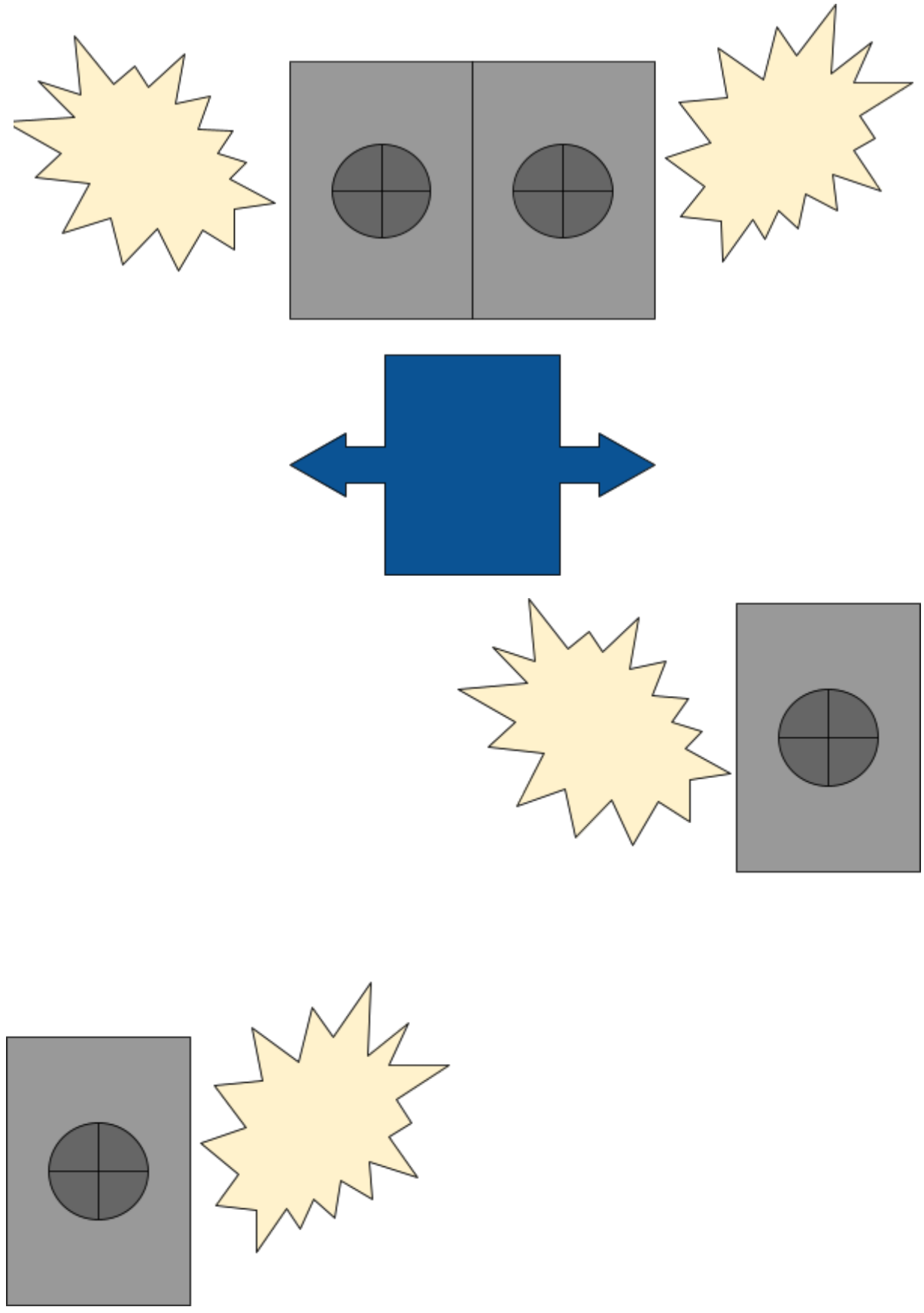
Group 1: Bluetooth WiFi Speaker Hub High Level Design



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1 Introduction

The aim of this design project is for senior engineering students Ben Colfer, Mia Gorman, Callie King, Deirdre Sheridan, and TJ Sims to apply their knowledge of electrical engineering principles to design a high-quality, flexible, and portable speaker configuration. Each member of the group is either currently or has taken the Audio Technology course offered by the University and will apply this knowledge to the project as well.

2 Problem Statement and Proposed Solution

Portable speakers have become an integral part of every person's day-to-day life. They're used socially on the beach, on bike rides, and at picnics. They come in all different shapes and sizes. But they lack the sound quality that other non-portable speakers provide. They also lack the surround sound experience that makes music and other media forms so enjoyable.

The problem that this project aims to solve is simple: portable speakers cannot truly fill larger spaces with high-quality audio. Often, when choosing the portable option for a speaker, the consumer has to sacrifice high-quality audio. Speakers are plagued with audio distortion, limited loudness, popping or humming sounds, and so enjoyment of the media is lessened. When having an outdoor party, having one portable speaker means that only a small subset of the audience gets to enjoy the music.

The goal of the Bluetooth WiFi Speaker Hub team is to design a speaker configuration that provides high-quality sound on the go for its users. The speaker design will be composed of smaller speaker units that will be flexible in their orientation. They can function as one large speaker or be broken up and distributed to create a more surround sound experience and allow music to be synced at various parts of a larger space. We will need to utilize rechargeable batteries and Bluetooth-enabled chips for each speaker that we have onboard memory.

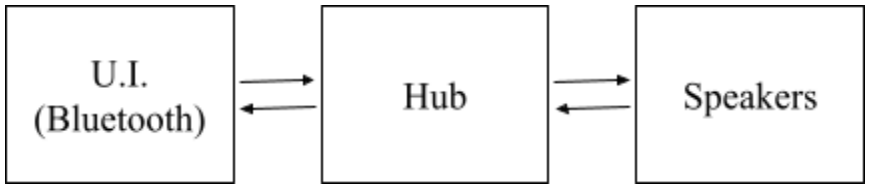
3 System Requirements

The major features that our bluetooth speaker must have include portability, surround sound capability, high-quality sound, bluetooth topology, connection stability and time synchronization. The system is made up of a hub and two auxiliary speakers. It is used by connecting the phone to a hub which in turn communicates with speakers to play music. The speakers can be separated and work outside of the hub, but they are also 3D printed to fit inside of the hub. Given these goals and the outline of the speaker, here are the requirements for our system:

- bluetooth topology: hub needs to be able to receive information from a phone and also be able to send it to speakers,
- bluetooth topology: speaker needs to be able to both send and receive information to the hub
- In the hub, there should be a status LED which is on if the hub is connected to the phone
- In each speaker, there should be a status LED which is on if the speaker is connected to the hub
- In each speaker and the hub, there should be a battery LED that is red if battery is low, otherwise it is green
- There must be a cyclic redundancy check between the peripheral speakers to ensure they have all received the same data and will play the same thing
- The hub and speaker must have rechargeable batteries to make them portable. It would be best if we could configure the charging so that while charging the hub's battery via a wall outlet, the hub will charge the speakers' rechargeable battery if it is loaded into the hub.
- It is required that the hub can be up to 20 feet from either speaker or the phone and maintain bluetooth functionality. Up to three devices must be bluetooth supported by the hub (1 phone and 2 speakers)
- To connect the hub to a phone, the hub must be recognizable to the phone via the settings app.
- The material surrounding the drivers of the speaker must be 3D printed to fit within the hub, but those dimensions are to be determined.
- To maintain the portability of the speaker hub configuration, we want to keep it under 20 lbs.

4 System Block Diagram

4.1 Overall System:



The system will have three main subsystems, each containing their own various subsystems. The main subsystems are the user interface, the hub, and the peripheral speakers. The subsystems of the user interface include the capability to connect to bluetooth and send data successfully via phone to the hub. The subsystems of the hub include charging capabilities, an LED display to show battery life and connection status, and the ability to send/receive data packets. The subsystem of the speakers include the ability to receive data packets, a cyclic redundancy check between the peripheral speakers to ensure they have received the same packets, and constructing a case for the speakers using CAD.

4.2 User Interface Requirements:

The user interface entails being able to utilize bluetooth to send data via the phone and the hub. For this subsystem to work we will need the hub to be able to broadcast itself via bluetooth for other devices to connect to it. For this we will need the chip within the hub to be bluetooth enabled. Once the phone connects to the hub it will be the master and the hub will be the slave as the phone transmits the music to the hub over bluetooth. The hub will show up as “Bluetooth Speaker Hub” to any device that is able to connect to it.

4.3 Hub Interface Requirements:

The subsystem of the hub includes charging capabilities, a display to show battery life and connection status, and the ability to send/receive data packets. There will be a rechargeable battery board within the hub with capability to interface with wall outlets. This will allow the user to be able to charge and then use the system completely wireless. There will also be a display on the hub, which will be a combination of software and hardware components. This will include a power button to turn the system on and off. Additionally, it will include LEDs to indicate the battery life status as well as the bluetooth connectivity status. Finally, the hub will have the ability to send/receive data packets. This will include hardware required for bluetooth communications.

4.4 Speaker Interface Requirements:

The subsystem of the speakers include the ability to receive data packets, a cyclic redundancy check between the peripheral speakers to ensure they have received the same packets, and constructing a case for the speakers using CAD. Each speaker will have the ability to receive incoming data packets from the hub. This will include hardware required for bluetooth communications. Then, the software will perform a cyclic redundancy check between the peripheral speakers to ensure that each speaker has received the same packets of data. Once the system passes the CRC, the speakers will play the sound packets. Finally, the speakers will need a 3D printed case built using CAD.

4.5 Future Enhancement Requirements

There are multiple features that aren’t going to be part of this initial release of the product but could be added in the future. One of these features would be increasing the amount of peripheral speakers in order to enhance the surround capabilities of the system. Additionally, another enhancement that could be done is making higher quality speakers in order to increase the sound quality output. Eventually, spatial audio could also be explored, enabling wireless surround sound capabilities.

5 High Level Design Decisions

Broken down by subsystem and major interface, this section presents your high level design of each subsystem or interface. Your design decisions should be guided by choosing options which best support your system requirements.
For each subsystem or major interface, you should describe the function or interface and the devices that will be used to realize the functions performed by the subsystem. The decision level is not to the level of a complete schematic, ***but it is necessary to identify the major components that will be used because those choices affect other design decisions.***

If a subsystem contains embedded intelligence, the requirements listed earlier should allow you to specify a microcontroller (based again on requirements like cost, power (electrical), power (processing power), I/O and interface requirements, etc.)
Keep in mind related issues, like how each subsystem is going to be powered, how clocked devices will get required clocks, etc.

5.1 User to Hub Subsystem and Interface

The first subsystem of our design is the interface between the user and the main speaker hub. The main devices of this subsystem are the user's personal device, typically a bluetooth enabled smartphone, the processor of the main hub (ESP32), and the embedded subwoofer. The ESP-32 has a built in 2.4 GHz Wifi and bluetooth combo chip, so the ESP32 should work fine for stage 1 interfacing. The rest of the components to this subsystem should be fairly arbitrary, as any rechargeable battery and charger combination with necessary power, voltage, and current requirements for the ESP-32 and embedded subwoofer should work. The main hub will be the provider of power to the peripheral speakers' batteries as well as the components of the main hub, so we must consider using a large enough battery with necessary output and possibly a separate regulation or conversion circuit to manage power inputs to the different devices. The overall function of this interface is to allow the user to send audio data to the main hub. There, digital processing can be used to filter and send low frequency content to the subwoofer and high frequency content to the peripheral speakers in the next subsystem. An additional function in the hub will be communication with the peripheral speakers as detailed in the next section. For this function, we may wish to explore an amplification circuit at the input of the antenna to boost working range of the wireless system.

5.2 Hub to Peripherals Subsytem and Interface

The second subsystem is the interface between the main hub and the peripheral speakers. The main components of this interface will be the processor within the hub, bluetooth enabled processors within each peripheral speaker, and the mid-range drivers of the peripheral speakers. The necessary functions of the peripheral subsystem will be sending of mid to high frequency audio content from the hub to the chips in the peripheral speakers. As this content is received, embedded intelligence will be used to

track data received (likely by number of packets) and communicate back to the hub when each peripheral has successfully received X amount of audio data. When all peripherals have communicated this to the hub, the hub will send back a “green light” signal to peripherals initiating audio playback. The necessary processors for the peripherals run as low as $7 on digikey, some even with built in DSP capabilities. We will need to consider operating frequency (majority of processors function over 2.4 GHz) as well as data rates, as the higher data rates will allow for a shorter delay before playback begins. Other components of this subsystem will be the rechargeable batteries within the speakers as well as their charging devices to be embedded in the hub. Recharging power will be handled by the hub subsystem, while power management for the peripheral drivers and processor will be included in this subsystem. As is the same for the hub, an amplification circuit could be considered at the input of each speaker’s antenna for additional range.

6 Major Component Costs

The major system components will be the speaker drivers. The speaker kit we are considering costs $50 for one kit. We will need two kits for our project, costing around $100. To make the system completely portable, we will need to buy battery boards to supplement the kit. Each battery board is $10, for a total of $20. A 6 pack of the 18650 batteries costs $29 dollars. A ten slot battery charger costs $18. The total for the speaker system with two auxiliary speakers would end up costing $167.

3D printing will also be a main part of our project that we will need to budget for. We will allocate $20 for this cause.

The rest of our budget will be used for obtaining circuit elements and any unknown costs that may come up throughout the design and construction of the speaker project.

7 Conclusions

As of now, there’s no product on the market that gives customers the ability to create surround sound from anywhere. The 2 rechargeable speakers connected via Bluetooth to the main hub will solve this problem. Since the speakers and hub are rechargeable they will be extremely portable. The customer will connect their phone or any other Bluetooth-enabled device to the main hub which all the speakers will be connected to. This will elevate the portable speaker market as current portable speakers are either not loud enough or too loud.

References