Team 11: Wireless Speaker Sharing System (WSSS)

Requirement Summary

Module Name	High Level Requirement	Points
Power Subsystem	• Supply: the subsystem supplies 5V to the microcontroller and 3.3V to the RF transceiver • Charging and overcharge protection: the battery can be charged using a mini-USB cable. The charging stops when battery voltage reaches ~4.2V, indicated by the charging LED. • Short-circuit protection: the system can recover from an accidental short circuit.	15
Control Subsystem / Audio Quality	• The music played is recognizable for the listeners • The audio quality should be comparable to that of AM radio • The latency between playback from two speakers is small enough to be indiscernible for the human ear.	20
RF Transceiver	• Range: the audio stream is sustained within 10 meters. • Omnidirectional: RF signal coverage has no obvious blind spots.	15
	Total	50

High-level Requirements

1. Users must be able to successfully play music through our WSSS with more than two speakers.
2. Both transmitter and receiver should work without any setup process. Turn on power switches and plug-in both transmitter and receiver to start the transmission right away.
3. The receiver should pick up the signal instantaneously upon powering up, making it behave like a wired connection.
4. The audio signals from different speakers should be in sync, with indiscernible latencies among them (typically < 15ms)

R&V Tables

Power subsystem

1. Li-Po battery charger

Charge the Li-Po battery so that it can power the whole system. This charger circuit is needed as we have to prevent Li-Po overcharge, which can cause a safety hazard if not careful. This charger circuitry will ensure the proper handling of a Li-Po battery.

Requirement	Verification
Must charge the Li-Po battery to 4.2 V ± 50 mV per cell, which is the nominal full-charge voltage for this kind of battery cells	(a) Discharge a li-Po battery cell to ~3.3 V (b) Charge the battery using a Li-Po charging IC with 5V input voltage. (c) When the charging process is finished (indicated by the charger IC), connect a voltmeter to check that the battery is at 4.2 V ± 50 mV per cell

2. Li-Po battery:

The battery must keep the system powered. We choose a Li-Po battery because of its great energy density. Using a 1Ah battery allows us to achieve a ~10hr uptime per charge, which is ideal.

Requirement	Verification
1. The battery must store 1Ah charges, which is enough to power the system at 100mA for 10 hours. 2. During the discharging period, the battery provides power at voltage 3.6V to 4.2V 3. The battery's temperature should stay below 50°C when discharging	(a) Charge the battery to full capacity, use a multimeter to ensure that the voltage across it is <= 4.2V (b) Connect the battery to a 40-ohm resistor and discharge the battery at ~100mA for ten hours. (c) Use a multimeter to measure the battery voltage again after discharging, it should remain above 3.7V (d) During verification steps (a)-(c), use an IR thermometer to ensure the battery stays below 50°C

3. Li-Po Battery Voltage Booster:

To achieve stable operation of our 16MHz ATMEGA-328P Arduino microcontroller, we need to supply it with a stable 5V power. This is achieved by using a switch power booster circuit that can boost the Li-Po batteries voltage to a constant 5V.

Requirement	Verification
Must be output a clean and stable 5V DC at a sustained the current draw of ~ 200mA	(a) Connect a lab bench power supply to the boost circuit input. (b) Attach 25 ohms resistor as load (200mA load) (c) Attach a voltmeter across the load (d) Sweep the supply voltage from 3.5 to 4.2 V (e) Ensure the output voltage always stays at 5.0 ± 0.1V

4. Voltage Regulator

This integrated circuit supplies the required 3.3V to our relatively power-hungry nRF24 module during receiving. A good 3.3V power source is crucial to the stable transmission and nRF24 can't be powered by the same 5V that Arduino uses.

Requirement	Verification
Must be able to handle the 5V input from the battery boost circuit at the peak current draw (~200mA when transmitting/receiving w/ amplifying circuit).	(a) Attach 25 ohms resistor as load (200mA load) (b) Attach a voltmeter across the load (c) Supply regulator with 3.7 V ± 0.4V DC (d) Ensure output voltage remains 3.3 ± 0.1V

Signal processing subsystem

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 RF modules, as RF modules transmit digital signals instead of analog voltages.

Requirement	Verification
Must be able to do A/D at 8-bit resolution and 44kHz sampling rate.	1, A/D verification: (a) Use a 20kHz sine wave as the input to the A/D submodule on the microcontroller. (b) Save the output digital signals and use an ideal DAC (with a reconstruction filter) to theoretically reconstruct the analog signal and get the original 20kHz sine wave back.
Must be able to do D/A at 8-bit resolution and 44kHz sampling rate.	2, D/A verification: (a) Once A/D verification passes, we can directly use the digital signal output from the A/D submodule and make that as the input of the D/A submodule. (b) Verify that the output analog signal is a reasonably clean 20kHz wave. (Not a sine wave as Arduino cannot output a real sine wave. However, the output should sound similar)

2. Status LED

Display the status of transmission via some red LED, this would allow users to see the working state of the transmitter and receiver.

Requirement	Verification
The status LEDs must be flashing when the RF module is transmitting or receiving payloads.	(a) Put one RF module in transmission mode and the other in receiving mode. (b) Ensure LEDs on both nodes are flashing. (c) Turn off the transmission mode on the first RF module. (d) Verify that both LEDs are no longer flashing.

Radio Frequency Transceiver Subsystem

1. Antenna

An antenna will be connected to our RF modules. This greatly enhanced the effective range of our RF module, which in turn gives us a better reception and audio signal.

Requirement	Verification
An omnidirectional antenna with a gain rating at about 5dBi will be used. This allows our RF module to have a ~10m range for indoor usage with no positioning requirements.	(a) Use both transmitter and receiver without connecting the antenna. (b) Verify that the status LED is not flashing properly when these two modules are 10 meters apart. (Indicating a bad reception) (c) Install 5dBi omnidirectional antennas on both transmitter and receiver. (d) Verify the usefulness of the Antenna by placing them 10m apart and look for the constant flashing of both status LEDs to ensure that a good connection is established.

2. RF module

RF module should reliably transmit and receive digital audio signals via the antenna and send them to the signal processing module. It must operate in the 1Mbps Bandwidth mode consistently within a 10m radius to ensure proper transmission.

Requirement	Verification
The module should use the 2.4 GHz band and it can sustain a single-direction wireless transmission bandwidth of 350 kbps (calculated in Tolerance Analysis) consistently within a 10m radius.	(a) Use the nRF24 library on Arduino to set both transmitter and receiver to use the 1Mbps bandwidth mode. (b) Program the timer interrupt to send a 32-bytes counter packet at a frequency of 1367 Hz. (c) On the receiver side, constantly check if there's data to be read and store the received data in memory (d) Place the two nodes ~10m apart. (e) Start program on both nodes and keep running for 1 minute (f) Dump the received packets to a file and verify that it is below a BER of 0.1%