DESIGN AND CONSTRUCTION OF A HEARING AID

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DEDICATION

This project is dedicated to God almighty, the creator of heaven and earth.

DECLARATION

I, Wabari Johnson, declare that this was done by me and has never been presented elsewhere for the award of a degree to the best of my knowledge. I also relinquish the copyrights of this project to the Federal University of Technology, Minna.

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ABSTRACT

In the world we live today, there is a great increase in the number of hearing impaired persons due to noise pollution in urban areas, over exposure to industrial noise, infections, deformities at childbirth and ageing. As the need to correct this problem increased, it has led to the development of electronics hearing aids which are devices that amplify sound signals, and boost sound level to compensate for defects in the eardrum structure of the impaired ear. The various units consist of the power unit which is made up of 9volt battery. The preamplifier stage which is made up of a micro power operational amplifier LM358 that amplifies the picked up voice signal from the input transducer (microphone) which then converts the signal (sound) into electric signals. The electric signals is fed into the power amplifier stage (LM386), which amplifies the signals and the amplified signal is converted back to sound at the output stage (earphone) i.e. the output transducer. The implementation of the entire work was achieved with the real-time implementation of the constructed and tested circuit.

TABLE OF CONTENTS

CHAPTER THREE

Theoretical Background/Design and Implementation

CHAPTER FOUR

CHAPTER FIVE

LIST OF FIGURES

LIST OF TABLES

CHAPTER 0NE

INTRODUCTION

1.1 INTRODUCTION

The use of explosive by civil engineers to break down rocks, hills or mountains when constructing roads, bridges across them, exposure to loud music played in concerts, and loud music blasting from loud speakers, loud noises from the horns of motor vehicles, noises from railway stations and airports, the use of heavy machines in operations in factories, ageing, birth defects, the actions of viruses, bacteria and other disease has increase the rate of hearing impairment in the society. Due to this, the designing and construction of hearing aid which is the device used to aid hearing by those affected.

Hearing aid is an electronic device which converts sound signals to electrical signals and back to sound signal. However, it is an electro-acoustic body worm device or apparatus which is typically fits in or behind the wearers' ear and is design to amplify and modulate sounds. The device works on the principle of amplification of sound.

1.2 AIMS AND OBJECTIVES

The aims and objectives of this project are as follows;

1. To design and construct a device which would help to alleviate the suffering of people with partial hearing disabilities in our society.

2. To ensure that the electronics components used in the construction of this device can be easily sourced and available locally at an affordable price for the poor masses suffering from hearing disabilities.

3. To ease learning for children and adults along- side their mates with proper hearing abilities in convectional schools, thereby reducing the burden of expensive school fees paid by parent of children with hearing disabilities in special school made for them.

4. To ensure social inclusion for those with hearing problems, and also reduce the stigmatization always inflicts in them.

1.3 METHODOLOGY

In order to meet up with the aims and objectives if this project "design and construction of a hearing aid", a condenser microphone with a high sensitivity was selected among many. Similarly, in the amplifier stage, an LM358, a dual operational amplifier which has the capacity of amplifying low level millivolt-range microphone signals was also selected. Besides, LM386; a power amplifier which is capable of amplifying the signal from the pre-amplifier stage was chosen because it meets the system requirement such as a power gain of 46 dB, high power output, high sensitivity, and high efficiency. A volume control was integrated to help in a great deal to regulate the variation of signal before it is fed into the power amplifier. A 9 volt battery was used because it has the best trade off in terms of size and lifespan.

In the construction of the device, a high sensitive condenser microphone was connected to the small signal amplifier (LM358), configured in the inverting mode to reduce noise pickups.

1.4 SCOPE OF WORK

The main focus of this project is to provide comfort to those having partial hearing problems. The frequency range at which the device is designed to operate is 20HZ and 20000HZ which is the range at which human beings can hear.

1.5 SOURCE OF MATERIALS

The whole electronic components used in the design and construction of this device were all sourced and gotten in Minna, Niger State. This was done so as to make the final product of the project easily affordable. Other sources of informations include the internet, the school library, past project report, friends and some experts in the field.

1.6 PROJECT OUTLINE

Chapter one; this include introduction, aims and objectives, methodology, scope of work and sources of materials.

Chapter two; this includes literature review and historical background of the device.

Chapter three; this includes the theoretical background and design of the circuit.

Chapter four; this includes the testing of the device, result and discussion of the results obtained.

Chapter five; this chapter includes the summary of the project and recommendation.

CHAPTER TWO

LITERATURE REVIEWS/HISTORICAL BACKGROUND

2.0 INTRODUCTION

Since the advent of medicine, especially in the study of otology, early scientists and Otologist had strived to obtain a solution for the problems suffered by individuals with hearing impairment. They strive to obtain solution to this problems led to the invention of the earliest hearing aid which were in form of ear trumpets invented sometimes in the 17^{th} century. The trumpets were made of long horns with a large opening at one end, and smaller at the other end, which was placed in the ear. The trumpet work under the principle that; sound pressure waves entering the large end re-condensed into smaller volumes, hereby increasing the audible sound pressure. Different types of hearing aids are also explained in this chapter.

2.1 HISTORICAL BACKGROUND

. With the invention of the telephone by Alexander Graham Bell in 1876, came the next phase of development of the hearing aid. This type of hearing aids were referred to as carbon aids, and worked on the principle that sound waves were converted to electrical waves, and the back to sound waves. However, they had some major drawbacks in the sense that they used very large batteries and could only help people with moderate hearing loss.

By the 1920s a more sophisticated telephone type of hearing aids were developed which looked modern days hearing aids; with a microphone, electrical circuit, diaphragm and battery. But this type of hearing aids used vacuum tube technology. It was popularly used through the 1930s. With the advent of transistor in 1948, hearing aids of greatly reduced sizes and weights were invented. In the year 1969 the first direction microphones was developed and was incorporated into hearing aids, thereby leading to a more natural sounding hearing aids[13].

By the mid 70s, integrated circuits were applied to the hearing aids to help users distinguish between speech and background noises, also the use of the latest tiny batteries allowed for the In-the-canal (ITC) hearing aids to be developed. Facilitated by the introduction of lithium batteries and the advent of digital signal processing (DSP) in the 1980s, hearing aids were beginning to return into mini computers. By this period also ideal of surgical implants to the cochlea was widely anticipated as cures for deafness were the use of hearing aids could not do much.

By the 90s,hearing aid that could boast of two channel sounds automatic volume control , or remote control for the smallest of ITC(in-the anal) instruments by now when worn were totally indivisible to all. By this time also, fully digital audio processor were developed, global researchers took it upon themselves to produce a working hearing aid system which they named adaptive speech alignment, which could boast of multi tone banding, and dual processing, one for recognizing vowels and consonants respectively[13,15].

Hearing aids of present time have self assessment of listening comfort, and memory cards for the remote controls. Micro-magnets implanted next to the eardrum, which will never need to be replaced is being foreseen as a major development in the hearing aids of the future. The development of the electronic hearing aids was described as the biggest advancement ever made by science and engineering technology in helping deaf people.

There are many types of hearing aids, which vary in size, power and circuitry. Among the different sizes and models are:

Behind the ear (BTE)

In the ear (ITE)

In the canal (ITC)

Completely in the canal (CIC)

Bone Anchored Hearing Aids (BAHA)

Body worn aids

BTE (behind-the-ear)

The BTE hearing aids are pre-made, not custom made; this is one reason for the lower cost. They are used by children and persons with severe to profound hearing losses. They connect to an ear mold which fits in the ear. Because of the rate a child's ears grow they are more economical than custom shelled hearing aids because only the ear mold needs to be replaced[11,12].

Key Benefits

- Most powerful of the hearing aid styles for severe to profound losses
- Good for children because ear molds can be changed more economically than the hearing aid shells
- Can more easily be used with auditory trainer or loop system

- Although the hearing aid mold can become plugged with ear wax and drainage, the hearing aid is away from the ear canal and is protected.

ITE (in-the-ear)

The ITE hearing aids are the largest of the custom made hearing aids. They can be fit in a wide range of patients, from mild to severe hearing losses. Because of the size they are much easier to build than the smaller custom hearing aids[11,12].

Key Benefits

- Inexpensive
- Microphone closer to ear level than BTE
- Can fit a wide range of patients

Key Disadvantages

- Is susceptible to damage by ear wax and ear drainage.
- Not as cosmetically pleasing

ITC (in-the-canal)

The ITC hearing aids are the next smallest custom made hearing aids. They are visible, however smaller than the ITE hearing aids. They are more difficult to build because they are smaller and the placement of the electronics takes more time[11,12].

Key Benefits

- Microphone is even closer to ear level than BTE and ITE
- More cosmetically appealing
- Fits hearing losses in the mild to moderate range

Key Disadvantages

- Tend to be expensive
- Changing the battery can be difficult since battery and battery compartment is small
- Is susceptible to damage by ear wax and ear drainage.

CIC (completely-in-the-canal)

CIC hearing aids have many benefits besides being discrete. They are the smallest of the custom made hearing aids. The electronics in the CIC hearing aids are miniaturized to the smallest possible size and carefully placed by hand in the tiny shell. They are much more difficult to make than the other custom made hearing aids[12].

Key Benefits

- Increased Gain
- Increased Output
- Reduced Distortion
- Reduction of the Occlusion Effect

- Reduction of Acoustic Feedback
- Ease of Removal
- Comfort
- Security of Fit
- Telephone Use
- Listening with Headsets
- Improved Localization
- Reduced Wind Noise
- Cosmetic Appeal

Key Disadvantages

- Tend to be the most expensive
- Changing the battery can be difficult since battery and battery compartment is small
- Usually, does not have a manual volume control, often this is a small screw which requires a small screwdriver to adjust.
- Of all the hearing aid types, is most susceptible to damage by ear wax and ear drainage.

Bone Anchored Hearing Aids (BAHA): This auditory prosthetic which can be surgically implanted, the BAHA uses the skull as a pathway for sound to travel to the inner ear. For people with conductive hearing loss, it bypasses the external auditory canal and middle ear, stimulating the functioning cochlea. For people with unilateral hearing loss, it uses the skull to conduct the sound from the deaf side to the side of the functioning cochlea.

Body worn aids: This was the first types of hearing aid invented by Harvey Fetcher while working in at Bell laboratories; thanks to development in technology they are now rarely used. This consists of a case containing the components amplification and an ear mold connected to the case by a cord. The case is about the size of a pack of playing cards and is worn in the pocket or on a belt. Because of large size, body worn aids are capable of large amount of amplification and were once used for profound hearing loss[11,12].

CHAPTER THREE

DESIGN AND IMPLEMENTATION

3.0 INTRODUCTION

This chapter tells the design and implementation of the circuit. The theoretical background of the circuit is been explained which tells how the device picks up signals and amplify the signals picked. Also the block diagram of the circuit is shown in this chapter and it is explained one after the other. The block diagram comprises the input stage which picks up the signals from the environment. A condenser microphone is used as the input in this circuit. The amplifying stage which amplifies the signal picked from the environment using LM358 and LM386 amplifiers. Also some capacitors were connected to the amplifiers to filter noise from the signals picked by the input. The output stage which is an earpiece is used in this circuit to send the amplified sound to the human ear. And the power supply stage which is basically a 9volts battery. Some calculations were made in the process of designing the circuit. These calculations are shown in this chapter

3.1 THEORETICAL BACKGROUND

Hearing aids are simple acoustic amplifying system. Hearing aids are made up of four basic parts which includes;

1 A microphone which picks up sounds and converts to the sound to electrical signal.

2 A 9volt battery which is used as the power source.

3 Amplifiers which is used to amplify the sound picked by the microphone.

4 An earphone to return the electrical signal into an acoustic one which is fed into the ear through an ear mould.

A typical block diagram of the hearing aid is shown below.

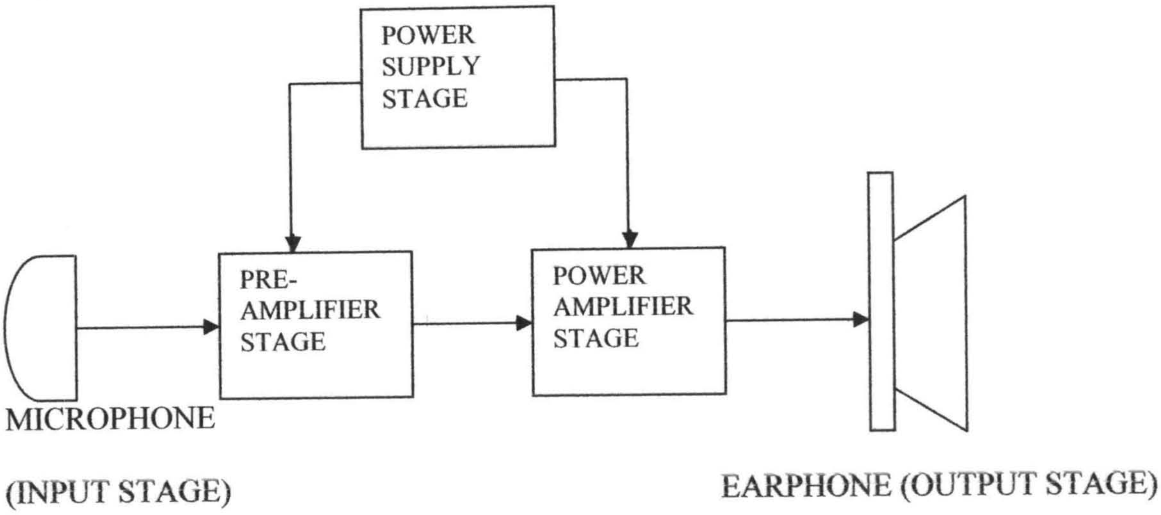

Fig. 3.1 Block diagram of a hearing aid.

3.1.1 THE INPUT STAGE

A microphone makes up the input stage of a typical hearing aid. Microphones are devices which acts as transducers to convert acoustic signals (sound waves) into electrical signals[10]. Microphones come in all shapes and sizes. When choosing a microphone for any particular application, the following features needed to be considered;

The frequency response on axis: The microphone should respond equally to sounds over the whole range of frequency range of interest. Thus in high quality system the graph of signal output voltage plotted against frequency for a constant acoustic level input over the range 20-20000Hz(the normal limit of human hearing) should be a straight line.

Directivity: Microphone directivity is its ability either to respond equally to sound arriving from all directions or to discriminate against sounds from particular direction.

Frequency response off-axis: Ideally any high quality microphone whatever its directivity pattern, should maintain the same frequency response at all angles; there is a need for polar pattern uniformity.

Sensitivity: The conversion efficiency of a microphone i.e. the output voltage produced by a given incident sound pressure level, should be as high as possible.

Self noise: The inherent noise level of a microphone and this include any built-in-amplifier should be as low as possible.

Distortion: For the waveform of the electrical signal to be a faithful representation of the original sound wave, on-linear distortion must be as low as possible. Such distortions are mainly associated with high signal levels and the onset of overload or saturation effects in the transducer mechanism [1].

The following are the types of microphones;

1. The moving-coil (dynamic) microphone
2. The ribbon microphone
3. The condenser microphone (capacitor or electrostatic)
4. The electrets microphone
5. The piezoelectric (crystal) microphone
6. The carbon (loose contact) microphone.

Microphones use diaphragms which respond to sound waves in the following ways: The magnitude of the change in air pressure on the diaphragm as in the case of carbon-granules and crystal microphones) has a direct effect on the electrical output. The difference between the pressure at closely situated points, i.e. pressure gradient (as in the case of a moving-coil, and ribbon microphones) may results in an electrical output. The microphone used in the construction of this hearing aid is the condenser microphone. The condenser microphone was chosen because of its high sensitivity, portability, and due to the fact that it could be made very small and rugged.

3.1.2 AMPLIFICATION STAGE

The main component of the amplification stage in a typical hearing aid is the audio amplifier. Audio amplifiers are electronic amplifiers that increase low audio signals (composed of frequencies between 20Hz to 20 kHz, which makes up the human hearing range) to a level high enough for driving a load speaker[10]. In this case an earphone which normally makes up the final stage of audio playback system. Certain stages precede the amplification stage. The following parameters are to be considered when designing an audio amplifier.

Frequency response of the amplifier: This is the measure of the system response to a signal of varying frequencies at the output with respect to constant amplitude. It is usually measured in decibels.

Gain of amplifier: This is defined as the mean ratio of the signal output of a system to the signal input of the same system. When measured in decibels (dB), power gain is given as;

$$Gain = 10 \log \left[\frac{P_{out}}{P_{in}}\right] \textbf{dB} \qquad (3.1)$$

Where p_{in} and p_{out} are input and output power respectively.

If voltage is used to calculate the gain of an amplifier, we obtain from the expression,

$$P = I^2 R \tag{3.2}$$

$$I = \frac{V}{R} \tag{3.3}$$

Substituting equation (3.3) into equation (3.2), we obtain;

$$P = \left[\frac{V}{R^2}^2\right] R \tag{3.4}$$

$$P = \frac{V^2}{R} \tag{3.5}$$

Substituting equation (3.4) into equation (3.1) we obtain;

$$Gain = 10 \log \left\{\frac{V_{out}^2}{R_{out}} \middle| \frac{V_{in}^2}{R_{in}}\right\} \tag{3.6}$$

Since input and output impedances are usually equal in most cases, equation (3.6) could be simplified as;

$$Gain = 10 \log[\frac{V_{out}}{V_{in}}]^2 \text{ dB} \tag{3.7}$$

Therefore,

$$Gain = 20 \log \left[\frac{V_{out}}{V_{in}}\right] \text{ dB} \tag{3.8}$$

Equation (3.8) is used to calculate gain in decibels only when both input and output impedances are equal.

Distortion of the amplifier: This is the alteration of the original shape to unwanted waveform by the amplifier. Distortion of audio systems could be corrected by using special filters known as equalizers[1].

3.1.3 OUTPUT STAGE

The output stage of a typical hearing aid system is made up of tiny loudspeakers known as earphone or headphones in some cases. The headphones act as transducers which convert the amplifier electrical signals from the audio amplifier, back to sound waves. The headphones have an advantage of not exciting room resonances and thus giving the listener a more accurate sense of the recorded acoustics[1]. There are different types of earphones and are classified based on their principle of operation. These include;

Moving iron earphones: This type of earphones lie on the use of a fine wire wound onto magnetic yoke held lose to stiff disc made of soft magnetic alloy such as stalloy. Permanent magnet is used to pull the thin disc towards the yoke with a constant force, and audio signal fed into the coil causes this force to vary with respect to the input. Moving iron earphones are very sensitive, needing hardly any power to drive them. They have very poor sound quality and are used in telephone receivers.

Moving coil earphones: Here is a coil of wire suspend in a radial magnetic field in an annular magnetic gap is connected to a small radiating cone. When alternating audio signals are applied to the coils, the coil vibrates axially with respect to the signals, thereby recreating an analogue form of the original wave shape. The cone then converts this into the corresponding fluctuations in air pressure with the listener then perceives as sound.

Electrodynamic/othodynamic earphones: These types of earphones are similar to the moving coil type, but in this case the coil is unwound and fixed to a thin light plastic diaphragm. The annular magnetic gap has been replaced by opposing bar magnets which cause the magnetic field to be squashed more or less parallel to the diaphragm. The coil in this case is now a thin conductor zigzagging or spirally its way across the surface of the diaphragm, oriented at right angles to the magnetic field, so that sending a constant direct current through the conductor results in a more or less equal unidirectional force which displaces the diaphragm from its rest position. As a result of all this, an alternating sound signal therefore causes the diaphragm to vibrate with respect to it. Thereby creating an analogue form of the sound waves[1].

Electrostatic earphones: Just like the electrodynamics earphones, the electrostatic earphones use thin plastic diaphragms, but in this case, instead of a copper track, the diaphragm is treated to make it very slightly conductive and that the surface can hold an electrostatic charge. This makes it usually light. The diaphragm is stretched under low mechanical tension between two perforated conductive plates to which the audio signal are fed through a step up transformer. There is a central diaphragm which is kept charged to a very high voltage with respect to the outer plates using special type of power supply, capable of non-dangerous, low current, high voltage from the house mains or alternatively by an energizer which uses some of the audio signal to charge the diaphragm to a similarly high but safe voltage as a result of this, the diaphragm experiences electrostatic attractions toward the outer plates. Care is taken to ensure that the film does not collapse on any of the plates, but stays stable between the outer plates and is attracted to each one equally during non-signal condition. When an audio signal of a few milivolts is applied to the primary terminal of the step-up transformer, it is stepped up at the secondary to around a thousand volts. This unbalances the force on the diaphragm with respect to the audio signal, causing it to be attracted alternately to each plate, thereby reproducing an analogue form of the original sound.

Electrets earphones: These types of earphone are similar to the electrostatic types but use the electrostatic equivalent of a permanent magnet (i.e. a material which permanently retains electrostatic charges) unlike the electrostatic types, the electrets earphone does not require the use of an additional power supply[14]. Earphone could be further classified based on the mode of wearing them such as;

1. Circum aural
2. Supra aural
3. Ear buds
4. Canal earphones.

The moving coil earphone was made use of in the construction of this hearing aid. The type used is the ear bud type and this was chosen because of its high sensitivity of the earphones and its matching impedance with the hearing aid unit and also its availability.

3.1.4 POWER SOURCE

This section of the hearing aid deals with the type of power source required to power the audio amplifier and the pre-amplifier stages of the hearing aid. There are various sources of power which could be used to power the hearing aid amongst which includes,

1. Solar power
2. Batteries.

The power source used in this hearing aid is a battery since it is cheaper and easily available.

3.1.5 AUDIBILITY OF THE HEARING AID

The purpose of the hearing aid is to amplify the sound sufficiently so that they can be heard by listener. Audibility is the key concept underlying speech perception.

Generally speaking, the more speech sound we hear, and the better we understand. In describing audibility, the following characteristics are considered.

Audible range: The limit of frequencies which are audible. The normal ear of young adult detects sound hearing frequencies in the range 16Hz to 16 kHz; although it is possible for some people to detect frequencies outside these limits.

Decibel [dB]: The level of noise is measured objectively using a sound level meter. This instrument has been specifically developed to mimic the operation of the human ear. The human ear responds to moderate pressure variation in air. These pressure variations can be likened to the ripples on the surface of water. The pressure variation in air causes the ear drum to vibrate and this is heard as sound in the brain. The stronger the variation, the louder the sound. The pressure of sound waves is normally quoted in Pascal (Pa); but because of the range of pressure involved, logarithmic unit, the decibel was introduced. It is important to state that the range of decibel of the hearing aid is from 0 to 46dB. The table below shows the pressure of sound in Pascal and in Decibel.[10]

Table 3.1: Pressure of Sound in Pascal and in Decibel.

Decibel(dB)	Pascal(Pa)	Comments
-6	10μ	Inaudible
0	20μ	Threshold of hearing
40	2000μ	Very quite speech
80	0.2	Loud speech
100	2	Damaging noise
120	20	Becoming painful

3.2 DESIGN AND IMPLEMENTATION

In other to produce a stereophonic hearing aid of a very high quality, the following systems requirements were put into consideration;

1. High power output (at least 1 watt),
2. High sensitivity,
3. Low noise distortion,
4. High efficiency,
5. High sonic clarity.

Based on these requirements mentioned above, the system components were selected from among many. A power amplifier capable of providing the required power output level, coupled with a less voltage operation as low as 4volts was required, and the LM386 integrated circuit meets this requirement. Besides, LM386 was chosen because of the following characteristics.

1. Few external components,
2. Low voltage consumption (this makes it ideal for battery operation),
3. Wide supply voltage range 4-12v or 5-18v,
4. Low quiescent current drain of 4mA,
5. Voltage gains from 20 to 200 (i.e. 21 to 46 dB)
6. Low distortion of 0.2%.

Similarly, in the preamplifier stage, the LM385 micro power 3-terminal voltage reference operational amplifier was chosen. This is as a result of its unique characteristics such as;

1. Extremely low power drain,

2. Low temperature coefficient,

3. Low noise,

4. Low dynamic impedance,

5. Wide dynamic operating range varying supplies with excellent regulation,

6. Adjustable voltage range from 1.24 to 5.3v and good temperature stability.

In other to obtain high sensitivity, a condenser microphone capable of picking sound signals over a wide range was used. Similarly, a moving coil ear bud type of earphone was used to obtain a high sonic clarity from the hearing aid.

The step taken in the design of this hearing aid system is a modular approach. Here each module would be carefully explained, and their circuit diagrams drawn. The hearing aid system comprises the following subsystems;

1. The input unit
2. The pre amplification unit
3. The power amplifier.
4. The power supply unit

3.2.1 THE INPUT UNIT

One condenser microphone was use as the input transducer.

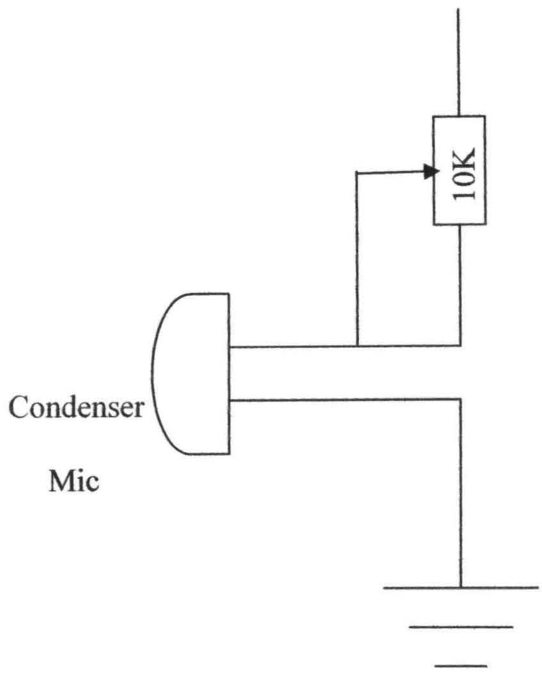

Fig 3.2 the input unit

A 10kΩ preset resistors were connected across the 9 volt supply. The DC biased levels were adjusted until a high-enough fidelity in the amplified version of a test sound source was obtained. The resistances were chosen high enough to reduce the drain on the power supply.

The current drain by the resistor was easily calculated using

$I = V/R$

$= 9/10000$

$= 0.9A$

Where V=9V (operating voltage)

3.2.2 SMALL SIGNAL AMPLIFIER

An LM358 dual operational amplifier was used for amplifying the low level milivolt-range microphones signal. The operational amplifiers were configured in the inverting mode to reduce noise pick up.

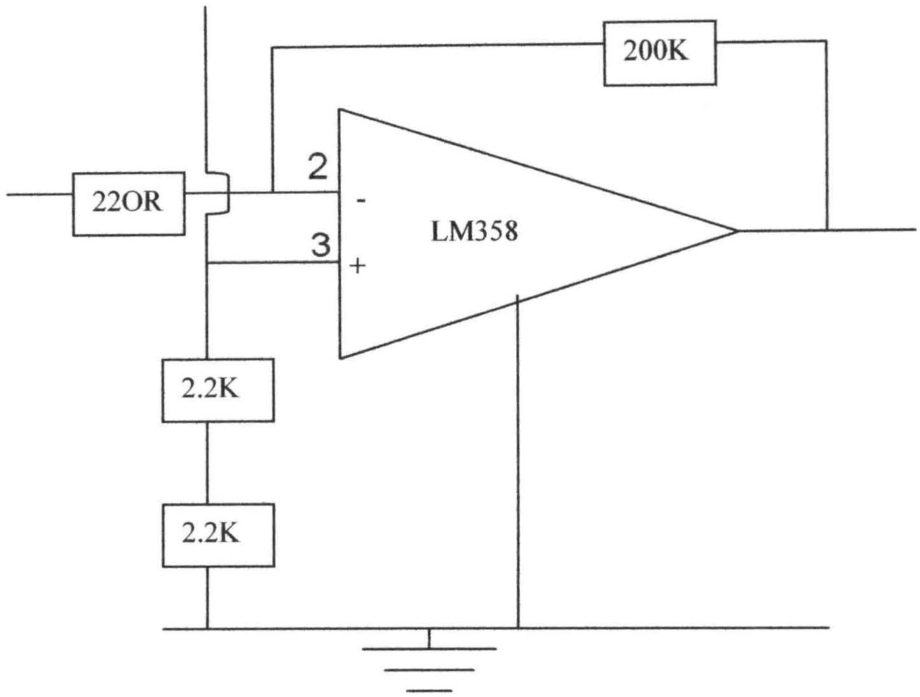

Fig 3.3 LM358 amplifier

The gain factor of the LM358 amplifier was deduced from the expression below;

$$\frac{V_{out}}{V_{in}} = -\frac{R_f}{R_i + R_s}$$

Where R_f =200kΩ (The feedback resistance)

R_i = 220Ω (The input resistance)

R_s = 2.2kΩ (The Microphone impedance)

Thus, the amplifiers voltage gain:

Thus, the amplifiers voltage gain:

$$^{Vout}/_{Vin} = -\,^{Rf}/_{Rin}$$

$$= -\,^{200000}/_{2420} = 83$$

Where Rf = 200kΩ

Rin =220Ω + 2.2KΩ=2420 KΩ, where 2.2kΩ =impedance of the microphone.

An input high pass filter was formed by the 10uF coupling capacitor and the reset 220Ω resistance. The cut-off frequency was evaluated using:

$F = 1/2\pi RC$

$=1/2\pi\,(220 \times 10 \times 10^{-6}) = 71.43$ Hz

3.2.3 POWER AMPLIFIER

An audio power amplifier was employed in the final stage of the final stage of audio reproduction. The devices were configured for a gain of about 200 by connecting a 10uF capacitor between pin 1 and 8 as in the figure 3.11. 220uF capacitors were used to couple the amplifier to the loudspeaker. The power supply to the LM386 was bypass by the 0.1 capacitance to prevent high frequency noise appearing on the reproduced audio information.

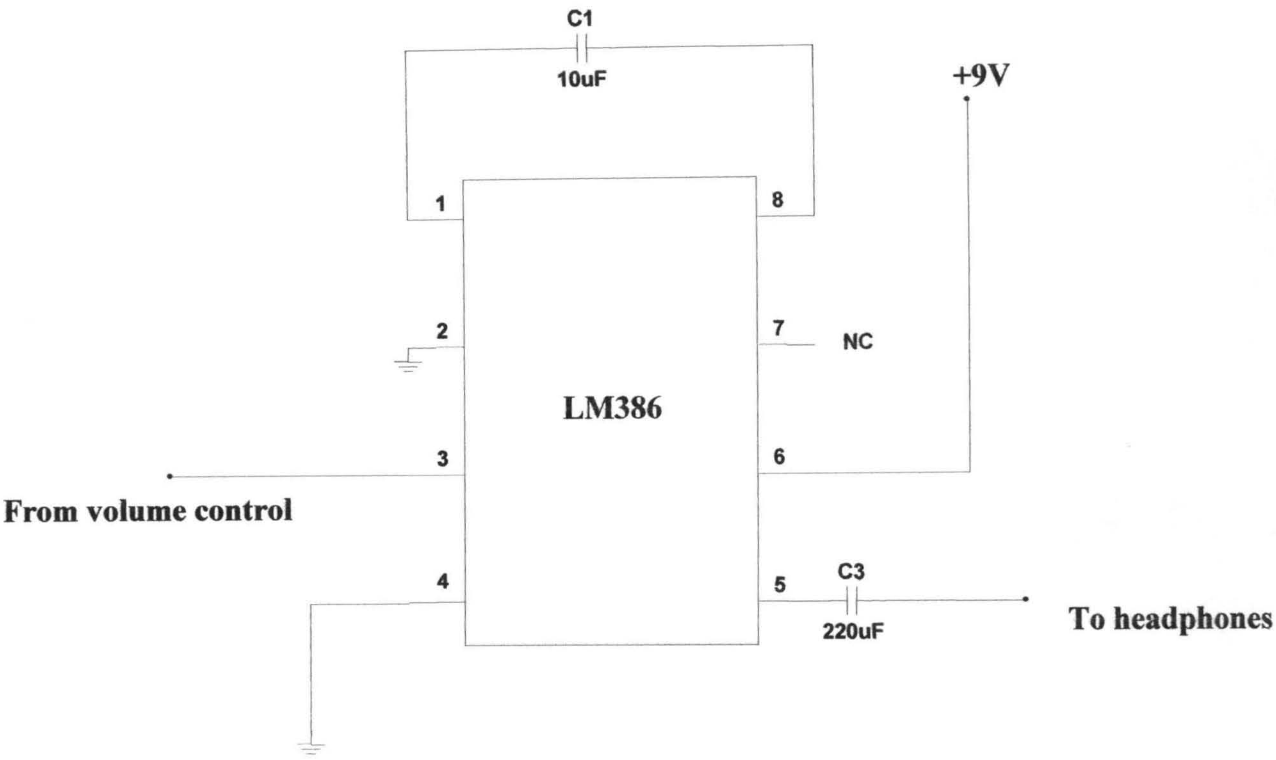

Fig 3.4: Power amplifier

3.2.4 POWER SUPPLY

One end of the switch is connected to the 9 volts battery while the other end of the switch was connected to IN4001 diode. The IN4001 diode is used so that if there is polarity swap of the switch, the circuit will not be damaged. An LED is used as an indicator so as to indicate the when the circuit is on. A 330Ω resistor was connected to the LED to resist the flow of high current into it. Also a 100µf to increase the system performance of the indicator and to filter ripples.

The circuit diagram of the power supply section is shown below;

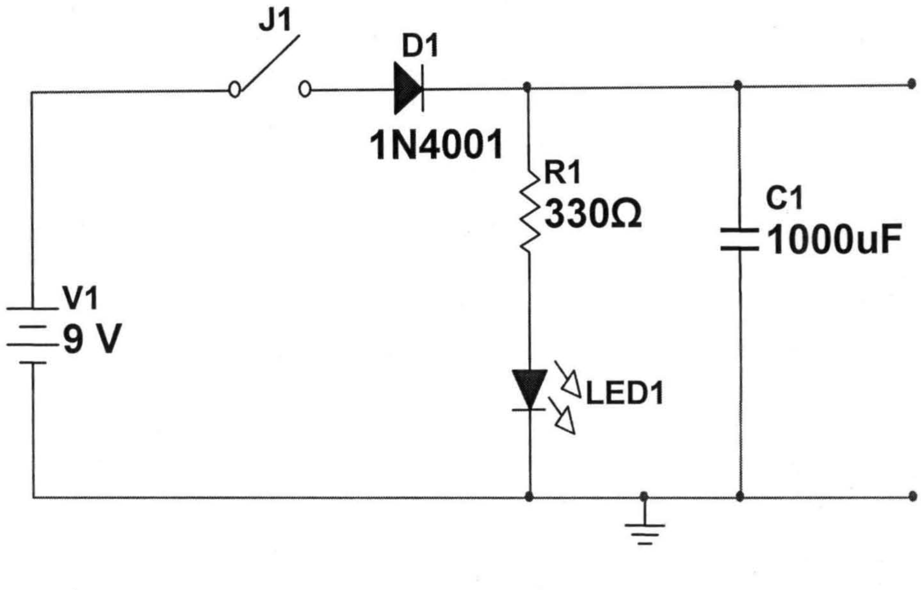

Fig 3.5 Circuit diagram of supply unit

The current of the indicator is calculated below

$$I = {}^{V}/_{R}$$

R=330Ω

V=9V

$$I = {}^{9V}/_{330}\,\Omega$$

=0.03A

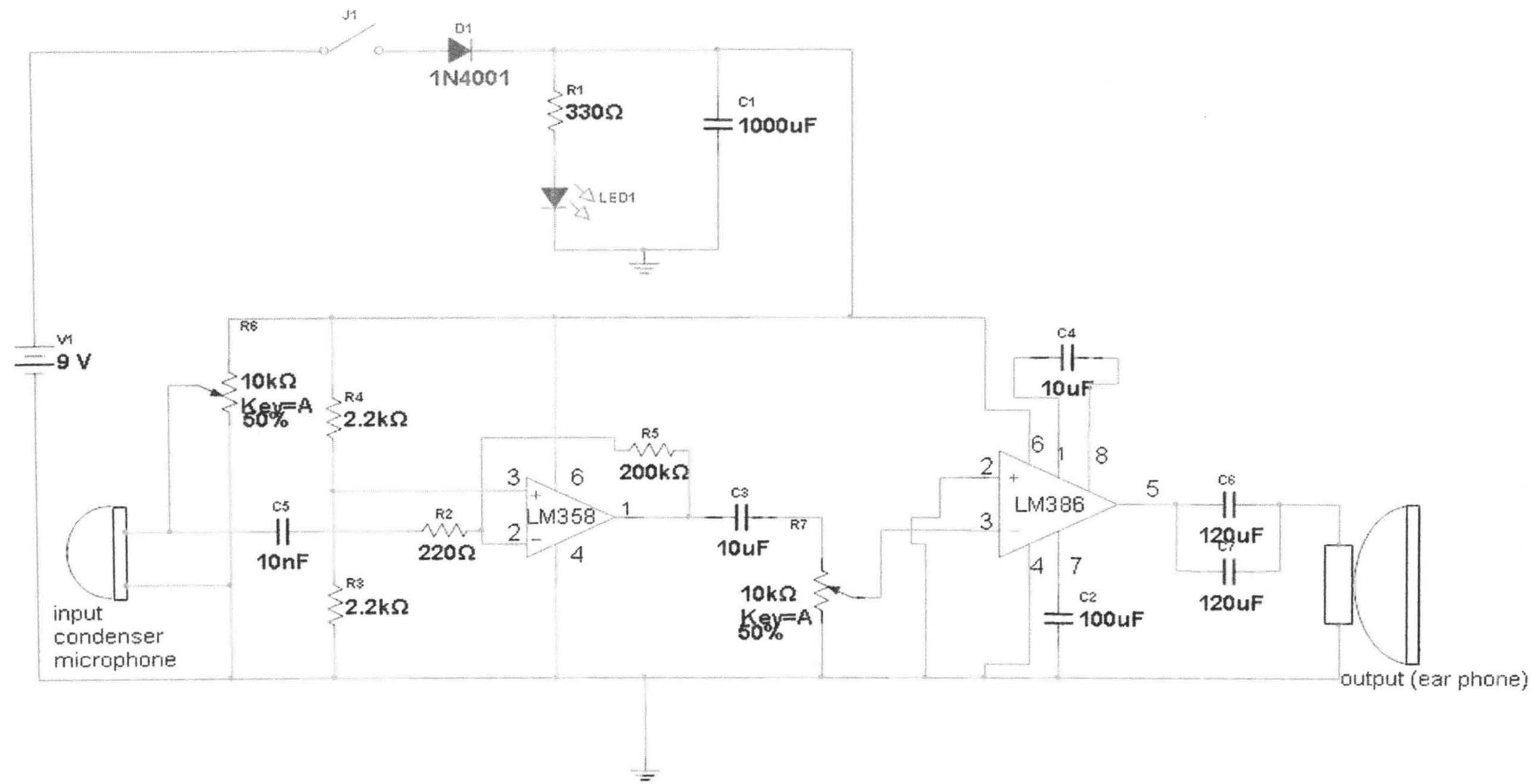

Fig 3.6 The complete circuit diagram of hearing aid

CHAPTER FOUR

TEST, RESULTS AND DISCUSSIONS.

4.1 TESTING OF THE WORK

After the construction of the circuit, the following steps were taken in testing the work;

Loudness

Range

Standby time of the power source

Clarity

Loudness: The loudness is the extent to which the input signal is amplified at the output by the amplification unit so as to accommodate the various hearing levels of user. The loudness was measured in Decibels (dB).

Range: This is the distance between the source of the sound and the user of the hearing aid. That is the extent at which the user can hear the sound very clearly from the source. The distance was measured in meter (m).

Standby time of the power source: This is the length of time the battery can continue to supply power to the hearing aid continuously over a period of time. It was measured in hours (hrs).

Clarity: This describes how clear the sound signal produced at the output is. It is a function of the distance from the source of signal to the user.

4.2 RESULT OBTAINED

Table 4.1 Test Carried Out and Results Obtained

S/N	TESTS CARRIED OUT	RESULTS OBTAINED
1	The Range	The test on the range of the hearing aid was carried out and it was discovered that it is 90 meters. But at a distance above 55 meters, the audibility begins to fall.
2	The loudness	With the help of the volume control, it was observed that the loudness of the hearing aid could be adjusted to fit various levels of hearing impairments suffered by various users.
3	The standby time of the power source	When the standby time of the device was tested, it was observed that using non-rechargeable battery; hearing aid could be powered for approximately 336hours (2 weeks).But when rechargeable battery is used longer operating time could be achieved.
4	Clarity	When a test on the sonic clarity of the device was conducted, the result obtained was that, the transducers (i.e. the earphones and the microphones) were responsible for the sonic clarity of the device. That is when a high quality earphones and microphones are used, the sonic clarity improved.

4.3 DISCUSSION OF RESULTS

The range of the hearing aid is a very important test parameter to be considered. At distances above 55 meters, the amplification of sound signals picked by the microphones was not high enough to be heard loud enough, thus at this distance, the audibility of the device tends to fall. Therefore, people tend to raise their voices which serve as compensation for the low signal level.

Sequel to the standby time, the power supply was designed in such a way that a non-rechargeable and rechargeable battery could both be used, with the former having its advantage of easily available and affordable. While the later last much longer, and as a result can be used to power the device for a longer period of time.

The sonic clarity of the hearing aid is dependent of the quality of the transducers (microphones and the earphones) used. A good and quality transducer gives a clear sonic quality.

The suitability of the device is of utmost importance. It is required that the hearing aid takes care of as many levels of impairments as possible. The volume control of the device takes care of that. The gain of the device was found to be 46dB which is within the range humans can hear. This also proved the suitability and efficiency of the hearing aid.

4.4 LIMITATIONS AND PROBLEMS

During the testing of this device some limitation and shortcomings were encountered.

1. When the microphone is blocked, it was noticed that it still picks and amplify sounds from the environment as when it was not blocked.

2. Power failure was rampant during the period the project was carried out; as a result the progress of the work was slowed down.

3. Similarly, some of the components due to their high degree of sensitivity to temperature changes were damaged during the process of soldering, and this drastically slow down the progress of the work.

4. Inability to get a severely deaf person the testing.

4.5 TROUBLESHOOTING TIPS

The following are the troubleshooting tips to be observed by the users when any form of malfunction arises.

Table 4.2. Trouble Shooting Tips

	Likely Faults	Possible Remedies.
1	Unit does not turn ON	Ensure that the switch is turn on. Check that the battery is properly fitted and is working fine.
2	Unit turns ON but there is no sound.	Check the volume control. Ensure that the earphone is properly plugged in.
3.	Loud whistling sound heard at the earphones.	Reduce the volume Move earphones as far as possible from the microphones on the unit.
4.	The signal at the earphone is too low.	Check the volume control. Check if the battery is too low or needs replacement.
5.	Poor sonic clarity.	Check if the battery is too low. Check the quality of the earphones.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The entire electronic components used in this project were easily sourced and affordable. These components were all gotten in Minna, Niger State.

The components used in this projects are; condenser microphone, resistors, LM358 and LM386 amplifiers, IN4001 diode, LED, connecting wires, variable resistor, capacitors and earphone. The entire components were connected together to produce a hearing aid for amplification of sound.

The device covers a range of 9.0meters, a loud sound level high enough to amplified faint sound. The device is capable of accommodating various level of hearing disorders. The stand by time of the device last for a minimum of 11days depending on the type of battery used.

The condenser microphone which acts as a transducer was used to achieve a high sonic clarity.

5.2 RECOMMENDATION

I recommend that students should be exposed to complicated practical works so as to help them in their final year project and to give them more experience in their course of study.

Also, I recommend that anybody interested to do this work should work on the following;

- How to use low voltage source to achieve this work
- The use of wireless earpiece
- The use of rechargeable batteries

- How to achieve the project with the use of small components so as to make the project cheaper and easily affordable.

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