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March 11, 2010

Dr. Andrew Rawicz
School of Engineering Science
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RE: Design Specification for the Vehicle Lock-Out Prevention System

Dear Dr. Rawicz,

I have attached a copy of our design specification document for our vehicle lock-out prevention system. Our system is used to prevent drivers from locking their keys in their car. Sensors installed in the car will sense the presence of the keys within the vehicle. If the keys are found inside, the system alerts the user with a buzzer. Then, the system checks if the doors are locked. If all the doors are locked, the system unlocks a door so that the user can retrieve their keys and turn off the system.

In the document, we lay out the implementation methods for our overall system design and each individual part. This document applies to the proof-of-concept design requirements as outlined in our Functional Specification document.

Undent Solutions is composed of Marissa Hun, Daphne Mui, Dona Patikiriarachchi, and Elisa (Xuan) Lu. If you have any questions or comments regarding our design specifications, you can contact us through email at mmh2@sfu.ca.

Sincerely,

Daphne Mui

Daphne Mui
CEO
Undent Solutions

Enclosure: Design Specifications for the Vehicle Lock-Out Prevention System

Design Specification for the Vehicle Lock-out Prevention System

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EXECUTIVE SUMMARY

The design specification for the Vehicle Lock-out Prevention System presented by Undent Solutions contains a detailed description of the design and development of our proof-of-concept model. The design specifications mentioned in the document is entirely for the proof-of-concept model. Therefore, we will only discuss design considerations related to the requirements marked with I or II, as given in the document *Functional Specification for the Vehicle Lock-out Prevention System* [1].

This document outlines the design of the Vehicle Lock-out Prevention System and provides detailed justification for the design choices made. Furthermore, it provides potential design improvements for future releases of the system. The sensors placed at the main doors detect car door open-close sequence and checks if the override button has been pressed. If the override button has not been pressed, the system uses RFID technology to search for registered RFID tags attached to the keys that are in the vicinity of the car. The RFID reader, also known as the transceiver, is programmed to search for the tags within a search range that best fits the area of the car. A buzzer is used to alarm the user if the system detects the keys inside the car. Additionally, sensors attached to the door locks tell the microcontroller whether the doors are locked or unlocked. If all the doors are locked, a DC motor attached to the power lock actuator is driven to unlock the driver's door. All of the hardware and software components included in the Vehicle Lock-out Prevention System are controlled by a central microcontroller. The system comes with a user interface mainly consisting of LEDs to indicate system status and battery status.

A detailed description of selection of resources and microcontroller requirements is provided. A general system process flowchart with integrated hardware and software programs is also provided. A system test plan with ample test scenarios is provided at the end of the document. The system-wide tests will ensure that the Vehicle Lock-out Prevention System is fully functional and ready to be deployed.

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GLOSSARY

RFID	Radio Frequency Identification
USB	Universal Serial Bus
LED	Light Emitting Diode
Microcontroller	A small computer built on a single integrated circuit consisting of a simple CPU, clock timers, I/O ports and memory
CPU	Central Processing Unit
I/O ports	Input/Output ports
API	Application Programming Interface
A/D conversion	Analog to Digital conversion
PWM	Pulse Width Modulation
dB	Decibel

1. INTRODUCTION

Our product is the vehicle lock-out prevention system. It is used by vehicle owners to prevent them from locking their keys in their car. When the keys are sensed to be inside the vehicle, an alarm indicates to the user that the keys are still inside. If all the doors are locked, the built-in unlocking mechanism unlocks a door for the user. The user can then access the vehicle, retrieve their keys, and shut down the system.

This design specification document uses the functional requirements as a basis for our design. Only the proof-of-concept design requirements are being implemented at this time.

This document is written for Undent Solutions. It is to be used as a guideline for design engineers. The test plan is to be used by the test engineers. The resulting product should be as described in this document. However, components may differ slightly depending on differences in car models and may not appear identical to drawings introduced in this document.

2. SYSTEM SPECIFICATIONS

Our vehicle lock-out prevention system notifies users immediately if their keys are locked inside the car and unlocks the door using an unlocking mechanism, so the user can retrieve the keys. The unlocking takes place within 5 seconds to prevent unauthorized access to their vehicle. The system also provides a manual override button that temporarily stops the system from searching for keys and the system will remain in an idle state until triggered by a door opening and closing.

3. OVERALL SYSTEM DESIGN

The following section focuses on system design specifications common to the entire system. The main individual components: unlocking mechanism, RFID transceiver sensors and tags, microcontroller, door sensors and buzzer will be discussed in further detail in their own following respective sections.

3.1 Mechanical/Physical System Design

Our system's mechanical aspects include the unlocking mechanism, door open-close sensors, door lock sensors, and user push-button.

The unlocking mechanism will be installed inside the driver's door of the vehicle. The gear train and motor will be encased in a plastic box. Overall, the entire mechanism is to be put inside the vehicle's door and wires connecting the motor extend to the power source.

Door status sensors check for the open-close sequence of the doors. These will need to be installed on every door. We are using momentary push buttons to implement this function and switching to harder plastic or rubberized push buttons if necessary. We will be using our own buttons, but it has been suggested to tap into the car's existing door status sensor to lower the cost of parts for our system.

Door lock sensors check if the lock buttons have been depressed. These sensors will also be installed on all the doors. However, if the vehicle is equipped with power locks, the door lock sensors will only need to be installed on one door.

All buttons needed by the user will be installed as part of the box unit on the dashboard. This is to make it easier for the user to access the controls of the system and retrieve any visual feedback.

3.2 Electrical System Design

The main RFID transceiver will be placed inside a plastic enclosure along with the microcontroller, buzzer and 3.3V battery supply. The 3.3V battery will consist of two AAA batteries to provide enough power to meet the power requirements of the components. Also, the batteries are easy to replace. To make the product more environmentally friendly, the two AAA batteries can be replaced with rechargeable batteries to reduce landfill waste and promote reusability.

The tags will each use a 3.3V button cell battery. Using button cell batteries will allow the tags to be portable and light and it will provide long lasting power for an estimated battery lifetime of 6 months.

The microcontroller will be directly connected to the unlocking mechanism through standard copper wiring. The DC motor itself will be remotely powered using a separate battery to provide enough power to operate the unlocking mechanism.

3.3 High-level Design

Our system uses a microcontroller to process tasks requested by the RFID transceiver. The RFID transceiver sensor is used to locate the tag and send all relevant information to the microcontroller for processing.

The figure below depicts the input/output data flow between the components in our system.

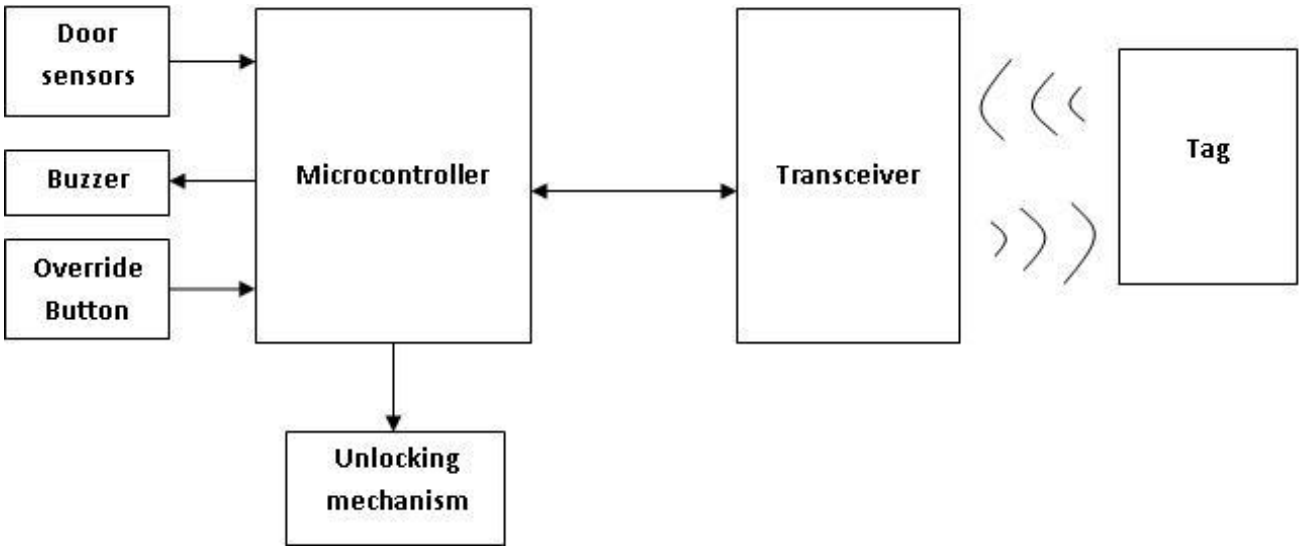


Figure 1: Block diagram with inputs/outputs to system.

Inputs to the microcontroller include sensing whether the door is open-closed, locked or unlocked and if the override button has been pressed. The outputs of the microcontroller include turning on/off the buzzer and unlocking mechanism which unlocks the car door.

The data sent between the microcontroller and RFID transceiver is bi-directional. When a car door has been opened and closed, the microcontroller sends a signal to the transceiver to check for the location of the tag. If the transceiver detects the tag within the car it sends a signal back to the microcontroller to handle the situation.

A wireless signal is transmitted between the RFID transceiver and tag. The RFID transceiver continuously checks for authorized tags and the tag sends back data containing its signal strength.

3.4 Component Placements

The system unit comprising of the main RFID transceiver sensor, microcontroller, buzzer and batteries are placed at the front end of the vehicle. The secondary transceiver sensor is located underneath the middle back car seat. This configuration is shown in the figure below:

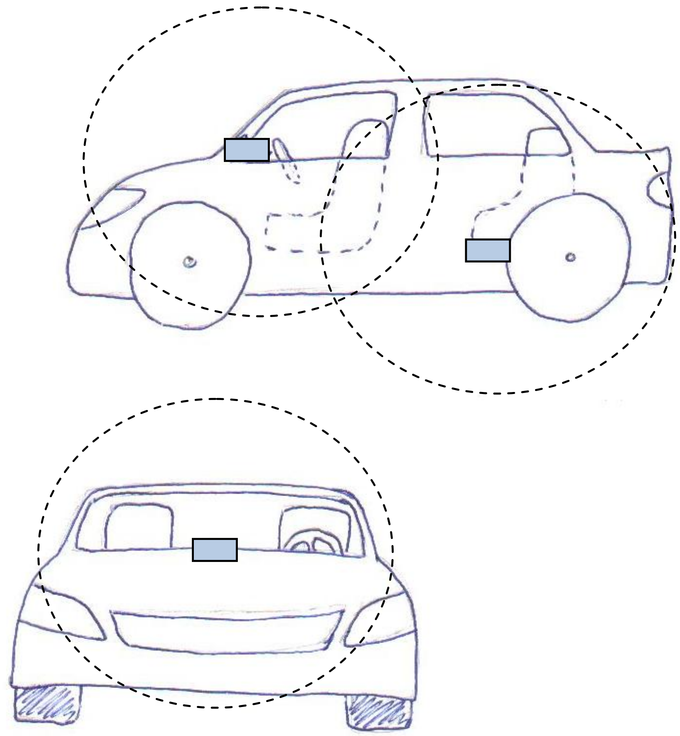


Figure 2: RFID transceiver range and placement within the vehicle

We chose these locations for the sensors because it is the optimal solution to limiting the sensor range within the confines of the vehicle without the addition of more sensors. Furthermore, we placed the secondary transceiver sensor closer to the floor of the vehicle because the sensor range would cover the entire back end of the car as well as sensing the signal down into the ground. Since it is highly unlikely the keys will be located underneath the car and in the ground, we have opted to place the sensor closer to the floor of the vehicle.

The placement of the components within the system unit is shown in the figure below:

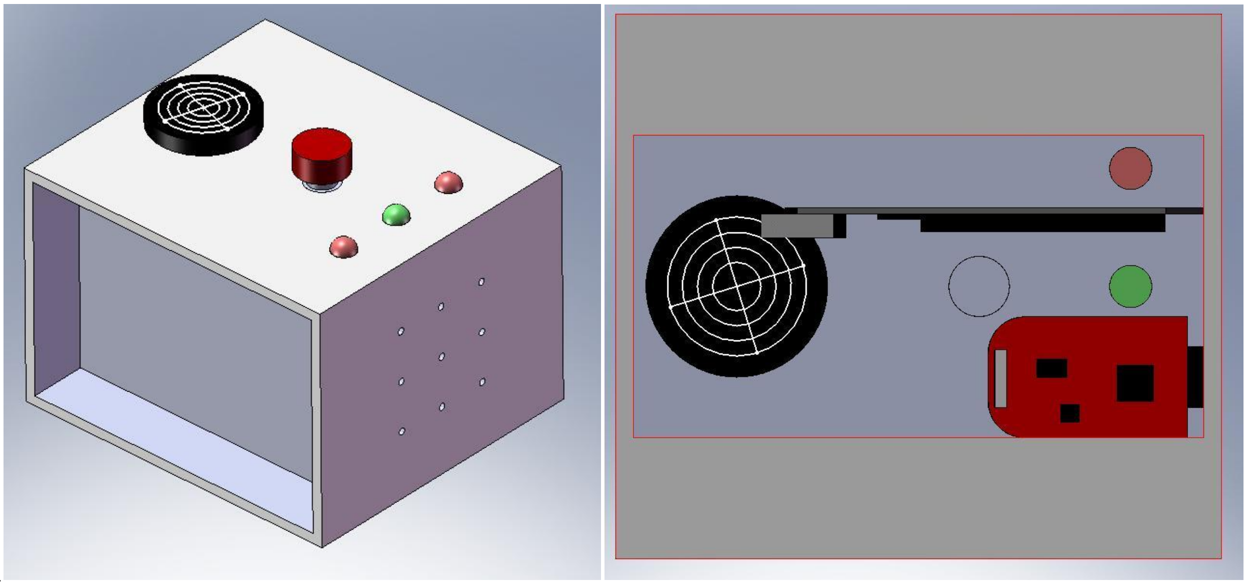


Figure 3: Isometric view (left) and bottom view of system unit (right)

The batteries will be placed at the sides of the system unit. In the final production product, the system unit will have cases at the side to hide the batteries and also provide easy access to changing the batteries. We also decided to place the microcontroller vertically and the RFID transceiver horizontally to maximize airflow through the box. Moreover, the system unit has perforated holes at the sides to prevent overheating inside the box as a precautionary method. Generally, the microcontroller and RFID transceiver do not emit large amounts of heat.

The unlocking mechanism will be installed inside the driver's car door. The following figure illustrates the placements of the gears and motor of the unlocking mechanism:

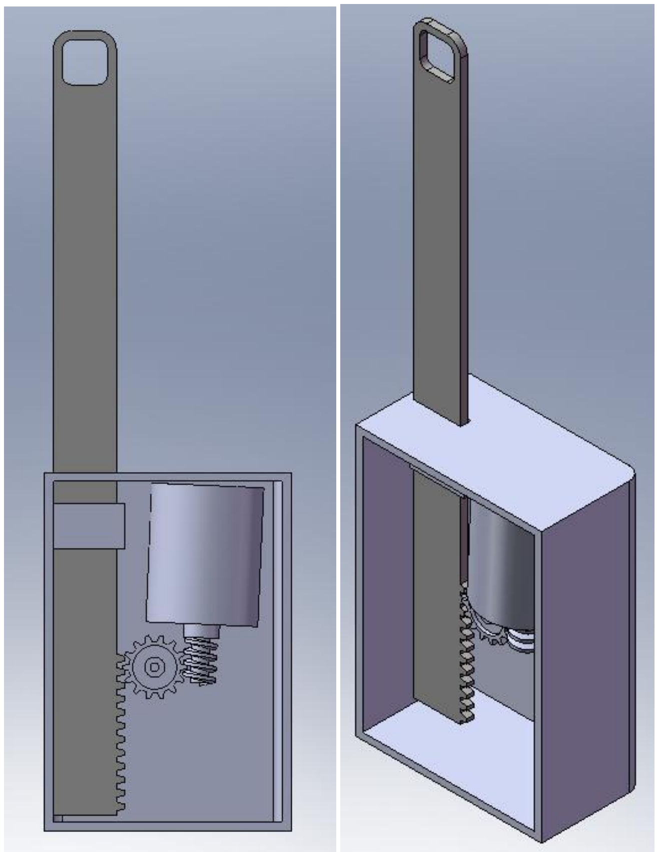


Figure 4: Isometric view and front view of the unlocking mechanism

We are using door sensors to detect when the door opens and closes and whether the door is locked. Ideally, sensors will need to be placed in every door to check if it's locked. For vehicles with power locks, only the driver's car door will need the sensor installed. The door sensors that detect the open-close sequence will be placed where the door meets the vehicle door frame.

4. MICROCONTROLLER

The microcontroller is the heart of our design. It controls all of the hardware and software associated with the Vehicle Lock-out Prevention System. The main requirements of choosing the ideal microcontroller were cost, power consumption, CPU speed and ease of use. We therefore selected the reasonably priced Arduino Duemilanove microcontroller board based on the ATmega168 microcontroller which operates at a low 5V, has a clock speed of 16MHz and comes with ample API functions and reference material [2].

4.1 Overview of the Microcontroller

The microcontroller communicates with the buzzer, override push button, RFID readers, door and lock sensors and the unlocking mechanism motors. The system uses 1 buzzer, 1 override button, 2 RFID readers, 4 door sensors (for a 4 door vehicle), as well as door lock sensors at every door (4 door sensors and 1 door lock sensor for power lock vehicles), and 1 unlocking mechanism motor at the driver's side door. We have determined that the microcontroller will have seven tasks to complete throughout the system run, as presented in the functional specifications document. Evidently, the microcontroller requires a considerable amount of processing power.

4.2 Control Hardware

This section provides a description of the selection criteria used for the microcontroller. We examined the number of digital I/O pins required, interrupts, communication, and hardware protocols given in the microcontroller. We also examined packaging, cost, on-board memory and built in peripherals. The final decision of which microcontroller to use was based upon cost, power consumption, CPU speed and ease of use.

Table 1 shows different digital input and output signals utilized by the system and attached to the microcontroller. We have determined that a total of 12 digital signals will be used by the Vehicle Lock-out Prevention System. Each I/O signal will be connected to a dedicated pin on the microcontroller and we will use software interrupts and timeouts to control dataflow to/from each pin. Note that the RFID reader acts as a digital input. When the microcontroller is ready to check if a tag is detected inside the car, it will establish a serial communication with the reader and listen to the data: a yes/no signal sent by the reader.

Table 1: Digital signals

Name	I/O	Quantity	Description
Override button	I	1	To temporarily idle the system upon user request
Door sensor	I	4	To detect door open-close sequence
Door lock sensor	I	2	To detect whether the door is locked/unlocked
RFID reader	I/O	1/2	To ask each reader to start checking for tags and receive reply from reader
Buzzer	O	1	To alert the user when the keys are detected inside the car
DC motor on/off control	O	1	To enable/disable the door locking motor

There are no analog signals connecting to the microcontroller, hence, no A/D conversion is necessary. Table 2 shows the only PWM signal connected to the microcontroller.

Table 2: PWM signals

Name	I/O	Quantity	Description
Motor power control	O	1	PWM line for motor power output control

Summing up all the different PWM and digital I/O signals, we need 13 programmable I/O pins on the microcontroller. Therefore, we need a microcontroller that contains at least 13 digital pins with some pins that can be PWM configurable.

Related research enlightened us with numerous microcontrollers that would suit our application. An 8-bit microcontroller seemed accurate enough for all system operations. Some of the potential microcontrollers we found were: PIC microcontrollers (Microchip Technology Inc.), MSP430 (Texas Instruments (TI)) and AVR ATmega168 (Atmel). A wide range of third-party vendors offer these microcontrollers within a reasonable time period and at a reasonable price. The amount of memory available varies for each microcontroller. Our aim is to use a microcontroller with flash memory, due to ease of programming. Other considerations of microcontroller selectivity include low power consumption and ability to handle multiple hardware devices.

4.3 Control Software

The control software of the Vehicle Lock-out Prevention System will consist of multiple tasks/functions as shown in Table 3. A main process will coordinate and communicate with the scheduled tasks.

Table 3: List of functions

Function	Priority	Amount of processing	Frequency of execution (Hz)	Description
Scheduler	1	Heavy	100	Schedules and prioritizes all the functions to be executed by the microcontroller
Door position sensing	2	Light	50	Checks if a door open-close sequence has occurred
Manual override	3	Medium	75	Temporarily shuts off the system + turns off the buzzer if beeping
RFID data transfer	4	Heavy	100	Receives data read by the RFID readers
Buzzer	5	Light	50	Sends an audio signal when keys are detected inside
Door lock sensing	6	Light	50	Checks if the door is locked/unlocked
Unlocking mechanism	7	Heavy	50	Powers up the motor to unlock the main door
Main process	8	Heavy	10	Issues commands to each function for completion of tasks, assigns delays and deals with software interrupts

As mentioned in Table 3 above, the scheduler decides which function is to be executed at a given time. Since the scheduler has the highest priority, it will have the control token until it idles or terminates. All other functions will yield to the scheduler and wait until the token is given to them. Once those lower-priority functions end, the token is passed back to the scheduler which will prioritize functions and continue normal operation.

Some of the high-priority functions include door position sensing, manual override and RFID data transfer. A switch placed at the front door frame detects state changes (pressed/released), the microcontroller waits until the switch detects two consecutive state changes (from pressed to released and from released to pressed) and detects if the input from the manual override button is high (pressed). If the override button is pressed, the scheduler resets the system and goes to idle state, meaning that the user has chosen to override the system. If no override is detected, the scheduler gives access to read data from a serial object such as the RFID reader. If the data read is valid and the RFID reader sends a message indicating that an authorized tag is detected inside the vehicle, the scheduler indicates that the keys are detected inside the car.

The medium-priority functions are operating the buzzer, door lock sensing and controlling the unlocking mechanism. The buzzer is set to go off when the doors are closed and the keys are detected inside the car. The scheduler will assign the main process to listen to the door locking sensors. If the sensors detect that the doors are locked, the scheduler will give power to the DC motor to unlock the main door. The buzzer will stop when the manual override button outputs a high (override button is pressed).

The lowest priority function is the main process. The main process examines the current state of the Vehicle Lock-out Prevention System and calls necessary functions according to scheduler commands. The main process is given a more detailed explanation in the following section.

4.3.1 Main Process

The main process calls the necessary functions for completion of tasks as shown in the flowchart of Figure 5.

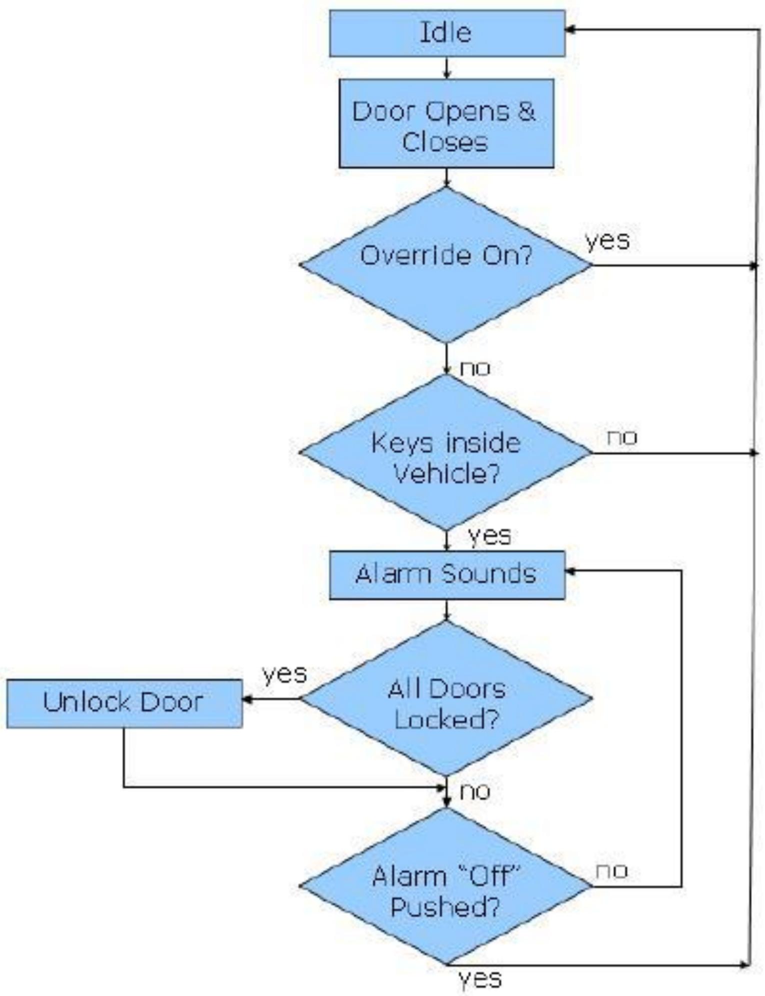


Figure 5: System flowchart

The main process is always on as long as the batteries are attached. The main process initializes the motor, sensors, buzzer and other peripherals attached to the microcontroller. The main process is idle until the door is opened and closed. The main process will activate the system and call the door sensors to check if the user has selected the manual override option. If so, the main process goes back to the idle state. If not, it calls the RFID reader function to read serial data received from the reader. Upon retrieval of valid data, the main process calls the buzzer function to alert the user of possible lock-out scenario. Then main process then reads data from the door lock sensors. If the door is locked, it will call the motor function to unlock the main door. If the doors are not locked, the main process goes straight to checking if the override button has been pushed so that the buzzer can be stopped. The main process will keep looping through the door lock sensor function until the buzzer is turned off, upon which the system will go back to an idle state. This looping function is implemented for the case where vehicles have doors that automatically lock themselves after a certain amount of time has passed.

5. RFID TRANSCEIVER AND KEY TAGS

The purpose of the RFID transceiver and tags is to provide a wireless method of detecting where the car keys are located. We looked into finding a cost effective, simple and portable device capable of receiving data wirelessly. For our system, we chose the eZ430-RF2500 development tool with the eZ430-RF2500T target boards manufactured by TI. It gave us freedom to program the target boards to act as a transceiver (Access Point) or tag (End Device). Also, multiple tags can be connected to the transceiver network and each tag can be detected by more than one transceiver, which is needed by our design. Moreover, the RFID transceiver had multiple development pins available, extensive user documentation and sample tutorial guides for programming the boards.

5.1 Physical Design

The following table outlines the measurements of the transceiver and tags.

Table 4: RFID sensor and tag measurements

	Length (cm)	Width (cm)	Depth (mm)
Transceiver & Tag	3.3	2	1

For the final product, the transceiver will be encased in the system unit and the tag will be placed in a plastic case with a 3.3V button cell battery.

5.2 Electrical Design

Both the transceiver and tag have low current consumption, which is desirable because we want the device to be both reliable and long lasting. There are 21 development pins for programming, which can be further expanded using an expansion board which provides 6 additional pins. Furthermore, the transceiver and tag can be detached from the USB debugging interface and embedded into another board with an external 3.3V power supply. The eZ430-RF2500 boards contain a MSP430F2274 microcontroller and CC2500 radio chip for wireless data transfers. The following table outlines basic operating specifications for the MSP430F2274 and CC2500 chips.

Table 5: MSP430F2274 and CC2500 specifications [3]

Parameters	Value
MSP430F2274	
Operating Voltage	1.8-3.6 V
Current consumption (active mode)	270 uA
Current consumption (standby mode)	0.7 uA
Operating Frequency	16 MHz
CC2500	
Operating Voltage	1.8-3.6 V
Current consumption RX	16.6 mA
Current consumption TX	21.2 mA
Frequency range	2.4 GHz
Data rate	1.2-500 kbps

For the transceiver, we are using two AAA batteries (3.3V) and a single button cell battery (3.3V) for the tags. Our design integrates the transceiver into the system unit while leaving the tag as a stand-alone device, so that it is portable and can be attached to a key ring.

5.3 Inputs and Outputs

The transceiver is always active and continually checks for new or existing tag requests to join the network. Upon receipt, the transceiver stores the unique ID and waits for data from the tags. The tag will flash both its red and green LEDs indicating it's still trying to establish a link with the transceiver. Once the tag has been established in the network, it sends data containing its signal strength and battery level at intervals of 1 sec while flashing only the green LED. Unlike the transceiver, the tag remains in a sleep mode drawing low amounts of power and only wakes up when sampling its own signal strength and battery level. The transceiver then processes this data and determines whether or not the tag is located inside the vehicle and sends a message to the microcontroller for processing if the tag is found. Otherwise, the transceiver sends another message to the microcontroller indicating no tags were found and it returns to an idle state.

Since any tag can request to join the network, each tag will be assigned a unique ID and only those tags with the correct ID will be authorized. This is also a precautionary measure because any tag can join the network. This prevents a security and safety threat to the owner.

6. DOOR SENSORS

Door sensors are used to detect and determine the current vehicle door states: open or closed. Although most of the current vehicle models already incorporate sensors exclusively for door open-close detection, our product still uses independently installed door sensors to enforce better stand-alone modulation and easier installation process. We have future plans to investigate integrating with the built in door sensors found in some vehicles.

6.1 Door Sensor Overview

The vehicle door status is one of the most important indicators used to determine how the integrated system should work. Each sensor needs to be reliable with high tolerance to any external interference. It also needs to have a very good response time. We have two potential door sensor design approaches: momentary push buttons or electromagnetic proximity sensors.

6.2 Door Sensor Hardware

Our first design approach is to use plastic or rubber momentary push buttons as the door sensors. When the door opens the push button will release and when it closes the push button will become depressed. This push button sequence of opening and closing of the door will trigger a signal to the microcontroller for processing.

If through testing we find that the plastic or rubber push buttons do not withstand the forces exerted on them, we will use electromagnetic proximity sensors. For each door sensor, one set of electromagnetic proximity sensors is used to determine the proximity between the vehicle door and vehicle frame. The proximity sensor consists of a magnetic strip (secondary winding) which is constantly outputting a magnetic wave which is only strong enough to be detected within a certain range (such as when door is closed) by the primary loop installed on the vehicle frame. The primary winding is a similar magnetic strip that is connected to the main microcontroller. The door sensor should also be contact free to minimize any chance of damage to the vehicle or the sensor itself [4].

6.3 Electromagnetic Proximity Sensor Operation Principle

Each of the proximity sensors for each vehicle door will constantly monitor the distance between the primary and secondary windings and generate a signal whenever the status changes. This signal of change is used as an interrupt signal for the microcontroller. Depending on the current state (open/closed) and the previous state, the system will determine its next logical decision. Proximity sensors generate an analog signal and its output voltage varies according to the excitation by the primary winding. Through experimentation, the cut-off voltage for distance determination will be determined.

This cut-off voltage will be accomplished by filtering the analog output from the proximity sensor with a simple high-pass filter, in which the signal is either a logical high (1) or low (0) after filtering.

7. UNLOCKING MECHANISM

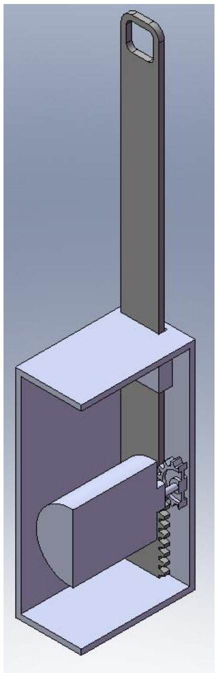
7.1 Unlocking Mechanism Overview

The unlocking mechanism is to be installed in the driver side door. When the door lock sensors indicate that all the car doors are locked, the microcontroller sends a signal to the unlocking mechanism and it unlocks the door.

7.2 Physical Design

The unlocking mechanism consists of a motor and a gear train, created to mimic the "up and down" motion used to lock and unlock a vehicle.

We have two proposed designs for the gear train used in the unlocking mechanism. Figure 6 illustrates our two designs. As seen in figure 6, the difference in the two designs is the helical gear and angle placement of the motor.



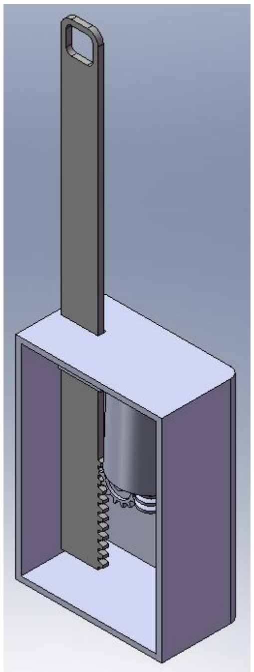


Figure 6: Horizontal placement (left) and vertical placement of the motor (right)

Both models can be applied, based on the space available inside different car doors. The model without the helical gear is preferred because the gear train is shorter and would result in less energy loss due to friction between gears. However, due to space limitations within the car door, this configuration may not always be possible. Actual components may differ slightly from the figures due to component availability and space limitations. After building the proof-of-concept model, an optimal unlocking mechanism will be built.

8. BUZZER

The buzzer is used as an audio indicator to notify the user that their keys are inside their vehicle.

8.1 Buzzer Overview

The buzzer should have a distinct sound. It should not be easily confused with other sounds such as: music, human conversation or other alarms. Furthermore, the buzzer should not output excessive volume deemed harmful to the human ear, which is above 85 dB [5]. The buzzer should be small, compact and able to fit into the small plastic casing containing the system unit.

8.2 Buzzer Operation Principle

The buzzer should be activated whenever the on-board microcontroller determines that the key is left inside the vehicle. In this case, the buzzer will be activated by the voltage supplied by the microcontroller. When activated, the buzzer will play a series of pre-programmed tones to warn the user. It will deactivate when the user presses the override button on the system unit.

9. USER INTERFACE

The user interface (UI) allows the user to manually control the product. Since we are designing a product requiring minimal configurations by the user, only one user configurable button and a few LED indicators are used by the UI.

9.1 User Interface Hardware

Product UI will consist of one button which turns off the system. There will be three LED indicator lights which represent system unit power, main RFID transceiver battery power and secondary RFID transceiver battery power level.

9.2 Override Button

The purpose of this button is if the user wants to turn off the buzzer sound. Once this button is engaged in the ON position, the buzzer will no longer output any warning signal.

9.3 Low Battery Indicator

Several AAA batteries will be used for the operation of the system. A low battery warning LED is incorporated into the user interface to warn the user when the RFID transceiver battery level is running low. For the tags, the low battery level can be observed on the tag itself and indicated by a flashing LED.

10. SYSTEM TEST PLAN

Our Vehicle Lock-out Prevention System will undergo thorough testing before rolling the final product out to production. The individual system components will be tested first followed by entire system tests with several normal and extreme cases.

10.1 Unit Testing

To ensure safety and accuracy, each individual component of the system will be tested. The success of the tests will be determined by the outcome of the following scenarios:

1. Establish communication between the RFID reader and only the authorized RFID tags.
2. Display serial data received by the RFID reader through the microcontroller.
3. Test the door open-close sequence and verify the microcontroller receives correct data from the sensors.
4. Verify that the override button makes the system idle; also verify that it stops the buzzer when the buzzer goes off.
5. Ensure proper functionality of the buzzer as well as the power of the audio signal
6. Test the functionality of the door lock sensors.
7. Test the DC motor to make sure the door is unlocked when the lock sensors indicate that the doors are locked and override option is not selected.
8. Use 2 sets of batteries: one with more than 75% power left, another with less than 75% power left to test the low-battery status indicator circuit and the status LEDs for each individual reader, tag as well as the microcontroller.

10.2 Normal Case 1: Keys inside the car, door opened + locked + closed

User Input: None

Conditions: The user has opened the door, locked the door and closed the door while leaving the keys inside the car. This is a typical lock-out scenario.

Expected Observation: Within approximately 2s, the buzzer goes off. Within another 5s, the main door unlocks. The buzzer turns off when the user hits the override button.

10.3 Normal Case 2: Keys inside the car, door opened + closed + locked

User Input: The user who is still in the car pressed the override button

Conditions: The user has opened the door, closed the door and locked the door. The keys are inside the car with the user.

Expected Observation: If the override button was pressed immediately (before the buzzer is activated), nothing is observed. However, if the override button was not pressed immediately, the buzzer will go off until the button is pressed. The doors will remain locked if the override button was pressed within 5s of buzzer activation. Otherwise, the main door will be unlocked automatically.

10.4 Normal Case 3: Keys inside the car, door opened + closed + user inside

User Input: The user presses the override button

Conditions: The user has opened and closed the door. The user is still inside the car along with the keys.

Expected Observation: If the override button was pressed immediately (before the buzzer is activated), nothing is observed. However, if the override button was not pressed immediately, the buzzer will go off until the button is pressed. If the car is a newer model that automatically locks the doors when left unlocked for about 30s, and if the user has not pressed the manual override button until the doors are locked automatically, the main door will unlock. If the car is an older model, the door remains unlocked.

11. CONCLUSION

In this document, we have outlined our design specifications for the Vehicle Lock-Out Prevention System. We have looked at the design as a whole and also its individual components. We have also provided test cases for verifying the correct operation of the system. The designs and test cases are to be followed by engineers working for Undent Solutions. It is expected that these specifications are followed as closely as possible when building the system. Any changes to the design must still follow the guidelines set in the *Functional Specification for the Vehicle Lock-out Prevention System* [1] document.

12. SOURCES AND REFERENCES

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