HEAR FUSION

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Hearing Aid, Digital Signal Processing, ASIC, RTL, Raspberry Pi Pico.

Introduction:

Hearing impairment impacts communication and also it affects social interaction. Overall, the quality of life suffers from hearing loss. People with sensorineural hearing loss, they often struggle to understand speech. This is most pronounced in noisy settings, it's really tough. Conventional hearing aids generally amplify all sounds. However, those conventional hearing aids cannot distinguish speech from background sounds. Therefore, this leads to discomfort for the user. This also means there is reduced speech intelligibility, leading to dependence, on external help.

Elderly users or those with limited dexterity find this difficult and it can cause problems. Features may be missing too, especially from many low-cost aids. The missing settings such as adaptive filtering. Also, there could be issues with feedback suppression, which is a hassle. Sound enhancement is often poor, it really needs attention, it could use environmental awareness.

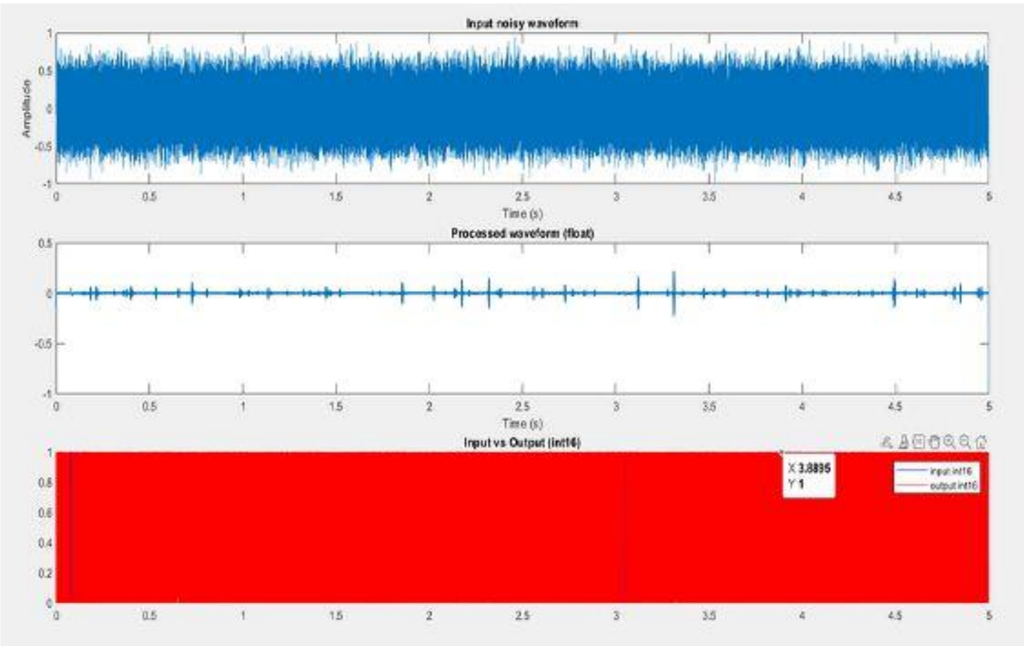

Figure 1: DSP Processed Waveform

Objectives:

1. To design a real-time DSP-based hearing aid that enhances speech clarity and suppresses unwanted background noise.
2. To develop a low-cost and portable prototype using a MEMS microphone, Raspberry Pi Pico, and DAC output.
3. To validate DSP algorithms using MATLAB simulations and evaluate hardware feasibility using Verilog RTL.
4. To create a user-friendly system that improves listening comfort, intelligibility, and accessibility for individuals with sensorineural hearing loss.

Methodology:

The project Hearing Aid using DSP-based Custom ASIC is developed in three stages to ensure that the final device is accurate, reliable, and suitable for chip-level implementation. First, in MATLAB, we design and test the DSP algorithms such as filtering, noise reduction, and gain control, because MATLAB allows us to easily visualize and verify whether the sound is improving before moving to hardware. In the second stage, we build the hardware prototype using Raspberry Pi Pico, INMP441 I2S microphone, MCP4725 DAC, LM386 amplifier, and earphones/speaker. This stage helps us check if the algorithm works in real time on an actual device and lets us tune the audio quality for the user. Finally, in the third stage, we convert the MATLAB algorithms into digital logic (Verilog) and simulate them in Xilinx Vivado, showing how the same functions would work inside a real custom ASIC chip. Together, these three phases allow us to develop a complete, low- power, real-time smart hearing aid system from algorithm design to hardware testing and finally to ASIC realization.

Result and Conclusion:

In conclusion, the proposed Smart Hearing Aid using DSP and Custom ASIC is expected to deliver a fully functional, low-cost prototype that can capture real-time audio, suppress background noise, enhance speech clarity, and provide clear amplified output for hearing-impaired users. By implementing advanced DSP techniques such as noise reduction, adaptive filtering, and automatic gain control on the Raspberry Pi Pico and later translating these algorithms into a custom low-power ASIC, the project aims to significantly improve audio quality while reducing size, power consumption, and overall cost. The outcomes include a working hardware model, measurable improvements in speech clarity in noisy environments, user-friendly operation, and strong potential for large-scale manufacturing. This project is designed to benefit society by offering an affordable alternative to expensive commercial hearing aids, making hearing assistance accessible to rural communities, elderly users, and economically challenged individuals. The final prototype will demonstrate the feasibility and impact of converting DSP algorithms into a dedicated ASIC, establishing a strong foundation for future commercial development and real-world adoption.

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Future Scope:

The future scope of this project includes:

1. **AI-Based Enhancement:** Implement AI-driven adaptive noise cancellation and automatic environment classification for better real-time audio processing.
2. **User-Friendly Features:** Add gesture-based volume control, Bluetooth connectivity, and smartphone app integration for improved user experience and customization.
3. **ASIC Implementation:** Convert the RTL design into a fabricated ASIC to achieve lower power consumption, reduced size, and a fully wearable solution.
4. **Advanced Audio Techniques:** Explore multi-microphone beamforming and battery optimization methods to enhance sound quality and device efficiency.