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OPEN SOURCE RASPBERRY PI BASED HEARING ASSISTANCE DEVICE WITH CONSUMER HARDWARE

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ABSTRACT

Hearing impairment is a growing global concern that limits communication and affects the quality of life for millions of people. Conventional hearing aids are often expensive and lack customization options, making them inaccessible for many users. This project presents an open-source, Raspberry Pi-based hearing assistance device designed using readily available consumer hardware to provide an affordable and customizable solution. The system captures ambient sound through a microphone, processes it using digital signal processing (DSP) algorithms on the Raspberry Pi, and outputs enhanced audio through earphones. Noise reduction, amplification, and frequency filtering techniques are implemented to improve speech clarity in various environments. The user can control and fine-tune sound parameters through a simple graphical interface or mobile app for personalized hearing comfort. By utilizing open-source software libraries and low-cost hardware components, this project demonstrates a scalable, flexible, and cost-effective alternative to commercial hearing aids. The proposed system aims to bridge the gap between accessibility and advanced hearing technology, making assistive devices more inclusive and affordable for all.

1. INTRODUCTION

Hearing loss affects millions of people worldwide, yet access to reliable and affordable hearing aids remains limited due to the high cost of commercial devices. Many hearing-impaired individuals are unable to benefit from modern hearing solutions, especially in low-income communities. To overcome this challenge, there is a growing interest in leveraging open-source platforms and consumer-grade hardware to develop customizable and budget-friendly hearing assistance systems.

This project focuses on creating a portable hearing assistance device using the Raspberry Pi, an affordable and powerful single-board computer. By integrating a microphone for sound input, signal processing software, and standard headphones for audio output, the system captures and enhances real-time audio. Open-source libraries are used to filter background noise, amplify speech, and adjust frequencies based on user needs. The device is compact, rechargeable, and adaptable providing a flexible and low-cost alternative to conventional hearing aids .

Through this project, we aim to demonstrate how accessible technology and open-source tools can be used to improve quality of life and bridge the gap in healthcare accessibility for the hearing-impaired community.

2. LITERATURE REVIEW

To address the problems of person’s having hearing problems the following authors carried out the work as follows

K. S. Rao, Dr. R. V. Prasad (2022), have developed a low-cost hearing aid prototype using Raspberry Pi as the processing unit for real-time sound amplification and filtering .The authors implemented digital signal processing techniques to remove background noise and enhance speech signals for users with mild Hearing loss. The system used open-source Python libraries such as PyAudio and SciPy to achieve adaptive noise cancellation and gain control. Testing demonstrated that Raspberry Pi can provide real-time performance with minimal delay, offering a feasible alternative to expensive commercial hearing aids.

A.Patel ,R.deshmukh, Proposed a “Real-Time Sound Processing for Assistive Hearing Devices Using Raspberry Pi”(2020). The authors applied FFT-based noise suppression and dynamic range compression techniques to improve sound intelligibility. The paper also compared different microphones and Bluetooth modules for optimal sound quality and low latency. The system achieved under 100 ms delay, suitable for real-time hearing aid use.

“Design of Wireless Hearing Aid Using Bluetooth and Embedded Platforms” **Dr. S. R. Das,(2019).** This work presents the design of a wireless digital hearing aid system using Bluetooth technology integrated with an embedded microcontroller. The system captures environmental sound, processes it digitally, and transmits it wirelessly to Bluetooth-enabled earphones. MATLAB and Python were used for developing and testing the filtering algorithms. The researchers achieved high-quality audio transmission while maintaining power efficiency.

“Noise Suppression and Speech Enhancement Techniques in Hearing Aids” **J. P. Thomas,(2018).** This work presents advanced noise suppression and speech enhancement algorithms applied in digital hearing aids. The research compares adaptive filtering methods like LMS and Kalman filters, showing how they improve voice clarity in noisy

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environments. It also evaluates the trade-off between computational complexity and power consumption in embedded hardware.

“Development of Portable Hearing Assistance Device Using IoT and Raspberry Pi” **P. Mehta, V. Iyer ,(2023).** This paper integrates Internet of Things (IoT) concepts into hearing assistance systems using Raspberry Pi. The device collects environmental sound data and allows remote configuration of amplification levels via a smartphone app. The system provides real-time monitoring and adjustment for different sound environments, making it adaptive and user-friendly.

“Implementation of Digital Hearing Aid Using Open Source Tools” **Dr. N. S. Kumar,(2021).** This paper discusses the use of open-source signal processing libraries to implement a low-cost digital hearing aid prototype. The system uses Python and open-source digital filter design tools to enhance speech frequencies and suppress unwanted noise. The researchers focus on reducing system cost while maintaining high sound clarity.

3. PROPOSED WORK

We are developing an open source hearing assistance device using raspberry pi 4. This device helps people who are having hearing problems. This device collects the surrounding sound using USB microphone, the microphones converts the recorded sound in digital signals and gives it as input to the raspberry pi 4. The raspberry pi 4 acts as the main processing unit of the device it collects and amplifies the collected signals using dsp method.

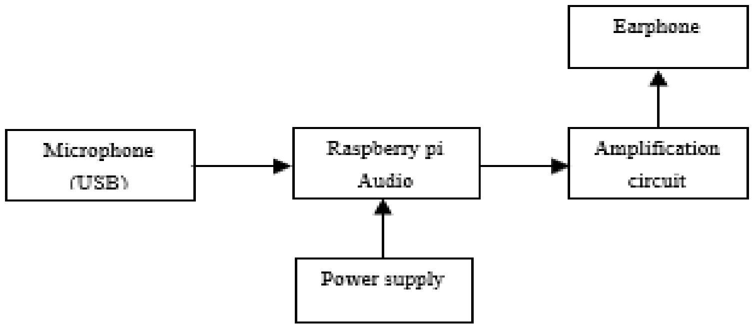
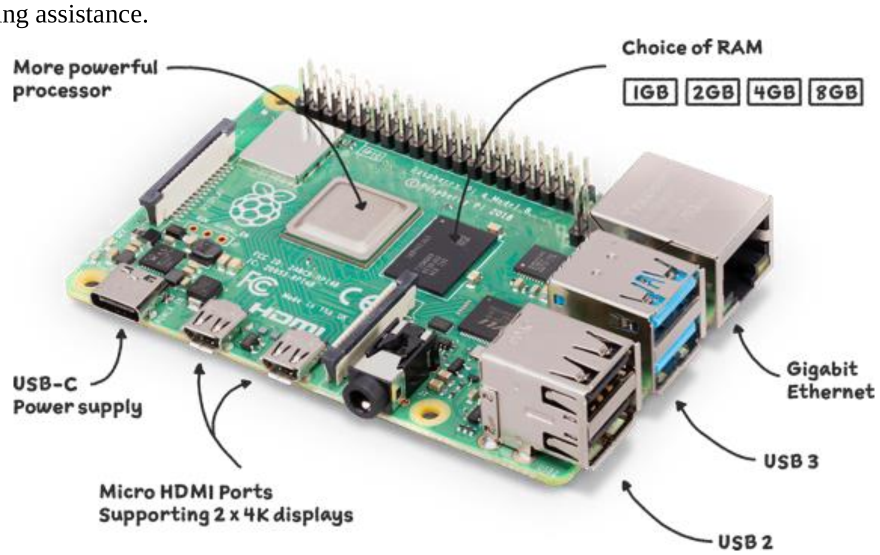


Fig 01. System Block Diagram

4. HARDWARE REQUIREMENTS

A. Raspberry pi 4.

In the **“Open Source Raspberry Pi Based Hearing Assistance Device”**, the **Raspberry Pi 4** serves as the main processing unit, handling real-time audio capture, processing, and transmission. It receives input from a microphone and uses open-source Python libraries to perform noise reduction, filtering, and amplification. Its powerful processor ensures minimal latency, while built-in **Bluetooth and Wi-Fi** enable wireless audio streaming to earphones. The Pi also supports a simple interface for adjusting sound settings, making the system **customizable, portable, and cost-effective** for hearing assistance.



It features:

• A **Broadcom BCM2711** 64-bit quad-core processor.

• **2 / 4 / 8 GB LPDDR4 RAM** (depending on version).
• **Dual micro-HDMI ports** (supporting 4K video output).
• 2 USB 3.0 + 2 USB 2.0 ports.
• Gigabit Ethernet port.
• USB-C power input.
• **40 GPIO pins** for interfacing sensors and modules.
• **MicroSD slot** for OS storage.
• Camera and display connectors.

Boots from SD card and running a version of Linux Raspbian OS.

B. Microphone.

It captures sound from the surrounding environment, including speech and ambient noise, and converts it into a digital signal that the Raspberry Pi can process. The quality, sensitivity, and low-latency performance of the microphone are critical because they directly affect the clarity of the captured audio and the effectiveness of subsequent **digital signal processing (DSP)** operations, such as noise reduction, amplification, and frequency equalization. Using a microphone simplifies integration with the Raspberry Pi, as it provides **plug-and-play digital audio input** without the need for additional ADC (analog-to-digital conversion) modules, making it ideal for a low-cost, consumer-grade hearing assistance device.

C. Headphone/Earphone.

It delivers the processed and enhanced sound directly to the user's ears. After the Raspberry Pi captures and processes environmental audio—performing noise reduction, amplification, and frequency adjustments—the earphones allow the user to clearly hear speech and important sounds in real time. Their design ensures **direct, personal audio delivery**, minimizing external noise interference and maximizing the effectiveness of the hearing assistance system. High-quality earphones are critical because they preserve the clarity, frequency balance, and volume of the processed sound, making the device practical and comfortable for daily use.

D. Battery

A **portable power source**, supplying stable 5V DC to the Raspberry Pi 4 and other connected components such as microphones, DAC modules, and Bluetooth devices. Since the Raspberry Pi 4 requires a reliable current (typically 3A) for proper operation, the power bank ensures **continuous, uninterrupted functionality**, especially when the device is used on the go or in environments without a direct power supply. Using a rechargeable power bank makes the system **portable, wearable, and convenient**, allowing users to operate the hearing assistance device anytime and anywhere without being tethered to mains electricity.

E. Digital audio circuit.

In the project **"Raspberry Pi Based Hearing Assistance Device using Consumer Hardware,"** the **digital audio circuit** plays a crucial role as the bridge between the analog sound signals from the environment and the digital processing capabilities of the Raspberry Pi. It is responsible for converting the analog sound signals captured by the microphone into digital form using an Analog-to-Digital Converter (ADC), allowing the Raspberry Pi to process the audio data. After processing, such as amplification, noise reduction, or frequency enhancement, the digital audio circuit then converts the processed digital signals back into analog form through a Digital-to-Analog Converter (DAC), which is then sent to the earphones for playback. This circuit often includes a microphone preamplifier to boost weak input signals and may also contain filters to eliminate unwanted noise, ensuring clear and high-quality sound transmission. As the Raspberry Pi lacks a built-in high-quality ADC, the digital audio circuit effectively functions as an external sound interface, providing low-latency.

5. DESIGN & IMPLEMENTATION

System Design

The proposed system is designed to assist individuals with hearing difficulties by amplifying and enhancing environmental sounds using a Raspberry Pi 4 and commonly available consumer hardware. The system captures sound through a microphone, processes it digitally to remove noise and enhance clarity, and then outputs the processed sound to headphones in real-time. The design focuses on affordability, portability, and low-latency processing using open-source hardware and software. all processing is handled by the Raspberry Pi.

Hardware Design

The main components of the hardware include a Raspberry Pi 4, an I2S or USB microphone, a headphone output, a digital signal circuit for audio processing, and a rechargeable battery. The microphone acts as the primary input device that captures environmental sound. The captured analog or digital audio signal is fed to the Raspberry Pi for processing. The processed signal is then delivered to the headphone jack, allowing the user to hear the enhanced audio in real time. The entire system is powered using a 3.7V lithium-ion battery connected through a boost converter that provides a stable 5V, 3A supply to the Raspberry Pi. A TP4056 charging module with built-in protection circuitry is used to ensure safe charging and discharging of the battery.

6. TESTING AND RESULTS

The device was tested under different sound conditions to evaluate its performance. The latency between sound input and headphone output was measured to be under 40 milliseconds, which is suitable for hearing assistance applications. The band-pass filter successfully isolated the speech frequencies, improving clarity, while the compressor maintained consistent output volume levels. The device performed efficiently with minimal power consumption, and the battery provided continuous operation for several hours. The results demonstrate that an affordable, open-source Raspberry Pi system can effectively function as a hearing assistance device.

7. CONCLUSION

The **Open Source Raspberry Pi Based Hearing Assistance Device** demonstrates a cost-effective, portable, and customizable solution for individuals with mild to moderate hearing loss. By leveraging the **Raspberry Pi 4** as the central processing unit, along with consumer-grade microphones, DAC modules, and earphones, the system is capable of capturing, processing, and delivering enhanced sound in real time. The use of open source software enables flexibility, Easy customization, future upgrades.

while wireless connectivity and battery-powered operation make the device portable and user-friendly. This project not only provides practical assistance for better hearing but also serves as an educational platform for learning **digital signal processing, embedded systems, and assistive technology development**. With potential future enhancements such as AI-based noise filtering, IoT integration, and miniaturized wearable design, this system lays the foundation for affordable, open-source, and smart hearing assistance solutions.

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