Hearing Damage Detector and Alarm System
Project Proposal

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1 Introduction

1.1 Problem

Middle and high school musicians can be subjected to harmful levels of noise on a daily basis between rehearsals, practice sessions, and performances. Cheap and effective hearing protection is available, but many students neglect using it until they start noticing the effects of their hearing damage years later. Even without considering hearing loss, long-term hearing damage can disturb the normal "balance between excitation and inhibition in the central auditory system" that can last several times longer than the time required to cause the damage [1].

1.2 Solution

Our solution is a device that provides live feedback to musicians about their noise exposure in an attempt to encourage more regular use of existing hearing protection equipment.

Our solution accomplishes this feedback through our LED system. Tentatively, LEDs corresponding to safe (green), potentially dangerous (yellow), and dangerous (red) indicate both instant danger and daily exposure danger by a static color and a flashing color. These LEDs, along with a more detailed csv report outputted using a USB connection, will be controlled/outputted by our microcontroller, which in turn is fed by our microphone subsystem. The microcontroller should be able to distinguish frequencies, especially those pertinent to humans, as well as the sound pressure level (SPL) at a given moment, instantaneous, and over a certain period, integrated. Our microphone subsystem feeds our microcontroller subsystem through the use of a microphone tuned to the human ear and a pre-amp circuit to prepare the raw data from the microphone. Last, all of these subsystems should be powered by a 3.3 V USB connection. Thus, our system should be powered by USB connection, able to read relevant sound from the environment, convey both instantaneous and daily exposure danger through LEDs, and give a detailed report through USB connection and a software program to aid musicians in combating dangerous sound.

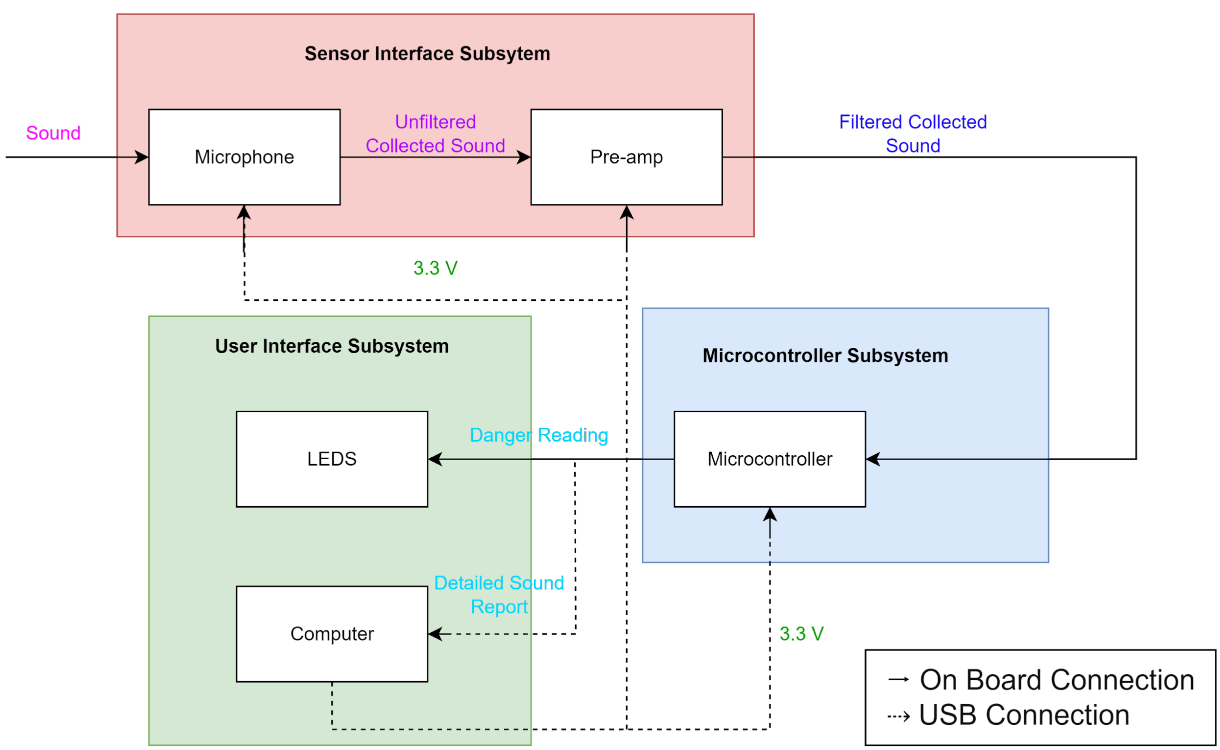
1.3 Visual Aid

1.4 High-Level Requirements

1. The device needs to be able take signals from a microphone and accurately calculate SPL from the data. The data transferred to the microcontroller should be correct within 5% of an industry grade SPL detector or equivalent.
2. The device needs to be able to display instantaneous and integrated SPL data in the form of lit-up LEDs. These LEDs should accurately convey instantaneous SPL within a 5% dB tolerance range and integrated SPL exposure given by the overview below.
3. The device needs to be able to upload recorded SPL data to a computer to perform the integration and generate a report. This report should include frequencies primarily that the human ear can listen to as well as the instantaneous and integrated SPL over the period the device was active. The report should be consistent with an industry grade SPL detector or equivalent.

2 Design

2.1 Block Diagram



2.2 Subsystem Overview

Subsystem 1 — Sensor Interface (Microphone)

To capture the sound pressure levels, we'll need a microphone that is omni-directional, responsive to the frequencies that the human ear is responsive to (about 10Hz-20kHz), and has a suitably high signal-to-noise ratio (~60dB or above). One microphone that fits these criteria is the TOM-1537L-HD-LW100-B-R.

Accompanying this microphone will be a pre-amp circuit to filter out DC noise and prepare readings to be used by the microcontroller.

Subsystem 2 — Microcontroller Unit

Our microcontroller will need to be able to take input data from the microphone interface and turn it into useful information for the user. There are two types of feedback we'd like to be able to provide: 1 - instantaneous SPL readings in dB and 2 - integrated SPL over time (also called "sound exposure") to gauge potential hearing damage accumulated over a session. A potential MCU to use for our device is the ATMega4808, which contains a 10-bit analog-to-digital converter and 48 kB of RAM.

Although a future version of this device could be powered by a rechargeable lithium-ion battery for the sake of portability. Due to time and scope limitations of the course, we will be powering this device via USB.

Subsystem 3 — User Interface

To present live feedback on instantaneous SPL, the device could feature a series of LEDS that light up in response to recorded dB. They should range from green for safe sound levels up to red for potentially dangerous sound levels. Statically, for instantaneous exposure, green should indicate from 0 dB to 90 dB, the limit of safe exposure according to OSHA [2]. Yellow should indicate from 90 dB to 105 dB, or the maximum noise level OSHA limits for a 1 hour period. Last, red should denote anything above 105 dB, when 1 hour of exposure is too much. Flashing should occur if the integrated SPL exposure limit is breached.

We use and define our LEDs to be easily discernible at glance and relevant to our problem, i.e., to musicians. Since 1 hour intervals are fairly common for structures like middle and high school bands, we would like to warn if the exposure for a 1 hour period is too high.

To present a report of sound exposure over the course of a session, we will plan to pull the data from the device onto a computer (just like the computers that would be located in a practice room or classroom) and perform the necessary integration operation there to conserve system resources. This operation will produce a report detailing the amount of sound exposure and what hearing damage it has the potential to cause.

2.3 Subsystem Requirements

Subsystem 1 — Sensor Interface (Microphone)

As indicated by our first high level requirement, the sensor interface needs to be able to detect sound in frequencies that the ear is responsive to as well as the intensity/SPL measured in decibels.

Quantitatively, the interface needs to be able to transfer this data to the microcontroller subsystem without loss of information within a 5% tolerance concerning frequency and SPL.

Subsystem 2 — Microcontroller Unit

The microcontroller unit needs to accurately convert the sound data it receives from the sensor interface into data the LED and computer can use.

As such, its instantaneous and SPL readings should be accurate to a 5% tolerance leaning more so on the conversative side.

Subsystem 3 — User Interface

The user interface responsible for both warning the user of the short-term dangers and long-term dangers as well as the power that fuels the system.

As such, it should be able to provide a 3.3 V source to the other subsystems with a tolerance of 10% (subject to exact specs of microcontroller, microphone, and pre-amp).
The warning lights using the microcontroller data should be accurate within a 5% dB tolerance leaning on the conservative side. In other words, if we have 90 dB, OSHA's standard for when noise can begin to harm, show up as green, that is unacceptable. However, if we have 89 dB show up as yellow, we can accept the discrepancy [2].

Last, the report generated by our software should at the very least capture the frequencies and SPL levels of sound, both instantaneous and integrated, to a 5% tolerance.

2.4 Tolerance Analysis

The most critical part of our project is the LED warning system, as it conveys the entire purpose behind our project. If the LEDs erroneously go off too much when there's no danger, then our project will rarely be used. However, if the LEDs go off too little when there is danger, then our project will not have fulfilled its purpose: it has not warned musicians when they are unsafe.

However, we believe that it will still be feasible. Given the abundance of commercially available instantaneous exposure devices, the static warning should be more than effective. The only difficulty is then showing the industry grade integrated SPL, i.e., LEP'd via the flashing. The LEP'd equation is given by [3]:

$$LEP'd \ or \ L_{EX}, 8h = L_{eq} + 10 \times log_{10} \left[\frac{T_2 - T_1}{T_n} \right] \text{ dB}$$

- *Leq* = frequency weighted (A or C), equivalent-continuous sound pressure level in dB
- T_n *Tn* = normalization period on criterion duration (8 hours by standard)
- $T_2 - T_1$ *T*2 - *T*1= measurement period or Run Time

Given that all of these functions are fairly simple mathematical operations, we believe that our microcontroller should be more than qualified to calculate integrated SPL to a 5% tolerance leaning on the conversative side. 5% should be enough to allow for some error, and the conservative qualifier indicates that we accept being more safe than sorry than allowing possible danger.

3 Ethics and Safety

Given that our project aims to give industry level safety to groups that otherwise would not have it, ethics and safety are a primary focus.

On ethics, one issue we have to keep in mind is that some people may be suspicious that since the project uses a microphone, it may be used to secretly record people. This misuse in turn would violate the IEEE code of ethics I.1 [4]. To dissuade these fears, we believe we would have to make sure the microprocessor only keeps track of what it needs to: instantaneous and integrated SPL and frequency.

On safety, as our project is primarily devoted to promoting safe SPL according to the previously mentioned OSHA standards, we would have to guarantee that our final product accurately, within our defined tolerance levels, converys SPL safety through both the LEDs and report. During the project, we would have to be careful to not expose any of ourselves and/or others to unsafe sound levels during testing. We would alleviate these concerns through simulating when possible and soundproofing and testing remotely when necessary.

Appendix: Works Cited

[1] J. J. Eggermont, “Effects of long-term non-traumatic noise exposure on the adult central auditory system. hearing problems without hearing loss,” *Hearing Research*, vol. 352, pp. 12–22, 2017.

[2] “Department of Labor Logo United Statesdepartment of Labor,” *Occupational Noise Exposure - Standards | Occupational Safety and Health Administration*. [Online]. Available: https://www.osha.gov/noise/standards. [Accessed: 13-Sep-2022].

[3] “Noise dosimetry terminology,” *Larson Davis*. [Online]. Available: http://www.larsondavis.com/learn/industrial-hygiene/noise-dosimetry-terminology. [Accessed: 13-Sep-2022].

[4] “IEEE code of Ethics,” *IEEE*. [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed: 13-Sep-2022].