Cheap and Versatile Breathalyzer Box

ECE 445 Final Report

Cameron Palte, Kush Patel, and Stanley Zhao
Team 1
TA: Shaoyu Meng
Professor: Wei He

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Abstract

The aim of this document is to describe our semester long final project, to build a cheap and versatile breathalyzer box. The box consists of a solenoid, LEDs, alcohol gas sensor, passcode switches, an RFID cage, and various control circuitry / PCBs. The box allows users to put in their car keys and lock the box. After doing so, the user can only retrieve their car keys by blowing into the alcohol gas sensor with a blood alcohol content that is below the legal limit, and entering the correct passcode into the box. The passcode prevents a different user from blowing into the box to steal the user's car keys. Due to the RFID cage, the box works with push-to-start cars. Overall, the box proved successful in tests at functioning properly and meeting its stated objectives. It had a small critical error rate of <4%, with a false positive rate of <2% versus the 23% rate ProctorsCars found for commercial police breathalyzers.

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1. Introduction

1.1 Overview

On average, two in three people will be involved in a drunk driving accident within their lifetime [2]. In 2017, 10,874 people, or 29% of all road deaths in the United States, involved someone whose blood alcohol content was above the legal limit [3]. Despite continued efforts to stop this, intoxicated driving remains one of the largest preventable causes of death, especially for young adults. Being intoxicated significantly lowers one's inhibitions [4], and as a result, increases the chance of someone making a poor decision.

1.2 Incentive for Project and Solution

Our incentive for this project stemmed from the fact that current solutions to prevent drunk driving are inefficient and expensive. Current systems to prevent drunk driving involve an ignition interlock placed on the car. These systems require a 1+ hour appointment with a certified technician to be installed, and must be used by every single driver of the vehicle, regardless of their drinking history [5]. They also cost $900, a strong financial barrier at a time when 40% of Americans cannot afford a $400 expense [6].

Our proposed solution is a key-based breathalyzer box. Its attachment to car keys means it does not require any installation and would not inconvenience any other users of the car. The RFID blocking feature of the box would mean that it would still work for push-to-start cars. Users place their keys within the box and lock it at the start of a night out. For users to retrieve their keys, they would need to enter the correct passcode into the switches on the side, and blow into the breathalyzer. After they blow into the breathalyzer, their blood alcohol content will be calculated and displayed on the LED display. If their blood alcohol content is below the legal limit, the box will unlock, and the user will be able to retrieve their keys.

In terms of proposed uses, the device could be used by bars or institutions who would mandate its usage to serve customers. Alternatively, individual users who are trying to find a low cost way to stay responsible, with comments like,

> "I was court ordered to have an interlock in my car for 24 months and after I was done I purchased this volunteer interlock devices so I would never have to go through this experience again" [7],

would have a system that does not inconvenience other users of their car, and takes advantage of the fact that these people, while sober, would not drive intoxicated.

A recent pilot study with commercial drivers in Sweden showed that investigators believed voluntary breathalyzers to have an overall positive effect on safe driving. However, 61% of the companies with the commercial drivers said their main reason for not having installed them was cost [8]. Our easy to use device should help fill provide a product with new levels of convenience and low cost in the voluntary safe-driving market.

1.3 Block Diagram

Our project was broken up into 7 major blocks, shown in Figure 1, the power supply, lock mechanism, user interface, breathalyzer, LED displays, and future work. The overall block diagram is shown in Figure 1. The power supply generates 12 V and 5 V power for use by the rest of the device. It also contains the battery to power the device. The lock mechanism contains the relay, which is triggered by the microcontroller, and the solenoid which controls the box locking. The breathalyzer consists of the alcohol gas sensor to measure and send the blood alcohol content to the microcontroller. The User Interface consists of the on/off switch and the passcode switches to communicate with the device. The LED displays display the blood alcohol content, and other relevant information. The microcontroller consists of an Arduino Pro Mini 328 to do all our processing. Lastly, the Future Work consists of the keypad we added on to be able to gather and process more information from the user in the future.

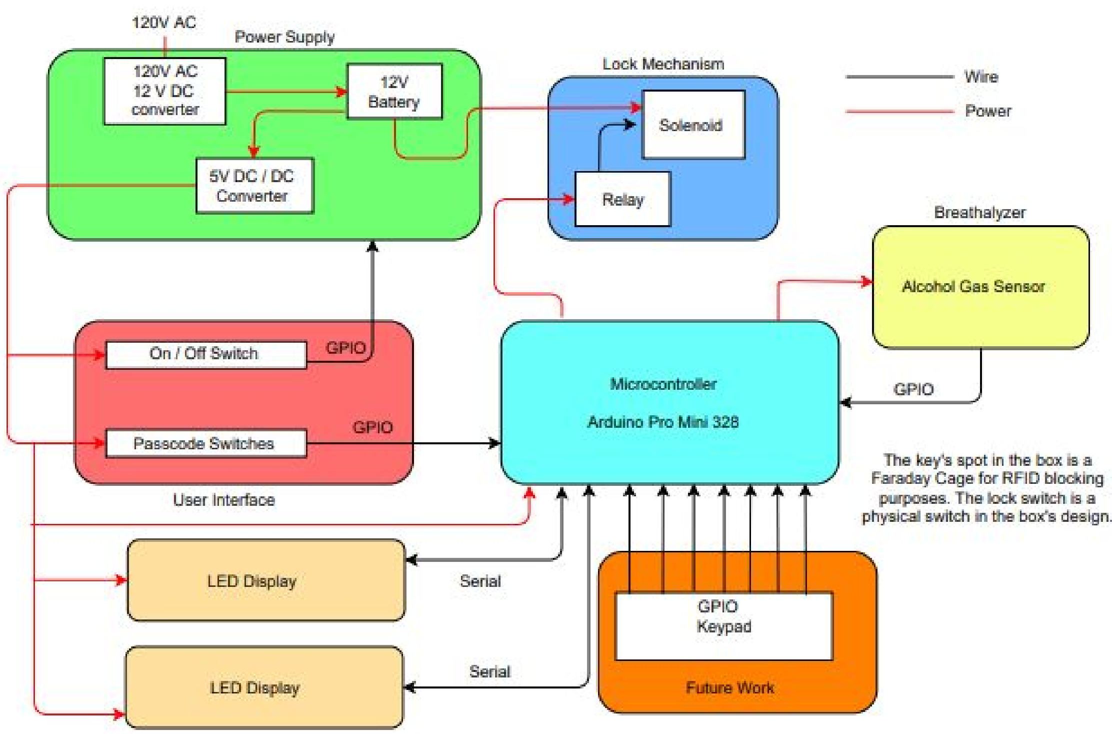

Figure 1. Project Block Diagram.

1.4 Block-level Changes

As we progressed through our project, we made a number of changes. However, the net result of all of these changes were that we were able to either maintain or improve the functionality offered by our box.

In the power supply, we removed the 5 V and 12 V regulators. The 5 V was supplied from a 5 V DC/DC converter, while the 12 V output came straight from the battery. The reason for this is the 5V DC/DC converter was much more efficient, allowing greater battery life. The 12 V regulator was removed because at voltages below 12 V, it simply decreased the voltage, drawing up power, while moving the voltage further away from our targeted specifications. As a part of this, the on/off switch came with our battery and simply controlled the battery, so we did not have to add it separately.

In the lock mechanism, we changed the relay to have its power supplied by the microcontroller. This change was due to how the relay we picked was triggered. In the User Interface we removed the electronic lock switch, incorporating it into the physical design of our box instead. As a part of this, we added a second LED to provide additional relevant information to our users. Lastly, we added a keypad to the box, originally discussed in the Future Work section of our Design Document. The purpose of this was to be able to gather additional information from users in the future.

1.5 Functionality and Performance Requirements

Our goal was to build a breathalyzer box that would help to efficiently prevent intoxicated driving. To accomplish this, we decided on three high-level requirements.

- Breathalyzer box can accurately measure user's blood alcohol content to a precision of 0.02% and display that information on a 7 segment LCD display.
- An inaccurate passcode will prevent the user from unlocking the breathalyzer box regardless of their blood alcohol content.
- The breathalyzer box can prevent a push-to-start key from being used, and be manufacturable from less than $100 of parts.

1.6 Broader Project Impacts

The potential for broader impacts from our project are enormous. Road traffic injuries kill an estimated 1.3 million people worldwide each year [9]. In developed countries, roughly 20% of fatal accidents involve drivers with excess alcohol in their blood, while in poorer countries, this number can be as high as 69% [10]. As the world moves away from individual car ownership, having a key-based low-cost breathalyzer, that can help decrease the chance of intoxicated driving could save lives [11].

2. Design

2.1 Design Procedure

The box is responsible for securely holding the user’s keys, as well as allowing them to retrieve it if they are sober. We had an RFID cage in our physical design as that was the only way to prevent push-to-start keys from being effective in the box. The user interface with the passcode allows them to control the box, while preventing another sober person from getting access. The power supply and 12 V battery were picked based on our power consumption levels, and the desire to allow the box to last users the entire night out. Using a 12 V battery, and dropping it down to 5 V, allowed us to get more capacity and battery life versus using a 5 V battery and stepping it up. The LED displays are a low power and effective way to communicate with the user. Lastly, the alcohol gas sensor on the external side of the case provides the user with a way to test their blood alcohol content when the box is securely locked.

2.2 Design Details

2.2.1 Physical Design

The physical design of the case, a picture and drawing of which appear in Figure 2, consists of everything we need to accomplish the project. On the right-side, it consists of holes through which our alcohol gas sensor and passcode switches were attached. It also consisted of a hole on the back to feed wires to the LEDs and take power from the battery. The solenoid, on the bottom right of the box, extends into the lid, allowing us to easily lock the box. The PCB sits in the main compartment of the box. Everything is super glued or screwed down to allow the box to be moved around without damage. The box was constructed out of balsa wood, which we cut with a dremel, allowing the project to be both simple for us to construct, lightweight, and low cost.

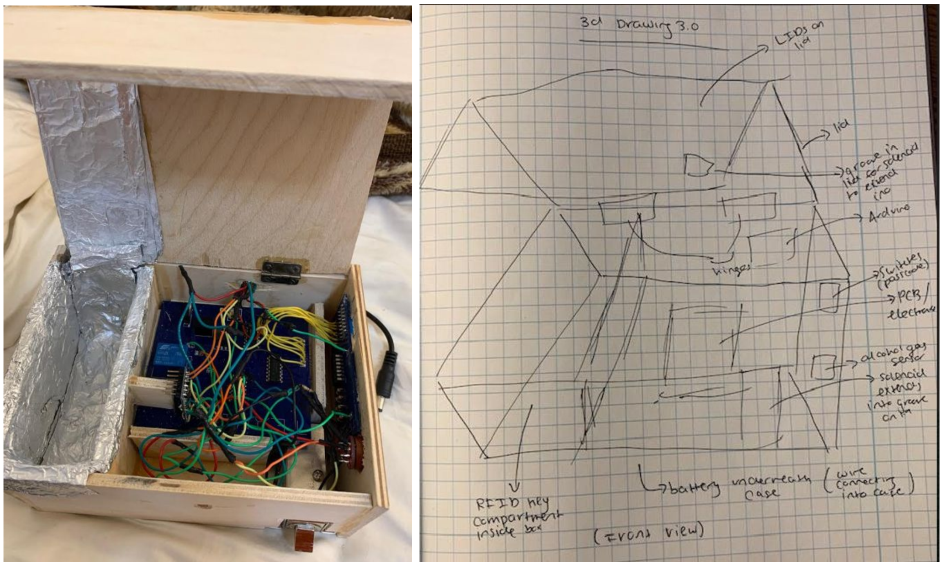

Figure 2. Project Physical Design.

2.2.2 Microcontroller

Our microcontroller consists of our Arduino Pro Mini 328 and the circuitry for our hardcoded passcode. Out of this, the most important aspect is the Arduino Pro Mini. The Arduino controls every aspect of the box. It receives input from the Alcohol Gas Sensor and power input from the battery, which is controlled by the on-off switch. The pin connections to the Arduino Pro Mini 328 are shown in Figure 3.

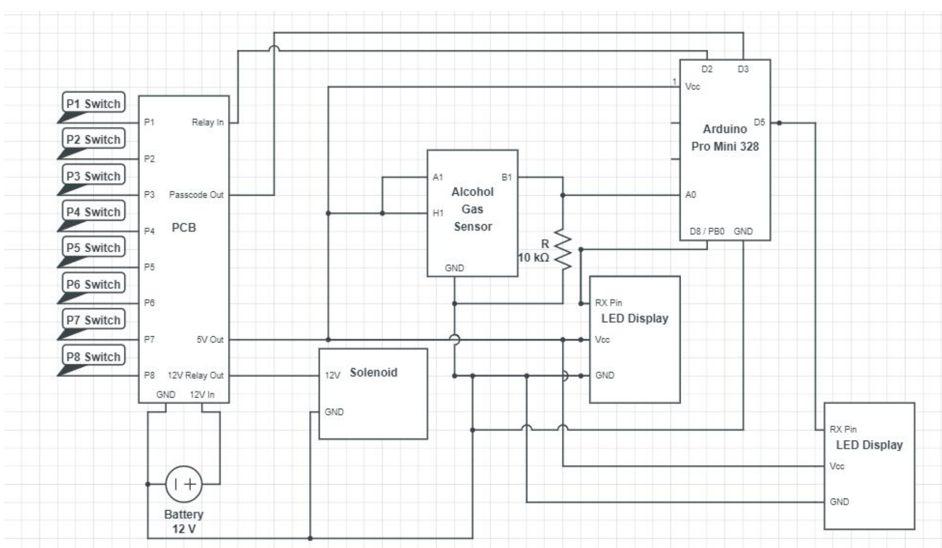

Figure 3. Arduino Pro Mini 328 Connections.

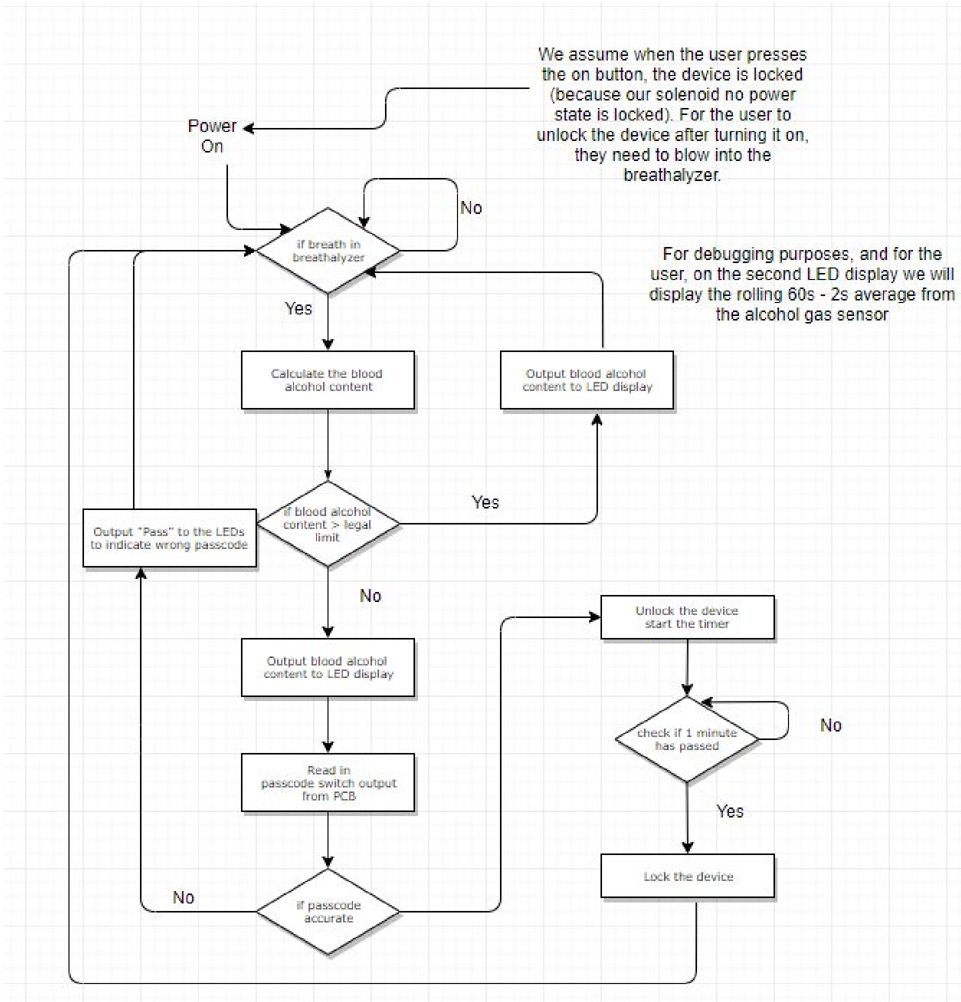

Figure 4. Software Flow Control Diagram.

For software control, the Arduino Pro Mini 328 will be controlled by the software flow diagram in Figure 4. This flow diagram will allow the user to retrieve their keys if their blood alcohol content is below the legal limit and the passcode is correct, which is the stated goal of our project.

2.2.3 Passcode Switch

The purpose of the passcode switch was to prevent a sober person, who does not own the box, from gaining access and taking the user's car keys. The passcode switches consisted of 8 binary switches mounted on the side of the box providing a total of 256 combinations. We chose to hardcode the passcode, using TTL chips on our PCB. The Passcode Switch input circuit is highlighted in Figure 5.

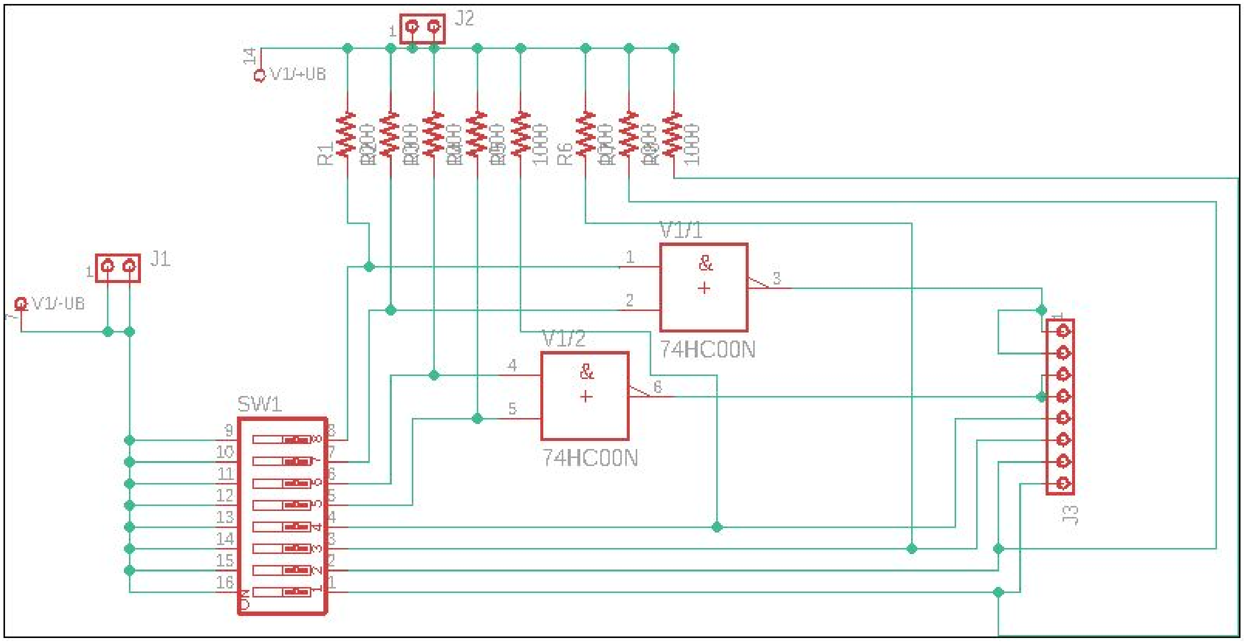

Figure 5. Passcode Switch PCB Circuitry.

The benefit of this was that it prevented someone else from being able to change the box's passcode. It also helped simplify the logic and the user gaining access to the box because the value from the switches could be read and analyzed as the blood alcohol content was calculated, rather than needing to wait a variable amount of time for the user to enter the passcode if we had used, for example, a programmable keypad.

2.2.4 12V Battery and Wall Charger

The 12V battery for our project along with the selected charger needed to be capable of fully charging overnight, and then providing the required power output and duration for our project. Our calculations for the required battery current output and capacity were as follows:

Arduino Pro Mini 328 = 5.0 V at 150 mA - peak power draw [12]
MQ-3 Alcohol Gas Sensor = 5.0 V at 160 mA [13]
Solenoid = 12 V at 600 mA [14]

Max Current Draw (at 12 V with 10% error margin) = 802 mA
Total Consumption (alcohol gas sensor preheat) = 19.20 watt-hours
Total Consumption (150 minute peak operation time) = 24.06 watt-hours

Minimum Battery Capacity (mAh) = 3605 mAh at 12 V

Using this information we chose the TalentCell Rechargeable 12 V / 5000 mAh battery pack. The battery has a 50% error margin on our required capacity, and a peak current output ability of 3 A, which is well above our requirements [15]. It also contains an on/off switch which we used to control our overall device. Lastly, it is small and portable making it easily attached too and carried with our box.

2.2.5 5V DC/DC Converter

Our 5V DC/DC converter was used to supply the various components that needed it 5V power. This included the Arduino, Alcohol Gas Sensor, and passcode switches. Our considerations here were centered around the desire for power efficiency, while being able to supply adequate current. Our calculations were as follows:

Minimum Current: 310 mA (160 mA alcohol gas sensor + 150 mA Arduino)
Minimum Efficiency: 76%

Our minimum efficiency requirements were based off of the fact that many small chips can only dissipate ~0.5 watts [16]. As a result, at 5 V, we could not have more than 100 mA wasted before we risked overheating the chip.

We ended up selecting the R78-E 5 V DC/DC converter. This converter can handle 1A output, and has 91% efficiency. Its low cost also contributed to our project goal of minimizing cost. According to the datasheet, it can dissipate 0.4 watts, and handle input voltage from 4.75 to 18 V. The dissipate easily covers our estimated 0.15 watt dissipation requirement, and the voltage range covers the 12 V input from the battery.

2.2.6 Solenoid

For the solenoid, we had two main goals. The first was that the solenoid could not use too much power. The second was that the solenoid had to be able to securely lock the box. We resolved the first issue by using a solenoid that had a default state of extended. That meant the box, which spends the majority of its time in the locked state, would not use any power during this time. As a result, using the 12 V 600 mA solenoid was well within our power availability. For the second requirement, we cut a groove into our box as a part of the physical design. This allowed the solenoid to extend into the groove, and securely lock the box.

2.2.7 Relay

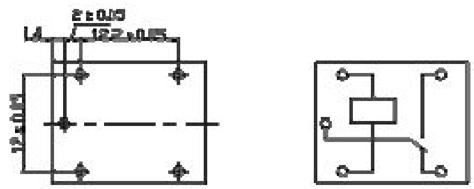

Figure 6. Single Pull Double Throw Relay [17].

Our relay was selected to be able to control the Solenoid. The reasoning for this was the need to control the 12 V solenoid with our 5 V microcontroller. As a result, we needed the relay to be SPDT, where its default position would be outputting 0 V (lock) to the solenoid, while its triggered position would be outputting 12 V (unlock) to the solenoid. The relay coil would need to take the 5 V output from the Arduino. The internal switch setup of our relay is highlighted in Figure 6.

We selected the Songle SRD 05VDC model relay. This relay was capable of both accepting 5 V for its coil, and controlling the 12 V access for the solenoid. One issue we ran into was the relay's coil resistance meant that its current draw (71 mA) was above the max (40 mA) of an Arduino. We resolved this issue by using 3 outputs from the Arduino so that they could each provide a proportional amount of the current.

2.2.8 Alcohol Gas Sensor

The alcohol gas sensor is the core of our project, as it makes up the breathalyzer that allows us to detect the user's blood alcohol content. We needed an alcohol gas sensor that could distinguish between a blood alcohol content ranging from 0.00% - 0.20%, per our high-level requirements, with an accuracy of 0.02%. We did not have much of a selection for our alcohol gas sensor. Most other sensors we could find were more expensive and had worse public documentation so we chose to go with the MQ-3 sensor. Our test circuit for this sensor is in Figure 7.

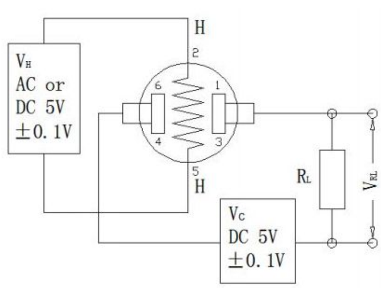

Figure 7. Alcohol Gas Sensor Test Circuit.

Our sensor's data sheet states it can detect 0.04 - 4 mg/l concentration [13]. 1 liter of blood weighs approximately 1.05 kg [18]. The ratio between alcohol in the breath and in the blood is standardized at 2100 in most commercial breathalyzers [19]. That means that the breathalyzer can detect blood alcohol concentrations from 0.0084% to 0.84%. That covers our range of 0.00% to 0.20% with a +/- 0.02% error margin.

Our methodology for computing the blood alcohol content from our voltage divider circuit containing the alcohol gas sensor was based on rolling averages. Our box usage involves the user breathing, with a straw, at the breathalyzer for approximately 3 seconds. For our calculations, we did a 60 second - 2 second rolling average. We then took this voltage difference, and converted it to a value from 0 to 1000, where each number represents 0.005 V. We then assigned different blood alcohol content levels to different thresholds based on comparison to a commercial breathalyzer.

2.2.9 LED Displays

For the LED displays, we wanted a way to communicate vital information with the users of our box. Namely, we wanted to be able to include the user's blood alcohol content, so that regardless of whether someone successfully unlocked the box, they could see their current blood alcohol content. We also wanted a simple and low cost solution that would use minimal power, and could use only a single pin on the Arduino. That prevented us from needed a more complicated and expensive Arduino, which we would have needed if we were using multiple Rx / Tx pins.

We chose to go with the Sparkfun Serial 7-Segment Display. The display can use 2.4 - 5.5 V power, which allows us to supply it using the 5 V power output of the Arduino. It draws a maximum of 14.1 mA, well below the Arduino output limits, and means that the display uses a maximum of 70 mW, or very low power usage. Lastly, the display is programmable over serial output, meaning we could control it with any individual digital pin on the Arduino. The circuit of this display is shown in Figure 8.

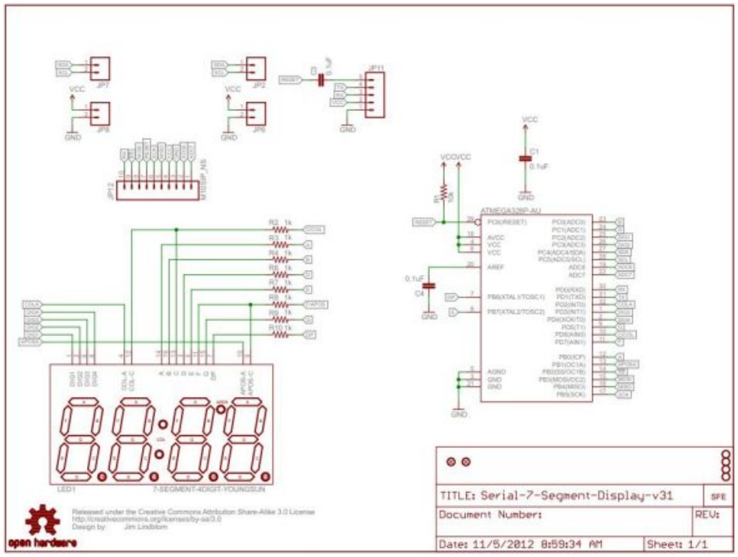

Figure 8. Seven-Segment LED Display Schematic [20].

2.2.10 RFID Case

Our physical design is discussed above, however, one specific requirement we had for our case was that it would be RFID blocking. The reason for this is because of the explosion in push-to-start car keys, and our desire to make the device useful in that scenario. Having an RFID-proof key chamber would prevent someone from starting their car without unlocking the box.

We chose to construct our RFID blocking using a Faraday cage we constructed inside the box. This is because construction a Faraday cage is a cheap and simple way to block RFID signals. We started by using copper sheets on the sides of the container. This provided most of our signal blocking. Unlike alternative materials, such as aluminum foil, the metal sheets are also very difficult to damage or penetrate. We then supplemented the gaps and corners of the metal sheets with aluminum foil to make a complete seal. The completed RFID cage is shown in Figure 9.

Figure 9. Completed RFID Cage.

3. Verification

3.1 Overall Verification

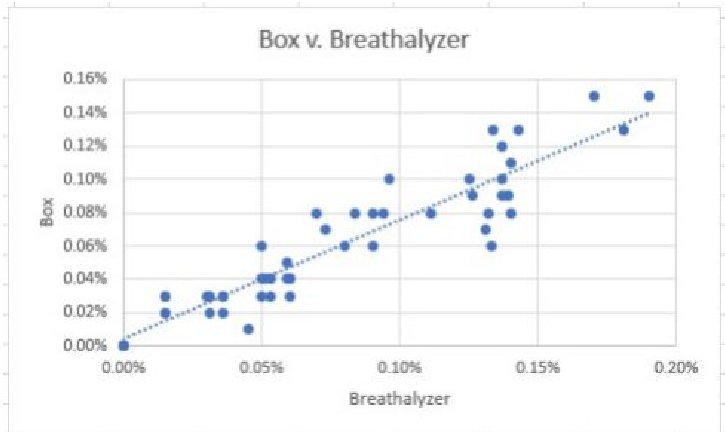

Figure 10. Box v. Breathalyzer Data.

Table 1. Result Statistics.

Error Rate (box determines blood alcohol content > 0.02% outside commercial breathalyzer).	30.90%
Critical Error 1 (box determines user is sober when user is above the legal limit)	1.82%
Critical Error 2 (box determines person below the legal limit is in fact above)	1.82%

To test the overall success of our project, we compared the stated blood alcohol content from the breathalyzer to the blood alcohol content from a commercial breathalyzer. The results of this testing are shown in Figure 10.

The summary of our results is in Table 1. Overall, we are proud of these results. It does not reach our stated high-level requirement of a 100% success rate to an accuracy of 0.02%. However, our results were good in reference to commercial police breathalyzers, where studies show that up to 23% of drivers charged with a DUI might be the victim of inaccurate results. They also exceeded the specification we found in our original tolerance analysis after implementing the 24-hour warmup period.

As Figure 10 shows, our sensor and the commercial breathalyzer have a fairly linear relationship. The majority of the errors are non-critical and occur close to our upper limit. Out of the critical errors, each occurred at a rate of less than 2%. Critical Error 1 is most concerning, while Critical Error 2 is less concerning as its low rate of occurrence means the user can blow into the device again. As a result, we could help alleviate this by lowering the cutoff threshold for a blood alcohol content of 0.08%, resulting in an increased rate of Critical Error 2 vs. Critical Error 1.

We believe that our lack of reliability with the alcohol gas sensor could be improved by three things. The first is gathering additional data across the entire range of potential blood alcohol contents so that we can better define cutoffs. The second is testing different, including potentially longer warm-up time. The last is standardizing and accounting for other variables that could affect the sensor, that we did not pay attention too, for example, the ambient temperature in the room.

Some other tests we did to verify the functioning of our box were tests of the overall output of the passcode circuit, along with tests about the state of the device based on the output from the Arduino to the relay. We also did tests of the RFID proofing and the LEDs. The results are summarized in Table 2.

Table 2. Block Test Results.

Test	**Result**	**Metric**	**Theoretical Ideal Result**	**Acceptable Result**
RFID	0.00%	Can car start with key inside the box.	0.00%	0.00%
Correct Passcode Avg Output Volts	4.472 V	Measured output from passcode circuit on switch.	5.000 V	> 2.000 V
Relay - 0V Controller Input	100%	Solenoid remains retracted when relay has no microcontroller signal	100%	100%
Relay - ~5V Controller Input	100%	Solenoid retracts when relay has microcontroller signal	100%	100%
LED Counting Test	100%	Have LED display cycle through numbers to confirm they can be displayed	100%	100%

The above tests, which were done incrementally as the box was constructed, indicate all major blocks of the project operated as expected.

3.2 R&V Table Verification

For our individual R&V tables from the design review, as can be seen in the tables in the Appendix, which include the updates from the individual progress reports, we managed to verify all of our stated requirements.

The 5V and 12V Voltage Regulators that were originally included in the Design Review could not meet their specifications and were very power inefficient, and were removed as a part of the Individual Progress Report. However, we managed to resolve this by replacing the 5V regulator with the 5V DC/DC converter, which met our 5V regulator specifications. Additionally, while without the 12V regulator, the battery voltage dropped over its lifecycle, the 12V regulator simply made this problem worse. We did validate that even as the voltage dropped the battery output could trigger the solenoid over its entire power lifecycle, which was the only item we needed 12V for. The data for this is in Table 3.

Table 3. Solenoid and 5V DC/DC Tests.

Battery Level	Battery Output Voltage (Volts)	Solenoid Trigger	5V DC/DC Converter Output (Volts)
100%	12.05	yes	5.167
80%	11.15	yes	5.090
60%	10.50	yes	5.081
40%	9.30	yes	5.110
20%	8.70	yes	5.103

Since the net goal of the raw battery output power was to be able to retract the solenoid, the battery's output power met our overall objective here.

4. Costs

4.1 Parts

Table 4. Project Parts Cost.

Item	**Part # / Manufacturer**	**Quantity**	**Total Price**	**Mass Purchase Price**
RFID Case	N/A	1	$10.00 wood / RFID	$5.00 (est.)
Seven Segment LED Display	COM-11441 / Sparkfun	2 (mass version 1)	$23.72	$10.67
Alcohol Gas Sensor	SEN-08880 ROHS / Hanwei Electronics Co. Ltd.	1	$4.95	$1.19
Relay	G5LE / Omron	1	$1.95	$0.31
DC / DC Converter	R-78E / RECOM	1	$4.95	$2.98
Rechargeable 12V Battery	YB1206000-USB / TalentCell	1	$33.99	$33.99
DIP Switch - 8 position (passcode)	Switch DIP8 / 4UCON Technology	1	$1.50	$0.71
Arduino Pro Mini 328	Arduino-Pro-Mini 5V / Arduino LLC	1	$9.95	$1.67
Solenoid 12V	ROB-15324 / Sparkfun	1	$9.95	$3.10
Quad 2-Input NAND Gate	74LS00 / Electronics Salon	1	$1.06	$0.10
Quad 2-Input AND Gate	74LS08 / Electronics Salon	1	$1.06	$0.10
Quad 2-Input OR Gate	74LS32 / Electronics Salon	1	$1.06	$0.10

Total Cost (parts): $92.28 (consumer version) - $104.14 (our version).

Total Cost: Mass Produced Version: $59.92

Our calculations for part-by-part expenses are shown in Table 4.For bulk purchases, we assumed Sparkfun Volume pricing would be 10% off of their sale prices, if the product could not be found for sale in bulk elsewhere.

4.2 Labor

Our labor costs are based on the formula provided by the class of ideal salary (hourly rate) x actual hours spent x 2.5.Using the salary from the 2017-2018 new grad report, we get an ideal salary of $44.7 per hour [21]. We ended up working more than our planned 12 hours per week in the design review, or approximately 15 hours per week. Over the 16 weeks, this comes out to 240 hours / partner. As a result, the labor cost is, $44.7 x 3 partners x 240 hours x 2.5. or $80,460.

4.3 Result

Our net results for price for each of our three versions are:
Our demod version: $80,564.14
Consumer version (1 less LED than demo): $80,552.28
Mass produced version: $80,519.92

4.4 Schedule

Table 5. Schedule.

Week	**Cameron**	**Kush**	**Stanley**
10/7	DR Feedback	DR Feedback	DR Feedback
10/14	Design PCB.	Design PCB.	Construct case.
10/21	Continue PCB.	Breathalyzer circuit.	Construct case.
10/28	Connect passcode.	Power circuit.	Lock circuit.
11/4	Interfacing LED.	Incorporate power.	Incorporate project.
11/11	Integration / testing.	Integration / testing.	Integration / testing.
11/18	Mock Demo.	Mock Demo.	Mock Demo.
11/25 (Thanksgiving Break)	Final Demo.	Final Demo.	Final Demo.
12/2	Report / Presentation.	Report / Presentation.	Report / Presentation.

5. Conclusion

5.1 Executive Summary

In the end, we were able to design our device to function as we originally envisioned. From a critical error perspective, the device functioned better than modern day police breathalyzers, however, it did not meet our original 100% specification.

5.2 Accomplishments

Our project managed to function completely as anticipated, where we could unlock the box, place our keys inside, and relock the box. The box would then not unlock unless we had a blood alcohol content below the legal limit, and entered in the correct passcode. We managed to meet all of our high-level requirements, except for 100% determining the blood alcohol content to within 0.02%, where we were at 70%.

5.3 Uncertainties / Performance Specifications

Our two major sources of uncertainties and deviations from the original specifications were the battery voltage dropping from 12 V and the uncertainty in the breathalyzer. We believe we can solve the battery voltage drop in the future by adding a buck-boost converter [22]. This could maintain the output, as the battery voltage drops, at 12 V.

To help resolve uncertainty in the breathalyzer there are two approaches we could take. The first is we could try a variety of different versions of the same sensor, or other more complicated and higher end sensors [23]. We could also gather significant different data across a number of different commercial breathalyzers, and average out that data, to get better cutoffs for our alcohol gas sensor.

These two things could help our project be significantly more reliable as we pursue it after the class.

5.4 Ethics and Safety

Our project is much smaller and does not deal with many substantial safety or ethical dilemmas, but there are still some considerations that we need to account for. These come in a myriad of legal, ethical, and health based issues.

First and foremost, since our project is intertwined with alcohol consumption we need to make sure that our product is tested with people who are of legal age in the country of testing. In our case, we are only using people who are over the age of 21 to test our product. This ensures we comply with all legal legislature in the area of consumption to prevent any sort of legal issues with regards to underage drinking. We also want to make sure all alcohol consumption in regards to testing is controlled and completed responsibility to ensure no dangerous health conditions on the tester.

We have determined the most effective way to collect data for our product is to put it in the environment it will be used. That means testing it ourselves. Since our entire group is 21, age is not an issue, however, we will make sure to always test it in an environment with a fully sober group member present, and make sure that no group member feels pressured to drink in order to gather the required data.

Since our consumer product will require a breathing apparatus, we want to make sure that the module in which consumers breathe is clean or easy to clean. Having a clean breathing module will help protect consumers from any sort of bacteria development and potential health effects. From our testing, using a clean straw provided us better results that reusing the same dirty straw. To provide the most accurate reading, we will ensure that the module is able to be separated and cleaned.

Our product will deal with some electronic components, so it needs to be enclosed in a tight manner to prevent it from getting damaged from the elements. Some potential elements that could cause problems are water/drinks or powders like salt and sugar. Making our product element-proof well help provide more longevity to the product as well as prevent any sort of untimely malfunctions. .

We will be using an internal battery to power this product throughout the duration of its usage. We have opted to buy a rechargeable battery so we can allow this product to be taken on the go. Because of this, we want to make sure that the battery and voltage supplied to the rest of the circuit is of safe amounts. We can test this by measuring voltage values at various positions within the circuit to and validating that with the expected values.

Referring to the ACM Code of Ethics, all products developed using modern technology need "Honor Confidentiality" [24]. Our device does deal with some sensitive consumer data, and to honor confidentiality, we will need to use the passcode to verify the information of the user. If we do decide to pursue our future work, we will keep all biometrics saved and safely away from display so that comply by that rule. All information collected will not be used outside the scope of this project.

Another ACM Code of Ethics, we need to guarantee that our product will "do no harm [24]. Being under the influence can cause a lot of damage to the person drinking but also to the other people, for example victims of drunk drivers. While the legal limit is a blood alcohol content of 0.8, we will have a safety tolerance to account for the potential errors in calculation by the sensor. The mental difference between .079 and .08 is almost non-existent, and to prevent any bad decision being made especially during the use of our product, we will err on the side of caution. As an extension, in the testing phase of this product, if we are consuming any drinks ourselves we need to make sure we take the necessary precautions to stay safe from the potential negative effects of alcohol consumption.

5.5 Future Work

For future work, we have a few ideas in mind, in addition to the plans discussed in the uncertainties / performance specifications section.

The first plan involves the keypad that we attached to the side of our box. We can program this keypad to have a setup mode that receives the user's weight, height, and age. We could then add a button on the side of the box. The user could press that button, and the next time they blow into the box, rather than receiving their blood alcohol content, they could be given a time estimate until they are sober enough to receive their keys.

Another change we could make is incorporating a bluetooth module into the device. You could then set up the module with the device such that anytime a breath is detected above the legal limit, it could send a text, perhaps to a loved one to come pick you up. Or it could order an Uber with your address and display the Uber driver's license plate on the display. Either way, it could help promote safe driving and decrease the desire to retrieve your keys from the box if you are intoxicated.

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Appendix - R&V Tables

Note: All requirements met. 12V and 5V regulator not included because they were removed from the project. Where the verification standards changed from the original plans, the changes are highlighted in the result column.

Microcontroller Requirement	Microcontroller Verification	Results
Based on the inputs into the microcontroller, the correct output is sent to the relay.	Set passcode input and breathalyzer resistance to 1 and <0.08% BAC respectively and confirm that a 1 output is sent to relay. Confirm a 0 output is sent for any other combination of inputs.	Verified successfully.
Microcontroller runs code to read and analyze blood alcohol content automatically upon being turned on.	Provide 5V from regulator and confirm that the Arduino boots and correct code executes, by having the code turn on and off LEDs on the board as it reaches certain stages.	Verified successfully.
Microcontroller outputs blood alcohol content (%) to the LEDs.	Write code to input simulated resistance values and confirm that the correct blood alcohol content is calculated and sent to LEDs over serial connection.	Verified successfully.
Microcontroller can adequately receive input from the switches.	Use a multimeter to verify that the microcontroller receives the correct input from switches and PCB.	Verified successfully.

On / Off Switch Requirement	On / Off Switch Verification	Results
Container can not be opened when off (and the circuit is unpowered).	Turn switch to off position and make sure that the container cannot be opened.	Verified successfully.
Once turned on, user can unlock box assuming blood alcohol content is at the correct level.	Once the device is built, test turning on and confirming that the device can be unlocked without needing to execute code.	Verified successfully. (based on requirement - verification was a typo, code needs to execute to verify)

Lock Switch Requirement	Lock Switch Verification	Results
Pressing switch causes container to lock.	Take an unlocked container version and press the lock switch. Confirm that the container is subsequently locked.	Verified successfully. Physical switch. Changed to closing lid locks container.
Flipping the switch does not change the state of a locked container.	Try moving switch when container is locked to confirm it does not unlock.	Verified successfully. Once the lid is closed cannot unlock.

Passcode Requirement	Passcode Verification	Results
User can input their passcode on the switches, while the box is closed.	Close the box and use a voltmeter to confirm that the switches can be set to low or high.	Verified successfully.
The passcode switch logic gates output a 1 if the passcode matches the hardcoded passcode, otherwise a 0 is outputted.	Construct the passcode circuit using the logic gates for the hardcoded [11110000] passcode. Verify that the passcode circuit output is a 1 when the correct passcode is in switches.	Verified successfully.

12 V Battery / Wall Charger Requirement	12 V Battery / Wall Charger Verification	Results
The off the shelf charger is capable of fully charging the 12 V battery overnight.	Plug the 120 V off the shelf charger into the 12 V battery and confirm it is fully charged after 8 hours.	Verified successfully.
Battery can output 12 V +/- 0.5 V when fully charged.	Fully charge battery and confirm the required voltage is outputted with a voltmeter.	Verified successfully.
Battery capacity can handle keeping case powered and unlocked for 150 minutes.	Unlock case through the microcontroller and confirm that it remains unlocked and powered for 150 minutes.	Verified successfully.
Battery can output enough current to support our entire circuit.	Our calculations above show that the battery we're planning to purchase should be more than capable of handling this. Verify empirically by drawing load from battery with a resistor and using an ammeter.	Verified successfully.

5V DC/DC Converter Requirement	5V DC/DC Converter Verification	Results
Outputs voltage at 5 V +/- 0.25 V (based on datasheet) assuming battery at >40% capacity.	Connect to 12 V input from 12 V regulator and measure output with voltmeter.	Verified successfully.
Capable of outputting current at 375 mA without overheating.	Construct test circuit using 5 V output designed to draw 375 mA and confirm the R78-E can provide this.	Verified successfully.

Solenoid Requirement	Solenoid Verification	Results
Solenoid must retract to allow the box to open when powered with 12 V +/- 0.5 V.	Power the solenoid with 12 V and confirm that the box can be subsequently locked.	Verified successfully.
Solenoid must be able to lock the device when powered off.	Once the solenoid is in the device, with no power being supplied, confirm the device is locked and the lid is unable to open.	Verified successfully.
Solenoid must be able to maintain device locked state despite movement / being carried around.	Solenoid in device will be carried around in a backpack on (3) 1 mile runs to confirm that it can hold box locked when powered off.	Verified successfully.

Relay Requirement	Relay Verification	Results
Upon receiving a signal from the microcontroller, relay can activate solenoid.	Power the relay with 5 V from Arduino output and confirm that the solenoid retracts.	Verified successfully.
Relay prevents solenoid from activating, even with device on, if no signal from microcontroller.	Power Arduino while keeping output from microcontroller at 0 V and confirm that the solenoid remains unactivated.	Verified successfully.

Alcohol Gas Sensor Requirement	Alcohol Gas Sensor Verification	Results
Alcohol gas sensor and circuitry can distinguish between someone blowing into the breathalyzer and someone not blowing into the breathalyzer to prevent it from opening when no one is blowing into the breathalyzer.	Read resistance from the alcohol gas sensor and circuitry and confirm a difference in the alcohol gas sensor resistance value between when someone blows into the sensor and when no one is blowing.	Verified successfully.
Alcohol gas sensor provides sufficient precision to detect between below and above 0.08% blood alcohol content with resolution of 0.02%.	Create alcohol solutions with a concentration of 0.07% and 0.09% and confirm that the alcohol gas sensor resistance value changes detectably between these two values.	Verified successfully.
Alcohol gas sensor can adequately detect blood alcohol content up to 0.20% in increments of 0.02% so that we can have a value for the LED.	Create alcohol solutions with concentrations varying by 0.02% increments and then test the alcohol gas sensor at each increment to read the resulting resistance values and confirm a difference.	Verified successfully.

LED Display Requirement	LED Display Verification	Results
The output voltage from the microcontroller is sufficient to power the LED display.	Use a multimeter to confirm the microcontroller can supply the LED with a minimum of 3.3 V at 3.8mA.	Verified successfully. Supplied 5 V instead (within LED voltage range)
The LED Display is able to communicate with the microcontroller through serial communication.	Use oscilloscope to confirm that we can send a serial output from the Arduino and that the LED Display can receive it.	Verified successfully. Did not use oscilloscope, simply tested through displaying numbers on LED.
The LED Display can adequately display the blood alcohol content outputted by the microcontroller.	Send various numbers from the microcontroller (00.00, 00.01, etc.) over serial protocol to confirm the LED displays these.	Verified successfully.

RFID Case Requirement	RFID Case Verification	Results
When the key is inside the case, and the case is closed, a push-to-start car must not be able to start regardless of where the closed case is positioned.	Put push-to-start key in box, close box, and make sure the car cannot start. Test by positioning box in multiple different places around the car.	Verified successfully.
When the case is closed, the user can still blow into the breathalyzer from the port on the side.	Close the case and verify that the breathalyzer can still pick up values from the user.	Verified successfully.