ECET 491 SENIOR DESIGN PROJECT PHASE II

2.4 GHZ WIRELESS TRANSMITTER/RECEIVER FOR AUDIO SYSTEM

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OVERVIEW

- Executive Summary
- Problem Statement & Solution
- System Requirements
- System Analysis
- System Design
- Testing & Validation
- Problems
- Lessons Learned
- Conclusion

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EXECUTIVE SUMMARY

- Constructing a wireless system makes this project unique in regards to customers have more freedom with where they can listen to music within their house.
- Once the project is completed, customers will save cost in connecting the furthest speakers through speaker cable.
- This system is more compact and a lot less expensive than brand name products that are already available.
- My motivation for this project is that I would like to understand more about the technology behind transmitting and receiving audio wirelessly, as well as I would like to avoid the extra hours of labor associated with connecting my own audio system speakers up once I move.

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PROBLEM STATEMENT

- Typically when installing a surround sound audio system in a home it requires a well thought out plan on how to properly hide the speaker wire needed for all of the speakers that will be connected to the whole system.
- This is a very time consuming project and can really hinder the full capability your audio system has if the speakers can't be placed in the proper location for feedback to the system's receiver.

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PROBLEM SOLUTION

- The proposition to address this problem consists of a wireless transmitter connected to the audio system that transmits played audio wirelessly utilizing 2.4GHz signaling, to a wireless receiver connected in line with the speakers furthest away.
- The wireless Transmitter (TX) and Receiver (RX) will operate by means of the 2.4GHz frequency band with a distance up to at least 20 feet away from the audio source.
- Freedom of moving the speakers to multiple rooms and still listen to their music without the confines of running wires to each room.

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SYSTEM HARDWARE REQUIREMENTS

- Transmitter shall send audio signals wirelessly to the receiver
- Receiver shall play amplified audio signal from speaker
- Transmitter shall amplify line audio for transmitting
- Both TX & RX shall communicate on Wi-Fi 2.4 GHz band
- Both circuits powered by 9V DC to supply +3.3V to +5V
- Overall system weight shall be less than 5 pounds.
- Full operating temperature range of 32°F to 100°F

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SYSTEM HARDWARE ANALYSIS

- With the FM approach deemed obsolete, the major focus now became how to operate the project via WI-FI to utilize the 2.4 GHz ISM band.

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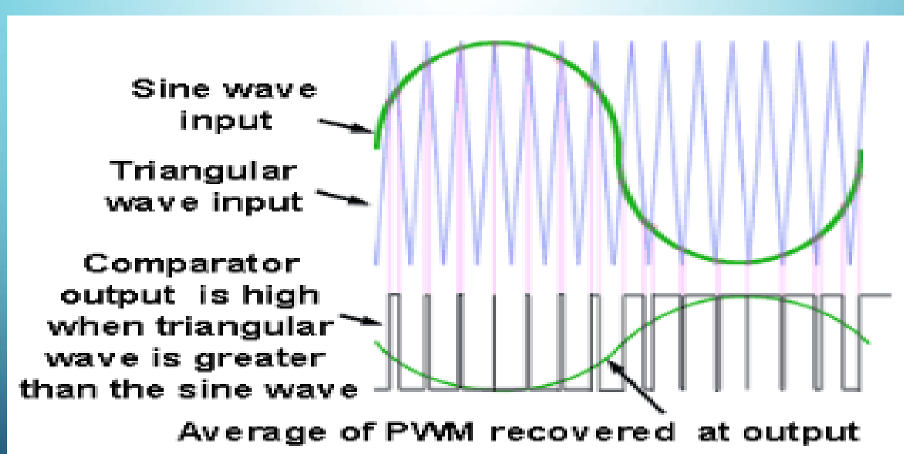
PULSE WIDTH MODULATION



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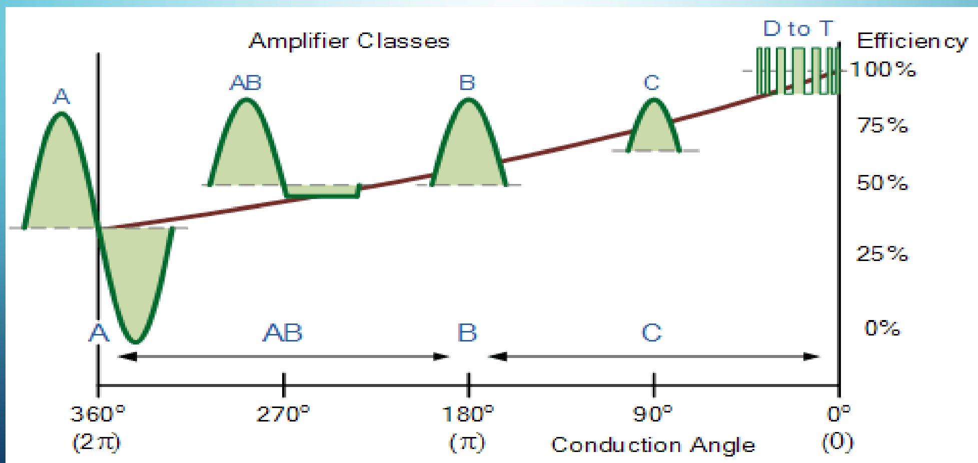
COMPARISON OF CLASS EFFICIENCY



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CLASS PROS & CONS

AMPLIFIER CLASS	TYPICAL EFFICIENCY	PROS	CONS
A	~15-35%	• No possibility of crossover distortion.	• Inefficiency = heat • Single ended designs prone to hum and higher levels of distortion.
B	~70%	• Relatively high efficiency.	• Potential for significant amounts of crossover distortion and compromised fidelity
A/B	~50-70%	• More efficient than Class A • Relatively Inexpensive • Crossover distortion can be rendered moot	• Efficiency is good, but not great.
C	>90%	• Lowest physical size for a given power output	• Lowest linearity • Not suitable in audio applications.
D	>90%	• Best possible efficiency • Lightweight.	• Pulse width modulators operating at relatively low frequencies can compromise high frequency audio reproduction.

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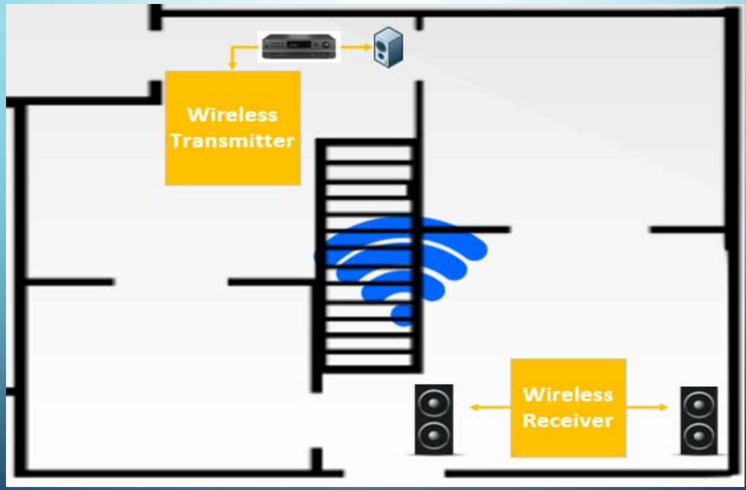
OV-1



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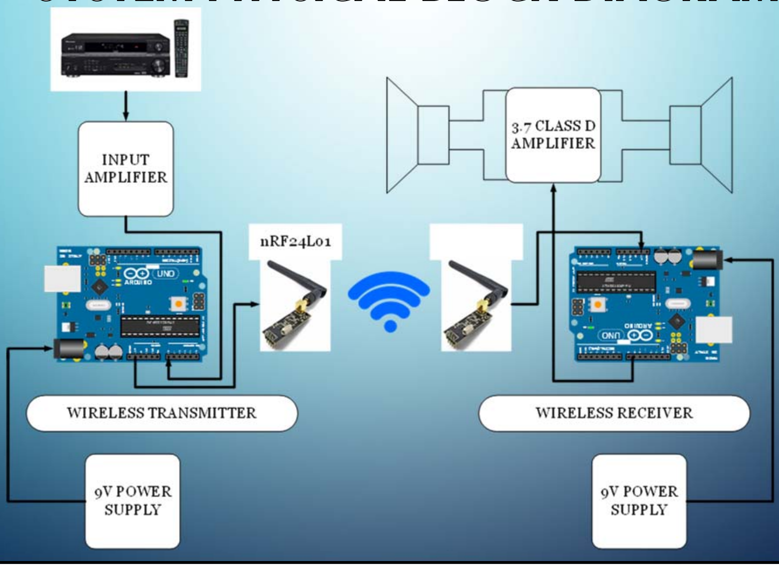
SYSTEM PHYSICAL BLOCK DIAGRAM



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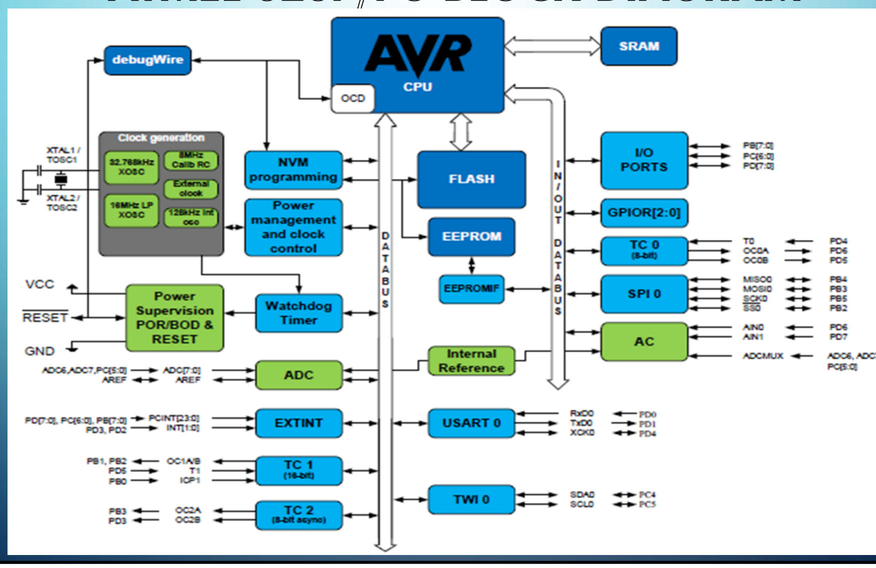
ATMEL 328P/PU BLOCK DIAGRAM



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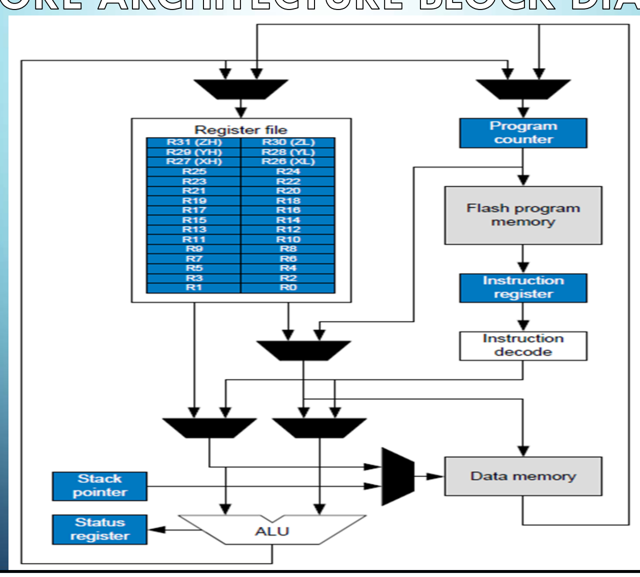
AVR CORE ARCHITECTURE BLOCK DIAGRAM



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NRF24L01 BLOCK DIAGRAM

CE – Chip Enable

CSN – SPI Chip Select

DVDD - Internal digital supply output

IREF – Reference current

IRQ – Maskable interrupt pin. Active low

MOSI – SPI Slave Data Input

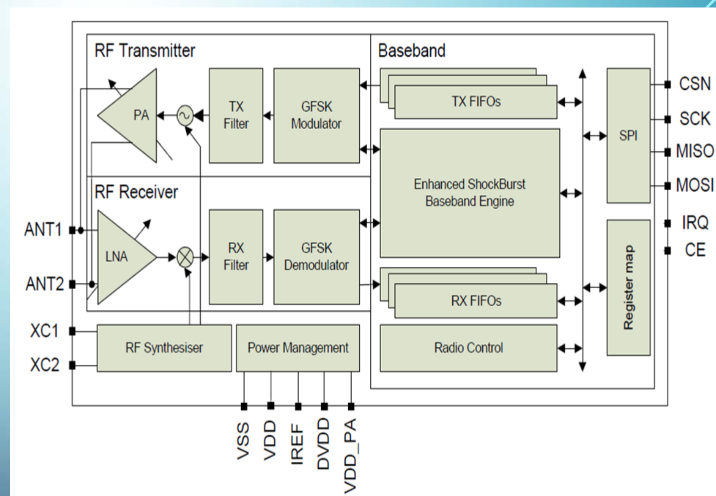
MISO – SPI Slave Data Output

SCK – SPI Clock

VDD – Power Supply (+1.9V - +3.6V DC)

VDD_PA – Power Supply Output/ Internal Power Amplifier

VSS - Ground



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SYSTEM HARDWARE DESIGN

Hardware Subsystems

- TX
  - 9V 1A Power Adapter
  - Base-biased amplifier circuit
  - Arduino UNO constructed with an Atmel 328P/PU microcontroller
  - Nordic nRF24L01 transceiver module with antenna
  - ForceTronics Transceiver shield
- RX
  - Same Components as TX without shield and base-biased amplifier circuit

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SYSTEM HARDWARE DESIGN

Hardware Subsystems

- Class D Amplifier
  - 3.7W Filterless design with adjustable gain.

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CALCULATIONS

<u>10-Bit ADC</u>

V_{FS} = 5V (Full-Scale Range Voltage)

Unipolar ADC

m = (Number of bits)

L = 2^m (Number of quantization levels) L = 2^{10} = 1024

$\Delta_q = \frac{V_{FS}}{L} = \frac{5V}{1024}$ = .00488V or 4.8mV (step size of the quantizer or resolution)

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CALCULATIONS (CONT'D)

Quantization Error

$$q_e = \sqrt{\frac{{\Delta_q}^2}{12}} = 1.4mV$$

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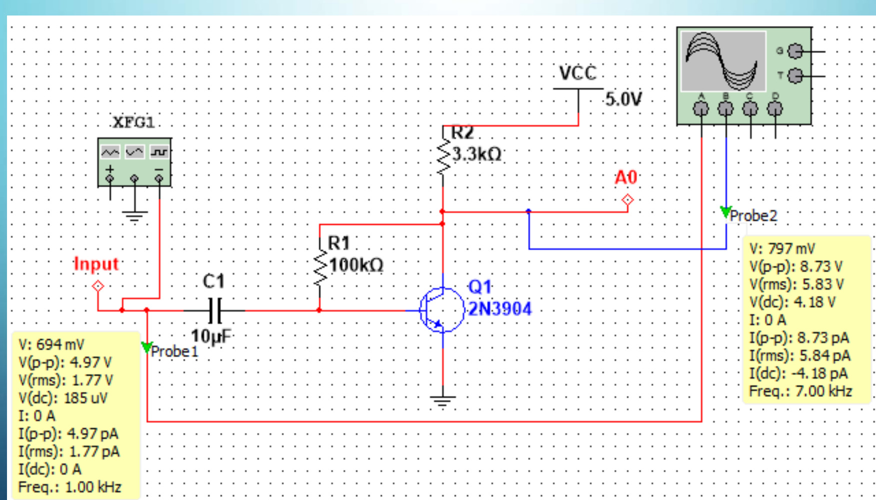
SIMULATION OF BASE-BIASED AMPLIFIER



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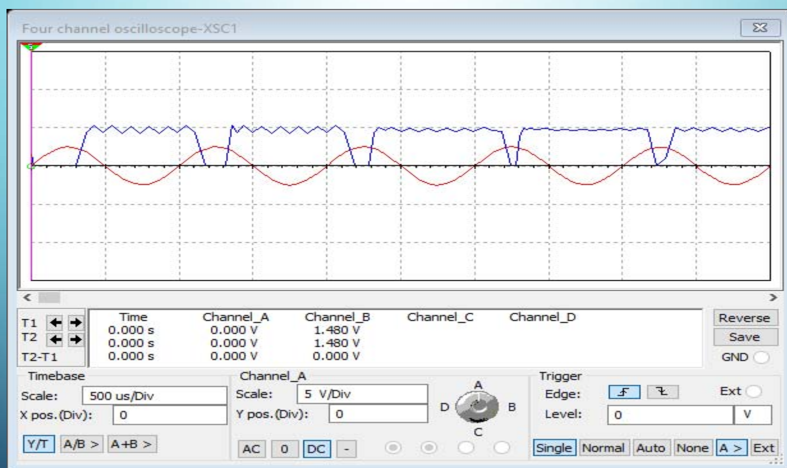
BASE-BIASED SIGNAL DISPLAY



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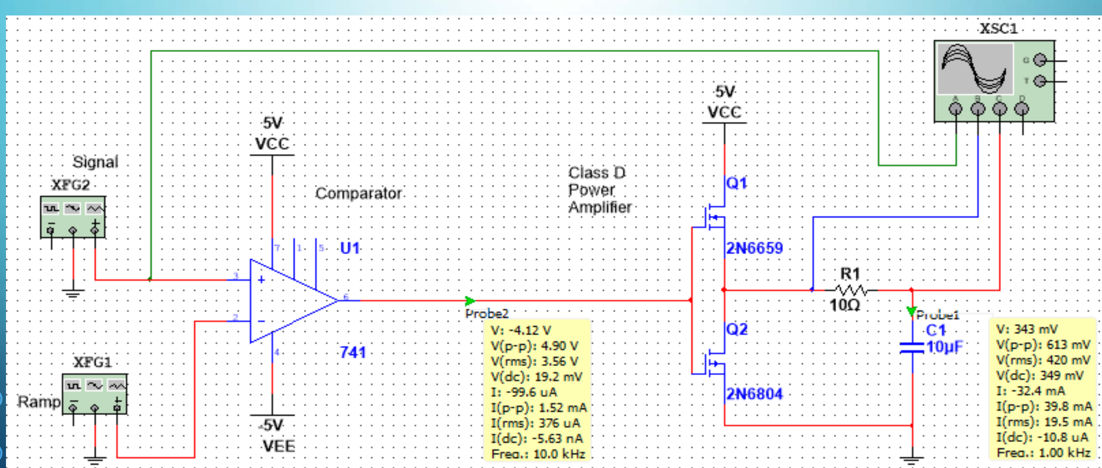
SIMULATION OF CLASS D AMPLIFIER



CLASS D SIGNAL DISPLAY

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SYSTEM INTEGRATION & TESTING

- Testing verified that the Class B amplifier selected first would not be applicable within the time frame of the project.
- Replaced with Class D amplifier.

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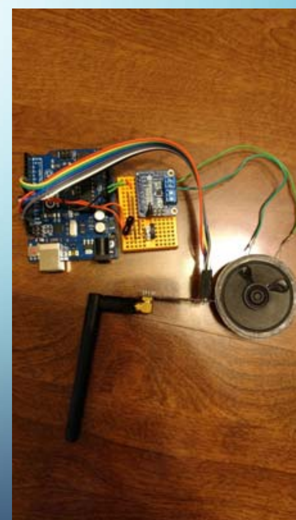
TRANSMITTER & RECEIVER



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VALIDATION

- Validated that the physical, functional and performance requirements listed previously were met.

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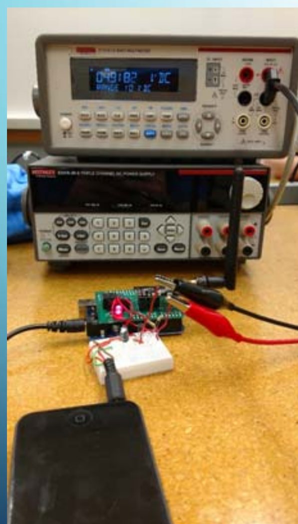
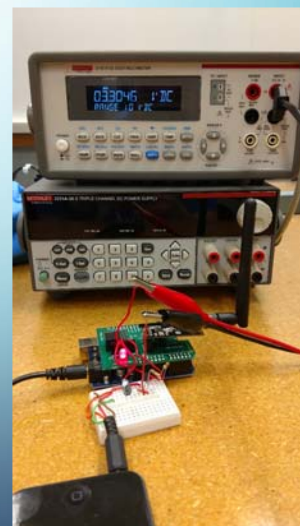
VERIFICATION OF POWER SUPPLIED TO TX





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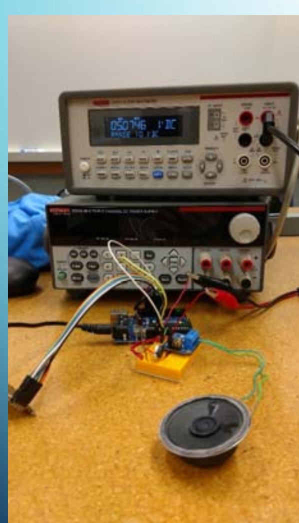
VERIFICATION OF POWER SUPPLIED TO RX



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VERIFICATION OF OVERALL SYSTEM WEIGHT

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VERIFICATION OF OPERATING TEMPERATURE RANGE

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VERIFICATION OF OPERATING TEMPERATURE RANGE CONT'D

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PROBLEMS

- My first choice for transmitting radio frequency (RF) signals was utilizing the frequency modulation (FM) frequency band which gave me the ability to tune my circuits to the same frequency.
- After constructing the circuits to test functionality and to determine proper communications between the circuits, I realized that this approach was not the best way of completing this project.
- The quality of transmissions was very poor and a working prototype was not attainable.

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CORRECTIONS

- Assessed the situation to determine my options.
- Further research determined that if I incorporated microcontrollers into my project that I would receive better quality transmissions
- Using microcontrollers all allowed me to transmit over the 2.4 GHz ISM band. Providing a stronger signal and increasing my range of transmissions.

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LESSONS LEARNED

- Time management
- Ability to follow a schedule
- Ability to estimate overall time for each task
- Importance of research
- Capabilities and applications for this project

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CONCLUSION

Overall, project was successful and fulfilling. The knowledge gained over the course of two semesters was extremely beneficial and I'm very grateful for the opportunity to learn from the best professors that I've ever met. I plan on continuing my research into the capabilities of wireless communication and continue to grow as an engineer in a fast pace and exciting career.

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Q/A?

- Questions
- Comments

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DEMO

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1ST PROBLEM SOLUTION

- The proposition to address this problem consists of a wireless transmitter connected to the audio system that transmits played audio wirelessly utilizing FM signaling, to a wireless receiver connected in line with the speakers furthest away.
- The wireless TX and RX will operate by means of tuning them to an unused frequency within the frequency modulation (FM) spectrum of 88 to 108 MHz.
- This will allow the audio to be played wirelessly up to at least 20 feet away from the audio source.

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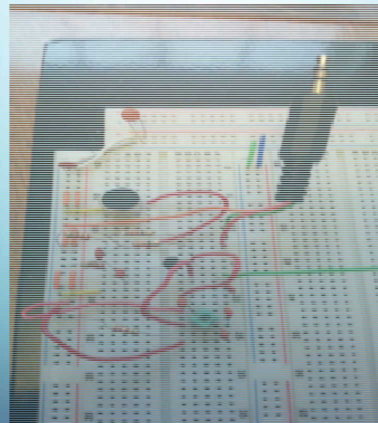
INITIAL APPROACH



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CALCULATIONS (CONT'D)

Cutoff Frequency

$$f_c = \frac{1}{2\pi RC} = \frac{1}{2\pi(10)(796nF)} = 20\text{ KHz}$$

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CALCULATIONS (CONT'D)

- I determined the cutoff rate of 20 KHz and after proper calculations I found that the RC circuit needed would need to include a 10Ω resistor and a 796nF capacitor.

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