Design Review 1

Subsystem 1: Signal processing system

(bluetooth connection from phone to speaker, unison sound sharing between hub and peripheral speakers)

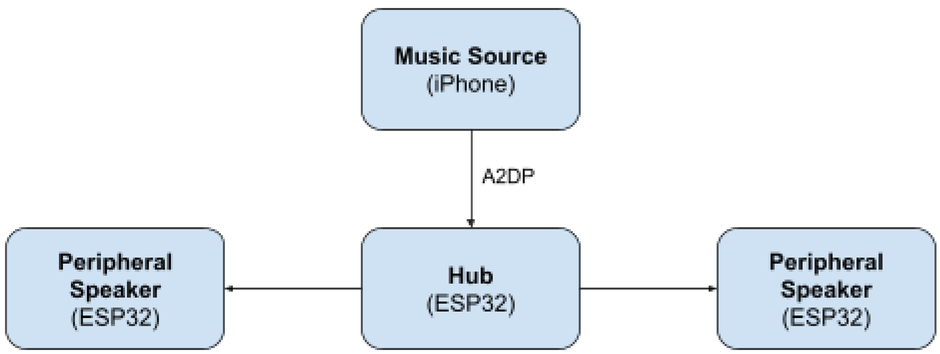


Figure 1: Diagram representing the signal processing system. This includes communication from a music source to our ESP32 hub via bluetooth. This also shows the snapcast communication between the hub and the two peripheral speakers.

The ESP32 has a Bluetooth interface that can connect to multiple peripheral speakers to play audio. To connect a phone to the hub, the AD2P will be used. This allows for a bluetooth audio source (such as a phone or laptop) to connect a source to the speaker hub.

Snapcast is a multi-room client-server audio player, where all clients are synchronized with the server to play perfectly synced audio. It acts as an extension that will turn our existing speaker configuration into a multi-speaker solution. All data that is fed into the server's audio input will be sent to the connected clients in a named pipe. The snapserver (our hub) reads the chunk from the pipe, and the chunk is encoded and tagged with the local time. Then, the chunk is sent via TCP connection to the snap clients (our peripheral speakers). Each snapclient does continuous time synchronization with the server, so the client is always aware of the local server time. The chunk is decoded and added to the clients' chunk-buffer before it is played out using ALSA at the appropriate time (according to the local server's time). When deviations occur, it will sound like skipped music, silence, or sped-up/slowed-down versions of the song. This deviation is normally around 1 ms, so it won't affect the overall user experience. The only requirement to use snapcast is that the player's audio can be redirected into the Snapserver's fifo.

The challenge of using snapcast is that it is typically done with Raspberry Pi, but we are using ESP32.

Subsystem 2: Audio output system

(amplifier and external speakers)

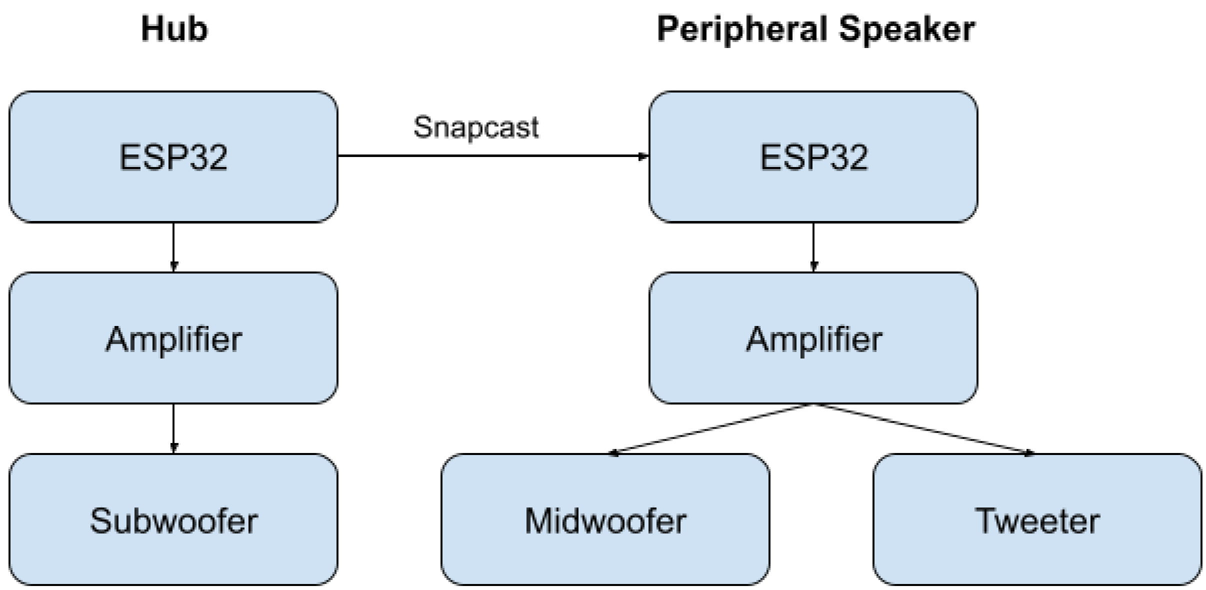
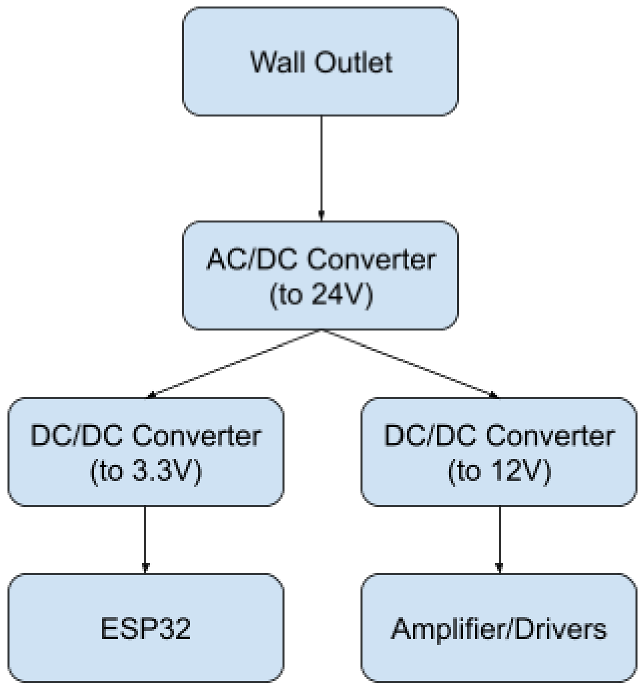


Figure 2: Diagram representing the audio output system. This image describes the major components in the hub: the ESP32 for software filtering and bluetooth connectivity, the amplifier, and the subwoofer for low frequency components of the audio input. On the right handside are the components of the peripheral speakers: an ESP32 for wifi connectivity to the hub and filtering, the amplifier, the midwoofer for medium frequencies and the tweeter for high frequencies.

For high quality sound, we require high quality speaker components that fit our budget. The subwoofer signal will be low pass filtered and the midrange drivers will be high pass filtered both with cutoff frequencies around 5 kHz. Doing this will simulate the crossover network of a system with one source. After filtering, the signals will be sent to an amplifier circuit. The hub and peripheral speakers will each have their own amplifier circuits. The hub will have the subwoofer while the peripheral speakers will include the mid woofer and tweeters.

Subsystem 3: Power system

(power and charging capabilities for the hub and peripheral speakers)



We require power to drive the speakers. This includes an isolated AC/DC power supply, input power protection, energy storage, and non isolated DC/DC power supply. This will ensure that the speaker hub can carry and store energy to charge the peripheral speakers. The hub will be charged through wall outlets. The peripheral speakers will charge from the main battery source at the hub through inductive charging. This way, when the peripheral speakers are back on the hub, they will be charging. We selected a 12V battery with 10 Ah so that the peripheral speakers will have approximately a ten hour battery life (calculations below).

Battery Life (in hours) = Battery Capacity (in Ah) / Load Current (in A)

BL = 5 / 0.417

BL = 12 hrs

To be safe, the battery should be recharged after reaching 9.6 hours of use. This accounts for leaving twenty percent of battery life in the system so that it can recharge as expected. There will be an on board regulator to 3.3V for on board components, because of the ESP32. To power the hub, there will be an AC/DC adapter into the hub (120V AC to 24V DC). Within the hub, there will be a DC/DC converter (24V DC to 12V DC).

Our design includes seven major components: ESP32s, amplifiers, tweeters, midwoofers, subwoofers,inductive charging coils, and batteries.

1. ESP32

The ESP32 will serve as the processor for our speaker system. They run off of 3.3V of power. Each of the speakers (the hub and the two peripherals) will have their own ESP32. A phone will have a bluetooth connection to the hub's ESP32 using A2DP protocol. The hub's ESP32 will then use snapcast to communicate the data to the peripheral speakers' ESP32s via WiFi. ESP32 is a low power board which will benefit our power system.

2. Amplifier

We are planning on using three class D amplifier boards for this project that use 2x50W of power and output 8 ohms of impedance. The hub and the peripheral speakers will each have their own amplifier board. The amplifiers will receive information from the data pin on the ESP32, either from bluetooth using A2DP (hub) or from WiFi using snapcast (peripheral speakers). The amplifiers then boost the signal so that it is loud enough to be heard when played by the respective drivers. The amplifier is one of the most important components because we need the speaker to have loud volume capabilities, as outlined as a goal for this project.

3. Tweeter

Tweeters are drivers that output high frequency sounds. They will drive frequencies between 2 kHz and 20 kHz. Tweeters convert electrical signals into acoustic waveforms. We are choosing to include tweeters in our design to produce a clearer, more balanced sound from the speaker system. The crossover network will direct the correct frequencies to the tweeter, and subsequently, the other drivers. Each peripheral speaker will contain one tweeter.

4. Midwoofer

Midwoofers are drivers that output medium frequency sounds. They will drive frequencies from 200 Hz to 5 kHz, but will have the best sound between 500Hz and 2kHz. Mid-range drivers are the best kind of drivers for mid-range frequencies, which are, arguably, the most important frequencies to human hearing. Each peripheral speaker will contain one midwoofer.

5. Subwoofer

Subwoofers are large drivers that output low frequencies. They drive frequencies from around 35 Hz to 200 Hz. The purpose of the subwoofer is to create a deep, clear bass sound. We will utilize one subwoofer in our hub. The subwoofer receives frequency signals and amplifies the current. It then converts it to sound by the magnetic coil, which causes vibrations.

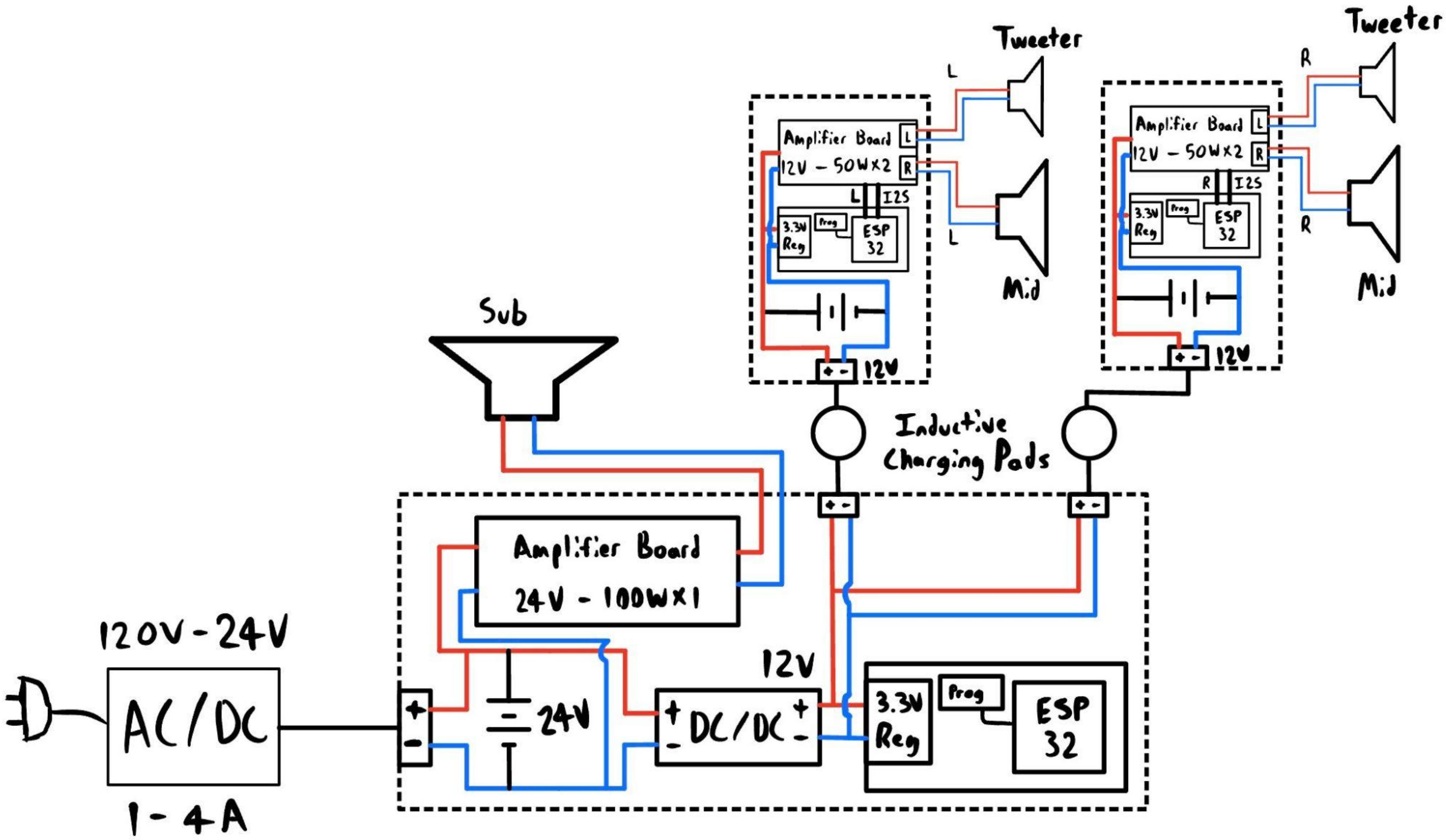
6. Inductive charging coil

Inductive charging is a way of powering a device without a direct wire connection. These chargers work by taking a power transformer and splitting it in half, an AC waveform is generated into one, and couples into the second coil. The coils need to be fairly co-axial, we will try to get them to be parallel and have the circles line up for the best power-transfer.

7. Batteries

We are planning to use a 24 volt rechargeable battery for the hub that will charge from a wall outlet. The way we are planning to achieve this is having 4 6 volt batteries in series; however, this looks to be ineffective from a budget standpoint. When the hub is plugged in it will run off of the outlet while the battery charges. The peripheral speakers will run off 12 volt rechargeable batteries. We are again planning to use 2 6 volt batteries in series which do not look to be budget friendly. The 12 volt batteries will recharge by inductive charging with the 24 volt battery.

Essential Connections



For our power system we are planning to have an AC/DC power supply which takes the 120 V AC down to 24 V DC with 1 to 4 amps of current which will go into the hub. From there the hub will have a 24 V rechargeable battery which will power the whole system when it is not plugged into the wall. There will also be 24 V running to the amplifier within the hub. We will then have a DC/DC converter which will bring the 24 V down to 12 V, the 12 V will go into our hub board which will have a voltage regulator to bring the voltage down to 3.3 V. The 12 V will then be connected to an inductive charging set which will charge the batteries within the peripheral speakers. The batteries within the peripheral speakers are going to be 12 volts and rechargeable. The 12 volts from the peripheral batteries will power the 2 output amplifiers for the midrange and tweeter drivers. The 12 volts will also go into the ESP boards which will have a voltage regulator down to 3.3 volts.

Parts List

- Amps
  - Want 24 V for hub
  - Peripheral Amps - 5-24V, 50W X 2
- Converters/Regulator
  - 24V-12V DC/DC
  - 120V-24V AC/DC
  - 12V - 3.3V on board regulator
- Batteries/Charging
  - Inductive Charging Coils
  - 24V Hub Battery - 4, 6V, 4.5 AH Batteries in Series
  - 12V Peripheral Battery - 2, 6V, 4.5 AH Batteris in Series
  - 12V-3.3V Switching Regulator

Part ideas:

- Batteries commonly used in DIY speakers
- Battery Board with protective circuit
- 3 Output Amp Board

1. The challenge of using snapcast is that it is typically done with Raspberry Pi, but we are using ESP32.
    a. Action plan: conduct further research on past projects.
    b. Answer: Can we use raspberry pi in our set-up?
    c. Can we adjust the software for this to work with an ESP32?
2. The challenge of using multiple batteries in series
    a. Action plan: Research more into if it would be cheaper to purchase single 24 V or 12 V batteries
    b. See if we can find cheaper 6 V batteries then we have currently found or possibly drop to 4 V batteries?
    c. Battery imbalance? Overcharge? How do we protect our power supply?
3. Voltage regulator
    a. Would a switching regulator be better than a linear regulator for our application?
    b. What is a buck regulator?