repeat themselves
- Frequent complaints by others that the TV is too loud
- Ringing, roaring, or hissing sounds in the ears, known as tinnitus.

2.6 Causes of hearing loss:

- Hearing Loss at Birth (Congenital Hearing Loss)
- Hearing Loss After Birth (Acquired Hearing Loss)
- Ear Infections (Otitis Media)
- Noise
- Ototoxic Medications (Medication Effects)
- Chemical Exposure Effects of Hearing and Balance.

2.7 Types of Hearing Loss:

There are three main types of hearing losses:

1. **Conductive:** Middle ear pathology

Conductive hearing loss occurs when sound is not conducted efficiently through the outer ear canal to the eardrum and the tiny bones (ossicles) of the middle ear. Conductive hearing loss usually involves a reduction in sound level or the ability to hear faint sounds. This type of hearing loss can often be corrected medically or surgically.

Some possible causes of conductive hearing loss:

- Fluid in the middle ear from colds
- Ear infection

- Poor Eustachian tube function
- Benign tumors
- Infection in the ear canal

2. **Sensorineural:** Damage at the inner ear (cochlea)

Sensorineural hearing loss (SNHL) occurs when there is damage to the inner ear (cochlea), or to the nerve pathways from the inner ear to the brain. Most of the time, SNHL cannot be medically or surgically corrected. This is the most common type of permanent hearing loss.

SNHL reduces the ability to hear faint sounds. Even when speech is loud enough to hear, it may still be unclear or sound muffled.

Some possible causes of SNHL:

- Illnesses
- Drugs that are toxic to hearing
- Hearing loss that runs in the family (genetic or hereditary)
- Aging
- Head trauma
- Malformation of the inner ear
- Exposure to loud noise

3. **Mixed:** Both cochlear damageθ & outer/middle ear pathology

Sometimes a conductive hearing loss occurs in combination with a Sensorineural hearing loss (SNHL). In other words, there may be damage in the outer or middle ear and in the inner ear (cochlea) or auditory nerve. When this occurs, the hearing loss is referred to as a mixed hearing loss.

2.8 Degrees of Hearing Loss:

Doctors classify hearing loss by degrees: from mild, moderate, severe, or profound. As the stages progress, the person with hearing loss becomes increasingly cut off from the world of speech and sounds. The symptoms of these categories include:

- Mild hearing loss: One-on-one conversations are fine but it becomes hard to catch every word in the presence of background noise.
- Moderate hearing loss: You often need to ask people to repeat themselves during in-person and telephone conversations.
- Severe hearing loss: Following a conversation is almost impossible without a hearing aid.
- Profound hearing loss: You cannot hear other people speaking, unless they are extremely loud. Without a hearing aid or cochlear implant you cannot understand speech.

The intensity of sound is measured in decibels (dB)

The following table show the degree of hearing losses in dB .

Table 2.1: the degree of hearing losses[5]

Degree of hearing losses	Hearing losses range (dB)
Normal	-10 to 20
Slight	16 to 25
Mild	26 to 40
Moderate	41 to 55
Moderately server	56 to 70
Server	71 to 90
Profound	+91

2.9 Diagnostic of hearing loss:

The doctor will do a physical exam and ask about the patient symptoms and past health. He also may look in its ears with a lighted device called an otoscope.

Fig. 2.2: Otoscpe device [5]

If the doctor thinks that the patient have hearing loss, he will do hearing tests to check whether the patient have hearing loss and find out how severe it is. They may be referred to an audiologist to do the tests. These tests may include:

- A tuning fork test, which helps the doctor know which kind of hearing loss they have.
- Other tests to find out what kind of hearing loss or which part of the ear is affected.

2.10 Audiometry:

An audiometry exam tests the ability to hear sounds. Sounds vary based on their loudness (intensity) and the speed of sound wave vibrations (tone). Hearing occurs when sound waves stimulate the nerves of the inner ear. The sound then travels along nerve pathways to the brain.

Sound waves can travel to the inner ear through the ear canal, eardrum, and bones of the middle ear (air conduction). They can also pass through the bones around and behind the ear (bone conduction).

The intensity of sound is measured in decibels (dB) as we show in the previous table.

The tone of sound is measured in cycles per second (cps) or Hertz:

- Low bass tones range around 50 - 60 Hz
- Shrill, high-pitched tones range around 10,000 Hz or higher[5].

The normal range of human hearing is about 20 Hz - 20,000 Hz.

2.10.1 Performing of the test:

The first steps are to decide whether the patient need an audiogram. The procedure most often involves blocking one ear at a time and checking the ability to hear whispers, spoken words, or the sound of a ticking watch.

A tuning fork may be used. The tuning fork is tapped and held in the air on each side of the head to test the ability to hear by air conduction. It is tapped and placed against the mastoid bone behind each ear to test bone conduction.

Audiometry provides a more precise measurement of hearing. For this test, they wear earphones attached to the audiometer. Pure tones of controlled intensity are delivered to one ear at a time. they will be asked to raise a hand, press a button, or otherwise indicate when hear a sound.

The minimum intensity (volume) required to hear each tone is graphed. A device called a bone oscillator is placed against the bone behind each ear (mastoid bone) to test bone conduction

This test can detect hearing loss at an early stage. It may also be used when having hearing problems from any cause.

2.10.2 The Normal Results:

- The ability to hear a whisper, normal speech, and a ticking watch is normal.
- The ability to hear a tuning fork through air and bone is normal.
- In detailed audiometry, hearing is normal if you can hear tones from 250 Hz - 8,000 Hz at 25 dB or lower.

2.10.3 The Abnormal Results:

There are many kinds and degrees of hearing loss. In some types, they only lose the ability to hear high or low tones, or lose only air or bone conduction. The inability to hear pure tones below 25 dB indicates some hearing loss.

The amount and type of hearing loss may give clues to the cause, and chances of recovering the hearing.

2.11 The treating:

The doctor can help the patients decide on the best treatment. Noise-induced or age-related hearing loss can be treated with hearing devices, such as hearing aids. Other devices can help alert they to sounds around the house like the phone or doorbell. If hearing aids don't work, cochlear implants may be an option.

Fig. 2.3: Hearing aid and cochlear implants [6]

2.12 Tinnitus:

Tinnitus refers to "ringing in the ears" when no other sound is present. Tinnitus can sound like hissing, roaring, pulsing, whooshing, chirping, whistling, or clicking .Tinnitus can occur in one ear or both ears.

Almost everyone at one time or another has experienced brief periods of mild ringing or other sounds in the ear. Some people have more annoying and constant types of tinnitus. One third of all adults experience tinnitus at some time in their lives. About 10%–15% [7] of adults have prolonged tinnitus requiring medical evaluation. The exact cause of tinnitus is often not known. One thing is certain: Tinnitus is not imaginary.

Causes of tinnitus:

The most common cause of tinnitus is damage and loss of the tiny sensory hair cells in the cochlea of the inner ear. This damage typically occurs as a result of the normal aging process, and from prolonged exposure to excessively loud noise. Hearing loss coincides with tinnitus .

Other possible causes of tinnitus are:

- Cardiovascular diseases
- Ear infection
- Diabetes
- Head and neck injuries

Chapter 3

Basic of hearing aids and solar cell

3.1 Introduction

Hearing aid is small electronic devices that wear in or behind ear. It makes some sounds louder so that a person with hearing loss can listen, communicate, and participate more fully in daily activities. A hearing aid can help people hear more in both quiet and noisy situations, primarily useful for Sensorineural hearing impairment (disease, ageing, injury).

Hearing aids need for power to run, these power taken from batteries, in our project will be recharge batteries by solar power.

Solar photovoltaic system or solar power system is one of renewable energy system which uses PV modules to convert sunlight into electricity. The electricity generated can be either stored or used directly, fed back into grid line. Solar PV system is very reliable and clean source of electricity that can suit a wide range of applications.

3.2 Growth factors for the hearing aid industry:

- Aging is the most important cause of prevalence of hearing impairment more than 85% of cases
- Improved working environment fewer work-related hearing losses
- Music
- Other influencing factors - diabetes, medicine etc.
- War

The following table shows the relationship between the growth of population and size of manufacture of hearing aids. **see table 3.1.**

Table 3.1: Growth factors for the hearing aid industry [6]

Growth in 65+ population			
	Share of global market 2010	2005-2010	2010-2015
Western Europe	36%	1.2%	1.7%
Eastern Europe	4%	0.6%	1.9%
North America	40%	1.9%	3.1%
Asia	11%	3%	3.3%
Latin America	4%	3.3%	3.6%
Oceania	4%	2.8%	3.6%
Rest of the world	1%	-	-
World	100%	2.3%	2.9%

3.3 Medical purpose of hearing aids:

Hearing aids are primarily useful in improving the hearing and speech comprehension of people who have hearing loss that results from damage to the small sensory cells in the inner ear, called hair cells. This type of hearing loss is called sensorineural hearing loss. The damage can occur as a result of disease, aging, or injury from noise or certain medicines.

A hearing aid magnifies sound vibrations entering the ear. Surviving hair cells detect the larger vibrations and convert them into neural signals that are passed along to the brain. The greater the damage to a person’s hair cells, the more severe the hearing loss, and the greater the hearing aid amplification needed to make up the difference. However, there are practical limits to the amount of amplification a hearing aid can provide. In addition, if the inner ear is too damaged, even large vibrations will not be converted into neural signals. In this situation, a hearing aid would be ineffective.

3.4 Hearing aids principle of operation:

Hearing aids are electronic devices that collect sound, amplify it, and send it to the medial layer in ear. While the style of hearing aid may vary, all hearing aids have similar components:

- A microphone to pick up sound
- An amplifier to make sounds louder
- A receiver (miniature loudspeaker) to deliver the amplified sound into the ear
- Batteries for power

3.5 Classification of hearing aids:

- design
- technology used to achieve amplification (i.e. analog vs. digital)
- special features

3.5.1 Hearing aids classified according to designs:

1. **Behind-the-ear (BTE) aids:** Most parts are contained in a small plastic case that rests behind the ear; the case is connected to an earmold or an earpiece by a piece of clear tubing, treatment of a wide range of hearing losses. This style is often chosen for young children because it can accommodate various earmold types, which need to be replaced as the child grows. Also, the BTE aids are easy to be cleaned and handled, and are relatively sturdy[7]. See Fig 3.1

Fig. 3.1: Behind-the-ear (BTE) aids [8]

2. **In-the-ear (ITE) aids:** In-the-Ear hearing aids are larger, and may offer more features. They also accommodate larger receivers. This type of hearing aid is easier to handle than CICs and ITCs. Treats a wide variety of hearing impairments.

3. **In-the-canal (ITC) aids and completely-in-the-canal (CIC) aids**: The smallest hearing aid is almost invisible in the ear. These hearing aids are suitable only for people with ear

canals large enough to accommodate the whole hearing aid. Often used in cases of mild to moderate hearing losses.

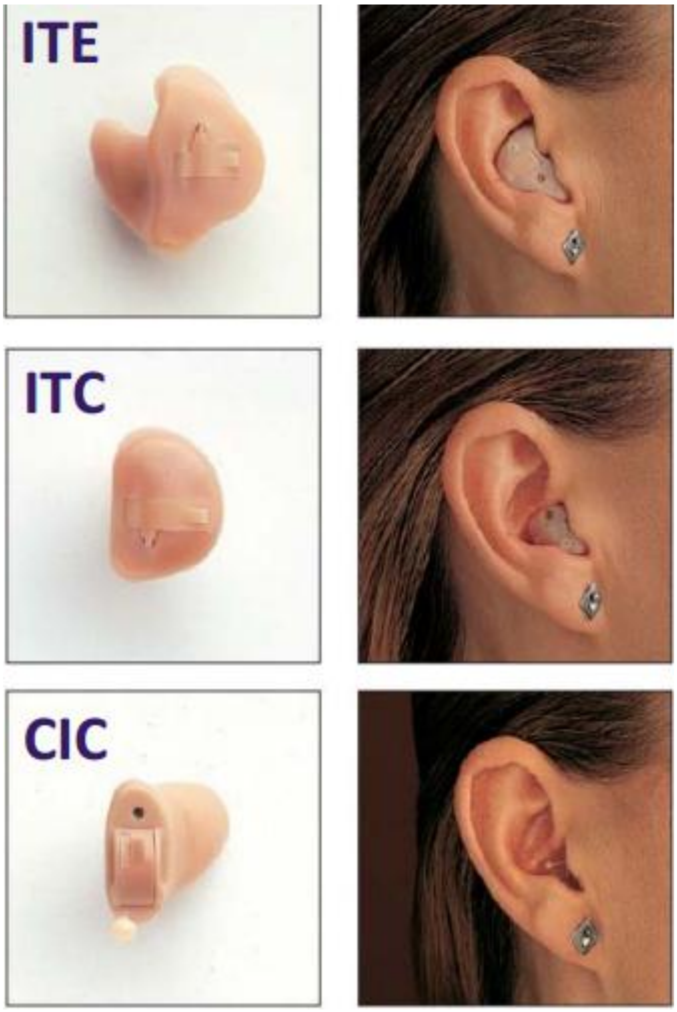


Fig. 3.2: Hearing aids classified according to designs[8]

3.5.2 Hearing aids classified according to technology:

1. **Digital hearing aids:** use digitized sound processing (DSP) to convert sound waves into digital signals. A computer chip in the aid analyzes the signals to determine whether the sound is noise or speech. It then makes modifications to provide a clear, amplified, distortion-free signal.

Advantages of digital hearing aids:

- Noise reduction.
- Improvement in programmability.
- Management of loudness discomfort.

2. **Analogue hearing aids:** Analogue hearing aids amplify sound signals picked up by a microphone and convert them into small electrical signals. These signals are transmitted

into the ear in real time. They can be altered according to the needs of the individual user within the limits of the analogue technology.

Some degree of programming is possible with the most advanced analogue hearing aids.

Advantages of analog hearing aids:

- Long time hearing aid users sometimes find the sound more acceptable because they are used to it.
- Cost is less than digital.
- Sometimes more powerful than digital.

3.6 Common Hearing Aid Features:

Directional microphones

- Sound from a specific direction amplified to a greater level
- May help listeners to understand speech in noisy environments

In our project will be use omnidirectional microphone, meaning that they pick up sounds equally well from either side of the microphone.

3.7 Benefits and limitations of hearing aids:

Benefits:

- Ability to hear sounds that could not be heard previously, and help oral communication.
- Ability to hear speech over the telephone.

Limitations:

- Do not restore normal hearing.
- All sounds, including background noise and undesired sounds, are made louder.
- Sounds, including own voice, might seem too loud at first.
- May need to be replaced every several years.

3.8 Types of hearing aid batteries:

While there are **rechargeable batteries** available on the market, the most common type is still the **zinc-air button battery**. Traditionally hearing aid batteries were produced using trace amounts of mercury to assist with conductivity and stabilize internal components, but all major battery manufacturers now sell a mercury-free variety.

Because zinc-air batteries are air-activated, a factory-sealed sticker allows them to remain inactive until it is removed. Once peeled off the back of the battery, oxygen in the air will interact with the zinc in the battery and “turn it on.” To get the best performance from a zinc-air battery, the battery should be left open to the air for at least one minute to fully activate before placing it in the hearing device. The battery will not be deactivated if the sticker is placed back on the device, so once it is removed the battery will remain in an active state until the power is drained.

3.8.1 Zinc-air batteries sizes and life:

Hearing aids come in many different sizes and styles. Because there are various sizes of hearing aids with different features, the amount of power needed for the device to run differs. Larger hearing aids generally require larger hearing aid batteries. Additionally, hearing aids used for individuals with severe or profound hearing losses typically require larger batteries because more power is needed to help them operate.

There are five sizes of hearing aid batteries available on the market. The sizes, from smallest to largest, are 5, 10, 312, 13 and 675. Size 5 hearing aid batteries are very rare. The four most common hearing aid battery sizes are all smaller than the diameter of a dime:

- Size 10 - 5.8 mm wide by 3.6 mm high
- Size 312 - 7.9 mm wide by 3.6 mm high
- Size 13 - 7.9 mm wide by 5.4 mm high
- Size 675 - 11.6 mm wide by 5.4 mm high

Because size differences may appear trivial to the regular eye or can be difficult to remember, battery packaging is generally color-coded to making finding and purchasing the correct ones easier. Size 5 batteries are labeled red, size 10 batteries are labeled with yellow, size 312 are marked in brown, size 13 are packaged in orange and size 675 are usually designated using blue. The most common battery size for hearing aids in the US market is the brown, size 312 battery. See Table 3.2

Table 3.2: Zinc-air batteries sizes

Size	Color Code	Dimensions (WxH)	Typical Uses	Average Lifespan
675	Blue	11.6mm x 5.4mm	Power BTE hearing aids	9-20 days
13	Orange	7.9mm x 5.4mm	BTE hearing aids ITE hearing aids	6-14 days
312	Brown	7.9mm x 3.6mm	Mini BTE hearing aids RITE hearing aids ITC hearing aids	3-10 days
10	Yellow	5.8mm x 3.6mm	Mini RITE hearing aids CIC hearing aids	3-7 days

Zinc-air batteries life:

One of the most common questions individuals have about hearing aid batteries is how long they will last. Generally speaking, they can last anywhere from five to 14 days, based on a 16 hour per day use cycle. This is of course dependent upon the size of the battery and power needed by the hearing aid. Typically, smaller ones don’t last quite as long because their size restricts the amount of power stored in them.

The average life span of hearing aid batteries is as follows:

- Size 10 - three to seven days
- Size 312 - three to 10 days
- Size 13 - six to 14 days
- Size 675 - nine to 20 days

If a hearing aid user is experiencing shortened battery life, it’s possible there is an issue with the hearing device. A hearing aid wearer should consult their device manual or contact their hearing healthcare professional to make sure everything is working properly.

3.8.2 Rechargeable hearing aid batteries and charger :

Power One ACCU Plus rechargeable hearing aid batteries are the only nickel metal hydride (Ni-MH) rechargeable batteries on the market. These quality-made batteries are designed to replace zinc air batteries and must be used with a Power One ACCU plus charger.

1. **PowerOne ACCU plus Size 10 Rechargeable Hearing Aid Batteries**

- Environmentally friendly product.
- Nickel-metal hydride batteries.
- Size 10, 1.2V 12mAh, 2 batteries
- Voltage 1.2v

Fig. 3.3: PowerOne ACCU plus Size 10 rechargeable hearing aid batteries[9]

2. **PowerOne ACCU plus Size 13 Rechargeable Hearing Aid Batteries**

- Two batteries per pack.
- Voltage 1.2v

Fig 3.4: PowerOne ACCU plus Size 13 rechargeable hearing aid batteries[9]

3. **PowerOne ACCU plus Size 312 Rechargeable Hearing Aid Batteries**

- Fast chargeable batteries
- Excellent reliability and quality
- Ecologically sound
- Do not contain any heavy metals like mercury, cadmium or lead
- Voltage 1.2v

Fig 3.5: PowerOne ACCU plus Size 312 rechargeable hearing aid batteries[9]

PowerOne Accu Plus size 10 Hearing Aid Pen Charger (as shown in the figure3.6) :

- Convenient and elegant pen charger charges Accu Plus size 10 batteries.
- Average charging time of five hours.
- Original parts from PowerOne.
- Cost $35.00

Fig 3.6: PowerOne Accu Plus size 10 hearing aid pen charger[9]

The Battery will be used in this project:

3V MS412FE (Tiny Rechargeable Battery Coin Cell Button with Tabs)

- High operational voltage range of 2V to 3.3V.
- Tiny Rechargeable batteries have a Capacity of 1.0mAh.
- Stable capacity characteristics even after the battery is over discharged down to 0.0V.
- Very long charge/discharge cycle life.
- Dimensions are 4.8mm x 1.2mm (0.07 grams).

Charger by using PV cell charges (3V MS412FE) less cost than other charger in the market.

3.9 Factors affects on hearing aid battery life:

Statistics show that, in most of the cases, the reasons for a short running time are not necessarily production faults, but rather[10]:

- Environmental influences (e.g. humidity, temperature).
- Personal hearing habits have changed (longer period of use per day, higher noise level, new features of the hearing aid are being used).
- The hearing aid was in use longer than usual (e.g. night at the theater).
- Improper handling can also reduce the running time of the hearing aid battery
- The battery tab is removed and activation period as too short.

3.9.1 Environmental Influences:

- **Humidity**

As humidity is reduced batteries may dry out reducing the battery life. This can be an issue if you are indoors during winter months in northern climates, using wood burning stoves to heat homes, and keeping batteries in dry aid kits in an already dry environment.

- **Temperature**

As temperature is reduced, hearing aid battery voltage is lowered, which reduces battery life.

- **Altitude**

As altitude increases the percentage of oxygen in the air is reduced, lowering the hearing aid battery voltage. This can cause the battery to reach the endpoint earlier.

- **Personal Environment**

The noise around the patient can affect battery life.

3.10 Solar cells principle of operation:

Photovoltaic modules, commonly called solar modules, are the key components used to convert sunlight into electricity. Solar modules are made of semiconductors that are very similar to those used to create integrated circuits for electronic equipment. The most common type of semiconductor currently in use is made of silicon crystal. Silicon crystals are laminated into n-type and p-type layers, stacked on top of each other. Light striking the crystals induces the “photovoltaic effect”, which generates electricity. The electricity produced is called direct current (DC) and can be used immediately or stored in a battery. For systems installed on homes served by a utility grid, a device called an inverter changes the electricity into alternating current (AC), the standard power used in residential homes. See Fig 3.10[11]

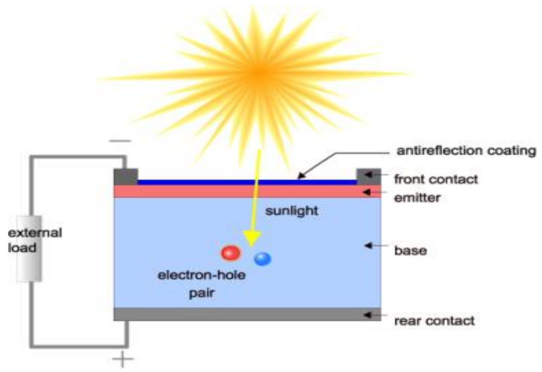


Fig. 3.7: Solar cells principle of operation[10]

3.11 Equipment are required for solar power system to work:

1. **Solar Panel:**

Converts sunlight into DC electricity . Solid panels are more rugged and produce more power than the flexible ones but are not be as portable.

2. **Charge Controller:**

For smaller systems, a charge controller is not necessary, but the relatively inexpensive cost more than justifies the added performance and protection. These units will automatically disconnect the battery from the solar panel once the battery is fully charged, charge controller only if the battery is very large relative to the solar panel array.

Make sure that the controller can handle more than the peak amount of current from the solar panel. If more than one panel is used, ensure that it can handle the total amount of current from all of the solar cells put together.

3. **Inverter:**

The DC voltage of the battery is 12 V but most household appliances run at 120 V AC. An inexpensive inverter , can be used to make the stored energy in the battery usable to your household devices. The current rating of the device should be enough to accommodate your load. Look for one with the amount of sockets you will need.

4. **Batteries:**

Store energy gathered during good times to be able to use it during the bad. Many possible battery technologies, it is the familiar lead-acid battery that continues workhorse of PV systems. In addition to energy storage, batteries provide several other important energy service for PV systems , including the ability to provide surges of current that are much higher than the instantaneous current available from the array.

Competitors to conventional lead-acid batteries include nickel-cadmium, nickel-metal hydride , lithium-ion, lithium-polymer, and nickel-zinc technologies[12].

3.12 Advantage of solar electricity generation:

- Consumes no fuel, no greenhouse gases.
- No pollution.
- No moving parts, little or no maintenance.
- Sunlight is plentiful & inexhaustible.
- Considerably cheaper than electricity.
- Great promise for solving global warming and fossil fuel depletion problems.

Chapter 4

Design hearing aid and charger

4.1 Design principle:

This chapter describes different steps for designing complete circuit of hearing aids with suitable charging circuit to recharge the battery that is needed in operating of hearing aid .

The following block diagram shows different stages that are needed for design of hearing aids.

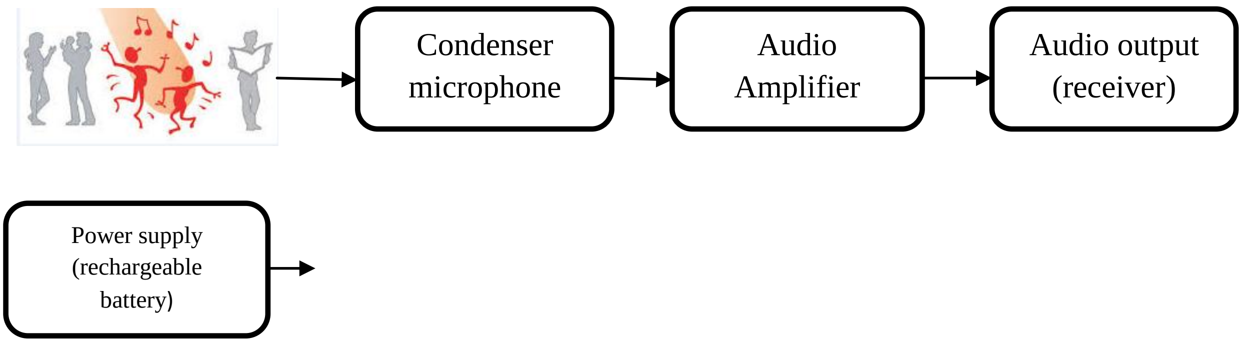


Fig. 4.1: Block diagram of hearing aid

4.2 system components:

4.2.1 condenser microphone:

Condenser microphone is a transducer device which converts audible sounds into voltage signal.

Different types of microphone:

1. **Directional Microphones:**
- Reduce the loudness of sounds and noise coming from behind.
- Help the hearing aid user hear speech that is coming from the front. This can be helpful when listening in noise

2. **Dynamic Microphones:**
- Construction is simple and comparatively sturdy.
- No power supply is required.

- Relatively inexpensive.
- Uniformity of response to different frequencies does not match that of the ribbon or condenser microphones.
- Convert sound to current quantity.
- Large in size.

3. **Ribbon microphone:**
- Omnidirectional , meaning that they pick up sounds equally well from either side of the microphone.
- Flatter response at high frequencies
- Expensive.
- Convert sound to voltage quantity.
- Large in size.

4. **Condenser microphones:**
- Good sensitivity at all frequencies.
- Power supply is required.
- Vulnerable to structural vibration and humidity.
- Convert sound to voltage quantity.
- Middle in cost .

The transducer used in this project is the condenser type microphone.

4.2.1.1 Condenser Microphones principle of operation:

Condenser mean capacitor, capacitor has two plates with a voltage between them. In the condenser mic. , one of these plates is made of very light material and acts as the diaphragm. The diaphragm vibrates when struck by sound waves, changing the distance between the two plates and therefore changing the capacitance. [13].

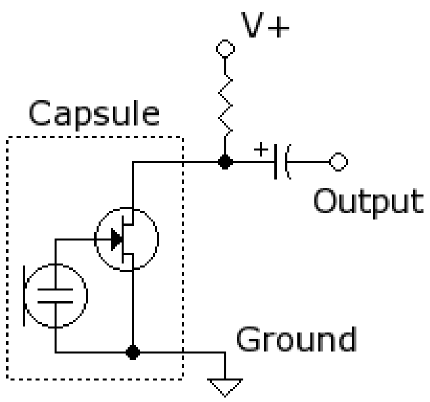


Fig. 4.2: Electrical equivalent circuit of condenser microphone[14]

the choose type is electret condenser microphone (model **MAX9814**) that specify:

- **Sensitivity:**

The ratio of the analog output voltage or digital output value to the input pressure, is a key specification of any microphone[15], For an analog microphone, sensitivity, in linear units of mV/Pa (-44dB)

- **Output impedance:**

The microphone impedance is usually made quite low to allow a reasonable current to flow and the amplifier impedance is made large enough for that current to develop a reasonable voltage across its input.

- **Frequency Response:**

Frequency range (20Hz-20KHz), from the lower to the higher range.

Directivity (Omnidirectional):

Omnidirectional microphones are microphones that pick up sound with equal gain from all sides or directions of the microphone. This means that whether a user speaks into the microphone from the front, back, left or right side, the microphone will record the signals all with equal gain,(like human ear).

- **Weight:**

Use these microphone that it weight (0.8g). **See appendix B**

4.2.1.2 Calculations:

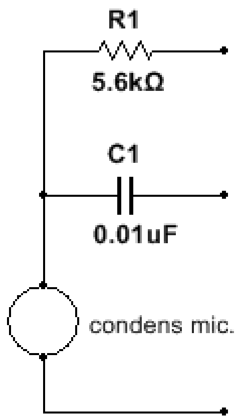


Fig. 4.3: Condencer microphone circuit

$V_{cc} = I_{dc} \times (RT)$....................(1)

RT:effective series resistance of microphone

$3.6 = 0.5 \times 10^{-3} \times (RT)$

$RT = 6K\Omega$

The microphone used has a DC resistance of 600 Ω , so :

$RT = R_1 + micDC_{resistance}$....................(2)

$R_1 = RT - micDC_{resistance}$

$R_1 = 6K\Omega - 600\Omega$

$R_1 = 5.4K\Omega$

A standard 5.6K Ω resistor has been selected.

The coupling capacitor C1 should have a reactance (X c) of few kilo-ohms at the main audible frequency of about 20Hz

coupling capacitor to remove dc and frequency lower than 20kHz, so that use minimum frequency 20kHz. Thus 1600Ω is chosen to be used.

$$C_1 = \frac{1}{2\pi \times f \times x_C} \text{....................(4)}$$

$$C_1 = \frac{1}{2\pi \times 20 \times 1600}$$

$$C_1 = 0.01\mu f$$

Capacitors C1 are called coupling capacitor. Their functions are to block any DC components in the input and outputs of the pre-amplifier to prevent upsetting the DC bias of the pre-amplifier.

4.2.2 Medium Power Amplifier Stage:

The medium power amplifier amplifies the output of the pre-amplifier. It comprises of the (TDA2822M IC) that amplify to an audible level, and those external components from datasheet needed to make the IC function properly. See appendix B.

Supply Voltage rang (1.8-15) V

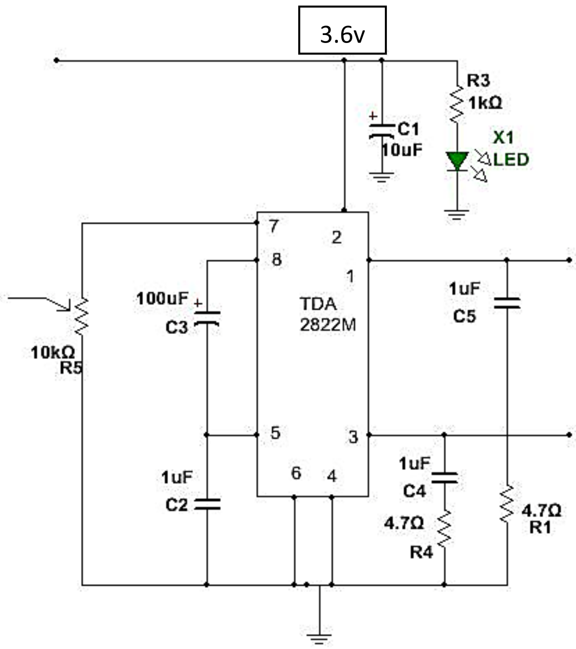


Fig. 4.4: Medium power amplifier circuit

4.2.3 Output Unit:

A 32 ohms earphone is used in the output unit of this project as recommended by the manufacturers of the TDA2822M IC. According to the IC's datasheet, this 32 ohms earphone will produce an output of about 1.3 watts.

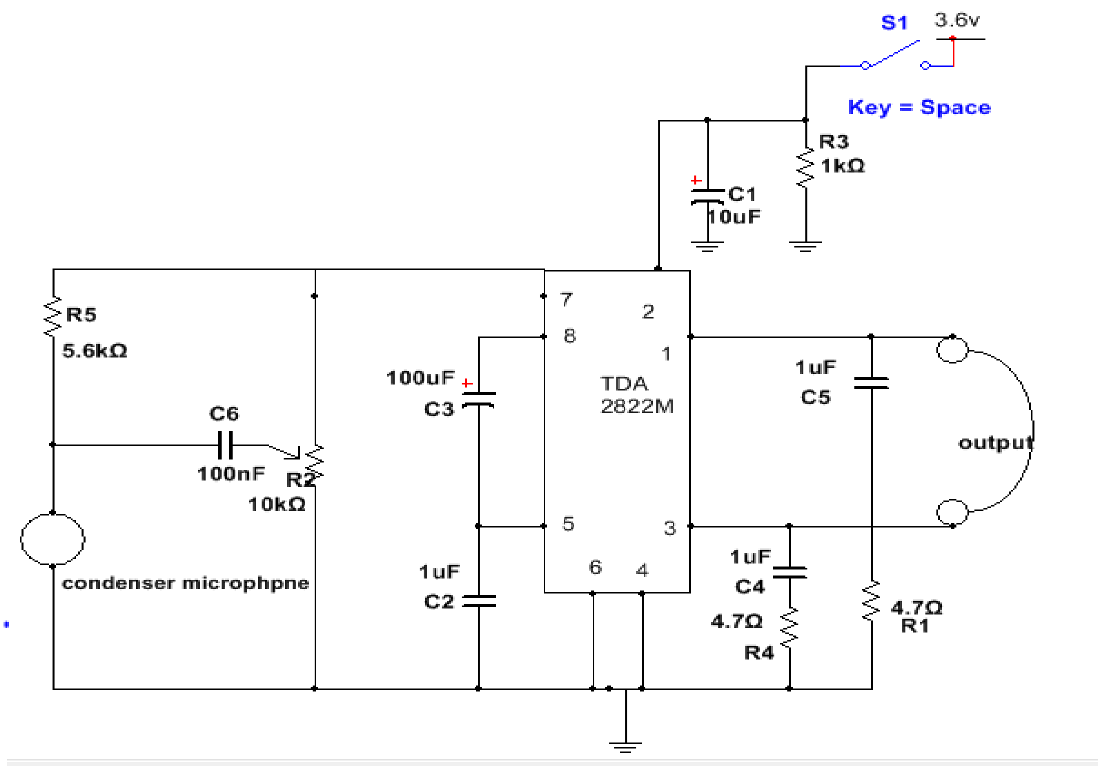


Fig. 4.5: Schematic circuit of hearing aid

4.3 Power supply unit:

The internal circuit of hearing aid device designed in this project consumes a very small amount of typical power within the range of 10 mW. The voltage requirement of every major component is within the range of 1.8 volts and 15 volts. Therefore, for portability, a 3.6V DC rechargeable battery is used to power the circuit.

4.3.1 Design photovoltaic charger:

The following block diagram show different parts that are needed for design photovoltaic charger.

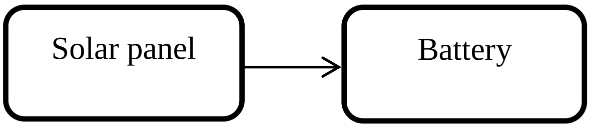


Fig.4.6: Block diagram of PV charger

4.3.2Equivalent Circuit for a Photovoltaic Cell:

A simple equivalent circuit model for a photovoltaic cell consists of a real diode in parallel with an ideal current source as shown in Fig.4.8. The ideal current source delivers current in proportion to the solar flux to which it is exposed.

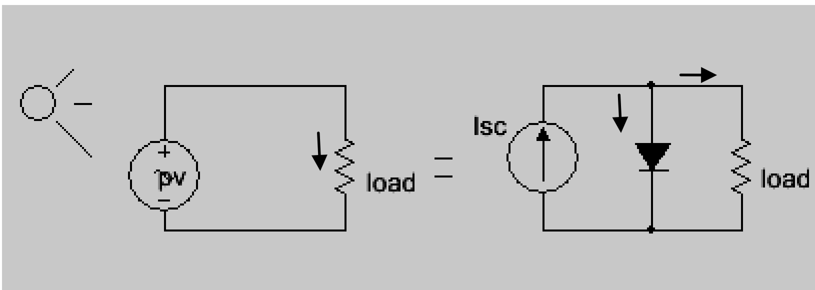


Fig.4.7: Simple equivalent circuit for a photovoltaic cell[12]

Important parameter for the actual PV to work:

1. The current that flows when the terminals are shorted together (the short-circuit current, Isc).
2. The voltage across the terminals when the leads are left open (the open-circuit voltage, Voc).

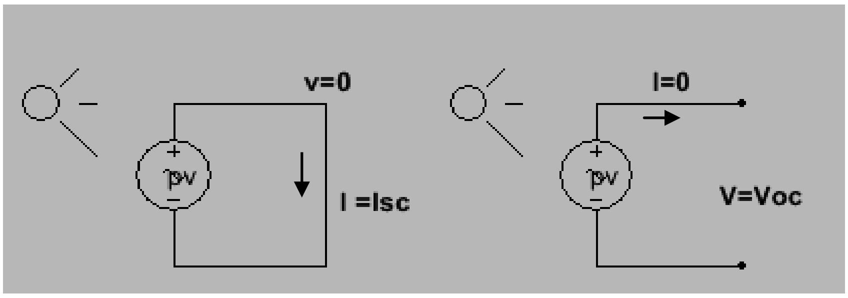


Fig.4.8: Two important parameters for photovoltaic[12]

When the leads of the equivalent circuit for the PV cell are shorted together, no current flows in the (real) diode since Vd = 0, so all of the current from the ideal source flows through the shorted leads. Since that short-circuit current must equal Isc, the magnitude of the ideal current source itself must be equal to Isc. While the leads of the equivalent circuit for the PV cell are opened the current (Isc=0), since Voc = volt of PV cell, show in fig. 4.9.

Calculations:

PV module: converts sunlight into DC electricity.

We choose module give (4v and 50mA) for recharge battery (3.3V and 1mA), **see appendix B**.

Fig.4.9: (4.0V, 50mA) solar cell

Potentiometer: using potentiometer for control to the current flow from PV cell to the battery.

Load: Is electrical appliances that connected to solar PV system (batteries).

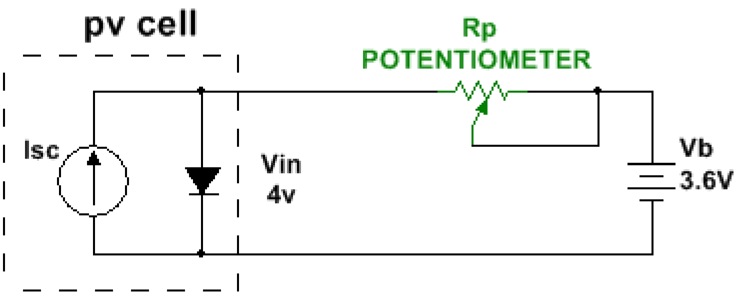


Fig.4.10: Schematic circuit of charger

$$R_L = \frac{V_L}{I_L} \text{....................(15)}$$

$$R_L = \frac{3.6V\ -\ 4V}{0.2mA}$$

$$R_L = 2K\Omega$$

$$R_L = R_{Battery} + R_p \text{....................(16)}$$

$$2K\Omega = 500m\Omega + R_p$$

$$R_p = 1500K\Omega$$

Chapter 5

Result And Analysis

In this chapter we discuss the construction and the result of the project on the final shape of the design of the hearing aids .

5.1 Construction of the design:

The initial implementation of the hearing aid was on bread board as the following figure .

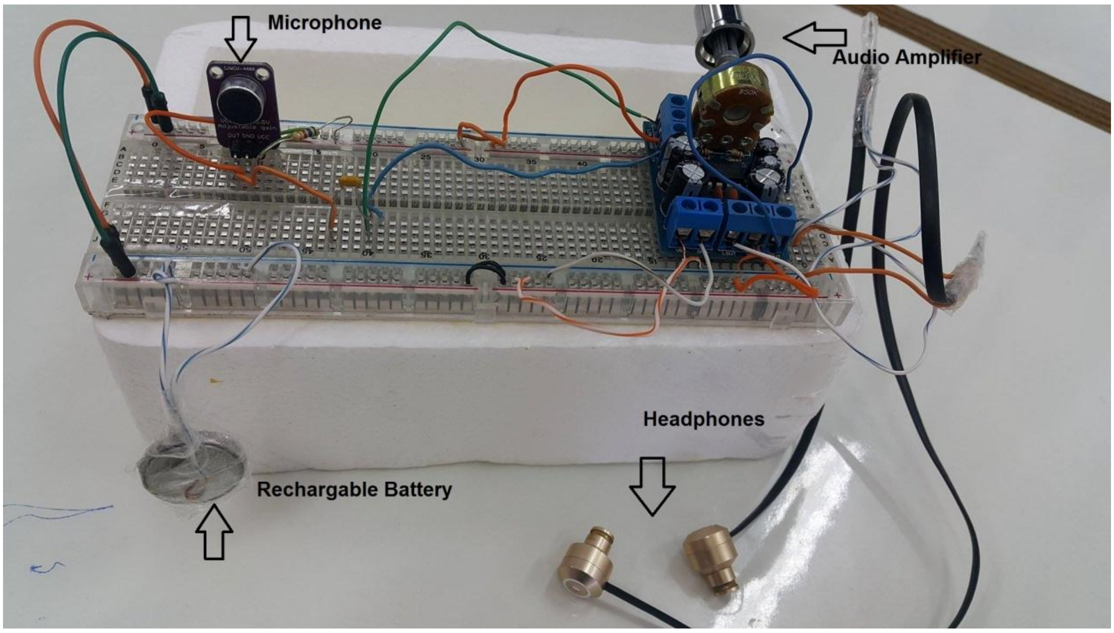


Fig.5.1 :The hearing aid on bread board

Then we implement the charger , as the following figure 5.2.

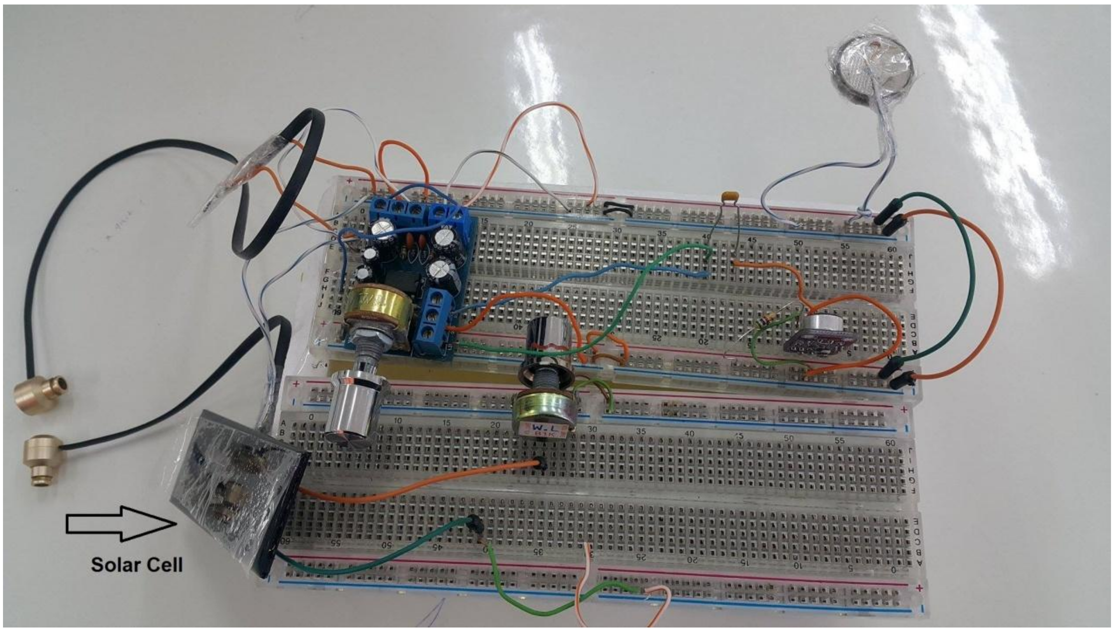


Fig.5.2 : Hearing aid with charger

The final shape of the hearing aid was in the form of hat with all component inside it which isolated from the head of the patient as shown in the following figure 5.3.

Fig.5.3 : Final design of hearing aid with charger

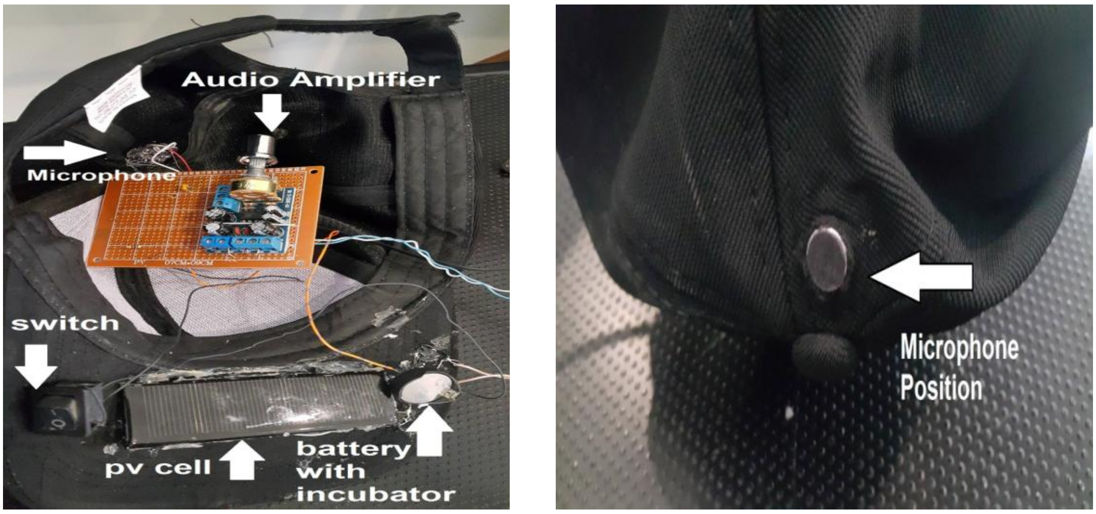


Fig.5.4: Internal component in final design

5.2 Results and analysis:

By using Audiometer device was tested on 19 people with various degrees of hearing , these people was checked their hearing degree as shown as table 5.1.

After the construction of the amplifier stage, it was subjected to tests to determine its frequency response which indicates the range of frequencies for which the appliance is suitable. To do this, a signal from microphone was used to feed signals of fixed amplitude but varying frequency to the amplifier. The gain at each signal variation was found by using a double beam oscilloscope to measure and compare the output and input signals.

For more details about the results see appendix C.

Table 5.1 : Audiometer result for student

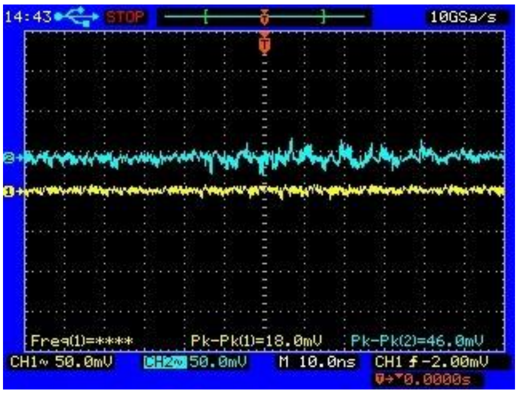
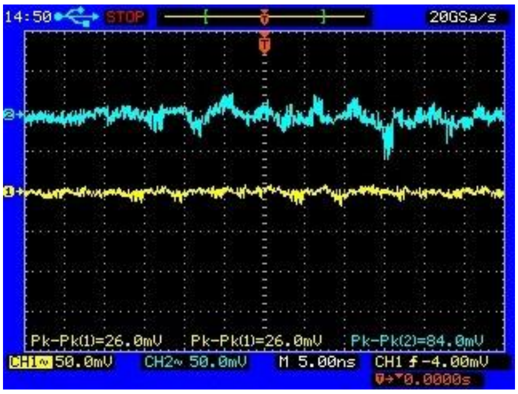
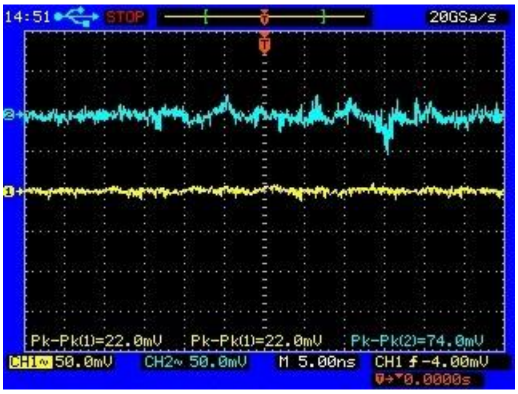
Student number	**Left ear (Hz , dB)**	**Right ear (Hz , dB)**	**solution**
1	Problem {250,40} , {500,40}	Problem{250,35}{500,30} {1500,30} {3000,30}	**All frequencies was heard by using the hearing aid**
2	Problem{250,40}{500,40} {1000,30} {8000,25}	Problem {250,35} {500,35}	
3	Problem {250,25} {500,30}	Problem {500,30 }	
4	Problem{250,35}{500,25} {1500,25}	Problem {250,25}	
5	Problem {500,25} {1000,25}	No problem	
6	Problem {250,25} {1000,25} {2000,25} {8000,30}	Problem{250,30}{500,35} {2000,25} {6000,30}	
7	Problem {250,30} {500,30} {1000,25}	Problem{250,30} {500,30} {1000,30}	
8	Problem {250,35} {500,35} {1000,25}{1500,25} {4000,25}	Problem {250,25} {4000,25}	
9	Problem {250,25} {500,25}	No problem	

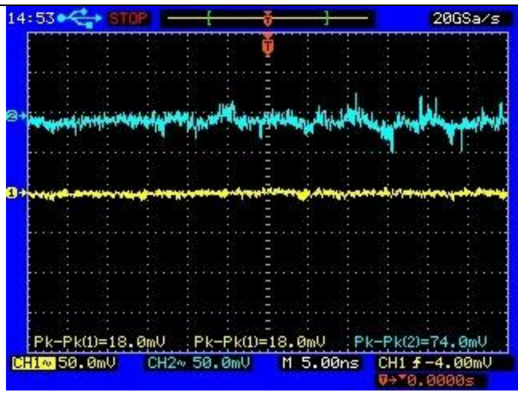
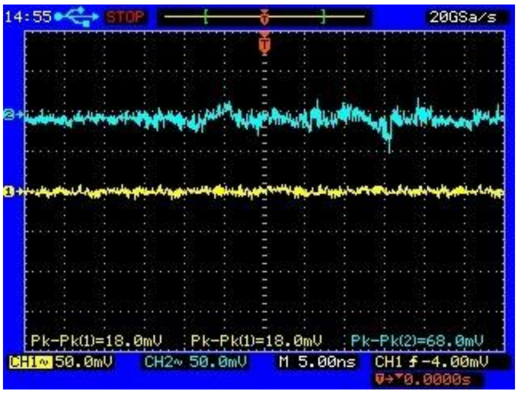
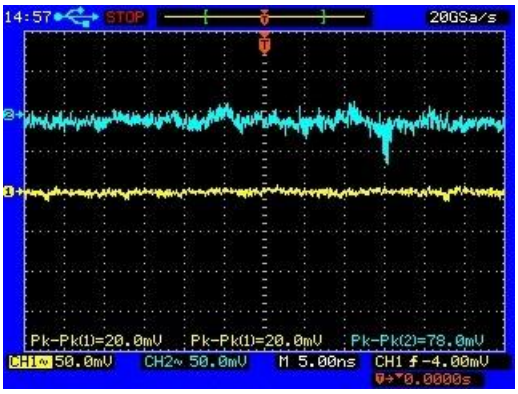
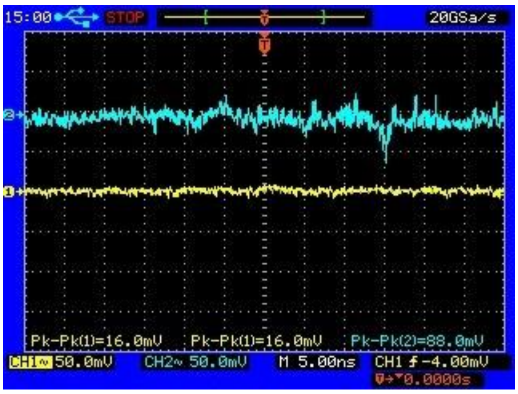
10	Problem {250,35} {500, 25} {3000,30}	Problem {250,35} {500, 25} {3000,35} {4000,30}	**All frequencis was heard by using the hearing aid**
11	Problem {250,25} {500,30}	Problem {250,30} {500,25}	
12	Problem {250,40} {500,30}	Problem {250,25} {500,35}	
13	Problem {250,30} {500,30}	Problem {250,30} {500,30}	
14	Problem {250,25} {500 , 45} {1000,35} {1500,35} {2000,35} {3000,35} {6000,35}	Problem {250,40} {500 , 30} {1500,25} {2000,25} {8000,25}	
15	Problem {250,40} {500, 40 } {1000,25} {1500,25} {2000,25}	Problem{250,40} {500 , 45} {1000,30} {1500,30}	
16	Problem {250,35} {500, 35 } {1000,30} {2000,25} {3000,25} {4000,25}	Problem {250,30} {500,25}	
17	Problem {250,35} {500 , 35} {1000,25} {1500,25}	Problem {250,35} {500 , 40} {1000,25} {8000,25}	
18	Problem {8000,30}	No problem	
19	Problem {1000,25}	No problem	

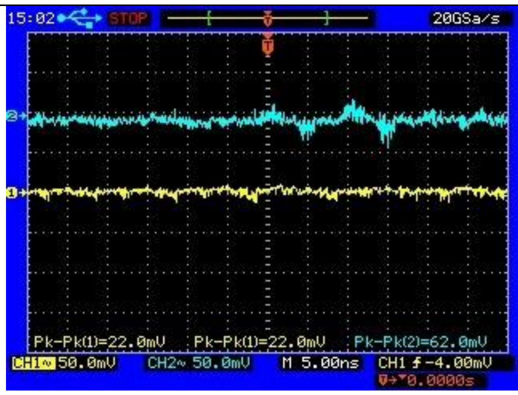
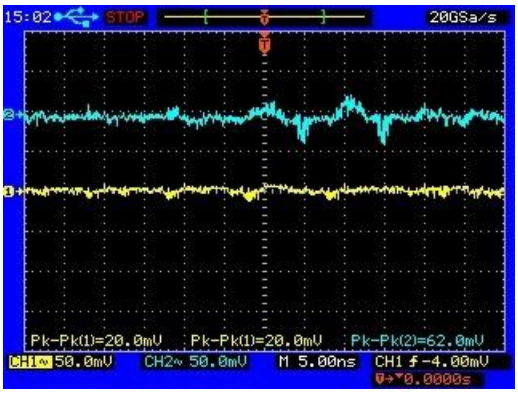
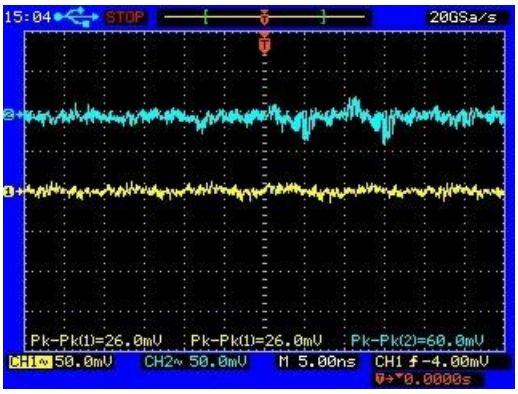
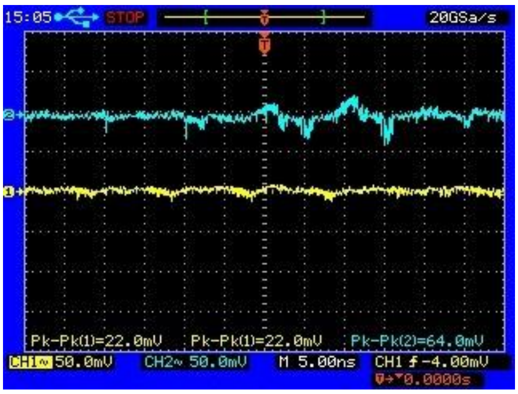
To conduct the test a tape recorder was placed at a distance from the patient. With the headphone placed on the ears. The hearing aid was then removed to see if they could still hear the sound. This process was repeated severally using different sounds of different frequencies and magnitude.

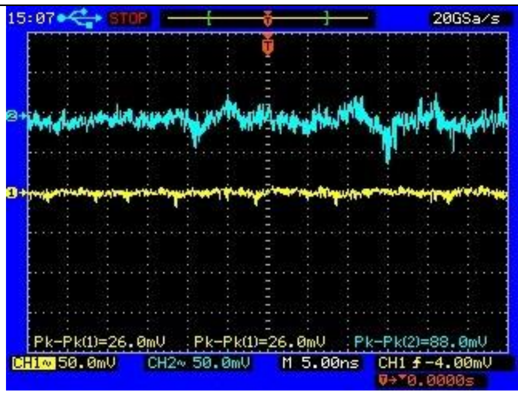
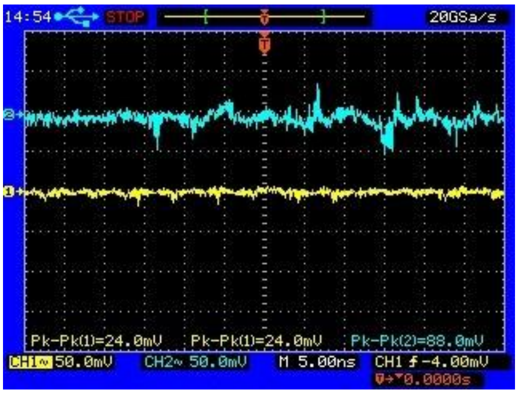
The output from the design can be shown in two forms either by using oscilloscope to show the amplification of the input signal (sound) or by using headphones (output as a sound) , the following table show the output from oscilloscope (table5.2).

Table 5.2: Results from oscilloscope

Types of sound	Magnitude of gain	Result on oscilloscope
Normal dialogue	Input voltage = 18mv output voltage =46mv Gain $=\frac{\text{output voltage}}{\text{input voltage}}$ $=\frac{46\text{mv}}{18\text{mv}}$ =2.5	
Quran sound	Input voltage = 26mv output voltage =84mv Gain $=\frac{\text{output voltage}}{\text{input voltage}}$ $=\frac{84}{26}$ =3.2	
Quran sound **(Another reader)**	Input voltage = 22mv output voltage =74mv Gain $=\frac{output\ voltage}{input\ voltage}$ $=\frac{74}{22}$ = 3.36	

Music tone	Input voltage = 24mv output voltage =88mv Gain $=\frac{output\ voltage}{input\ voltage}$ $= \frac{88}{24}$ =3.6	
Dialogue with music	Input voltage = 18mv output voltage =68mv Gain $=\frac{output\ voltage}{input\ voltage}$ $= \frac{68}{18}$ =4.7	
French speaker	Input voltage = 20mv output voltage =78mv Gain $=\frac{output\ voltage}{input\ voltage}$ $= \frac{78}{20}$ =3.9	
Maher Almaikuli Quran sound	Input voltage = 16mv output voltage =88mv Gain $=\frac{output\ voltage}{input\ voltage}$ $= \frac{88}{16}$ =5.5	

Italian sound	Input voltage = 22mv output voltage =62mv Gain =$\frac{output\ voltage}{input\ voltage}$ $\frac{62}{22}$ =2.8	
Athan sound **صوت الآذان**	Input voltage = 20mv output voltage =62mv Gain =$\frac{output\ voltage}{input\ voltage}$ $= \frac{62}{20}$ =3.1	
Presenter	Input voltage = 26mv output voltage =60mv Gain =$\frac{output\ voltage}{input\ voltage}$ $= \frac{60}{26}$ =2.3	
Sound of child laugh	Input voltage = 22mv output voltage =64mv Gain =$\frac{output\ voltage}{input\ voltage}$ $= \frac{64}{22}$ =2.9	

Saddam Hussein sound	Input voltage = 26mv output voltage =88mv Gain $=\frac{output\ voltage}{input\ voltage}$ $=\frac{88}{26}$ =3.3	
English speaker	Input voltage = 24mv output voltage =88mv Gain $=\frac{output\ voltage}{input\ voltage}$ $=\frac{88}{24}$ =3.6	

as shown from the previous table we conclude that the system of hearing aids can be distinguish between different sounds .

5.3 Discussion:

The amplifier is useful for the purpose for which it is being designed. On the test of the final product on people with hearing impairment the result showed that there was significant improvement in their hearing ability in all the cases. The volume control was also found to be very useful as the user is able to control the level of signal he listens to. Signals that are two loud may course further damage to the ears.

It was realized that hearing aid device is in capable of truly correcting a hearing loss, but an aid to make sound more accessible. In situations where the primary auditory cortex does not receive regular stimulation, this part of the brain losses cells which process sound. As cell losses increases, the degree of hearing loss increases. When the loss of cell is not much, hearing aid can be of enormous importance.

5.4 Conclusion:

The aim of this project was to design a system that pre-amplify an acoustic signal Picked up by a condenser microphone. The pre-amplified signal is then further amplified before being converted to sound by another transducer (speaker). The designed and constructed circuit was tested on different set of people with different degree of hearing problem. The final test showed that the device could prove very useful for people with partial hearing problems.

Chapter 6

Future Work

- Recharging the battery for hearing aid wireless.

- Connect hearing aid with phone by using special application to make volume control.

- Use serves mounted component to become hearing aid with charger lighter on the patient head.

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Appendix A

Appendix B

Appendix c

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