DESIGN AND CONSTRUCTION OF A HEARING AID

Achonu Uchenna Kingsley

2001/11897EE

A Thesis submitted to the Department of Electrical and Computer Engineering, Federal University Of Technology Minna, Niger State, in partial fulfillment of the award of a Bachelors Degree in Engineering (B.Eng).

NOVEMBER, 2007

DEDICATION

This work is dedicated to my father Mr Kingsley E.C Achonu, for all the sacrifices he made to ensure he gave to me the best treasure a father can ever give a son "Education" and for teaching me to believe in myself.

DECLARATION

I Achonu Uchenna Kingsley, declare that this work was done by me and has never been presented elsewhere for the award of a degree. I also hereby relinquish the copyright to the Federal University of Technology, Minna.

Achonu Uchenna Kingsley

Name of student

Signature and Date

Mr David Michael

Name of supervisor

28/11/07

Signature and Date

Engr Musa D. Abdullahi

Name of H.O.D

Signature and Date

Name of External Examiner

Signature and Date

ACKNOWLEDGEMENT

I am really indebted to a number of individuals who have contributed immensely in various ways to see to the success of this work.

First and foremost my gratitude goes to my parents Mr and Mrs K.E.C Achonu, for all the financial and moral support they gave me in the course of carrying out this work., my project supervisor Mr David Michael, for putting up with all my disturbances and guiding me through the rudiments of how a proper project should be carried out, my classmates, especially my group members, for the positive criticism and wonderful suggestions they made towards this work.

Finally and most importantly, I wish to express my profound gratitude to God almighty for ever being so faithful to me.

ABSTRACT

This project which has its main objective as the design and construction of a hearing aid to help people with hearing impairment was carried out with the use of some basic electronic components such as the Mitsubishi M5182L and the TEA2025 transistors (which made up the pre-amplification and amplification stages respectively). Transducers such as the condenser microphone and the ear bud type moving coil earphone (which made up the input and output stages respectively). A battery was used as the power source, and other components such as resistors, capacitors, headphone jack etc were also used as well. The principle used was the principle of sound amplification.

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CHAPTER ONE

INTRODUCTON

We are constantly exposed everyday to factors which could pose a dangerous threat to our hearing as we go about our daily activities. These factors could be present in our places of work as in the case of;

1. A factory worker who is constantly exposed to the loud noise produced by heavy machinery in his operation.

2. The use of explosives by civil engineers to break down rocks, hills or mountains when building roads or bridges across them.

These factors mentioned above could have a detrimental effect on the hearing ability. Also other factors which could pose a threat to our health is the exposure to loud music played in live concerts, and loud music blasting from loud speakers, loud noises from the horns of motor vehicles and also as a result of living in areas very close to train stations, airports etc.

Finally our hearing could also be partially impaired by some factors which we cannot control such as ageing, birth defects, and the actions of viruses, bacteria and other disease causing organisms.

This is where hearing aids come into play. A hearing aid is a device used to help hard-of-hearing people hear sounds better.

1.1Aims And Objectives.

The aims and objectives of this project are as enumerated below;

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

2. To ensure that this device is made from electronic components that is easily sourced and available locally and at an easily affordable price for the poor masses suffering from hearing disabilities.

3. To enable children and adults as well, with partial hearing disabilities to learn with ease alongside their mates with proper hearing abilities in conventional schools, thereby reducing the burden of expensive school fees paid by parents of children with hearing disabilities in special schools made for them.

4. Another objective of this project is to ensure that social inclusion for those with hearing problems, and also reduce the stigmatization always accorded them.

5. Finally to ensure the comfort and convenience of individuals suffering from one form of hearing disability to another, and also to ensure the efficiency of such individuals if employed.

1.2 Methodology.

In the construction of this hearing aid, a high sensitive condenser microphone was used, and it was connected to a class AB amplifier with low noise distortion IC of output power 1 watt which is dependent on the power supply.

A normal stereo earphone with an impedance of 32 ohms was connected to the output of the amplifier through an earphone jack.

A 9 volts pp-9 battery was used to power the hearing aid unit.

1.3 Scope of the work.

At frequencies in the range of 100 to 10,000 Hertz, the performance of the hearing aid is affected by the transducers.

At low frequencies, the microphone causes a limitation to the performance of the hearing aid, while at high frequencies; it is the earphone that is responsible for the limitation of the hearing aid.

The maximum acoustic output of the hearing aid is dependent on the power handling ability of the output transistors and the earphone used. This is also affected by the amount of current that can be drawn from the battery.

Finally the range of the hearing aid is between 0 to 46 decibels.

1.4 Sources of materials used.

Most of the materials used (in form of electronic components) in carrying out this work were sourced locally here in minna at affordable prices in various electronic shops found all around town. This was done intentionally so as to make the final product to be easily affordable.

Also the sources of information used in the production of this project work includes the internet, libraries (both school and state libraries), consultation with friends, technicians, and other experts in the field.

1.5 Constraints to achievable performance.

The constraints to achievable performance could have risen as a result as a result of the following factors;

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

2. Also some of the components due to their high degree of sensitivity to temperature were damaged by the soldering iron since it was difficult to obtain one which had a regulator.

3. Another constraint was the difficulty in getting some of the components used in constructing the device; as a result their substitutes were used, which might not function as accurately as the original ones.

1.6 Other persons involved.

In the course of this project work, the services of other persons such as professionals in the field, technicians, electronic engineers (inside and outside of the department), fellow classmates, members of my project group and my project supervisors were employed.

CHAPTER TWO

LITERATURE REVIEW

2.1 Historical Background

Since the advent of medicine, especially in the study of otology, early scientists and otologists had strived to obtain a solution for the problems suffered by individuals with hearing impairment.

The strive to obtain solutions to such problems led to the invention of the earliest hearing aids which were in form of ear trumpets invented sometime in the 17th century[1,2].

The ear trumpets were made of long horns with a large opening at one end, and a smaller one at the other end, which was placed in the ear.

The ear trumpet worked under the principle that; sound pressure waves entering the large ends are condensed into smaller volumes, thereby increasing the audible sound pressure.

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 then back to sound waves. However, they had some major draw backs 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 hearing aid s were developed which looked like modern day 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 the transistors in 1948, hearing aids of greatly reduced size and weight were invented.

In the year 1969 the first directional microphones was developed and was incorporated into hearing aids, thereby leading to a more natural sounding hearing aids.

By the mid 70s, integrated circuits (ICs) were applied to 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 turn into mini computers.

By this period also, the idea of surgical implants to the cochlea was widely anticipated as a cure for deafness were the use of hearing aids could not do much.

By the 90s, hearing aids that could boast of two channel sounds, automatic volume control, or remote control for the smallest of ITC (In-The-Canal) instruments by now when worn were totally invisible to all.

By this time also, fully digital audio processors were developed, global researchers took it upon themselves to produce a working hearing aids system which they named adaptive speech alignment, which could boast of multi-tone banding, and dual processing, one for recognizing vowels and consonants respectively.

Hearing aids of present time have self assessment of listening comfort, and memory cards for the remote controls.

Micro-Magnets implanted next to the ear drums, which will never need to be replaced is being foreseen as a major development in hearing aids of the future.

The development of the electronic hearing aids can be described as the biggest advancement ever made by science and engineering technology in helping deaf people [3].

2.1.1 Types of hearing aids.

Hearing aids are of different types which includes [4];

1. Body worn aids,
2. Behind the ear aids,
3. In the ear aids,
4. Receiver in the ear aids (RITE),
5. In-The-Canal (ITC), Mini-In-The-Canal (MIC) and Completely-In-The-Canal (CIC) aids,
6. Bone Anchored Hearing Aids (BAHA),
7. Eye glass hearing aids and
8. CROS (Contralateral Routing of Offside Signal) type hearing aids.

All hearing aids are fundamentally simple acoustic amplifying (that is sound amplifying) systems.

2.2 Theoretical Background

To understand the theory behind the hearing aids, there is an important need to appreciate the working principle of the human ear.

The human ear performs two important functions which include [5];

1 An organ for maintaining balance

2 An organ for hearing.

Considering the ear as an organ for hearing, the ear receives sound waves, and changes them into signals that the brain can translate into the sensation of sounds.

Sound waves travelling from a vibrating object through a medium which could be liquid, gas or solid gets to the outer ear and are funnelled into the ear canal were it bumps against the ear drum, making it vibrate.

The vibration causes the three tiny bones in the ear known as the anvil, hammer and stirrup to vibrate also thereby amplifying the sound waves, which leads to the oval window in the middle ear to vibrate also.

Due to all these vibrations, pressure waves are set up in the inner ear, and race up and down the coils of the cochlea. These waves push against the basilar membrane.

The hair cells of the organ of the corti are bounced about, and bend back and forth. Their movement is picked up by tiny nerve fibres attached to the hair cells.

The cochlea nerve carries message from the ear to the various part of the brain, were they are then sorted out and finally produced as the sensation known as hearing.

Any alteration in the smooth flow of this process either by biological or physical factors, could result in the situation known as deafness, and this is where hearing aids come into play.

All hearing aids are fundamentally simple acoustic amplifying systems and are made up of four basic parts which includes;

1. A microphone to pick up sounds and convert them into very small electrical signal.
2. An amplifier to increase the size of the electric signal.
3. An earphone to return the electric signal into an acoustic one which is then fed into the ear through an ear mould.
4. A power source which is usually a battery for powering the amplifier.

The figure on the next page is a block diagram of a typical hearing aids unit.

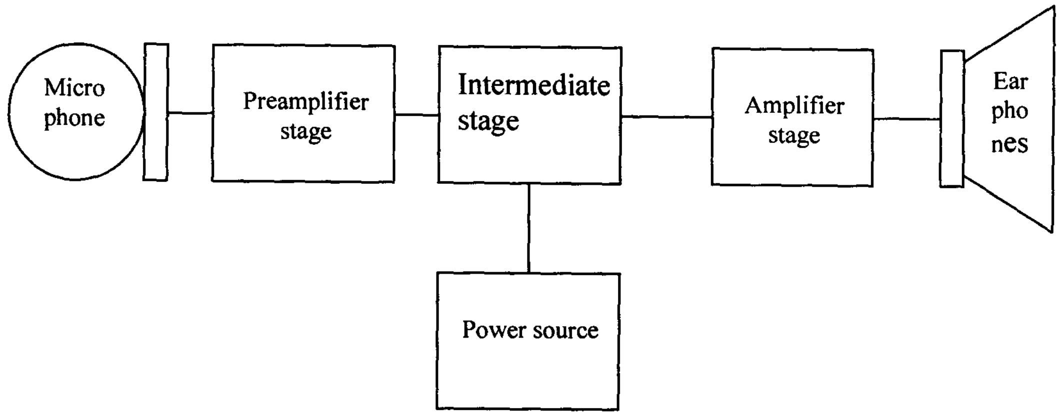

Fig. 2.1 Block diagram of atypical hearing aid

2.2.1 The input stage

A microphone makes up the input stage of a typical hearing aid. Microphones are devices which act as transducers to convert acoustic signals (sound waves) into electrical signals [6].

Microphones are of different types, and are designed for different applications. Microphones operate on one of the following principles;

1. Variable contact resistance (e.g. of such microphones includes carbon microphone).
2. Piezoelectricity (e.g. of such microphones includes crystal microphones).
3. Electrodynamics (e.g. of such microphones include moving-coil microphone, ribbon microphones).
4. Electrostatics (e.g. is capacitor microphone, also known as electrets or condenser microphones).

Microphones use diaphragms which respond to sound waves in the following ways;

1. 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.

2. The difference between the pressures at two closely situated points, i.e., pressure gradients (as in the case of a moving-coil, and ribbon microphones) may result in an electrical output.

The microphone used in the construction of this hearing aid is the condenser microphone. It was chosen, because of its high sensitivity, portability, and also due to the fact that it could be made very small and rugged.

2.2.2 Amplification stage

The main component of the amplification stage in a typical hearing aid is the audio amplifier. Audio amplifiers are electronic amplifiers that increases low audio signals (composed of frequencies between 20 hertz to 20,000 hertz, which makes up the human hearing range) to a level high enough for driving a loud speaker [7] or in this case an earphone, which normally makes up the final stage of an audio playback system.

Certain stages precede the amplification stage. When designing an audio amplifier for use in devices such as hearing aids for example, the following parameters are to be considered [8];

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

2. Gain of the 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;

$$\text{Gain} = 10\log\left(P_{out}/P_{in}\right)\ \text{dB} \quad \text{-------------------------1}$$

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

Similar calculations for the gain of an amplifier could be done using natural logarithms instead of decimal logarithms. The result obtained in this case is called the nepers instead of decibels.

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

$$P = I^2 R \quad \text{-------------------------------2}$$

But $$I = V/R \quad \text{----------------------------------3}$$

Substituting equation 3 into equation 2, we obtain;

$$P = \left(V/R\right)^2 R$$

$$P = V^2/R \quad \text{-------------------------------4}$$

Substituting equation 4 into equation 1 we obtain;

$$\text{Gain} = 10\log\left(\frac{V_{out}^2/R_{out}}{V_{in}^2/R}\right) \text{ dB} \quad \text{-----------------------------5}$$

Since input and output impedances are usually equal in most cases, equation 5 could be simplified as;

$$\text{Gain} = 10\log\left(V_{out}/V_{in}\right)^2 \text{ dB} \quad \text{----------------------------6}$$

Therefore

$$\text{Gain} = 20\log\left(V_{out}/V_{in}\right) \text{ dB} \quad \text{----------------------------7}$$

Equation 7 is used to calculate gain in decibels only when both input and output impedances are equall.

3. Distortion of the amplifier: This is the alteration of the original shape or other characteristics of the sound waveform usually to an unwanted waveform by the amplifier. distortion in audio systems could be corrected by using special filters known as equalizers.

There are various classes of amplifiers, and these includes[9];

1. Class A amplifiers (here 100% of the input signalsis used, and conduction angle a =360° or 2π).

2. Class AB amplifiers (here more than 50% but less than 100% of the input signal is used. Conduction angle a = 180° to 360° or $\pi < a < 2\pi$).

3. Class B amplifiers (here 50% of the input signal is used, and conductance angle a = 180° or π).

4. Class C amplifiers (here less than 50% of the input signal is used, and conduction angle a = 0° to 179° or $a < \pi$).

Most audio amplifiers are linear amplifiers operating in class AB [8].

A class AB audio amplifier was used in the construction of this hearing aid, because of its low noise distortion abilities.

The figures below shows the frequency response curve of the various amplifier classes discussed .

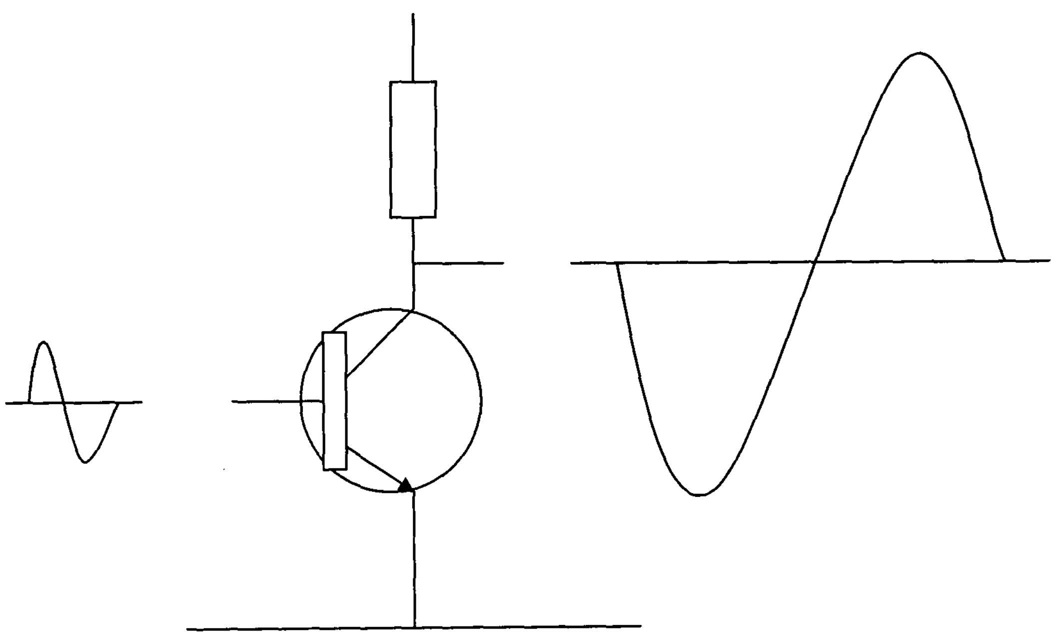

Fig 2.2 class A amplifier

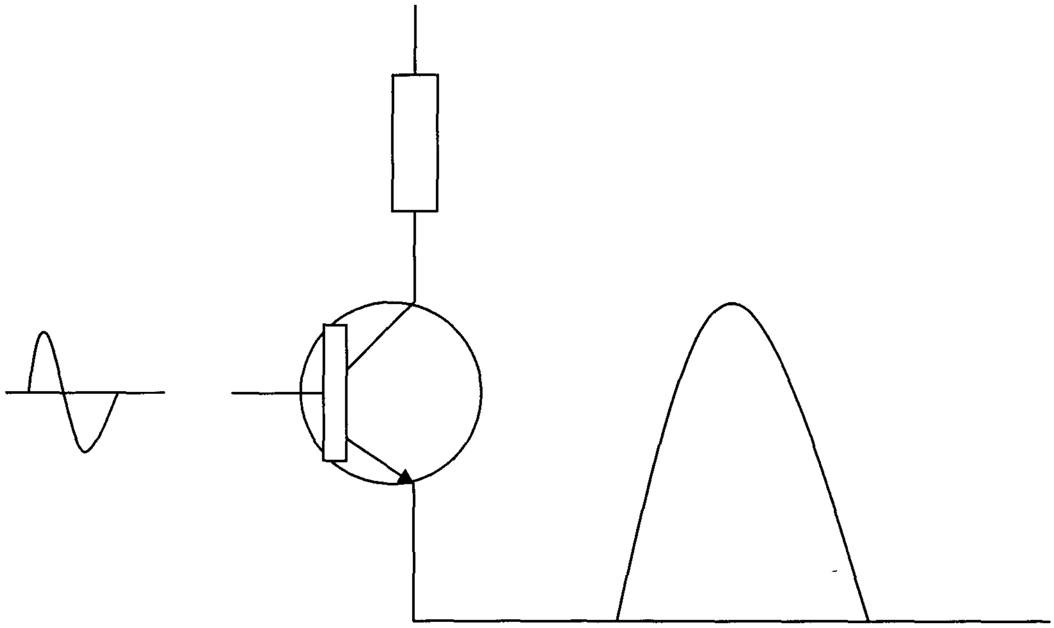

Fig 2.3 class AB amplifier

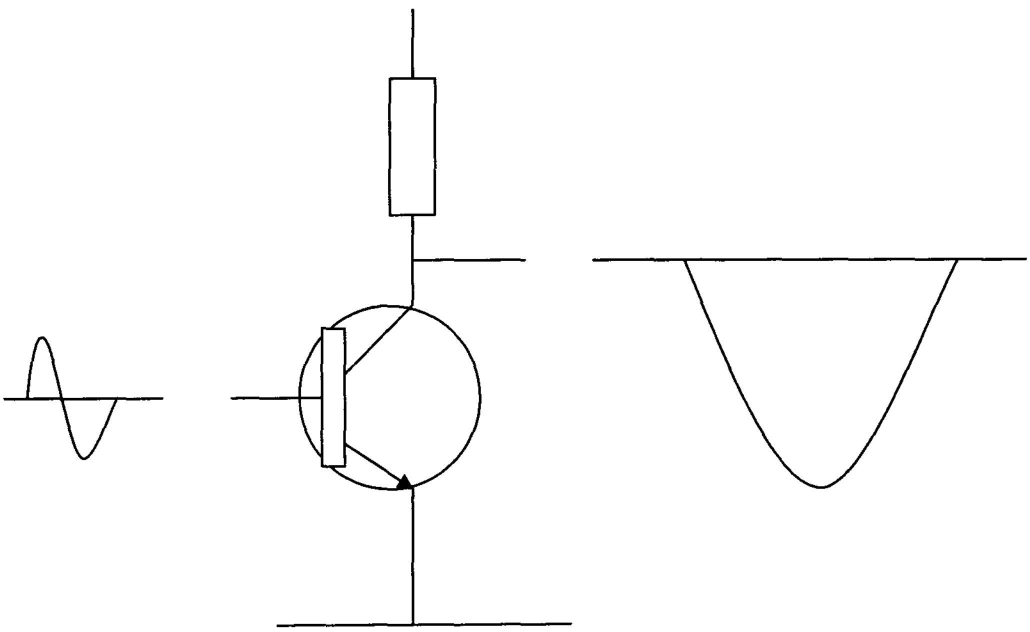

Fig 2.4 class C amplifier.

2.23 Output stage.

The output stage of a typical hearing aids system is made up of tiny loudspeakers known as earphones or headphones in some cases.

The earphones act as transducers which converts the amplified electrical signals from the audio amplifier, back to sound waves.

There are different types if earphones classified based on their principle of operation. These include [10];

1. Moving iron earphones: This type of earphones relies on the use of a fine wire wound onto a magnetic yoke held close to a stiff disc made of soft magnetic alloy such as stalloy. A permanent magnet is used to pull the thin disc towards the yoke with a constant force, and audio signals 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 also have very poor sound quality; they are used in telephone receivers.

2. Moving coil earphones: Here a coil of wire suspended 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 which the listener then perceives as sound.

3. 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 spiralling 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.

4. Electrostatic earphones: Just like the electrodynamic 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 so 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 signals 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 a special type of power supply, capable of non dangerous, low current, high voltage from the house mains or alternatively by an energiser which uses some of the audio signals to charge the diaphragm to a similarly high but safe voltage.

As a result of this, the diaphragm experiences electrostatic attractions towards 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 no-signal condition.

When an audio signal of a few millivolts 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.

5. Electrets earphones: These types of earphones 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.

Earphones could be further classified based on the mode of wearing them such as [11];

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 choice was made because of the high sensitivity of the earphones and its matching impedance with the hearing aids unit, and also its availability.

2.2.4 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, and the type used is a primary type battery since it is cheaper and easily available compared to the secondary type.

It is important to note that the performance of a hearing aid is largely controlled by the transducers, (i.e. the microphone and the earphone). The performance of these transducers can be indicated by the use of a frequency response curve which shows graphically how the microphone or earphone responds over a range of frequencies from 100 to 10,000Hertz.

At low frequencies, the limitation is largely due to the microphones, at high frequencies however, the earphone restricts the performance of the hearing aid.

The amplifier could consist of three or more transistors, depending on the amount of amplification required.

Usually the frequency response and power output from the amplifier are such that they almost do not place any limitations on the performance of the hearing aid. The amount of noise however generated by the first transistor stage is important because if it is too high, the listener will hear a continuous background rushing noise.

The maximum amount of sound available from the aid (called the maximum acoustic output) will depend upon the power handling ability of the output transistor and the earphone.

Also the power available will be limited to the current that can be drawn from the battery.

The amount of acoustic amplification required depends on the degree of deafness which the hearing aid is required to help, and may vary from 40dB (that is 100 times) to 80dB (that is 10,000 times).

The performance of hearing aids can be divided into three main groups based on their maximum acoustic output power and these are;

1. Low-power hearing aids (which has maximum output of about 110dB sound pressure level).

2. Medium-power hearing aids (which has maximum output of about 120dB sound pressure level).

3. High-power hearing aids. (This has maximum output of about 130dB sound pressure level).

CHAPTER THREE

DESIGN AND IMPLEMENTATION

The steps taken in the design of this hearing aid is the modular design method. Here each module would be carefully explained, and their circuit diagrams drawn.

The design and construction of this hearing aid comprises of the following subsystems;

1. The microphone (input stage),
2. The pre-amplifier stage,
3. The power amplifier stage,
4. The earphone (output stage) and
5. The power source.

A block diagram of the various subsystems which makes up the design of this hearing aid is as shown in the figure below.

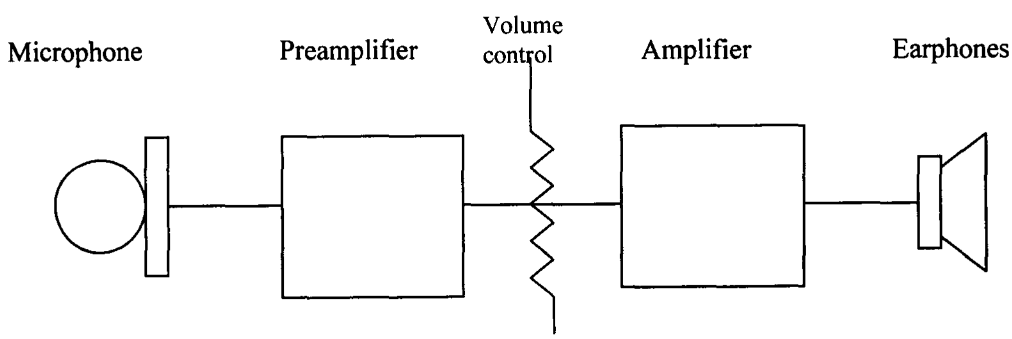

Fig. 3.1 A block diagram of the subsystem of the hearing aid.

3.1 System Requirements.

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

1. High power output (at least less than or equal to I watt),
2. High sensitivity,
3. Low noise and distortion,
4. High efficiency and
5. High sonic clarity.

Based on the requirements mentioned above, the systems components were selected from amongst many.

A power amplifier capable of providing the required power output level, coupled with a low voltage operation as low as 3 volts was required, and the TEA2025 meets these requirements and was as a result chosen since it also has the following specifications[12,13];

1. Few external components,
2. High channel isolation,
3. Voltage gain up to 45dB (adjustable with external resistors),
4. Soft clipping and
5. Internal thermal protection.

N.B for more information please see appendix 1

For the pre-amplification stage, a high quality operational amplifier which met the requirements for low distortion, wide frequency response and low-voltage operation was required. The Mitsubishi M5218L stereo hi-fi operational amplifier was chosen.

The M5218L has the following specifications [14];

1. It has a high gain,

2. It has a low distortion,

3. It has a high slew rate,

4. Low noise,

5. Operations with low voltage can be achieved and

6. High load current and power dissipation.

N.B for more information please see appendix 2.

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

3.2 The Microphone.

Due to the need for a hearing aid with high sensitivity to signals around the user, as earlier mentioned, an electrect (condenser) microphone was used in the construction of this hearing aid device.

The microphone is biased as shown in the figure on the next page.

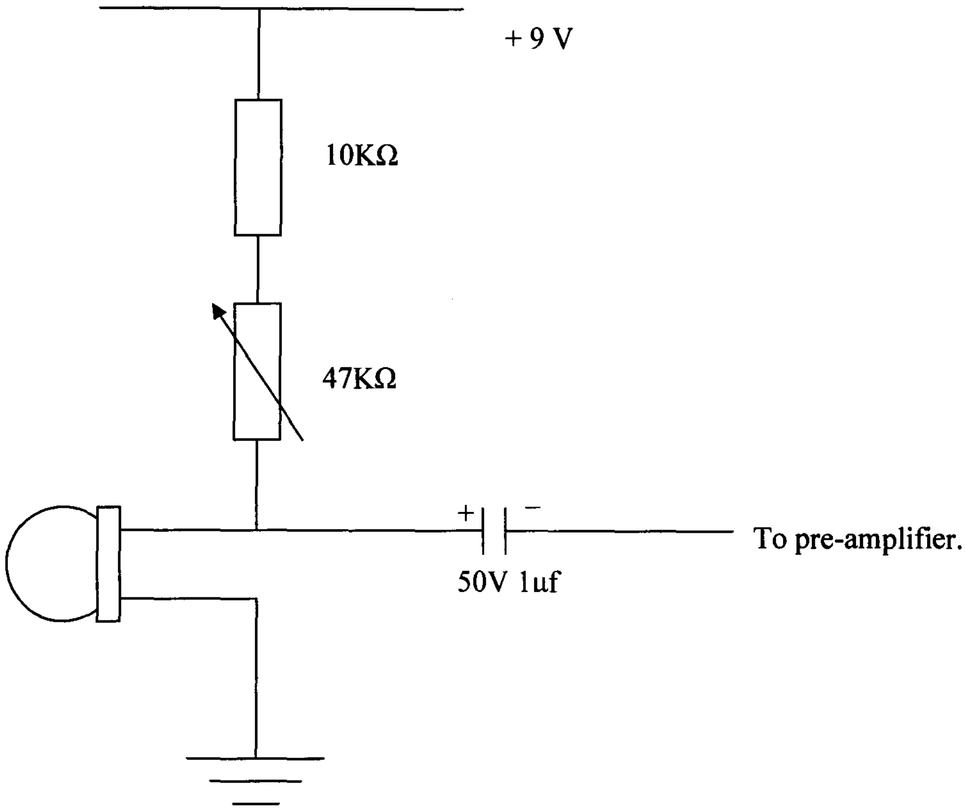

Fig 3.2 Diagram showing the biased microphone

The 47KΩ variable resistor allows any microphone sensitivity to be used. The preset 10KΩ resistor enables the bias voltage to be set to an optimum value, thereby providing the best response of the microphone.

3.3 Pre-Amplifier Stage.

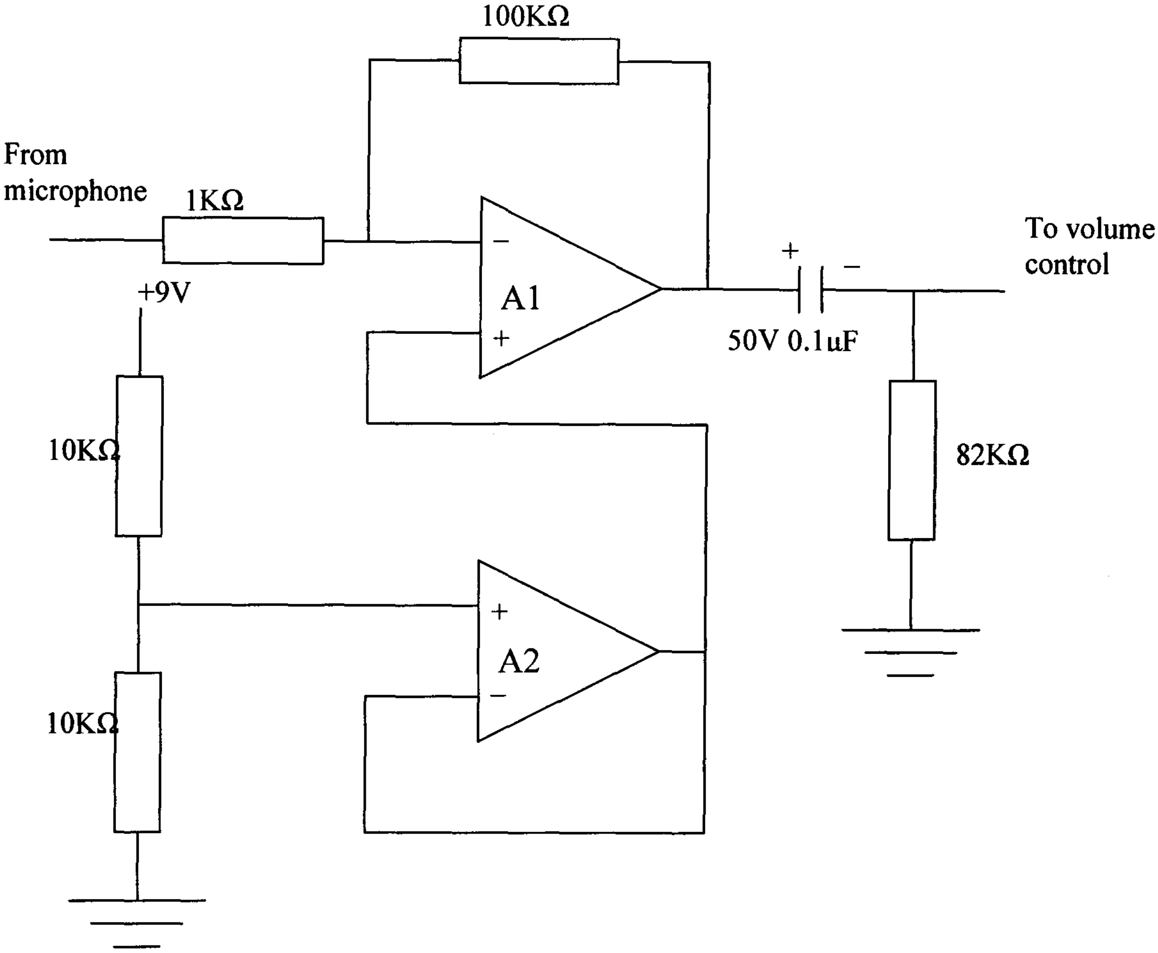

Fig 3.3 Circuit diagram of the pre-amplifier stage.

The pre-amplifier stage is designed around a high quality operational amplifier, the M5218L from Mitsubishi. For maximum equal output swing, the quiescent DC voltage at the pre-amplifiers output is biased to $Vcc/2$ this biasing network comprises of two equal 10KΩ resistances.

The M5218L is a dual operational amplifier; one half of the operational amplifier is connected to the biasing network in a voltage-follower configuration, to provide zero output impedance for the $Vcc/2$ DC reference.

The buffered output connects to the non-inverting input of A1. A1 is configured inverting, with a maximum gain given by the following equations;

$$V_O / V_{in} = -R_F / R_{in}$$

Where $R_F = 100K\Omega$, and $R_{In} = 1K\Omega$

$$A_V = V_O / V_{in} = -100K\Omega / 1K\Omega = -100$$

The amplifier feeds into a loudness-volume control network as shown in the figure below.

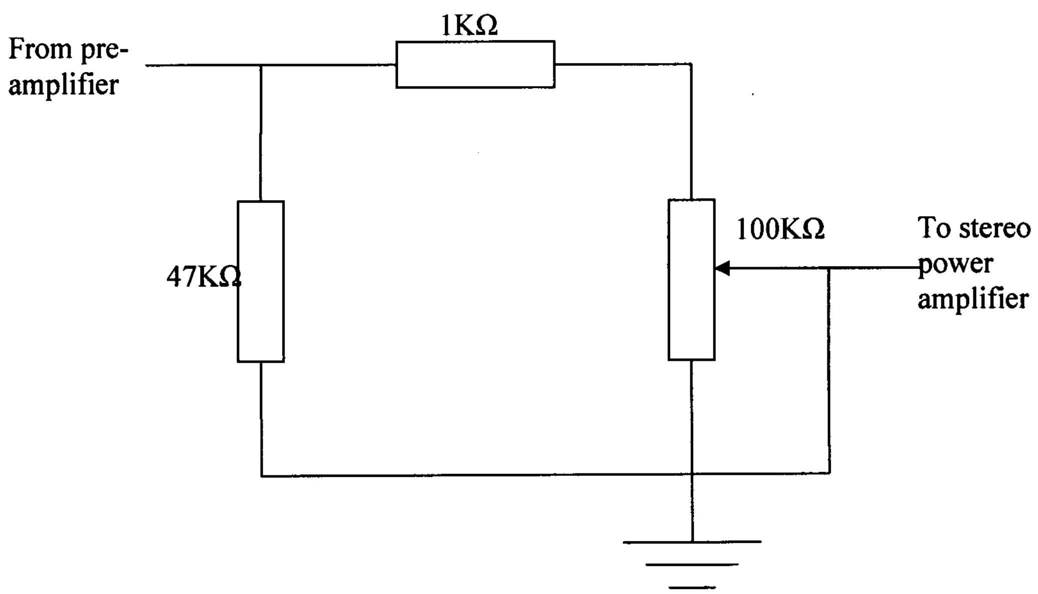

Fig 3.4 circuit diagram of the loudness-volume control network.

The Mitsubishi M5218L stereo hi-fi operational amplifier was chosen because of its low distortion, wide frequency response and low-voltage capabilities.

3.4 Power amplifier stage.

The power amplifier stage uses a TEA2025 low-power (2W) hi-fi stereo amplifier to drive a stereo earphone to an appreciable level. The TEA2025 has its configuration as shown in the figure below.

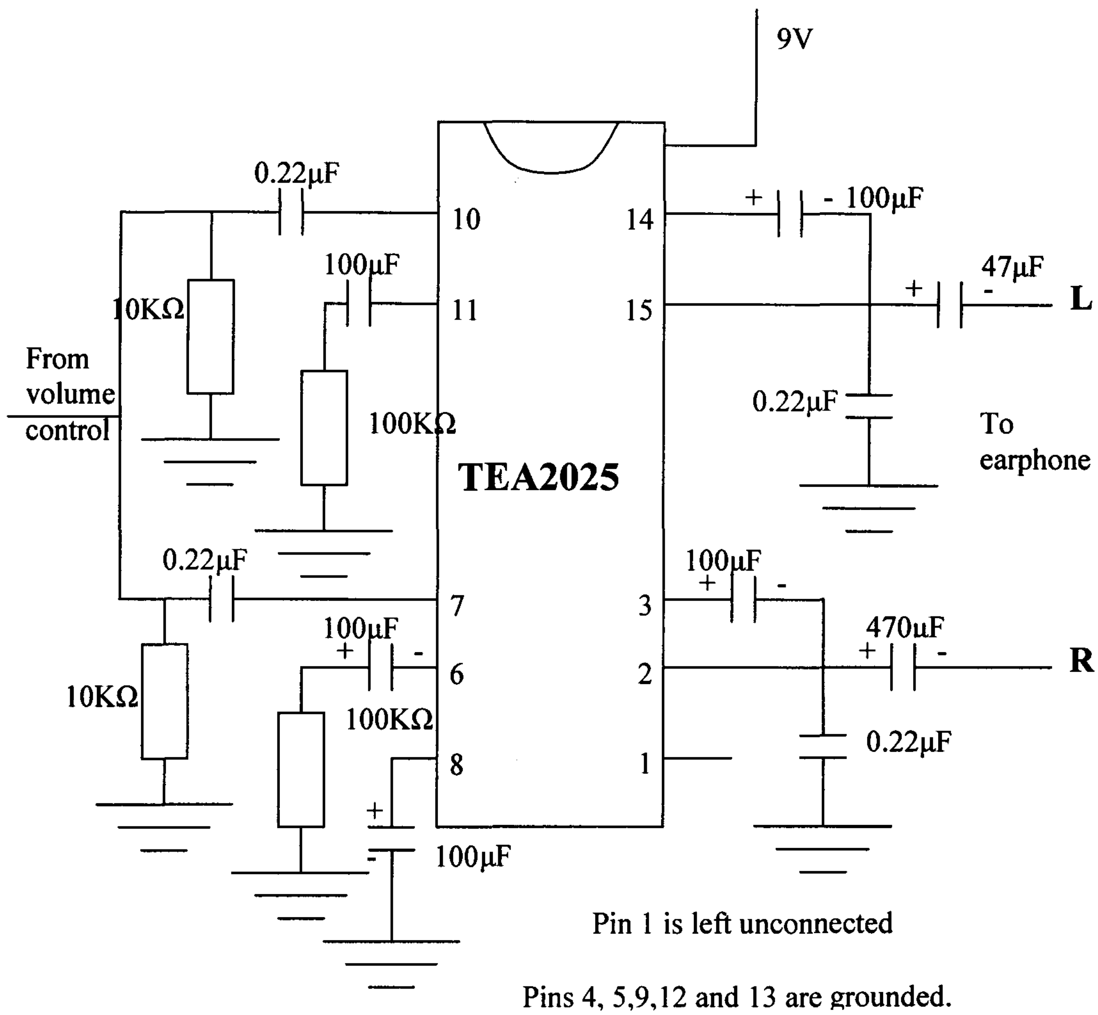

Fig 3.5 The TEA2025 pin configuration

The TEA2025 stereo audio amplifier has the following specifications;

1. Supply voltage down to 3 Volts,
2. Maximum gain of 45dB (externally adjustable),
3. Maximum gain supply voltage of 15 Volts,

4. Output peak current of 1.5 Amperes,

5. Input impedance of 30KΩ and

6. A distortion of 0.3%, typically at 9 Volts.

The TEA2025 has a PNP-type input stage, allowing a signal source to be referenced to ground, thereby eliminating the need for a coupling capacitor, although it can still be used if desired to, to adjust the lower F_3 dB frequency.

When operated in the stereo mode, the two amplifiers separately drive a load. The voltage gain is sent by on-chip resistors, together with an external capacitor series connected between pins 6 (11) and ground as shown below.

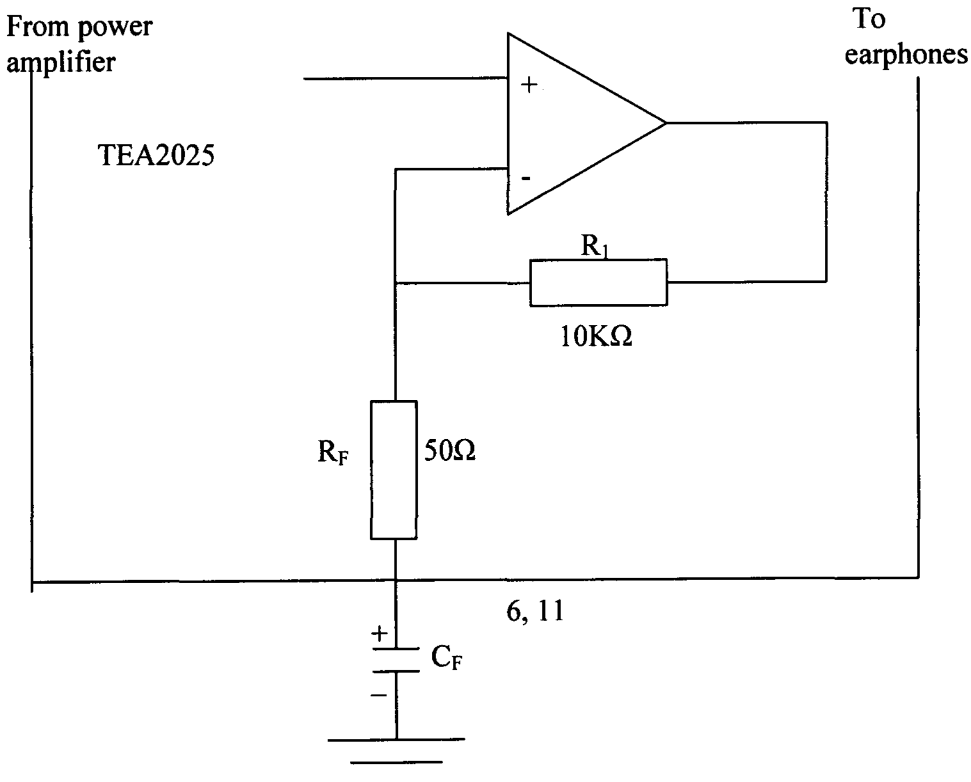

Fig 3.6 Diagram showing the grounding of pins 6 and 11 of the TEA2025.

With C_F at 100μF, the gain scales to 46dB, with pole at 32Hz. When the full gain (46dB) was used, oscillation was observed at the high volume levels. To cure this, the gain was reduced to a lesser value by inserting an external resistor R_F of value 100Ω into the feedback network, thereby reducing the gain to the value given by the expression;

$$V_{out}/V_{in} = \frac{R_1}{(100 + RF)} + \frac{1}{j\omega C1}$$

Where $R_1 = 10K\Omega$, $R_2 = 50\Omega$, $R_F = 100\Omega$, $C_1 = 100\mu F$.

The low cut-off frequency due to the output capacitor depending on the load is given by;

$$F_L = \frac{1}{2\pi C_{out} R_L}$$

Where $C_{out} = 470\mu F$, $R_L = 4\Omega$

$$\text{Therefore } F_L = \frac{1}{2\,(3.142)\,(470\times10^{-6}\times4)}$$

$$=84.6Hz$$

$F_L = 80Hz$

An input coupling capacitor of 0.22µF was used. This alongside the 30KΩ input resistance forms a high pass filter with a cut-off frequency given by;

$$F = \frac{1}{2\pi R_L}$$

$$= \frac{1}{2\pi\,(3\times10^{4})(2.2\times10^{-7})}$$

$$= 24.1Hz$$

Therefore F = 20Hz.

Since nominally expected input frequency range is about 100Hz – 10 KHz, this does not impose any restrictions on the sonic performance of the hearing aid unit.

The TEA2025 was chosen for this purpose because of its ability to provide the required power output level, together with the fact that it does this at a low voltage operation, down to 3 Volts.

3.5 The power supply unit.

The hearing aid unit runs off an unregulated 9 Volts battery power source. The 9 Volts battery power supply is buffered by a 25V 2200μF capacitance and supplies power to the pre-amplifier circuit through a power supply decoupling network.

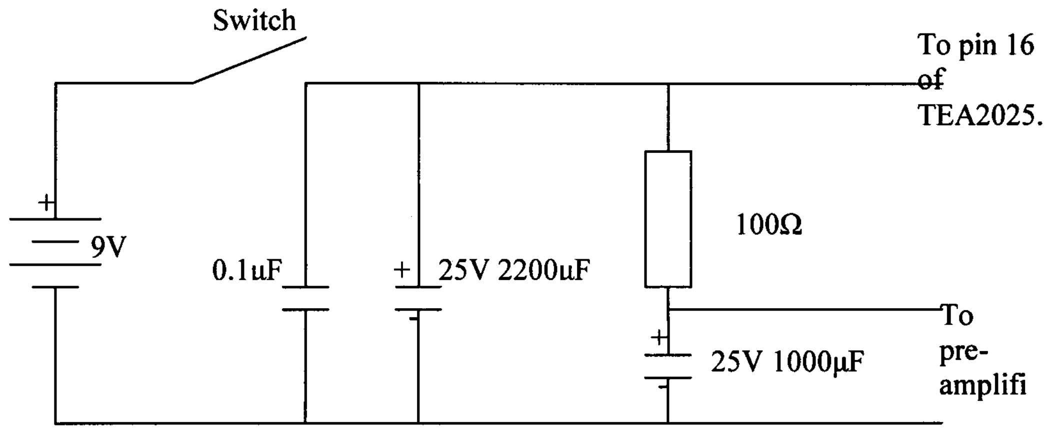

Fig 3.7 circuit Diagram of The Power Supply Unit of The Hearing Aid.

Since both the power amplifier and the pre-amplifier ICs are capable of operation on extended voltages, the need to have a regulated power source is eliminated. The powering of this gearing aid was chosen because of its high efficiency and long standby time.

The entire subsystems were finally assembled together module by module to form the complete work, with the microphone stage connected to the pre-amplifier stage, and the pre-amplifier stage connected to the volume control which was in turn connected to the TEA2025 stereo power amplifier. The earphone section was connected to the TEA2025 stereo power amplifier and finally the pin 16 of the TEA2025 stereo power amplifier and also the pre-amplifier stage were connected to the power supply unit of the hearing aid unit.

A complete circuit diagram of the entire hearing aid unit is shown on the next page.

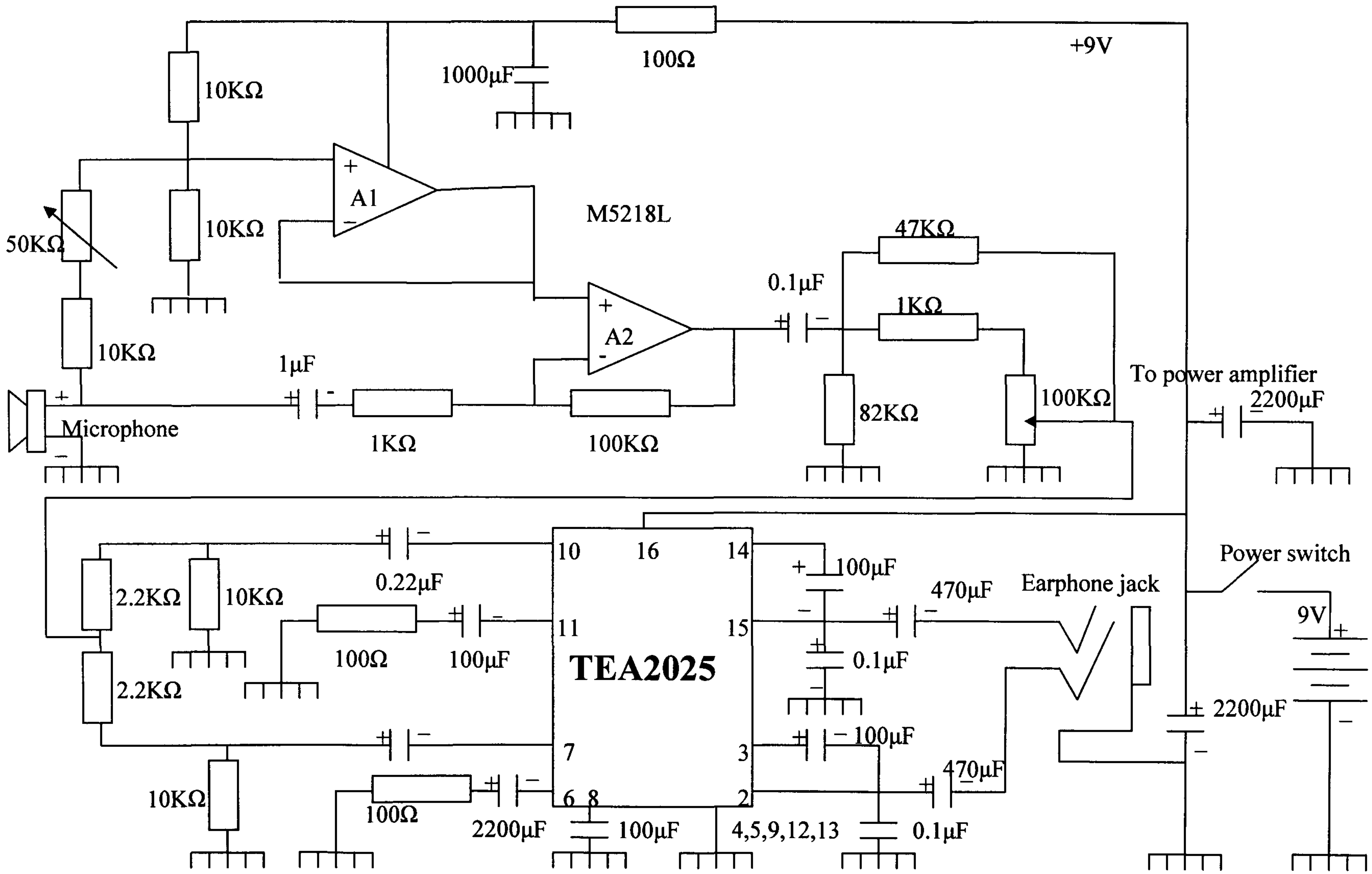

Fig. 3.8 complete circuit diagram of the hearing aid

CHAPTER FOUR

TESTS, RESULT AND DISCUSSIONS.

4.1 Testing of the work.

The following steps were taken to test the work upon completion, and they include:

1. The range: This involves the extent of the distance of the user from the source of sound in order to hear the speaker properly and clearly. It was measured in metres.

2. The loudness: This involves the extent to which the input signal is amplified at the output by the amplification stages so as to accommodate the hearing level of the hearing impaired user. It was measured in decibels (dB}.

3. The standby time: 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.

4. The sonic clarity: This describes the how clear the sound signal produced by the hearing aid is and it is determined by the distance of the source of sound signals from the user.

5. Suitability: This test deals with what level of deafness the hearing aid constructed was suitable for. Unfortunately it was not possible to get a person with a very high level of deafness to try it on so the test was carried out on someone with a moderate hearing deficiency.

4.2 Results Obtained.

After carrying out the various tests described above, the following results were obtained and tabulated as shown below.

Table 4.1 tests carried out and results obtained.

	Tests carried out.	Results obtained.
1	The range.	After carrying out tests on the range of the hearing aid, it was discovered that at distances above 50 metres, the audio quality 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.	When the standby time of the hearing aid was tested, it was observed that using non-rechargeable battery; the hearing aid could be powered for approximately 336 hours (about two weeks). But when a rechargeable battery is made use of, longer operating time could be achieved.
4	The sonic clarity.	When a test on the sonic clarity of the hearing aid unit was conducted, the result obtained was that, the transducers (I.e. the earphones and the microphone) were responsible for the sonic clarity of the unit. When high quality earphones and microphones are used, the sonic clarity of the unit is improved.
5	Suitability of the hearing aid unit.	This test was not properly carried out because of the unavailability of a severely deaf person. But when carried out on a moderately deaf individual, it was discovered that the

		hearing aid at a particular volume suited the hearing level of that individual. As a result it was concluded that the volume control could be used to adjust the hearing aid to fit persons with varying degree of hearing loss.

4.3 Discussion of Results.

The range of the hearing aid is a very important test parameter to be considered when constructing a hearing aid. In the case of this particular unit, at distances over 50 metres, the sound signals picked by the microphone of the hearing aid unit might not be amplified high enough to be heard loud enough by the user. Although at such distances, people tend to raise their voices, thereby compensating for the low signal level.

The loudness level is also an important point to consider also since it helps in accommodating the different levels of hearing impairment suffered by different users, and also helps to compensate for the effects caused by the distance of the source of sound to the user.

The standby time is another important factor that was considered in the design of the power supply unit of this hearing aid. The power supply was designed in such a way that a non-rechargeable battery and a rechargeable battery could both be used, with the former having its advantage in the fact that it is cheaper and easily available, while the later has its advantage in the fact that it lasts much longer and as a result can be used to power the hearing aid for a longer period of time.

The sonic quality of the hearing aid was another factor considered in the design of this hearing aid. In order to have a hearing aid with a good sonic quality, and one which would be clear, then there is the need to make use of high quality microphones and earphones in the construction of such a hearing aid.

The suitability of the hearing aid to the person using it is of utmost importance. It is required that the hearing aid takes care of as many levels of hearing impairment as possible. The volume control in this hearing aid unit takes care of that a much as possible. During the testing of this hearing aid, some other limitations were and shortcomings were experienced.

For example sometimes at very high volumes, a loud noise is produced at the earphone, and this was as a result of signal feedback. Measures taken to correct this were to reduce the volume to an appreciable level, and also to keep the earphone and the microphone as far as possible from each other.

It was also observed that when the full gain (46dB) was used, oscillation was observed at high volume levels. To take care of this, the gain was reduced to a lesser value by inserting an external resistor RF of value 100 ohms into the feedback network.

4.4 Troubleshooting tips.

In order to help the user take care of some minor malfunctions of this hearing aid unit, the following troubleshooting tips on the other page is given as shown.

Table4.2 tips on troubleshooting of the hearing aid device.

	Likely faults	Possible remedies
1	Unit does not turn ON	Ensure that the switch is turned 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 earphone as far as possible from the microphone in the unit.
4	Signal at the earphone is too low.	Check the volume control. Check if the battery is too low or needs replacing.
5	Poor sonic clarity.	Check if the battery is too low. Check the quality of the earphones.

CHAPTER FIVE

CONCLUSIONS

5.1 Summary.

The entire work carried out in this project involved the use of various easily affordable and readily sourced electronic components which included microphones, pre-amplifiers, audio power amplifiers, earphones, capacitors, resistors etc connected together to produce a hearing aid, using the principle of sound amplification.

This process resulted in the design and construction of a hearing aid which could boast of a range exceeding a little over 50 metres, a loudness level high enough to accommodate various levels of hearing disorders suffered by various individuals which was adjustable with the use of the volume control, a standby time which is dependable on the type of battery used (i.e. non-rechargeable or rechargeable type), a hearing aid with a high sonic clarity which was achieved by the use of high quality transducers in the form of microphones and earphones and most importantly a hearing aid which is suitable for people with various level of hearing disabilities.

Also in the process of constructing this hearing aid, and testing it, some problems and difficulties were encountered and these included the problem of feedback signals which generated noises at the earphones, oscillations at high volumes, rampant power outages experienced during the period the device was in construction, inability of getting a severely deaf individual so as to properly test the device, the use of alternatives for some of the components due to the difficulty of obtaining the original ones, unavailability of some instruments to work with in the school laboratory, difficulty in sourcing information and materials required in carrying out this work, and not forgetting the financial difficulties involved.

5.2 Possible Improvements/Additions.

The following possible improvements could be added to this work in future. They include;

1. The work could be made more compact and portable by reducing its size.
2. A lighter and more durable method of packaging could be employed.
3. The use of a wireless earpiece could also be considered.
4. A battery charging unit could also be incorporated into the system.
5. The range of the hearing aid could be improved on.

5.3 Recommendations.

It is highly recommended that a more robust exposure to practical works should be accorded the students so as to help them carry out their final year project and also enable them have a better understanding of the various theories taught to them in class, since it is obvious that the SWEP and SIWES programmes coupled with the normal practical classes is not enough to achieve this.

Also the various workshops and laboratories should be adequately furnished with up-to-date equipments and tools so as to make the student conversant with the new technologies available in carrying out their project works or any other work the students might embark upon.

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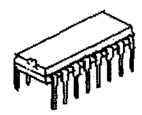
APPENDIX 1

TEA2025 LINEAR INTEGRATED CIRCUIT

STEREO AUDIO AMPLIFIER



DIP-16

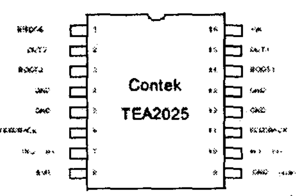
DESCRIPTION

The Contek TEA2025 is a monolithic integrated audio amplifier in a 16-pin plastic dual in line package. It is designed for portable cassette players and radios.

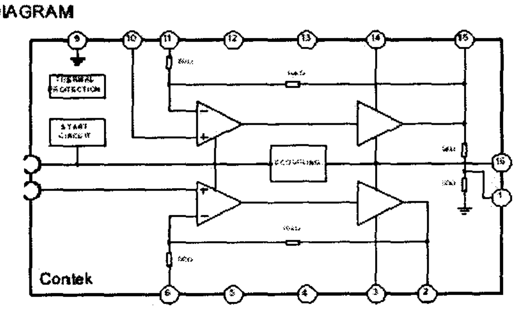
FEATURES

*Working Voltage down to 3V
*Few External components
*High Channel isolation
*Voltage gain up to 45dB (Adjustable with external resistor)
*Soft clipping
*Internal Thermal protection

PIN CONFIGURATIONS



BLOCK DIAGRAM



MITSUBISHI ICs (AV COMMON)

M5218AL/P/FP

DUAL LOW-NOISE OPERATIONAL AMPLIFIERS (DUAL POWER SUPPLY TYPE)

DESCRIPTION

The M5218 are semiconductor integrated circuits designed for a low noise preamplifier in audio equipment and a general-purpose operational amplifier in other electronic equipment. Two low noise operational amplifier circuits displaying internal phase-compensated high gain and low distortion are contained in an 8-pin SIP, DIP or FP for application over a wide rage as a general-purpose dual amplifier in general electronic equipment.

The devices have virtually the same characteristics as the 4557, 4556, 4559 and 741 operational amplifiers.

The units can also be used as a single power supply type and amplifier in portable equipment. It is also suitable as a headphone amplifier because of its high load current.

FEATURES

- High gain, low distortion ······ G_{VO}=110dB, THE=0.0015%(typ.)
- High slew rate, high f_T ······ SR=2.2V/µs, f_T=7MHz(typ.)
- Low noise(R_S=1kΩ)FLAT ······ V_{NI}=2µVrms(typ.)
  RIAA ······ V_{NI}=1µVrms(typ.)
- Operation with low supply voltage ······ V_{CC}≧4V(±2V)
- High load current, high power dissipation ······ I_{LP}=±50mA, P_d=800mW(SIP) P_d=625mW(DIP), P_d=440mW(FP)

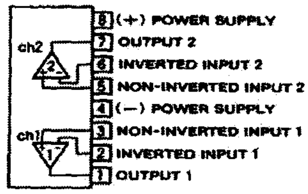
APPLICATION

General-purpose amplifier in stereo equipment, tape decks, and radio stereo cassette recorders; active filters, servo amplifiers, operational circuits in other general electronic equipment.

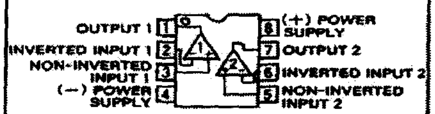
RECOMMENDED OPERATING CONDITINON

Supply voltage range ······ ±2~±16V
Rated supply voltage ······ ±15V

PIN CONFIGURATION (TOP VIEW)

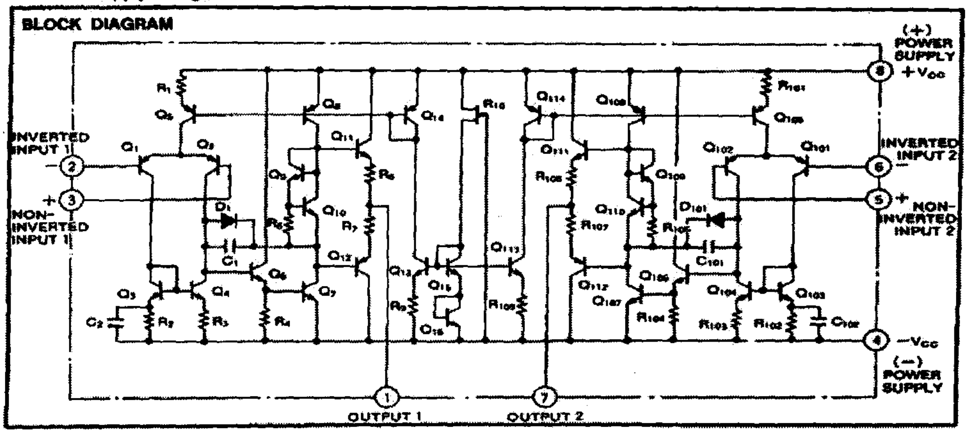


Outline SP5 (AL)



Outline SP4 (AP)
SP2S-A (AFP)

BLOCK DIAGRAM



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MITSUBISHI ELECTRIC

APPENDIX 3

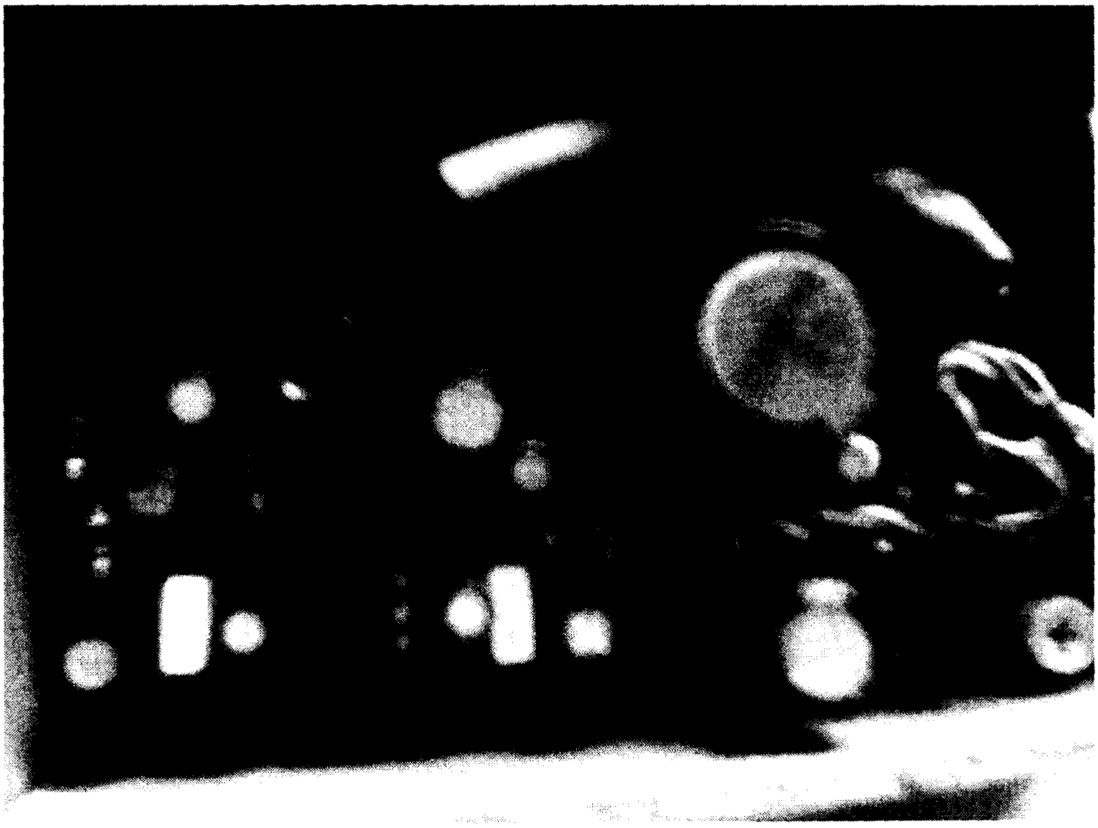

Plate1 internal structure of the hearing aid

APPENDIX 4

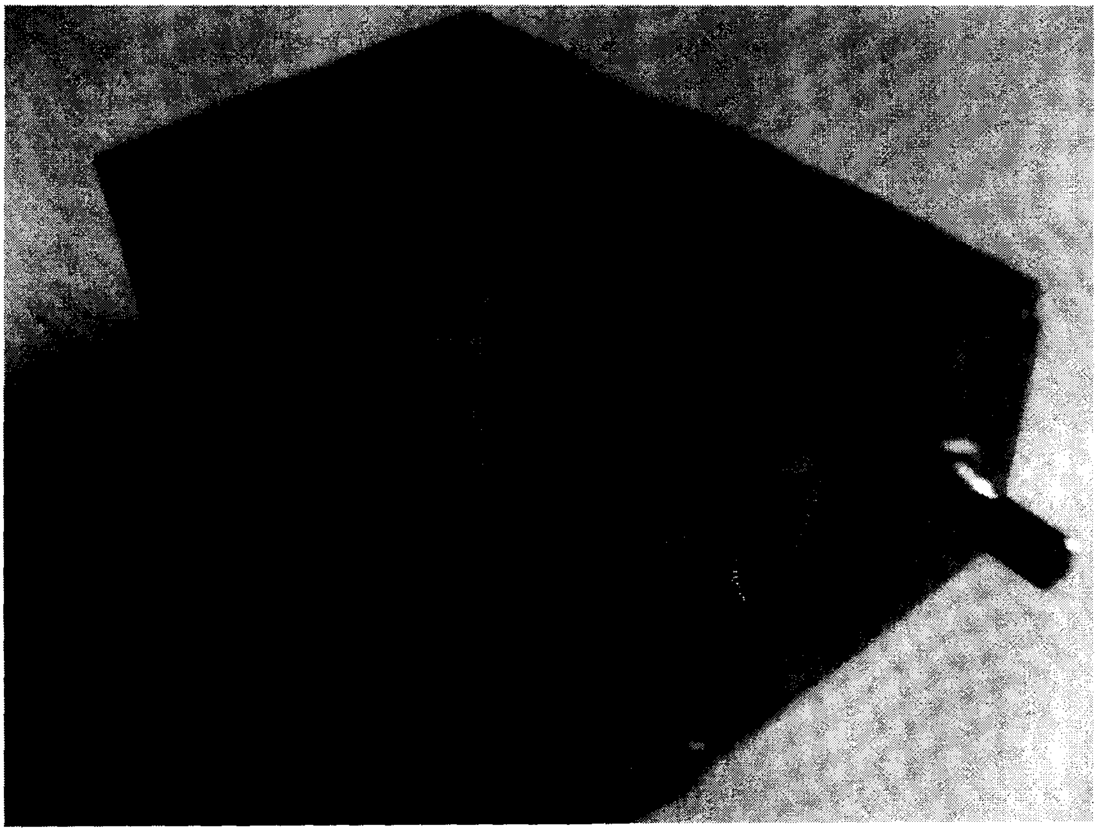

Plate 2 picture of the finished hearing aid