Mesh Network Headphones

ECE445 Design Document 2

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1 Introduction

1.1 Objective

When using an audio system, it is very difficult to come up with an organized and presentable solution that offers a quality listening experience. Such a system is even more challenging when there is a desire to make it portable and shareable with friends and family. Bluetooth has made its mark on recent technology as the dominant close-range wireless communication protocol in the electronics industry. However, Bluetooth is typically limited to one connection for audio, which means users who wish to share audio with friends are left unable to do so. Our system offers a unique solution to a portable, modular, and shareable audio system that lets consumers take their music where they want to and share it with who they want to, all without the clutter of cables and other hardware restrictions.

The proposed solution allows for multiple headsets to form a mesh network, in order for all of their audio to be completely synced. Only one of the headsets will be connected over Bluetooth, while the rest of them will connect over a proprietary connection, in order to reduce interference with Bluetooth and increase the ease of use.

1.2 Background

One solution would be to simply play the audio out loud, but that isn't always an option. Additionally, many people will share earbuds, but that can be unsanitary, and can actually cause more health problems [1]. This cannot be done with headsets either, because it is not possible for them to come apart, and sometimes it is preferable to use headsets.

The original group that had this project is Team 6 from this semester. The original proposed solution is a Bluetooth audio splitter, like an aux splitter, so any device can connect to the system. This would have the same audio in each of these devices, but both of the devices would have the need to connect separately to the Bluetooth enabled device. This then limits the maximum amount of devices to two, because there are two transmitters in the bluetooth splitter device. On the other hand, the solution proposed in this document has only one Bluetooth connection, which connects to a master headset, whichever headset the user chooses to connect over Bluetooth, as each headset can be connected to over Bluetooth. The headsets are then daisy chained through a separate connection that runs at a different frequency. This allows each headset to connect to each other, with an increased maximum number of devices, and an interchangeable master and slave configuration due to each headset being identical.

Other products exist in the marketplace that function using the same theory as the original group's implementation. Examples would include the Monoprice 109722 [2] and the Anker Soundsync [3], both of which are available commercially and utilize the Bluetooth 5.0 protocol. These commercially available devices do not have the capability to connect to more than two Bluetooth audio devices at the same time. Our product intends to extend the quantity of Bluetooth devices that can be connected to the host audio source by implementing a mesh network instead of utilizing the two-device feature seen in commercial products.

1.3 High-Level Requirements List

- Can support listening for at least 3 slave devices in addition to the master
- Can provide audio at full volume for at least 8 hours on battery charge
- Can support a distance of at least 3m from the Bluetooth device to the acting master headset, as well as from the acting master headset to any one of the acting slave headsets
- System must support high data rate PCM signals (192khz PCM)

1.4 Pictorial Representation

Figure 1. Pictorial representation. This shows 2 users listening to the same song from a single source using a pair of our headphones.

2 Design

The hardware portion of the system consists of a wireless system, a DAC, amp, and driver combination. The wireless system will use both open and closed source protocols to communicate sound, and the battery and battery management circuit handles powering the system while also taking in power from a USB connection. The DAC, Amp, and Driver system handles ensuring all the digital sound provided is converted into a pleasant listening experience for the user.

The Software side handles authenticating headphones, trusted users, trusted devices etc. It will also control the mesh network making decisions as to how to hand off connection order to preserve fidelity if users are moving all while minimizing broadcast bandwidth usage to increase the number of possible users.

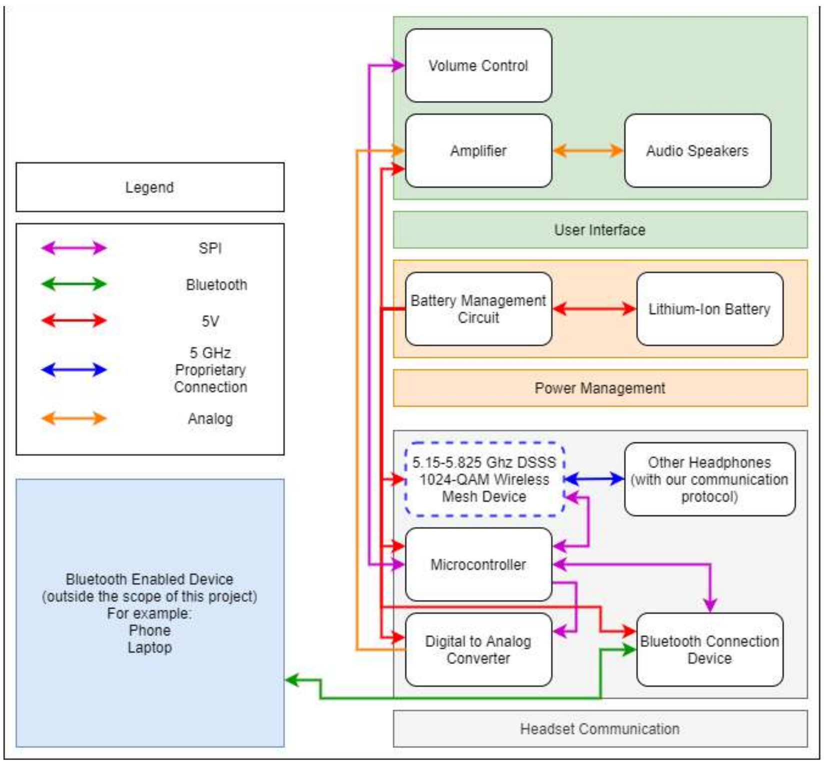

Figure 2. Block Diagram This shows the interactions between systems for our project. There will only be one pcb for this device to make the device as small as possible. The button interface and the battery will be in one ear cup and the other will contain the pcb and antenas.

2.1 Physical Design

Figure 3. Headphone Dimensions. This is a photo of the body of the headphones from the same family as the drivers that we are using, all the measurements for our device will be the same except the ear cup has been adjusted to accommodate the thickness of the electronics as the original model is driver only.

Figure 4. Example of the planned button layout and closed back design for our drivers

2.2 Functional Overview

2.2.1 Lithium-Ion Battery

This is the battery to store charge for the system. The battery must be rechargeable, thus the choice of the lithium-ion battery, as that is commonly chosen for projects that need rechargeable batteries. Lithium batteries are lightweight and have good power density, but can pose some safety concerns that we will have to address.

Given the maximum power draw of 278.22 mW by drivers, a 95 percent efficiency on the amplifier with a base operating power of 6mW making the driver power draw 278.22/.95 + 6 = 298.86 mW. The power draw of the DAC is a maximum of 210mW. The maximum draw from the microcontroller given the expected data rate is 348.47 mW. The total power of the headphones comes out to a maximum of ~855.33mW , a required endurance of 8 hours at full volume, and a battery voltage of 3.7V, with a buck boost efficiency of 95%, the minimum battery capacity needed is equal to $8/95\% * \frac{P}{V} = 1.947Ah$ or 7.20 Wh. This has made us choose the Lithium Ion square battery 103450 (standard size) it is 3.7v and 2Ah and some models come with overcharge protection which makes our circuit cheaper.

Requirements	Verification
1. Starting from full charge, the battery is able to output 860mW (our system maximum power draw) for 8 hours continuously without sagging below 3.3V, the battery's minimum allowed voltage.	1. a. Connect a fully charged battery to an electronic load set to draw 860mW b. Allow the battery to discharge into the electronic load for 8 hours. c. Ensure that the battery has not

	fallen below its minimum rated voltage with a multimeter while under the above load.

2.2.2 Battery Management Circuitry

This should allow for battery charging over USB, and should have current protection to make sure that there is no fire or other hazard when charging is happening. Additionally the circuitry should not allow the battery to be discharged below dangerous levels.

The battery management circuitry of the battery will be achieved with the microcontroller and a linear regulator. The linear regulator will be designed to receive a 5V (+/- 0.2V) input and output a constant current of 1A +/- 0.2A. Over voltage protection is not needed as it is built into the battery pack, and the microcontroller will monitor voltage and enter a sleep mode if it detects a battery undervoltage.

Requirements	**Verification**
1. Successfully charges the device without causing harm to the battery, device, or user.	1. a. Connect the linear regulator to a 5V input, and a resistive load on the output. b. Ensure the linear regulator maintains a constant 1A (+/- 0.2A) current output through the load.

2.2.3 Proprietary Connection Hardware

Because there can be interference with Bluetooth, as well as pairing issues, the headsets should be able to talk to each other over a proprietary connection to avoid the user having to do any of this set up. This should be around 5GHz in order to avoid interference with WiFi and Bluetooth, among other common radio frequency applications. Bluetooth and Wifi can both run at 2.45 GHz, which can cause non-negligible interference. However, Wifi can also run at 5 GHz, but this will cause much less interference, so it will not be a problem for this project. Each headset must have this hardware, and up to 3 devices should be able to connect to the master at any one time.

Requirements	**Verification**
1. Can join a mesh network	1.

2. Can broadcast a mesh network for other headsets to join	a. Pair a second pair of headphones to a bluetooth device so it enters broadcast mode b. Turn on the pair of headphones and verify enters into the mesh network and mirrors the audio when told to enter the mesh network

2.2.4 Bluetooth Connection Device

There needs to be a Bluetooth connection from the main headset to a cellular telephone or other Bluetooth enabled device, so the user can connect this system to their device with ease. Any of the headsets need to be capable of being the master device, so each one must be Bluetooth compatible.

Requirements	**Verification**
1. Can connect to a modern smartphone (Bluetooth device)	1. a. Turn on headphones and enter pairing mode b. Verify the device appears in the smartphone's pairing menu, and select it c. Verify the device plays Bluetooth audio from the smartphone

2.2.5 Digital to Analog Converter (DAC)

This is an audio grade DAC to take the Bluetooth data and produce a waveform that can be read by the microcontroller. Because Bluetooth is a digital waveform, this cannot be read directly from the microcontroller, so the DAC is necessary for the conversion from Bluetooth signal to an analog signal in the form of a differential pair that can be read by the microcontroller.

Requirements	**Verification**
1. The DAC can convert a digital signal to an analog output with a signal to noise ratio of at least 80 db and within 7 bits of accuracy (0 - reference current) including overshoot.	1. a. Send a known digital signal into the DAC. b. Use an Oscilloscope to observe that the DAC outputs the correct

	analog waveform within expected error and accuracy.

2.2.6 Amplifier

The amplifier takes the audio signal from the DAC and amplifies it, in order to adjust the volume of the analog signal. This will take input from the microcontroller based on the user selected volume level and amplify it accordingly.

Requirements	Verification
1. Have a Total Harmonic Distortion of no worse than -80 db	1. a. Send several frequencies into the amp from the DAC b. Test the integrity of the signal with an oscilloscope and use it to programmatically calculate the Total Harmonic Distortion

2.2.7 Audio Headset

The speakers must be able to output to the ear, and be acceptable quality. The range on the volume control should have a maximum of at least 75 decibels [4], and should be able to go down to 0 decibels with at least 10 increments.

The drivers to be used for our audio headset will be the Sennheiser HD 800 S, which is a 300 ohm driver characterized by a sensitivity of 103.8 dB/V SPL (Sound Pressure Level) [5]. Using the headphone power tool created by digiZoid [6], to meet a requirement of 120 dB a requirement of 6.46 Vrms and 21.53 mA to power the drivers. This yields a maximum power draw of 139.11 mW per driver or 278.22 mW for the pair of headphones at full power.

Requirements	Verification
1. Have a +-3db response from 20hz to 20khz	1. a. This can be tested using a calibrated microphone and a noise isolation box. This would require a frequency sweep to identify the sound levels. b. This is not necessary for the most

	part due to the drivers we purchased guaranteed from the manufacturer to be responsive within 1db for 3hz-30khz.

2.2.8 Microcontroller

The microcontroller is a necessary component in order to connect the Bluetooth and the proprietary connection together, as well as the volume control and the audio output. The MAX32660 can support up to two of each SPI, I2C, UART, and RTC outputs. This gives enough necessary GPIO to support these four functions. Additionally, the microcontroller needs to be low power in order to prolong the battery life.

Requirements	Verification
1. Ensure that the microcontroller works. 2. Ensure that the microcontroller can communicate with each part of the system correctly.	1. a. Connect a programmer to the JTAG breakout for the microcontroller. b. Verify that the microcontroller can be successfully programmed. 2. a. Send a test program that validates each connection independently b. Send final product program that demonstrates all systems working together.

2.2.9 Volume Control

Because different volumes are useful in different scenarios, it is essential for the user to be able to adjust the volume at any point in the listening experience. On the headset, there should be volume adjustment buttons to ensure that the volume is able be set to their desired value.

Requirements	Verification
1. Ensure that the volume button buttons will increase and decrease the volume of the device's sound.	1. a. Press the increase volume button and verify that the output of the media is louder than before.

	(Provided that the system did not start at maximum volume) b. Press the decrease volume button and verify that the output of the media is quieter than before. (Provided that the system did not start at minimum volume)

2.3 Risk Analysis

The hardest part of this project will be ensuring that our proprietary radio transceiver will work properly without being susceptible to interference from other devices that use similar spectrums (ie 5GHz WiFi). We have chosen the 5GHz band due to the wide availability of transceivers that can be purchased allowing us to avoid the tuning and testing of a system which requires equipment not available to us. This will allow us to build a mesh network with a custom protocol over the same widely used bands. The protocol itself is the highest risk item. 5GHz Wifi uses anywhere from 20-160 mhz bands where our solution will need significantly less than that so we cannot use wifi off the shelf. We will also have many more devices that require transmission than most people have wifi routers. This means we will have to find out how to implement narrow band communication over many devices without interference but at data rates higher than bluetooth. With narrow band communication DSSS starts to fail, FHSS may be required which would increase collisions and decrease total number of allowable devices. FHSS though would allow configuration to be easier due to no channel claiming. Also with this many small bands there may be an issue with 5 GHz WiFi not realizing a channel is being used and broadcasting over it, causing interference. We will most likely use QAM1024 encoding since that provides a suitable 5 b/s/hz (bits per second per hertz, ex: with a 1 MHz band this would push 5 mbps) going any higher will make interference more significant but it would allow more total devices since it allows a narrower band and that is another optimization problem.

2.4 Tolerance Analysis

The gain in between the DAC (digital to analog converter) and the amplifier controls the volume of the audio output. The user should be able to control this, to adjust the volume settings with the provided volume buttons, however, if the volume range is too low, it can be difficult for the user to hear at all, and if the maximum volume is too high, it can be a safety concern. Therefore we are opting to use a lower limit on the maximum volume, and restrict it to safe levels in software.

In order to drive the headphone drivers to produce our maximum volume output of 120 dB, the drivers need to receive a peak-peak voltage of 18.28 V. The gain of the INA1620 can be derived by equation 6 of its datasheet, $Vout = Vdac * \frac{R2}{R1+Rout}$. We can take Rout to be a constant 300 Ohms based on the drivers datasheet, and R1 and R2 are both equal to 1 kOhm +/-0.004%. Because we want a lower limit on the value of Vout, Vdac must have an output of at least 23.77 V. Because the DAC outputs a maximum current of 8.64 mA, the DAC-Op Amp resistors must be at least 2750.7 Ohms. A resistor selection of 3 kOhms +\- 1% will allow our design to meet its output requirements.

2.5 Schematics

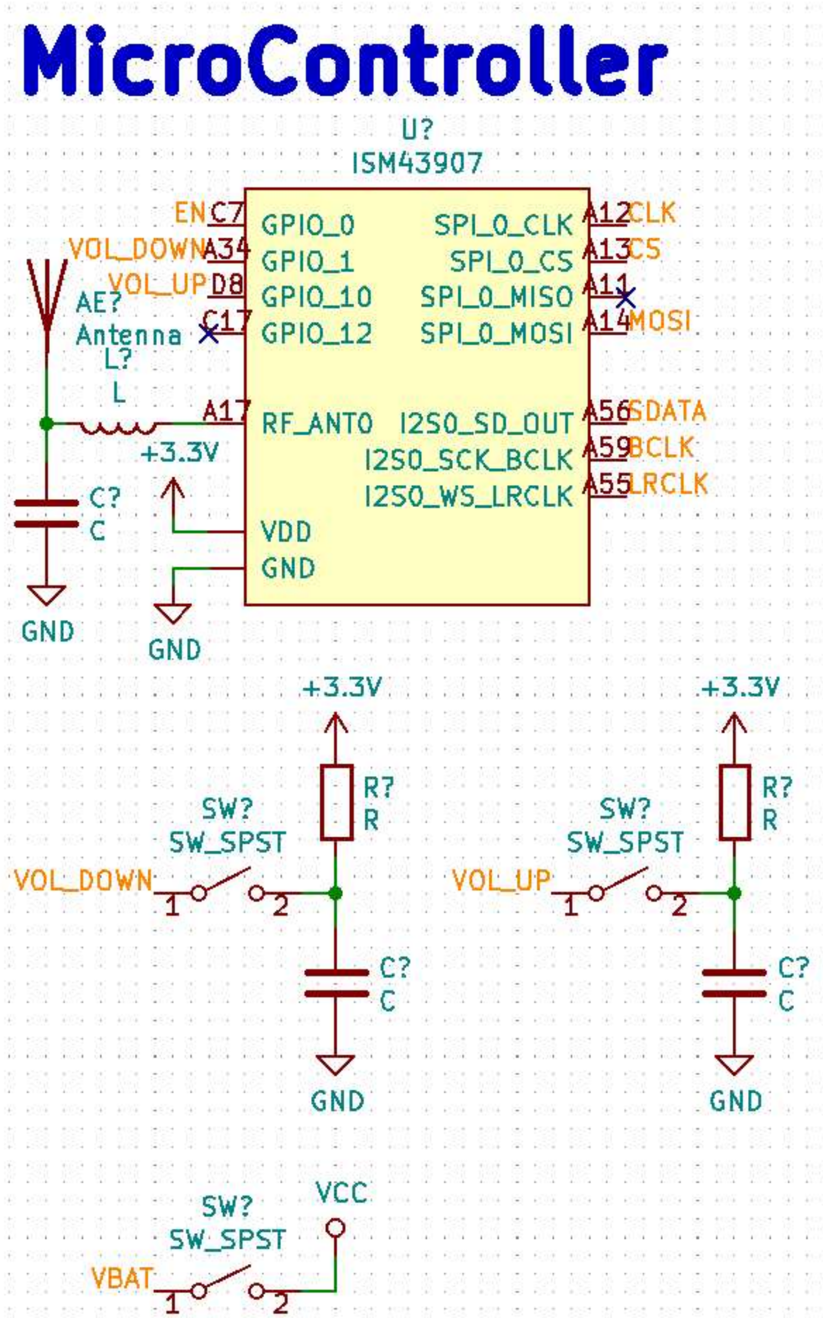

Figure 5: The microcontroller sends and receives data via bluetooth, as well as sends data to the DAC to be processed into an analog signal. It also interprets user inputs from the volume buttons.

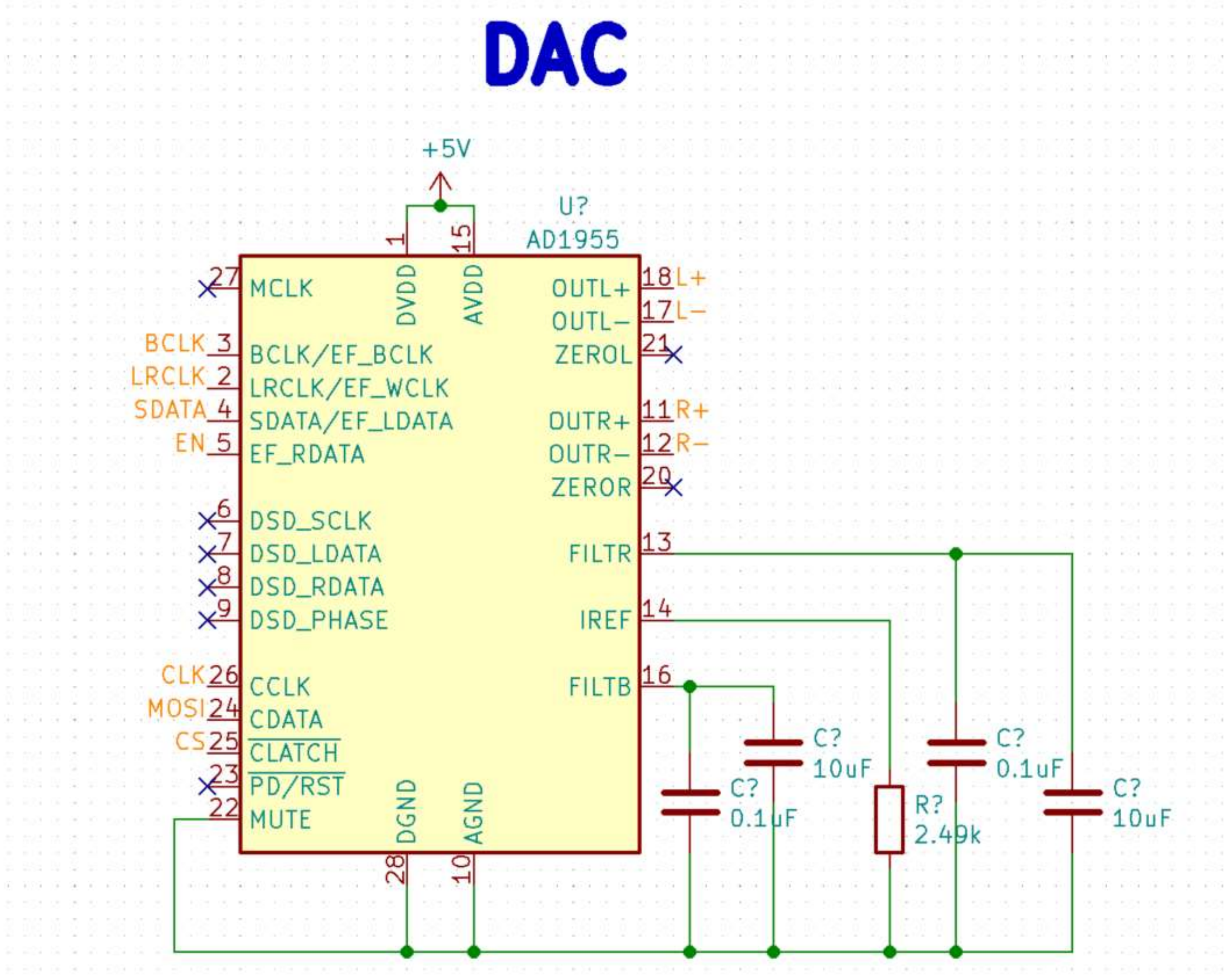

Figure 6: The digital to analog converter, or DAC, converts digital signal received from the microcontroller to an analog output that is amplified before being sent to the headphone drivers.

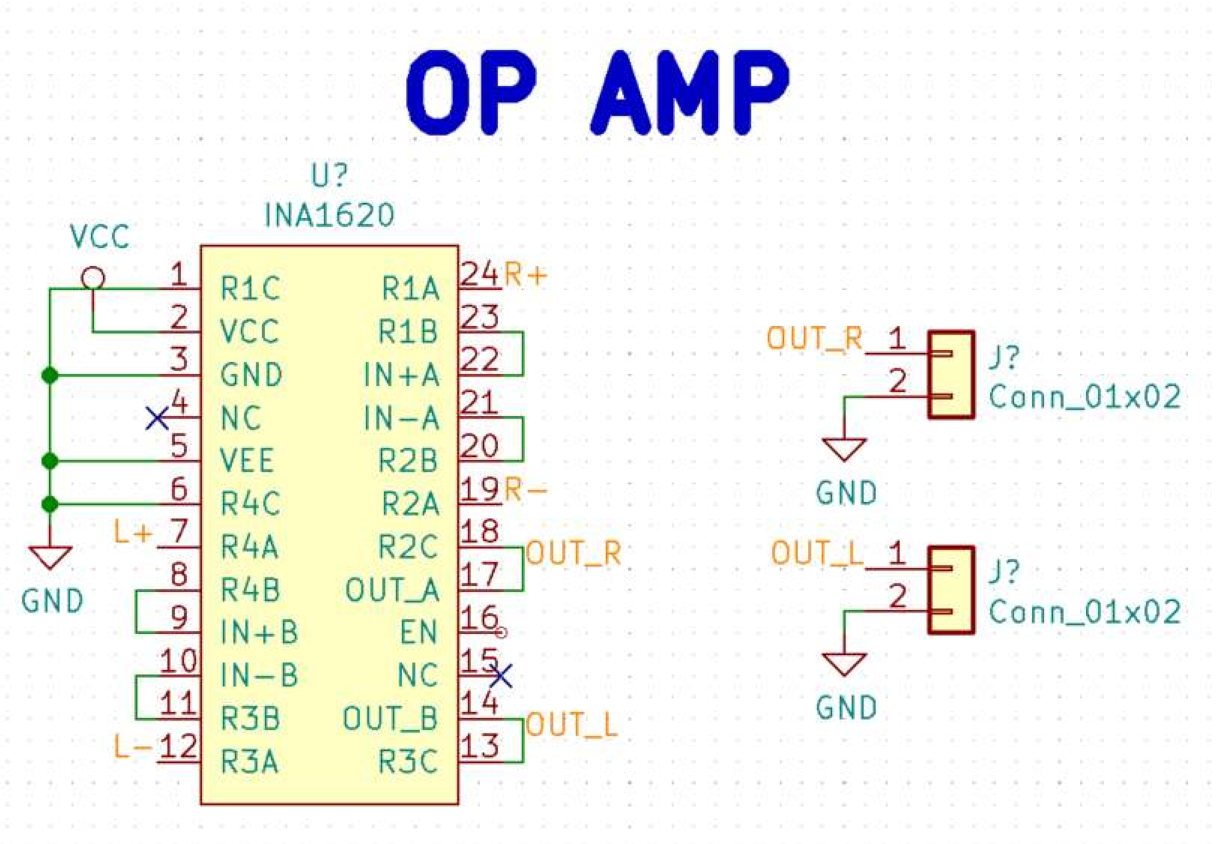

Figure 7: The OP Amp boosts the DAC's input to the 18.5V output needed to achieve the maximum dB output required to meet specifications.

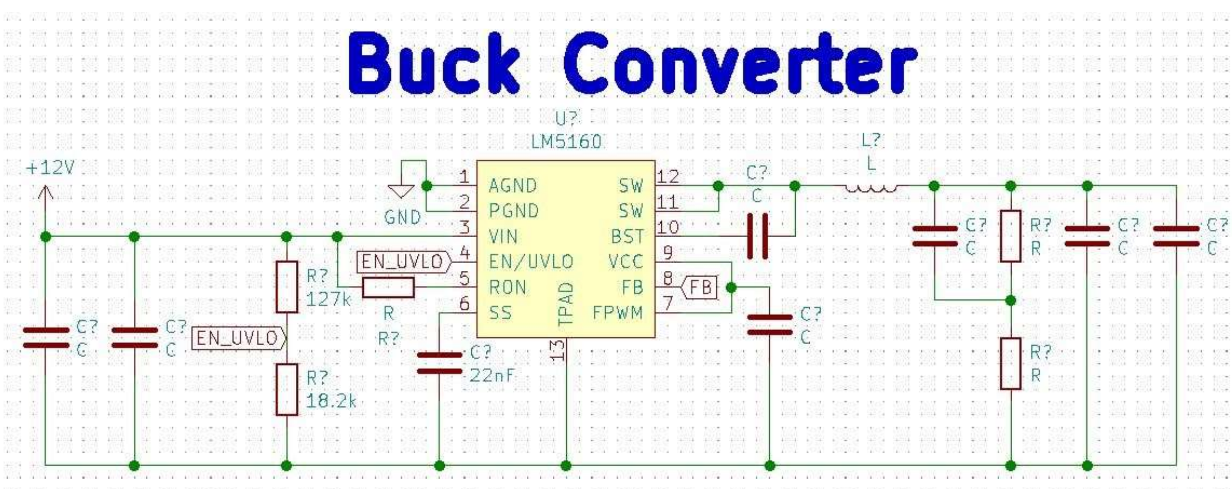

Figure 8: The buck converter will convert the battery voltage to the 3.3V needed for the microcontroller

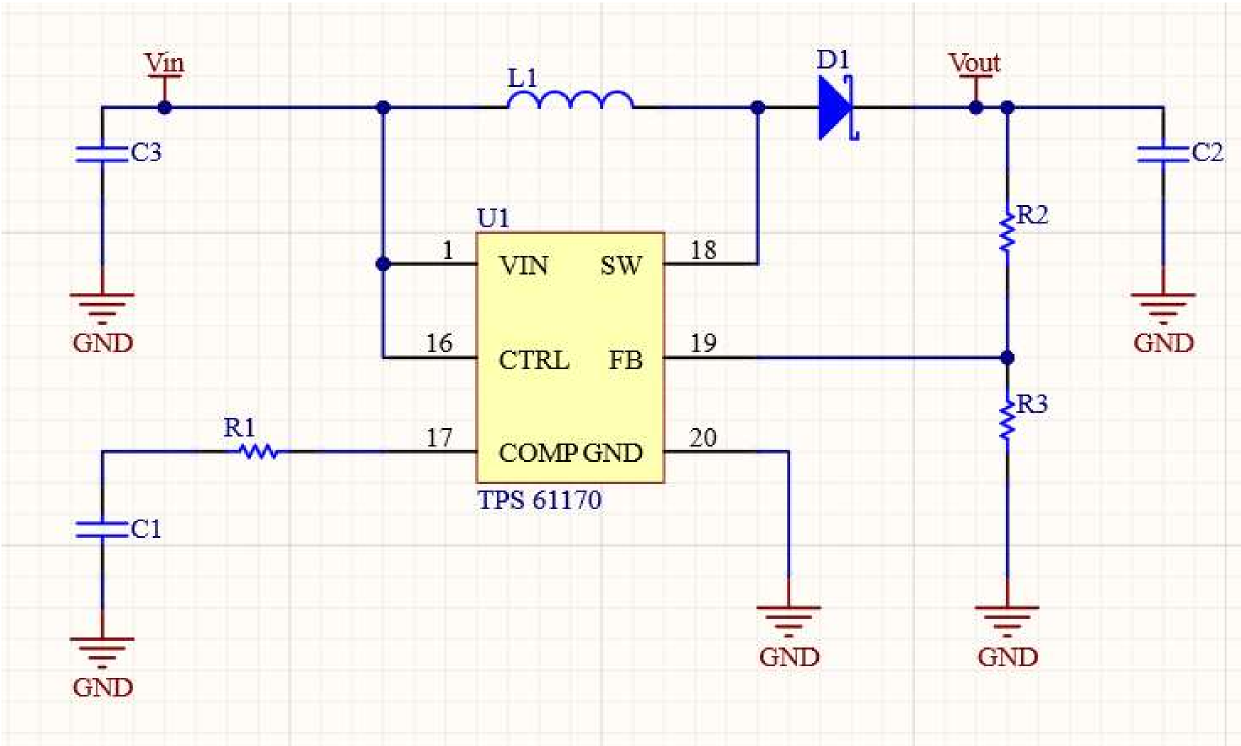

Figure 9: The boost converter is needed to convert the battery voltage to the 5V needed for the DAC and the 18.5V needed for the OP-Amps that drive the headphone drivers.

2.6 Software

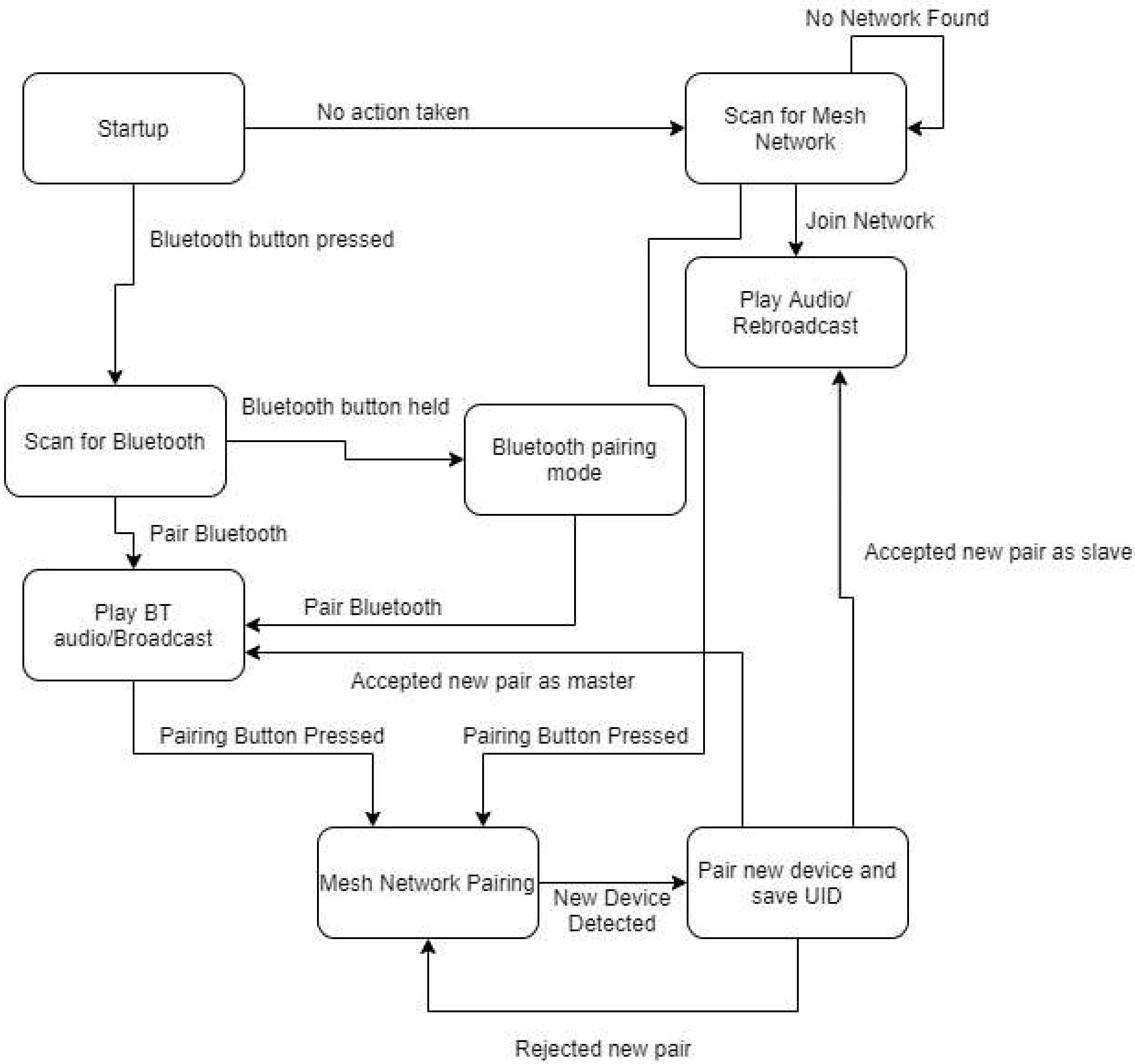

Figure 10: High level software flow chart for each pair of headphones:
Depicts the top level state machine that the microcontroller will run for each headset

Once the device starts, if the device is put into Bluetooth mode via the user holding the Bluetooth button it will go into a standard pairing search or pair directly with a device if already setup and it will become the master. For this we will follow the published Bluetooth protocol. Once the Bluetooth pairing has completed the master will start up a mesh network using a uid based on unique hardware identifiers to identify that network and using other devices unique identifiers to authenticate slave mesh nodes.

The mesh network portion of our software will be significantly more involved than the Bluetooth implementation. The headphones will each have at least two connections. The master will have one connection to Bluetooth and one or more to another headphone pair. To add slaves for the master to connect to they must be paired. To pair the headphones in the mesh network both headphones (slave and master) must be put into mesh network pairing mode. They will automatically discover each other and pair. A sound will play on both headphones when they have authenticated each other allowing the users to know which devices have been paired. Both devices will have 10 seconds after pair to reject the pair incase of pairing to the wrong device. The pairing will also be allowed to be cleared through headphone settings controllable over bluetooth or button sequences.

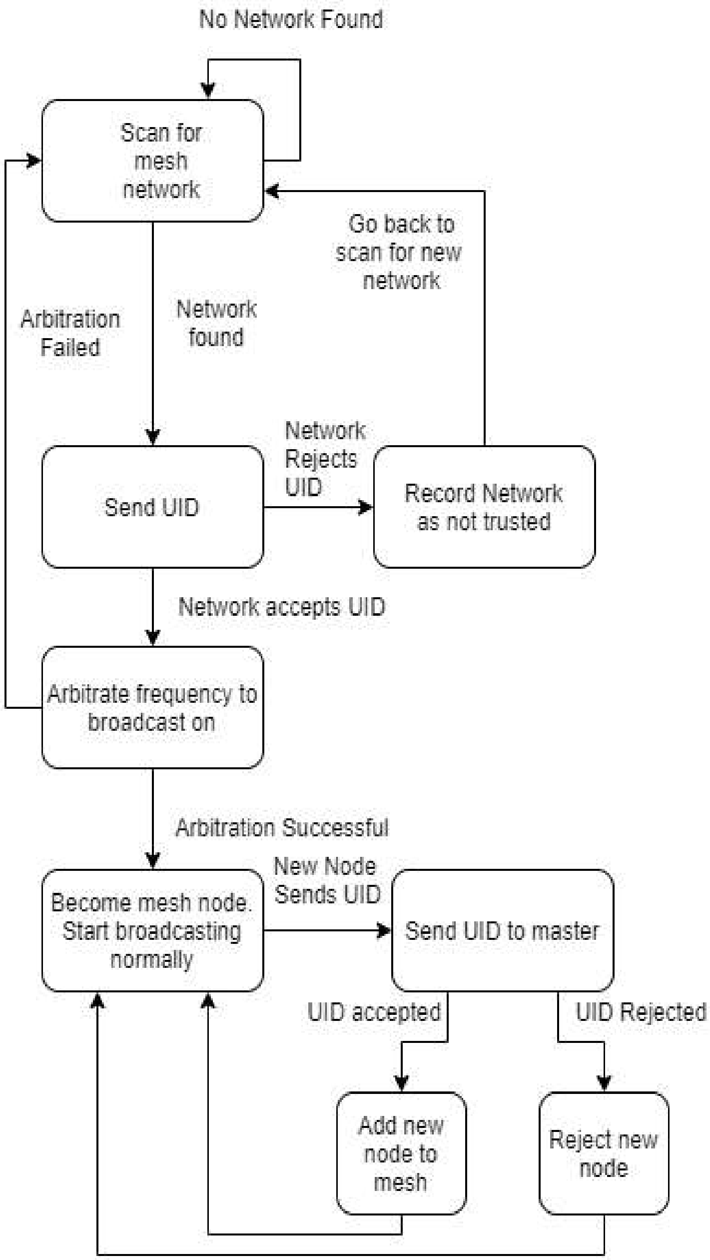

Figure 11: This is the process a slave node uses to join and run on the mesh network

The mesh slaves will each connect to one or more pairs of headphones allowing them to rebroadcast their audio. On startup, a slave headphone will look for a headphone in broadcast mode, and connect to it assuming it was properly authenticated by the master. Once it has been authenticated by the master the slave will arbitrate which frequency it will transmit on in order to not interfere with nodes around it. Providing that the arbitration was successful and it could join the network it has now become another node allowing for new connections to join. It will now be capable of sending UID requests up the parent structure in the mesh to get to the master and authenticate new users and perform arbitration for new nodes.

When the headphones are in their broadcast mode, figure 12 can be used to approximate the states that they will go through. When a packet is received it is verified by the wireless system on a chip. If the packet is not a valid signed packet from the mesh network the slave is expecting to be connected to the packet will be rejected. If the packet was from the network but otherwise compromised the packet will be

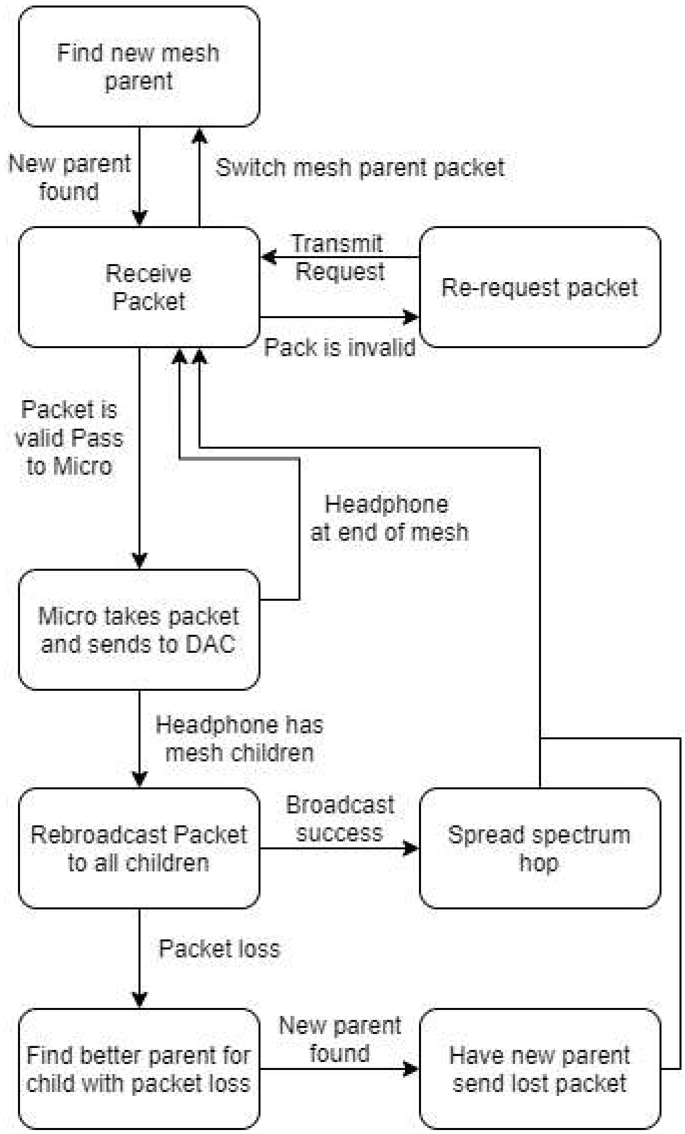

Figure 12: Flowchart of the normal mesh broadcast mode

requested from the parent to ensure that there is no audio loss on playback. If the packet that is received is a packet requesting a parent switch the slave will disconnect from its current parent and arbitrate with all of its known companions on the network in order to find a new parent that can deliver a more reliable connection. This will cause a restart in the process seen in figure 11. Once a new parent has been found the slave will continue normal operation (usually followed up by an audio packet that was previously dropped causing the new parent request). If an audio packet is properly received it will be passed to the main microcontroller. This microcontroller will first pass this on to be rebroadcast, and then add it to the queue to be decoded by the dac. For simplicity the figure seems to indicate that the audio is played before being rebroadcast. This is not the case, the buffering system was not necessary for this high level flowchart. Once a packet has been sent for rebroadcast it will be sent to all of the children. If one of the children needs to re-request a packet, meaning there was packet loss, the system will tell it to find a better parent starting the sequence described above. If there was no packet loss the system will spread spectrum hop to reduce the chance of interference from wifi or other systems on the same wireless bands. More specifically the system will broadcast and receive using 1024-QAM or lower signals (Quadrature Amplitude Modulation with the number indicating number of distinct amplitude levels, eg 1024 is equivalent to 10 bits per period). Each pair of headphones will take a wireless band of a maximum width 20MHz between 5.150 GHz to 5.850 GHz. The headphones will optimize the mesh to allow smaller bands depending on signal clarity and the lack of other interferences. Best case scenario is a 1024-QAM signal hopping over 1MHz bands. Worst case would be a 64-QAM signal over a 20 MHz band. Both of these signals would have the data rate capable of transmitting the audio signals needed but the wider band signals are much more resilient to interference and are easier for other competing 5GHz systems to detect and avoid. The smaller bandwidth signals provide less of an obstacle for other 5GHz systems causing less disruption to existing infrastructure, it also allows a larger and more dense mesh network.

3 Costs

The costs for the engineers for this system is $50 an hour, for approximately 10 hours a week for this semester. This should be also multiplied by 2.5 for the cost of overhead. This comes to $80,000 [eq.7] in total as a cost of labor.

$$4 * \frac{\$50}{hr} * \frac{10\ hrs}{wk} * 16\ wks * 2.5 = \$80,000 \quad \text{eq.7}$$

The table below contains the items needed for physical construction:

Item	**Price**
Tenergy 103450	$ 10.00
HD 800 HD 820 Headband padding	$ 31.52
HD 800 and HD 800S pair of Earpads black	$ 75.66
HD800s Protective grille	$ 13.65
HD 800 S Capsule 300 ohm (black)*2	$ 419.34
HD 800 S Acoustic baffle right and left side (1 pair)	$ 71.45
SUNLU PLA (For headset shell)	$ 23.99
Total	$ 645.61

The table below contains the items needed for the Audio interface PCB:

Item	**Price**
INA1620	$ 6.40
ISM43907-L170	$ 17.77
AD1955	$ 14.84
TPS61170	$ 2.45
LM5160 QPWP RQ1	$ 4.95
.1uf Cap * 8	$ 0.13
1uf Cap * 5	$ 0.23

22nf Cap	$ 0.03
127k Res	$ 0.0064
18.2k Res	$ 0.0061
10k Res * 6	$ 0.42
2.49k Res	$ 0.12
Total	$ 48.20

In total, the price of the system is $80,693.81.

Item	**Price**
Labor Costs	$ 80,000.00
Mechanical Parts	$ 645.61
Audio Interface PCB	$ 48.20
Total	$ 80,693.81

4 Schedule

This schedule is split into two parts to improve readability, as we have four members in our group.

Week	**Abby**	**Alex**
1	Complete main board design and layout	Complete/finalize schematics
2	Order components for main board	Begin PCB Layout
3	Assemble the main user interface board.	Complete PCB Layout
4	Start testing main board	Buck converter testing
5	Finish testing	Boost converter testing
6	Test BT with software	DAC testing
7	Test Mesh Network with software	Op Amp Testing
8	Test Bluetooth with Mesh Network	BMS Testing
9	Full system testing	System integration
10	Full system testing and preparing for final demo	Full system testing, and Final Demo
11	Finish writing final paper	Finish writing the final paper

Week	**Aditya**	**David**
1	Design software state diagrams	Design software state diagrams
2	Start Bluetooth Software	Start Bluetooth Software
3	Finish Bluetooth Software	Finish Bluetooth Software
4	Start mesh network software	Start mesh network software

5	Finish mesh network software	Finish mesh network software
6	Test Bluetooth software with hardware	Test Bluetooth software with hardware
7	Test Mesh Network software with hardware	Test Mesh Network software with hardware
8	Test Bluetooth with Mesh Network	Test Bluetooth with Mesh Network
9	Mock Demo, finish up loose ends for demonstration	Mock Demo, finish up loose ends for demonstration
10	Demonstration, start on final paper, system testing	Demonstration, start on final paper, system testing
11	Finish final paper	Finish final paper

5 Project Differences

The original solution involves a “puck” device that the phone connects to, that rebroadcasts the audio signal to many devices using multiple antennas. This limits the number of headphones that can be connected total, and the previous solution proposed only having two antennas. On the other hand, our solution consists of headphones that form their own mesh network, so that only one Bluetooth connection to the source is required, and then the mesh network allows the original audio to be broadcasted many times. This solves the limitation of Bluetooth antennas in order to allow more devices than the two from the original solution to connect. However, our solution will require additional new hardware to be purchased, and users cannot use their existing Bluetooth headphones. Once the user has these headsets, they would not need to carry around a puck device, only the new headset to replace their existing headset.

The original problem proposed involved sharing audio with friends in order to experience songs/movies with them. The original solution works well if you only have one friend, but would not work with more people, or would require additional rebroadcaster pucks leading to a high chance of interference and extreme audio delay due to the bluetooth protocol. Our solution scales to a much greater number of people, and would easily allow you to watch a movie with your entire social group without disturbing your neighbors. Our solution would theoretically lead to less interference, as different bands could be used, and we would not be using Bluetooth which already is a populated band (2.4 GHz). With the exception of the fact that purchasing new headsets is a necessity, our solution improves upon the old solution in every way. It would also be very easy to manufacture a conversion kit based on our work for 3rd party bluetooth headsets at the same cost as the original solution making even other headsets more versatile than the original solution.

One of the tradeoffs needed to make this solution is cost. The estimated cost for the new proposed solution is $80,693.81, while the cost of the previous solution was estimated to be $24,045.07. Some of this additional cost is labor, with an additional member of the group and additional time to develop the solution as it requires more complex RF (radio frequency) design and software design. This adds up to the additional $56,000 in labor costs. There is an additional physical cost, which is due to the fact that in the newly proposed solution, a headset must be developed, as opposed to a single puck. However, when looking at the additional benefits from the newly proposed solution, the cost seems to not matter as much as said benefits, so it has been chosen to move ahead with this new solution. It also remains to be seen how pricing is affected at volume since headset components are rarely purchased as individual parts there is a large “repair” markup currently factored into our costing that would disappear in actual manufacturing.

6 Ethics and Safety

We intend to follow the IEEE Code of Ethics 7.8.1-7 and 7.8.9-10 [7]. Some of the Code of Ethics is not applicable due to the nature and methods of our project. In the case of any violations of this code we will take them seriously. Due to the physical nature of our device we do not foresee any sort of physical injury possible without extreme misuse. For this reason we will focus on the nonphysical component when designing and operating our device according to the Code of Ethics 7.8.1 [7].

It is important to ensure that our device will not harm the user's ears, or emit excess radiation as per FCC regulation. Our device is classified as an intentional radiator by the FCC [8]. The chosen frequency is well within the FCC regulations, so any radiation emitted is within the healthy limit [9] that will not negatively impact the users quality of life any more than any other consumer devices. Additionally, as with any battery charging, it is necessary to ensure that the battery will not catch on fire, either when the battery is charging or during normal use. To solve the charging issue, a standard off the shelf charging system will be used that is UL rated in order to limit the amount of power that can enter the system at any one time.

To prevent harming the users ears we will ensure that our internal amplifier is limited to being able to drive any common off the shelf headphone speaker to a maximum of 130dB (roughly the SPL of a rock concert) with a warning at 80dB to alert the user that long term effects could occur. This works out to anywhere from 3mW on earbuds to 16,000 mW for the highest impedance large form factor headphones. This exact value will be chosen based on our voice coil selection specifically [10]. We will also not exceed the maximum voice coil rated power and current in order to prevent destruction of our products and burns to the customer.

7 References

[1] B. Gibson, “Here's Why You Should Never, Ever Share Earbuds with Anyone,” *The Healthy*, 26-Nov-2017. [Online]. Available: https://www.thehealthy.com/ear-nose-throat/never-share-earbuds/. [Accessed: 03-Apr-2020].

[2] Suellen, “Monoprice 109722 Bluetooth Transmitter and Splitter - Other Bluetooth,” *Walmart.com*, 19-Feb-2017. [Online]. Available: https://www.walmart.com/ip/Monoprice-109722-Bluetooth-Transmitter-and-Splitter-Other-Bluetooth/39457824. [Accessed: 04-Apr-2020].

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