Urban Noise Pollution Monitoring System

ECE 445 Senior Design

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Introduction

What is the project and why is it important?

What Problem Needs to be Solved?

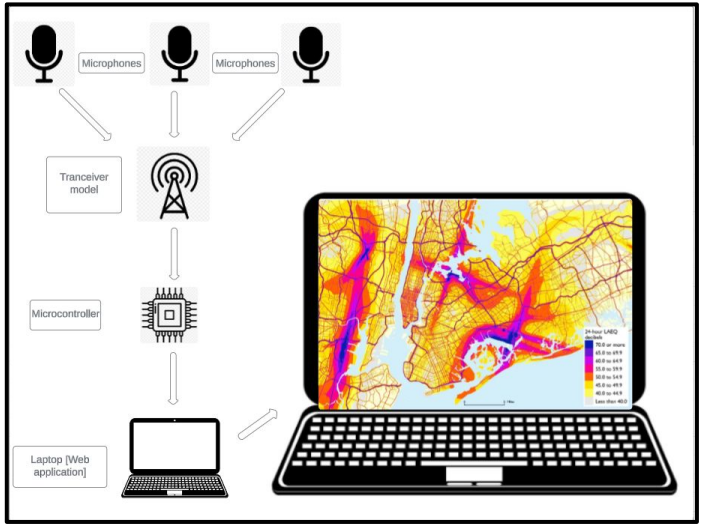
- Noise pollution in urban areas is often overlooked.
- Can lead to permanent hearing loss over time.
- Noises above 85 dB can damage the thin hairs in the human ear, which can not grow back.

World Health Organization Study

- Researchers did 200,000 hearing test in NYC in 2007.
- Data came back as if their hearing was 10-20 years older than their actual age.

[1]

Introduction - The What



Noise Level (dBA)	Common Sound Level	Color Indication
< 60	Conversation	
60 - 85	Vacuum Cleaner	
> 85	Heavy Traffic	

What is the Urban Noise Pollution Monitoring System?

- A system of wireless, battery-powered microphones strategically placed outdoors
- Utilizes a central hub to collect and process data from distributed microphones
- Processed data is sent to a web server and displayed via heat map

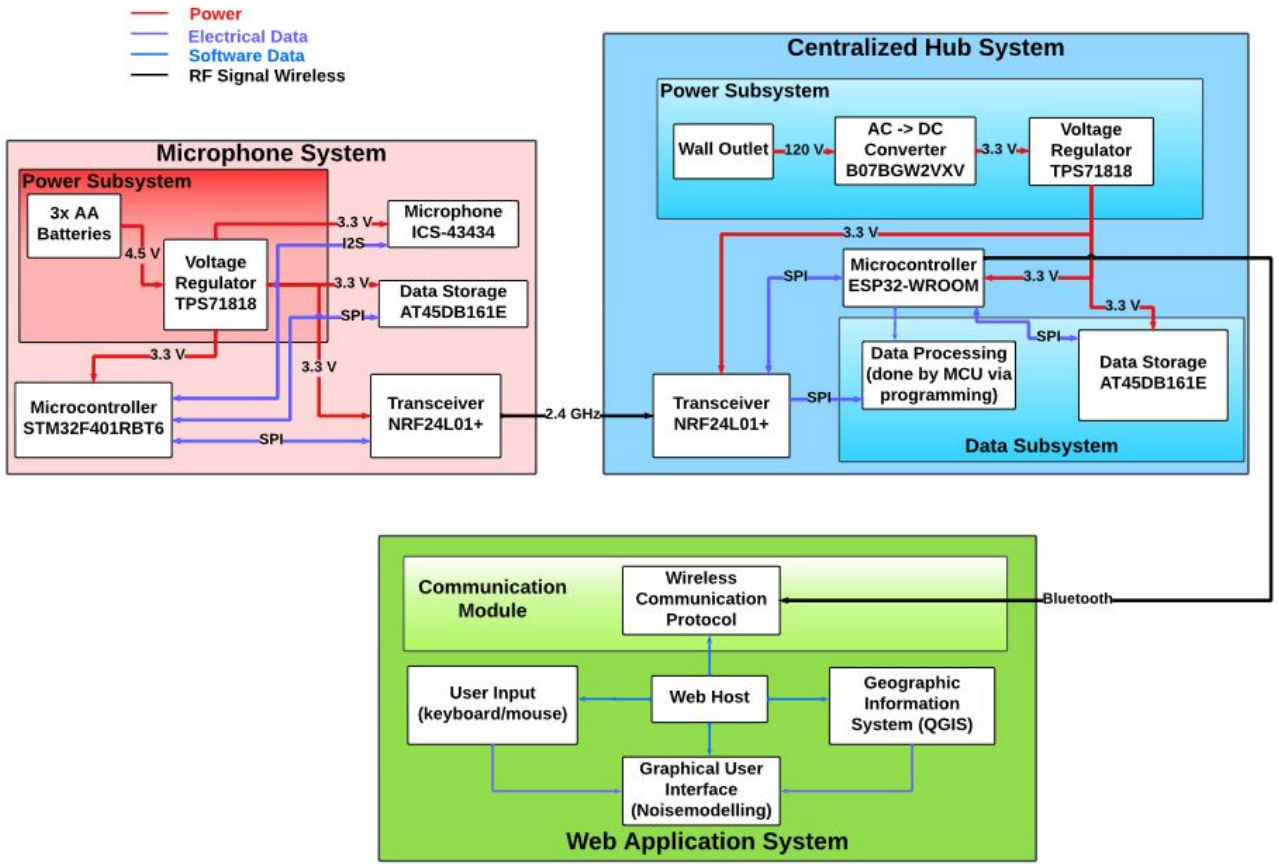
Introduction - High Level Requirements

1. **Updating of Noise Map**: Noise map updates with each hourly upload from the central hub, ensuring an accurate representation of the space being monitored and will be display various sound levels with green, yellow and red.
2. **Operation Longevity:** Our system should be capable of running for at least a month utilizing a combination of proper battery choice and activation protocols. This will ensure that the system will not have to be frequently taken down in order to be charged.
3. **Real-time Monitoring and Hourly Data Reporting**: The central hub system should successfully report noise data to the central web application every hour, providing a consistent and reliable stream of information for analysis and decision-making with a latency of 5 minutes.

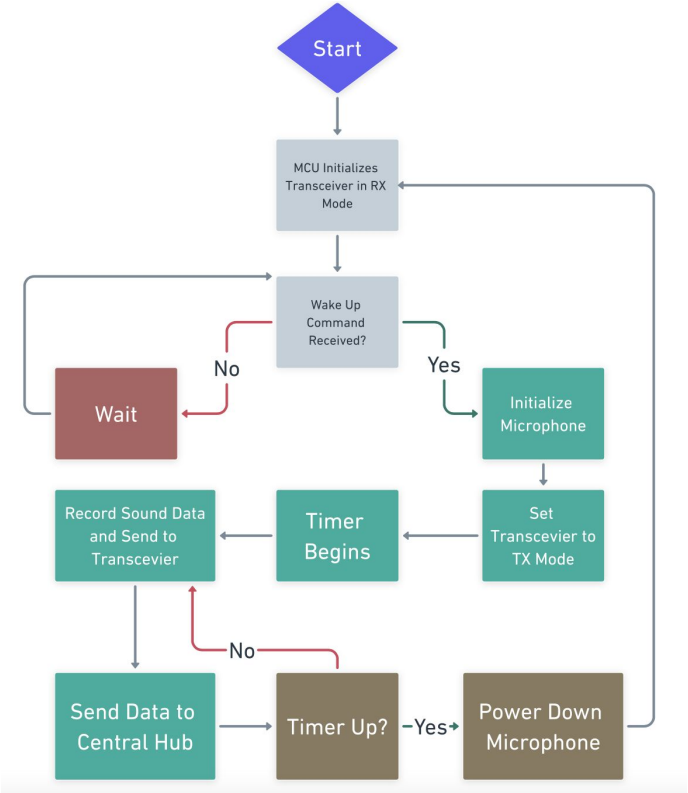
Design

How did the project come together?

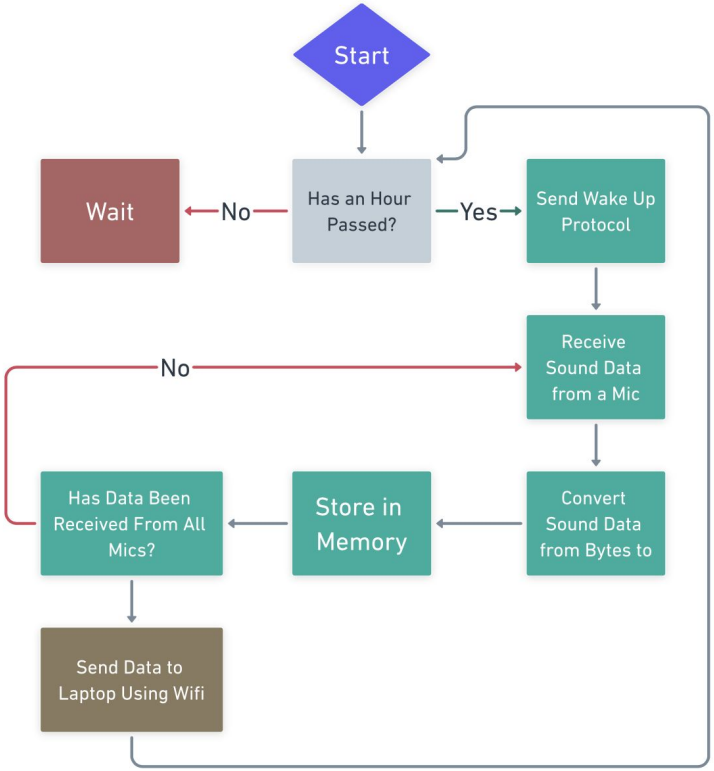
Design - Original Block Diagram



Design - Code Flow Charts

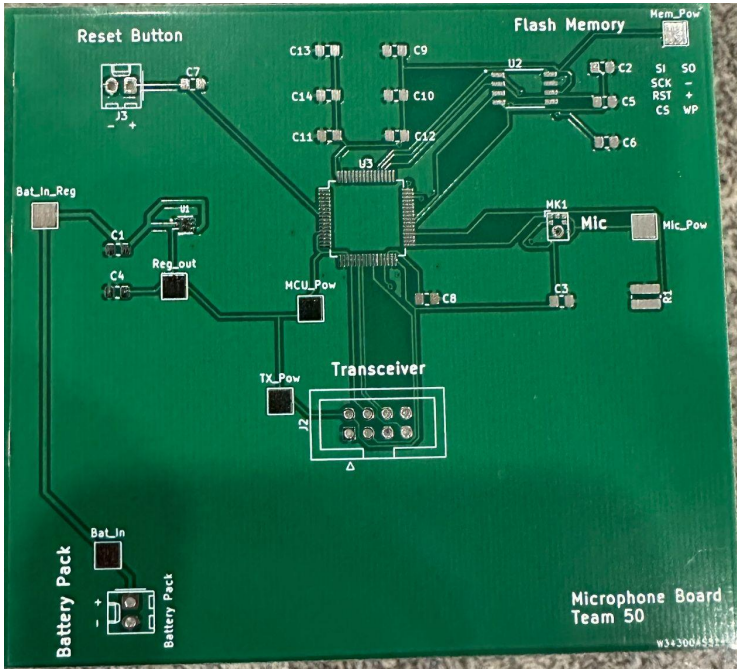


Microphone Flow Chart

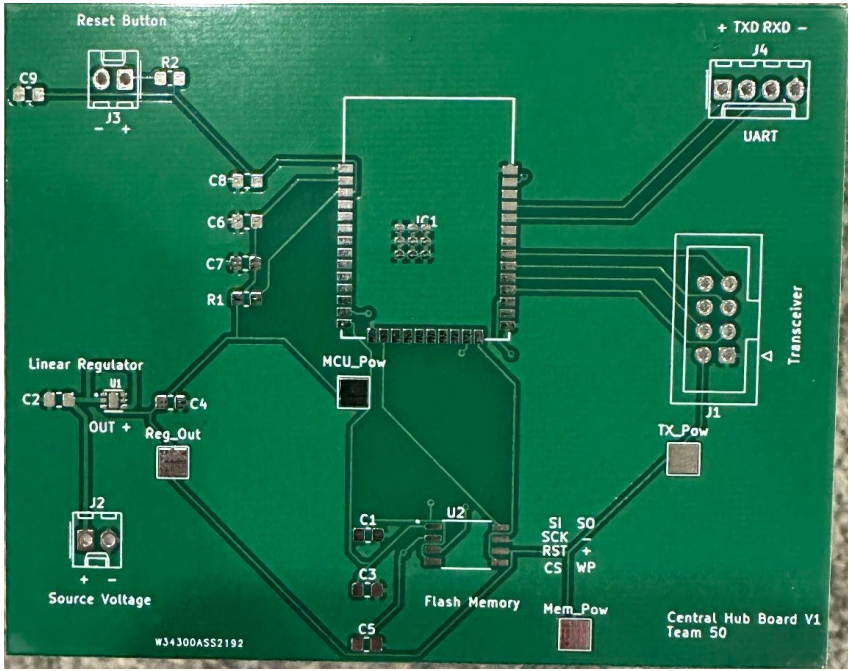


Central Hub Flow Chart

Design - Original PCB Boards

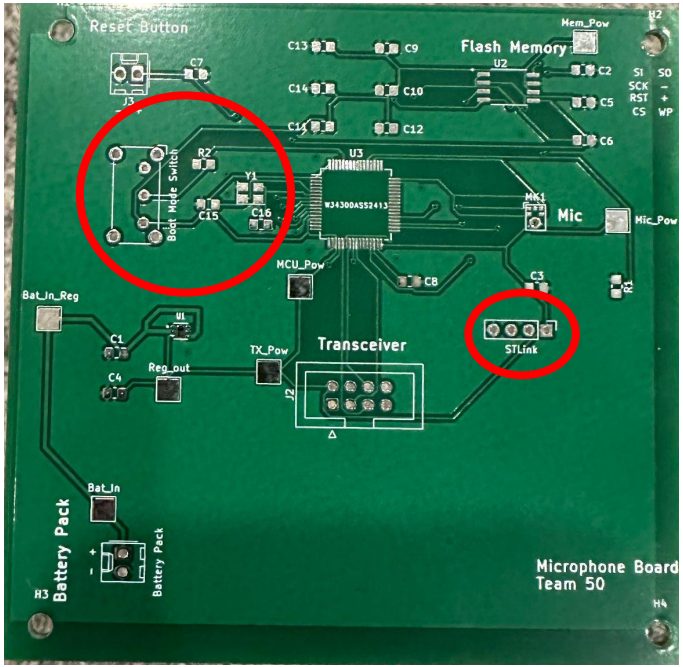


Microphone PCB Board



Central Hub PCB Board

Design - Updated PCB Board: Microphone



Updates Made to the Board

- Boot Mode Switch
- Mounting Holes
- Programming Connections
- Crystal

What it Corrected

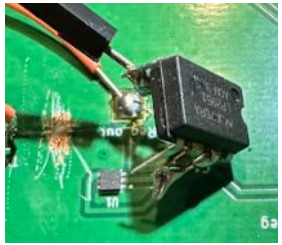
- Ability to Program the Board
- Easy housing installation
- Timer Considerations

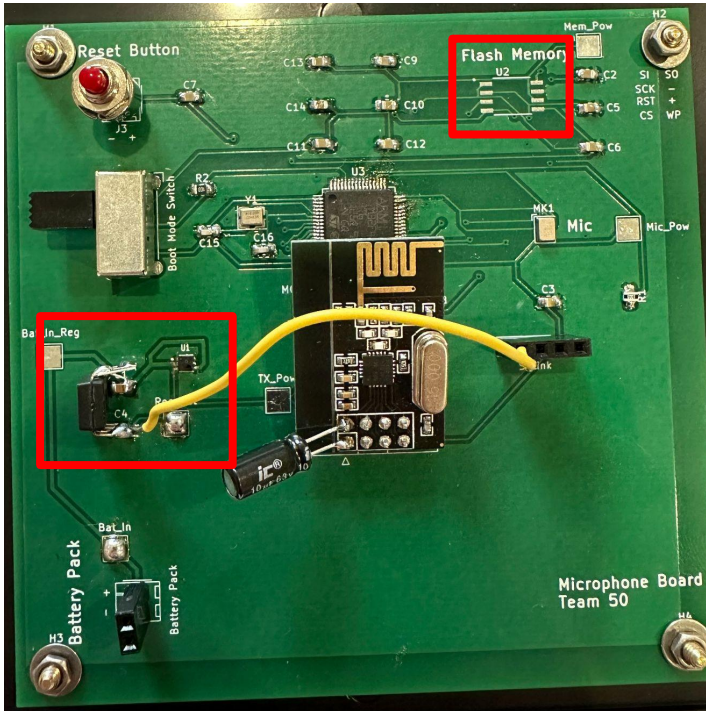
Removal of Flash Memory

- Ability of Transceiver and MCU to process data quickly
- Extra current draw in Microphone System

Linear Regulator Change

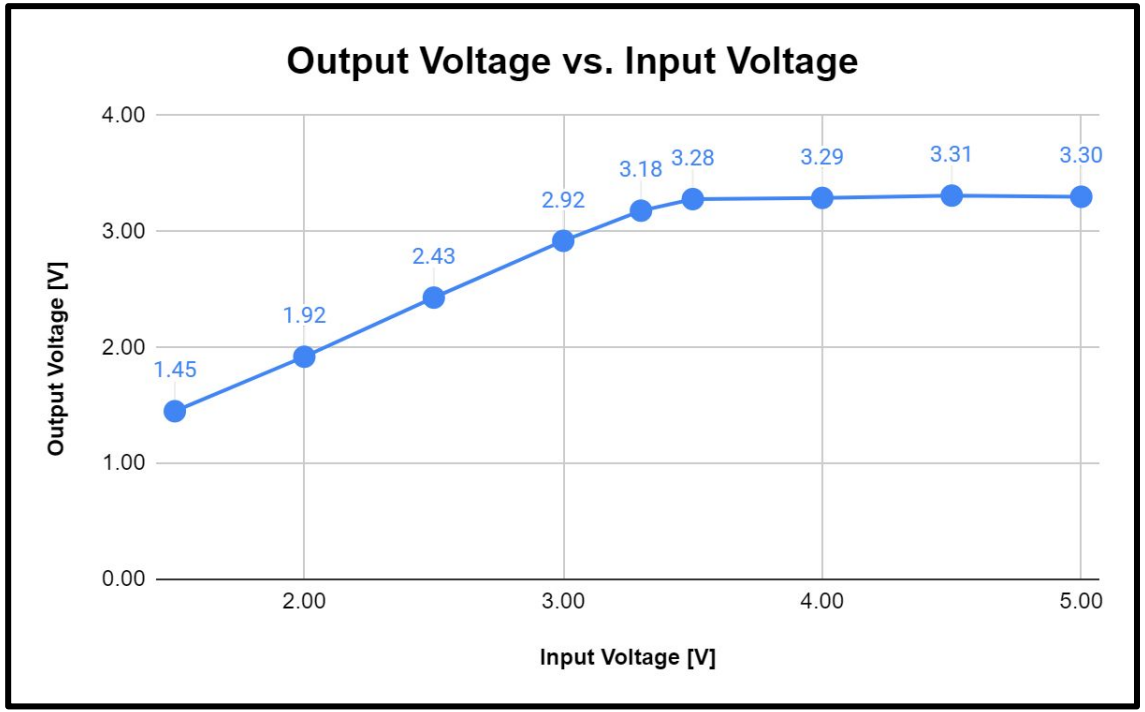
- Component Change to LP2951
  - Lower current draw
  - Bigger footprint





Design - Changes to Microphone: Linear Regulator

Input Voltage [V]	Output Voltage [V]
1.50	1.45
2.00	1.92
2.50	2.43
3.00	2.92
3.33	3.18
3.50	3.28
4.00	3.29
4.50	3.31
5.00	3.30



Removal of Flash Memory

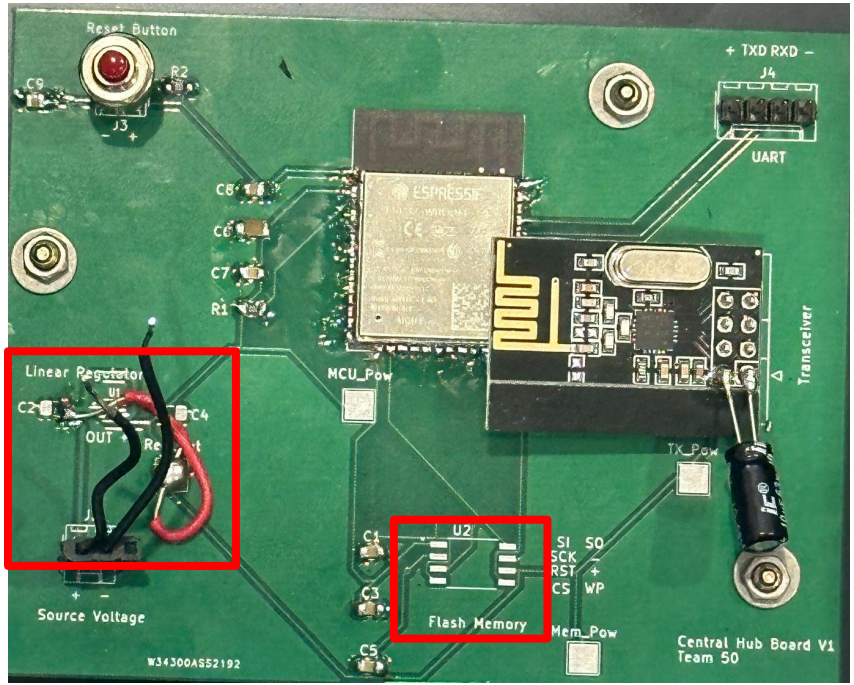
- Ability of Transceiver and MCU to process data quickly

Linear Regulator Removal

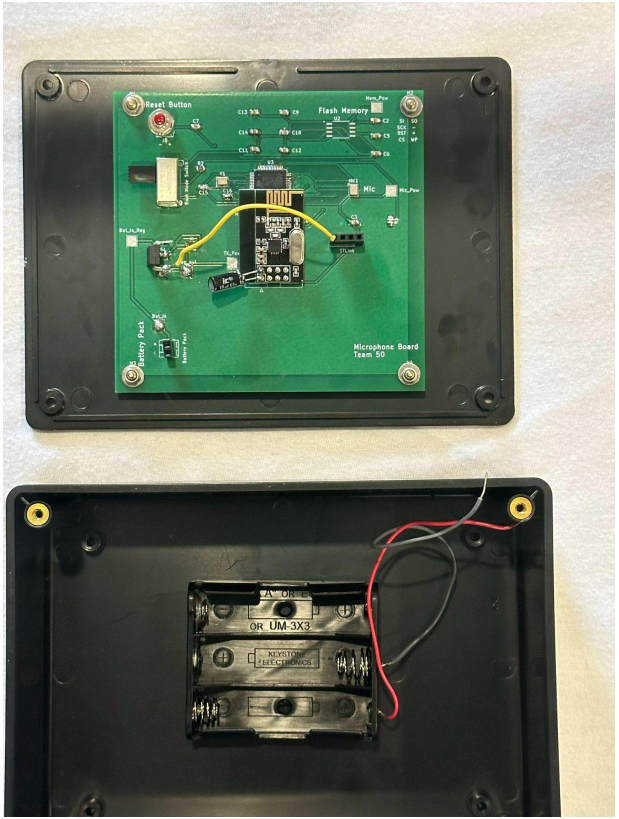
- Central Hub power supply delivers 3.3 V

Communication with Web Application

- Bluetooth -> Wifi



Design - Subsystem Housing: Microphone



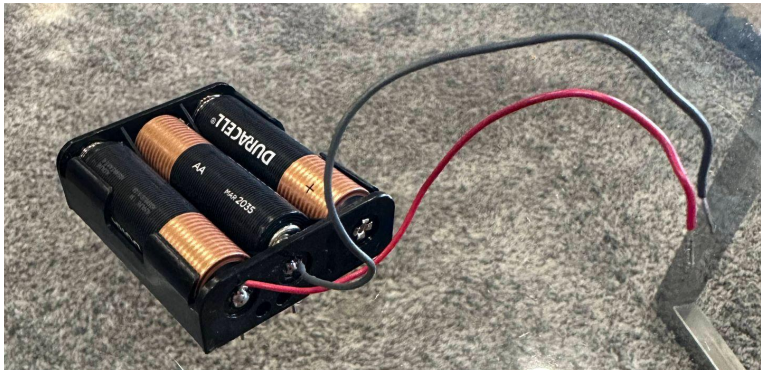
Design - Subsystem Housing: Central Hub

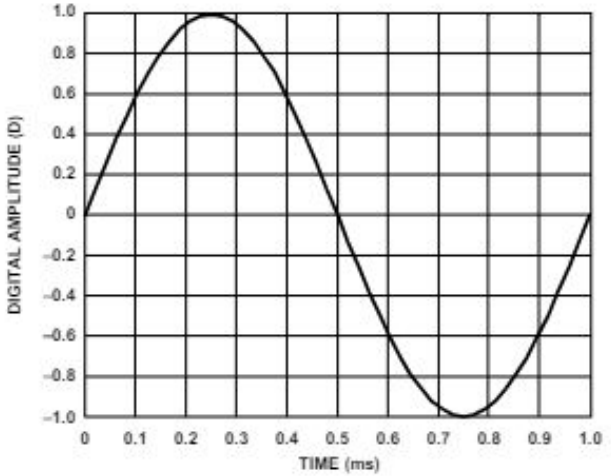
Data Collection and Transmission

- Collect sound data from microphone
- Deliver data to Central Hub via transceiver

Power Each Component with 3.3 V for 1 month

- Enact power management protocols





[2]

Design - Power Consumption for Microphone System

ON Every 15 Minutes:

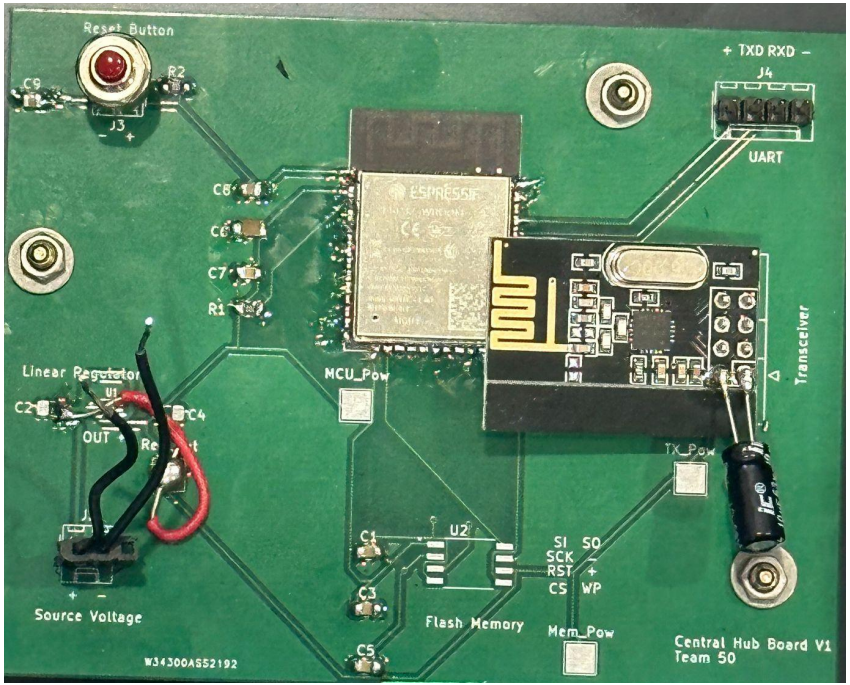
Typical AA Battery mAh:	2850 mAh

Component	Max Current Consumption	Duration	Current Consumption in hours
Microphone (Active)	550 uA	48 hours	26.4 mAh
Microphone (Sleep)	20 uA	672 hours	13.44 mAh
Transceiver (Active)	8.5 mA	48 hours	408 mAh
Transceiver (Standby)	26 uA	672 hours	17.472 mAh
Linear Regulator	75 uA	730 hours	54.75 mAh
Microcontroller (Sleep Mode)	2.9 mA	672 hours	1968 mAh
Microcontroller (Active Mode)	8.0 mA	48 hours	384 mAh
		Total	2862.112 mAh

[2, 3, 4, 5]

Data Control and Processing

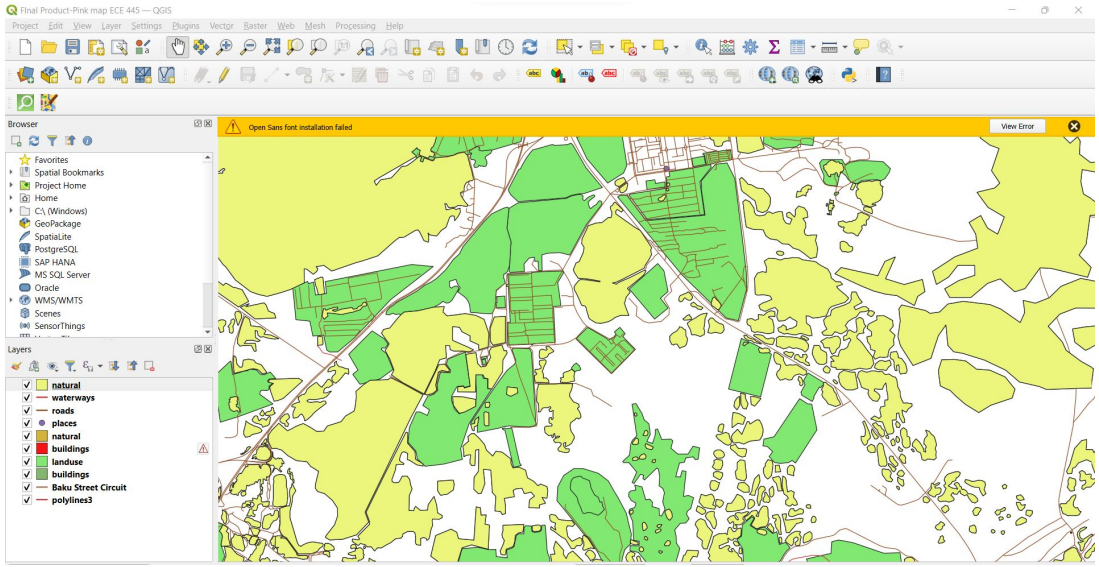
- Send Wake Up protocol to Microphones
- Receive data from Microphones and process it
- Send to Web Application via WiFi/BT



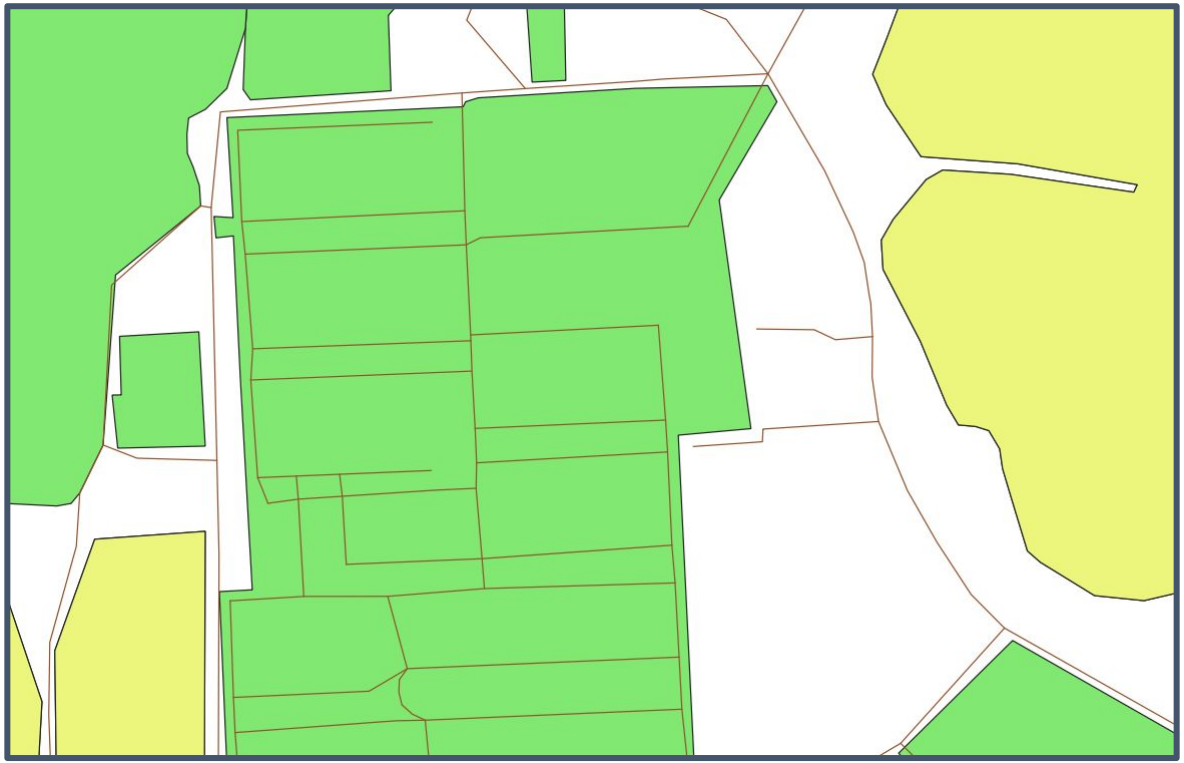
User Display and Interface

- **Receive data from central hub**
- Display sound data as colors Corresponding to loudness.

  (Ours is simulated for ECEB)



Noise Maps via QGIS



(Noise Data Map of ECE Building and surroundings.)

Functionality

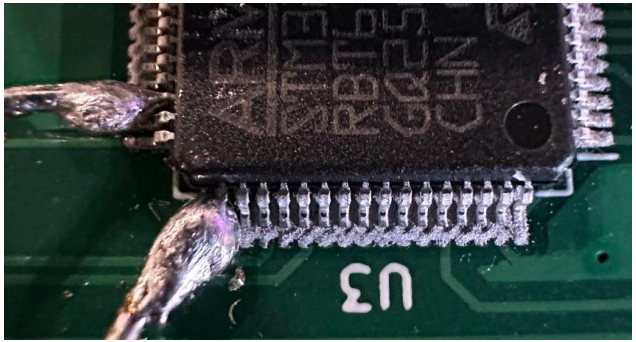
What were we able to implement and how to fix our mistakes

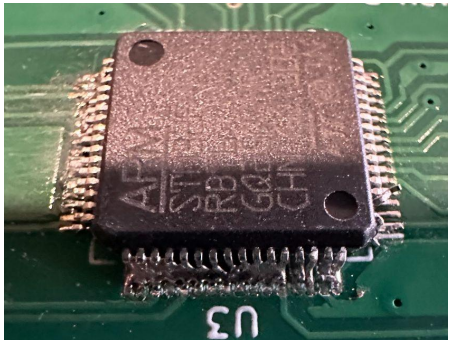
Overall Functionality

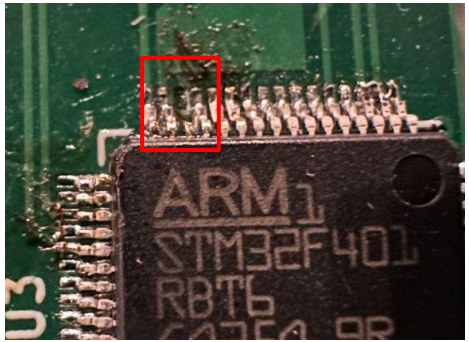
1.) Could not program MCU on board
   - Bridged Pins/Shorts
   - Soldering issues
   - Incorrect Pin Layout in KiCad
2.) Transceiver could not receive data
3.) Microphone not able to be tested

How to Address the Issues

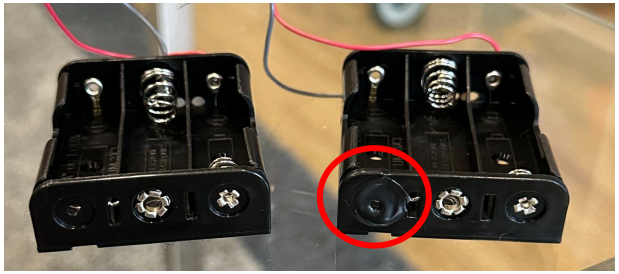
1.) Utilize Soldering Oven with less paste
   - Prevents connection of adjacent pins
   - Thinner tips
   - Double Check Schematic
2.) Activate Registers in Transceiver Properly
3.) Use of new microphone setup/microphone

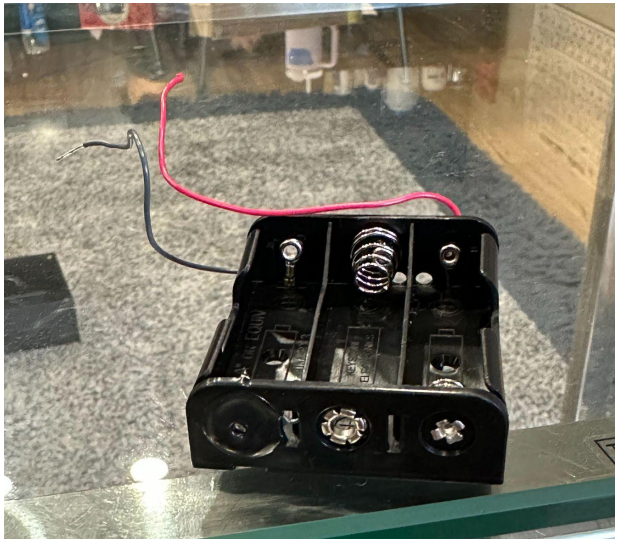






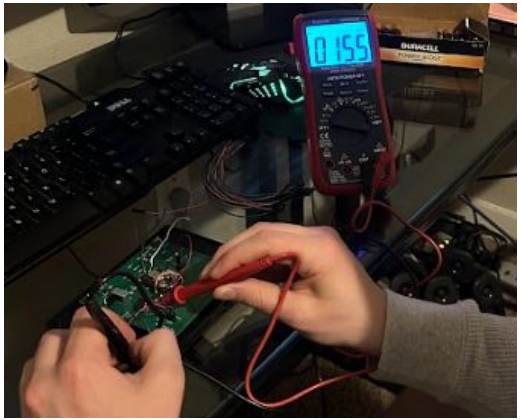
Functionality - Microphone System: Board Issues

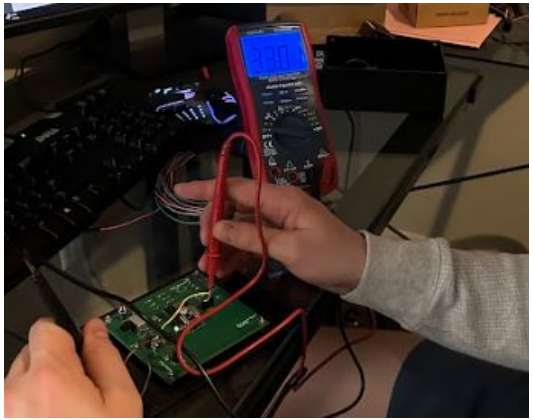




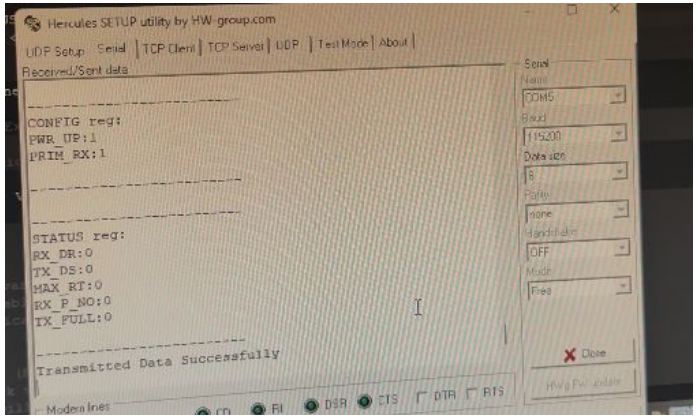
Shorting Issue

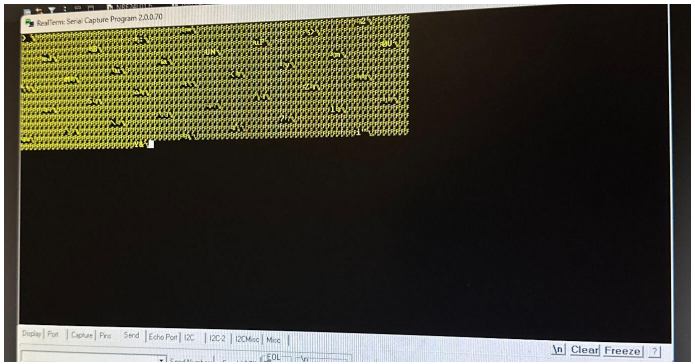
- Transported housing with batteries caused a short
  - Melted battery pack as indication
  - Due to shorting of MCU pins





Functionality - Microphone System: Transceiver





TX Worked but RX Issues

- Able to transmit data
- Could receive sometimes with junk data

Need to correctly write to registers

- STATUS register on transceiver stuck in RESET state
- Not storing the data in the correct location
- Printing default junk to terminal

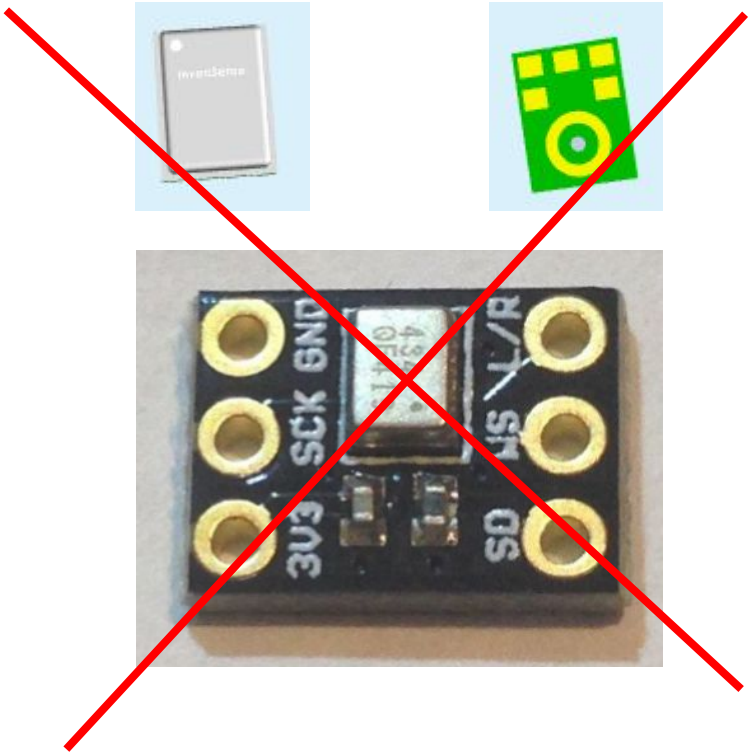
Unable to Test Microphone

- Inability to connect to MCU hindered mic testing
  - Too small to directly solder wires

Options to Fix

- Create small testing board for microphone
- Utilize a different microphone

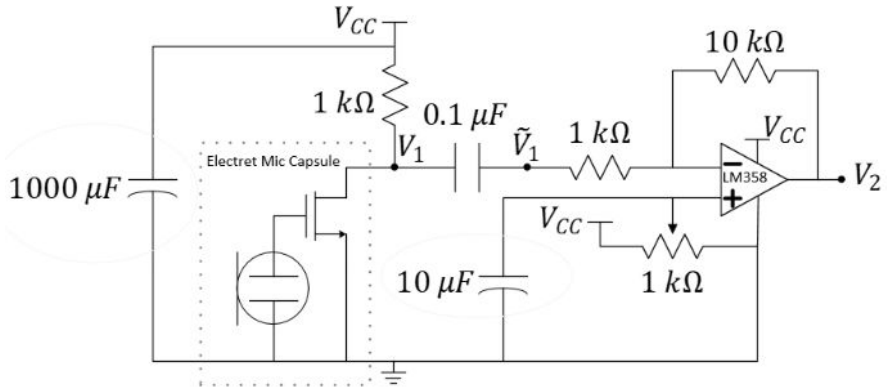
EM-9745P →

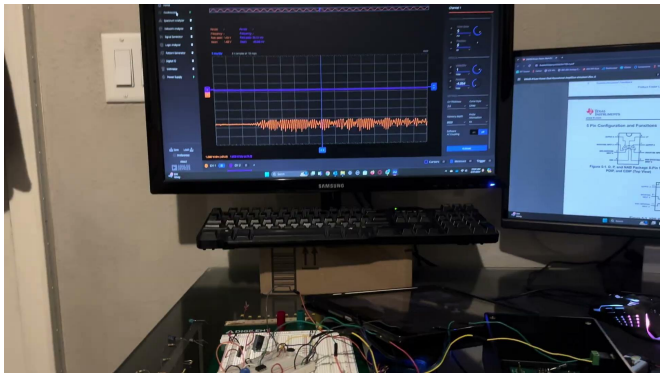


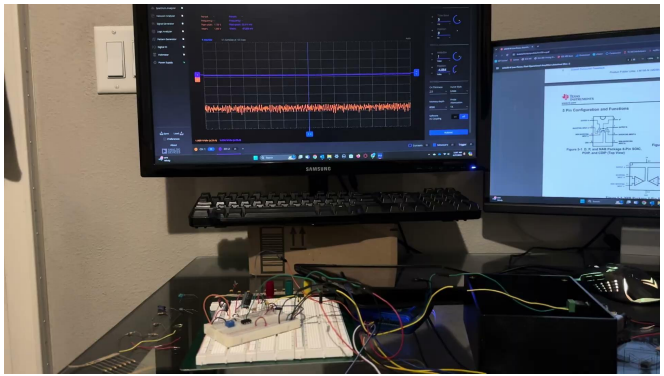
[6, 7, 8]

Created New Microphone Circuit

- New microphone and amplifier
  - Produce voltage pulses in response to sound data



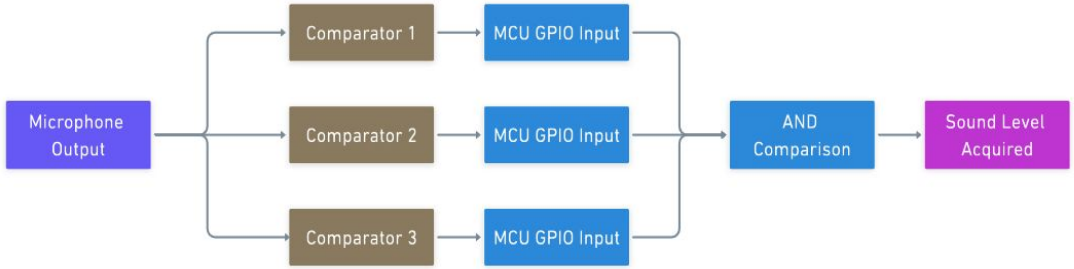


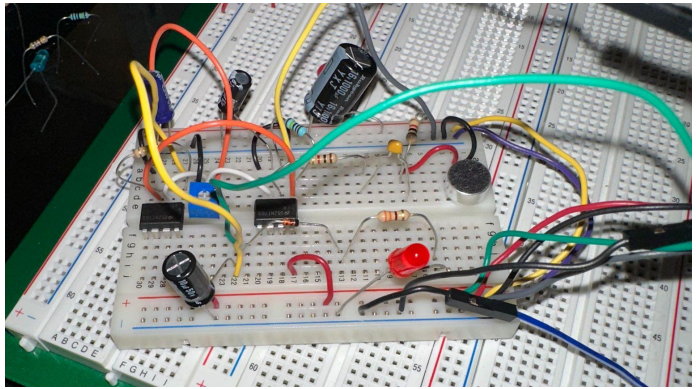


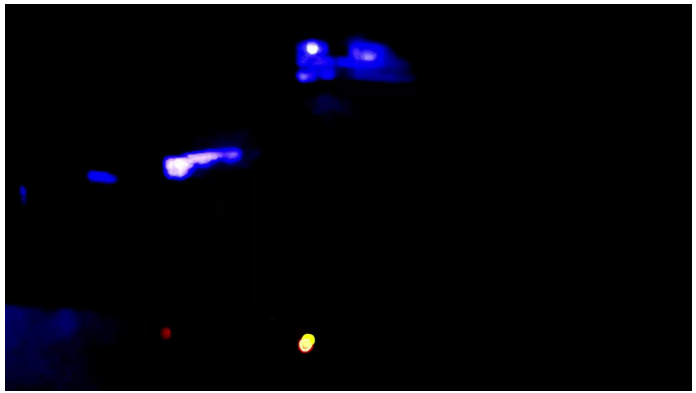
[9]

Making it Compatible with Project

- Adding second amplifier
- Crude Implementation
  - Output to zener diode
    - Acts like a switch
    - Diode ON → Harmful dB reached
- More Sophisticated Implementation
  - Output to 3 comparators
    - Each set at voltage level for dB set on noise map

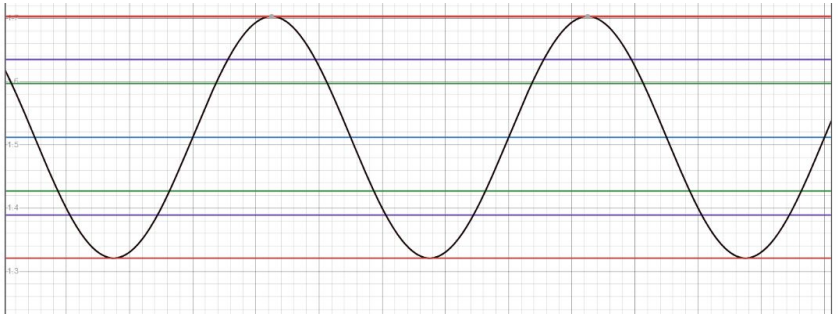






Data Collection From New Microphone Setup

Sound Input	Parameter	Voltage [V]	Swing [V]
Max Volume Music on Speaker	Voltage Min	1.321	0.382
	Voltage Max	1.703	
Loudly Talking	Voltage Min	1.389	0.208
	Voltage Max	1.635	
Talking at Conversation Level	Voltage Min	1.427	0.17
	Voltage Max	1.597	



dB of Measured Data (Collected from iPhone Microphone)

Sound Input	Avg dB Recorded
Max Volume Music on Speaker	86.2
Loudly Talking	67.3
Talking at Conversation Level	59.1

Create calibration for comparators

- Get data for cutoff dB levels
- Set reference voltages on comparators

Advantages/Disadvantages of New Setup

Advantages	Disadvantages
No data processing on MCU	Calibration concerns
Easy to show visual feedback	More current draw
Ability to switch MCU	Bigger board footprint
Breadboard testing	Cost Increase

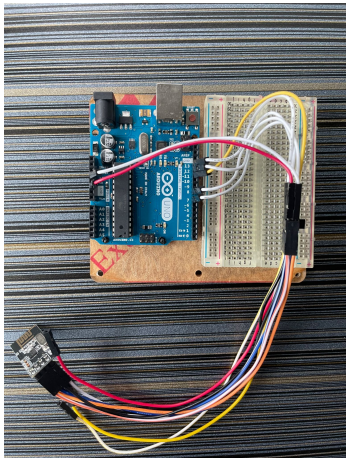
Functionality - Central Hub System

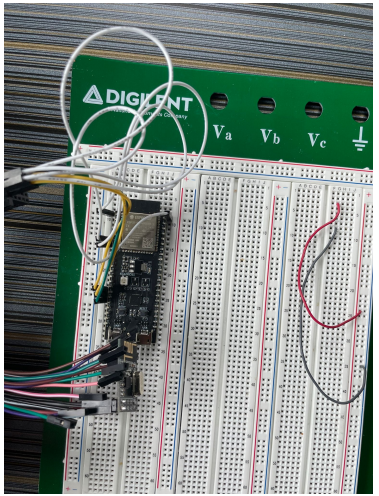
Functionality of System

- Ability to transmit data with 80% success rate
- Ability to receive data
- Ability to connect to Laptop via Wifi

Inabilities of the System

- System could receive data but not process it
- Unable to communicate with Microphone system
- Unable to connect to PCB





Data Transmission and Reception

- Used ESP32 Dev Board in conjunction with Arduino Uno with ESP32 as both transmitter and receiver

Problem 1:

- Receiving board always said to be reading data when there was no data

Solution 1:

- Removal of radio.available() function

Problem 2:

- Received data would print but was processed improperly

Solution 1:

- No solution found but we believe that the error may have been data speed issues been transmitter and serial monitor

Communication with Microphone System

- Used ESP32 Dev Board in conjunction with STM32 with ESP32 as receiver

Problem :

- Data was unable to be received by the ESP32

Thoughts on Problem:

- Issue was unable to be solved but we believe it was due the different initialization protocols between the MCUs and their transceivers

Communication with PCB

- Used UART to USB to communicate w/ PCB

Problem :

- Arduino IDE was unable to recognize PCB

Thoughts on Problem:

- Issues with UART to USB adapter
- PCB error

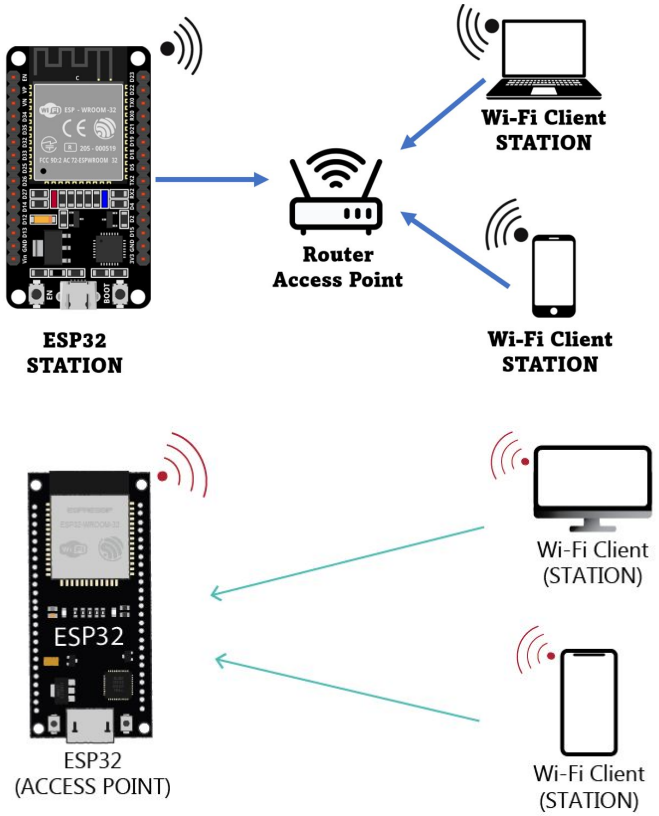
Functionality - Central Hub System: Design Change

Change from BT to WiFi Communication to Web Server

- Originally BT was going to be used for it compatibility
- BT initialization code error as well as inability to make web server led to conversion to WIFI

Change between WiFi modes

- Connect ESP32 and laptop via common wifi router but abandoned to operation criteria
- Connect ESP32 to laptop via ESP32 access point



Conclusion

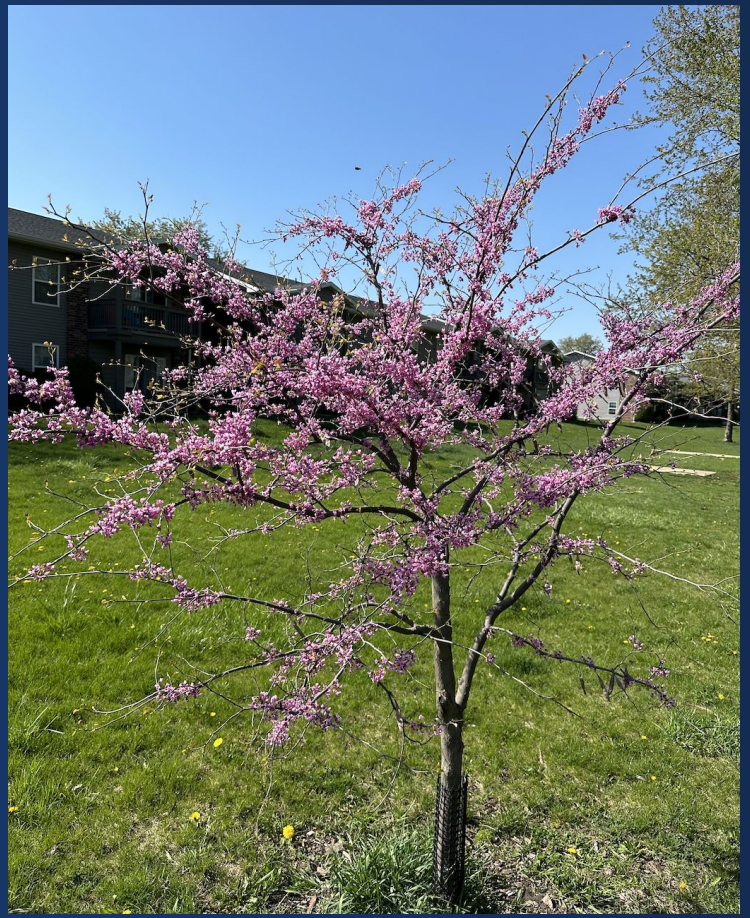
What work needs to be done

Conclusion - Future Project Work

- Same MCU for both subsystems
- Use a cloud based geo-mapping system to allow for easy synchronous noise data from the Central Hub
- Smaller housing design
- Increase transceiver transmission range with antennas
- Solar panel power for microphones

[10, 11]

Thank you for your time
Any Questions?



Citations

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