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PC Sound Card Based Diagnostic Audiometer

Group No: D11

Shiv Rama Krishna (03D07034) <shivram@iitb.ac.in>
Dixit Khalkho (03D07040) <dixit@ee.iitb.ac.in>
Nitesh Moundekar (03D07041) <niteshm@ee.iitb.ac.in>
Chandra Prakash Meena (03D07042) <chandra@ee.iitb.ac.in>

Supervisors: P. C. Pandey and V. K. Tandon

Abstract

The degree of hearing loss can be determined by PC sound card based diagnostic audiometer. The instrument will provide 2 – channel outputs, with stimulus generation from PC sound card and external programmable attenuators which can be controlled by giving instructions using Software which includes RS 232 serial port communication between PC and hardware. The system has automatic calibration for variation in amplitude of sound card signal. The audiometer can give standard frequencies 125 Hz, 250 Hz, 500 Hz, 1 kHz, 1.5 kHz, 2 kHz, 3 kHz, 4 kHz, 6 kHz, 8 kHz and noise as the inputs to the two channels separately. The subject can respond to the stimulus by pressing a switch. This data is recorded in software and plotted on audiogram.

1 Introduction

Early detection of hearing impairment and intervention can dramatically improve the lives of many people. A PC sound card based diagnostic audiometer can be used to determine the hearing threshold of a person and hence his hearing loss. The objective of this project is to construct an audiometer based on PC sound card with proper software and hardware to control acoustic output level and simultaneously recording user's response and plotting it on audiogram.

In acoustic measurements, sound level is often given in dB, taking sound pressure of 20 μPa as the reference level, and is known as sound pressure level (SPL).

Sound level in dB SPL = 20 log (measured sound pressure / 20 μPa)

However, in audiometry the sound level of pure tones is given in dB by taking average hearing threshold of normal hearing young adults as reference, and is known as hearing level (HL).

Sound level in dB HL = 20 log (measured sound / average threshold of human hearing)

Table 1 Threshold values in dB SPL for 0 dB HL (Adapted from [1])

Frequency (Hz)	250	500	1 k	1.5 k	2 k	3 k	4 k	6 k	8 k
dB SPL	25.5	11.5	7	6.5	9	10	9	10.5	13

2 Design Approach

The audiometer has been built to be cost effective and user friendly. The graphical user interface allows the user to control the sound outputs efficiently. This audiometer supports speaker of 8 ohms along with headphone. The patient's response can be recorded via RS 232 port terminals. The block diagram of above mentioned audiometer is shown in Fig. 1.

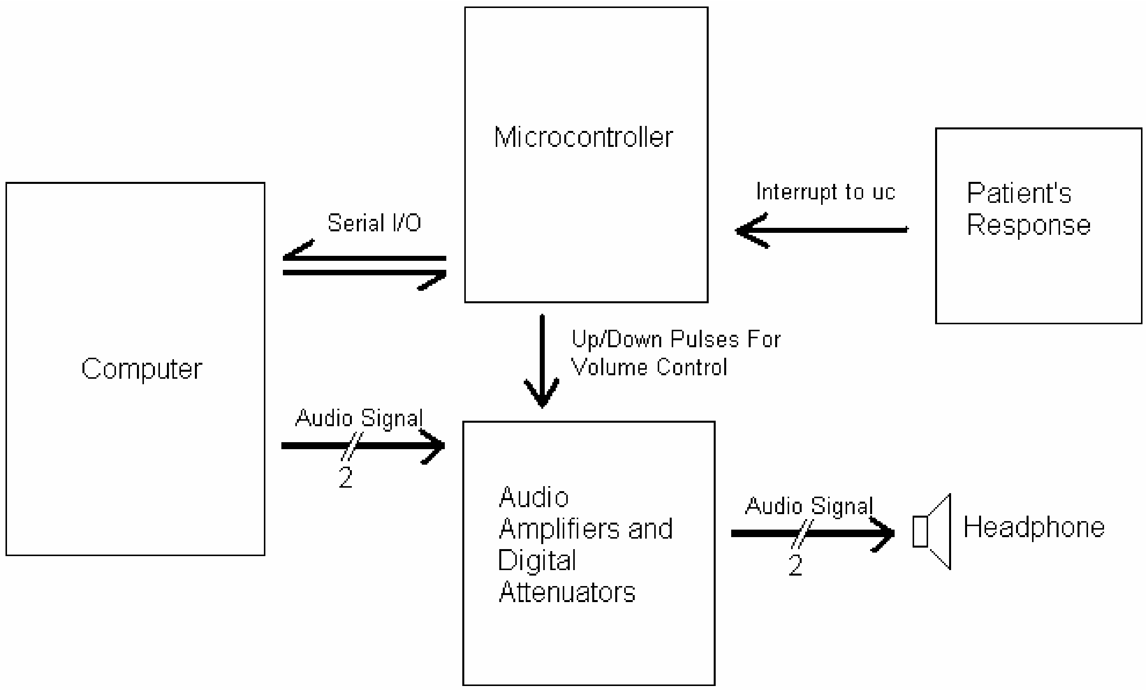

Fig. 1 Block Diagram of the Audiometer

3 Graphical User Interface

GUI includes all the software part of audiometer project. It is used to generate tone, control volume levels, record patient's response. This entire software module has been implemented in JAVA programming language [9]. To run this software, the PC should have JAVA runtime (JRE) previously installed. As the software is implemented in JAVA, it is platform independent i.e. it can run on both Windows as well as Linux platforms.

3.1 Sound settings: While operating PC based diagnostic audiometer GUI all extra sound enhancement features provided by sound card must be switched off. So as shown in Fig. 2 only master volume controls and wave controls are 'on' others are switched off by checking mute option. If these settings are not done properly as specified sound signal meant for right ear can come in left ear and vice versa.

3.2 Generation of tone signals: Human audible range is from 20 Hz to 20 kHz. The test frequencies used to detect hearing loss are 125 Hz, 250 Hz, 500 Hz, 1 kHz, 1.5 kHz, 2 kHz, 3 kHz, 4 kHz, 6 kHz, 8 kHz. These test frequencies are generated using PC sound card [10]. First of all signal of corresponding frequency of length 1 s is synthesized. This signal is repeatedly sent to PC sound card to generate continuous uninterruptible tone signals. To account for sudden change in signal i.e. from mute state to some tone signal these signal are tapered at both ends by increasing and decreasing amplitude continuously over a short time period. The tapering allows a smooth change from mute state to reception of some tone signal.

3.3 Controlling sound levels: Sound levels can be changed using software or hardware. Through software sound levels can be changed while synthesizing signals. But through PC we can attain maximum 80 dB attenuation. But for diagnostic audiometer we require attenuation levels of nearly 160 dB. So, appropriate hardware has been implemented. Sound levels can be changed in the steps of 1.25 dB, 2.5 dB and 5 dB. The up and down signals are sent to microcontroller to change the sound levels.

3.4 Serial IO interface: Serial IO interface has been used to communicate with microcontroller. Software is written such that it can detect hardware on any one of the four COM ports available and then continues communication on detected port. Sound up and down signal commands and also mute and operating commands are sent through COM ports. The baud rate is fixed at 9600.

3.5 User interface: User interface is designed to control the audiometer efficiently. It consists of three partitions above and two partitions below. It consists of all controls necessary to operate an audiometer. The two stimuli and masker available at both left and right ears are of 10 standard frequencies in addition with mute and noise signals which can be independently selected for each ear. Masker is continuously played in contra lateral ear. Three values for gain steps are available. They are 1.25 dB, 2.5 dB and 5 dB. User can select one of these values. This setting is applicable for manual as well as automatic testing. The response time option is provided to give patient time to respond for a particular stimulus. Also presentation time can be selected to be continuous or intermittent. User interface to play test audio signal is shown in Fig. 3.

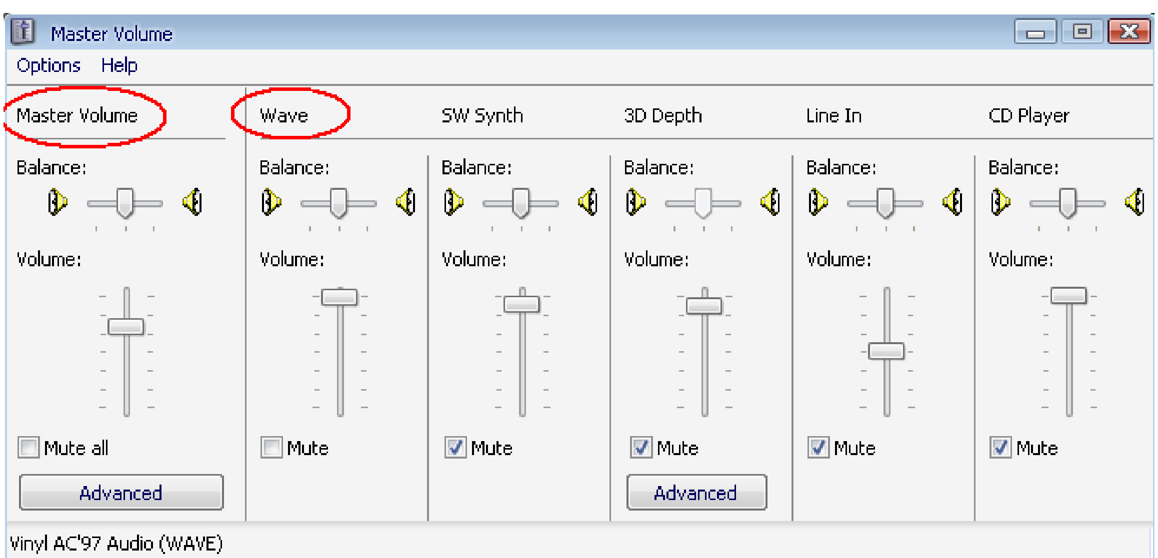

Fig. 2 PC sound settings

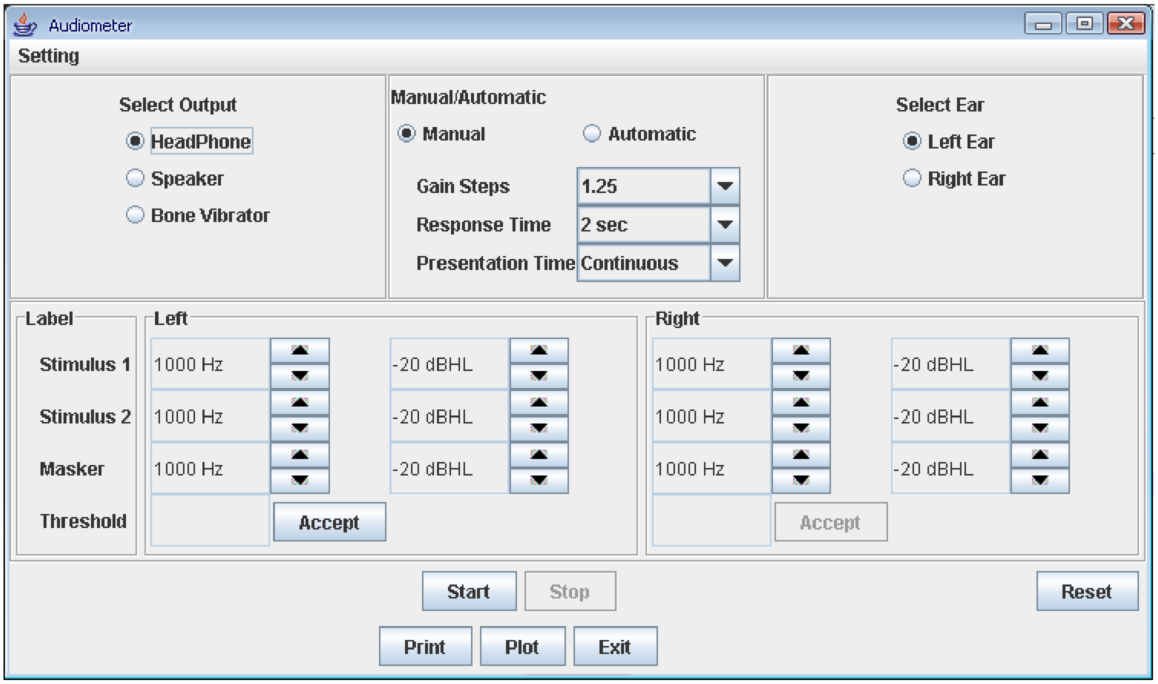

Fig. 3 Audiometer Main window

3.6 Audiometric test: GUI can be used to carry out patient's ear test either manually or automatically by selecting appropriate options.

3.6.1 Manual testing: By default GUI is designed to carry out manual testing of patient's ear. In this user can select particular stimulus and masker from available list. Also option is provided to change the volume level in 1.25 dB, 2.5 dB or 5 dB steps. Options are available for selecting interval needed for patient to respond. Stimulus can be continuous or of fixed time interval as per presentation time settings. Up down button is used to increase or decrease volume level. After getting response from patient the threshold value is displayed in accept box. If accept button is clicked then that value is stored as a threshold level against that test frequency.

3.6.2 Automatic testing: Automatic testing function can be activated by clicking automatic radio button. Also specify which ear is to be tested left/ right. Select test stimulus and masker and specify appropriate dB HL levels. Then press start button to start automatic testing. The automatic test algorithm converges to threshold value using responses received from patient. That threshold value is displayed in accept box. User can accept that value by clicking accept button. Also option is available for selecting time interval needed for patient to respond. Stimulus can be continuous or intermittent as per presentation time settings.

3.7 Output device: Diagnostic audiometer can drive speaker, headphone and bone vibrator. User must select one of the above output devices by selecting appropriate option before starting any testing.

3.8 Sound calibration: Sound calibration can be done using window shown in Fig. 4. Calibration can be done with respect to young person having normal hearing power or using artificial ear. At each test frequencies the gain step of digital attenuator ICs can be decreased or increased till the threshold hearing at that frequency is detected. This process can be repeated for each frequency and saved by using save option so that each time program is started these values of calibration can be loaded from that saved file.

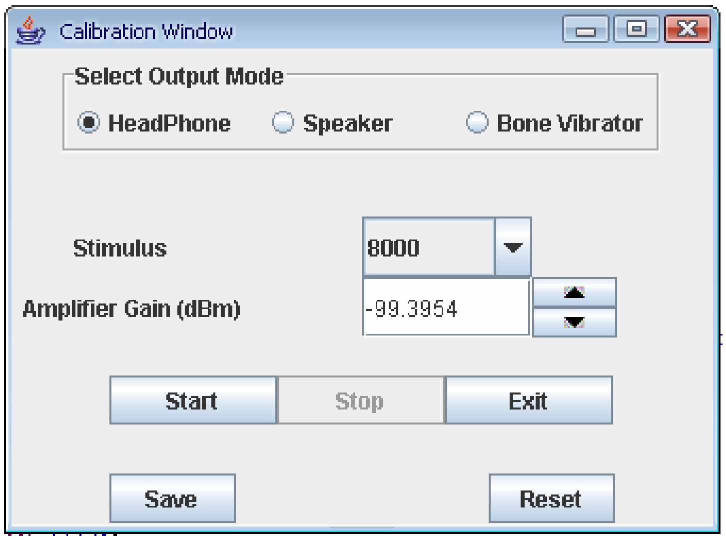

Fig. 4 Sound Calibration

3.9 Serial IO error: Serial IO error occurs when GUI is not able to establish connection with hardware. The reasons could be loose RS232 port connection or some problem with hardware.

3.10 Audiometry test result: Audiometry test result window can be obtained by clicking print button. It shows stimulus verses threshold values for left and right ear in tabular format. It contains columns for stimulus type, threshold values for both ear obtained using headphone, speaker and bone vibrator. Fig. 5 shows the audiometry test result window.

3.11 Audiogram: The response obtained for each frequency from microcontroller via RS232 is plotted on graph as shown in Fig. 6. This process can be invoked by pressing plot button present in main window shown in Fig. 3.

4 Hardware

Hardware full circuit is shown in appendix A.2. Following sections describe necessary parts of the circuits. Labels, if used, in any circuit matches with full circuit shown in appendix A.2.

4.1 Microcontroller: Microcontroller used by us is AT 89C52 as total 3 ports are required. Port 0 is used to give up/down signal to TDA 8551 ICs. Port 2 is used to control modes of TDA 8551 ICs i.e. mute mode and operating mode. Port 3 is used for RS232 interface, patient's response switch and for automatic calibration of sound card's audio output signal. Fig. 7 provides brief idea of connections to microcontroller.

4.2 RS232 interface: MAX 232 IC has been used for implementing serial interfacing with PC. Serial port is required to control the hardware by using GUI and also to note down patient's response. The connections to MAX 232 IC are shown in Fig. 8.

4.3 Switch (SW1): Switch is used to get patient's response by using interrupt 0 available on P3.2. Level triggered interrupt is used. When switch is pressed P3.2 is grounded and thus interrupts the microcontroller which tells PC software to note down reading.

4.4 Amplifier / Attenuator TDA8551: TDA8551 is 1 channel audio power amplifier capable of delivering 1w output power to 8 ohm load and operates on 5V supply. It contains a digital volume control and standby/mute logic. The attenuation level can be changed by giving up/down pulses to pin number 1. Input is given at pin number 4. Output is taken from pin 5 and 8. Pin diagram of TDA8551 is shown in Fig. 9.

4.5 TDA8551 connections: Connections of individual TDA8551 can be seen in Fig. 10. The Up/down pulse pin is connected as shown in Fig. 11. The mode pin is connected to Port 2 of microcontroller along with appropriate voltage divider circuit.

4.6 Cascading Of TDA IC: Cascading of TDA8551 has been used for two reasons. Firstly the initial 8551 IC is used in auto calibration leaving the cascaded IC untouched. Secondly the total attenuation required in audiometer is 120 dB which is easily attained by using cascaded procedure. Fig. 10 shows the cascaded ICs.

4.7 Attenuation control: Attenuation control can be done by sending up/down pulses to TDA8551 for adjusting volume up/down. As Port 0 of microcontroller does not have internal pull-ups so external pull up is required to make the output high at this port. This property is used to provide up down pulses to TDA8551. To generate one up/down signal pin we need 2 port pins connected as shown in Fig. 11. Table 2 shows signal levels generated by using Port pin 0 and 1 of Port 0. Fig. 11 shows one signal pin created by using P0.0 and P0.1.

Table 2 Attenuation Control

P0.0	P0.1	Voltage (V)
0	0	0.0
0	1	0.0
1	0	2.5
1	1	5.0

Audiometry Test Result

Stimulus	Left HeadPhone	Right HeadPhone	Left Speaker	Right Speaker	Left Vibrator	Right Vibrator
125 Hz	1.25	2.5	1.25	2.5	1.25	2.5
250 Hz	2.5	3.75	2.5	3.75	2.5	3.75
500 Hz	3.75	5.0	3.75	5.0	3.75	5.0
1000 Hz	5.0	6.25	5.0	6.25	5.0	6.25
1500 Hz	6.25	7.5	6.25	7.5	6.25	7.5
2000 Hz	7.5	8.75	7.5	8.75	7.5	8.75
3000 Hz	8.75	10.0	8.75	10.0	8.75	10.0
4000 Hz	10.0	11.25	10.0	11.25	10.0	11.25
6000 Hz	11.25	12.5	11.25	12.5	11.25	12.5
8000 Hz	12.5	0.0	12.5	0.0	12.5	0.0

Fig. 5 Audiometry Test Result

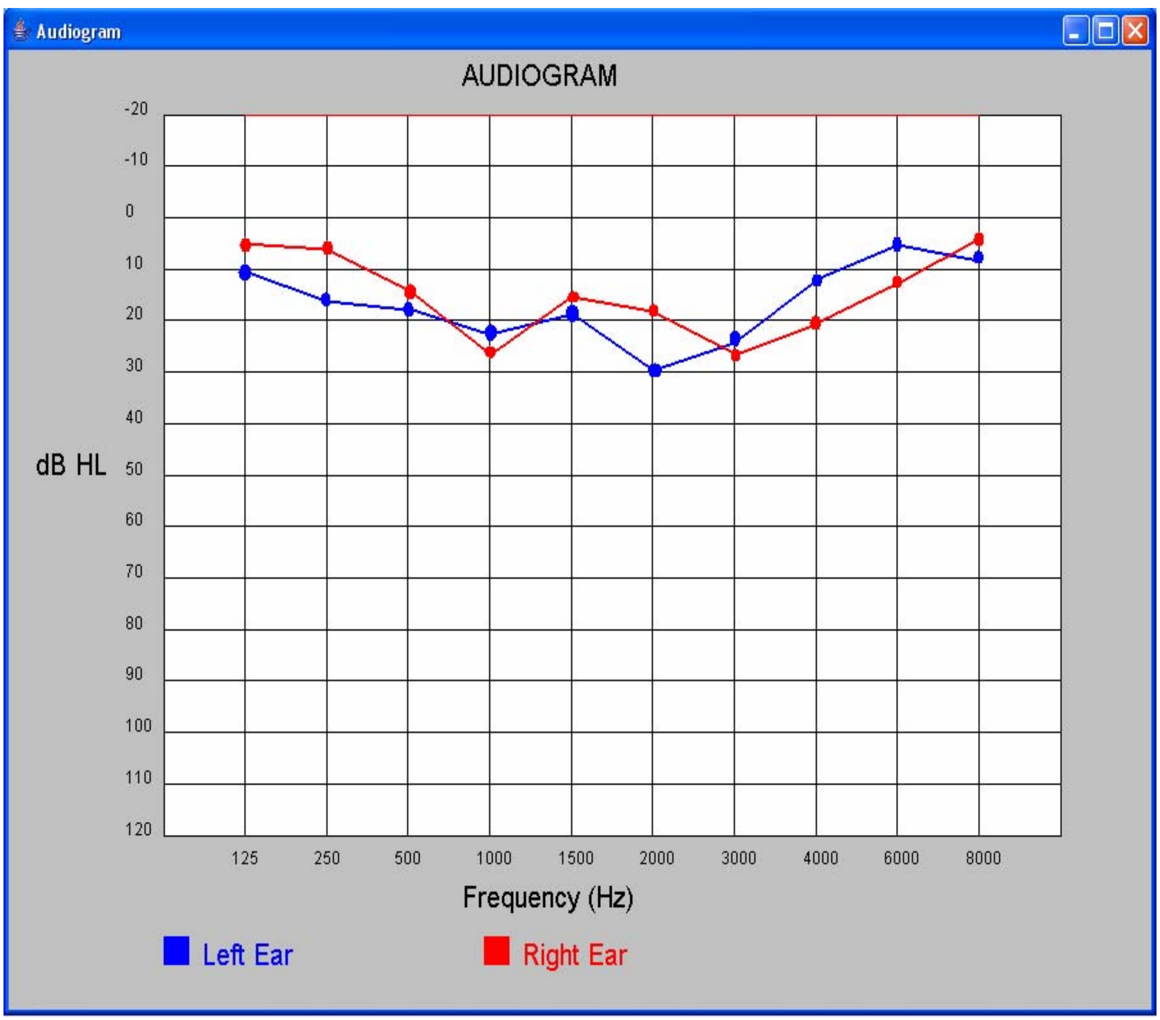

Fig. 6 Audiogram

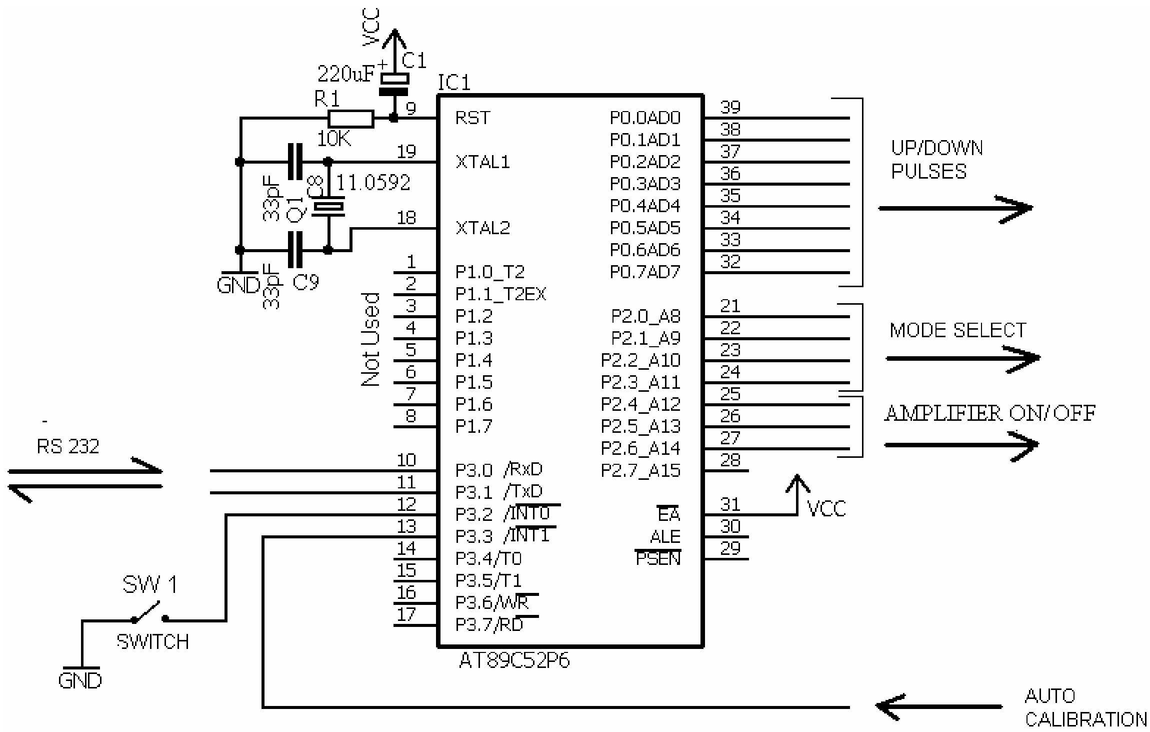

Fig. 7 AT89C52

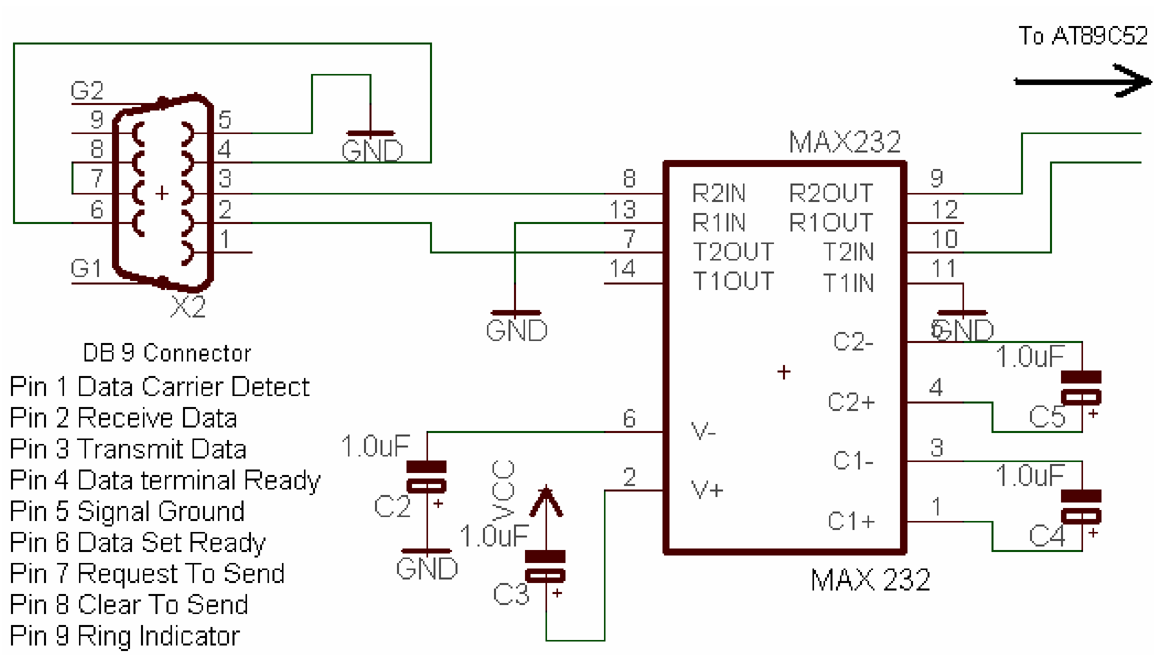

Fig. 8 Serial Interfacing

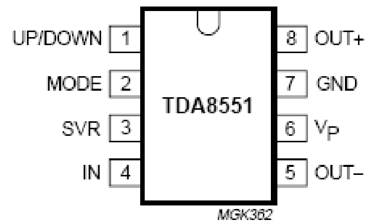

Fig. 9 Pin diagram of TDA8551 (Adapted from [6])

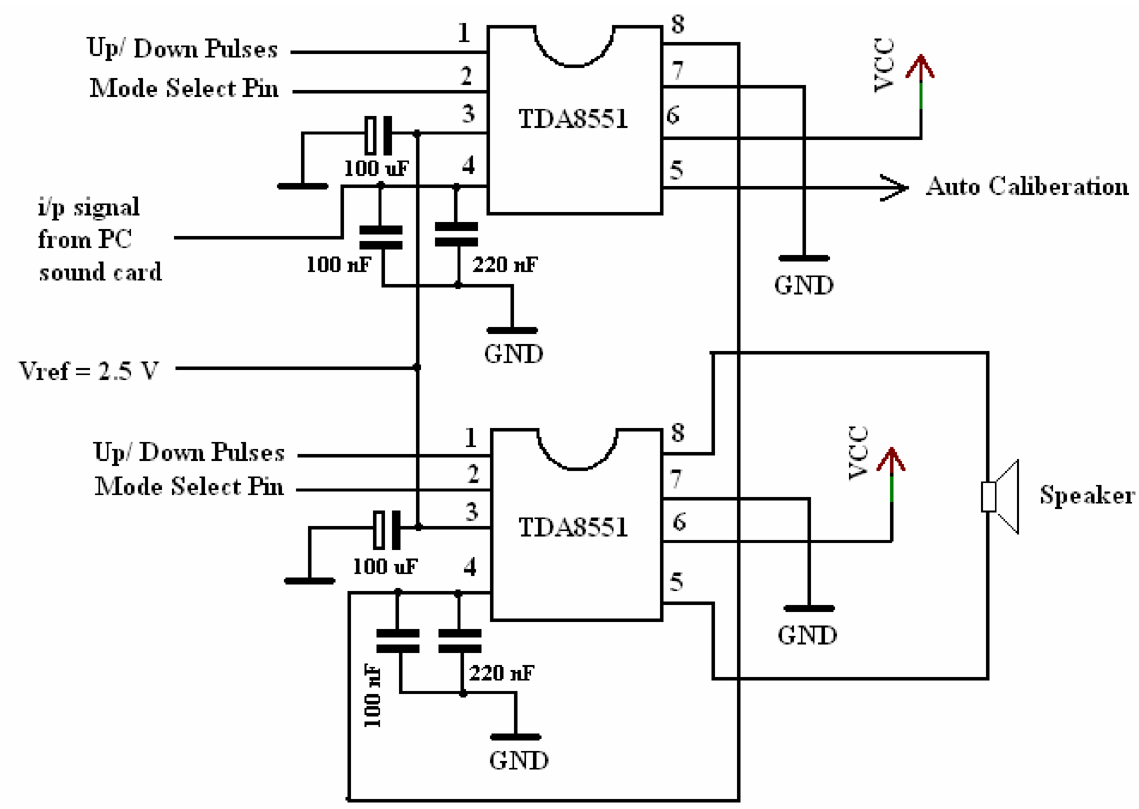

Fig. 10 Cascading Of TDA 8551 ICs

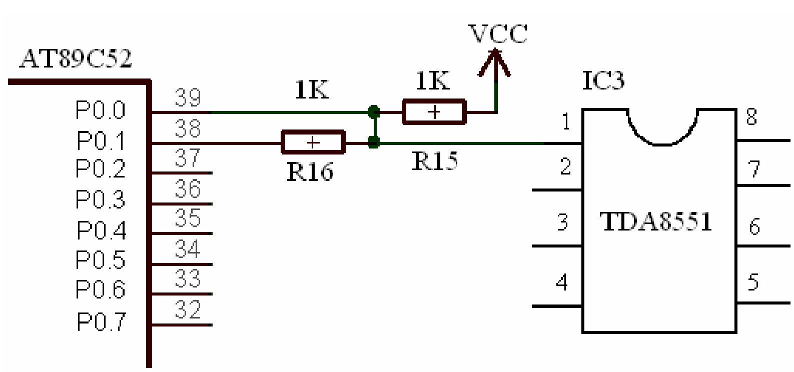

Fig. 11 Up/Down Pulse generation

4.8 Mode control: Different modes of TDA 8551 ICs are attained using Port 2 of AT89C52. A high on Port 2 pin after passing through voltage divider gives 2.5 V, which when given to Pin 2 of TDA IC, sends it to mute mode. Operating mode can be obtained by a low on Port 2 pin.

4.9 Auto calibration feedback circuit: Comparator is used for comparing output of TDA8551 in cascaded attenuator to a reference signal which is 3.3V dc here. The audio output of TDA8551 rides on 2.5V dc. Initially the gain of TDA IC is brought to its lowest level then it is increased step by step. Output of comparator goes to interrupt 1 of microcontroller. Comparator output remains low till audio output is less than 0.83V peak. The square wave is generated at the output of comparator when audio signal peak voltage surpasses 0.83V. As interrupt is edge triggered so the first high to low transition interrupts the microcontroller to stop increasing gain of TDA ICs. This interrupt then sends the gain step to software via RS 232 port to calibrate the hearing threshold frequencies respectively. Fig. 12 shows the calibration circuit.

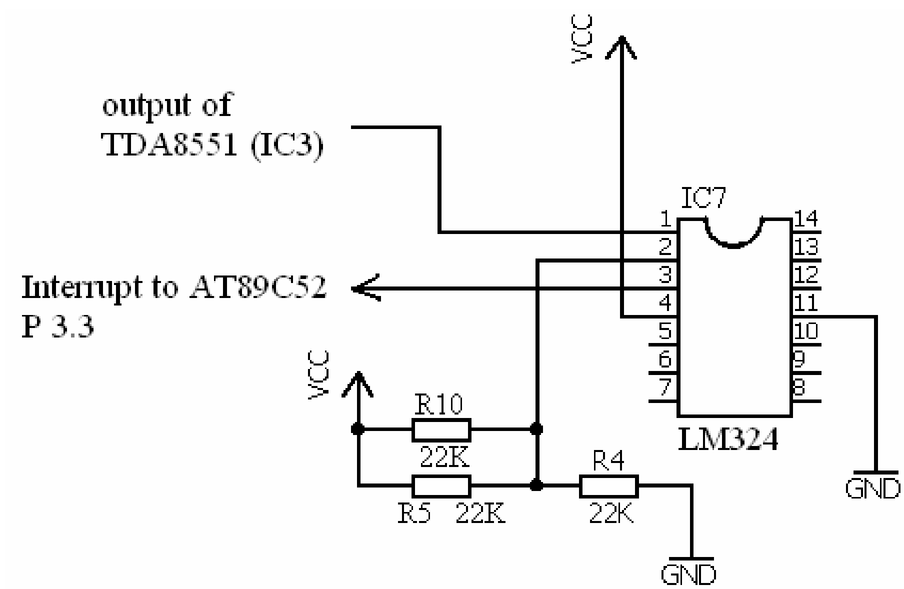

Fig. 12 Auto Calibration

4.10 Power Amplifier TDA7056B: TDA7056B is a 5 W mono BTL audio amplifier with DC volume control. The maximum gain of the amplifier is fixed at 40.5 dB. The DC volume control stage has logarithmic control characteristics. Therefore, the total gain can be controlled from 40.5 dB to -33 dB. If the DC volume control falls below 0.4 V, the device will switch to the mute mode. Pin diagram of TDA7056B is shown in Fig. 13.

PINNING

SYMBOL	PIN	DESCRIPTION
n.c.	1	not connected
V_P	2	positive supply voltage
V_I	3	voltage input
GND1	4	signal ground
VC	5	DC volume control
OUT+	6	positive output
GND2	7	power ground
OUT−	8	negative output
n.c.	9	not connected

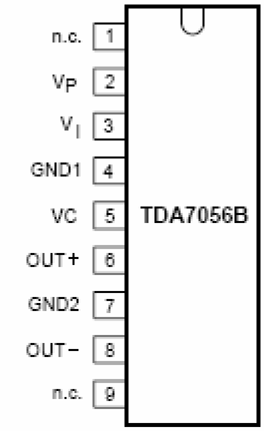

Fig. 13 Pin diagram of TDA7056B (Adapted from [7])

4.11 TDA7056B connections: TDA7056B is used to provide higher peak voltage compared to TDA8551. It can provide a maximum of 5 W compared to 1 W max power available at the output of TDA8551. Here output from cascaded TDA8551 ICs' is given as an input to TDA7056B and the gain is fixed at 10 dB. It can be switched to mute mode by switching the port 2 pin to signal value 0 V. Fig. 14 shows TDA7056B IC connections.

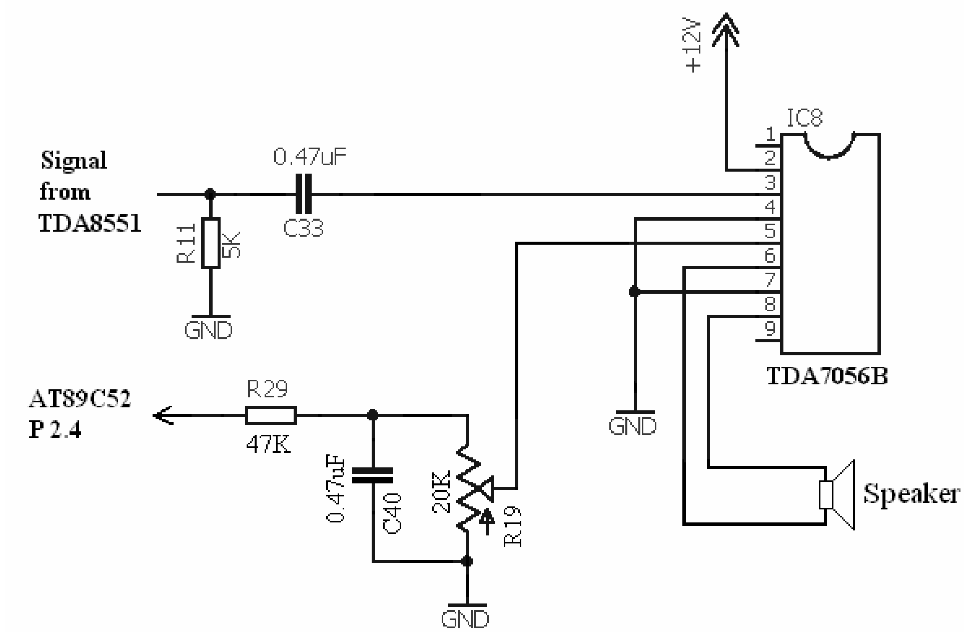

Fig. 14 TDA7056B Connections

5 Algorithmic flow diagrams

A GUI flowchart is shown in Fig. 15 and microcontroller code flowchart is shown in Fig. 16.

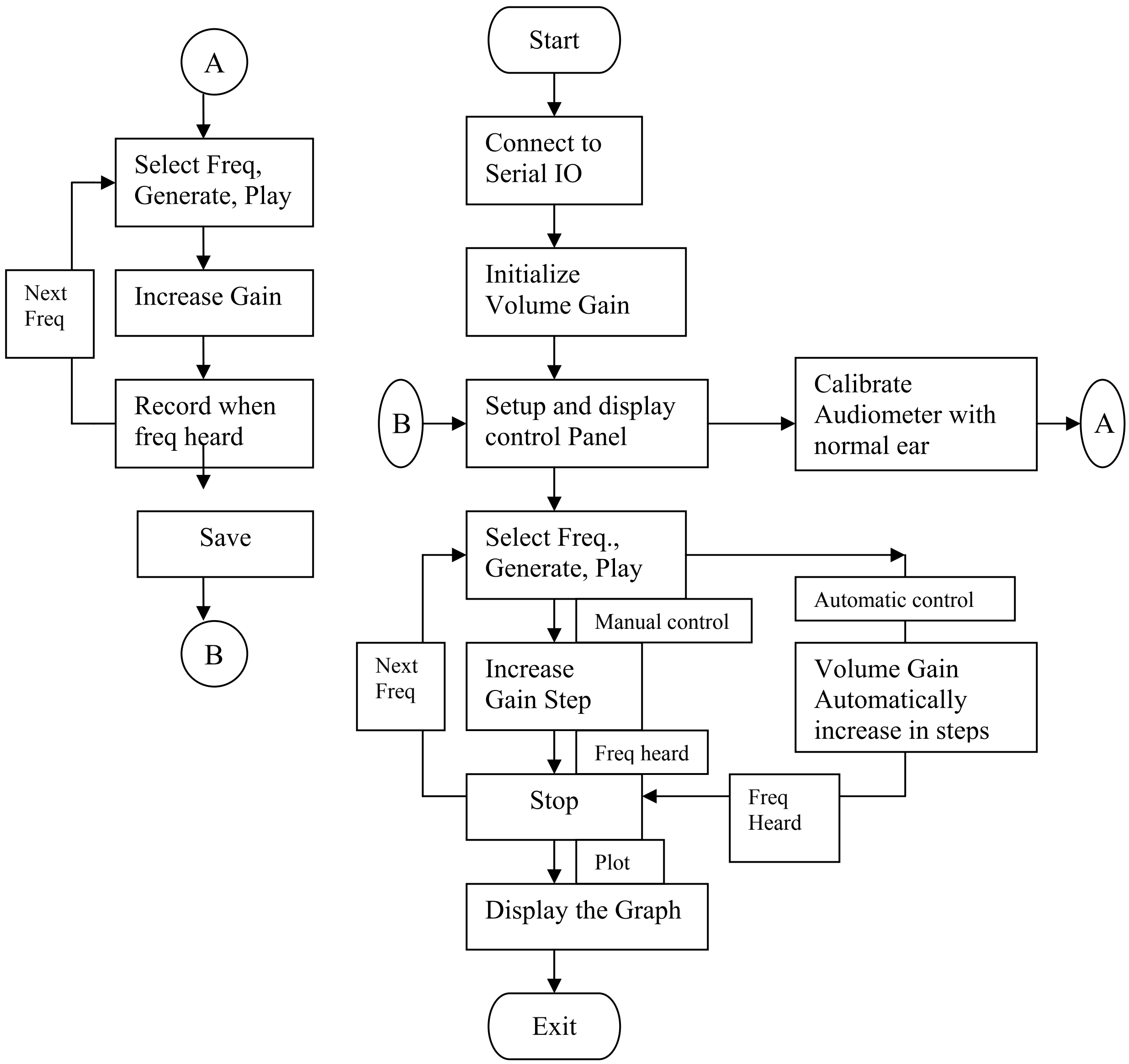

Fig. 15 GUI Flowchart

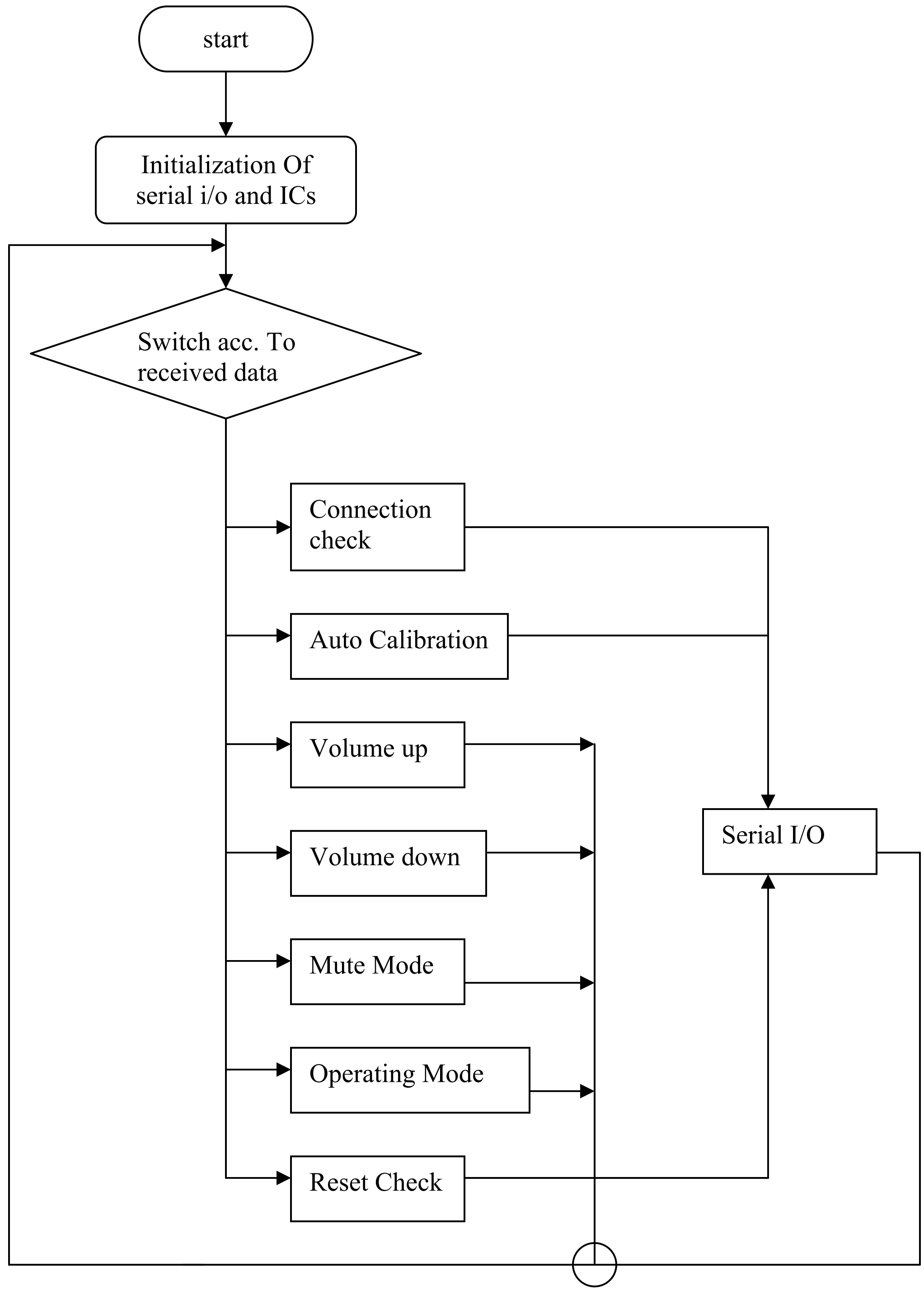

Fig. 16 Microcontroller code flowchart

6 Test Procedure

The procedure to test the audiometer is the standard one as used by a practitioner. When running this software for first time, sound calibration must be done so that actual dB HL values are plotted on audiogram. The sound calibration can be done with respect to young person with good hearing power or using artificial ear. After calibration the actual testing of patient’s ear can be performed. The audiometer is independent of sound card used, this can be checked by running this software at different PC volume settings.

7 Test Results

Results obtained by above process can be checked by comparing audiogram obtained from different diagnostic audiometers.

8 Conclusions

PC sound card based diagnostic audiometer can be used for detecting the hearing loss. Graphical user interface makes it easy to operate. Test results can be acquired in a short time. This test can be performed with the availability of a PC. It is also platform independent i.e. it can run on both Windows as well as Linux machines. The audiometer designed is a portable device, used for measuring hearing functions.

Appendices

A.1 PCB

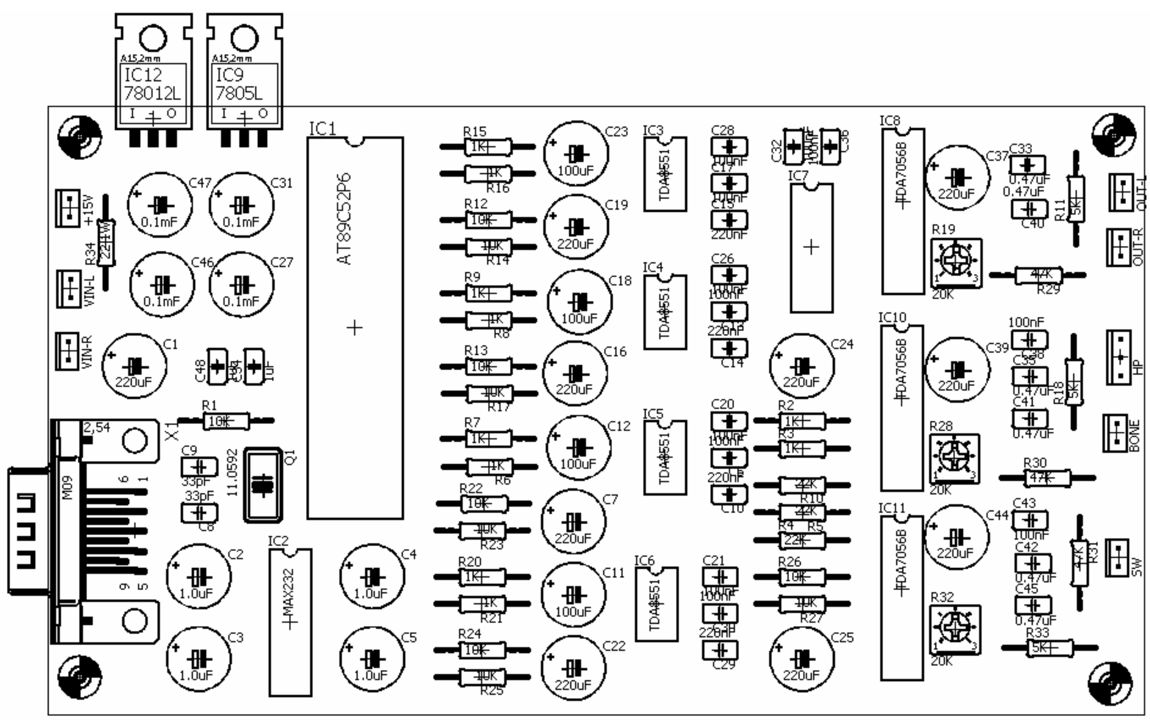

Fig. 17 Component Placement 6.0 inch x 3.5 inch

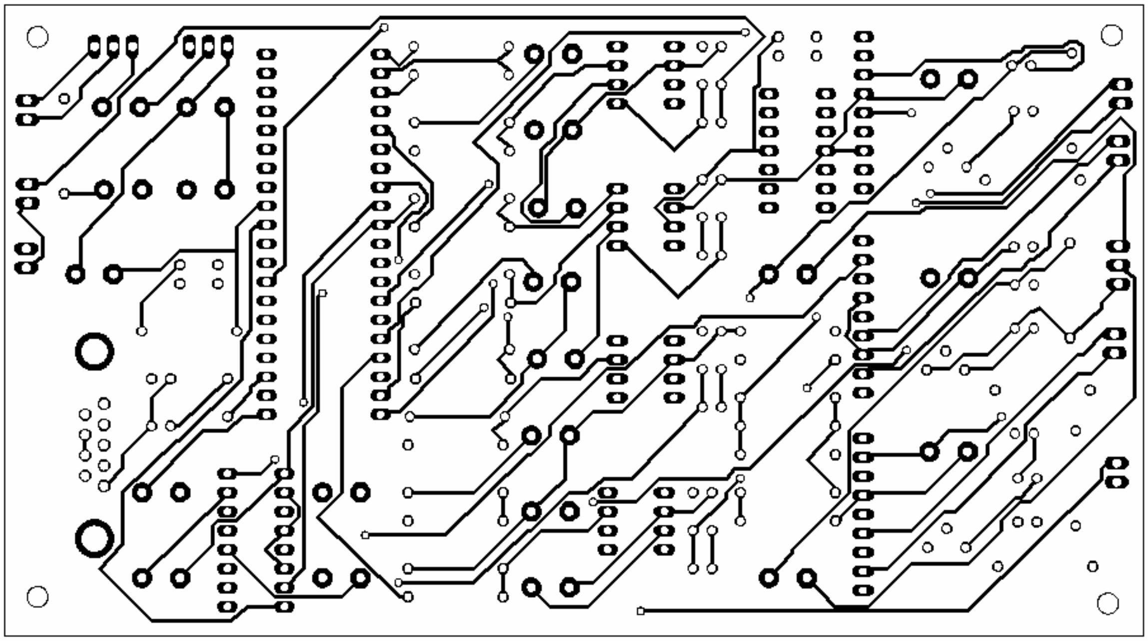

Fig. 18 Top Layer

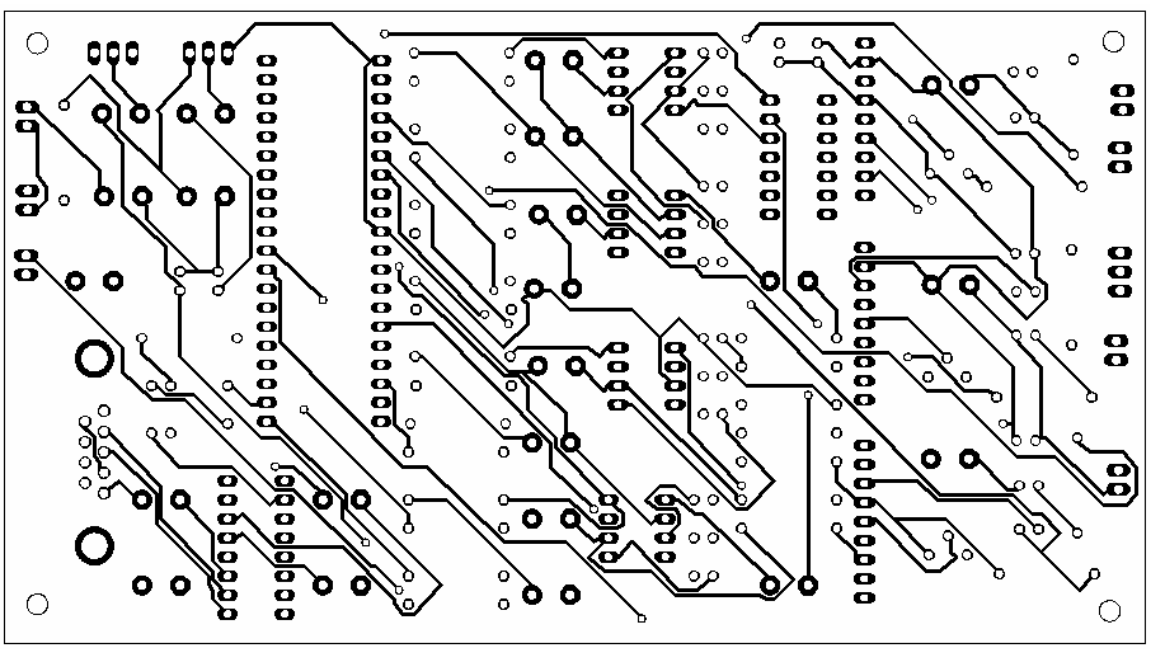

Fig. 19 Bottom Layer

A.2 Full Circuit

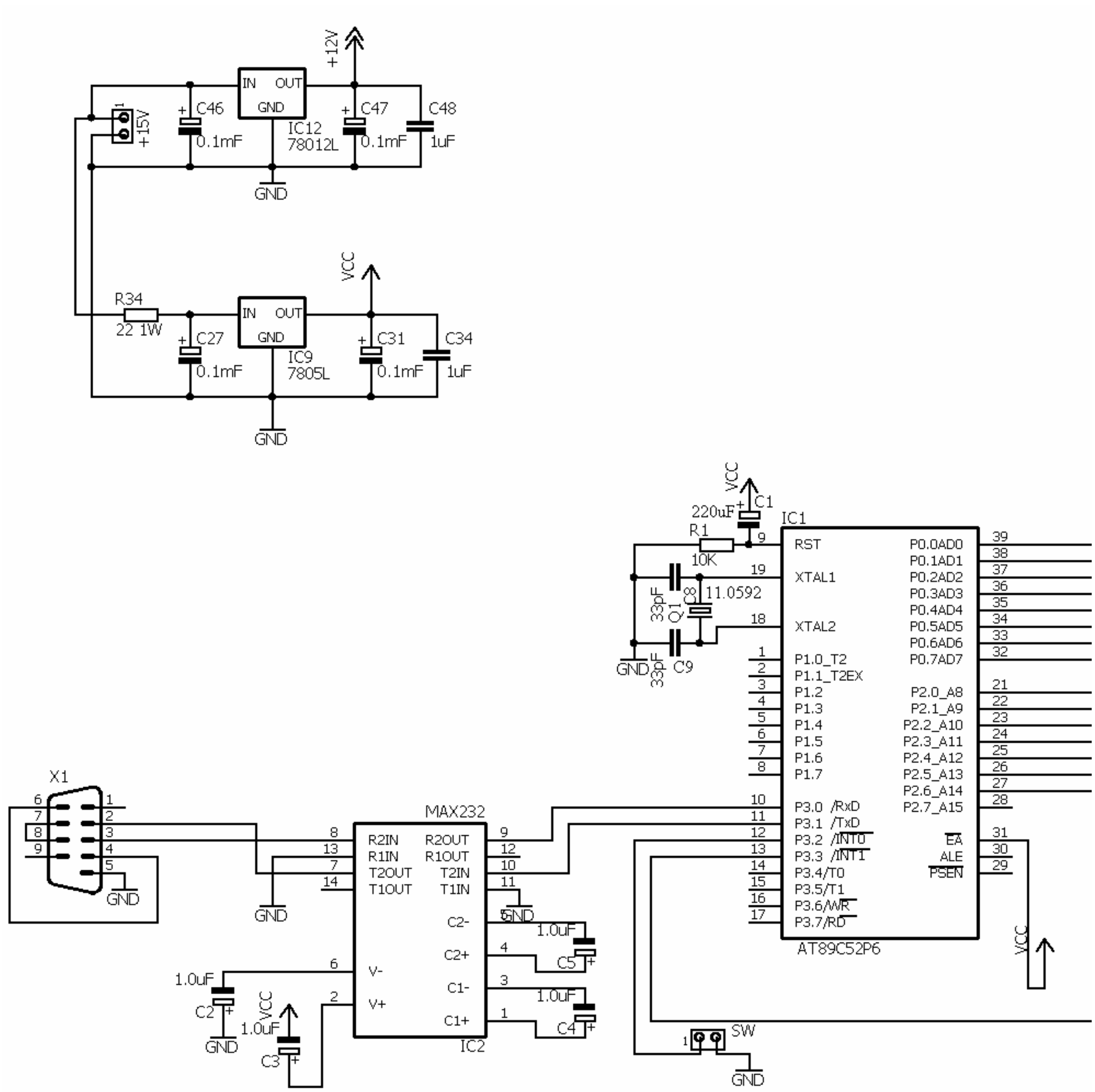

Fig. 20 Block I of full circuit

PC diagnostic audiometer circuit is shown here. To accommodate the full circuit it has been divided in two halves namely Block I and Block II. Block I is shown in Fig. 20 and Block II is shown in Fig. 21. Labels, if used, in any previously shown circuits matches with circuits shown in Fig. 20 and Fig. 21.

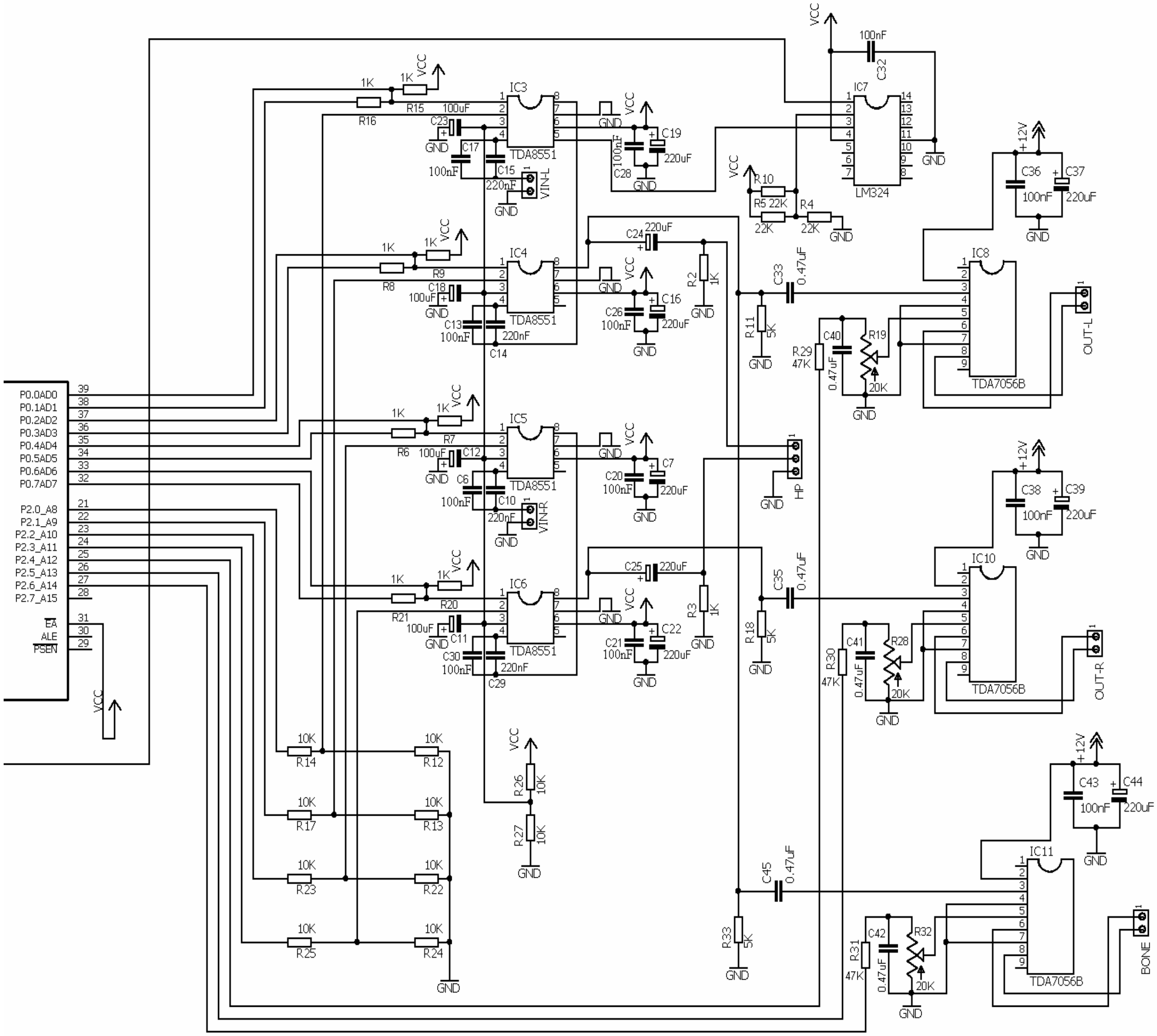

Fig. 21 Block II of full circuit

A.3 Top view of final product shown in Fig. 20

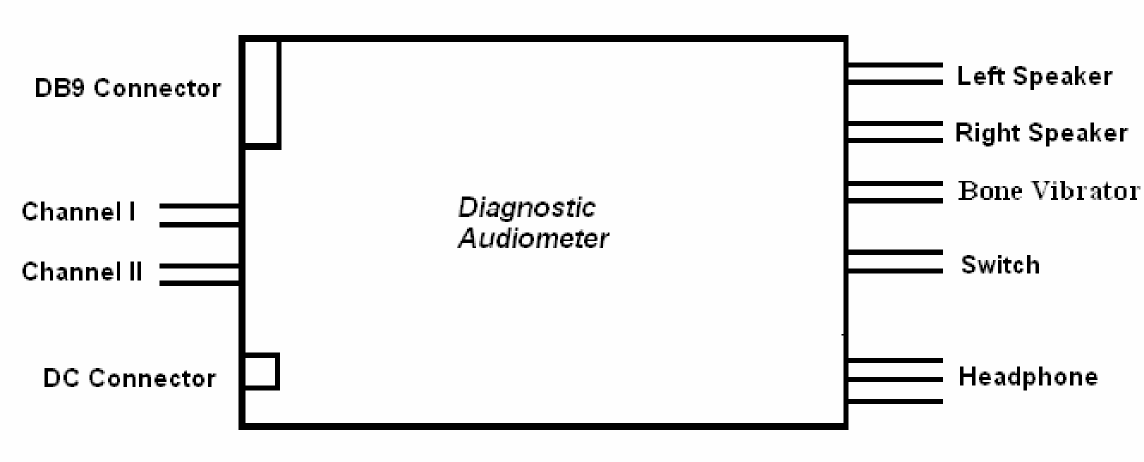

Fig. 22 Top View

A.4 List of components

A.4.1 Attenuator circuit:

1.	Disc Capacitor	100 nF/50 V	8
2.	Disc Capacitor	330 nF/50 V	4
3.	Electrolytic Capacitor	100 uF/25V	4
4.	Electrolytic Capacitor	220 uF/25 V	6
5.	Resistance	1 K/ 250 V	10
6.	Resistance	10 K/ 250 V	8
7.	TDA8551		4
8.	TDA7056B		3

A.4.2 Serial Communication Circuit:

1.	IC Max 232		1
2.	Electrolytic capacitor	1 uF/25 V	5
3.	F09H Serial Port Socket		1

A.4.3 Microcontroller circuit:

1.	Microcontroller	AT89C52	1
2.	Crystal Oscillator	11.0592 MHz	1
3.	Disc capacitor	33 pF/ 50 V	2
4.	Electrolytic Capacitor	22 uF/ 25 V	1
5.	Resistance	10K/ 250 V	1

A.4.4 Comparator circuit:

1.	IC LM324		1
2.	Resistor	22K/250 V	1
3.	Resistor	11K/250 V	1

References

[1] Dipak M. Patel / P. C. Pandey (Guide), A Microcontroller Based Audiometer, M.Tech. dissertation, EE Dept., IIT Bombay, 2002.

[2] Rahul Pratap Singh and Avdhoot Bane, "PC sound card based diagnostic audiometer", EE 389 EDL Project Report, EE Dept., IIT Bombay, December 2005.

[3] Manish Nalamwar, "Advanced Audiometer: A Novel Signal Generator Technique", M. Tech. Credit Seminar Report, Electronic Systems Group, EE Dept., IIT Bombay, November 2004.

[4] Kenneth J. Ayala, *The 8051 Microcontroller Architecture, Programming, & Applications*, Second Edition, Thomson Asia Pte. Ltd., Singapore, 2005.

[5] Michael J. Pont, *Embedded C*, Pearson Education Limited, 2002.

[6] Datasheet Search System, "Datasheets Philips TDA8551", http://www.alldatasheet.com/datasheet-pdf/pdf/19507/PHILIPS/TDA8551.html , last accessed on Nov. 1, 2006.

[7] Datasheet Search System, "Datasheets Philips TDA7056B", http://www.alldatasheet.com/datasheet-pdf/pdf/19425/PHILIPS/TDA7056B.html , last accessed on Nov. 1, 2006.

[8] Electrical Engineering Dept, IIT Bombay (2006), "Datasheets and general information", http://www.ee.iitb.ac.in/uma/~wel

[9] Sun Microsystems, "Java Tutorial", http://java.sun.com/docs/books/tutorial/, last updated on November 10, 2006.

[10] Developer Solutions, "Java Sound, Creating, Playing, and Saving Synthetic Sounds", http://www.developer.com/java/other/article.php/2226701, last updated on December 1, 2006.