Designe An Electrical System for Adjustable Hearing Aid Based on Smartphone

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Abstracet

In this project we have designed an adjustable hearing aid by using android smartphone application via Bluetooth connection for controlling the amplification process. Arduino Nano is used to execute all commands and HC-06 Bluetooth module is used in this system. The Bluetooth connection transmit the data to Arduino to provide digital outputs to the programmable gain amplifiers (PGA) and outputs the tone during the tuning state. The final constructed hearing aid's device was experimented on different set of people with different hearing loss degree .The final test showed that the device could improve the hearing for people with partial hearing problems.

Keywords: *Smartphone application, PGA (Programmable Gain Amplifier), adjustable hearing aid, Bluetooth module, Arduino Nano.*

Introduction

Hearing is one among the five sense of human being. A number of studies in the recent years has shown that the hearing aid benefits increases over the time after the initial fitting[1-3]. About 10% of the world's population suffers from hearing loss. For these individuals, the most common amplification choice is hearing and are potential users of hearing aids. While some people are born with hearing problem some others develop it as they grow. This problem can occur as a result of disease, aging, injury from noise or intake of certain medicines(N.I.D.C.D, 2010). Digital hearing instruments [4], [5] uses advanced digital signal processing like multichannel compression, multiple memories and intelligent signal processing, which improves the performances of the hearing instruments and the satisfaction of the user. With the development of VLSI microelectronics technology, it is now possible to incorporate greater function modules of electronic circuits in a very small area, and hearing instruments now can be positioned completely inside the ear canal.[6]. Over the years, improvements in hearing aids and hearing aid features have centered on the same goal: improving user satisfaction with hearing aids by improving comfort and speech recognition in noise. So that the introduction of digital wireless technology such as Bluetooth and newer methods of digital magnetic transmission is expanding hearing aid fitting possibilities and the way patients can connect to external devices. Wireless technology is becoming integrated into hearing aids and other instrumentation used in the profession of audiology in many more shapes and forms [7].

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Existing System

Hearing aids are exactly same except the fact that the microphone, amplifier and loudspeaker are placed in a small plastic package which are usually worn inside the ear canal or behind the ear. The hearing-aids are of two types, Analog hearing-aids picks up the sound converts them and amplifies the current and converts it back to louder sound. The other type is much more sophisticated digital hearing-aid. The sound which is picked up is converted into a numerically coded signal and then it refines and processes the signal before converting it back to sound. This type of hearing-aids are mostly tuned so that they point up the sounds of a particular frequency and to block the unwanted noises

with more efficiency, whilst the analog hearing-aids usually amplifies everything where the background noises will also be amplified. The digital hearing aid works by the combination of different techniques very broadly referred to as DSP (digital signal processing), including: Mic, Pre-amplifier, Anti-aliasing filter, Microprocessor, A/D converter, Digital filters, D/A converter and output.

Proposed System

The aim of the system is to build a low power, cost-effective hearing aid that has tuning functionality that allows the wearer to tune the amplification to his or her needs which adjusted wirelessly by using an application based on android smartphone via Bluetooth technology and keeping loud sounds within the range of comfort. This system's device is a very easy user interface to keep operation quick and simple and saves all data to memory so that the device can be quickly powered up and ready to use. The working of hearing aid's device is as follow: Firstly, the tuning state; patient with a specific hearing loss pattern can adjust the amplification function of the specific frequency by the hearing aid application in the android smartphone and programmable gain amplifier (PGA) that are programmed with Arduino. The tuning state is done very easy on a smart phone's application with Bluetooth technology. After the patient's satisfaction, all the tuning data will be saved to memory so that the device can be powered and ready to use. Secondly, after the tuning state, a signal picked up by the microphone first goes through a pre-amp stage. The signal then progresses to the filter stage where it goes through four parallel filters that divide the signal into four frequency ranges. The filtered signal is also passed to the gain-controlled stage where the signals are amplified based on tuning settings provided by the Arduino. The signal finally enters the output stage where it passes through a summer and the modified signal can be heard with a pair of ear phones.

Performance analysis of the proposed system

The Arduino Nano serves as the control center for this proposed project. HC-06 Bluetooth module works on serial communication. The Android app is designed to send serial data to the Arduino via Bluetooth module when a button is pressed on the app. The Arduino at the other end (HA device) receives information's data from the android application via Bluetooth (TX and RX). The Arduino provides digital outputs to the programmable gain amplifiers (PGA) and outputs the tone during the tuning state. The function of the Arduino is to provide the tuning. Once the user connects the android application to hearing aid device via Bluetooth, the application will run and the user will select the frequency that he needs to be amplified according to the audiogram hearing loss profile and the related filter's band will pass only the frequency of the specific band and attenuates the other band according to the user needs. The user will select the gain that he needs from the application, the arduino will receive the gain's information selection via Bluetooth and outs it as a three-bit signal (G0-G1-G3) to controlled gain op-amp (PGA) to be amplified. During tuning, the digital op-amps (PGA) that are not being tuned have their gains set at zero so only the specific bandpasses. After the user tuning is complete, the gains are recorded to EEPROM and the HA device is ready to use.

Android Application

uHear is an android app that has been developed using MIT App Inventor for pairing the smartphone with the developed system. MIT App inventor is an open source web-based application used for Android Application development[8].

Arduino IDE for uploading application sketches to the Arduino is as follow:

The Arduino IDE for generate tone and no tone (mute) for the specific frequency band using **tone** function (int pin number , Freq Hz, delay) as in figure (1(a)) and for reseting all setting gains to zero as in figure (1(b))

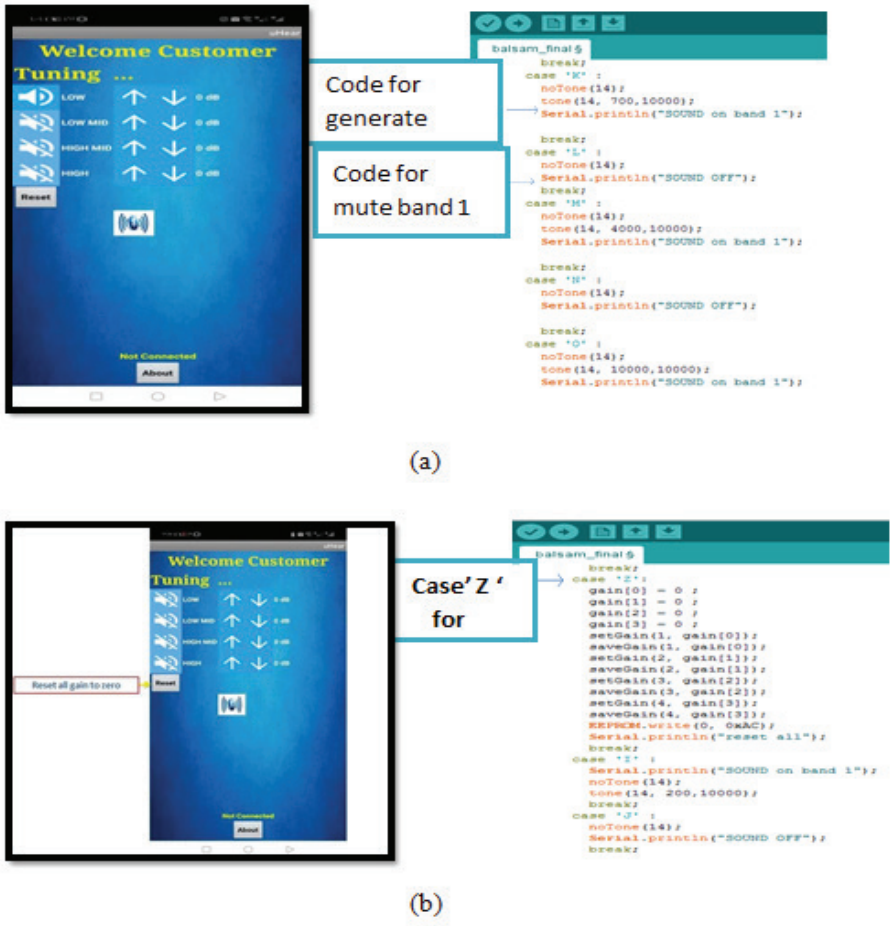


Figure (1). (a) Arduino IDE for Generate Tone and No Tone, (b) Arduino IDE for All- Reset Function

Arduino IDE for increasing –Decreasing gain according to patient's need as in figure (2). Where a two conditions (if-break) is made, one for increasing gain and the other for decreasing gain then save gain function is used to save setting to EEPROM.

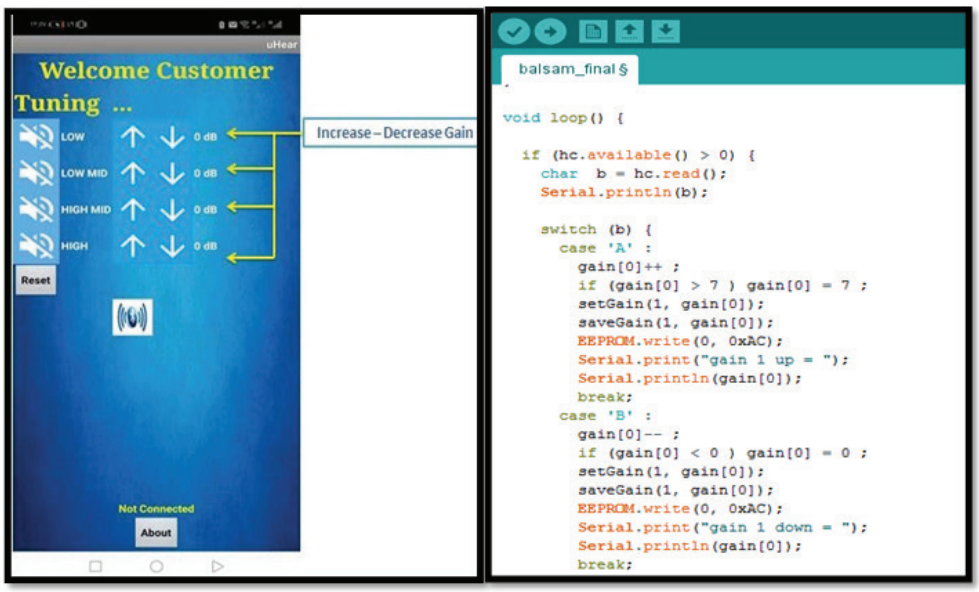


Figure (2). Arduino IDE for gain setting

Programmable Gain Amplifier (PGA)

For programming the PGA with arduino, firstly these three-bit digital outputs(G0-G1-G2) must be defined with Arduino IDE using for loop. On startup after Bluetooth connection, the EEPROM will be checked if there were a previous setting, outputs it and if not or want to start a new tune set all gain to zero and set gains from application as explained previously in 3.2 android application as in figure (3 (a,b))

```
for (int i = 2; i < 15; i++)
  pinMode(i, OUTPUT);


int check = EEPROM.read(0);
if (check == 0xAC)
{
  for (int i = 0; i < 4; i++ )
  {
    setGain(i + 1, EEPROM.read(i + 1));
    gain[i] = EEPROM.read(i + 1);

  }
  setGain(1, gain[0]);
  setGain(2, gain[1]);
  setGain(3, gain[2]);
  setGain(4, gain[3]);
}
else
{
  setGain(1, 0);
  setGain(2, 0);
  setGain(3, 0);
  setGain(4, 0);
}
```

(a)

```
void saveGain (int loc, int gain) {
  EEPROM.write(loc, gain);
}
void setGain (int start, int gain) {
  switch (start) {
    case 1:
      digitalWrite(5, (gain >> 0) & 0x01);
      digitalWrite(6, (gain >> 1) & 0x01);
      digitalWrite(7, (gain >> 2) & 0x01);
      break;
    case 2:
      digitalWrite(4, (gain >> 0) & 0x01);
      digitalWrite(3, (gain >> 1) & 0x01);
      digitalWrite(2, (gain >> 2) & 0x01);
      break;
    case 3:
      digitalWrite(8, (gain >> 0) & 0x01);
      digitalWrite(9, (gain >> 1) & 0x01);
      digitalWrite(10, (gain >> 2) & 0x01);
      break;
    case 4:
      digitalWrite(13, (gain >> 0) & 0x01);
      digitalWrite(12, (gain >> 1) & 0x01);
      digitalWrite(11, (gain >> 2) & 0x01);
      break;
  }
```

(b)

Figur (3). (a). Arduino IDE for PGA , (b) Save Gain and Set Gain Function Code

Results and Duscussion

The proposed system is used to perform the implementation of a programmable hearing aid device controlled by application using Android smart phone via Bluetooth. The final hardware is experimented on 3 people, their results were presented and discussed. Audiograms of patients have been taken for experimentation to correct the hearing loss of patients using programmable hearing aid with smartphone application. Losses can be corrected by varying the gain factor of the particular frequency band of filter at which losses occur by using the application. The HA's device circuit was experimented on 3 patients with different (age, gender, degree of hearing loss).

1)Female- 60years old

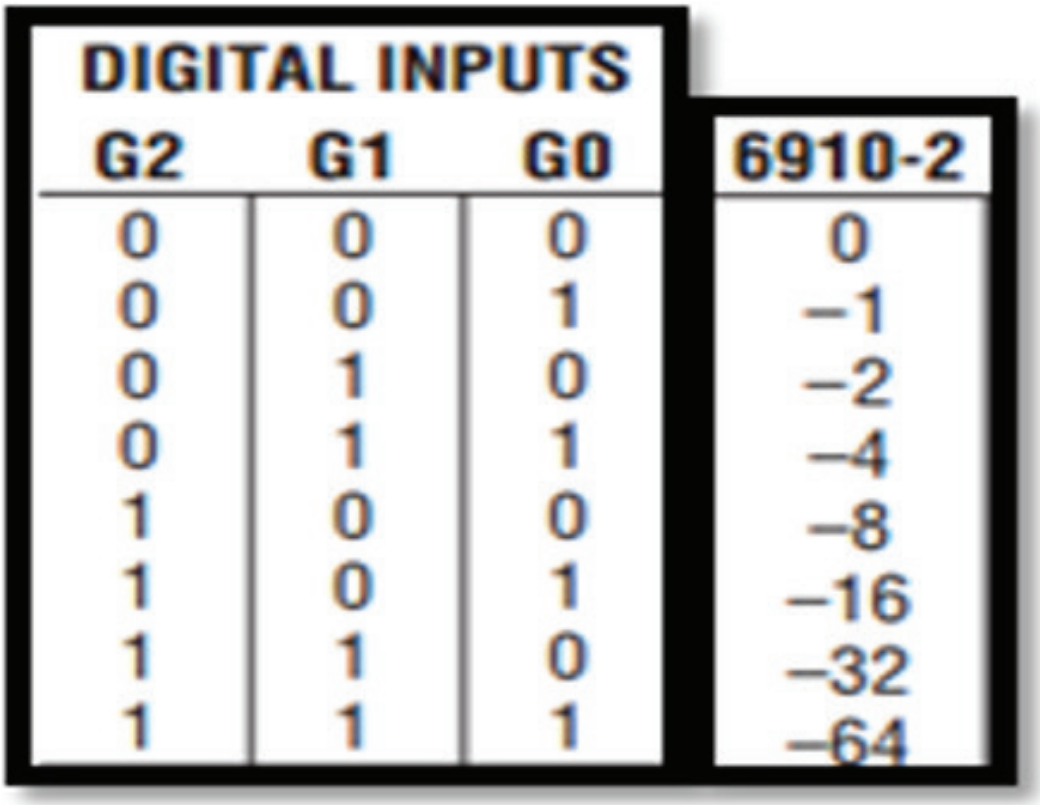
•Type of hearing loss: Bilateral sensory HL

•Degree of hearing loss: (Right ear) mild to moderate and mild (Left ear)

•Occupation: House keeper

•Aided side : Left side

The (PGA) gain selection relation state with the number of pressing button that the patient do is shown in figure (4).



DIGITAL INPUTS			6910-2
G2	G1	G0	
0	0	0	0
0	0	1	−1
0	1	0	−2
0	1	1	−4
1	0	0	−8
1	0	1	−16
1	1	0	−32
1	1	1	−64

Figure (4). LT6910-2 gain selection relation state with the number of pressing button

With **500 Hz (30 dB) HL** ,the patient press four times until she get hearing and restore normal hearing with (20dB).

With **1000 Hz (30dB) HL**, the patient press five times until she gets hearing and restore normal hearing with (15dB).

With **2000 Hz (40dB) HL**, the patient press six times until she gets hearing and restore normal hearing with (10dB).

The unaided-aided of the female's audiogram is shown in figure (5 (a)).

Male -32 years old

•Type of hearing loss: Bilateral sensory HL

•Degree of hearing loss: (Right ear) slight loss to mild and mild (Left ear)

•Occupation: Soldier

•Aided side : Right side

•Improvement: The same steps that have been mentioned in the first case are also will be followed in each next case .

With 500 Hz (25 dB) HL ,the patient press three times until he gets hearing and restore normal hearing with (20dB).

With 1000 Hz (30dB) HL, the patient press five times until he gets hearing and restore normal hearing with (15dB).

With 2000 Hz (30dB) HL, the patient press five times until he gets hearing and restore normal hearing with (15dB).

The unaided-aided male's audiogram is shown in figure (5(b))

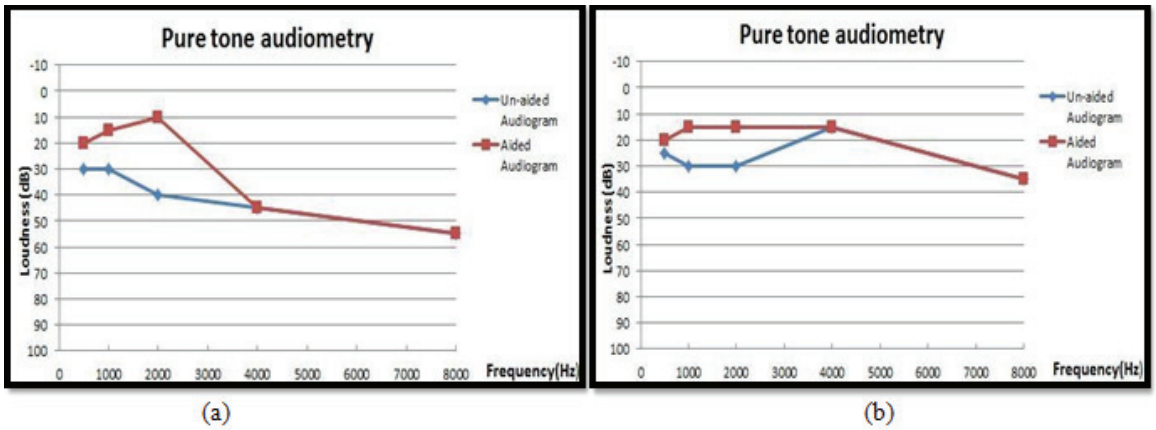


Figure (5). (a) The Unaided-Aided Female's Audiogram, (b) The Unaided-Aided Male 1's Audiogram

Conclusion

It can be seen clearly that a Smartphone's application programmable Hearing aid (HA) will have a bright future. It should be continued and developed in the future as it has a huge potential to improve its performance, reliability and safety. The best part for using android is an open-source electronics platform and it is able to read an input and convert it into an output. Arduino is cheaper compared to other microcontrollers and it can run on windows, Macintosh OSX and Linux operating system. MIT App Inventor is used to create the system application which is an application to transform a complex language of text-based coding into a visual and drag-and-drop building block. Its performance is very friendly to use and can be altered by add, remove or replace block according to designer needs. A command is a block that specifies an action to be performed on the phone. Some commands require one or more input values to completely specify their action. The main advantage of our programmable hearing aid is tuning the HA according to the needs of the individual patient hearing impairment by the patient himself by the using the application and it can be much more accurate rather than the technique used in analogue hearing aid fitting. The presented programmable hearing aid system offers the high reliability, low-power operation and ease of use as well as affordable cost.

Ethical Clearance: The Research Ethical Committee at scientific research by ethical approval of both environmental and health and higher education and scientific research ministries in Iraq

Conflict of Interest: The authors declare that they have no conflict of interest.

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