Wireless Speaker Sharing System (WSSS)

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ECE445 Senior Design Proposal

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1. Introduction

1.1 Objective

Having a single loudspeaker at parties is uncomfortable at times. The music is too loud if one's close but the volume attenuates as he/she moves further away. The proposal introduces a novel design, a standalone plug-and-play wireless audio sharing system that interfaces with the standard 3.5mm audio jack. There will be one broadcasting dongle and multiple receivers. Users can plug the broadcaster to any of their music players (phones, computers, or even game consoles), and plug in the receivers to an arbitrary amount of playback devices in proximity without any pairing or registration procedure. All audio signals will be in sync, so users can enjoy an immersive audio experience across all speakers.

1.2 Background

It's often to have parties where it's deafening standing beside the main speaker but not loud enough further from the speaker, so not all people can enjoy those beats. Purchasing a large and decent speaker for occasional parties is often too expensive. It will be great if people can utilize their existing small personal speakers and easily sync them up for a song for everyone to enjoy. That is why WSSS (Wireless Speaker Sharing System) is developed. It allows people to gather the power of multiple generic small speakers and host a great party.

1.3 High-level requirements list

- The power subsystem should consistently provide 5V at up to 500mA to the entire system for at least twenty minutes.
- The signal processing subsystem should sample the audio signals with a 16-bit resolution at no less than 10 kHz. The amplified audio output should have a voltage no less than 900 mVrms measured at the audio jack, a typical input voltage level for speakers.
- The wireless transmission subsystem should sustain a stable connection within 5 meters between transmitter and receiver.
- Users should be able to successfully play music through our WSSS with more than two speakers.
- The audio signals from different speakers should be in sync, with indiscernible latencies among them (less than 15 ms).
- Both the transmitter and the receiver should be plug-and-play devices.

2. Design

The design can be divided into three separate systems, namely, power system, signal processing system, and the RF transceiver system. The power system features a rechargeable Li-ion battery with corresponding charging and regulator circuits to power the rest of the design. The radio frequency (RF) module can sustain a bandwidth of around 250kbps, typical for music streaming services, within 100 meters in open space without any interference. While the range is expected to be lower indoor, where more radio interference and obstacles are present, it should be well above the area of a typical use scenario. The signal processing system is responsible for converting analog audio input to digital signals suitable for transmission over RF, and vice versa on the receiver end.

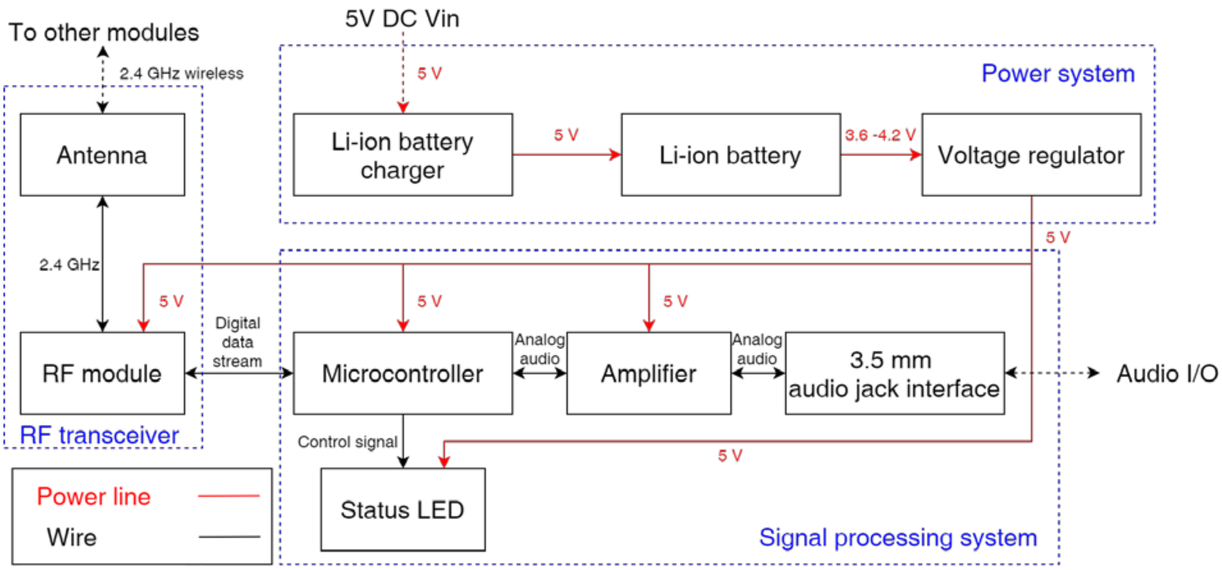

Figure 1 Block diagram

The physical appearance of the design is shown in Figure 2. It's a small dongle that has a 3.5 mm male audio jack and an antenna for wireless transmission. The users would plug in the transmitter on their playing device (e.g. phone) and the receivers to playback devices, *i.e.* speakers. The distance between transmitter and receivers need to be reasonably close, of about 5 meters.

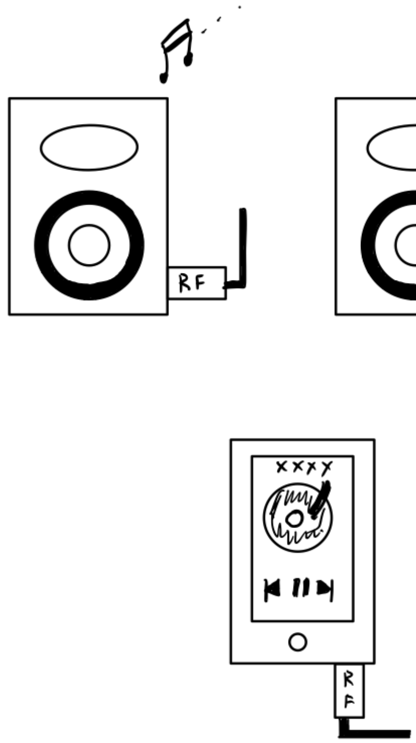

Figure 2 Physical design

2.1 Power Subsystem

A power subsystem is required to power the whole system to 5V/3.3V and keep the processing and transmission continually.

2.1.1 Li-ion battery charger: Charge the Li-ion battery to fully-charged voltage so that it can power the whole system.

Requirement: Must charge the Li-ion battery to 4.2 V ± 50 mV per cell, which is the nominal full-charge voltage for this kind of battery cells

2.1.2 Li-ion battery: The battery must keep the system powered.

Requirement: The battery must store enough to provide the power at voltage 3.6V to 4.2V for 8 hours

2.1.3 Voltage Regulator: This integrated circuit supplies the required 3.3V/5V to all components in our design.

Requirement: Must be able to handle the peak input from the battery (4.2V) at the peak current draw (~200mA when transmitting/receiving w/ amplifying circuit).

2.2 Signal Processing Subsystem

The signal processing subsystem is responsible for processing the signals to be transmitted or received and amplify/filter/convert them to Analog/Digital signals.

2.2.1 Microcontroller: The microcontroller is essential to do the A/D, D/A conversions to ensure usable audio quality and also send control signals to communicate with our nRF module.

Requirement: Must be able to do A/D, D/A conversions at 16-bit resolution

2.2.2 Amplifier: Amplifiers are supposed to amplify the received analog signal's so that they provide processable and distinguishable digital signals and sounds.

Requirement: Must be able to amplify the received signal to ~1.1 Vrms, which is about the average 3.5 mm audio output device's output capability.

2.2.3 Status LED: Display the status of the microcontroller via some red LEDs.

Requirement: The status LEDs must be clearly visible from within 2 meters with a drive current of 10 mA.

2.3 Wireless Transmission Subsystem

Wireless transmission subsystems should transmit the audio signals wirelessly within a certain range.

2.3.1 Antenna: An antenna will be connected to our RF modules.

Requirement: An omnidirectional antenna with a gain rating at about 5dBi will be used. This allows our RF module to have a ~10m range for outdoor usage with no positioning requirements.

2.3.2 RF module: RF module should transmit and receive the signals via the antenna and communicate with the signal processing module.

Requirement: The module should use the 2.4 GHz band and it can operate with baud rates from 250 kbps up to 2 Mbps within a 10m radius.

2.4 Risk Analysis

Signal processing could be a risk to the successful completion of this project. The subsystem is essentially a software-defined ADC/DAC, paired with an appropriate amplifier to sample the audio input on the transmitter end, converting it to data streams sent over RF, and recreate it on the receiver. Tuning this module could be challenging. We would need to use PWM waves to reproduce the sound signals received, which could be troublesome because a wide bandwidth of sound is involved.

There's an inherent risk with the wireless transmission system as well. The RF module shares the same frequency band with WiFi and Bluetooth and is susceptible to interference with those devices. It might be tough to get working as well.

3. Ethics and Safety

The power subsystem could be a potential safety hazard. As we are going to use Lithium-ion batteries as the major power source in the system, which can explode if overcharged or brought to extreme temperatures. However, we are planning to purchase a set of quality-controlled lithium battery modules so that minimize the risk.

The Wireless Transmission Subsystem in the design uses the nRF24L01+ single-chip radio transcriber for the worldwide 2.4 GHz ISM band. ISM bands refer to the industrial, scientific, and medical bands, which are defined by the ITU Radio Regulations. The 2.4 GHz ISM band is permitted for unlicensed operations here in the United States.

On the ethics side, according to the IEEE Code of Ethics, #1: "To accept responsibility..." [1], we might have an ethical breach on I.1, which states that we have to paramount the safety, health, and welfare of the public. This is because our wireless transmission subsystem emits radio waves, which might affect the general public's health. As a result, we will strictly restrict our wireless transmission power limit and make sure all wireless transmissions are within the FCC spec. This will keep that our public health impact to a negligible degree and thus avoid ethical breaches.

References

[1] Ieee.org. 2020. IEEE Code Of Ethics. [online] Available at: <http://www.ieee.org/about/corporate/governance/p7-8.html> [Accessed 17 September 2020].