Formi: A New Age of Music Listening

ECE 445 Design Document

Kshithij Kamal and Drew Stogner
TA: Jonathon Hoffman

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1 Introduction

1.1 Problem and Solution Overview

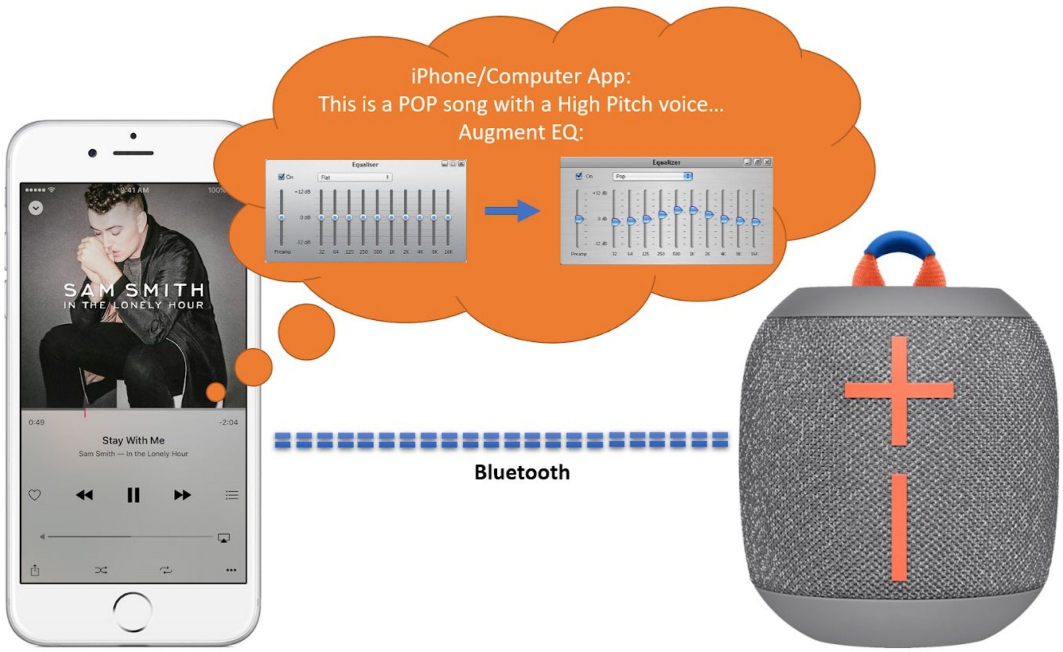
With Americans spending on average 4.5 hours per day listening to music, it is no doubt that we love music. [1] In fact, it has been used as a stress reliever for hundreds of years yet each modern speaker, headphone, etc optimizes for a limited range of music dictated by its sound signature. [2] [3] Sound signature emanates from two elements:

1) Programmed equalization into the DACs (Digital to Analog Converters)
2) Circuit Components.

As avid music listeners, we recognized this common problem that many musicians and music lovers alike have faced. In order to enjoy a wide and varied range of music genres, people have to buy multiple high-end headphones. This can become quite costly with the price of high end headphones ranging from eighty dollars to over three-hundred dollars. With every headphone having different sound signatures, each one works best for a specific genre or use case and may even cause fatigue when mismatched. This is especially troubling if you love multitudes of music genres, compose or record music. Concurrently, modern pop music is incorporating multiple genres into itself. With artists like Lil NasX, Billy Eilish, and Twenty One Pilots all in one genre, the difference in sound can be quite extreme.

Our solution targets all of these elements by optimizing circuit components for adaptability and utilizing a baseline neutral DAC equalization. Building on this, we will create a computer/phone (with Bluetooth connectivity) application that dynamically augments equalization based on the music itself allowing for the solution for genre mixing. For example, it should put *Old Town Road* to be viewed from a musical perspective of genre. [4] The goal is to create a neutral, but dynamic hardware system that allows for the equalization to change the sound signature in order to solve the issue of overspending on headphones in order to obtain multiple sound signatures.

1.2 Visual Aid



1.3 High-Level Requirements

- [1]Must be able to augment EQ on "wireless" POC speaker
- Must be able to dynamically change EQ based on file embedded (basic) genre
- [2]Must be able to dynamically change EQ based on ML derived genre/characteristics
- [2]Must choose between multiple "base" EQs for different genres/song characteristics

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Footnotes:

[1] Characteristics can differentiate types of genres. (i.e. high pitch vs low pitch singers)

[2] EQ or Equalization augmentation can be detected as change in decibels over frequency.

2 Design

2.1 Block Diagram

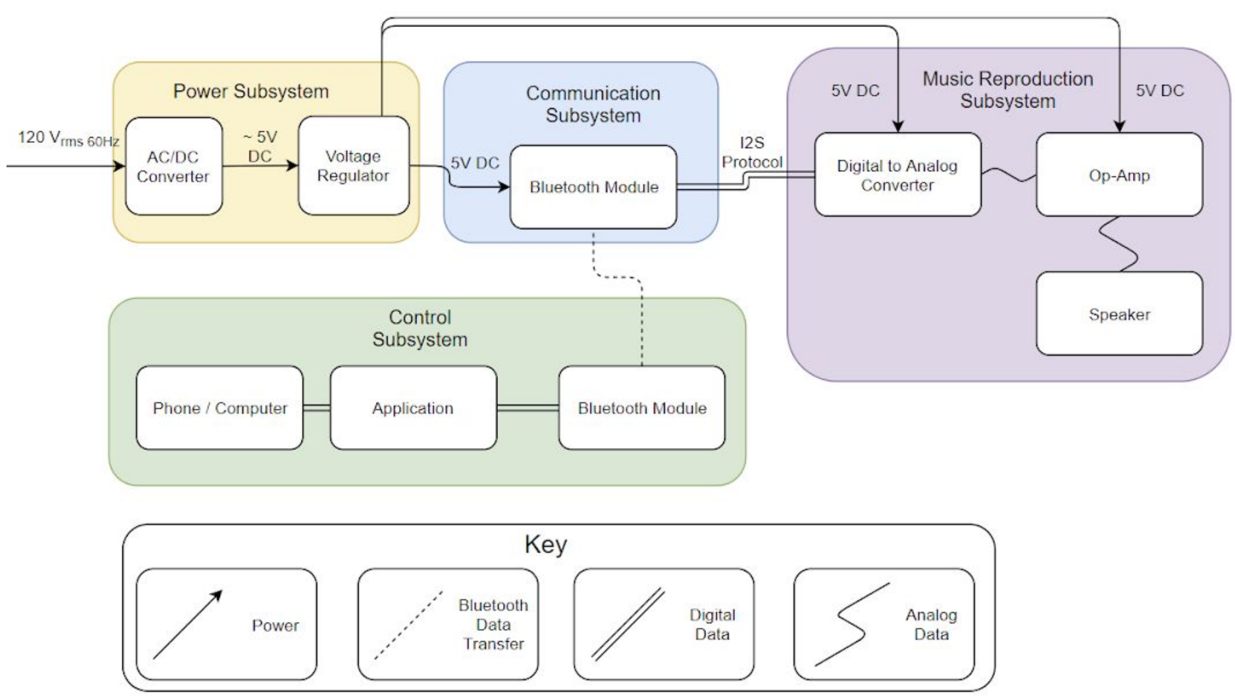

Fig 1. Block Diagram

Above, we can see that wall power is sent to the AC-DC converter (power subsystem) and , subsequently, the voltage regulator ensuring a safe 5V DC to power subsequent components. After conversion, power is sent to all other PCB components (including Communication and Music Reproduction Subsystem(sans Speaker which will be connected to terminals on the PCB)). The song is chosen, analyzed and augmented with chosen EQ within the control subsystem. Then, it is sent digitally to the Bluetooth module, converted to an analog signal through the DAC, and finally sent to the Op-Amp/Speaker.

2.2 Physical Design

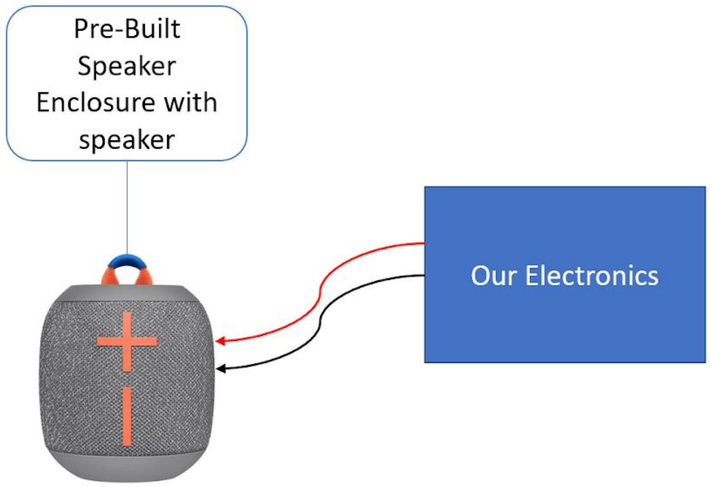

Fig 2. Physical Design Sketch

To alleviate the demands of fine-tuning the physical speaker design, we will use a pre-existing speaker and speaker enclosure setup with pre-tuned acoustics which will connect to our PCB (Printed Circuit Board). Our PCB will be connected to wall power to optimize current powering the speaker and long testing cycles when fine-tuning EQs. Since the control subsystem is a preexisting digital device, i.e. phone or computer, which communicates through Bluetooth to our PCB/electronics, we have not included it in our physical design.

2.3.1 Power Subsystem

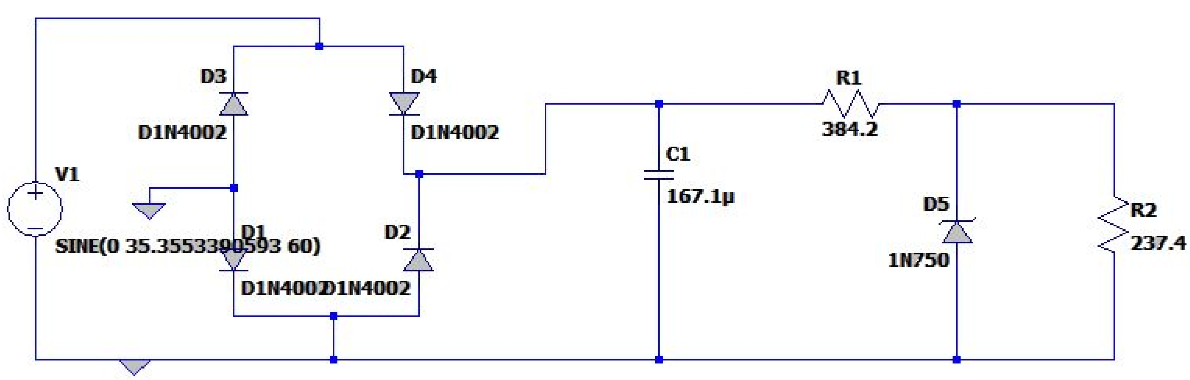

Fig 3. AC-DC converter and Voltage regulator

In figure three is our design for both the AC-DC converter and voltage regulator. What should be noted as well is there is a 5:1 transformer between the input from the wall source and the input to the circuit shown above. This circuit takes a 120 V at 60 Hz and successfully transforms it into anywhere from 4.7 to 4.95 VDC depending on the load resistance. This is mandatory because the DAC, Bluetooth and OP-AMP can be all powered by 3.3 VDC - 5 VDC.

Requirements	Verification
1. Output voltage must be regulated from 4.5 V to 5 V. 2. Output Current cannot exceed 57.5 mA.	1. Observe output voltage on an oscilloscope to ensure voltage remains between 4.5 and 5 V. Change output load from 100 ohms to 1000 ohms in increments of 100 ohms. 2. Observe output current on the oscilloscope to ensure current does not exceed 57.5 mA. Change output load from 1000 ohms to 100 ohms in increments of 100 ohms.

2.3.2 Communications Subsystem

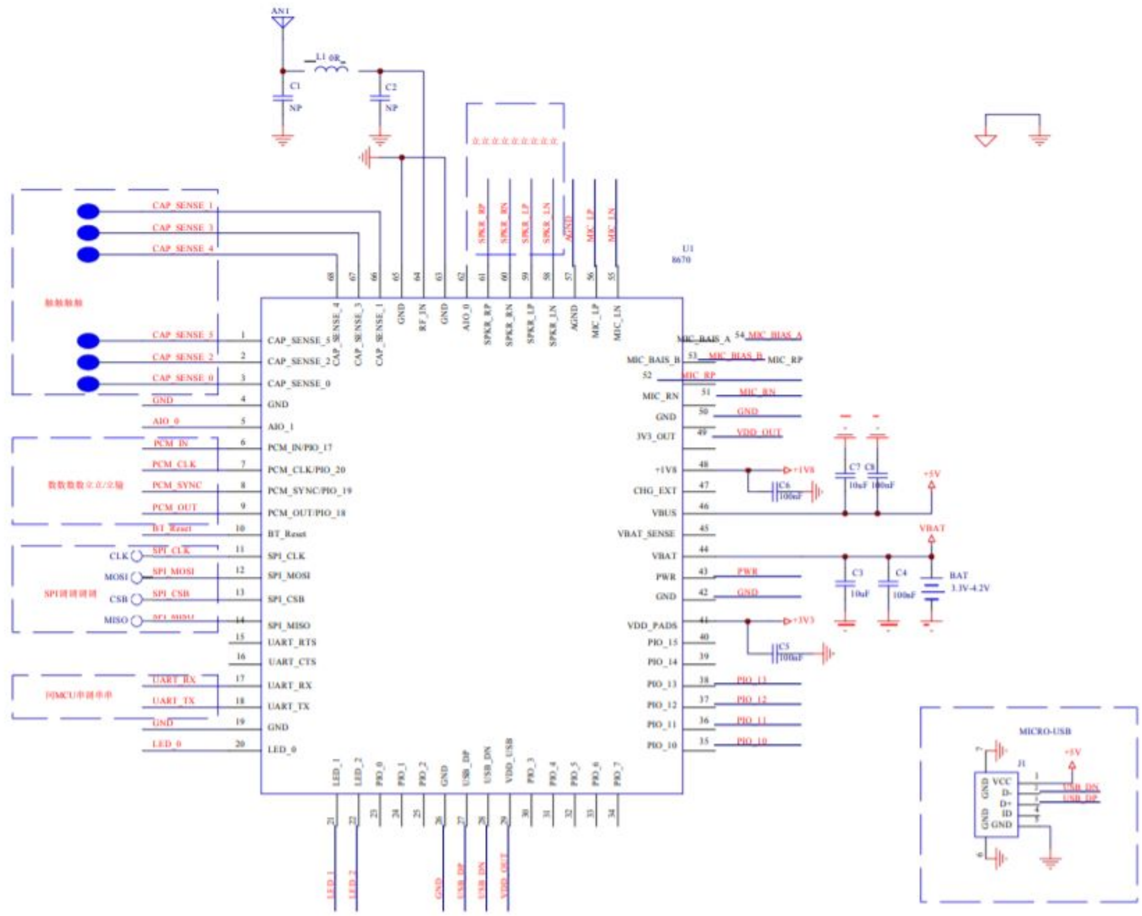

Fig 4. Bluetooth IC

The bluetooth module takes a signal from a computer or phone and then send a digital signal to the DAC. This module allows for wireless signal transferring and as a bonus allows us to bypass the DACs on computers and phones ensuring that the signal is unaltered by any other components other than ours.

Requirements	Verification
1. This module has to be able to take a signal from a phone and/or computer and then send that signal from its output.	1. This can be verified using a single tone signal from either a computer or a phone and then using an oscilloscope to measure the output of the bluetooth module allowing us to see if the signal was transferred correctly.

2.3.3 Music Reproduction Subsystem

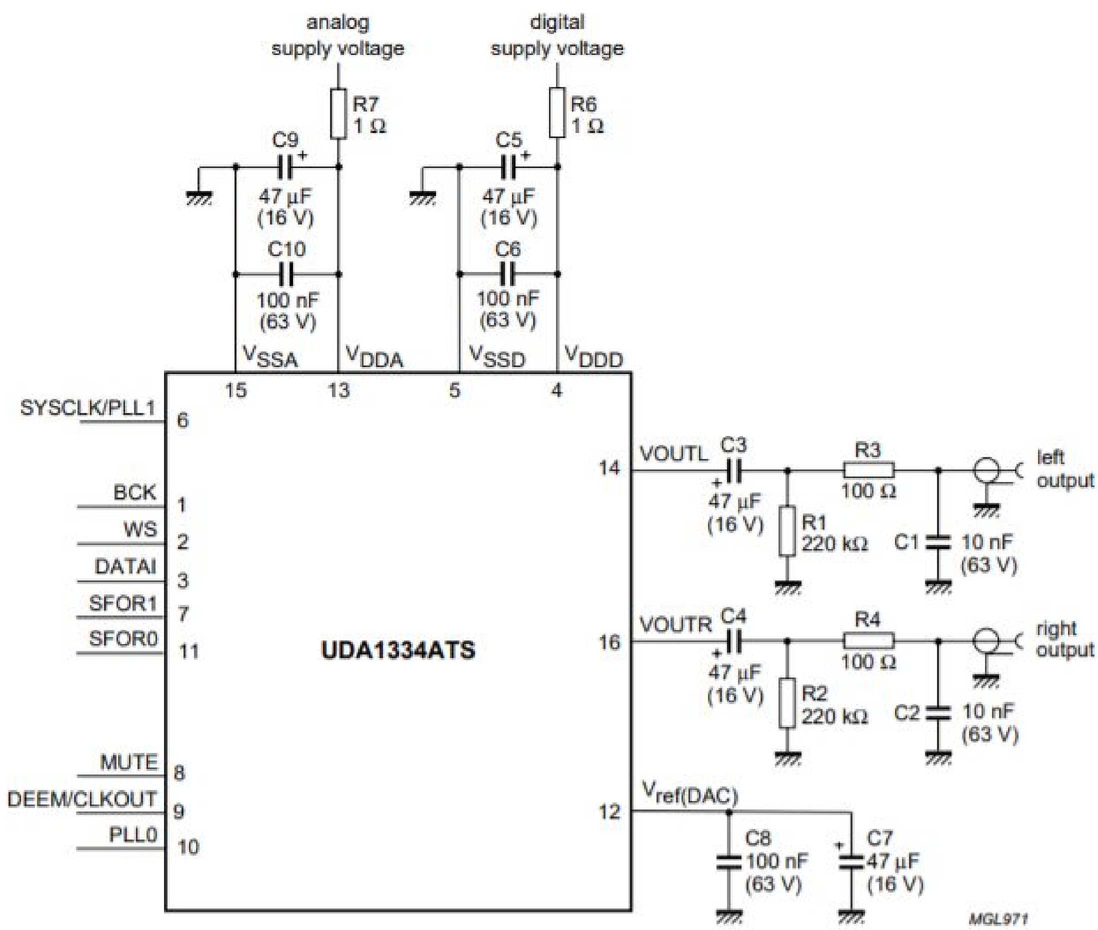

Fig 5. DAC

This component takes into its input the digital signal from the bluetooth module and outputs the analog data to be sent to the amplifier. This is important because in order for music to be played from the speaker it has to be changed from digital data into analog since the speaker will only play the analog signal correctly. [10]

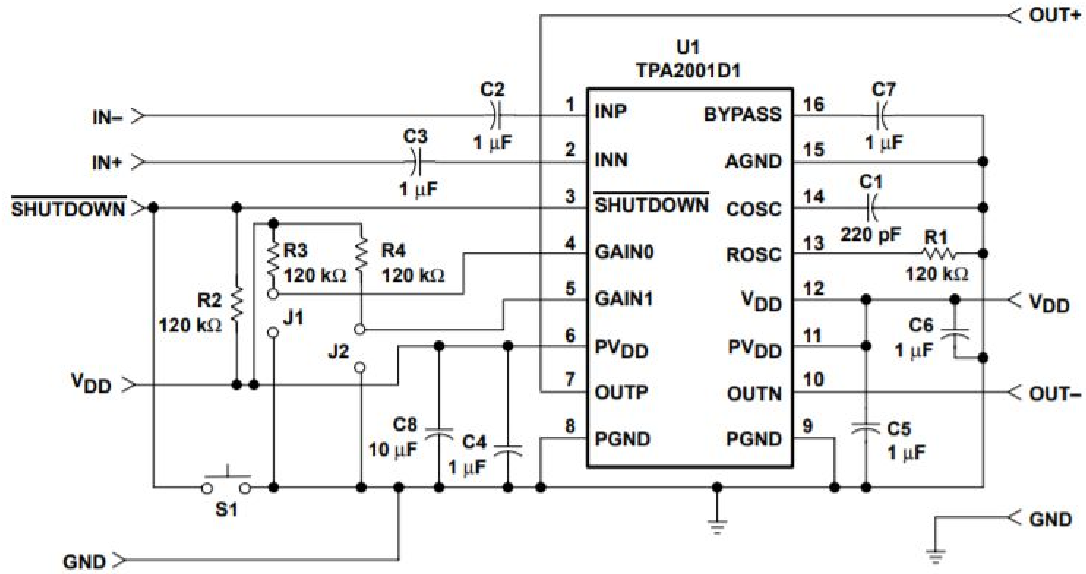

Fig 6. Class D Operational Amplifier

The operation amplifier would take the analog signal produced from the output of the digital to analog converter and then amplify the signal to be sent to the speaker. Without this component, the signal would not be strong enough to produce a recognizable volume from the speaker. The speaker is the final piece. The speaker takes the amplified analog signal from the operational amplifier and then transmit that energy into vibrations that produce sound waves.

Requirements	**Verification**
1. The DAC has to convert a digital signal into an analog signal correctly. 2. The operational amplifier has to be able to produce 1 watt of power for an 8 ohm load. 3. The speaker has to audibly play sound from an analog signal.	1. Using an oscilloscope on both the input and output of the DAC and sending in a periodic steady state digital signal, we can observe the output and compare to the predicted waveform. 2. Placing an 8-ohm load as the output of the operational amplifier, we can use a wattmeter to measure voltage and current through the load to ensure that 1 watt of power is produced. 3. Simply sending in a sufficiently powered analog signal should produce

	an audible result from the speaker.

2.3.4 Control Subsystem

The control subsystem is a software-based subsystem residing as a program on a phone or computer. This subsystem is software that using both basic codes in conjunction with machine learning to correctly identify the genre and change the equalization of the signal that is to be sent to the Bluetooth module.

Requirements	**Verification**
1. This must correctly identify the genre/characteristics of a song. 2. Also, it must change the equalization of the signal depending on the genre. 3. The machine learning aspect of code must be at least 70% accurate.	1. This can be tested by displaying the genre/characteristic identified and compared to reality. 2. Using an oscilloscope on the output of the operational amplifier and collecting an FFT on both the original unchanged version and the altered equalized version will allow us to observe the decibel changes on certain frequency bands that the equalization will provide. 3. Using controlled test cases and using a print function in the code will allow us to use a simple true/false result system and then computing the effectiveness of the system.

2.4 Tolerance Analysis

The subsystem with the greatest risk for failure is the control subsystem. This is due to the machine learning aspect of the code. The sheer amount of data points needed for a well functioning machine learning code can be quite large. A bit of common sense here tells us that the more data points the better and the easier the decision, the better the code will function. The decision that we plan on testing is changing equalization depending on the singers vocal range e.g. high versus low. This can be done by separating the vocals from the music itself and then averaging the frequency of the vocals. Using these as data points, we can start to build the decision making machine learning program. We plan on doing this hundreds of times in order to get healthy average marks for both the high and low categories and then using premade templates for equalization at the typical frequency of human vocals, we can alter the vocal equalization by comparing the current average frequency to both the low and the high averages.

In order to ensure that at least 50% are correct we will use this formula for determining its accuracy:

(Correct Decisions)/(Total Decisions) x 100% = Success Rate

This has to be done by comparing to data sets that we collected separately from our program in order to ensure accuracy.

3 Cost and Schedule

3.1 Cost Analysis

Assuming that a competitive salary would be approximately $35/hr and that we will spend 12 hrs/week on this project individually, an approximated labor cost can be calculated as such:

2 People x 2.5 x $35/hr x 12 hrs/week x 16 weeks

= $33,600

The total cost for our labor for this project can be estimated to be $33,600. Comparing this the average value for an electrical engineering graduate at $67,000 and calculating a yearly salary for this project, we would get $108,387. This is greater than the typical starting salary, but given that we are the engineering, marketing and research team, we feel as though this is a fair salary.

Part	Cost
1-W FILTERLESS MONO CLASS-D AUDIO POWER AMPLIFIER	$.96
Adafruit I2S Stereo Decoder - UDA1334A Breakout	$6.95
Bluetooth 5.0 APTX Audio Module - TS8670	$12.95
Speaker - 3" Diameter - 8 Ohm 1 Watt	$1.76
Assorted Components. E.G. Resistors, Inductors, Capacitors, Transformers, Etc.	$30
PCB	$10

The total cost for this project would come to be $33,662.56.

3.2 Schedule

Week	Drew	Kshithij
9/30	Buy components	Buy components
10/7	Assemble and bench test power subsystem, Bluetooth subsystem, the functionality of operation amplifier, DAC and speaker	Find Music Dataset w/ genre and sound clips
10/14	Circuit schematic and PCB Design (Order PCB)	Start Analyzing Dataset to find patterns; Liason with Musicians, Producers, etc.
10/21	Order PCB	Continue Analyzing Dataset to find patterns; Liason with Musicians, Producers, etc.
10/28	Create custom EQs for genres and test for errors in design (Order new PCB)	[1]Build Rudimentary ML derived genre/characteristic detector
11/4	Test for errors in design. (Order new PCB)	Build iPhone/Computer app that can augment EQ
11/11	Add functionality to augment EQ based on file embedded genre	Add functionality to augment EQ based on file embedded genre
11/18	Miscellaneous / Fine-tune EQs	Add functionality to augment EQ based on ML Algorithm
11/25	Miscellaneous / Fine-tune EQs	Miscellaneous / Fine-tune ML Algorithm
12/2	Miscellaneous / Fine-tune EQs	Miscellaneous / Fine-tune ML Algorithm
12/9	Project Demo and Final Report	Project Demo and Final Report

Footnotes:

[1] Characteristics can differentiate types of genres. (i.e. high pitch vs low pitch singers)

4 Ethics and Safety

4.1 Concerns and 4.2 Mitigating Procedures

There are numerous potential safety hazards that we may face when executing this project.

Concern	Mitigating Procedure(s)
There are numerous potential safety hazards that we may face when executing this project. There is some risk involved with using wall power since the voltage coming from the wall is 120Vrms.	- [8] To ensure safe practice, someone else should always be present in the laboratory when utilizing wall power. - Accordingly, having a TA check the circuit prior to plugging in or powering the circuit, should be adhered to. - The one-hand rule can be useful in ensuring that the person working on the circuit is never the quickest path to ground.
[ACM 1.2] There is a potential fire hazard if we raise the decibel levels through volume or EQ such that clipping occurs.	- We should place hard upper limits on the decibel levels in the code for the equalization. - Listen for signs of clipping and act appropriately. - As well, in case of emergency, a protocol for the laboratory fire emergency must be followed.
Listening to loud music for long periods can damage eardrums.	- Use ear protection when nuanced listening is not imperative. - Limit long periods of music listening.

While the ethical concerns are limited in the scope of this project, there are some key ones to point out.

Concern	Mitigation
[13] Mismatching EQs with Songs or distorting music can cause fatigue or dizziness	- Do not create EQs purposefully to cause mental harm - Do not pair songs with non-conforming EQs - Allow for plenty for breaks if the operator starts to feel fatigued or dizzy.

5 Citations

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