Portable In-Line Audio Equalizer

Project Proposal
Team Number 8

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1 Introduction

1.1 Objective

There are varying preferences to equalization (EQ) in audio, whether it is through personal preference or a need, such as helping with a hearing impairment. Some media players do not have a built-in equalizer nor do they allow for downloading EQ mobile apps. Due to this, users are unable to adjust the sound signature of what they're listening to. Also, many pre-existing EQ devices are too large or heavy to be portable.

The solution is the Portable In-Line Audio Equalizer (PIAE). Using the data from a desired media player, the PIAE uses signal processing algorithms to output audio data with a boost or attenuation at certain frequency ranges. This device allows for equalization while being inexpensive and convenient for easy, everyday use.

1.2 Background

Hearing loss can come in different ranges. One form of hearing loss to consider is a "notch" hearing loss, which is hearing loss at a certain frequency range [7]. In order to help with this type of issue, any desired frequency range can be boosted by an audio equalizer when using a media player. There are also people with personal preferences with sound signatures who use equalizers.

Some devices have built-in equalizers, like in computers and MP3 players, but that is dependent on the specific version and brand. Equalizer mobile apps can also be downloaded, but that is not possible for older devices, such as CD players.

There are also pre-existing portable audio equalizers. Typically, the more portable an audio equalizer is, the less operating ranges or bands it will have. Larger operating ranges allow for more options for the user, as well as a greater ability for the user to fine-tune the emphasis on the desired frequencies. This is especially important for users suffering from hearing loss. Commercial equalizers can have eight band filters, but those devices are not usable in a casual setting [5]. Portable devices are more convenient, but sacrifice performance by using less operating ranges [6]. The goal for the PIAE is to maintain the performance provided by commercial equalizers while also being usable by everyday people.

The performance of an audio equalizer is not only restricted to operating frequencies, but also latency. The limit for sound latency to be imperceptible by a performer hearing the sound that they are creating through their instrument is 10 to 12 milliseconds [4]. We can reason that this limit is also applicable to a user changing songs or resuming their music, which are situations where they would not want to perceive much lag between action and audio.

1.3 Physical Design

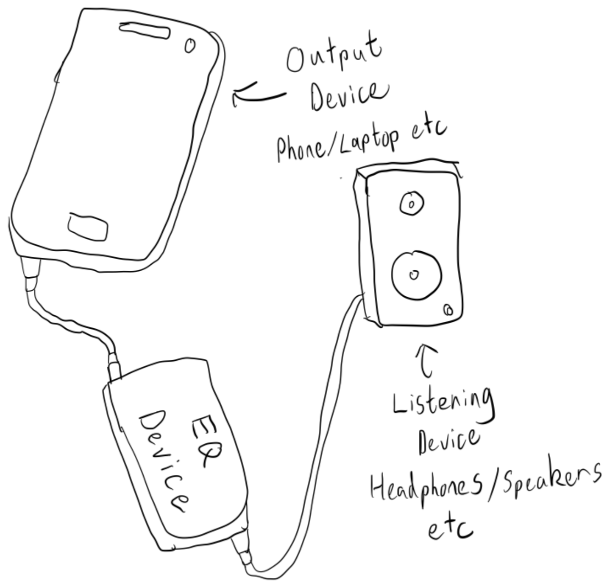

Figure 1: A Diagram of a Possible Use of the Portable Audio Equalizer

1.4 High-level Requirements List

- The PIAE must have a low latency of less than 12 milliseconds.
- The PIAE should use eight frequency bands when constructing its filters, instead of the typical 3 frequency bands.
- The PIAE must have a size of less than 11.4 x 8.9 x 5.1 cm in order for the device to be sufficiently portable.

2 Design

2.1 Block Diagram

The PIAE design has power, control, user interface, and audio input/output as the primary units. The power module generates an adequate amount of voltage for the other modules to use. The audio input/output module translates the audio data accordingly, which then allows the other components to understand the data. Using the data and desired filters that the user interface decides, the control module generates filtered data. This filtered data returns to the audio input/output module to then be outputted.

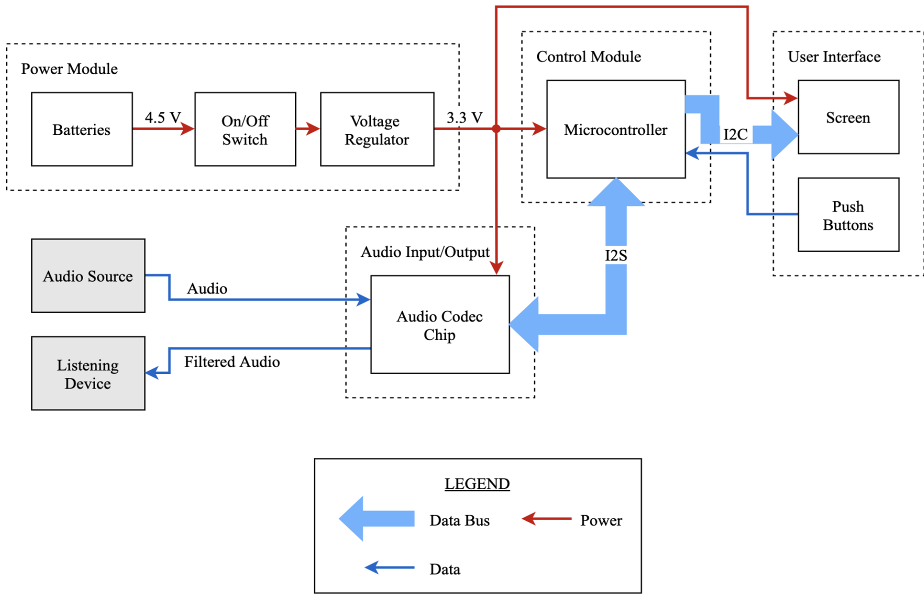

Figure 2: A Block Diagram of the Portable Audio Equalizer

2.2 Functional Overview and Block Requirements

2.2.1 Screen

Overview - This unit contains a screen that displays the currently selected EQ setting, as well as other possible EQ setting options. The screen receives signals from the microcontroller that represent the screen contents.

Requirements - The screen must be able to communicate with the microcontroller through I2C, as the microcontroller controls what the screen is depicting. Furthermore, it must operate on 3.3V.

2.2.2 Push Buttons

Overview - This unit consists of the push buttons which navigate the different EQ settings. The buttons send signals to the microcontroller indicating user input.

Requirements - Pressing the left and right buttons allows users to scroll between unique equalization settings. Pressing the confirm button allows the user to select the currently highlighted equalization setting, which will have immediate effect on the outgoing audio from the PIAE. In order to signal these events to the microcontroller, the buttons must be able to change the voltage across themselves when pressed.

2.2.3 Microcontroller

Overview - The microcontroller filters the I2S audio data from the audio codec chip according to the currently selected EQ setting and contains all possible EQ settings in memory. Additionally, the unit controls the screen display so that the currently selected EQ setting, as well as other possible EQ settings, are shown. Therefore, the microcontroller ensures that users can quickly and accurately change EQ settings to their preference. The microcontroller interfaces with all components of the device.

Requirements - The microcontroller must use eight frequency bands in the digital signal processing of the audio data within a frequency range of 200 Hz to 20000 Hz. Furthermore the microcontroller must sample at a rate of 40000 Hz and operate at a voltage between 2.0 and 3.6 V.

2.2.4 Audio Codec Chip

Overview - This unit converts the analog data, incoming from the media player's 3.5 mm audio port, to digital data for the microcontroller. It also converts the outgoing filtered digital data from the microcontroller to analog data for the listening device. Therefore, the audio codec chip interfaces with the microcontroller, the output device, and the listening device.

Requirements - A media player should connect to a 3.5mm audio jack in the PIAE, feeding analog audio data meant for conversion. The PIAE also has a 3.5mm audio port on the other end to feed digital data to the listening device. The audio codec chip should be able to sample at a rate of 40000 Hz, and should not have a latency of more than 1 millisecond when converting analog data to digital, and vice-versa.

2.2.5 Batteries

Overview - This unit provides power to the rest of the device through the use of batteries. It interfaces exclusively with the on/off switch, which then provides power to the rest of the block diagram.

Requirements - The batteries must supply 12.7 mA in order for the microcontroller to run. Additionally, the batteries consists of three AAA batteries in series, adding up to a total of 4.5V.

2.2.6 On/Off Switch

Overview - The switch powers the PIAE on and off so that the batteries will not be constantly draining. This makes the PIAE more sustainable. The on/off switch is connected to the batteries and the voltage regulator.

Requirements - The switch provides either 0V or 4.5V to the voltage regulator.

2.2.7 Voltage Regulator

Overview - This unit ensures that the voltage supplied to the circuit is maintained at 3.3 V. The voltage regulator interfaces with the batteries, and takes their 4.5V output to convert it to a usable 3.3V.

Requirements - The voltage regulator must maintain a 3.3V output, with a constant 12.7 mA current to the microcontroller, the audio codec chip, and the screen.

2.3 Risk Analysis

The microcontroller block in the block diagram poses the greatest risk to the successful completion of the project. It is the most complex block to implement, requiring both effective software design and hardware design. Therefore, there are many points of failure when it comes to the microcontroller, and more expertise is needed for its implementation. Specifically in software, the microcontroller must be able to filter the audio coming in from the audio codec chip according to the specifications of the currently selected EQ setting. Additionally, the microcontroller must control the state of the screen display and change its own internal state when the user interacts with the screen interface. These functions requires C programming language knowledge, as well as digital signal processing knowledge to implement the filters. Furthermore, the microcontroller will require hardware connections and interfaces, allowing it to interact with adjacent components in the block diagram, and it has more such connections than any other block.

3 Ethics and Safety

3.1 Development Issues

Our ethical considerations extend primarily to issues that could arise during the development of our project. Because the PIAE filters audio that is meant to be heard through headphones and speakers, we need to ensure that our product does not make the audio too loud. Audio at extremely loud volumes damages human hearing over time [1]. The IEEE Code of Ethics requires us "to hold paramount the... health and welfare of the public" [2], and therefore, the PIAE should not damage our user base's hearing without their knowledge. To this effect, the volume of the PIAE's output audio must be clipped at 100 decibels and it must warn users that listening to sound louder than 75 decibels could damage their hearing [1].

We may also encounter issues relating to the power unit. Alkaline batteries, which are used for the power unit, may leak or explode when used incorrectly [3]. Therefore, we intend to build a housing compartment for the power unit that allows enough temperature dissipation so that there is no threat of the batteries overheating. Furthermore, we must use a voltage regulator so that the batteries are not overloaded, and ensure that no short circuit or charging goes on during the equalizer's operation. Finally, the housing compartment should be designed to minimize damage to the user should the batteries malfunction.

3.2 Accidental or Intentional Misuse

The concern with accidental or intentional misuse is the scenario where a user increases the volume of the audio they are listening to by unsafe amounts using the PIAE. As stated before, we intend to mitigate this by clipping the volume of the device's output, and by warning users if the audio output of the device is greater than 75 decibels.

References

[1] "Hearing Loss - Symptoms and Causes." Mayo Clinic, https://www.mayoclinic.org/diseases-conditions/hearing-loss/symptoms-causes/syc-20373072. Accessed 14 Feb. 2021.

[2] IEEE Code of Ethics. https://www.ieee.org/about/corporate/governance/p7-8.html. Accessed 14 Feb. 2021.

[3] "Alkaline Batteries Handling Precautions for Safe Use." FDK, https://www.fdk.com/battery/alkaline_e/caution/. Accessed 15 Feb. 2021.

[4] Aug 06, Joe Albano on, et al. Monitoring Latency (How Low Can You Go?). http://ask.audio/articles/monitoring-latency-how-low-can-you-go. Accessed 17 Feb. 2021.

[5] Large commercial equalizer. https://www.cheapham.com/8-band-eq-by-w2ihy-special/. Accessed 14 Feb. 2021.

[6] Small Portable equalizer.https://www.amazon.com/Syba-SD-DAC63106-Control-Headphone-Amplifier/dp/B00TYYMHQS. Accessed 14 Feb. 2021.

[7] "Vital Signs: Noise-Induced Hearing Loss Among Adults — United States 2011–2012". CDC, https://www.cdc.gov/mmwr/volumes/66/wr/mm6605e3.htm. Accessed 14 Feb. 2021.