BLUETOOTH SPEAKER WITH MOTION-BASED AUTOMATED VOLUME ADJUSTMENT

Project Proposal

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Introduction

Problem

When driving and listening to music, oftentimes we want to change the volume based on the speed of the vehicle. For example, when moving at higher speeds, drivers will raise the volume to better hear the music, and when stopped at a stop light, will lower the volume significantly. This issue is a clear nuisance, but can also present a major safety hazard that takes the user's concentration away from driving and to adjusting the volume, especially for drivers who do not use the car sound system.

This problem doesn't only pertain to drivers. Anyone who is on any type of vehicle, be it a bike, scooter, or skateboard, will suffer from the same problem of not being able to hear their media at high speeds, or the volume being too high at low speeds.

Solution Overview

Our solution is to create a speaker that will automatically increase and decrease volume based on the speed that the speaker is moving. The speaker will be a portable Bluetooth speaker that the user can take in and out of the car. Users will also have the ability to set the minimum and maximum volumes to better personalize their listening experience. It will also contain a strip of LEDs that tell the user the current volume as more LEDs are lit. The speaker system will have two modes: one for when it is moving, and one for when it is stationary. When it is in the stationary mode, the user can increase and decrease volume with buttons. When it is in moving mode, the user will not be able to change the volume, so that the user focuses on driving.

Visual Aid

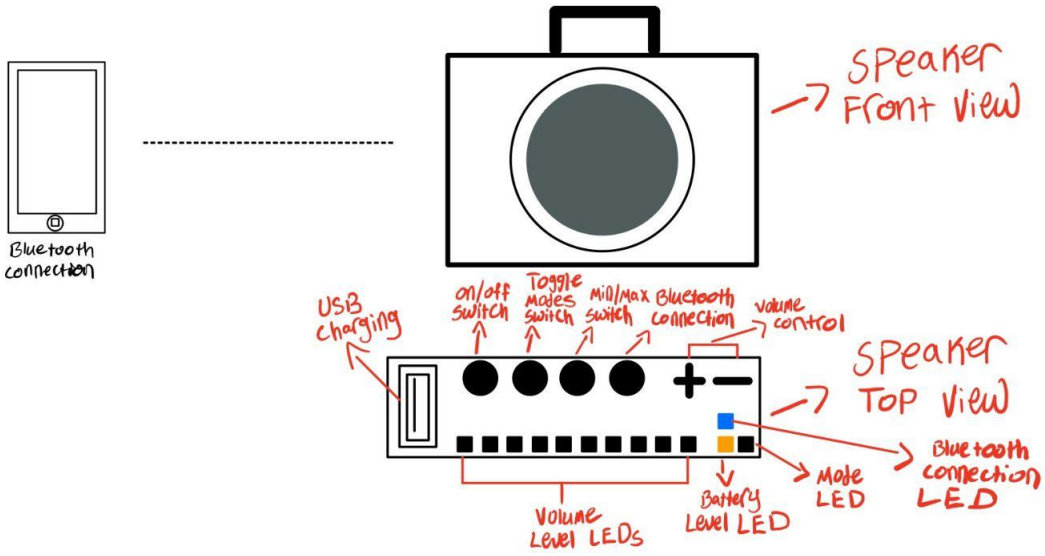

Figure 1: Visual aid for the speaker that will be built

High-Level Requirements

- Speaker volume changes automatically in driving mode at a fixed rate of 3dB for an increase/decrease of 15 MPH, while also staying in range of the users' minimum and maximum volumes.
- If in stationary mode, the speaker shouldn't change in volume depending on your speed, and instead should be controlled manually using buttons.
- Any bluetooth device should be able to transmit media continuously to the system at 2.1 Mbps and the system will play media at an audio quality of 80 dB Signal to Noise ratio [6]

Design

Block Diagram

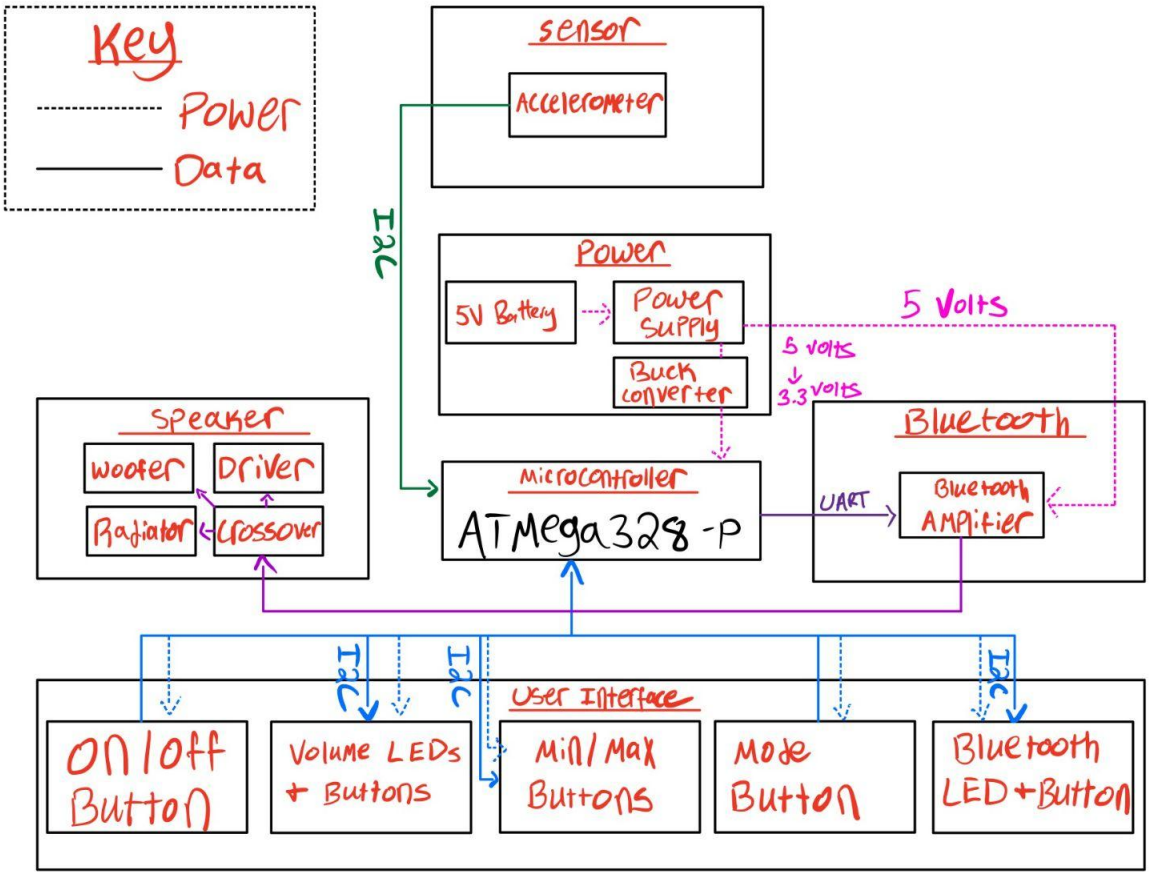

Figure 2: Block diagram for the subsystems in the speaker

Subsystem Overview & Requirements

Subsystem #1: Power

- Description: This part of our project will be key to making the remainder of our project operable. In order to power our speaker and change volume levels when in the “moving mode”, we will need a battery to power it.
- Requirement 1: Power supply needs to be able to steadily supply 7.4V to the entire circuit at 5200 mAh.
- Requirement 2: The speaker should be able to play music at 80 dB for 10 hours, which the specification for the Beats pill speaker [1]

Subsystem #2: Bluetooth Connection

- Description: Both the bluetooth module and bluetooth amplifier are essential for wireless communication between the speaker and a media device. Both the HC-05 bluetooth module and the TDA7492P amplifier board will be connected to the battery to receive power. The HC-05 module will then be directly connected to the microcontroller through the serial communication pins. The amplifier board’s audio output will be connected to the speaker subsystem and the board will also be connected to the microcontroller using the I2C pins [2].
- Requirement 1: Any device with bluetooth functionality should be able to connect to the speaker.
- Requirement 2: The Bluetooth data transfer speed should be at least 2.1Mbps [3]

Subsystem #3: Sensor System

- Description: Arguably the most essential subsystem for our project, the point of the sensor is to track changes in speed within our speaker so that it can use that information to adjust the volume of our speaker automatically based on a formula that we create (this formula will create a consistent change in volume values that correspond with the changes in speed). We plan on using an accelerometer sensor for this, which means we must also account for the fact that the sensor will only give us information regarding the speaker's acceleration, meaning we need to convert that to speed so that our speaker can properly change the volume [4]. This system will be connected to the PCB in addition to the bluetooth amplifier so that there is a line of communication between our subsystems which will allow the PCB to make changes to the volume itself based on the information provided by the system.
- Requirement 1: The sensitivity of the accelerometer should be ±2g
- Requirement 2: The resolution of the accelerometer should be ±8-10 bits

Subsystem #4: Speaker System

- Description: The physical build of the speaker itself is very important to our project, as the aesthetic appearance of our product will be directly correlated to its assumed value and durability. To build the speaker itself, we will need the bluetooth technology (see above), in addition to the physical parts of the speaker that produce sound. Given the

components below and wood, we would be able to ask the machine shop to put the parts together in a way that could complete the physical part of the speaker. With the case of the speaker completed, we can add the remaining subsystems to an empty part of the case and make the necessary connections for the speaker.
- Requirement 1: The max volume should be 85 dB. The minimum volume should be 60 dB, similar to the Beats pill speaker [1].
- Requirement 2: The speaker should be able to play music at 80 dB for 10 hours, similar to the Beats pill speaker [1].

Subsystem #5: User Interface

- Overview: The last module is what the user will see on the outside surface of the speaker. The main things we want to have here are buttons (on/off, switch between modes, min/max volume settings, bluetooth connection). We would also have LEDs that are visible to the user that indicate volume level, battery percentage, and driving mode vs stationary mode.
- Requirement 1: Each of the buttons should be debounced, so that the desired output from pressing a button only occurs when the button is fully pressed.
- Requirement 2: The LEDs should display the correct volume as the volume changes.
- Requirement 3: The LED to display battery level should show the correct color based off battery level (green 30-100%, yellow 10-30%, red 0-10%)
- Requirement 4: When in driving mode, the user should not be able to change the volume manually.

Tolerance Analysis

One of the major concerns for this project is the rate and intensity that the volume changes based on speed change. For example, the volume change should not be overly sensitive to speed change, which would cause rapid fluctuations, leading to an annoying listening experience. To avoid this, we would implement a slight delay and take a moving average of samples before changing the volume. The moving average (time span of 3-5 seconds) would be useful in lowering the impact of outliers, if for some reason an accelerometer value is very inaccurate. We will also add a function to gradually change from one volume to another, as opposed to just jumping to the next level. The following two figures demonstrate how the moving average (window of 5 seconds) is able to gradually adjust to data and also avoid a major impact from outliers.

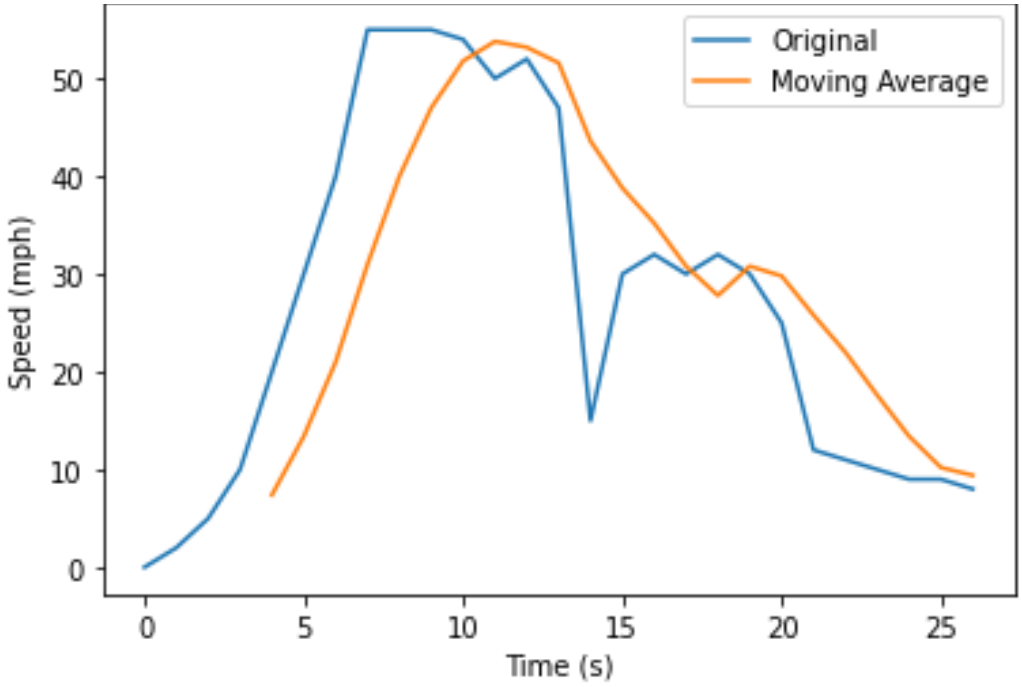

Figure 3: Moving average adjusting to the original data over time

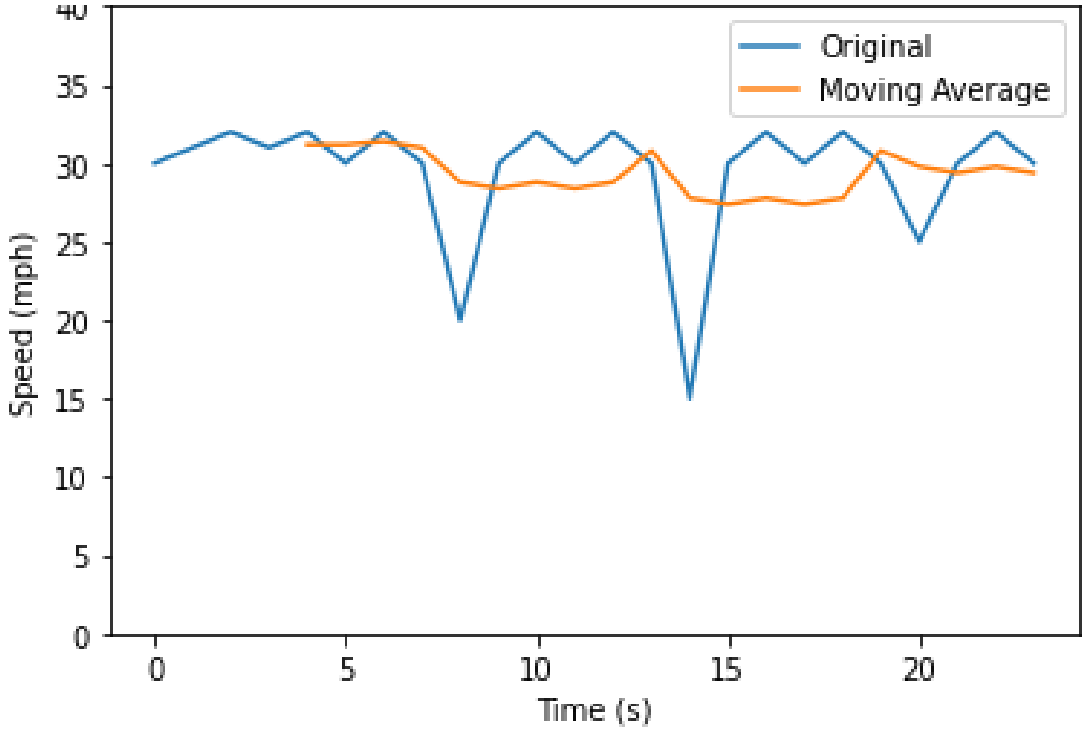

Figure 4: Moving average softening impact of outliers

Ethics and Safety

We believe that there are minimal ethical concerns and risks with this project. One potential concern is that the volume may be too loud after it is automatically adjusted. To combat this, we have highlighted that we would like the user to have the highest priority for controlling volume on the speaker. Another concern that may be a little far fetched is that if the speaker isn't in driving mode and the user is driving, they can be distracted from driving by trying to adjust the volume on the speaker, and potentially risking the safety of others with their distracted driving. However, this type of behavior from the user defeats one of the purposes of our product, which is to increase driver safety by making it easier to complete a task (changing the volume of the music in the car) that is traditionally considered to be a distraction. Thus, we feel that despite the potential risk that this creates, we are still abiding by the IEEE Code of Ethics [5], as our intent with the project is the responsible use of a product that we are creating to help the public mitigate a risk that exists even without our product.

References

[1] J. Pollicino, “Beats by Dre Pill Portable bluetooth speaker...,” *Engadget*, 16-Oct-2012. [Online]. Available: https://www.engadget.com/2012-10-16-beats-by-dre-pill-bluetooth-portable-speaker-ears-on.html#:~:text=An%20internal%20battery%20is%20said,via%20its%20Micro%2DUSB%20input. [Accessed: 09-Feb-2023].

[2] “How does a bluetooth amplifier work?,” *Auris, Inc*. [Online]. Available: https://theauris.com/blogs/blog/how-does-bluetooth-amplifier-work. [Accessed: 09-Feb-2023].

[3] J. Blom, “Bluetooth basics,” *SparkFun*. [Online]. Available: https://learn.sparkfun.com/tutorials/bluetooth-basics/common-versions. [Accessed: 09-Feb-2023].

[4] “How to measure acceleration?,” *Omega Engineering*, 14-Oct-2022. [Online]. Available: https://www.omega.com/en-us/resources/accelerometers. [Accessed: 09-Feb-2023].

[5] IEEE, “IEEE code of Ethics,” *IEEE*. [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed: 09-Feb-2023].

[6] D. Moore, “How to measure audio quality,” *Phairs*, 26-Sep-2022. [Online]. Available: https://phairs.com/blogs/news/how-to-measure-audio-quality#:~:text=Signal%20to%20Noise%20Ratio&text=Usually%20the%20higher%20the%20decibel,for%20many%20discerning%20human%20ears. [Accessed: 21-Feb-2023].