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Bone Conduction Hearing Aid

Charan Kumar A[1], Hitendra K[2], Jampuram Sai Pavan Kalyan[3], T. R. Chenthil K
[1, 2, 3]Electronics and Communication Engineering, Jeppiaar Engineering College, ANNA University: Chennai

Abstract: The GSM based Soundbite hearing system allows people with hearing disability to hear the sounds via bone conduction to wear an intraoral device and a small microphone in the deaf ear to regain lost hearing. This device consists of GSM modem, PIC16F877A controller and audio amplifier unit. GSM modem will receive incoming calls and automatically answer the call via AT Commands. Then incoming voice signal is converted into low frequency vibration signal that fed through the teeth to cochlea. Unlike implantable bone conduction hearing aids, Sound Bite requires no surgery. Rather, it is the world's first removable and non-surgical hearing solution to use the well-established principle of bone conduction to imperceptibly transmit sound via the teeth. Custom made for each person, Sound Bite is simple, removable, and totally non-invasive. This paper introduces a novel hearing aid named artificial ultrasonic bone conduction hearing device, which is different from the traditional hearing aid in two sides: 1) sound conduction manner, 2) human perceptive principles. We focus on discussing the structure of the hearing aid and the research of frequency transposition algorithm. In addition, we design algorithm experimental platform and some sample electromechanical transducers.

I. INTRODUCTION

A. Overview

Bone conduction is the principle of sound propagated through the skull bone that results in a stimulation of the basilar membrane causing a hearing perception. Every person with normal hearing has experience with this; the reason we hear our own voice differently from a recording than when we listen to ourselves talking is largely due to the fact that approximately 50% of what we hear of our own voice when we speak is transmitted through the skull bone directly to the cochleae rather than through the air around the head to the ears. Try sticking you fingers in your ears and talk; you still hear a lot of your own voice.

Although the actual mechanisms that produces the hearing sensation when sound is transmitted through bone conduction is not known in detail, bone conducted sound is used in several fields. Bone conduction is utilized in audiology investigations and diagnosis of the hearing function, where it can be used to distinguish between conductive and cochlear dysfunction Bone conduction is the principle of sound propagated through the skull bone that results in a stimulation of the basilar membrane causing a hearing perception. Every person with normal hearing has experience with this; the reason we hear our own voice differently from a recording than when we listen to ourselves talking is largely due to the fact that approximately 50% of what we hear of our own voice when we speak is transmitted through the skull bone directly to the cochleae rather than through the air around the head to the ears. Try sticking you fingers in your ears and talk; you still hear a lot of your own voice.

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Conventional BCDs were developed in the beginning of the 20th century with a sound processor attached with spectacles, steel spring headbands, or soft headbands. The vibrations that are produced are transmitted through the skin to the skull bone, and further to the cochlea in the inner ear, bypassing a conductive impairment in the external or middle ear. The development of the conventional BCD was a big step forward in the rehabilitation of these patients; however, the devices have some drawbacks. The static pressure on the skin needs to be high enough to transmit the vibrations to the cochlea, leaving the skin compressed, which might lead to discomfort and skin problems in the attachment area. The primary issue with conventional BCDs, applied with a headband as well as with frames of a pair of glasses, is related to the static pressure of approximately 2 N towards the skin and the soft tissues. Furthermore, the skin attenuates the high-frequency vibrations, and therefore, the sound that reaches the cochlea has a lower content of high frequencies.

B. Purpose

This hearing device is designed to use the natural amplification of your ear. Any sound in that coming from GSM Modem. It uses a digital processor (PIC16F877A) to transmit to the sound to actuator which needs very little power to generate the vibrations that travel through bone, which in turn sends those sound vibrations into your cochlea through your teeth. This way, the sound is transported from your impaired ear directly to your hearing ear. This hearing device will be fitted to the upper left or right teeth in the back of your mouth. This doesn't require any of your teeth to be altered, and the device can be inserted and removed easily. This hearing device is a flat piece and has wireless capabilities that can pick up sound transmissions from the behind-the-ear microphone.

The inner ear receives sound vibrations in two different ways; through the ear canal, ear drum and middle ear (air conduction) and through the skull bone (bone conduction). Conventional hearing aids work using air conduction but for a number of reasons some deaf children can't wear conventional hearing aids. A bone conduction hearing device works better for them because of the type of deafness that they have.

A bone conduction hearing device (also known commonly as a BAHA) works by transmitting sound vibrations through the bone. The sound processor converts the sound picked up by its microphone into vibrations. The sound processor then transmits the vibrations through the bones of the skull to the cochlear of the inner ear. The inner ear then converts these (sound) vibrations into electrical signals that the brain interprets as sound. A bone conduction hearing device therefore allows a child to hear sounds that can't pass through the ear in the usual way, which is through the outer and middle ear.

A bone conduction hearing aid or the sound processor of a bone conduction hearing implant worn on a headband can both be used by children on a temporary basis if their hearing is expected to improve with time. They can also be used permanently by children when it is not advisable for them to have surgery.

A BCHD may be an option if your child has a conductive deafness and doesn't benefit from wearing a conventional hearing aid.

BCHDs are suitable for children who may have permanent or long-standing conductive deafness such as Microtia (malformation of the external part of the ear), atresia (absence of the ear canal), which means they can't wear a conventional hearing aids, Congenital syndromes, Middle ear disease, Mixed deafness combination of Sensorineural Hearing Loss (SNHL) and Conductive Hearing Loss (CHL), Permanent deafness affecting one ear only (known as unilateral or single sided deafness)

A bone conduction hearing aid may also be considered for children with perforations of the eardrum, glue ear, persistent ear infection (discharging ears) that prevents a child from wearing an ear mould in their ear and therefore can't use an Air Conduction Hearing Aid (ACHA) consistently

II. LITERATURE SURVEY

A. The Bonebridge active bone conduction system: a fast and safe technique for a middle fossa approach.

AUTHORS: C Carnevale, M Tomás-Barberán, G Til-Pérez, P Sarría-Echegaray

YEAR: 2019

The transmastoid pre-sigmoid approach is always the preferred choice for implantation of the Bonebridge active bone conduction system in patients with a normal anatomy. When an anatomical variant exists or a previous surgery has been performed, a retrosigmoid approach or middle fossa approach can be performed. The surgical time was shorter than 30 minutes in all cases, and only 14 seconds were needed to create a 14 mm bone bed. No complications were observed during the follow-up period (6-45 months). Use of the Neuro Drill for the middle fossa approach is an easy technique. It significantly decreases the surgical time, without increasing the complication rate.

B. A Comparative Study of a Novel Adhesive Bone Conduction Device and Conventional Treatment Options for Conductive Hearing Loss.

AUTHORS: Piotr H Skarzynski, Anna Ratuszniak, Kamila Osinska , Magdalena Koziel , Bartlomiej Krol , Katarzyna B Cywka , Henryk Skarzynski

YEAR: 2019

To compare the audiological performance with the novel adhesive bone conduction hearing device (ADHEAR) to that with a passive bone conduction (BC) implant and to that with a bone conduction device (BCD) on a soft band. Users of the passive BC implant received comparable hearing benefit with the ADHEAR. The mean aided thresholds in sound field measurements and speech understanding in quiet and noise were similar, when subjects were evaluated either with the ADHEAR or the passive BC implant. The audiological outcomes for the non-implanted group were also comparable between the ADHEAR and the BCD on soft band. Users of the passive BC implant received comparable hearing benefit with the ADHEAR. Based on our initial data, the ADHEAR seems to be a suitable alternative for patients who need a hearing solution for conductive hearing loss but for medical reasons cannot or do not want to undergo surgery for a passive BC implant.

C. Automatic localization of closely spaced cochlear implant electrode arrays in clinical CTs

AUTHORS: Y. Zhao, B. M. Dawant, R. F. Labadie, and J. H. Noble

YEAR: 2018

Cochlear implants (CIs) are neural prosthetic devices that provide a sense of sound to people who experience profound hearing loss. Recent research has indicated that there is a significant correlation between hearing outcomes and the intracochlear locations of the electrodes. We have developed an image-guided cochlear implant programming (IGCIP) system based on this correlation to assist audiologists with programming CI devices. A validation study was conducted on 129 clinical CTs of CI recipients implanted with three models of closely spaced arrays. Ninety-eight percent of the localization results generated by the proposed method had maximum localization errors lower than one voxel diagonal of the CTs. The mean localization error was 0.13 mm, which was close to the rater's consistency error (0.11 mm). The method also outperformed the existing automatic electrode localization methods in our validation study.

D. Hearing impaired aid and sound quality improvement using bone conduction transducer

AUTHORS: Arun Kumar, Dilli Ganesh, Sudhakar, Chinnusamy

YEAR: 2017

The project aim is to design a smart earplug system integrated with non-invasive bone conduction technique which is capable of doing some advanced audio processing to provide voice enhancing, noise filtered audio for the hearing-impaired people. People with hearing loss problem, often use low quality analog hearing aids, which are nothing but a simple analog audio amplifier or a passive audio reinforcement system. The system is also designed to work as an embedded music player, a life activity tracker and a smartphone companion. It can even read the SMS that is just received on your smartphone into your ear.

E. Adaptive Feedback Cancellation for Realistic Hearing Aid Applications

AUTHORS: Falco Strasser, Henning Puder

YEAR: 2015

Acoustic feedback is a well-known phenomenon in hearing aids. Under certain conditions it causes the so-called howling effect, which is highly annoying for the hearing aid user and limits the maximum amplification of the hearing aid. The standard adaptive feedback cancellation algorithms suffer from a biased adaptation if the input signal is spectrally colored, as it is for speech and music signals. Due to this bias distortion artifacts (entrainment) are generated. In this paper, we present a sub-band feedback cancellation system which combines decorrelation methods with a new realization of a known non-parametric variable step size. To apply this step size in the context of adaptive feedback cancellation, a method to estimate the signal power of the desired input signal, i.e., without feedback, is necessary. A major part of this paper is spent with the theoretical derivation of this estimate.

F. Improvement of voice quality and prevention of deafness by a bone-conduction device

AUTHORS: Hyung-Woo Park, Myung-Sook Kim and Myung-Jin bae
YEAR: 2014
The increasing use of mobile phones and other portable devices as a primary means of communication outside of homes makes the current noise condition even worse. During the exchange of information on these devices, the volume is usually set 15 dB higher than the surrounding noise in order for the sound to be perceived more clearly. Hence, the sum of noise on these devices is usually estimated to be around 110 dB. This level of noise can cause noise-induced hearing impairment or even hearing loss to users when continued for a long time. A bone-conduction system can be a possible solution to reducing the noise while enhancing the quality of voice signals in mobile phones. In this study, we suggest that the implementation of the bone-conduction feedback system in mobile phones will raise the ratio of signal to noise with about 17 dB, enhancing the quality of voice signals. In this paper, we propose a solution based on improving the sound quality of mobile phones with a bone-conduction system. The bone-conduction system uses a bio-engineered technology that can be operated for long periods of time, without causing any discomfort, while transferring sound directly to our inner ears.

G. Automatic Adaptation of the Time-Frequency Resolution for Sound Analysis and Re-Synthesis

AUTHORS: Marco Liuni, Axel Robel, Ewa Matusiak, Marco Romito, Xavier Rodet
YEAR: 2013
Presented an algorithm for sound analysis and re-synthesis with local automatic adaptation of time-frequency resolution. The reconstruction formula we propose is highly efficient, and gives a good approximation of the original signal from analyses with different time-varying resolutions within complementary frequency bands: this is a typical case where perfect reconstruction cannot in general be achieved with fast algorithms, which provides an error to be minimized. We provide a theoretical upper bound for the reconstruction error of our method, and an example of automatic adaptive analysis and re-synthesis of a music sound.

H. Transform domain prediction error method for improved acoustic echo and feedback cancellation

AUTHORS: Jose M. Gil-Cacho; Toon van Waterschoot; Marc Moonen; Suren Holdt Jensen
YEAR: 2012
The prediction error method (PEM) has been successfully applied in double-talk-robust acoustic echo cancellation (AEC) as well as in acoustic feedback cancellation (AFC). The main idea in both applications basically consists in decorrelating the adaptive filter input and error signals. This is done by whitening these signals with the inverse of a near-end signal model before the filter adaptation. The choice of the near-end model greatly affects the performance and complexity of the resulting AFC/AEC algorithms, oftentimes turning the algorithm impractical for real-world real-time applications. This paper proposes the use of discrete cosine transform (DCT), in conjunction with a simple near-end signal model, to boost the performance of PEM-based algorithms both in double-talk-robust AEC and AFC while only marginally increasing the computational complexity.

I. Just noticeable and objectionable group delays in digital hearing aids

AUTHORS: J Agnew, J M Thornton
YEAR: 2010
Group delay in a digital signal processing (DSP) hearing aid may be perceived as an echo in the sound heard by a wearer listening to his or her own voice, due to a combination of unprocessed sound received at the ear through head and air pathways and delayed sound reaching the eardrum through the hearing aid. Depending on the amount, this delay may be audible or objectionable and can even result in auditory confusion. This study presents results from 18 subjects listening to their own voices through a DSP hearing aid with a variable group delay. The subjects varied the length of the delay and determined the amounts that were noticeable and objectionable as compared to the undelayed condition, while listening to their own amplified voices.

Results indicated that a delay of 3 to 5 msec was noticeable to the listeners in 76 percent of the trials, and a delay of longer than 10 msec was objectionable 90 percent of the time.

J. Better speech recognition with cochlear implants

AUTHORS: B S Wilson, C C Finley, D T Lawson, R D Wolford, D K Eddington, W M Rabinowitz

YEAR: 2008

A cochlear implant system consists of one or more implanted electrodes for direct electrical activation of the auditory nerve, an external speech processor that transforms a microphone input into stimuli for each electrode, and a transcutaneous (rf-link) or percutaneous (direct) connection between the processor and the electrodes. We report here the comparison of the new strategy and a standard clinical processor. The standard compressed analogue (CA) processor presented analogue waveforms simultaneously to all electrodes, whereas the new continuous interleaved sampling (CIS) strategy presented brief pulses to each electrode in a nonoverlapping sequence. Seven experienced implant users, selected for their excellent performance with the CA processor, participated as subjects. The new strategy produced large improvements in the scores of speech reception tests for all subjects. These results have important implications for the treatment of deafness and for minimal representations of speech at the auditory periphery.

III. PROPOSED SYSTEM

A. Existing System

People with hearing loss problem, often use low-quality analogue hearing aids, which are nothing but a simple analogue audio amplifier or a passive audio reinforcement system. They are less flexible and are just designed to gather sound energy and direct it into the ear canal at higher volumes. But with the availability of miniature microphone sensors and extremely low-power digital signal processors, hearing aids can be constructed with audiometric and cognitive intelligence that matches the hearing loss, physical features and lifestyle of the wearer, thus delivering more value and benefit for the hearing-impaired person.

Several hearing devices were found for outer drum problem only. Inner drum problem is usually a permanent condition which impairs one's ability to tell the direction a sound is coming from. It can also be responsible for difficulty understanding speech or conversations on the deaf ear side, particularly in a noisy environment. Some medical treatments have been proposed but that needs surgery. Due to that surgery, it may lead to additional problems.

1) *Drawbacks:* The conventional BCDs are less powerful than the BAHA. The MPO limits the output force level of the device, and the patient must have sufficient headroom for ordinary speech levels to avoid distorted sound. A reduced MPO also limits the useful gain of the device. In active transcutaneous BCDs, the MPO is reduced about 10–15 dB by using an inductive link through the skin. The engagement of inserting screws into deeper areas of the temporal bone in humans is hazardous, with a high risk of damaging the facial nerve, semi-circular canals, and other delicate structures. The deeper the engagement in the bone, the more complicated the surgery. This statement might be a reason why none of the middle-ear implants have reached the success that many believed they would in the 1990s.

B. Proposing System

This hearing device is designed to use the natural amplification of your ear. Any sound in that coming from GSM Modem. It uses a digital processor (PIC16F877A) to transmit to the sound to a piezoelectric actuator which needs very little power to generate the vibrations that travel through bone, which in turn sends those sound vibrations into your cochlea through your teeth. This way, the sound is transported from your impaired ear directly to your hearing ear. This hearing device will be fitted to the upper left or right teeth in the back of your mouth. This doesn't require any of your teeth to be altered, and the device can be inserted and removed easily. This hearing device is a flat piece (in Real-Time Product) that contains the capabilities that can pick up sound transmissions from the GSM module.

1) Benefit of Proposed System: The benefit of proposed system is that it overcomes the drawback of the existing system as it supports multiple functionalities and is easy to use on a daily basis. It provides better hearing ability and is less painful to use.
2) Architecture of the Proposed System: The Architecture of the optical character recognition system on a grid infrastructure consists of the three main components.

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They are: -
- PIC16F877A
- SIM800A GSM Module
- UART Cable
- Voice Module
- Speaker
- Relay
- Vibrating Motor

C. Block Diagram

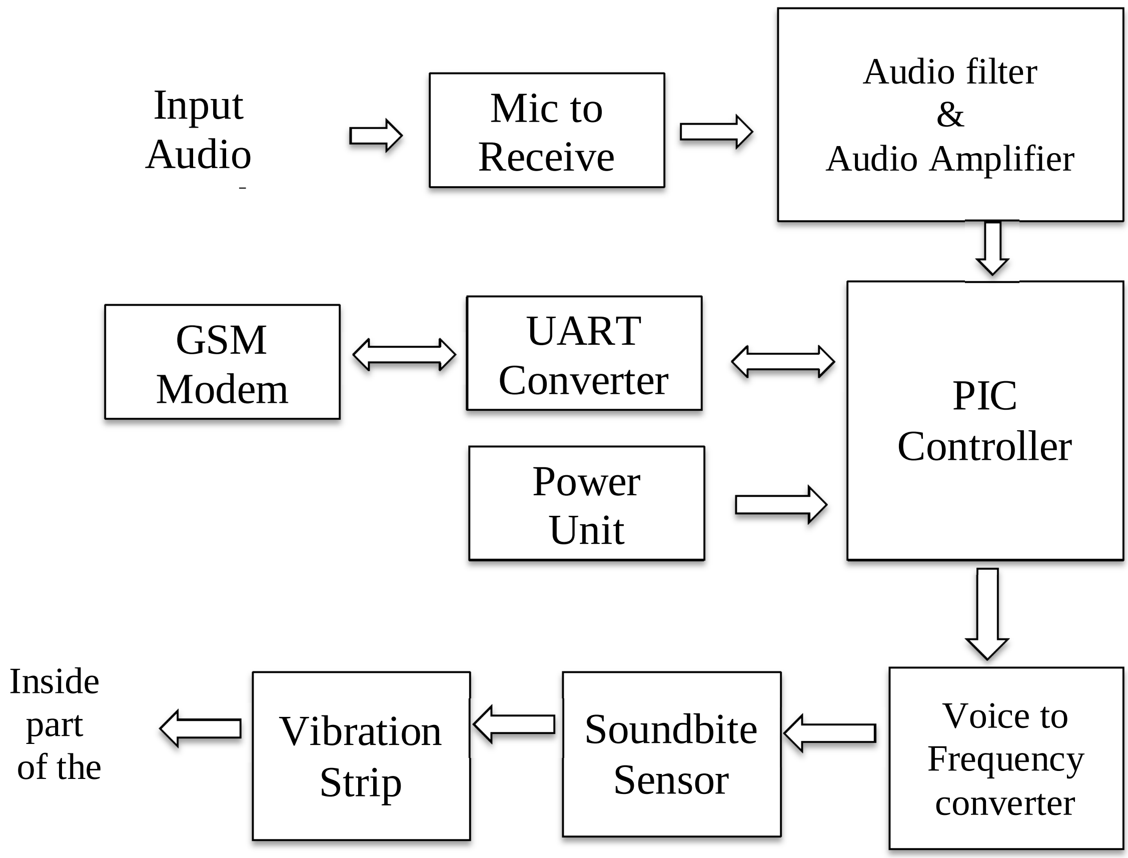

Figure 3.1 Block diagram

D. Hardware

1) PIC16F877A

The PIC microcontroller **PIC16F877A** is one of the most renowned microcontrollers in the industry. This microcontroller is very convenient to use, the coding or programming of this controller is also easier. One of the main advantages is that it can be write-erase as many times as possible because it uses **FLASH memory technology**. It has a total number of 40 pins and there are 33 pins for input and output. PIC16F877A is used in many **pic microcontroller projects**. PIC16F877A also have much application in digital **electronics circuits**.

PIC16F877a finds its applications in a huge number of devices. It is used in remote sensors, security and safety devices, home automation and many industrial instruments. An EEPROM is also featured in it which makes it possible to store some of the information permanently like transmitter codes and receiver frequencies and some other related data. The cost of this controller is low and its handling is also easy. It is flexible and can be used in areas where microcontrollers have never been used before as in microprocessor applications and timer functions etc.

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Figure 3.2 PIC controller

2) SIM800A GSM Module

Designed for global market, SIM800A is a Dual-band GSM/GPRS module that works on frequencies EGSM 900MHz and DCS 1800MHz . SIM800A features GPRS multi-slot class 12/ class 10 (optional) and supports the GPRS coding schemes CS-1, CS-2, CS-3 and CS-4. With a tiny configuration of 24*24*3mm, SIM800A can meet almost all the space requirements in users' applications, such as smart phone, PDA and other mobile devices.

Figure 3.3 SIM800A GSM Module

3) UART Cable

The USB 2.0 Hi-Speed to UART cable incorporates FTDI's FT232H USB to UART interface IC device which handles all the USB signaling and protocols. The cable provides a fast, simple way to connect devices with 3.3-volt digital interfaces to USB. The digital interface of the cable is made up of ten individual wires which are terminated with single pole connectors which can be connected next to each other on a male header.

4) Voice Module

The voice module consists of a amplifier and a mic to communicate with the other person. The voice is transmitted to the receiver side with the help of the mic.

Figure 3.4 Voice Module

5) Relay

Relay is an electromagnetic switch which is controlled with a small current and is used for turned on or off high electric circuits or appliances. Means its magnetic coil is turned on or off with a small current but its magnetic contacts are used for controlling high currents. Two types of relay modules are commonly used; first one is ac relay module whose magnetic coil is operated at ac voltages, second one is dc relay module whose magnetic coil is operated at dc voltages. Both relay modules are easily available in market or online shop. But in this article, we will only talk about dc voltages relay module.

Relay modules are available in different channels such as single channel and multi-channel etc. Single channel consists of only single relay and multi-channel consists of multi relays which are connected in parallel with each other.

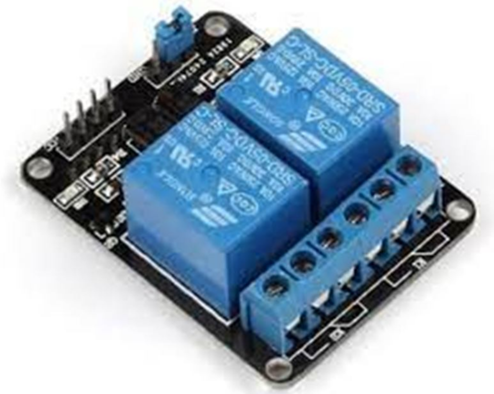

Figure 3.5 Relay

E. Software

1) MPLAB IDE

MPLAB IDE is a Windows-based Integrated Development Environment (IDE) for the Microchip Technology Incorporated PICmicro microcontroller (MCU) families. MPLAB IDE allows you to write, debug, and optimize PICmicro MUC applications for firmware product designs. MPLAB IDE includes a text editor, simulator, and project manager. MPLAB IDE also supports the MPLAB-ICE and PICMASTER emulators, PICSTART Plus and PRO MATE II programmers, and other Microchip or third-party development system tools.

The flexible and customizable MPLAB X IDE interface allows you to have multiple debug tools connected to your computer at the same time. You can select any tool you desire for a specific project or configuration within a project. With complete project management, visual call graphs, a configurable watch window, and a feature-rich editor that includes code-completion and hyperlink navigation, MPLAB X IDE is fully equipped to meet the needs of experienced users while remaining flexible and user-friendly for even those who are new to the IDE.MPLAB X IDE brings a host of features to help debug projects and minimize development time.

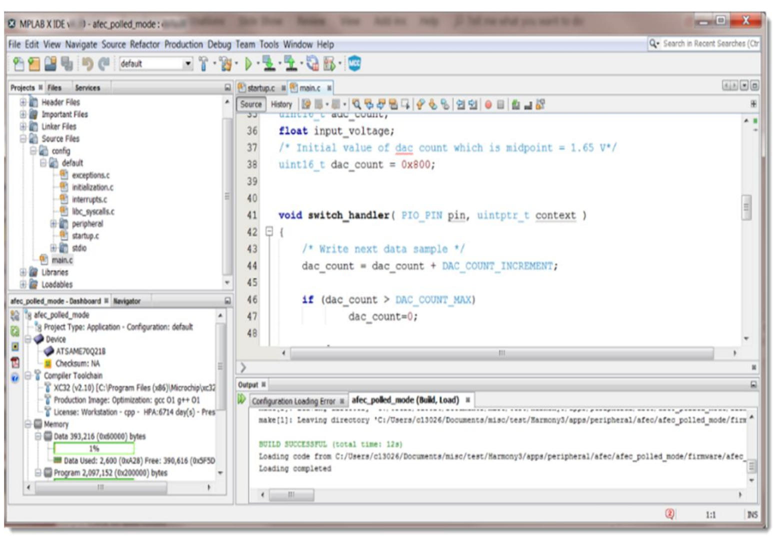

Figure3.6 MPLAB IDE

2) PicKit-3

PICkit is a family of programmers for PIC microcontroller made by Microchip Technology. They are used to program and debug microcontrollers, as well as program EEPROM. Some models also feature logic analyzer and serial communications (UART) tool.The PICkit 3 programmer/debugger is a simple, low-cost in-circuit debugger that is controlled by a PC running MPLAB IDE software on a Windows platform. The application usage can vary from software development to hardware integration. The PICkit 3 programmer/debugger is a debugger system used for hardware and software development of Microchip PIC microcontrollers (MCUs) and dsPIC Digital Signal Controllers (DSCs) that are based on In-Circuit Serial Programming (ICSP) and Enhanced In-Circuit Serial Programming 2-wire serial interfaces. In addition to debugger functions, the PICkit 3 programmer/debugger system also may be used as a development programmer.

IV. RESULTS AND DISCUSSIONS

A. Final Results

The project has been implemented successfully. The Bone conduction hearing device is a device which transmits sound as vibrations to the inner part of the ear. Since the introduction of bone conduction hearing technology, numerous devices have been developed to optimize signal transmission, limit skin and wound complications, and rehabilitate hearing for patients with conductive and mixed hearing loss and single sided deafness.

The introduced device, take advantage of new electronic signal transmission, optimize bone conduction efficiency, and reduce the incidence of skin complications. The current landscape of devices is described here and includes fitting criteria, patient selection, and benefits and drawbacks of each device. This condensed information is intended to be a resource for patients and providers alike to assist with proper device selection for each situation.

B. Discussions

When the device is switched on the power is stepped down to safeguard the circuits using a step-down transformer. The project consists of a GSM module which receives the call from the user. A full-sized sim is inserted in the GSM module with reference to the sim, call is connected. The call gets connected and the audio from the GSM module is passed through the PIC controller. The PIC controller then processes the audio and all the filtering and amplifying is taken care by the circuits. Then the relay circuits continuously switch to the available mobile network for steady transmission of the information. The audio is transmitted to the vibrating motor (SoundBite) sensor.

The user can keep the sensor in the mouth and can hear that the sound which is transmitted through the vibrations. The user can also respond to the caller with the help of a mic. A reset button is available if the call is not connected properly one can use it to reset the device.

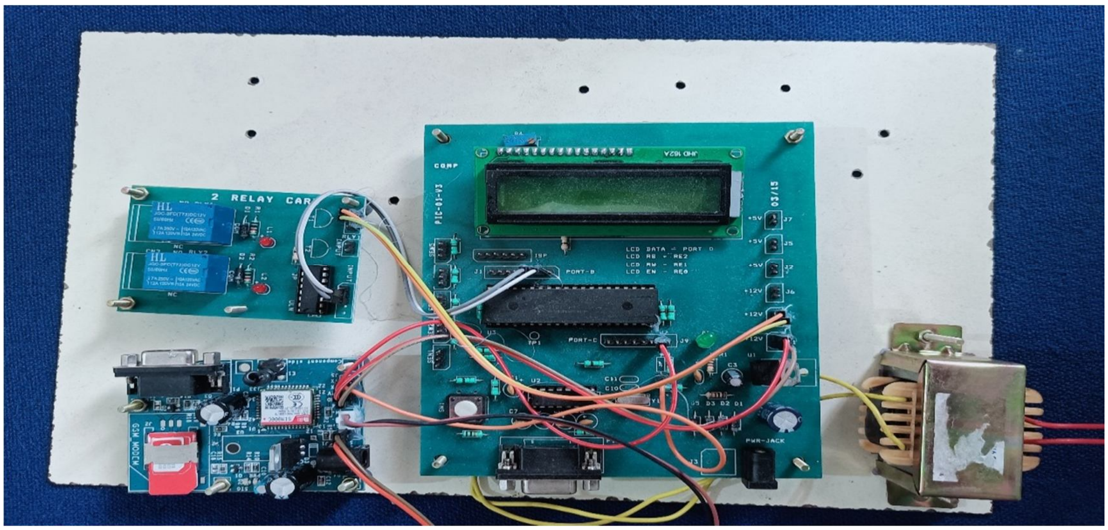

Figure 4.1 Bone conduction hearing device

The audio is heard by the person with hearing problem via the soundbite sensor, which is a vibrating motor which produces mild vibrations.

V. CONCLUSION

A. Conclusion And Future Scope

It has been designed a smart earplug system integrated with non-invasive bone conduction technique which is capable of doing some advanced audio processing to provide voice enhancing and noise filtered audio for the hearing-impaired people. The results show an excellent performance regarding entrainment prevention and adaptation speed. The system has a strong practical relevance because of the acceptable computational complexity and the ability to perform very satisfactorily under a large variety of audio signals and acoustic feedback scenarios.

General trends in hearing devices are to either make them more esthetically appealing or to make them as invisible as possible. By changing the sound transmission from percutaneous to transcutaneous, the visibility of wearing a hearing aid reduces. The size and effectiveness of the project can be improved by miniaturizing it. The Bone Conduction Hearing aid is an emerging solution for people with ear drum problem, we can expect these types of devices to be prevailing in the future with more precision, more usability and hassle-free inserting and removing of the device.

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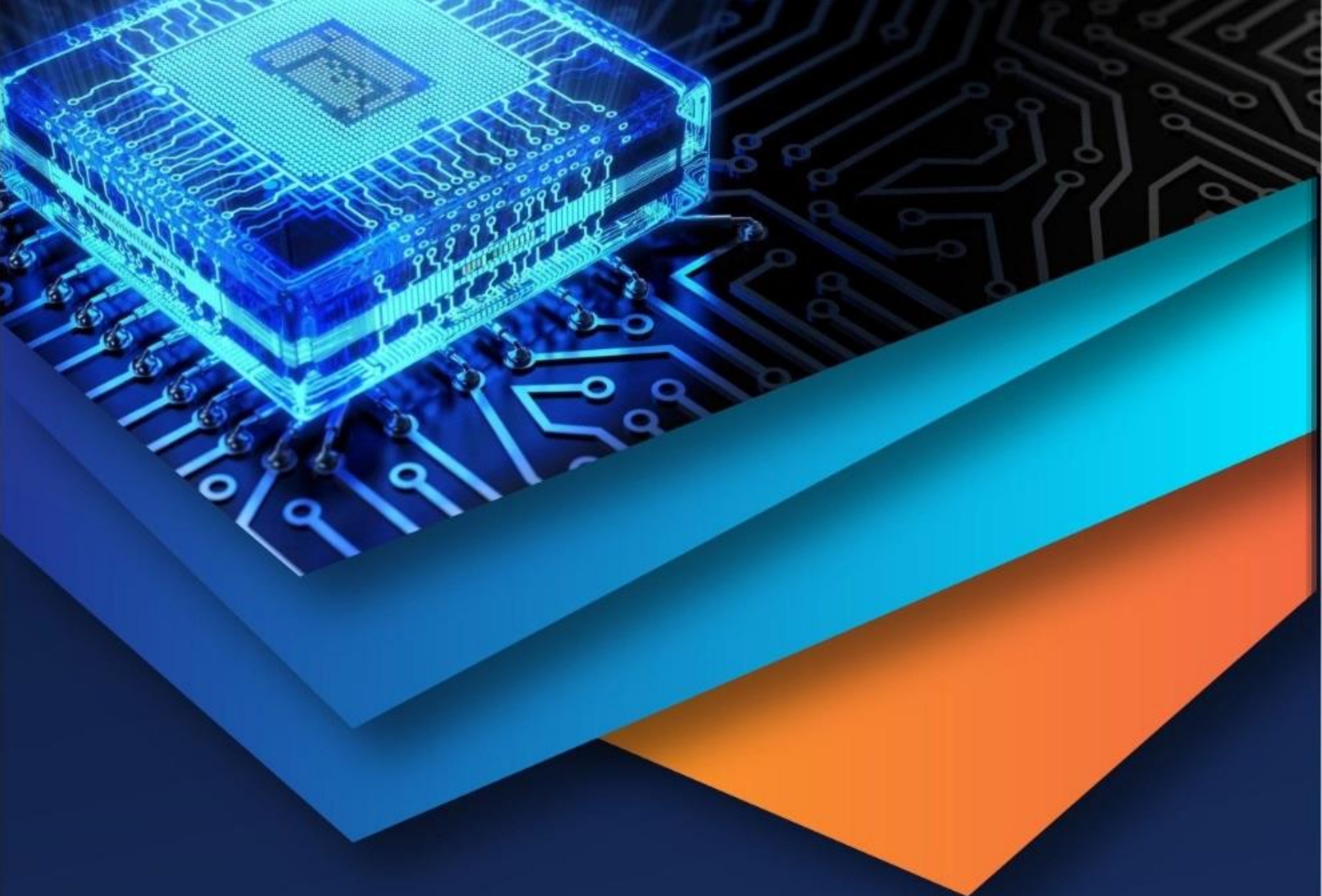

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