Road Safe Phone Case

DESIGN DOCUMENT

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1 Introduction

1.1 Acknowledgement

This project has been made possible by the Iowa State University ECpE Department's professors and resources. The team is grateful to have the opportunity to receive technical advice and guidance from Dr. Diane Rover. She has served as a knowledgeable point of contact as the project, providing valuable information to help the project progress. The individual that proposed this life-saving device, Christine Shea-Hunt, is also the sole provider of financial aid for the project materials. The team is committed to using the funds wisely, so that the road safe case will be created efficiently and inexpensively. The Electronics Technology Group (ETG) has also provided the team with equipment and advice that have improved the product's design.

1.2 Problem and Project Statement

Phones have become an integral part of everyone's lives. Communication, entertainment, and organization are only a few of the advantages a phone offers. However, this small device can also serve as a fatal distraction. According to the Centers for Disease Control and Prevention, in the U.S. alone, approximately 9 people are killed and more than 1,000 injured in crashes involving distracted drivers daily (2017). Talking on the phone, sending a text message, using navigation systems, and more are just a few ways that drivers easily endanger themselves and others on the road.

To help make the road a safer place, the amount of distracted drivers must be reduced, which can be accomplished by removing the temptation of a phone. The approach to this problem will be to create a device that locks away the keys to car, unless the phone is swapped for the keys. Progress towards safe driving can be achieved by creating a two-sided case, in which one of the two sides always remains locked. One side will securely store the keys until the other side detects, verifies, and secures the driver's phone. Then, to reacquire the phone, the keys would need to be returned, verified, and secured in the case. In case of emergency, access to either the phone or keys will be made available, and the case can be reset to function normally and protect the drivers and the roads once again.

1.3 Operational Environment

The road safe case will mostly operate in a car, which should endure various temperatures. The case will need to be able to withstand normal and hazardous weather conditions inside a car, whether it be extreme cold or heat. The case should also fit in a spot within the car so that it remains stationary while in a mobile vehicle. The interior of a car also often gathers dust and at times trash, though this does not pose a threat to the case unless there was direct interaction with the case. Other potential environments are inside a home, because the case will portable and may be moved to other locations if the user needs to take the case to a parent to reset it or for other

reasons. However, the case does not have functions that primarily relate to being outside of the car environment.

1.4 Intended Users and Uses

The intended use of the road safe phone case is as its name implies. To keep the roads and drivers safe, especially drivers that are easily distracted by their phones. The case restricts the driver's ability to access their cell-phone while driving, which will increase the safety of driving for themselves and others significantly. More specifically, the road safe case not only locks away the driver's phone, but their car keys as well. In order to access one item, the other must be locked in the case. Audio capabilities such as GPS or music can still be utilized while the phone is in the case; however, the screen will not be visible.

Studies have shown that compared to adults, teenage drivers are four times more likely to get into car crashes or near-crashes when talking or texting on a cell-phone, with approximately 21% of fatal teenage driving accidents resulting from cell-phone distractions (Edgar Snyder and Associates, 2016). As a result of these trends in distracted driving, the road safe case will primarily be used by teenagers. However, an AAA poll that showed while 94% of teen drivers acknowledge the dangers of texting and driving, 35% admitted to still doing it anyway (Edgar Snyder and Associates, 2016). This demonstrates that many teenagers would not impose phone restrictions on themselves. Thus, the case will be marketed to parents who have to the ability to oversee their children, and choose to enforce safer driving for them.

Distracted driving due to cell-phones is not only abundant in teens, but especially in drivers in age groups above 20 years-old as well (National Highway Traffic Safety Administration, 2012). Thus, the road safe case may also attract responsible drivers that choose to limit their distractions on their own, unlike a young teenager whose parents may buy the product for them. However, to use the product to its full potential, an additional individual should assist the driver by serving as the "parent" figure and holding the driver accountable for maintaining use of the case and not engaging in distracted driving.

1.5 Assumptions and Limitations

Assumptions:

- The case will operate off a battery as opposed to a car source.
- The case will only detect if an object placed inside is a phone and a key.
- The driver will only have one phone.
- The driver will be capable of accessing their phone in an emergency.
- The driver has a designated individual in which notifications can be sent.
- The cost to fabricate the case will be under $500.
- The case will be sold to other individuals.
- The case will fit in a car comfortably.

Limitations:

- The system will operate from a battery supply because the case will be portable.
- The phone case will only detect one phone at a time; thus, it cannot restrict other passengers in the car.
- The phone's features, such as GPS or music, will only be accessible through audio because visuals will be covered/restricted by the case.
- The case must be small and lightweight to avoid restricting passenger seating, to be easily portable, etc.
- The road safe case will function as a two-person system, so that if the driver uses the emergency access to open it, an emergency contact will be alerted.
- The project must be completed with a budget of $500.
- The end cost of the product should be relatively inexpensive because this product will be made available to other potential consumers.
- The project must be completed by the end of the year.

1.6 Expected End Product and Deliverables

The entire design of the road safe case will be completed by the end of April, possibly with a prototype as well so that some of the parts can be tested before constructing the end product in the fall. The capabilities of the case will continued to be tested and discussed between the team and the client throughout the year, so that the final, fully-functioning product can be produced by December.

The vision for this final product is the physical, portable case that easily fits in a car, and will store the car key and store or release the phone based on the circuitry built and programmed by the team to protect the user from distracted driving. This will require a locking unit powered by a motor and controlled by the Arduino, a GSM module to send emergency notifications, and possibly a printed circuit board for further capabilities. These components will be safely and neatly stored in the case within the case, creating the Road Safe Phone Case that can either be further improved with additional software applications or marketed as is to other parents or responsible drivers that wish to purchase the product.

2. Specifications and Analysis

2.1 Proposed Design and Methods

For this senior design project, the team's goal is to eliminate the fatal distraction from the cell phone usage while the user is driving and minimize the chance of a car accident. In order to achieve this goal, the team researched approaches other than what was originally proposed by the client. Some other options explored were making a software that can sense the moving speed of the vehicle and use that to determine whether the phone should be accessible or creating an app or some form of an interface with the vehicle to force the driver's phone to enter "Air Mode" during the drive. The disadvantage of this approach is that the software does not have firm control over cell phone usage, the user can delete or turn off the app easily, and could not discriminate if the user is a driver or passenger.

A further analysis of the software-based and hardware-based solutions are shown in the tables below. For hardware the team focused on the advantages and disadvantages of the case, which would be a new product, a physical case that is portable and more restrictive on the user. For software, an improvement on an existing app or creating interface with car to restrict users when they choose to was explored

PROS	CONS
• Can't touch or look at the phone • Safer because a parent or designated person has more control over driver's phone usage • Easy emergency access • Has not been made before, first of its kind • Possibly more preferable by older generation or protective parents because this option is more restrictive and physical	• Physical case - needs to be carried at times and must have space in the car to accommodate it • More expensive to purchase • If another phone is in the car, driver could use friend's phone • Difficult to fully enforce this tactic on a driver • Infotainment and GPS capabilities are more limited because they can only be accessed through audio and speech

Table 1: Hardware Approach

PROS	CONS
• The product is already on the phone, so it is easier/more convenient to access • Ability to look at the navigation (also a drawback) • Easy emergency access • Cheaper to make and purchase • Blocks or replies to calls for the driver to let others know they are driving • Possibility for driving analysis or parental control/communication options	• Driver can look at and touch the phone at all times • Less control over usage because apps or plug-ins can easily be disabled ○ To undo 'safe-driving mode', user can tap to unset easily or if the app relies on vehicle speed, it may allow for traffic usage while driving • If another phone is in the car, driver could use friend's phone • Difficult to fully enforce this tactic on a driver

Table 2: Software Approach

There are several disadvantages that may arise in the presence of additional passengers allowing the driver to use a friend's phone or in the case that a driver attempts to find a way to escape any possible restrictions. These cons would be applied to both the software and hardware approaches. After analyzing different approaches, the consensus reached was that the project should combine both software and hardware design. Hardware can provide relatively more control over cell phone usage while the user is driving, and the software can provide a quick, efficient command for mechanical operation and more advanced functionalities. However, the team is more knowledgeable in hardware and will pursue this aspect of the project more heavily until the end of the year. If time allows, the team hopes to also further integrate the case with subsystems that regulate the car, to offer more features to the user.

As of now, the hardware design includes a durable double-sided case with covers for storing either the cell-phone or the car key, a motor-operated locking mechanism for performing the interlock operation, and multiple sensors for sensing the mechanical activities and object inside of the case. The software design includes an Arduino Board for giving output commands to execute the mechanical locking operation, and a GSM module for sending out an alert when an intrusion is detected/emergency access is triggered.

2.2 Design Specifications

The project has four subsystems. All subsystems work though Arduino. The Arduino was coded to sense the mechanical activities through mechanical sensing subsystem and send output to control the locking operation. The emergency override is an independent subsystem, which is used for bypass all the sensing circuits and send an alert to notify the designated receiver. Expected

Product Size and Weight : Length: 30 cm, Width: 8 cm, Height: 5 cm, Weight: 0.8 lbs

Expected Subsystems : Software control, mechanical sensing, locking, emergency override

Expected Product Performance :

1. Perform proper interlock operation between cell phone case and car key case.
2. Perform proper cell phone recognition for the user.
3. Perform proper emergency override and intrusion detection function.
4. Allow the cell phone to have Audio and Bluetooth access to the vehicles.

2.3 Design Analysis

With this senior design project, so far, the "Design Thinking Workshop" methods have been actively implemented for the project to design and expand the possible approaches. Also, we have met with our project advisor to discuss our proposals for this project and coordinated with our client to finalize the project details.

The initial design has began to be implemented into an actual circuit during February; however, the team has experienced numerous problems. This includes issues with the locking device consuming too much power which then causes the coil of the lock to generate a tremendous amount of heat, the circuit board not receiving or generating the correct inputs and outputs which cause the mechanical devices to operate inappropriately, and the mechanical locking operation not following the correct sequence which causes us could not achieve required functionalities. The team has put tireless effort into solving these problems and have been able to correct a few issues for our project design, though there is still much work.

For the power consumption problem of the lock, it was discovered that the locking device that initially chosen must be constantly energized to maintain the locking condition, making the locking device become very hot after a long period of energization. In order to minimize the power consumption, the electrical lock was changed to a motor-operated lock, which only consumes power when the device needs to change the locking status. This change not only helped minimize the power usage but also reduced the amount of the lock that we need to use (because the motor-operated lock can lock the cases from both sides).

For the input and output problem for the Arduino board, it was learned that the Arduino board is a low voltage operating device. After energized, it accumulates some charges on different components. These charges could cause the input and output pins to send and sense false signals. A few ground wires were attached to the circuit to discharge unnecessary charge that interferes with software operation and solve the problems.

For the incorrect mechanical operation sequence, there is no valid approach for this problem. There have been attempts to add more sensors and edit the code, but still this did not solve the problems. For the next few weeks, the team will review finite state machines and attempt to use this method to resolve this issue.

3 Testing and Implementation

3.1 Interface Specifications

Sensors will be used to detect the system's inputs which comprise of the cell-phone itself and the cover for its portion of the case, the car key itself and the cover for its portion of the case, and the user's emergency button/sensor. This detection data will communicate with the Arduino Uno, which is programmed to lock or unlock based on which sensor(s) have been activated. The detection data will also be used to command the GSM A7 module to transmit a message to alert emergency access usage.

The outputs for the system are clear. However, the sensors that will be used to detect the inputs are still under debate. For the covers on each side of the case and the emergency button, a simple, inexpensive pressure detection sensor or push button are sufficient. The phone and key detection sensors require more complexity. The team plans to use a RFID card and reader for the cell-phone, but has also examined a wide range of different sensors that operate differently. These options will be explored until the most secure and satisfactory sensor can be determined.

3.2 Hardware Description

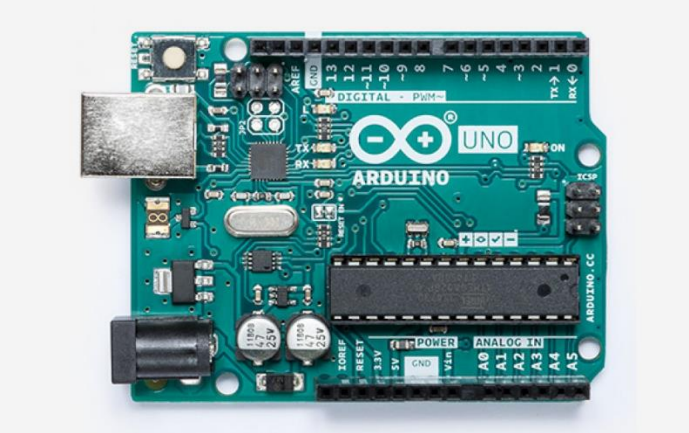

Figure 1: Arduino Uno Rev3

Microcontroller:
Arduino is an open-source platform used for building electronics projects. The Arduino consists of both a physical programmable circuit board (often referred to as a microcontroller) and a piece of software, or IDE (Integrated Development Environment) that runs on a computer, used to write and upload computer code to the physical board (Arduino Uno Rev3, 2019). In this project, microcontrollers will be used to implement the logic for controlling the locks in different situations.

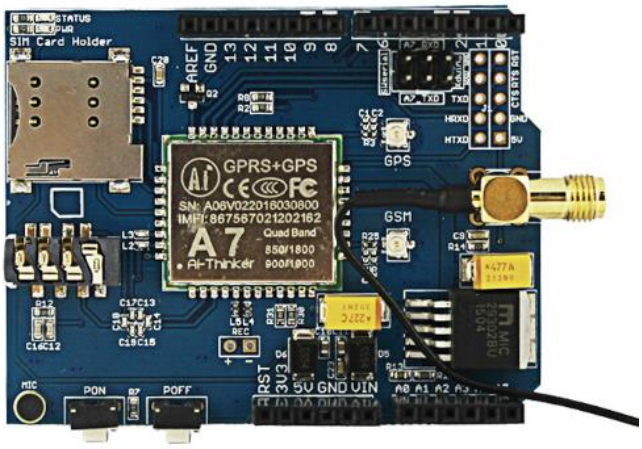

Figure 2: GSM A7 Module

GSM module:
A GSM system is necessary for allowing the circuit to establish communication with the parent of the driver or another designated individual in an emergency situation. The team plans to pair the GSM A7 module with the Arduino, so that a text message will be sent to an outside individual's phone when the Arduino senses the emergency button has been pressed.

Corresponding Locking Circuit:
The team will build a circuit on a printed circuit board, using general components such as bipolar junction transistors, resistors, and so on, which will send information from the sensors. This circuit will be combined with the Arduino platform to perform the locking status according to different sensor activations.

3D Printer:
Team will use the 3D printer to print the design from Autodesk fusion software to create the physical case.

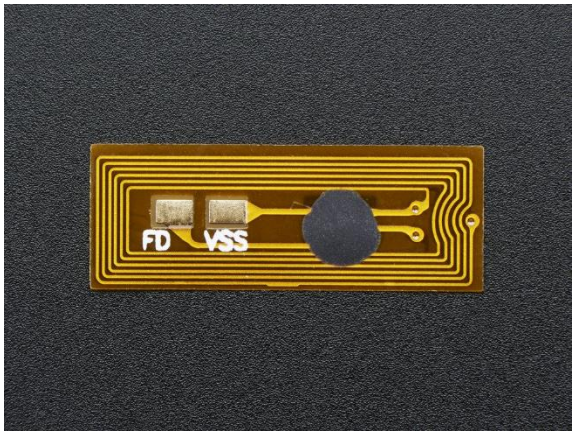

Figure 3: Radio-Frequency Identification (RFID)

RFID Card and RFID Card Reader:
The team plans to use an radio-frequency identification (RFID) Card and RFID Card Reader in this project. Each RFID Card should be register to a specific user by their parents which contains their information to let the system know that the phone is in the case. The RFIC Card will be placed in the back of the user's phone, and the system will use the RFID Card Reader to read the information in the RFID Card to determine whether this card belongs to the registered user.

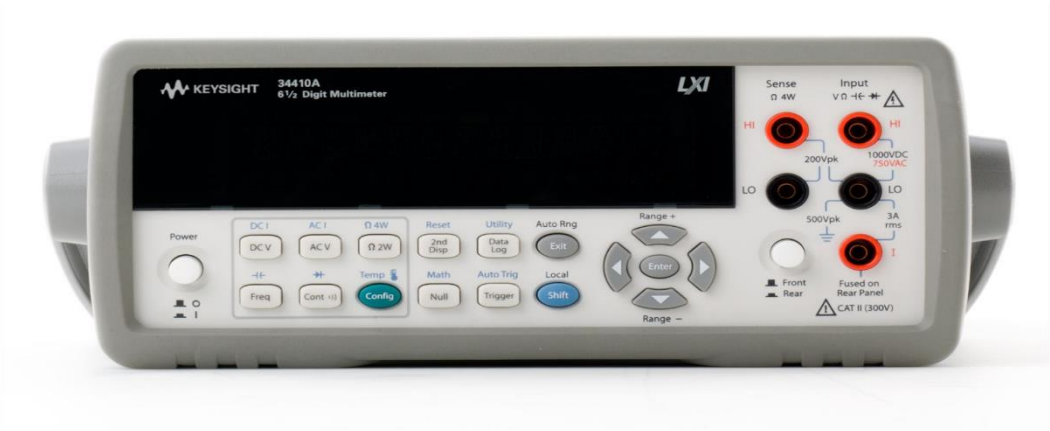

Figure 4: 34410A Digital Multimeter

Multimeter:
This device will be used in testing to measure the current, voltage and resistance for the corresponding locking circuit.

Figure 5: E3631A 80W Triple Output Power Supply

Power Supply:
The end product will have a portable power source. However, during the design process, the team use E3631A to simulate the power source for convenience purpose.

3.3 Software Description

Autodesk Fusion 360:
This software will be used to design the 3D model for the case and to create a simulation of the locking system.

Android Studio:
The team will use Android Studio to develop an android phone app that allows the users to edit the RFID Card, which communicates with the GSM module to send notifications to the parents during the use of this product. For example, when the drivers start their car or encounter an emergency situation, the system should also be able to send notifications to their parents through this app.

Multisim:
This software is a standard PSPICE simulation software for digital, analog, and power electronics. The team plans to use it to create circuit schematics and simulate the circuits.

Ultiboard:
This software can be used alongside Multisim. It can design printed circuit boards, and it is an essential tool to the build layout of the circuit.

3.4 Functional Testing and Non-Functional Testing

This project contains multiple key components and each component plays a significant role in this project. Thus, the reliability of each component is essential for the system to work as a whole. Therefore, subsystems will be tested individually first before assembling them together. There exists a priority among different components that must also be considered, which is why the team plans to conduct the functional testing in different stages.

Test 1:
In this stage, the functionality of the some of the basic elements in our systems which includes the battery life, sensors to detect the lid, locking systems, sending notification via phone app, emergency situation release, consistency of the 3D printed case, RFID Card edit and RFID Card read. The team expects those components will fulfill the following criteria:

- Battery life: the battery should be a rechargeable battery that can last for 5 hours
- Locking System: the internal locks should be able to lock and unlock as expected.
- RFID Card Edit: Be able to edit information to the RFID Card
- RFID Card Read: Be able to read the information out of the RFID Card.
- Sending notification: be able to send notification when users lock/unlock their phones, their parents should be receiving notifications.
- Emergency Situation Release: The system should be able to unlock when the user click the emergency button, but in the meantime, their parents should receive a notification.

- Consistency of the 3D printed case: The case should be relatively small, durable, open easily, and should be waterproof.

Test 2:
After successfully test all the components in Test 1, each individual component or subsystem can be integrated into the final product. In this stage, the parts will be gradually combined until they are all working in unison to create make the product whole. This will either be done at the very end or after a few parts have been completed individually to make sure they are compatible, though this is not a big concern because the components have been chosen specifically so that this issue does not arise.

3.5 Process

Battery life:
Connect the battery to a circuit with a motor that has the similar power compare to our system to determine how long until the battery runs out.

Locking System:
Connect the motor to the gear and gear rack to see if it can lock the case correctly. When one side of the box is locked, make sure the other side is unlocked.

RFID Card Edit:
Using the RFID card editing software to modify the card and read the output to see if it is already changed.

RFID Card Read:
Using the RFID card to approach the reader and analysis the output of the reader.

Sending Notification:
When the case is locked, the system should send a text message to the parents or designated individual. Also, when the case is unlocked, the system should also send a text message to the that person.

Emergency Situation Release:
Simulate the emergency situation (GSM module work with the emergency button). Once the button has been pressed, the Arduino will use GSM module to send message to parent's or designated user's phone.

Consistency of the 3D Printed Case:
Use a model phone to play the role of the actual phone and lock it inside the case. Then drop the case from a 1 meter height to see if the case got damaged or the fake phone got went off the locks and got damaged.

Full System Integration:
The final product is envisioned as the fully functioning case described as follows: Side 1 of the phone case would hold the key or key fob necessary to operate the vehicle. The driver would open Side 2 and place their cell phone in the case. When the cell phone is in place and the Side 2 door is shut and locked, Side 1 door would automatically snap open to deliver the key or key fob, thereby eliminating the use of the cell phone while driving. The phone could not be retrieved until the key/key fob is placed back into Side 1. Once the key/key fob is back in place, the door to Side 2 would open allowing access to the phone. If emergency button is pressed, the lid of Side 2 will immediately open to reveal the phone and send a notification to the parent or another designated user. The second user will remain informed of any emergency situations and possibly other statuses of the user and their interactions with the case during the use of the product.

3.6 Results

The project is still in its initial stages, so most of the testing has yet to be performed. The team has drawn preliminary schematics and made predictions as the designs have been developed. However, most of the subsystems remain as individual parts that still need integration before testing. Little testing has been performed on the locking mechanism, which has result in issues with the team's code and design that have been discussed in previous sections; This is information can be found in the Design Analysis section.

4 Closing Material

4.1 Conclusion

For the senior design, so far, the team has actively expanded the possible approaches based on the advisor suggestions and client demands. Using design thinking, multiple approaches were researched to guide our final solution, which is to combine the software and hardware together to provide reliable control over the cell phone usage while driving. This will be achieved through the Arduino Uno, GSM A7 Module, RFID card and reader, circuit components, sensor detection, locking mechanism, and custom software to regulate the case's functions.

As the solution is beginning to be implemented into an actual circuit, issues have also begun to arise concerning the team's circuitry and code. The current tasks that the team must focus upon are overcoming these errors because they are inhibiting the case from performing basic functions. Some of the components, such as the GSM module and sensors, have arrived and are new to most team members. Though the team has a plan for the implementation of these components in subsystems of the design, the actual testing of these components and becoming familiar with their usage is another task yet to be accomplished.

For now, the team will continue to test the functions one at a time so that a prototype can be created before the end of the first semester or at the the start of the second. Together, the team will continue documenting, testing, and improving the product design with the goal of creating a satisfactory case that will increase road safety by effectively eliminating distractions.

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Figures were from the following sources:

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- Figure 2: https://www.adafruit.com/product/2800?gclid=CjwKCAjwm-fkBRBBEiwA966fZPtzuKlMfB5iHO3xSrA8NDWPHuS3mbS7H5VNqwqukZmdiiWJ343LNRoC1zUQAvD_BwE
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