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Design of Low Cost Multi-Use, User-Friendly and Durable Hearing Aid

Sudip Paul[1, 4*], N. Rout[2], P. G. Waghmare[3], R. Patnaik[4]

[1]Department of Biomedical Engineering, North-Eastern Hill University, Shillong, Meghalaya, India
[2]National Institute for Empowerment of Persons with Multiple Disabilities, Chennai, India
[3]Ali Yavar Jung National Institute for the Hearing Handicapped, Mumbai, India
[4]School of Biomedical Engineering, Indian Institute of Technology, Banaras Hindu University, Varanasi, (U.P.), India

Abstract: *The aim is to design a low cost, multi-use, user-friendly and durable hearing aid. Hearing aid is a kind of device which facilitates hearing for hearing impaired person. In addition to have good quality, to keep the low cost was one of the major challenges. So, the plan was to design a hearing aid which will be cost effective and should have good additional features to support hearing impaired person. This will also benefit the poor people where economy is constrained. Looking into such possibilities we have planned to add some features like- wireless door bell vibrator system, light facility, rechargeable battery. Battery generally used is alkaline battery which has a lot of disadvantages and often proves damaging due to its leakage. So to overcome such hurdles, replacing the alkaline battery with rechargeable Li-ion battery was proposed. Although the battery cost is more but life time in comparison to alkaline battery is quite more to compensate the long term investment. For maintenance point of view, the EAC (*Electro Acoustic *Characteristics) is one of the important factors. So, EAC facility is also being added with the newly designed Hearing Aid system. Several types of hearing aid are available in the market, but this system is quite different among them designed using latest techniques for proper hearing. For demonstration purpose, the total work is divided into two working modules; one is for the hearing aid with receiver circuit for wireless door bell vibrator system. As well as torch light facility and low battery indication are there. Other is the transmitting module which is used for transmitting the signal for the wireless door bell vibrator system.*

Keywords: *Hearing Aid, Transmitter module, Receiver module,* Electro Acoustic *Characteristics*

1. INTRODUCTION

The ear is the organ that detects sound waves. It not only acts as a receiver for sound, but plays a major role in the sense of balance and body position. The ear is an integral part of the auditory system.

1.1. Hearing Impairment

A hearing impairment is a full or partial decrease in the ability to detect or understand sounds. Caused by a wide range of biological and environmental factors, hearing impairment generally occurs in human. *"Hearing impaired"* is often used to refer to those who are deaf due to conductive hearing loss while sensory neural hearing loss can also cause hearing impairment. Approximately 120 million people worldwide have significant hearing loss. More than 30% of people over 65 have some type of hearing loss, and 14% of the population between ages 45 and 64 have hearing loss. Close to 8 million people between the ages of 18 and 44 and 7 million children have hearing loss. Sensorineural damage, often referred to as nerve deafness, is the most common form of hearing loss. Sound waves vary in amplitude and in frequency. Amplitude is the sound wave's peak pressure variation while frequency is the number of cycles per second of a sinusoidal component of a sound wave. Loss of the ability to detect some frequencies, or to detect low-amplitude sounds that an organism naturally detects, is a major cause of hearing impairment.

Hearing sensitivity is indicated by the minimal sound that an individual can detect, called the hearing threshold. In the case of people and some animals, this threshold can be accurately measured by a behavioural audiogram. A record is made of the minimal sound that consistently prompts a response from the listener. The test is carried out for sounds of different frequencies. There are also electro-physiological tests that can be performed without requiring a behavioural response. Normal hearing thresholds are not the same for all frequencies in any species of animal. If different frequencies of sound are played at the same amplitude, some will be loud, and others quiet or even completely inaudible. Generally, if the gain or amplitude is increased, a sound is more likely to be perceived. Ordinarily, when animals use sound to communicate, hearing in that type of animal is most sensitive for the frequencies produced by calls, or in the case of humans, speech. This tuning of hearing exists at many levels of the auditory system, all the way from the physical characteristics of the ear to the nerves and tracts that conveys the nerve impulses to the auditory portion of the brain. The severity of hearing loss is measured by the degree of loudness, as measured in decibels, a sound must attain before being detected by an individuals hearing apparatus. Hearing loss may be ranked as mild, moderate, severe or profound. It is quite common for someone to have more than one degree of hearing loss (i.e. mild sloping to severe). Human ears detect sounds in the frequency range of approximately 20 Hz to 20 kHz.

1.2. Hearing Aids

A hearing aid is an electronic, battery-operated device that amplifies sound to allow for improved audition and communication. Hearing aids receive sound through a microphone, which then converts the sound waves to electrical signals. The amplifier increases the loudness of the signals and then sends the sound to the ear through a speaker. Approximately 5% to 10% of adult hearing problems are medically or surgically treatable. The percentage is higher in children if middle ear disease, such as ear infection, is the cause.

1.3. Low Cost

Hearing aids vary in price according to selected style, electronic features, and related needs for professional consultation and rehabilitation services. Purchase price is one of the important factors, and generally the sole consideration in buying hearing aids by people from low income group. Cost of a particular type of battery used by the hearing aid and the rate at which the battery needs to be replaced also influence the overall cost of owning and maintaining a hearing aid. Batteries may last from several days to several weeks depending on the power requirements of the aid, the type of battery, and whether the aid is used routinely with an assistive listening device.

1.4. Multi-Use

Now-a-days the hearing aids which are available in the market are used only for the hearing purpose. So we decided to design the multi functionality and user friendly hearing aids. After developing such kind of device hearing impaired persons will get more benefit from this. The features which will be considered and planned to be added along with the hearing aid are as follows:

1.4.1. Door Bell Vibrator System

The transmitter unit of the wireless door bell vibrator system will be placed outside the door. After pressing the push button switch it will transmit the signal of 33 KHz. The receiver circuit is placed within the hearing aid cabinet. When the receiver unit will receive the 33 KHz signal then vibrator will vibrate. Vibration is sufficient for recognition. It will not create any problem with the normal human body.

1.4.2. Battery Should Be Rechargeable

In this total circuitry, 3.7 Volt rechargeable Li-ion battery was used for power supply. They are currently one of the most popular types of battery for portable electronics, with one of the best energy-to-weight ratios, no memory effect, and a slow loss of charge when not in use. Here power requirement is minimum, so the battery will be charged condition for prolong time.

1.4.3. Light facility and Low Battery Indication

The light facility is also provided with this model. If the deaf person is facing any problem at night due to the unavailability of proper light they can use light. The light intensity is too good that they can be facilitated in vision. Also there is one option for low battery indication. If the battery voltage is not sufficient for driving the circuit, so at that time BLUE LED (low battery indication) will NOT glow. So, immediately charge is needed.

1.4.4. EAC (Electro Acoustic Characteristics) Facility

EAC is one of the important features in the hearing aid. It is generally used for testing the hearing aid gain of different frequencies, the overall gain, and most important- the noise factor. Electro Acoustic Characteristics is done by the help of Hearing aid analyser.

1.4.5. Acceptance of Hearing Aid

After studying all the conventional hearing aids, we were decided to develop the ***Body Level (Pocket Model) Hearing Aid***. This type of hearing aid is easy to handle and maintenance. The circuit and battery are fixed together. Body level hearing aids are sturdy, less expensive to buy and maintain. They also have lesser problems of feedback squeal if the ear moulds are not good. It is suitably kept in the pocket and easily carried by the children.

2. DESIGN

The detailed circuit description of the dissertation titled "Design of Low Cost Multi Use Hearing Aid" is explained along with circuit diagram. For better understanding total circuit diagram is divided into various sections and each section circuit description with its circuit diagram is provided in this chapter. The details are as follows:

2.1. Hearing Aid Circuit Description

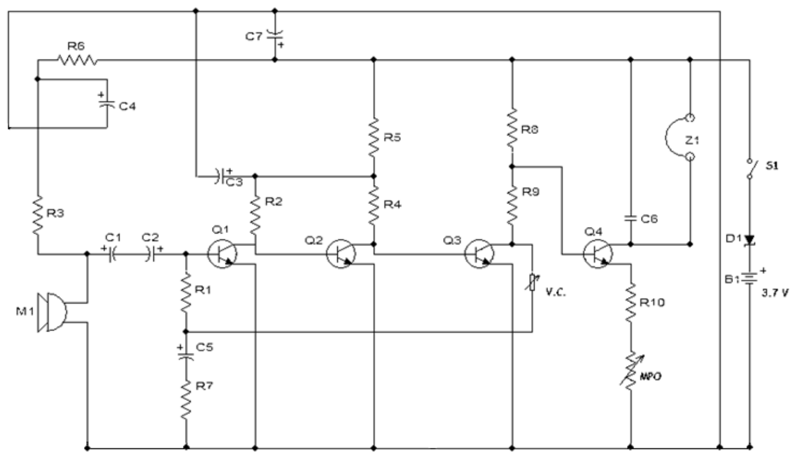

Figure1. *Detailed circuit diagram of Hearing aid*

The power supply to the hearing aid circuit Fig: 1 is drawn from a 3.7 Volt Li-ion rechargeable battery after sampling in to the hearing aid working voltage between 1.0V to 1.5V by adding a 2.4 Volt Zener diode (tolerance of +/-5%) in series with the battery supply. An on/off switch (S1) is placed for turning the hearing aid on and off. When hearing aid is switched ON, the power is fed to the base of the transistor Q1 (BC 549) through resistors (R1) and volume control (VC). Capacitors (C1 and C2) are used to block the DC signal and pass the varying electrical signal which is coming from the microphone. The main use of microphone is to convert the sound signal into corresponding electrical signal. When the transistor Q1 got the power to its base and to the collector via resistors (R5 and R2) the transistor will be ON according to the base bias. The emitter of Q1 is grounded. C3 is used to block the DC signal. The output of Q1 is fed to the base of the transistor Q2 (BC 549). Here also two resistors (R4 and R5) are connected to the collector for getting the proper amplifying signal and base bias to the transistor Q3, The emitter of Q2 is also grounded. The output of the transistor Q2 is coming from its collector as a amplified signal and fed to the base of the transistor Q3 (BC 549). Resistors (R8 and R9) are connected with the collector of the transistor Q3. After getting the proper voltages to the base circuit will active and transistor will be ON. The emitter of Q3 is grounded. Volume control which has connected with the collector of Q3 to the base of Q1works as a feedback path. R1 is used for proper controlling the signal. C5 is used for blocking the DC signal. C7 is used as a filter for eliminating the noise from the total circuit. The last stage of amplification is done by the help of transistor Q4 (BC 549). Here the base is getting voltages from the collector of Q3. MPO is used to control the output of the Earphone in the close vicinity of 20dB. Earphone is connected with the collector of Q4. C6 is used to block if any DC signal will come. Finally the output is coming from the earphone (Z1). So, Microphone is a device, which converts the variations of sound pressure in a sound wave into corresponding electrical variations in an electrical signal. This converted electrical signal is amplified (to increase the signal amplitude) by means of the amplifier with the help of active and passive components. The amplified electrical signal need to be converted into the sound signal for hearing and this was done by the receivers (earphones) and to deliver the sound through the ear canal.

2.2. Transmitter Circuit for Wireless Door-Bell Vibrator System

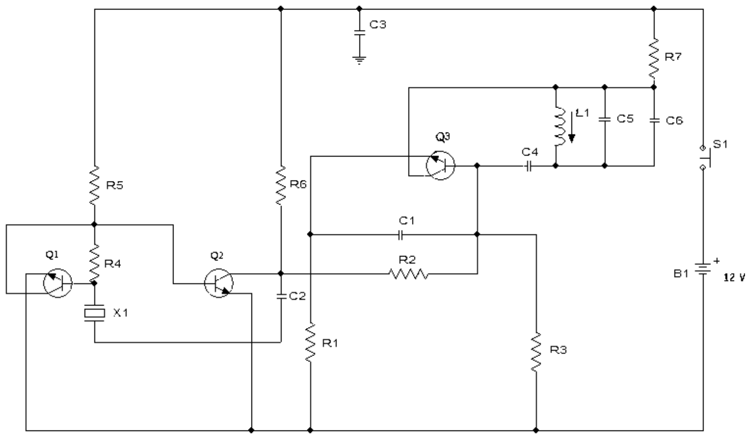

Figure2. *Detailed circuit diagram of transmitter circuit for wireless door-bell vibrator system*

The power supply of the transmitter circuit (fig: 2) is coming from the 12 Volt alkaline battery. One push button on/off switch (S1) is placed after power supply. When the switch is ON the power is fed to the base of the transistor Q1 (9014) through a resistor (R5). R5 is used for controlling the proper voltage of the base of the transistor. According to the base bias, the transistor will be ON condition. The output from the collector of Q1 is connected to the base of the transistor Q2 (9014). After getting the base drive the transistor will be ON. The output of the Q2 is connected with the base of the transistor Q3 (9018) for supplying the base bias voltage. For getting the proper voltages at the base of transistor 9018, the resistors (R6 and R2) are essential. The transistor is essential for tuning purpose. The signal, which is coming from the collector of the transistor Q3, is connected with the transmitting coil (L1) and capacitors (C5 and C6). The transmitting frequency is depending upon the value of L1, C5 and C6. In this circuit, 24 µH coil and 0.47 µF capacitors (two nos.) in parallel are used for getting the proper transmitting frequency.

According to the formula,

[$f = 1/\{2\pi\sqrt{(LC)}\}$], 33 KHz frequency was generated. This frequency is transmitted through air. R7 is used for delivering the accurate voltage at the transmitting end. The 33 KHz crystal oscillator (X1) is connected with the base of Q1 to the collector of Q2. Crystal is used for create an electrical signal with a very precise frequency.

2.3. Receiver Circuit for Wireless Door-Bell Vibrator System

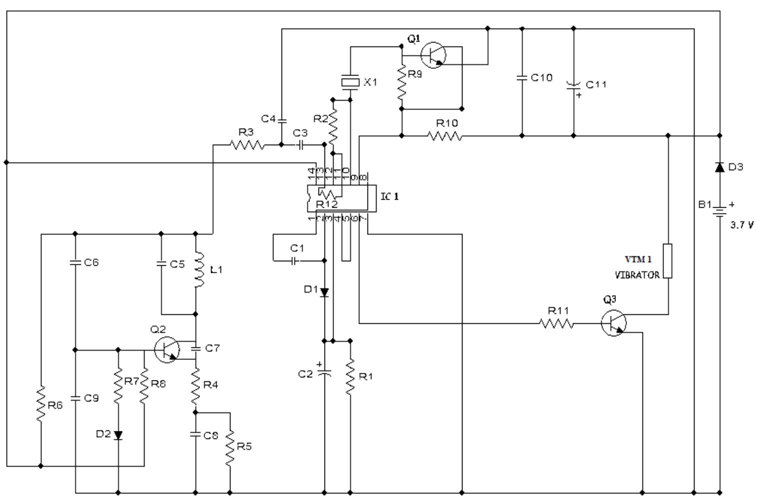

Figure3. *Detailed circuit diagram of Receiver Circuit for wireless door-bell vibrator system*

Fig: 3 describes the receiver circuit having supply voltage of 3.7 Volt. But this much of voltage is not applicable for the receiver circuit. So, a 1N4148 diode is used to operate the voltage at 3 Volt. This 3 Volt is supplied to the circuit. In this circuit the most important part is the tuning. The transmitting signal is 33 KHz. So, circuit is designed in such a way that it is receiving 33 KHz signal by the help of L1 and C5. Here we used L1 as 0.23 mH and C5 as 0.1 µF.

According to the formula,

[$f = 1/\{2\pi\sqrt{(LC)}\}$] the receiving frequency is also 33 KHz. So, it matches the transmitting frequency. It is working at the distance from 50 to 70 feet approximately. The receiving signal is fed to the base of the transistor Q2 (9018). C6 and C9 are used to eliminate the DC signal. Diode 1N4148 is used to maintain the appropriate voltage on the base of the 9018. Capacitor C7 is also responsible for proper tuning. After proper tuning the signal goes to the pin no. 13 of the CD 4069. Here C3 and C4 are used to block the DC signal and passes only the receiving signal. When the receiver circuit will receive the transmitting signal, the voltage of pin no 13 will be high. Correspondingly, pin no 12 will be low. Pin no 12 and Pin no 11 is shorted. So, pin no 11 will be also low. According to the pin configuration the pin no 10 will be high. This high signal will be connected to the 33 KHz crystal for maintaining the proper frequency. This oscillator is connected to the base of the transistor Q1 (9014). The transistor will be ON after getting base bias. The output is getting from the collector and connected to the pin no 9. So, pin no 9 will be high and according to the pin configuration pin no 8 will be low. This low signal is passing from the pin no 8 to pin no 1 and as per pin configuration, the pin no 2 will be high condition. Here one diode (1N 4148) is used to maintain the proper voltages on pin no 3 and this will also be high. As the voltage of pin no 3 is high, the pin no 4 voltage will be low. Pin no 4 and 5 are shorted. So, pin no 5 voltage is also low. Then the final output is coming from the pin no 6 as high signal. This is the actual receiving signal which is fed to the base of the transistor Q3 (BC 547) through a resistor R11. R11 is used to maintain the proper speed of the vibrator motor. When the transistor will get base drive it will also drive the vibrator motor which is connected to the collector of Q3. Finally we are getting output as vibration.

So finally, we conclude that when we press the transmitter switch which will be placed outside the door, the receiver unit will receive the transmitting signal (33 KHz) and send this signal to the vibrator circuit for proper vibration. This receiver circuit is receiving the transmitting signal from 50 to 70 feet distance approximately.

2.4. Low Battery Indication as well as Light Facility Circuit

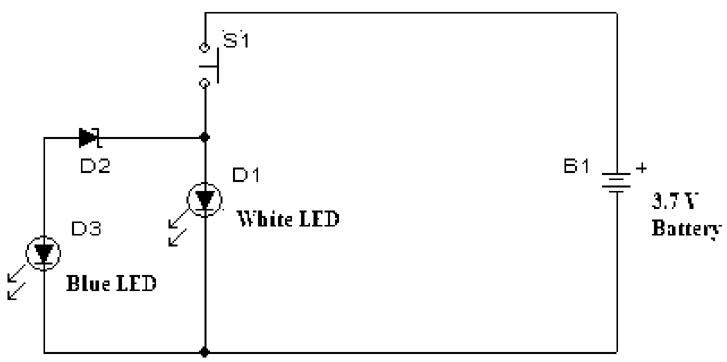

Figure4. *Detailed circuit diagram of Low battery indication as well as light facility*

The supply voltage is 3.7 Volt. After the battery one push button switch is used. After that the line is divided into two paths, one for torch light and another for low battery indication via Zener diode. When the switch is pressed the torch light (white LED) will glow and the light is sufficient at dark condition. If the battery voltage is sufficient, then only the blue LED will glow. Otherwise, the blue LED will not glow. So, at that time battery should be charged. So, above circuit is used for torch light and low battery indication also.

3. ANALYSIS

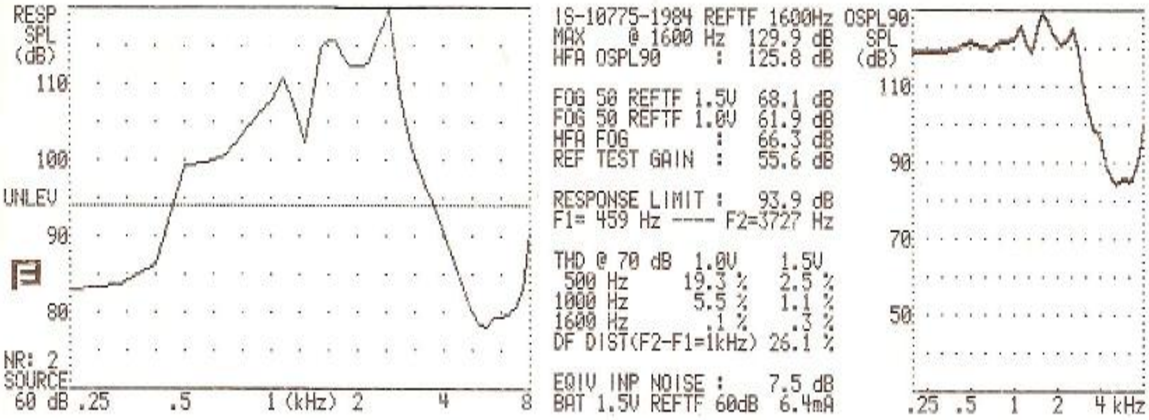

Figure5. *Analysis of the developed hearing aid*

The acoustic response characteristics (Fig. 5) of hearing aids are described in terms of frequency gain, input-output and output limiting. Gain of the hearing aid is the amount of sound that is added to the input signal. If a speech signal enters the hearing aid at 50 dB and is amplified to 90 dB, the amount of gain is 40 dB. The frequency gain response of a hearing aid is the amount of gain as a function of frequency. Because most hearing losses are greater at some frequencies than at others, the ability to manipulate gain selectivity in different frequency regions is important. An input-output characteristic of a hearing aid is the amount of gain as a function of input intensity level. The input-output function can be linear or non-linear. Output limiting refers to the maximum intensity of the amplified signal. If a signal of 100 dB were delivered to a hearing aid that had 40 dB of gain, without a limiting circuit, the output would be 140 dB. Such a high intensity signal would not only be intolerable, but would be damaging to the cochlea, so it is necessary to limit the maximum intensity level the aid can generate. The hearing aid performance was checked by the hearing aid analyser **(FONIX FD40-D).** According to the result shown above there are two different graphs, one is for 60 dB test and another one is for 90 dB test. As per result the maximum gain obtain from 90 dB graph is 129.9 dB. But hearing aid will work upto 125.8 dB. It is called as HFA or hearing discomfort level. FOG stands for Full on Gain, means minimum distortion with maximum gain. Here Full on Gain test was done in two modes, one is for 1.5 Volt supply and another one is 1 Volt supply. Less than 1 Volt the hearing aid will work. According to the result FOG in 1.5 Volt is 68.1 dB and 1 Volt is 61.9 dB. So, it works for two conditions. REF TEST GAIN means reference test gain which is the difference between maximum gain and minimum gain. According to the 60 dB graph the maximum gain is 130 dB and minimum is 77 dB. So the difference is 53 dB. Here the result shows as 55.6 dB. So, practical value closes to the theoretical value. THD stands for Total Harmonic Distortion. Here the test was done in three different frequencies of two different voltages. As per standard the percentage value for the case of 1 Volt always lies below 10 % and percentage value for the case of 1.5 Volt should lies below 7 %. Values are all in normal range. Only the percentage value for the case of 1 Volt in 500 Hz is slightly high. But that will not create any bad effect for hearing aid performance. One important parameter is Equipment Input Noise. Here the EQIP INP NOISE shows only 7.5 dB which is also within the normal range. The normal range of the EQIP INP NOISE is below 30 dB. After checking all the parameters it is suggesting that the instrument is ready to use and it will not create any harmful condition to the hearing impaired person.

4. CONCLUSION

Multi Use Hearing Aid unit was designed and fabricated successfully. This unit is economical, portable, durable and easy to handle. The output of the unit is found as desirable. The gain of the hearing aid is so good that it can be classified as strong class hearing aid. The transmitting frequency of the wireless door bell vibrating system is 33 KHz and it can cover the distance approximately 50 to 70 feets. Vibration is so good that any one easily recognise it. Rechargeable battery used for prolong life. There is low battery indication and the light facility is available. After a long time use of hearing aid, the instrument must be checked with the hearing aid analyser. So, Electro Acoustic Characteristics is also available with this model.

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