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A NOVEL RASPBERRY PI-3 BASED PURE TONE AUDIOMETER AND VERIFICATION OF CALIBRATION WITH STANDARD SYSTEM

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Abstract

Audiometry is the technique to quantitatively determine the degree of hearing loss of a person, so that suitable medical treatment or one of the appropriate hearing aids and assistive device can be prescribed.The electronic instrument used for audiometry is called pure tone audiometer. All audiometry instruments need calibration and maintenance from time to time. The Audiometry must meet the performance and calibration set by American National Standards Institute (ANSI) and International Electrotechnical Commission (IEC). Small Portable, user-friendly Raspberry pi based Pure tone Audiometer is designed and tested. The Present paper is on calibration of said Pure tone audiometer. This article is to discuss the calibration of newly designed Raspberry Pi based Pure tone Audiometer via an earphone and Bone transducers. The common types of earphones used in hearing testing are described and the importance of calibrating these transducers is discussed and the instruments used for calibration, the performance parameters measured in the calibration process are examined. The limitations of our current methods are discussed and areas for improvement are considered.

Keywords: Audiometry, Raspberry Pi, Headphones, Acoustic Coupler, Sound level meter

1. Introduction

The present paper the author is dealing with calibration of the headphones and bone conduction probes. There could be various disorders in the various parts of the ear. Audiological investigations help to diagnose the nature of deafness and localise the site of disorder. The method by which subject's hearing sensitivity can be determined is termed as audiometry. It helps in assessing the nature, degree, and probable cause of the hearing impairment. In this technique, Auditory stimuli with varying intensity levels are presented to the person who responds to these stimuli. The minimum intensity level of these stimuli to which consistent responses are obtained is taken as the threshold of hearing. Depending on this threshold, the subject’s hearing sensitivity can be estimated by obtaining an audiogram. An audiogram is a plot of threshold intensity versus Frequency.

The Fundamental Audiometry has two methods:

1. **Objective audiometry**
2. **Subjective Audiometry**

Objective audiometry measures electrical activity in the auditory pathway. It does not require the response from a patient. Subjective techniques test the patient's ability to hear words, frequencies, or tones at differing intensities. The participant will need to respond to the stimuli for an accurate evaluation. To ensure proper function, audiometers must comply with the International Electrotechnical Commission (IEC) manufacturing standards. They should also meet the performance and calibration requirements set by International Organization for Standardization (ISO) and ANSI1criteria. During calibration, the frequency is measured by the frequency counter and amplitude is measured using an artificial ear and sound level meter.

3. Design and Implementation

Raspberry Pi is a low cost, low powered, hand-sized computing Board. It has many interfaces (HDMI, multiple USB, Ethernet, onboard Wi-Fi and Bluetooth, many GPIOs, USB powered, etc.) which provide user friendly and advanced features integrated and have a wide range of future scope where latest technologies can be embedment for better advanced results. Continued growth is expected worldwide as 4G and 5G mobile networks become increasingly available. The global digital transformation enables computational audiology for advanced clinical applications that can reduce the global burden of hearing loss. By Using Raspberry Pi2, we can adopt emerging hearing-related artificial intelligence applications and argue for their potential to improve access, precision, and efficiency of hearing health care services. Also, we can raise awareness of risks that must be addressed to enable a safe digital transformation in audiology. We envision a future where computational audiology is implemented via interoperable systems using shared data and where health care providers adopt expanded roles within a network of distributed expertise. This effort should take place in a health care system where privacy, responsibility of each patient’s safety and autonomy are all guarded. There is also a trend towards the sousveillance which encourages the continuous use of personal tracking devices where Raspberry Pi supports it.

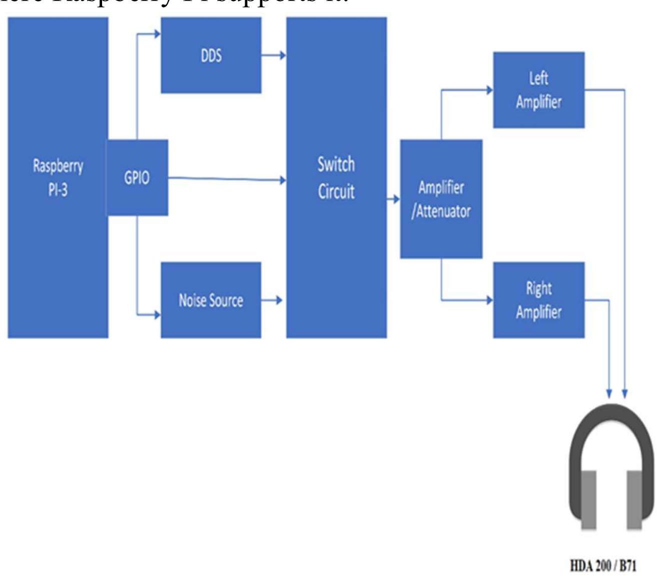

Figure 1 Raspberry Pi Based Pure Tone audiometer

Raspberry Pi GPIO's are connected to DDS and Noise Generator and relay switch circuit. DDS Generates Pure sine wave of different frequencies which is used for conducting the required Air and Bone Conduction, Noise Generator gives White Noise which is used for Masking View test. The Pure Tone and White Noise are controlled by Switch Circuit where the output analogy signal is shared to Left and Right Amplifier accordingly controlled by Switch Controller and the output of Amplifier signal is given to the Headphones.

The Existing Audiometers that are in the market are made of large no of controllers mostly operated. The Present Pure Tone Audiometer are computer. Laptop enabled systems, leading to high cost and software's are needed for the computers. The Raspberry pi-based system is a low cost having all the features of PC mother board such as USB, LAN interface Wi-Fi and Bluetooth. Due to availability of GPIO's all kinds of interfaces can be done. As raspberry Pi is supported with Various OS and Phyton, by using Open-source software cost is low. The dedicated software such development of raspberry pi based pure tone audiogram. The cost is very low compared to market instruments. Hence the newly designed Raspberry bi based Pure tone audiometer will be a great use to medical instruments. The objective of this development is to bring low-cost advanced Pure tone audiometer.

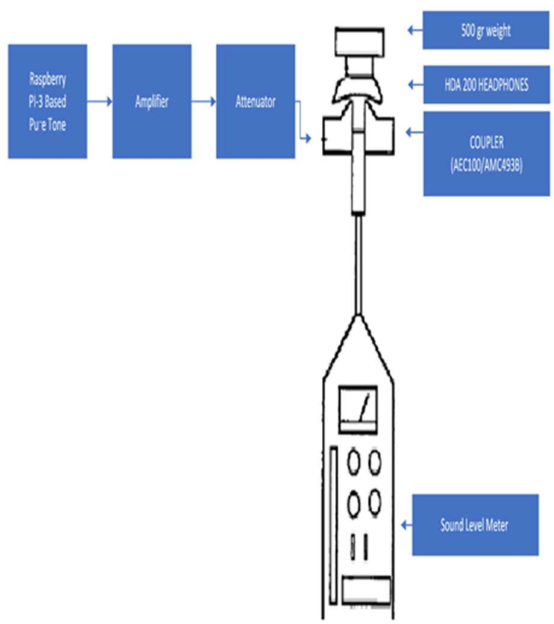

Figure 2: Block diagram of Calibration Process

DDS (Direct Digital Synthesis) output is processed through amplifiers and programmable attenuators. The output from the power amplifier is tested for distortion of the signal and noise. The output can drive audiometric headphone and bone conduction probes. In the present system HDA 200 audiometric headphones are used for calibration of the newly designed audiometry through AEC3 100 (Acoustic Coupler) and the system is shown in Fig-2

Output Level of Earphones and Bone transducers

For audiometric calibration, the most common conception is to measure the output level of an earphone. This is a relatively simple process, requiring only an appropriate coupler, microphone, and a sound level meter. In fact, if the equipment is available, it is advisable to measure output levels more frequently suggested at least 3-month intervals or once per year. The output level is assessed relative to known standardized hearing thresholds. These thresholds are known more formally as RETSPLs (ANSI S3.6 2010; ISO 389-5 2006). A subject's hearing level (dB HL) is evaluated in reference to the normative hearing threshold (0-dB HL), also called the reference equivalent sound pressure level (RETSPL4), specified in a relevant standard RETSPLs represent the SPL that is necessary to achieve absolute thresholds of hearing as measured in population of ontologically normal subjects. Additionally, the human ear is not equally sensitive across frequency due to the variation in its mechanics. These differences need to be accounted for in calibration, so RETSPLs have been established according to the type of earphone, coupler, and the test frequency. It is important when measuring output levels that background noise does not affect the results. To help minimize this problem, RETSPLs are acquired at a level that is well above typical hearing thresholds. Although any output level can be used, it is common practice to set the dial to 70-dB HL. The output level is then measured on the sound level meter. Recall that the sound level meter measures the output.

The AEC100 Coupler is a precision acoustic coupler designed primarily for the calibration and test of supra-aural earphones used in audiometry. It allows accurate and repeatable measurements within its frequency response (up to 8 kHz). It may also be used for production testing, where the correlation between the coupler and real-ear response is not a requisite. For use with either the pre-polarized or externally polarized, 1-inch microphone. The AEC 100 is shown in Fig-3.

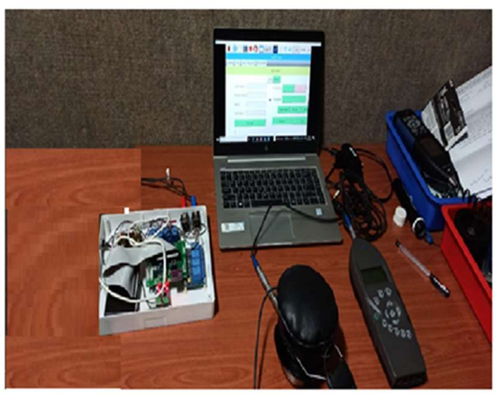

Figure 3: Hardware modules of AEC100 /AMC493B coupler

The experiment is repeated, and data obtained from the system is presented in Table 1 and Table 2. The desired system performance is matching with standard instrument. The AMC493B artificial mastoid is a precision mechanical coupler used to calibrate bone conduction hearing aids and audiometer bone vibrators. The AMC493B5 is cost-effective and simple to use. Its patented design converts the vibrator force output to an acoustic signal measured with the system's sound level meter. It is used with the AEC100 coupler Ear Simulator to perform bone vibrator tests.

AUDIOMETER					
AIR CONDUCTION CALIBRATION: PURE TONE					
Frequency	Type No: HDA200				
IN Hz	Input	RETSPL	Excepted Value	Measured Value	Error Value
	dB HL	DB	dB SPL	dB SPL	

250	10	18	28	28.4	1.408
500	70	11	81	83.8	3.34
1000	70	5.5	75.5	76	0.65
1500	70	5.5	75.5	76.5	1.3
2000	70	4.5	74.5	77.2	3.49
3000	70	2.5	72.5	73.7	1.62
4000	70	9.5	79.5	82.1	3.16
6000	70	17	87	90.8	4.18
8000	70	17.5	87.5	90.6	3.42

Table 1: Represents Calibrated Values of HDA 200

Air conduction calibration testing is the measurement of an individual's hearing sensitivity to calibrate pure tones at different frequencies. The basic audio logical assessment focuses on pure tone air conduction thresholds in the frequency range 250 - 800Hz. The test is conducted in a sound isolated environment. Each ear is tested separately using various transducers such as headphones, insert earphones or bone conductors. As it is a behavioural test, it is dependent on the response from the individual being tested. Pure tone thresholds at each frequency are plotted on a graph called an audiogram, which depicts the type, degree and errors of the hearing loss (table1).

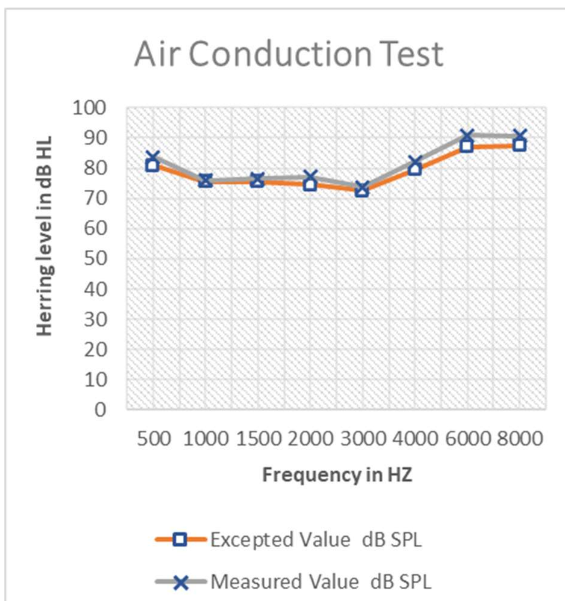

Figure 4: Air conduction plot (frequency vs hearing loss)

AEC 100 is coupled with system 824 for real-time analysis. System 824 is an electro and Precession sound level meter level, frequency, and FM Pulse Measurements are a small portion of 824. The 8246 output measures frequency amplitude in mil volts and SPL in Decibels. This is the heart of the measuring system. The HDA 200 headphone right or left headphones should be placed on the conical cap of AEC 100 and the headphone is firmed or facially keeping the weight of 4.5 kg. This enables proper contact to AEC100 coupler. The audio frequency is applied to HDA 200 through the raspberry Pi-based audio signal generator. The signal generator is programmable for frequency as well as applied voltage in DB's.

AUDIOMETER					
BONE CONDUCTION CALIBRATION: PURE TONE					
Frequency	Type No: B71				
IN Hz	Input	RETSPL	Excepted Value	Measured Value	Error Value
	dB HL	DB	dB SPL	dB SPL	
500	15	58	73	75	2.6
1000	25	42.5	67.5	69	2.17
1500	30	36.5	66.5	68.8	3.34
2000	35	31	66	67	1.49
3000	40	30	70	71.1	1.54
4000	40	35.5	75.5	77.5	2.58

Table 2: Represents Calibrated Values of B71

Bone conduction calibration testing is the measurement of an individual's hearing sensitivity to calibrate pure tones at different frequencies. The basic audio logical assessment focuses on pure tone air conduction thresholds in the frequency range 500- 4000Hz. The test is conducted in a sound isolated environment. Each ear is tested separately using various transducers such as headphones, insert earphones or bone conductors. As it is a behavioural test, it is dependent on the response from the individual being tested. Pure tone thresholds at each frequency are plotted on a graph called an audiogram, which depicts the type, degree and errors of the hearing loss (table 2).

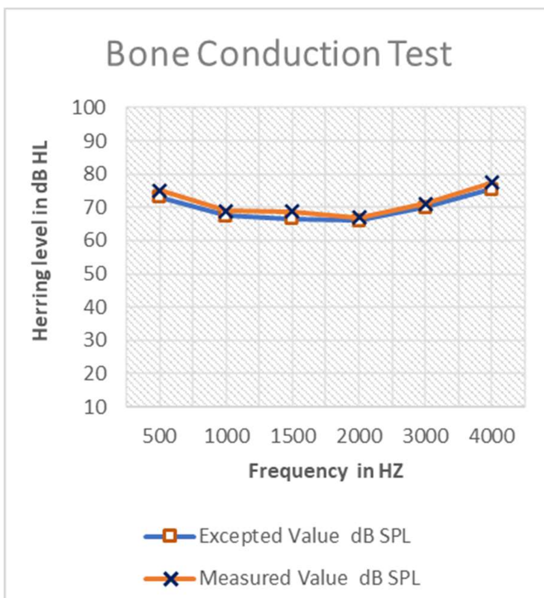

Figure 4: Bone conduction plot (frequency vs hearing loss)

The output of the system's voltage is applied to headphones as soon as the electric excitation takes place AEC 100 (Artificial Ear simulator) responds and gives the audio signal to the system 824 measuring system. The 824 measures applied frequency and sound power level generated by headphones. In the raspberry pi-based system the output is increased from 0 to (fine value) the output in SPL is recorded repeatedly and analysed the system the table shows the HDA 200 response through systems 824 and includes applied frequency and amplitude in the steps of DB's and the output is SPL. The Experiment is repeated many times and found the values fitting to standards of ANSI. Table 1 Represents the values of the standard and our newly designed PTA with HDA 200 and Table 2 refers Values with B71 Transducer.The Results are highly satisfied meeting the clinical standards.

Conclusion

In this paper a Newly designed system for conducting audiometry is presented. Algorithms embedded in one system with the help of hardware modules does the function of an audiometer and this system can be a part of add on card, which maybe used. this development will lead to further development of new products with low power requirements. Thus, technologies which are cost effective and user friendly can be employed for accurate diagnosis.

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