Design of a Remote-Controlled Racing Car Using a Wireless Audio Link

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A Little About Me

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Education
Pursuing a Bachelor of Science degree in Electrical and Information Engineering
IEB National Senior Certificate

Work Experience
Lab Technician
Data Science and Data Engineering
Tutor

Hobbies
Martial Arts
DIY Projects
Gamming and PC Enthusiast

Fun Fact
I hold the award for the best background actor in my junior primary play

Outline

Project objective

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Project objective

Design a wireless control scheme that will operate a remote-controlled race car where the wireless communication is facilitated through the audible frequency bandwidth

Constraints

01 Wireless communication

02 Volume limit (dB)

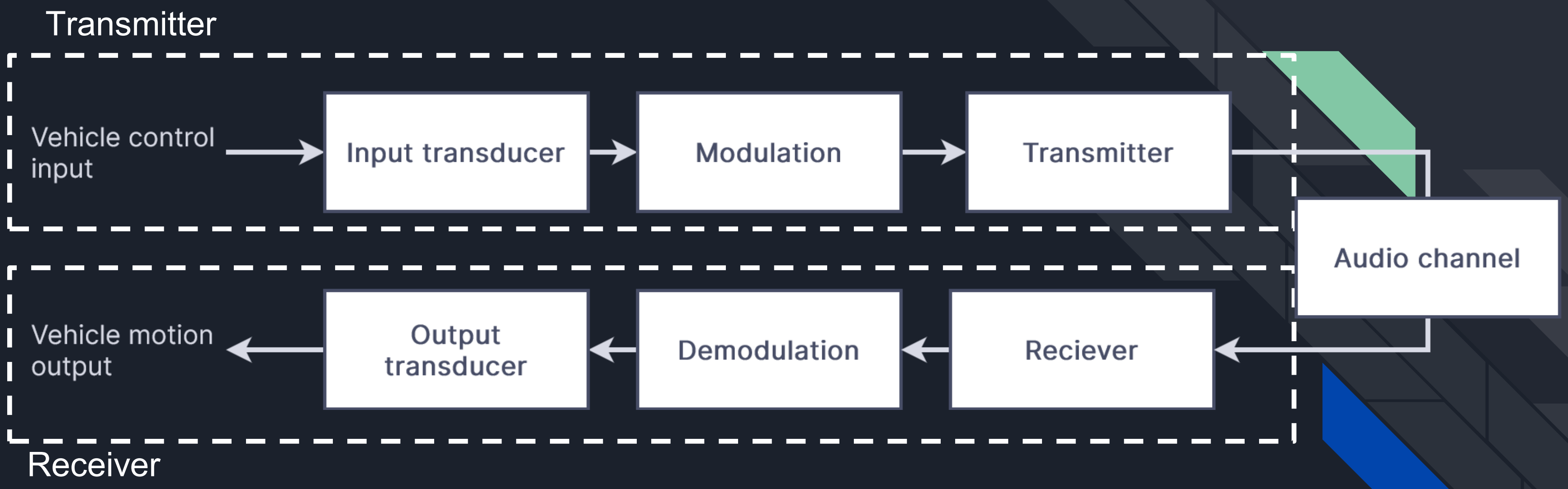
03 Frequency limit to human hearing range (20Hz - 20KHz)

04 Make use of supplied cart

Assumptions

- Unregulated noise operating environment
- Performance prioritised over efficiency
- Presence of electromagnetic interference
- No long-range communication

System level analysis



Design consideration

There are three main areas of focus

Controller

- Analogue or Digital Controller
- How to encode the data into the signal
- How many possible states can the vehicle be in
- How will the signal be transmitted

Communication System

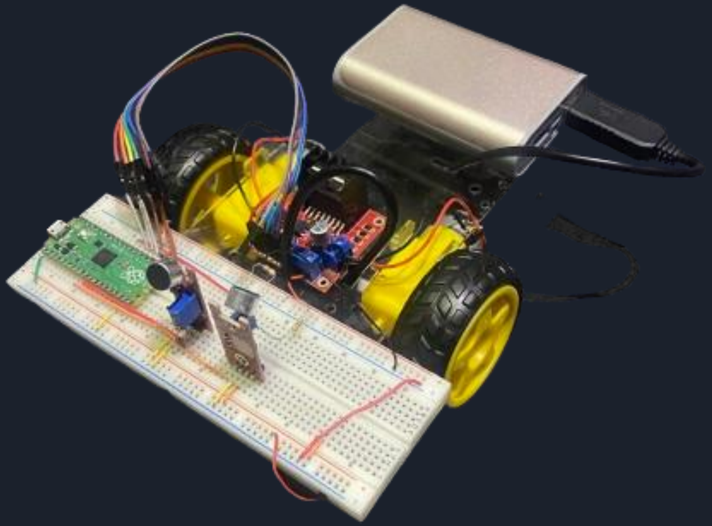
- Analogue or Digital communication
- What modulation scheme

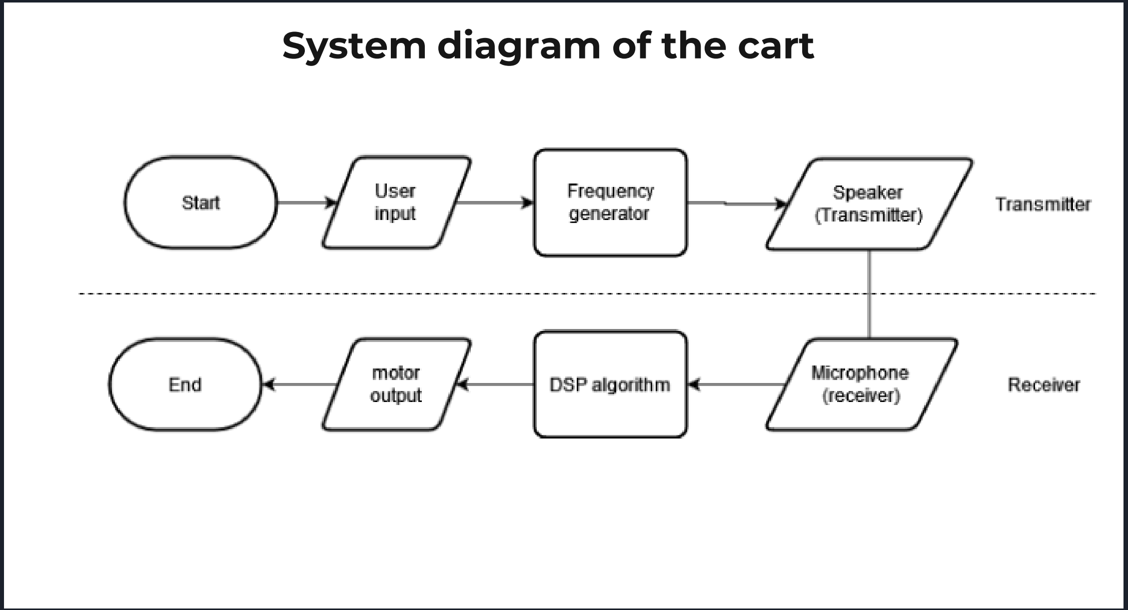
Vehicle Drive System

- How is steering going to be achieved
- How is the speed of the vehicle going to be controlled
- How the motors will be driven

Broad Overview of Implementation

Constructed Cart





Controller

Tone Generator App

The frequency generation and modulation was carried out though a tone generator app

Using a tone generator app, we were able to:

- Save on development time as we don’t need to develop an analogue circuit for frequency generation and modulation
- Allow us for rapid prototyping and testing other frequency ranges which would not have been possible with an analogue circuit
- The modulation of the carrier and message signal is built into the app

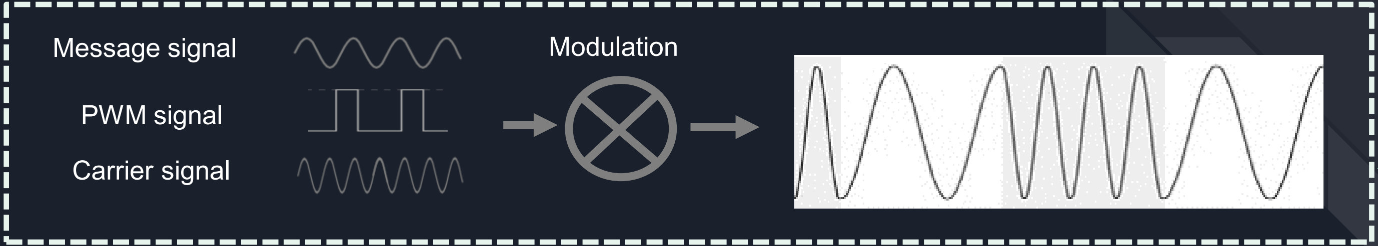
The controller can output 4 possible states:

1) Remain stationary
2) Power Both Motors
3) Power Left Motor
4) Power Right Motor

Choosing for the system to only have 4 possible states allows one to minimize the amount of data and frequencies needed to control the Cart. We use **4 frequencies** to represent each state.

Controller

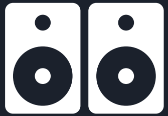
Data encoding using PWM



Using a **PWM** signal to encode data benefits as **no additional processing** is required after demodulation when compared to binary encoding

Sound Transmission

Bluetooth speaker



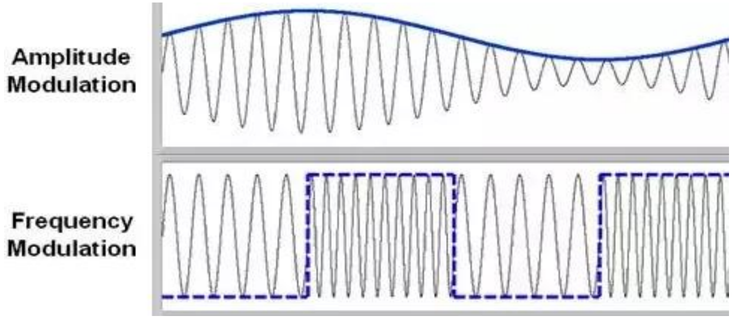
Design Iterations of the Controller

Microcontroller Binary Encoding → Microcontroller PWM Encoding → Tone Generator PWM Encoding

Communication System

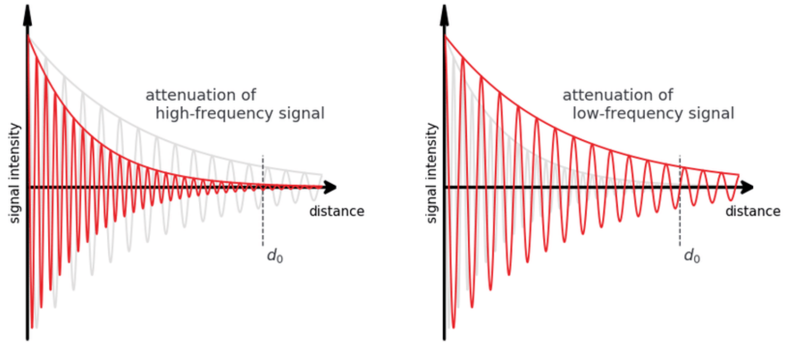
Frequency Modulation over Amplitude Modulation

- Noise resilience (SNR)
- Resilience to obstructing bodies
- Less signal attenuation at distances
- Easily implementable with a PWM signal



Frequency Bandwidth

An operating frequency bandwidth of **1KHz** to **5KHz** was chosen to avoid noisy parts of the spectrum measured in the test environment
Moreover, limiting the signal to lower part of the audible spectrum allows the signal to maximise distance while minimising signal attenuation



Modulation Scheme

The signal was modulated through **Frequency Shift Key** (FSK) as it has:

- High SNR
- Reduced implementation complexity

BFSK → PWM FSK

Receiver

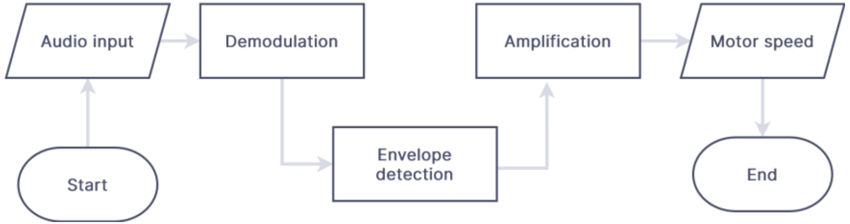
The receiver is comprised of 3 main components:

- Phased microphone array
- Microcontroller
- Motor driver circuit

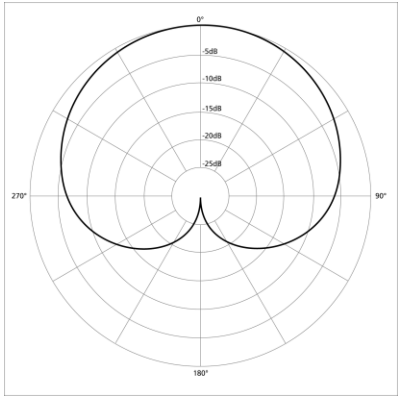
Microphone Design

The audio input was changed from a **single** to **phased array** microphone setup due to the **cardioid pattern of signal attenuation** at varying angles as the cart will undergo rotation changing the angle of incidence.

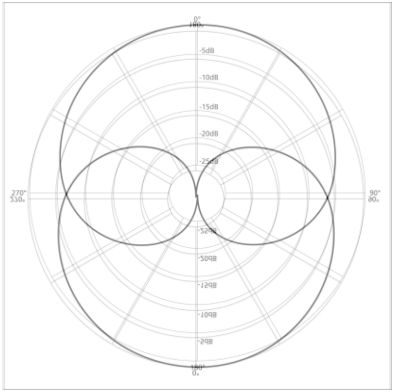
Receiver Block Diagram

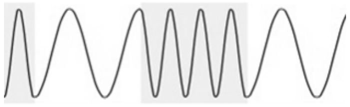


Single microphone

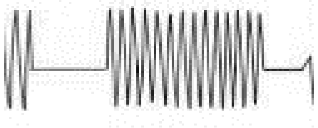


Phased microphone array

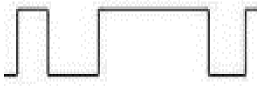




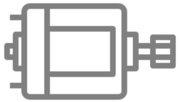
Demodulation



Envelope detection



Voltage output



Demodulation

The Raspberry Pi Pico was used for demodulation as the higher **clock frequency** allows for **greater sampling frequency** and response time of the cart

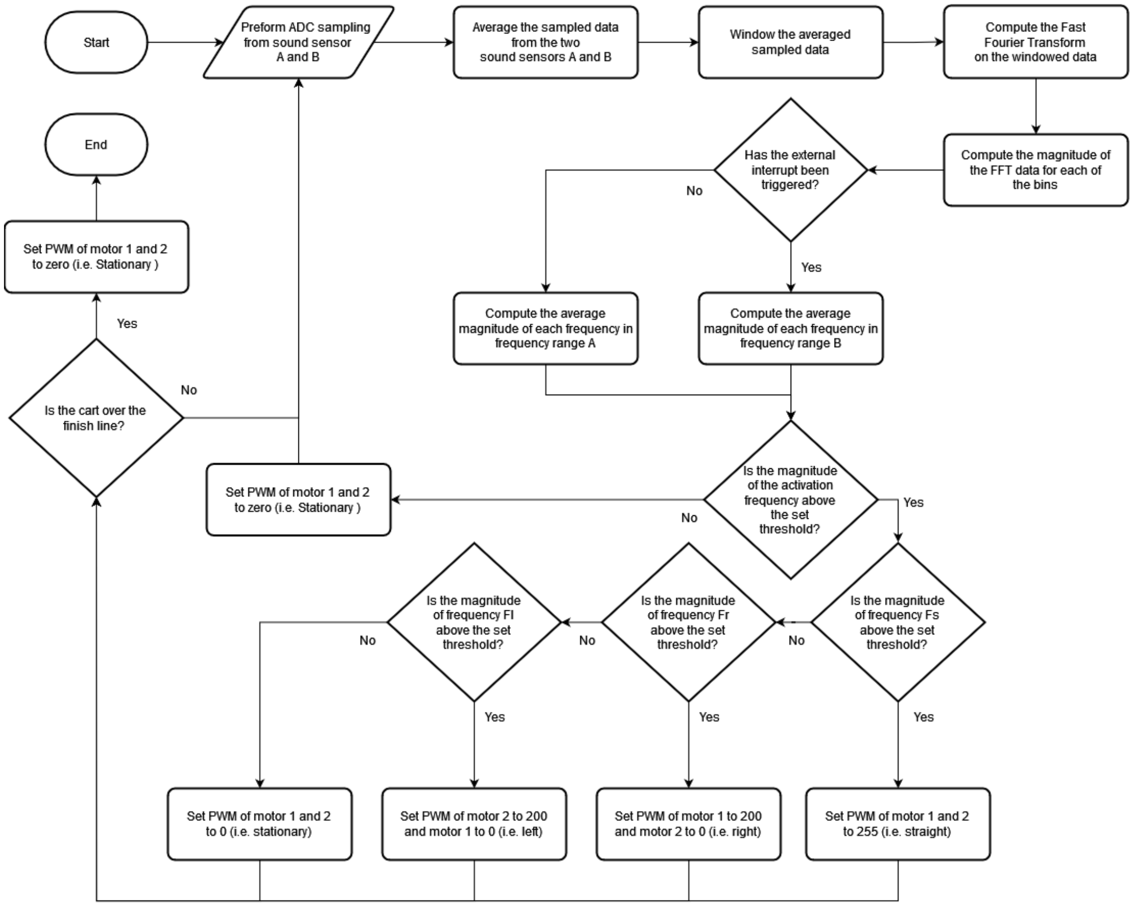
Demodulation was carried out using:

- Fast Fourier Transform algorithm
- Samples
- Hamming windowing function

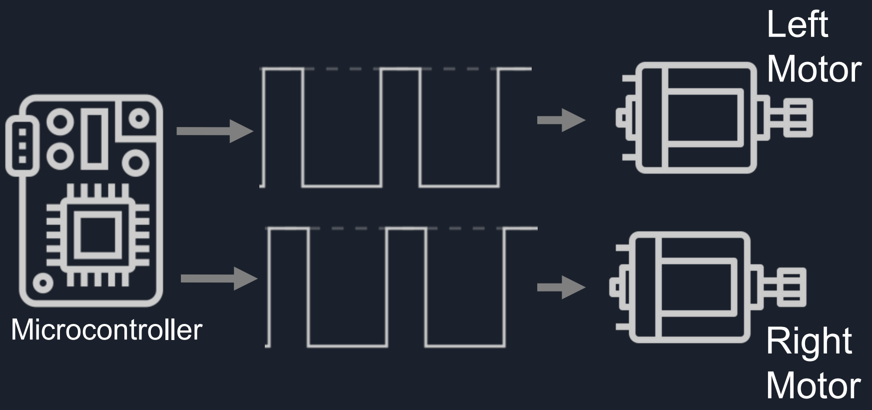
Design Iterations of the Filter

Analogue filter circuit → Microprocessor DSP

Demodulation Algorithm Flowchart



Motor and steering control



How will the motors speed be controlled ?

Pulse width modulation using a microcontroller and H-bridge motor controller

Advantage :

- Simple to implement
- Fast response
- Reliable

Disadvantage :

- Costly
- Back EMF induces large negative current

How will steering be controlled ?

Varying the voltage differential of the left and right motor

Advantage :

- High steering resolution

Disadvantage :

- Requires 2 channels

Critical Analysis

Controller

The controller successfully performed its task of taking in user input, producing a modulated signal and transmitting it as an audio wave.
This was achieved while maintaining a fast responsive system that is dynamic in its operating ranges and easily accessible.

However, some aspects could be improved on:

- Multiple frequencies are inefficiently used to transmit data
- The user interface is not intuitive

Receiver

The receiver successfully performed its task of taking in a signal, filtering any noise and driving the motor according to the given input. The system has a fast response time and has a wide operating range of frequencies

Some critical points to note :

- Spectral leakage form windowing function
- Noise filtering at greater distances
- Limited steering
- Asymmetric performance of left and right motors
- H-Bridge low power efficacy

Recommendations

- Reducing the number of frequencies used to 3
- Desing a user interface for the app
- Use a faster switching motor driver circuit
- Use a Nuttal Window for the FFT
- Create a frequency allocation to avoid interference
- Implement BFSK with bit error correction
- Make use of Dual tone multi-frequency
- Ultrasonic transmitter

Thank you!

ANY QUESTIONS