BreathaLock

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***Abstract* — This paper discussed the design procedure utilized to create a handheld device that implements technologies to prevent driving under the influence of alcohol. These technologies include but are not limited to: RF transmission, biometric recognition, gas sensing, and Bluetooth transmission. This paper discussed the methodology necessary and design parameters used to seamlessly combine these technologies together through microcontroller control in a modular environment.**

***Index Terms* — Bluetooth, fingerprint recognition, gas detectors, microprocessor chips, RF signals, semiconductor devices.**

I. Introduction

One requirement of the University of Central Florida CECS undergraduate graduation requirements is for students to create a project in their senior year. This process involves deep research into the technology of their choice and ultimately the realization and implementation of an approved project. As an added preference, this project will solve a new and innovative problem or improve an existing technology. This paper serves to describe the Breathalock device designed and created by group 31.

As part of a growing number of individuals attending college in the United States, members of this group are aware of the negative impacts that can come with driving under the influence of alcohol. Whether this impact is driven by physical injury or legal concern DUI prevention is behind where it should be in many aspects. It is intended that with education from the University of Central Florida the members of this team would contribute to DUI prevention by creating a handheld device that would act as a barrier between vehicle owners and driving under the influence of alcohol.

To ensure that this device effectively prevents users from DUI this device is designed to include verification criteria before allowing the user to enter they're vehicle before embarking on a trip behind the wheel. Primarily this device must be able to recognize the user is under the legal limit of intoxication before driving. This limit in the state of Florida is 0.08 blood alcohol content but in any state this device will be able to adjust to different limits if different laws apply. This will eliminate the possibility of legal prosecution and significantly decrease the physical consequences cause by accidents involving intoxicated drivers. The second technology integrated is biometric fingerprint recognition to eliminate the possibility of passengers using the device of a possibly impaired driver to get behind the wheel. Lastly Bluetooth functionality is integrated to allow for added features and visual indicators to be enabled using a handheld cellular device the user may already own.

This project is ultimately funded and guided by the decision made by the team under the supervision of the University of Central Florida Engineering Department. Due to limited funding, some decisions will be made not only on the performance provided by the components but also by the cost associated. These trade-offs will be discussed further in later sections.

II. Alcohol Gas sensor technology

To achieve the primary verification of the user being under the legal limit of alcohol the device must include an alcohol sensor. The alcohol sensor used in this device is the MQ-3 semiconductor based ambient alcohol sensor. This device utilized the sensitivity to alcohol of a thin layer of tin dioxide(SnO_2).[1] This sensitivity is caused by the conductance variation of tin dioxide under the presence of alcohol. By passing current through a heated piece of tin dioxide this device will output a relative voltage that is used to decipher the relative blood alcohol of the user due to the about of alcohol inside the users' lungs. This method is not new to breathalyzers by any means. In fact, it is the standard method for many breathalyzers on the market.

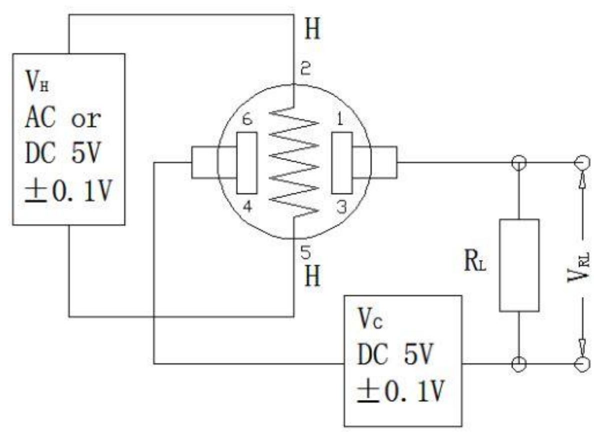

Fig. 1. Overall component and circuit diagram of internals of MQ-3 alcohol sensor.

The Breathalock PCB board is designed to output 5 volts to both the heater and the tin dioxide layer to provide the specified current necessary to operate this device effectively. As seen in the above image the output of the MQ-3 sensor is the voltage across the load resistor(R_L). By modeling the change in voltage vs. time we can accurately decide if the user is above the legal limit of alcohol. The direct relation of voltage read vs. change in conductance is shown in the below equation.

$$V_{RL} = \frac{V_c * R_L}{R_L + R_{Tin\,Dioxide}} \quad (1)$$

III. Biometric Fingerprint Recognition

By effectively implementing a biometric subsystem, the breath-a-lock device has an added step of verification before allowing the use to enter the vehicle. Its importance is recognized when investigating the use case of the device being tailored to a specific vehicle. The Breathalock device contains an image based fingerprint sensor. This sensor captures an image of a finger on a glass and then uses digital signal processing and image signal processing to store certain parameters into an onboard flash memory on the sensor itself. By communicating through TTL serial the Breathalock microprocessor can send instructions specifically: enroll, search, and delete. Through these three commands we can control and reference between user's biometric fingerprint.

Fig. 2. Raw image input to fingerprint sensor to be processed.

IV. Bluetooth Technology and Communication

As an added feature to the Breathalock device, Bluetooth enables an extra visual and interactive feedback system to the user. By connecting to an external cellular phone with Bluetooth connectivity and the help of a pre-loaded android app we can display many of the pass-fail conditions in real time such as the actual blood alcohol content while blowing.

Due to the inherent power challenges that come along with creating a battery powered device, this device needed to contain a low power communication protocol. For this specific application, the best option is Bluetooth Low Energy(LE)

TABLE I
Bluetooth tradeoff Table

Protocol	Classic Bluetooth	Bluetooth LE
Data throughput	2 Mbps	100Kbps
Range	Up to 1000m	Up to 250m
Power Consumption	Good	Very Strong

The above table lists the tradeoffs between classic Bluetooth and Bluetooth LE.[2] It is noted that the performance between the two is drastically different in favor of classic Bluetooth but in the two-main effected sections these characteristics are not key to the Breathalock device. Because the only pairing would be with a cellular device that would be within 1 meter the range of 250 meters is largely sufficient. Secondly our application is simply taking strings of data and sending simple commands to the Breathalock device. Our focus is concerned on finding a module that is low power consumption and for that reason it is imperative that the Breathalock operate using a module that uses Bluetooth LE.

A. MOSFET Switching

The operation and DUI prevention aspect of this device is rooted in the control of the RF signal to unlock the vehicle. To accomplish this task the Breathalock device wires into the two button terminals on the RF transmitter to tap into this functionality of the remote. For the lock signal the device simply extends the button with a tactile switch to the casing of the Breathalock without interrupting normal operation. In the case of the unlock signal the microprocessor takes control of the button access. To do this out PC board is design to implement a MOSFET switch driven but a high signal enabled by the microprocessor. The MOSFET circuit is design to operate only in ON or OFF as a switch so that we can enable the unlock or disable it.

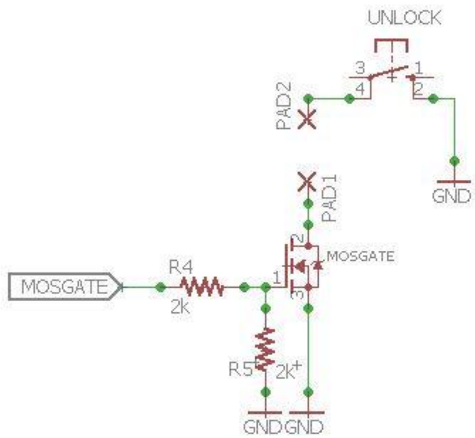

Fig. 3. MOSFET Switching circuit

This configuration of components allows us to control the click on the RF remote from the microprocessor. When the microprocessor supplies a high voltage, $V_{GS} > V_T$ the MOSFET will operates in saturation mode allowing for our button press signal to travel to the RF remote wired to "PAD1" and "PAD2" in figure 3. The MOSFET chosen for this application has a threshold voltage(V_T) of 2.4V.

$$V_{GS} = \frac{V_{MOSGATE} * R_2}{R_1 + R_2} \quad (2)$$

$$if\ R_1 = R_2 \ \ : \ \ V_{GS} = \frac{1}{2} V_{MOSGATE} \quad (3)$$

For this case, our resistor values are equal and our microprocessor high is 5V. This creates a V_{GS} = 2.4V which is greater than the V_T of our MOSFET. With these conditions met out switch can make contact and send a RF signal to unlock the vehicle.

V. PCB PROJECT DESIGN

software of choice for board layout and schematic design for the BreathaLock project is Eagle CAD. Eagle CAD was used because of how popular the program is when designing a PCB. The program itself is simplified and user friendly when compared to other PCB programs out there

A. Schematic

The schematic of the BreathaLock project is mainly comprised of the ATMEGA328-20P that has ports connected for a Bluetooth module, fingerprint sensor, alcohol gas sensor, and a MOSFETs switching circuit. In addition, there are ports for an FTDI breakout board to easily flash programs onto the microcontroller. Furthermore, the microcontroller has 3 status LEDs. One LED to show that the system is powered on and the other two LED to be program to show the status of the sensors. For the integration of the RF transmitter, there are four solder pads, of which a pair is connected to a lock push button, the other pair of solder pads are connected to an unlock pushbutton.

In terms of power, the whole schematic is powered on by a regulated 5V DC source. There is no short circuit protection for the entire project because the input power is preplanned be clipped on to a 9V battery via a standard 9V battery clip. There will never be an instance where the input voltage is connected backwards onto the BreathaLock project.

B. Board Layout

The board layout for the project is kept to a minimal dimension of 35.56mm x 82.55mm. The reason for a smaller board design is because it will ensure maximum portability as the BreathaLock project is meant to be a portable device.

In terms of component placement, the clock and its stabilizing capacitor are kept as close to the microcontroller as possible to safeguard the system from clock delays if there are any. For the sensor ports, the Bluetooth module, fingerprint sensor and FTDI ports are placed to the far-right side of the board to allow for ease of access. As far as the alcohol gas sensor goes, the ports are placed on the head of the board to mimic modern E-cigarettes. This too allows familiarity while using the BreathaLock as E-cig are becoming more and more popular. In addition, the lock and unlock push buttons on the BreathaLock project are placed from top to bottom respectively. This allows the BreathaLock to be used intuitively as all modern car key remoted are oriented in the same fashion.

VI. POWER

The BreathaLock project will have two power sources, one 6V source for the RF transmitter, and the other is a 9V source for the BreathaLock design integrated onto the transmitter. The reason for having a separate power supply for the RF transmitter is because the user should be able to send out a lock signal to the RF receiver regardless if the BreathaLock device is on or off. This ensures practicality of the design, when applied to real world application of key remote and vehicle. When wanting to send out an unlock signal, the 9V power will be switched on manually via slide switch to the turn the BreathaLock device on. This manual switching configuration rather than a low power mode allows for maximum battery life as there is no current drainage to keep the microcontroller in a low power state.

In terms of source selection, the 6V power source for the RF transmitter will be comprised of two 3V coin cell batteries. This is because the standalone transmitter package already came nicely with two 3V coin cell batteries along with a battery mount on the PCB board. As far as the power of BreathaLock project is concern, the 9V source will be a 9V standard battery with a capacity of roughly 500mAh. The reason for the standard 9V battery is because of the capacity of the battery. At 500mAh, the battery capacity is sufficient to satisfy the amount of current draw the BreathaLock project needs given the use time of the device.

When concerning about power optimization to meet project specifications, the maximum power consumption of each major component is compared to what is available on the market and then each part was be strategically selected. The selected components and its maximum power consumption is shown in the table below.

TABLE 2
Major Component Consumption

Component	**Component (specific)**	**Voltage (max)**	**Current (max)**
Micro-controller	ATMEGA328-20P	5.0V	50mA
Bluetooth module	Nordic NRF51822-UART LE	5.0V	20mA
Alcohol gas sensor	MQ-3	5.0V	150mA
Fingerprint sensor	ZFM-20 Series FP	5.0V	150mA

VII. Communication

A. RF Technology

The principle behind the BreathaLock project is RF transmission, and reception. Basic RF transmission works by first taking data and modulating the signal to encode the data. Once modulated, the signal then gets transmitted, via antenna, to the receiving end of the system which receives the modulated signal, also by antenna. Once the modulated signal gets received, the receiver then demodulates the signal and processes its data.

B. UART Serial

Before going into the details of how UART is implemented and how it works. Universal asynchronous receiver/transmitter (UART) takes bytes and transmits these individual bits in a sequential fashion to its destination, a second UART capable device assembles this into a complete message. Each UART contains a shift register; essentially, a means to convert serial to parallel format. The UART protocol benefits us as its cheaper to transmit across one wire as oppose to several wires.

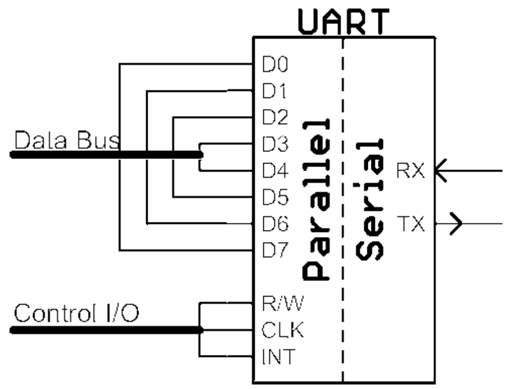

Fig 4: Shift Register UART

The UART does not directly create or receive the external signals used between different items of equipment. Separate interfaces will handle creating and converting the logic level signals of UART to and from external signaling levels. Some of these signals are usually different forms. There are three standards for transmissions:

- **Simplex** is in one direction only, with no provision for the receiving device to send information back to the transmitting device
- **Full duplex** both devices send and receive at the same time
- **Half duplex** devices take turns transmitting and receiving

VIII. Specifications

The project requirements for the BreathaLock project is divided by two sections: Physical specifications and Performance specification.

A. Physical Specifications

The physical requirement for the project is a maximum of 3”x 3”x7”. The reason for this specification is to allow the device to be portable and ensures the practicality of using the device. In addition, the device must be no heavier than 1lb. Anything over 1lb is too unreasonable to be portable thus destructing the practicality of using the device.

B. *Performance Specifications*

Regarding performance specifications, the device must operate within 4 watts of power. This specification allows the device to be energy efficient which is desirable in any portable electronic devices. Because of this specification, the amount of times to change out the batteries is reduced.

The device must be able to block the user to be able to send out an unlock signal if the user blows a blood alcohol content of .08 or above. This specification is critical to the BreathaLock project as it serve as the purpose of the project. In the state of Florida, anyone who has a blood alcohol content of 0.08% or above is considered over the legal limit for operating a motor vehicle. If the alcohol gas sensor reads a value below of 0.08% then the user should be able to send out an unlock signal to the motor vehicle. For the project a RF receiver will act as the motor vehicle.

Another performance specification for the project is that the device must be able to store the fingerprints of registered users. This specification is critical as it allows the BreathaLock system to have a level of security. If the device were to the to get to the hands of a unregistered user, then the unregistered user will not be able to unlock the motor vehicle. Once again, for the BreathaLock project a RF receiver will mimic a motor vehicle.

The last performance specification is that the device must be able to detect if the user if blowing into the alcohol gas sensor or not. This specification allows for device authenticity. If the BreathaLock device doesn't have breath detection then the intoxicated user may be able to fan clean air into the gas sensor and thus bypassing entire system.

IX. Hardware Testing Environment

The hardware testing environment consist of testing each major component for the BreathaLock project individually upon integration. The major components consist of the alcohol gas sensor, fingerprint sensor, the Bluetooth module, the MOSFET switch, and the microcontroller.

A. *Alcohol gas sensor*

The testing environment for the MQ-3 alcohol sensor first consist of feeling for the heater and seeing if the device is on or off. If the MQ-3 is powered on then there will be some significant amount of heat dissipated from the internal heater. In terms of testing the accuracy of the gas sensor, the output analog values of the MQ are compared to and correlated to the blood alcohol content to a real breathalyzer. In addition, when concerning with the upper and lower extreme of the alcohol sensor; i.g. pass or fail, testing the hardware was tested by squeezing a bottle of hand sanitizer onto the sensor. The hand sanitized is concentrated alcohol thus hitting a upper extreme values. To reach a lower extreme for the output of the sensor, the clean air was fanned into the MQ-3.

B. *Fingerprint sensor*

The testing environment for the fingerprint sensor consisted of two methods. The first method was first using its native interface supplied by the manufacturer: SFG Demo. Using the windows application SFG Demo will allow the user to register and test their fingerprint via the on-board memory that comes with the fingerprint scanner. After the users have been registered, the second method to testing the fingerprint scanner is through the Arduino IDE. Using some sample codes and libraries given with the product, the fingerprint sensor can take reading of various fingerprints. If the registered user was scanned then a status RGB LED will light up green, however if a nonregistered user was scanned then a RGB LED will light up red

C. *Bluetooth module*

Since the Nordic NRF51822 UART LE was bought from Adafruit.com the device already is well documented and well supported. To test the Bluetooth module the sample code was uploaded to the microcontroller via Arduino IDE. If the Bluetooth module is working correctly then a blue status light on the board itself will light up showing that there is a device connected.

D. *MOSFET Switching*

To test the MOSFET switch that drive the unlock signal on the RF transmitter, a pushbutton was used. Once the digital pin that is connected to the gate of the MOSFET is set to high, then an unlock signal can be sent out. Upon pushing the pushbutton, a status LED on the RF transmitter will flash red. However, if the digital pin is set to low, then an unlock signal cannot be sent out thus upon pushing the push button, the LED on the RF transmitter will not flash.

E. *Microcontroller*

Concerning the hardware testing environment for the ATMEGA328-20P, first the power LED must be on, if the LED if off then the microcontroller if off. Once the power LED is on, then the second method to test the microcontroller to run a blink code program through the

Arduino IDE. The programs simply flash the on-board LED at different delays. If the LED is flashing correctly then the microcontroller is working correctly.

X. SOFTWARE FLOW

The BreathaLock works in several phases: A startup phase to initiate a warm up phase for the gas sensor this phase also locks the user out from using the BreathaLock until they verify themselves with the fingerprint sensor, Locked phase, Idle phase which allows the user to begin blowing into the BreathaLock. Lastly Evaluation phase which will process the user's breath.

A. Warm-Up (locked)

The warm up phase is nearly a universal concept across any breathalyzer that utilizes the a MQ-3 gas sensor variety. This step is necessary since the tin dioxide must be heated to provide the necessary work conditions for work of sensitive components. We have found that by allowing roughly 15-30 seconds of warm-up time which gives the heater enough time to warm itself. This phase also will remain in warmup (locked phase) until the user verifies their fingerprint.

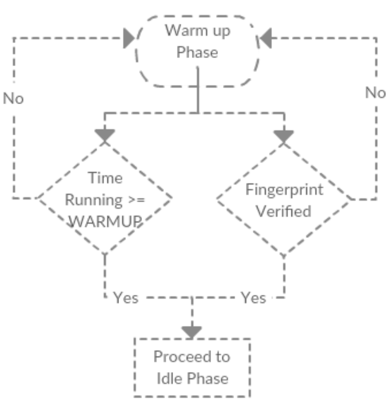

Fig 5: Warm Up Phase Process

B. Idle

The Idle phase is where the user will begin blowing this process is involves a few steps. First, the device must be able to detect if the user is blowing we do this by checking if air has passed over the gas sensor and detecting a delta predetermined by ourselves usually 0.5 volts across the tin dioxide; however, this value can be adjusted if necessary. Detecting if the user is blowing is an important check due to the ability of the user to power the sensor on, then the user can clear the Warm-Up phase, and leave the device this would be considered a pass. As the BAC of air passing over the gas sensor would be 0.00. We feel this resolves this exploit.

Lastly, after we have established that the user has blown over the gas sensor, we then can determine if that users' breath consist of alcohol. This process looks like the following:

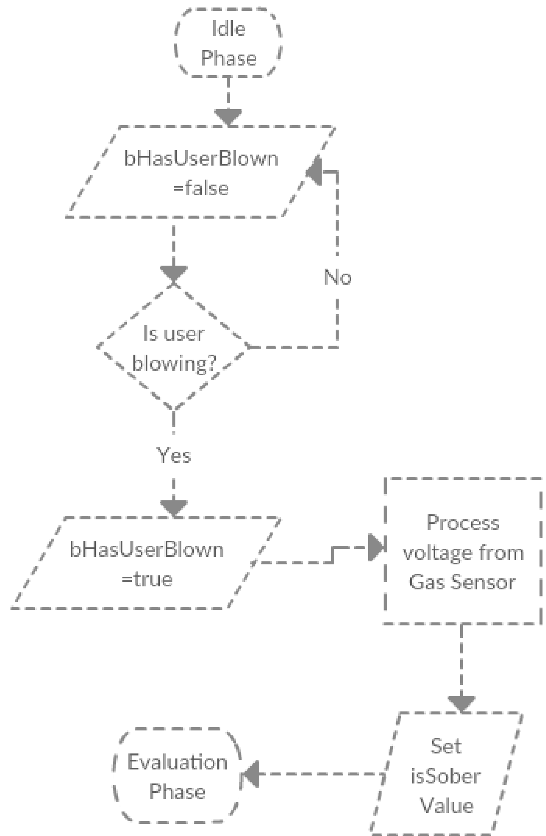

Fig 6: Idle Phase checking for potential exploit and passing gas sensor value to evaluation phase

C. Evaluation

The evaluation phase will do the heavy lifting of checking the users BAC against the voltage. If the user fails to pass this stage then the MOSFET gate will remain low powered and the user will not be able to unlock their car. Without restarting the device and trying again or waiting until enough time has passed so that alcohol has left their system.

If the user passes this stage the MOSFET gate will receive power from the ATMEL chip and the user will be able to unlock their car and gain entry to it.

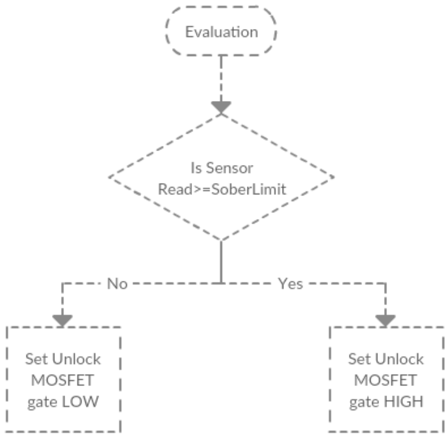

Fig 7: Evaluation process demonstrating the unlocking phase that allows the user to use the button

The total flow of our software process is demonstrated below including the Android application.

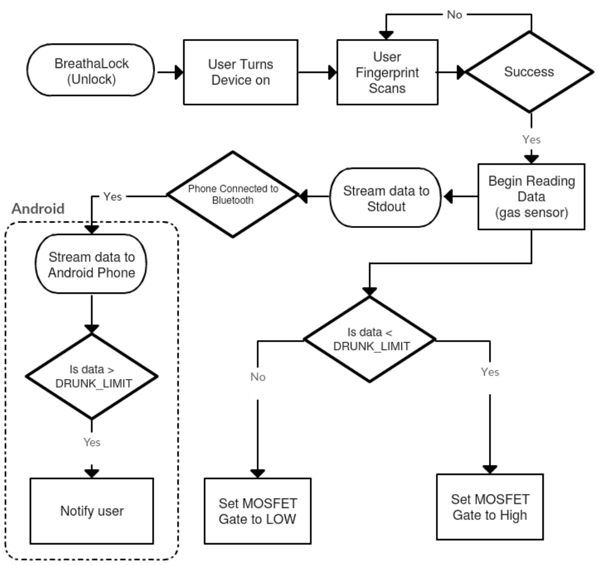

Fig 8: Software Flow Diagram including our android portion

XI. Legality

To understand how our device works it helps to put in perspective some of the laws and consequences that we felt justified some the use of this system. within the context of our paper we will be focusing on specifically Florida laws

A. The Law

In Florida, you can receive a DUI (driving under the influence) if you are driving or be in "actual physical control" of a vehicle in such a state of impairment. An intoxicated motorist who's found by police slumped over the wheel with keys in hand could be prosecuted for DUI even though the car never moved. [3]

B. Implied Consent

Florida law requires you to take a breath, blood, or urine test if you are arrested for a DUI. Florida's "implied consent" law [4]. Which details that if you are lawfully arrested by an officer who does have probable cause to believe that you have been driving under the influence, this will entitle the officer to have "implied consent" to a blood test.

C. Consequences

The severity of the consequences alone should be enough to disincentives people from drinking and driving. These consequences are enacted in various stages depending on offense [3]:

- First Conviction: Not less than $500, or more than $1,000. With Blood/Breath Alcohol Level (BAL) of .15 or higher or minor in the vehicle: Not less than $1,000, or more than $2,000.

- Second Conviction: Not less than $1,000, or more than $2,000. With BAL of .15 or higher or minor in the vehicle: Not less than $2,000, or more than $4,000.

- Third Conviction More than 10 years from second: Not less than $2,000, or more than $5,000. With BAL of .15 or higher or minor in the vehicle: Not less than $4,000.

However, we still suffer from a significant problem regarding a drinking and driving culture which we hope to help mitigate this with our project.

D. Limits

Under Florida law, DUI are one offense, proved by impairment of normal faculties or unlawful blood alcohol or breath alcohol level of .08 or above. The penalties upon conviction are the same, regardless of the way the offense is proven.[3]

XII. Conclusion

The final product created accomplished all anticipated functionalities to expected or exceeding levels. With that said, we realize that this product is by no means perfect and has very much potential to be improved if more time were invested. We are proud of the Breathalock device and all its functionalities.

This senior design project has been a very valuable and important learning experience for all involved. Namely team working skills, professional documentation and exercising concepts learned in undergraduate studies were greatly improved. Each member's contributions and thoughts were used to improve this product.

ACKNOWLEDGEMENT

The authors wish to primarily acknowledge the support and dedication of Dr. Lei Wei through the steps necessary to complete this project. We would also like to thank all professors in the University of Central Florida CECS department for providing us the fundamentals to accomplish and design a working device.

BIOGRAPHY

Nicholas Fraser is currently a senior at the University of Central Florida and will be graduating with a Bachelor of Science in Electrical Engineering in early May 2017. He will be starting an electrical engineering career in South Florida beginning in mid-May and may go onto continuing education later in life.

Nam Ngo is senior in electrical engineering at the University of Central Florida and will be receiving his bachelors in May 2017. His main interest is system level integration and analog signal processing.

Charles A. Taylor is a senior at University of Central Florida and will be graduating with a Bachelor of Science in Computer Engineering (CpE) in May 2017. In July 2017, he will begin a career in Houston, Texas working at NASA Johnson Space Center in the Spacecraft Software Engineering Directorate developing technologies such as Core Flight Software (CFS), and the Multi-Purpose Crew Vehicle (MPCV).

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