ECE 445

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Project Proposal

Automated Driveway Salt Dispenser

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Contents

1. Introduction

1.1 Problem

Freezing rain and extremely low temperatures during the winter season cause slippery driveways and sidewalks which make it difficult for people to walk and drive. Current methods of dispensing salt in these areas are done manually and are not very efficient. This is because salt is thrown randomly across these areas which results in wastage of salt and sometimes less salt in very icy areas. Also, these methods have safety risks as ice covering these areas makes it harder for people to walk to dispense the salt. It also increases the burden on homeowners to manually salt their driveways.

1.2 Solution

To solve this issue, we want to create a fully autonomous salt dispenser. Our solution would be a self-driving car that would dispense salt evenly across driveways and sidewalks. This would solve the issue of having slippery ice on the sidewalk/driveway when trying to leave your house. Also, by allowing the car to only dispense salt on driveways and sidewalks will help to reduce the amount of salt that is wasted from randomly dispensing salt manually. The dispenser will consist of two main components. The first component is the autonomous steering of the car which will prevent the car from driving out of bounds, such as on the grass or outside of the driveway. Also, the second component is the dispensing of the salt using motors to allow the salt to be spread evenly across the surface.

1.3 Visual Aid

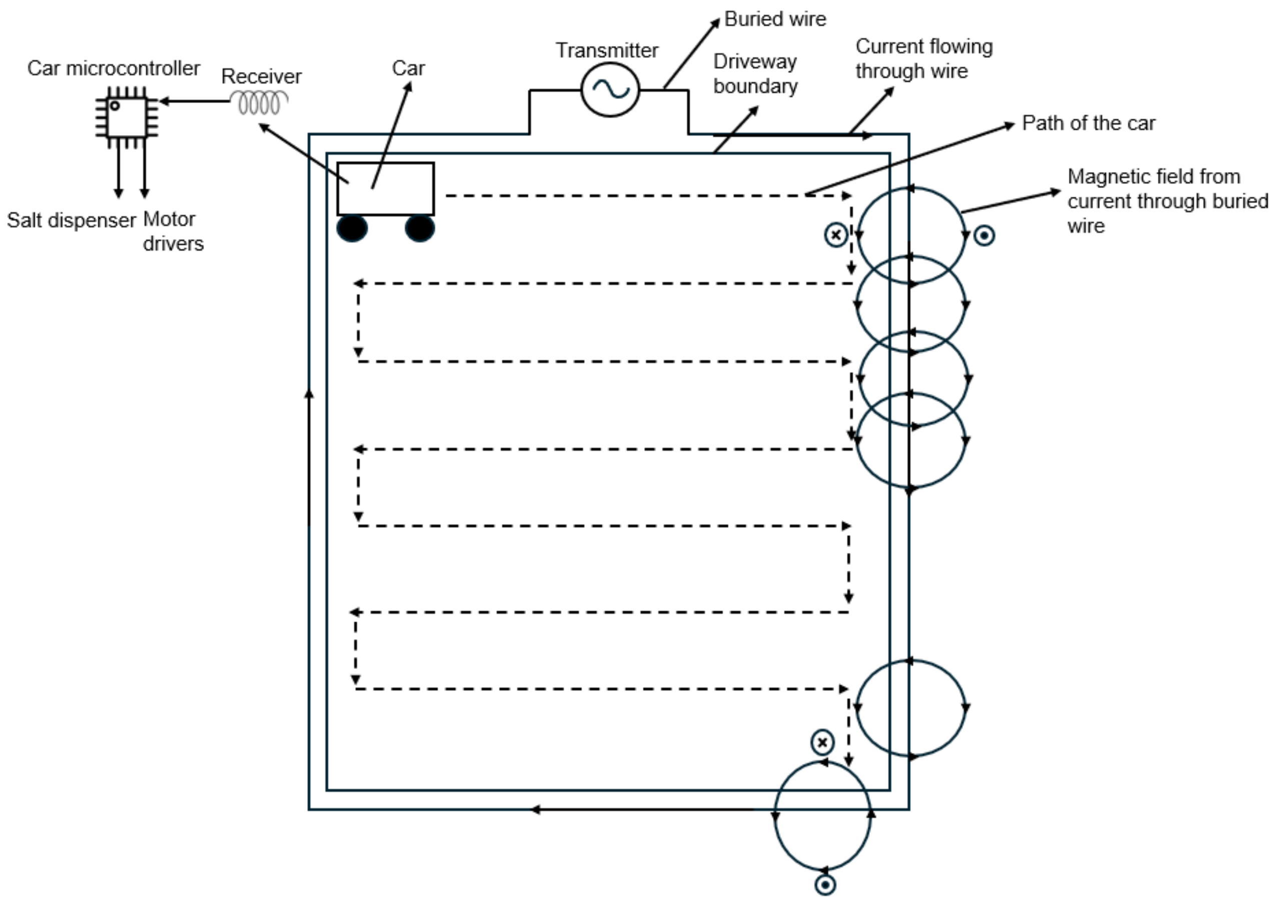


Figure 1: Movement of the car around the driveway and position of wire around the driveway

1.4 High-Level Requirements List

- The robot is able to distribute the salt onto a 2m x 2m driveway in under 10 minutes.
- The robot is able to detect the edge of the driveway within 10 inches of the edge.
- The robot is able to come to a complete stop once it has reached the end of the driveway in under 10 seconds.

2. Design

2.1 Physical Diagram

The basic layout of the car itself is laid out in Figure 2. Figure 3 only discludes the front 2 motors which connect to the front 2 wheels. The funnel placed at the top of the car will have a lid on top to ensure that anything other than salt won't be in the dispenser. Below the funnel, a servo motor is connected to a dispenser flap with a hole in it. This is the mechanism that will allow for the salt to start and stop dispensing. Right below that is the spinning disk connected to a DC motor. This is what the salt is dispensed onto. Once the disk starts spinning the salt will fly off and onto the pavement. The motor (which is attached to the spinning flap) will be held up by 2 thin metal beams mounted to the base of the car. This is shown in Figure 2 as the dashed lines. The last part of this diagram is the front enclosure which will hold the PCB, battery, and accompanying wires.

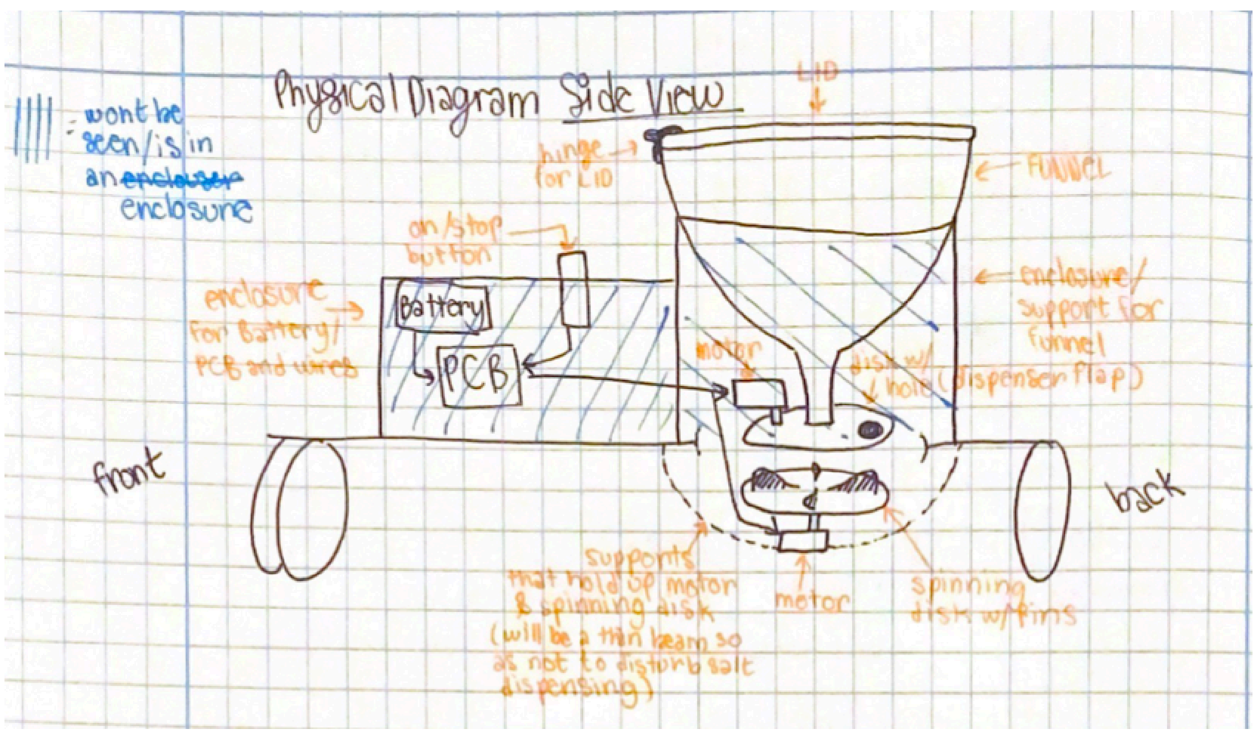


Figure 2: Side View of Physical Design of Car

Figure 3 depicts the portion of the car which was not covered in Figure 2, the front motors. This shows the 2 front DC motors will connect to the PCB on top of the car. Figure 3 also clarifies what the PCB will include: the microcontroller, receiver, servo, on/off button, motor driver for the DC Gear Motors, motor driver for the spinning disk, and a 12V battery.

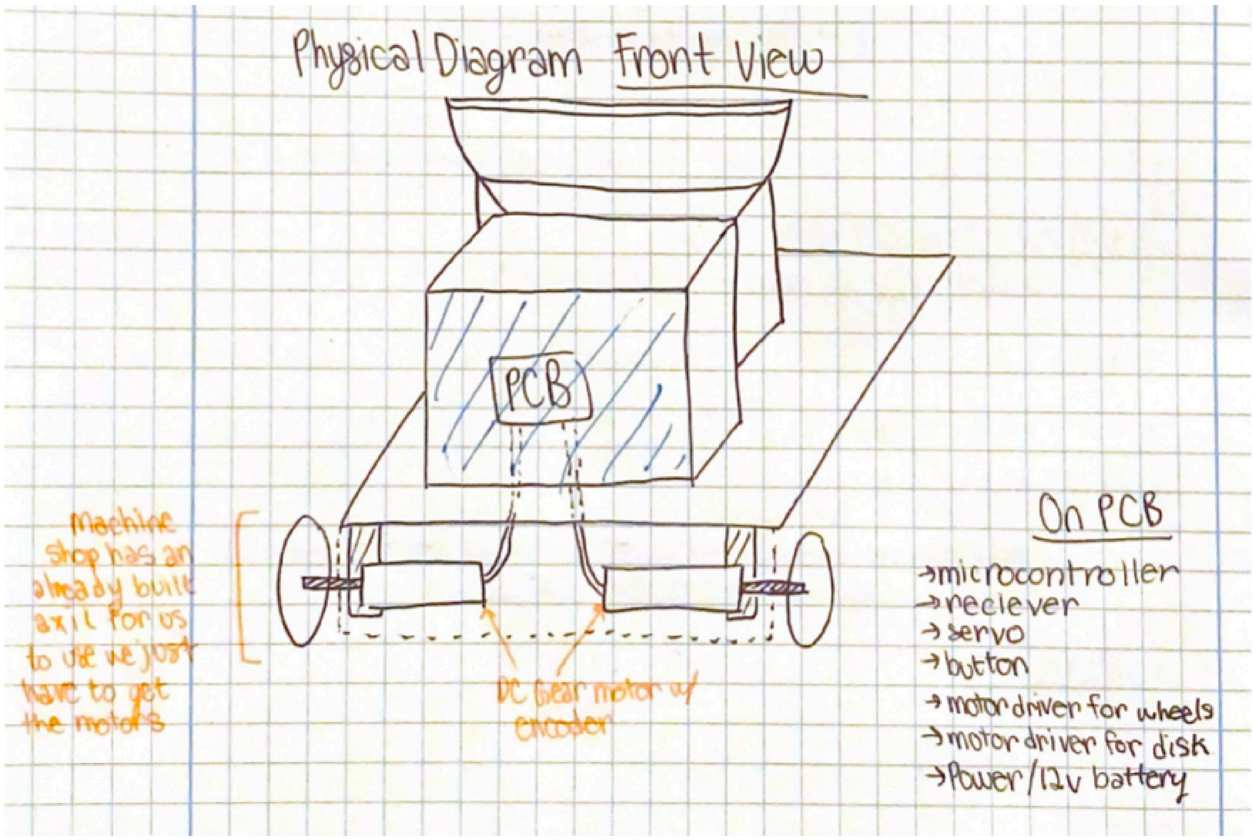
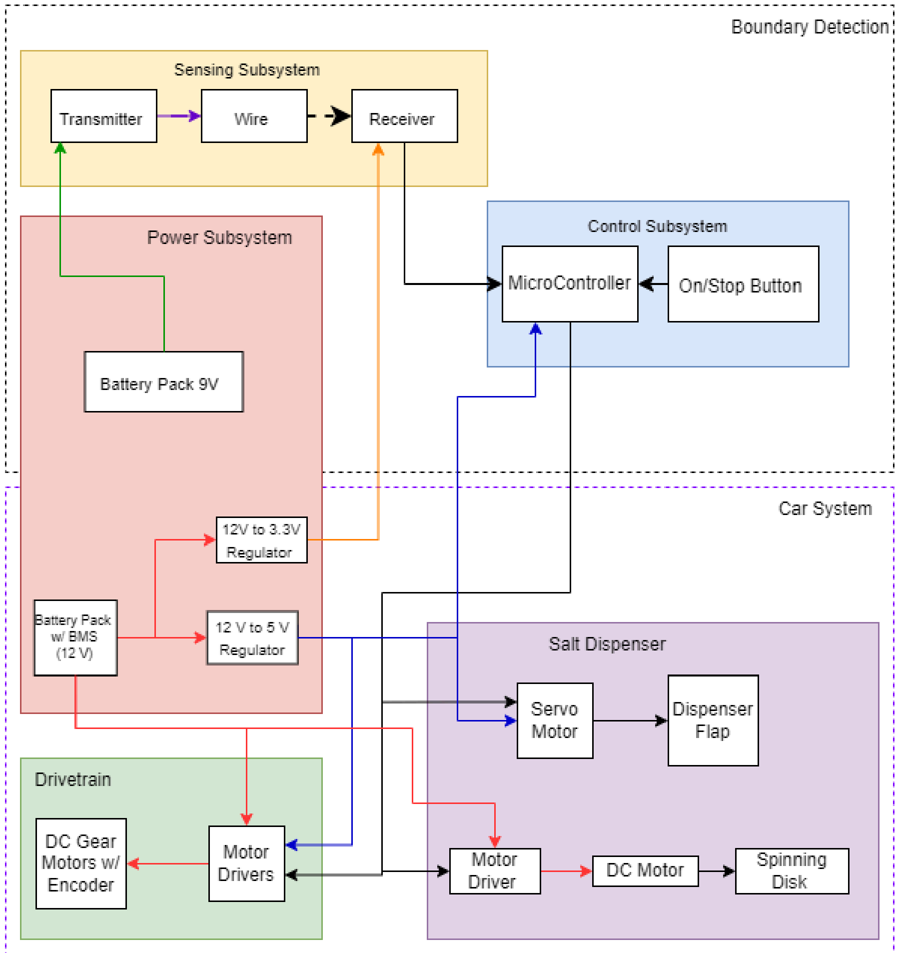
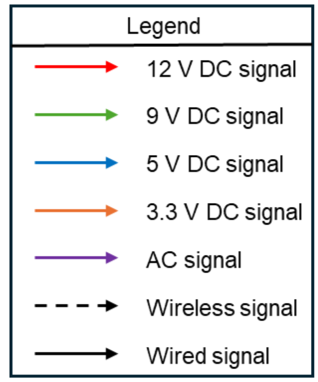


Figure 3: Front View of Physical Design of Car/ PCB components

2.2 Block Diagram





2.3 Functional Overview and Block Diagram Requirements

2.3.1 Sensing subsystem:

Overview:

The sensing subsystem will consist of the transmitter, wire, and receiver, which will be placed on the car. The transmitter will consist of an astable multivibrator comparator (TLC555) which will generate an AC signal using an RC filter that will travel through the buried wire [6, 9, 11, 12]. The changing current through the buried wire will create a changing magnetic field throughout the wire [8]. The receiver circuit will have a coiled wire which will induce a voltage once it has come in proximity to the changing magnetic field (buried wire). This voltage signal will then be sent to the ADC input pin of the microcontroller. Upon receiving the signal, the microcontroller will tell the car to turn away from the boundary of the driveway. To ensure that the bipolar voltage signal will be in the range of the unipolar ADC input, a rail splitter circuit is used to create a virtual ground.

Schematic:

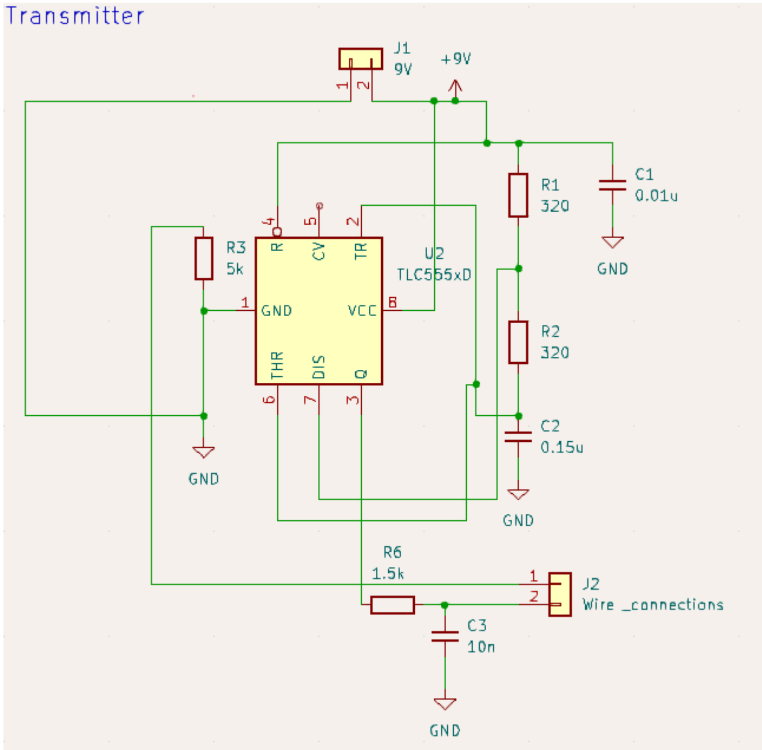


Fig 4. Transmitter Schematic

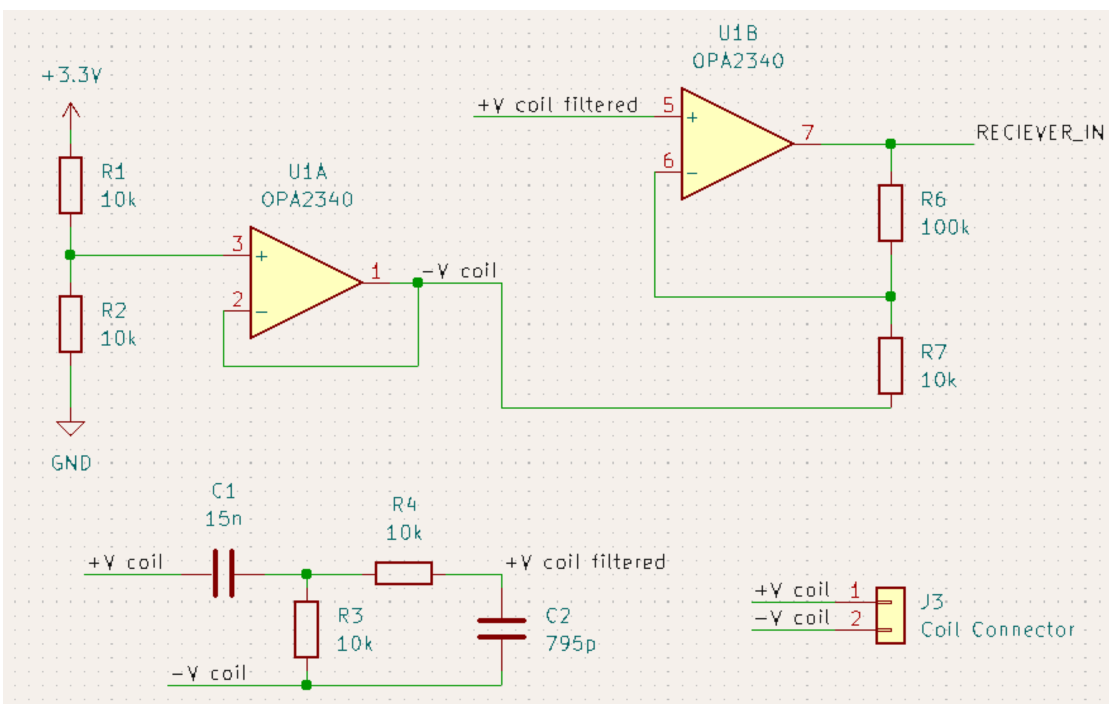


Fig 5. Receiver Schematic

Requirements	Verification
Once the transmitter has been powered on by the 9V battery, the voltage of the output pin and the wire must be sinusoidal and alternating between about 0V to about 9V.	● Ensure that the transmitter is powered off by ensuring that the 9V battery is not connected to the transmitter. ● Then, power the transmitter by connecting the 9V battery to the ‘Vdd,’ pin of the TLC555. ● Then, measure the output of the TLC555 and the wire using an oscilloscope. ● Confirm that the voltage read on the digital multimeter is sinusoidal and alternates between about 0V and about 9V.
Once the transmitter has been powered off after it has been on, the voltage of the output pin and the wire must be 0V.	● Ensure that the transmitter is powered on by ensuring that the 9V battery is connected to the transmitter. Also, measure the output of the TLC555 and the wire using an oscilloscope and confirm that the voltage read on the digital multimeter is alternating between about 0V and about 9V. ● Then, power off the transmitter by disconnecting the transmitter from the 9V battery. ● Then, measure the output of the TLC555 and the wire using a digital multimeter. ● Confirm that the voltage read on the digital multimeter is 0V.
The output from the receiver to the microcontroller must be able to output a voltage signal that is sinusoidal and alternates between 0V and 3.3V with a 10% margin once it has come within 10 inches of the buried wire.	● Ensure that the receiver is in the OFF state and is away from the buried wire ● Then press the ON/OFF button once ● Move the receiver toward the buried wire such that they are 10 inches apart and use an oscilloscope to view the output waveform ● Confirm that the output waveform on the oscilloscope is sinusoidal and alternates between 0V and 3.3V.

2.3.2 Power subsystem:

Overview:
The power subsystem is responsible for supplying power to all the subsystems. For the power subsystem, a 9 V battery pack will be used to power the transmitter (seen on the transmitter schematic). Another 12 V battery pack will be used to power all the other electrical components on the car (the microcontroller, receiver, drivetrain, and salt dispenser). The system will also include step-down voltage regulators to achieve the correct voltage levels that are required for the low-voltage components.

Schematic:

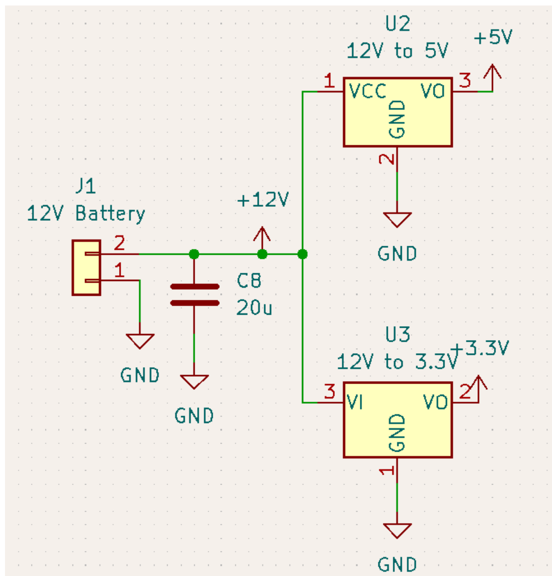


Fig 6. Power Subsystem Schematic

Requirements	Verification
Must provide a constant supply voltage of 12V with a ± 10% error to the DC motors	• Ensure that the car is in the ‘off’ state and the wheel and disk is not spinning • Then, press the on/off button once and use a digital multimeter to measure the voltage provided to the DC motor • Confirm that the value read on the digital multimeter is within range • Repeat same procedure for the other wheel DC motor and spinning disk DC motor

Must provide voltage in the range of 4.8-6.0V to ensure servo motor is operating correctly	● Ensure that the car is in the ‘off’ state and the dispenser flap is covering the opening on the dispenser. ● Then, press the on/off button once and use a digital multimeter to measure the voltage provided to the servo motor. ● Confirm that the value read on the digital multimeter is about 4.8V- 6.0V.
Must provide voltage in the range of 2.7-5.5V to ensure the DC motor drivers are operating correctly	● Ensure that the car is in the ‘off’ state and the wheel is not spinning ● Then, press the on/off button once and use a digital multimeter to measure the voltage provided to the DC motor driver ● Confirm that the value read on the digital multimeter is about 2.7-5.5V. ● Repeat the same procedure to verify the DC motor driver used for the spinning disk
Must provide voltage in the range of 2.7-5.5V to ensure ATmega328P microcontroller is operating correctly	● Ensure that the car is in the ‘off’ state ● Then, press the on/off button once and use a digital multimeter to measure the voltage provided to the microcontroller ● Confirm that the value read on the digital multimeter is within 2.7-5.5V.
Must provide a constant supply voltage of 9V ± 10% error to ensure the transmitter is operating correctly.	● Ensure that the transmitter is powered off by ensuring that the 9V battery is not connected to the transmitter. ● Then, power the transmitter by connecting the 9V battery to the ‘Vdd,’ pin of the TLC555. ● Then, measure the ‘Vdd’ of the TLC555 and the wire using a digital multimeter. ● Confirm that the voltage read on the digital multimeter is within range
Must provide a constant supply voltage of 3.3V with a ± 10% error to the receiver	● Ensure that the car is in the ‘off’ state ● Then, press the on/off button once and use a digital multimeter to measure the voltage provided to the receiver ● Confirm that the value read on the digital multimeter is within range.

Should shut off once the emergency stop button has been triggered. The car should turn off in 10 seconds.	● Ensure that the car is in the ‘on’ state (dispenser flap is opened, disk is spinning, and wheels are moving) ● Using the digital multimeter confirm that all components are turned off and the car is in the ‘off’ state (dispenser flap is closed, the disk has stopped spinning, and wheels are not moving)
Shut off automatically once it has finished salting the driveway. The car should turn off in 10 seconds.	● Ensure that the car is in the ‘on’ state (dispenser flap is opened, disk is spinning, and wheels are moving) ● Place the car at the corner of the wired boundary to mimic the position it will be at once it has reached the end of the driveway. ● Using the digital multimeter confirm that all components are turned off and the car is in the ‘off’ state (dispenser flap is closed, the disk has stopped spinning, and wheels are not moving)

2.3.3 Control subsystem:

Overview:

The control subsystem will consist of the board microcontroller and an on/stop button for the car. Once the button has been pressed, the microcontroller will send an ON signal to start up the salt dispenser and drivetrain subsystem. If the car has reached a boundary, the microcontroller will receive a signal from the car and will then communicate with the drivetrain motors to indicate which direction to turn. The microcontroller will ensure that the car has traveled throughout the entire area of the driveway by stopping only when it has reached two consecutive boundaries of the driveway. Once the car has completed dispensing the salt throughout the driveway or if the on/ off button has been pressed again (in case of an emergency stop), the microcontroller will send an OFF signal to the salt dispenser and drivetrain subsystem.

Schematic:

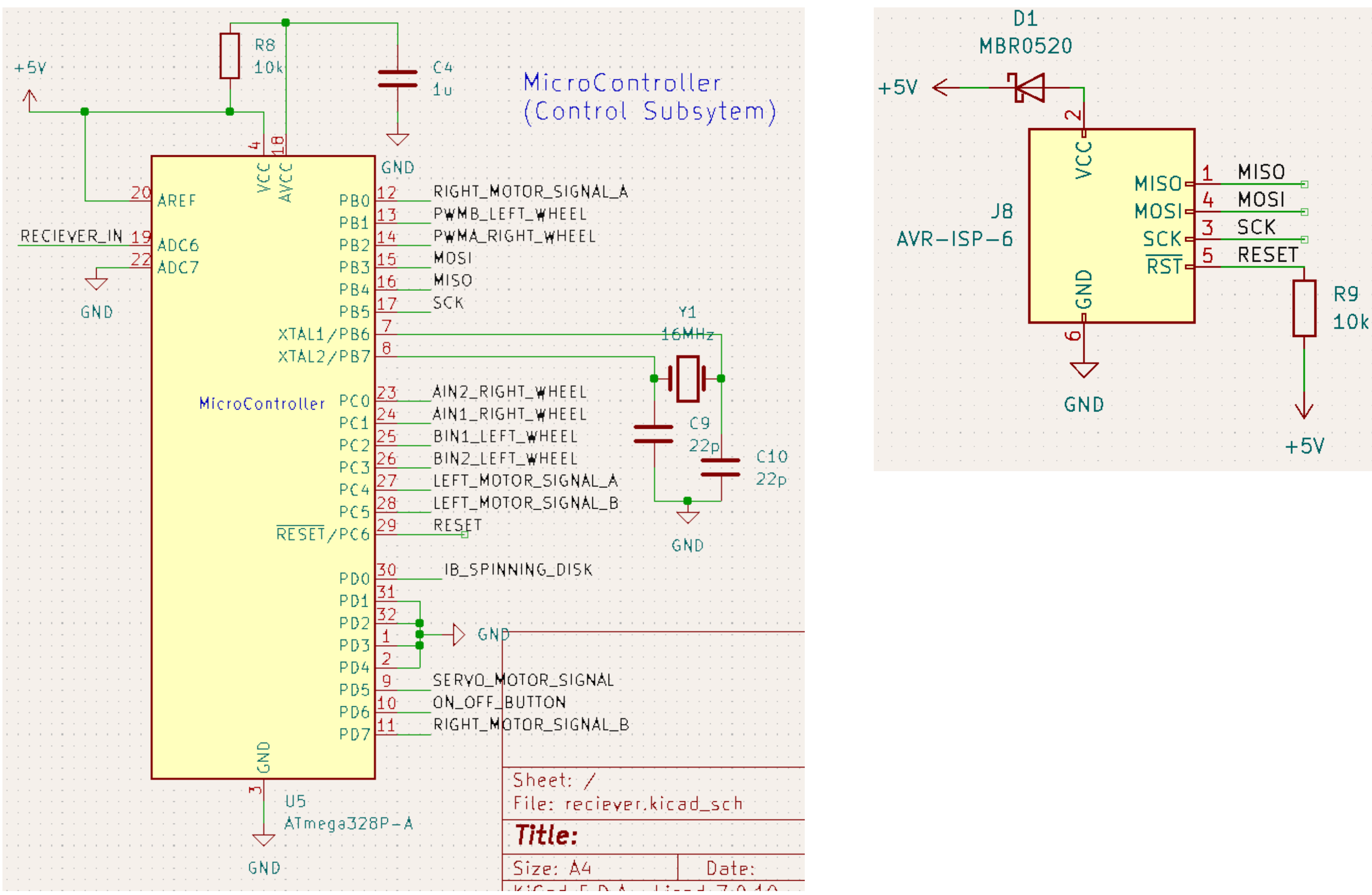


Fig 7. ATmega328P Microcontroller Schematic

Requirements	**Verification**
The initial press of the on/off button must start up the car and begin dispensing the salt.	● Ensure that the car is initially in the ‘off,’ state and the car is not moving. ● Then, press the on/off button once and ensure that the ATmega328 microcontroller has been powered using a digital multimeter to measure the voltage at the Vcc pin of the microcontroller which should be between the range of 2.7V to 5.5V. ● Then, measure the voltage at the pins that are connected to the motor driver for the servo motor, the motor driver for the DC gear motors with the encoder, and the motor driver for the DC motor to ensure that the motors have received the signal to turn on. ● Confirm that the dispenser flap on the car has opened, the car is moving, and the spinning wheel is rotating.
The second press of the on/off button must stop the car moving, the spinning disk rotating, and close the dispenser flap on the car.	● Ensure that the car is initially in the ‘on,’ state and the car is moving. ● Then, press the on/off button and ensure that the ATmega328 microcontroller has been powered off using a digital multimeter to measure the voltage at the Vcc pin of the microcontroller, which should be 0V. ● Then, measure the voltage at the pins that are connected to the motor driver for the servo motor, the motor driver for the DC gear motors with the encoder, and the motor driver for the DC motor to ensure that the motors have received the signal to turn off. ● Confirm that the dispenser flap on the car has closed, the car has stopped moving, and the spinning wheel has stopped rotating.
Once the car has completed dispensing the salt throughout the entire area of the driveway, the dispenser flap on the car should close, the car should stop moving, and the spinning disk should stop rotating.	● Ensure that the car is initially in the ‘on,’ state and the car is moving. ● Then, wait for the car to dispense all of the salt throughout the entire area of the driveway. The car will have completed traveling throughout the entire driveway once it reaches the wired fence two consecutive times, or the car receives the signal from the transmitter two consecutive times when it turns.

	● Then, ensure that the ATmega328 microcontroller has been powered off using a digital multimeter to measure the voltage at the Vcc pin of the microcontroller, which should be 0V. ● Then, measure the voltage at the pins that are connected to the motor driver for the servo motor, the motor driver for the DC gear motors with the encoder, and the motor driver for the DC motor to ensure that the motors have received the signal to turn off. ● Confirm that the dispenser flap on the car has closed, the car has stopped moving, and the spinning wheel has stopped rotating.

2.3.4 Drivetrain Subsystem:

Overview:

The drivetrain subsystem will consist of the motor driver and two DC gear motors which will each have an encoder and will be attached to the front two wheels of the car. The motor drivers will receive a signal from the microcontroller to determine which way the car should turn. For the car to turn, only one motor will be on depending on the direction. For example, if the car turns right, the left wheel will be on while the right wheel will be off. Likewise, if the car turns left, the right wheel will turn on while the left wheel will remain off. The encoders for the DC gear motors will be used for more precise control of the wheels' direction and speed.

Schematic:

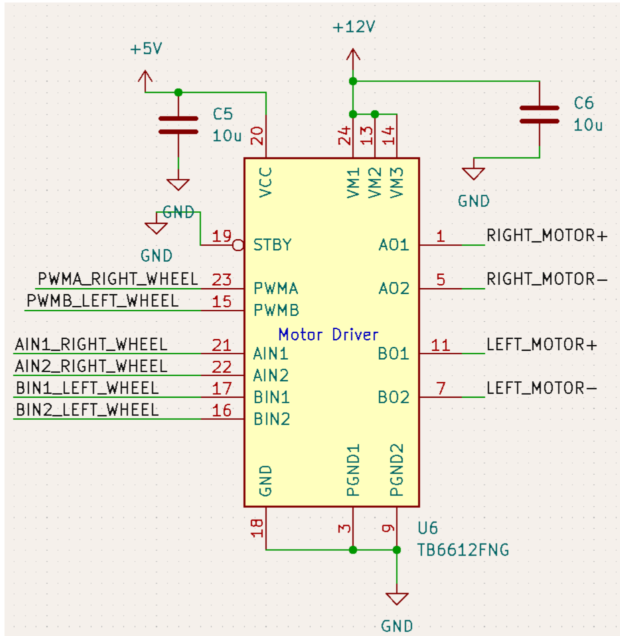


Fig 8. Encoder Motor Driver Schematic

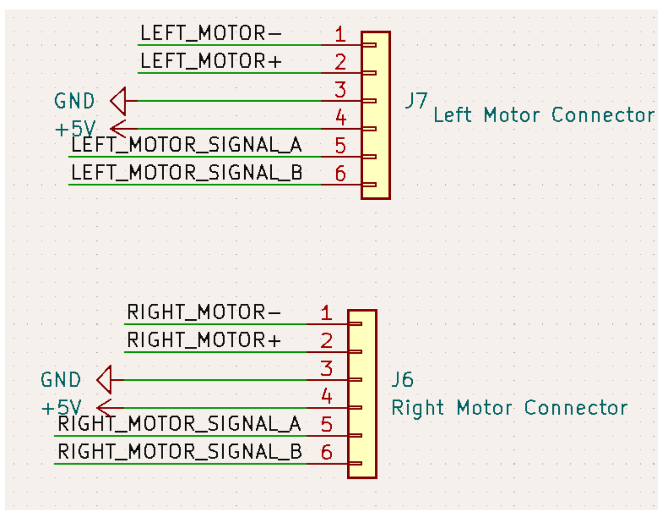


Fig 9. Encoder Motor Connections

Requirements	**Verification**
The Gear Motors connected to the two front wheels will always be at the same position to ensure they are traveling at the same rpm.	● Ensure that the car is in the 'off' state ● Ensure that the output pins of the DC Gear Motor (Yellow and White wires) are connected to Input pins of the microcontroller. ● The microcontroller should already be programmed to read the input of these wires. ● Then, press the on/off button once and wait for the car to turn on. ● Once the car is on, confirm that the output of the motor signals are the same.
Once the car reaches the edge of the driveway the car should turn 90 +/- 5 degrees.	● Ensure that the car is in the 'off,' state. ● Place the car within the driveway boundaries. ● Press the on/off button once and wait for the car to turn on. ● Once the car reaches the edge, mark where on the ground the direction the car is facing. ● After the car turns, again mark the direction the car is facing. ● Measure the angle between these two directions with a ruler and verify that it is indeed within the range of 90 +/- 5 degrees.
Once the car turns 90 degrees, the car should move forward 6 +/- 2 inches before turning 90 degrees again.	● Ensure that the car is in the 'off,' state. ● Place the car within the driveway boundaries. ● Press the on/off button once and wait for the car to turn on ● Once the car reaches the edge and turns, mark where on the ground the front of the car is. ● After the forward movement of the car, again mark the position of the car. ● Measure the distance between these two marks with a ruler and verify that it is indeed within the range of 6 +/- 2 inches.

2.3.5 Salt dispenser subsystem:

Overview:
The salt dispenser will consist of 2 motor drivers, a servo motor, and a dispenser flap that will be placed at the bottom of the salt dispenser. The motor driver within the salt dispenser subsystem will receive a signal from the microcontroller within the control subsystem when the on/ stop button has been pressed. If the on/ stop button has only been pressed once, the servo motor will open the dispenser flap. If the car has completed dispensing the salt throughout the driveway or if the on/ stop button has been pressed again, the motor drivers will receive a signal from the microcontroller and close the flap using the servo motor. The salt dispenser subsystems will also include the motor driver and DC motor for the spinning disk which will rotate once the car has been switched on.

Schematic:

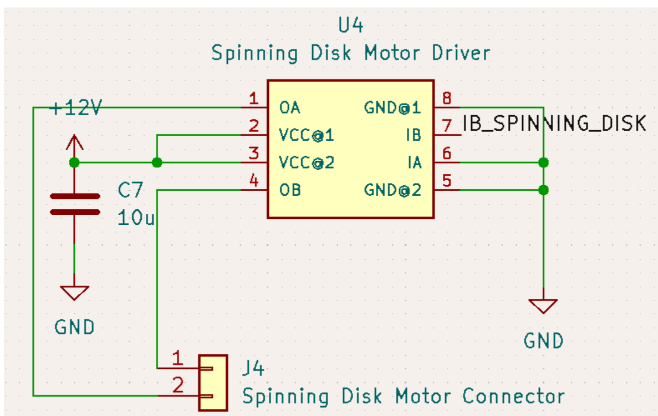


Fig 10. DC Motor Driver Schematic

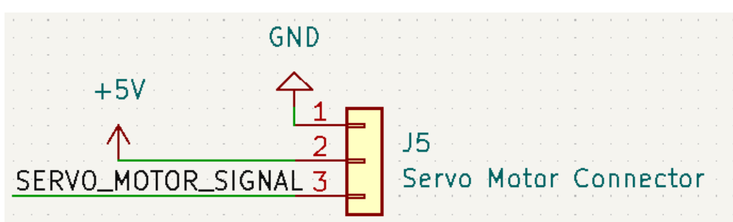


Fig 11. Servo Motor Connections

Requirements	Verification
The servo motor for the dispenser flap must rotate in the clockwise direction about 90 +/- 5 degrees to open the flap.	● Ensure that the car is in the ‘off,’ state and the dispenser flap is covering the opening on the dispenser. ● Then, press the on/off button once and record the value read from the microcontroller to provide the signal to the servo motor. ● Confirm that the dispenser flap rotates about 90 +/- 5 degrees to open the flap.
The servo motor for the dispenser flap must rotate in the counterclockwise direction for about 90 +/- 5 degrees to open the flap.	● Ensure that the car is in the ‘off,’ state and the dispenser flap is covering the opening on the dispenser. ● Then, press the on/off button once and record the value read from the microcontroller to provide the signal to the servo motor. ● Confirm that the dispenser flap rotates about 90 +/- 5 degrees to open the flap.
The servo motor for the dispenser flap must rotate back to the starting position once the car has traveled throughout the entire driveway.	● Ensure that the car is in the ‘on,’ state and the dispenser flap has been opened to allow the salt to fall through the dispenser. ● Then, allow the car to travel throughout the entire driveway. ● Then, use a digital multimeter to measure the voltage provided by the servo motor. ● Confirm that the dispenser flap has rotated back to its original position.
The servo motor for the dispenser flap must rotate back to the starting position once the on/off button has been pressed.	● Ensure that the car is in the ‘on,’ state and the dispenser flap has been opened to allow the salt to fall through the dispenser. ● Then, press the on/off button once and record the value read from the microcontroller to provide the signal to the servo motor. ● Then, use a digital multimeter to measure the voltage provided by the servo motor. ● Confirm that the dispenser flap has rotated back to its original position.
The spinning disk must rotate at a speed of about 200 rpm.	● Ensure that the car is in the ‘off,’ state and the disk is not spinning. ● Then, press the on/off button once and confirm that the spinning disk rotates at a speed of about 200 rpm.

The DC motor for the spinning disk must stop rotating once the car has traveled throughout the entire driveway or the on/off button has been pressed.	● Ensure that the car is in the ‘on,’ state and the spinning disk is rotating. ● Then, press the on/off button once and record the value read from the microcontroller to provide the signal to the DC motor. ● Then, use a digital multimeter to measure the voltage provided by the DC motor. ● Confirm that the spinning disk has stopped rotating.

2.3.6 Integration of subsystems:

The power subsystem has 2 main components, a 9V battery pack that powers the transmitter only and a 12V battery pack that powers everything else. The transmitter and the wire will be buried around the driveway. This is what will create a magnetic field that will allow the receiver to detect when it is near the wire. Once the receiver is within range, it will send a signal to the microcontroller through a physical connection on the PCB. The microcontroller has a button that is physically attached that tells the car what state we are in, On or Off. The microcontroller is responsible for sending out the correct signals to the motor drivers and the servo based on whether the microcontroller received a signal from the receiver. First starting with the servo, the microcontroller would send the servo the correct angle to move the dispenser flap to to open or close the flap. One of the two motor drivers connects to the spinning disk which allows the salt to be dispersed. The microcontroller will send the motor driver a signal to tell the motor to start spinning once the car is turned on. The microcontroller will also send the motor driver a signal to tell the motor to stop spinning once the car is turned off. The other motor driver we use will be connected to the two front motors with encoders. The microcontroller will communicate with the motor driver to tell the two motors to run or stop. Depending on whether the car is going straight or if the car is turning, we will need to turn on the corresponding wheels. This is how our subsystems work together and communicate.

2.4 Tolerance Analysis

2.4.1 Operation of Linear Voltage Regulator

Within the power subsystem, a 12V battery is used as the input voltage to different voltage regulators. We will use a 12V to 5V converter (BD50FC0FP-E2) to power the servo motor and microcontroller and motor controllers and a 12V to 3.3V converter (AZ1117CD-3.3TRG1) to power the receiver circuit. To ensure the correct operation, we must meet the dropout voltage given by the regulator. The dropout voltage is the minimum value of the voltage that is required between the voltage input and the voltage output of the voltage regulator (V_{in} - V_{out} > $V_{dropout}$). The BD50FC0FP-E2 voltage regulator has a dropout voltage of 200mV. As we are supplying 12V to the voltage regulator, the voltage across the input and the output of the voltage regulator will be 12V - 5V = 7V, which is greater than 200mV and thus satisfies the dropout voltage requirement.

The BD50FC0FP-E2 has an internally set thermal shutdown point of 150°C and operation near this point should be avoided as it will negatively affect the life of the device. To ensure we are well below this threshold, we can calculate the maximum output current we can draw using the power dissipation equation. The maximum power dissipation at any ambient temperature can be given as $P_{MAX} = (T_{JMAX} - T_A)/\theta_{JA}$ where T_{JMAX} is the junction temperature, T_A is the surrounding ambient temperature, and θ_{JA} is the junction to ambient thermal resistance (given by $\theta_{JC} + \theta_{CA}$). From the datasheet, T_{JMAX} is 150°C and θ_{JA} is approximately 20.8°C/W. We can set T_A to be around 17 °C since we are assuming our testing will take place around March/April which would be the worst case scenario since the actual practical use of our project would take place during the winter season. The calculated $P_{MAX} = (150 - 17)/20.8 = 6.3942$ W. Since the power dissipation across a device is given by : $P = I_{OUT} (V_{IN} - V_{OUT})$, we can find the maximum I_{OUT}. Therefore, the maximum allowable current for the 12V to 5V regulator used to power the servo motor is about 913.46mA. Also, the AZ1117CD-3.3TRG1 12V to 3.3V regulator has a thermal shutdown point of about 160°C. The value of T_{JMAX} for the AZ1117CD-3.3TRG1 was found to be about 160°C and the value of θ_{JA} was found to be about 70°C from the datasheet. Therefore for the 12V to 3.3V regulator used to power the motor drivers and the microcontroller, the maximum allowable current is 234.81mA.

2.4.2 Torque Calculation

We also need to ensure that the required torque provided by the DC gear motors for the front two wheels of the car is enough to move the car including the salt dispenser at the required speed of 80 rpm. Assuming the weight of the salt and the car is distributed evenly across the the two wheels, the torque required for each wheel can be calculated by the equation T = F*r, where ‘T,’ is the torque, ‘F,’ is the force, and ‘r,’ is the radius of the wheel, which is 3 inches, or 0.0762 meters [3, 4]. The force of the car is found by the equation, F = m*a, where 'm,' is the mass of the car in lbs, and 'a,' is the acceleration of the car. The mass of the car was assumed to be 11 lbs in total, with 10 lbs composing the weight of the base of the car and the salt dispenser, and 1 pound composing the salt. Therefore, the amount of weight carried by each wheel if evenly distributed would be equal to 5.5 lbs. The acceleration of the car was found by the velocity divided by the amount of time it should take the car to stop. The velocity of the car is calculated by (80 rpm)(2πr). The amount of time the car will take to stop was assumed to be ten seconds. Therefore, the acceleration of the car was calculated to be equal to (80 rpm)(2π(3 in))/(10 seconds) = 0.063 m/s^2. The force was then calculated to be F = (5.5 lbs)(0.063 m/s^2), which when converted to $kg*m/s^2$, resulted in 0.15687 $kg*m/s^2$, or 0.15687 N. Thus, the torque was calculated to be T = F*r = (0.15687 N)(0.0762 m) = 0.012 N*m, or 0.122 kg*cm. The rated torque of the 80 RPM gearmotor is about 1.6 kg*cm. Therefore, the torque required to move the car is less than the rated torque of the gearmotor which ensures that the motor will be able to support the specifications of the car.

2.4.3 Induced Voltage Calculation from Coils (Receiver)

For the car to detect the wire within 10 inches of the edge we need to ensure that the induced voltage on the copper coil is going to be large enough to detect. We will use the following equations to estimate how much induced voltage we can get and what variables we will be able to manipulate to achieve our needs [1, 2, 5, 8].

Faraday's Law of induction : $\varepsilon = N \times \frac{d\phi}{dt}$

Magnetic flux: $\phi = B \times A$ where A is the enclosed area of the coil: $A = \pi R^2$

Ampere's Law: $B = \frac{\mu_0 Iwire}{2\pi r}$ where I_{wire} is a function of time: $I_{wire} = Isin(\omega t)$

Variables:

N: Number of turns for the receiver, or the coil.
ϕ: Magnetic flux through the coil (Tm^2 or Wb).
B: Magnetic field of the current through the wire (T).
A: Area of the space enclosed by the coil, or the receiver, which is a circle of radius R (m^2).
μ_0: Permeability of free space (4π*10^(-7) H/m).
I: Magnitude of the changing current through the wire(A).
ω: Frequency of the current flowing through the wire (radians).
r: Distance of the receiver, or the coil, away from the wire (m).
R: Radius of the circle enclosed by the coil (m).
ε: Induced voltage of the coil (V).

Equations to find the induced voltage of the coil:

$$B = \frac{\mu_0 I sin(\omega t)}{2\pi r}$$

$$\phi = B \times A = \frac{\mu_0 I sin(\omega t) A}{2\pi r}$$

$$\varepsilon = N \times \frac{d\phi}{dt} = N \times \frac{\mu_0 A I \omega cos(\omega t)}{2\pi r} = \frac{N \mu_0 A I \omega cos(\omega t)}{2\pi r}$$

Magnitude of the induced voltage of the coil: $|\varepsilon| = \frac{N \mu_0 A I \omega}{2\pi r}$

Using the maximum specifications of the TLC555 timer chip [6, 11, 12], we will set I to 15 mA and ω to 1.2 MHz. According to our high-level requirements, the car needs to detect the wire 10 inches away therefore r is fixed at 10 inches or 0.254 m. The only factors we can manipulate easily to maximize the induced voltage are N (number of turns of the coil) and A (area enclosed by the coil). We will use N=100 since that seems like the maximum doable amount of rounds we can create with the budget. We also decided it was most feasible to fit a coil wire with a maximum radius of 2.5 inches or .0635 meters, on our car.

In Summary:

N = 100

$\mu_0 = 4\pi \text{ x } 10^{-7}$ H/m

A = $\pi R^2 = \pi\ (0.0635)^2\ m^2$

I = 15 mA

ω = 1.2 MHz

r = 10 inches = 0.254 m

Plugging these values in we get:

Induced voltage = $\frac{N \mu_0 A I \omega}{2\pi r} = \frac{(100\ turns)(4\pi \times 10^{-7} H/m)(\pi \times (0.0635\ m)^2)(0.015\ A)(1200000\ Hz \times 2 \times \pi)}{(2 \times \pi \times 0.254\ m)}$

Induced voltage = 0.112809 V

Although this calculation assumes the most extreme case, we still can see that there is a good amount of voltage induced by the coil. In our actual design, we also have an OpAmp to help amplify the induced voltage before sending it to the microcontroller which is another factor we can manipulate.

2.4.4 Power and Current Requirements

Lastly, another limitation of the car is the dependence on the battery capacity. First, we will need to calculate the maximum current and power that is required by the car.

Components	Max. Current	Voltage	Max Power (P=I*V)
DC gear motor with encoder (80RPM)	0.65A x 2 = 1.3 A	12 V	15.6 W
DC gear motor (100RPM)	0.92 A	12 V	11.04 W
Servo motor	0.7 A	5 V	3.5 W
Microcontroller	0.2 A	5 V	1 W
Motor Driver (wheels)	2.2mA	5 V	0.011 W
Motor Driver (spinning disk)	500 uA	12 V	0.006 W
Voltage regulator (5 V)	2.5 mA	12 V	0.03 W
Voltage regulator (3.3V)	10 mA	12 V	0.12 W
Total	**3.14 A**	**-**	**31.307 W**

With this in mind, the battery selected is a 12V 5200mAh 58Wh Rechargeable Li-ion Battery. This battery has a discharge rate of 1C, meaning it can supply 5.2 A for one hour. Therefore for a maximum current load, the car will be operational for 1.66 hours (5.2 Ah /3.14 A). For power consumption, the maximum power consumed by the car is 30.96 W which means that the car will be operational at maximum load for 1.87 hours (58Wh/30.96 W). Both of these calculated operational periods are more than enough for our purposes.

2.5 Other Considerations

2.5.1 Robot Control:

One issue that we have been struggling with in our design is ensuring that our robot will drive straight when necessary. Even though we bought identical motors for the front two wheels, there is a chance that the two motors will be running at a different rpm. This is a concern because of how we are planning on moving the robot and the path we designated for it. Our design requires the robot to be able to drive straight through the driveway and any slight deviation from the path will cause a larger effect in the future. Our first plan of action for this issue will be to use the motor encoders to monitor how fast the wheels are spinning. If we find that our car is still not moving on a straight path we will incorporate motor precision control chips. These chips allow us to monitor the rotation of the motors and make adjustments if the motors are not moving at the same speed.

2.5.2 External Factors:

External factors such as snow can significantly impact the creation and functionality of an autonomous salt dispenser. Snow reduces visibility, potentially hindering sensors and cameras used for navigation and obstacle detection. The altered surface conditions caused by snow can affect the mobility of the dispenser, posing challenges for traction and navigation. Additionally, snowfall may interfere with sensor readings, leading to inaccuracies in detecting obstacles or determining the areas requiring salt spreading. Material handling is also affected, as snow can clog dispenser mechanisms and impede salt distribution. Cold temperatures associated with snow can decrease battery life, necessitating careful consideration of energy management strategies. Maintenance requirements may increase due to snow buildup on components, leading to higher operational costs. Safety concerns arise in extreme weather conditions, emphasizing the need for robust safety protocols and fail-safe mechanisms. Addressing these challenges entails thorough testing, incorporating specialized features like heated components and advanced sensor fusion techniques, and designing ruggedized chassis to enhance durability in snowy environments.

Since we only have a semester to complete this project we won't be able to implement every possible solution but here are possible ideas if we want to continue with this project. To enhance visibility, advancements in sensor technology and software algorithms can improve the detection and interpretation of surroundings despite reduced visibility caused by snow. Designing specialized wheel or track configurations can enhance mobility on snowy terrain. Additionally, incorporating mechanisms to prevent snow buildup on dispenser components, such as heated elements or anti-clogging features, can ensure consistent salt distribution. To mitigate the impact of cold temperatures on battery life, optimizing battery management systems and using cold-resistant battery technologies can extend operational time. Regular maintenance protocols, including snow removal from critical components, can help minimize downtime and ensure optimal performance in snowy conditions. By implementing these solutions, autonomous salt dispensers can effectively operate in snowy environments while maximizing performance and safety.

2.6 Software Design

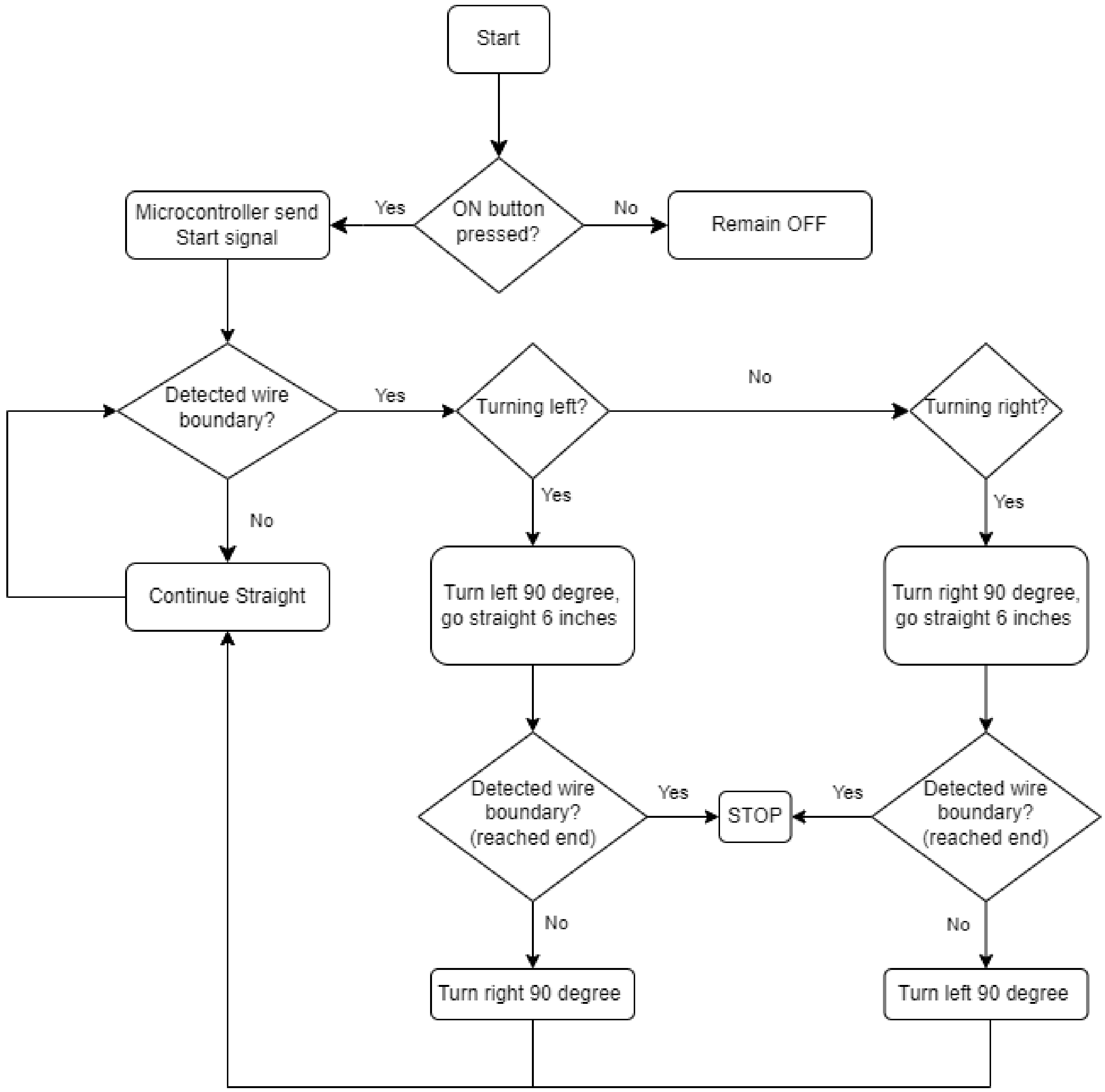


Figure 11. Flow Chart of Microcontroller programs

2.7 Cost Analysis

Part Cost

Description	Quantity	Unit Price	Link
GEARMOTOR 83 RPM 12V W/ENCODER (wheel)	2	$29.00	link
Hs-311 Standard Servo (dispenser flap)	1	Self-Service Inventory	datasheet
TB6612FNG (wheel)	1	$1.97	link
Linear Voltage Regulator IC Positive Fixed 1 Output 1A TO-252 (value: 5V) (BD50FC0FP-E2)	1	Electronic Service Shop	datasheet
Linear Voltage Regulator IC Positive Fixed 1 Output 1A TO-252-3 (value: 3.3V) (AZ1117CD-3.3TRG1)	1	Electronic Service Shop	datasheet
ATmega328P Microcontroller	1	Electronic Service Shop	datasheet
Push Button	1	Self-Service Inventory	
Motor control driver chip L9110 (spinning disk)	1	ECE Supply Center: $2.56	datasheet
Greartisan DC 12V 100RPM Gear Motor High Torque (spinning disk)	1	From machine shop	
Funnel for Salt	1	$9.49	link
KBT 12V 5200mAh Rechargeable Li-ion Battery	1	$32.99	link
9V Battery - Alkaline (transmitter)	1	ECE Supply Center: $2.32	datasheet
CMOS TIMER TLC555CP (transmitter)	1	ECE Supply Center: $1.14	datasheet
OPA340 Single-Supply, Rail-to-Rail Operational Amplifiers (receiver)	2	$4.06	link
1-CONDUCTOR 20GAUGE SHIELDED	Need 8 m long	ECE Supply Center: $0.46	datasheet
Total Cost			**$100.33***

total cost does not include the cost of wire as it does not specify the length sold on the ECE supply center website

Labor cost:

From the AY21-22, the average starting salary for a UIUC Electrical Engineering graduate is $87,769 and for a Computer Engineering graduate is $109,176 [7]. Assuming a 40-hour work week and 48 working weeks per year, the hourly salary is $45.71 for EE graduates and $56.86 for CE graduates. For a project that takes 9 weeks to complete and working 25 hours per week the total labor cost: 9 wk * 25hr/wk * (2*$45.71 + $56.86) = **$33,363**

2.8 Schedule

<table>
<tr><th>Week</th><th>Task</th><th>Person</th></tr>
<tr><td rowspan="4">February 18th - February 24th</td><td>- Research the transmitter and the receiver system for the fence.
- Talk with TA Jason
- Complete the Design Document by Thursday, February 22nd</td><td>Everyone</td></tr>
<tr><td>Order the parts needed for the prototype.</td><td>Arya</td></tr>
<tr><td>Create circuit diagram for drivetrain subsystem</td><td>Candy</td></tr>
<tr><td>Create circuit diagram for salt dispenser subsystem</td><td>Mayura</td></tr>
<tr><td rowspan="5">February 25th - March 2nd</td><td>Complete design review with the instructor and TAs.</td><td rowspan="2">Everyone</td></tr>
<tr><td>Order the remaining parts that are needed for the car</td></tr>
<tr><td>Create circuit diagram and prototype sensing subsystem (making sure receiver is getting signal from transmitter)</td><td>Mayura & Candy</td></tr>
<tr><td>Create circuit diagram and prototype power subsystem</td><td>Arya</td></tr>
<tr><td>Complete the PCB design and the PCB review.</td><td>Everyone</td></tr>
<tr><td rowspan="6">March 3rd - March 9th</td><td>Complete finalizing the PCB design</td><td rowspan="4">Everyone</td></tr>
<tr><td>PCB order by March 5th.</td></tr>
<tr><td>Complete teamwork evaluation.</td></tr>
<tr><td>Talk with the machine shop about physical design of car & make revision as needed</td></tr>
<tr><td>Work on Sensing subsystem prototyping</td><td>Mayura & Candy</td></tr>
<tr><td>Work on drivetrain subsystem
1. programming microcontroller
2. connecting motors to motor drivers</td><td>Arya</td></tr>
<tr><td rowspan="2">March 10th - March 16th</td><td>SPRING BREAK</td><td rowspan="2">Everyone</td></tr>
<tr><td>Can be used as catch-up week if needed</td></tr>
</table>

March 17th - March 23rd	Revise & Order PCB	Everyone
	Start working on salt dispenser subsystem: 1. Programming microcontroller for servo motor (flap) and dc motor (spinning disk) 2. Finalize physical dimensions for flap and spinning disk	Mayura
	Work on sensing subsystem prototype	Candy
	Work on drivetrain subsystem prototype	Arya
March 24th - March 30th	Revise & Order PCB	Everyone
	Give machine shop information to make spinning disk with fins/dispenser flap/funnel holder	
	Brainstorm enclosure designs	
	Continue working on salt dispenser prototype	Mayura
	Create final version of sensing subsystem	Candy
	Create final version of drivetrain subsystem	Arya
	Put together the drivetrain subsystem and the sensing subsystem and test & debug	Everyone
March 31st - April 6th	Create final version of salt dispenser	Mayura
	Add salt dispenser to drivetrain/sensing subsystem	Everyone
	Revise & Order PCB	
	Creating the enclosures, 3D print them and add to car	Candy & Arya
April 7th - April 13th	Revise & Order PCB	Everyone
	Test and revise salt dispenser/ drivetrain/ sensing subsystem together	
	Revise enclosures	
April 14th - April 20th	Fixing Minor Errors	Everyone
April 21st - April 27th	Final Demo	Everyone
	Work on Final presentation	
April 28th - May 4th	Final Presentation	Everyone
	Work on Final paper	
May 5th - May 11th	Lab Notebook due	Everyone

3. Ethics and Safety

Ethical Issues:

As outlined in the IEEE Code of Ethics II, we strive to create a fair and non-discriminatory working environment throughout the entirety of the project development. To achieve this, all work will be distributed evenly and fairly and all members will be expected to treat each other and any mentor TA and Professor with respect. In addition, according to IEEE Code of Ethics I.1 and I.5, we will take in any feedback and practice proper testing procedures to produce honest and accurate results to ensure the functionality of the device and address any safety concerns.

Safety Issues:

One possible safety concern that may arise is the exposure of electrical components. This device is intended to work during the winter season, we will need to ensure that all electrical components are properly secured on the car and protected from any possible water damage. One way to accomplish this is by creating a small 3D-printed enclosure to conceal everything. In addition, as we will be using batteries as power supply

Even though the car will be autonomous and should stop once it has covered the entire driveway, we also have to consider the case where the car fails to respond to the boundaries and goes out of control. We plan on adding a stop button on the car that will allow the user to manually stop the car.

Another safety concern for the demo and the practical use of the salt dispenser car is if there are obstructions within the driveway that may be in the path of the car which could result in damage to the car or to the obstacle. These obstructions include people, electrical wires, trash, or debris. To ensure that the car is impacted by the obstacles, the wired fence will be placed to surround an area that is clear of any obstructions. The emergency stop button can also be pressed if there is an obstacle in the path of the car.

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