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February 17th, 2014
Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
V5A 1S6

Re: ENSC 440/305W Design Specification for an Impaired Driving Prevention System

Dear Dr. Rawicz,

Attached is the document from AlcoShield Company describing the functional specification for the Impaired Driving Prevention System. We are designing and implementing a system that would focus on preventing intoxicated individuals from operating their vehicles by terminating the ignition of the engine if they are suspected to be over the local Blood Alcohol Content (BAC) limit. The system includes a breathalyser to measure the BAC and a method to authenticate the driver via image facial recognition.

The system will consist of a breathalyser, a camera, an ignition kill switch, and a central processing unit all of which will be integrated into the final design to perform the task of preventing impaired driving. The enclosed design specification document describes the hardware and software technologies which apply to satisfy the device requirements outlined in our functional specification document. The enclosed document also explains the reasoning behind our design choices and details our approach to authenticating the driver. The technologies described in this document are intended for development of a proof-of-concept system. In order to commercialize the product, additional design work will be necessary.

Our accomplished team of senior engineers who are committed to this project include Moataz Billeh, Ashraf Jerbi, Ritik Looned, Mohammed Naghshineh, and Nima Soroudi. We look forward to your support over the term and if you have any questions or concerns please contact me via email at rlooned@sfu.ca.

Sincerely,

Ritik Looned

Ritik Looned
Chief Executive Officer
Alcoshield

Enclosed: Design Specification for an Impaired Driving Prevention System

Design Specification for an

IMPAIRED DRIVING PREVENTION SYSTEM

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Submitted to
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March 13, 2014

Executive Summary

Impaired driving is an unfortunate prevalent occurrence in today's society. It is estimated that 2,541 individuals were killed in motor vehicle accidents in Canada in 2010 of which at least 1,082 were impairment-related [1]. The aim of the project is to design a system which prevents any form of drunk driving while over the legislated legal limits. There are two scenarios which are targeted in our system: the first in which the user is intoxicated and thus are not allowed to operate the vehicle, and the second in which the user is sober and no immediate restrictive action is taken. The entire system consists of a breathalyser, an ignition kill switch, a driver authentication strategy all of which will be integrated into the vehicle as an aftermarket device. While blood alcohol detection is a relatively simple task with current breathalysers in the market, the 'seller' in our system would be the user authentication feature. We are focused on designing a vigorous system which will ensure that it is the driver who is performing the breath test and not anyone else.

The design specifications document for the SoberJack device provides a descriptive and informative overview of the design, implementation, and development of our product. In this document, we discuss the design considerations relative to the functional requirements as specified in the document *Functional Specification for an Impaired Driving Prevention System* [2]. Further, all design choices for the system are included within this document with supportive reasoning of component selection. Future design improvements intended for the commercialization of the SoberJack device are also discussed.

Included in this document are also all hardware and software components related to the functioning of the device which are described in full detail. Software data flow charts, along with hardware component schematics are highlighted explicitly to provide a thorough understanding of the device design and operation. Further, a fully descriptive test plan for the system and its subcomponents is provided at the end of the document which is intended for assessment purposes.

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Glossary

BAC	Blood Alcohol Content
CSA	Canadian Standards Association

FDA	US Food and Drug Administration
FPS	Frames per Second
ISO	International Organization for Standardization.
MOH	Minister of Health Canada
MOT	Ministry of Transportation Canada
MCU	Micro-Controller Unit
PCB	Printed Circuit Boar

1. Introduction/Background

The impaired driving prevention system is a novel design which is intended to deter any form of drunk vehicle operation. In fact, impaired driving is still a major concern in today's society and contributes to almost 50% of the total number of motor vehicle accidents each year in Canada [3]. Excessive and unnecessary resources are then dedicated to resolve such incidents which could frankly have been easily avoided. The financial implications of these activities resulted in an expenditure of over $20.62 billion in Canada in the year 2010 [4]. Realizing the urgent need to mitigate such accidents, the team at AlcoShield has taken up the responsibility of making the streets safer and sober with their SoberJack product.

Figure 1: Photos of severe car accidents due to impaired driving

1.1 Scope

The design specification documentation illustrates our design approach leading to the selection of the various hardware and software components for our impaired driving prevention system. The functionalities of the proposed system are justified with explicit components and their design and operation details. System design information is specified primarily for the product development phase for proof-of-concept but expands in certain aspects for the final commercialized product.

1.2 Intended audience

The aim of this document is to clearly highlight the design approach to fulfil the proposed features and requirements of the system. All engineering team members of AlcoShield will be required to reference this text to ensure that the device complies with the planned operations. Testing and verification protocols will be designed such that it allows all aspects of the design will be carefully examined. Other readers of this document may require a technical background.

2. Overall System Design

The general system design of the Impaired Driving Prevention system is presented in this section. This includes an overview of the hardware components with details on the high level view of information flow through the system, as well as the underlying software algorithms. Justification for the chosen design approach is provided in the respective sections for each component. Finally, sketches of the possible appearance of the vehicle fitted device as an aftermarket product are illustrated.

2.1 System Overview

The high level system overview of the chosen design approach is visualized in Figure 2. Specifically it focuses on the two scenarios which are targeted in our system:

1. The user is intoxicated and thus is not allowed to operate the vehicle.
2. The user is sober and although no immediate restrictive action is taken further authentication is required.

The entire system consists of a breathalyser, an ignition kill switch, and a driver authentication strategy all of which would be integrated into the vehicle as an aftermarket device. Figure 1 illustrates the general flow of information through the system. It is vital to realize that upon entering the key into the ignition keyhole and turning it to the Accessory (ACC) position, the camera must initialize. Following that, once a breath sample is provided to the breathalyser, the camera must immediately capture images of the driver and store them for comparison. As in scenario 1, if the Blood Alcohol Content (BAC) is above the legal limits, the ignition kill switch is actuated to prevent operation of the vehicle. In scenario 2, where the BAC is below the legal limit, the driver is permitted to operate the vehicle but a further identity check must be performed to authenticate the driver with the breath sample. Additional images are captured which are compared with the stored database to verify a match. In case of a mismatch, various notification strategies to the authorities are considered.

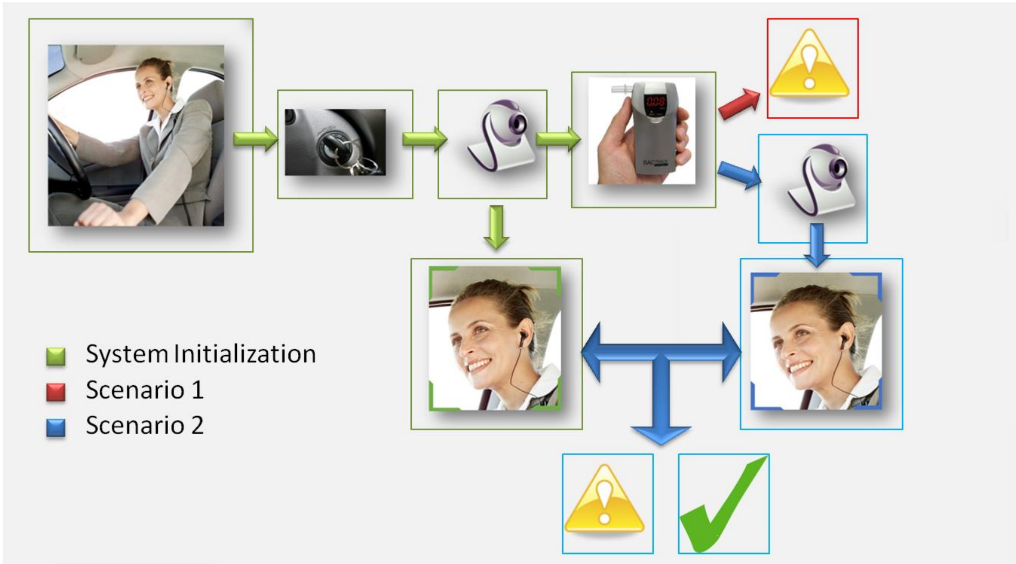


Figure 2: System overview illustrating the high level operation of the device

2.2 Design Justification

One can argue that the software algorithm is not optimized in the sense that an image need only be acquired if the driver passes the test but careful examination will reveal that implementing such a design results in vulnerabilities in the system. The issue lies in the fact that if initialization of the camera and image capture occurs at any other point besides as illustrated in Figure 2, it will render the authentication system useless. It is essential to capture an image at the time the driver is performing the breathalyser test. Only this strategy provides successful authentication that the driver was the person who did the breathalyser test. Capturing an image after the results from the breathalyser will not allow confirmation as to who provided the breath sample. Details of the software algorithm follow below in Figure 3.

A modification to the original design has also been made which now enforces a stricter operation. The system will capture periodic driver images during operation of the vehicle to prevent any means of cheating by replacing drivers during the driving cycle. Since the original limitation of the system was that it acquires a breath sample only upon initialization, it is possible drivers may alternate without turning off the ignition. Although the current modification fixes that issue, there is still a concern that the original driver may begin drinking once he has passed the test. Combating such cases would require additional breath samples which may cause disturbances to the average user. In extreme cases, a custom algorithm could be designed when required but this is beyond the need for an average user hence avoided considering the scope of the project.

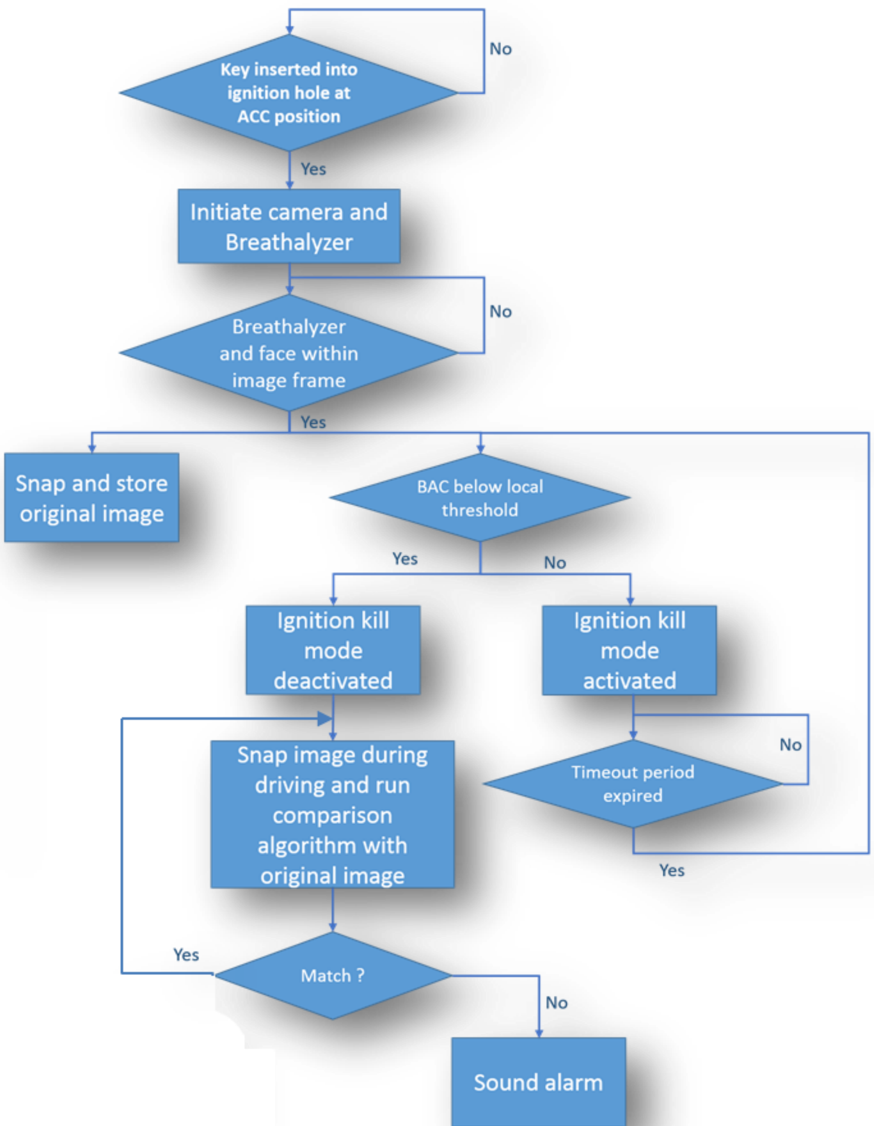


Figure3: Basic control flow of the system

Figure 4 below represents the general flow of information and linking of components in the SoberJack device. It provides the basic structure of the three phases of the device and demonstrates how the interconnected components communicate from a high level point of view. The two sensors in the system include the Raspberry Pi camera and the BacTrack breathalyser. The computation device is the Raspberry Pi and the actuation device is electromechanical relay.

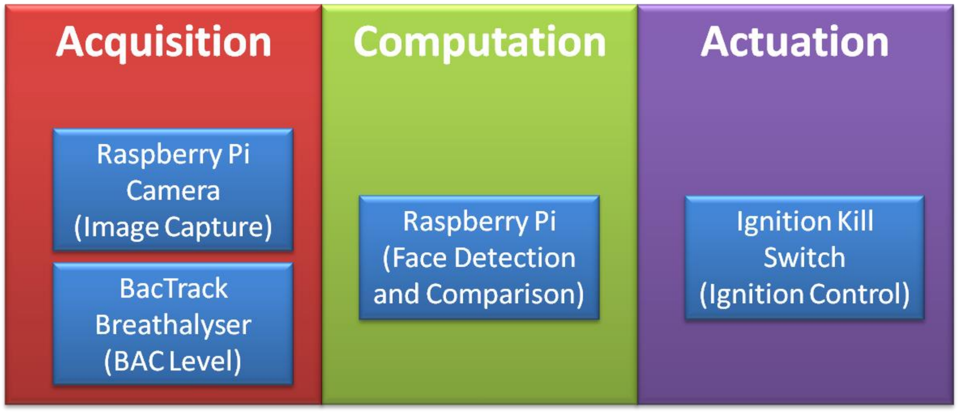


Figure 4: Phased block diagram illustrating the partitioned operation of the system

2.3 Design Expansion

To further enhance the functionality of the system (if all proceeds according to plan), we wish to implement a notification scheme to the local authorities upon detection of drunk driving. Wireless transmission of the driver image and car information will be sent to the law enforcement officers who can then take further corrective actions. A more thorough detection system will also target abusers who drink while they drive. They may begin driving sober and pass the breathalyser test but then later start drinking while operating the vehicle. For such individuals, a more rigours system would be in place which would perform periodic BAC checks.

There are many expansion possibilities of this system but given the circumstances, we will be pursing the basic design to cover Scenarios 1 and 2. This alone will put a dent in the intoxicated driving statistics and lead to safer streets. The expanded features were mentioned in the Functional Specifications Document and classified as level III indicating low priority. Despite their immediate insignificance, the design specifications are still highlighted in the respective section.

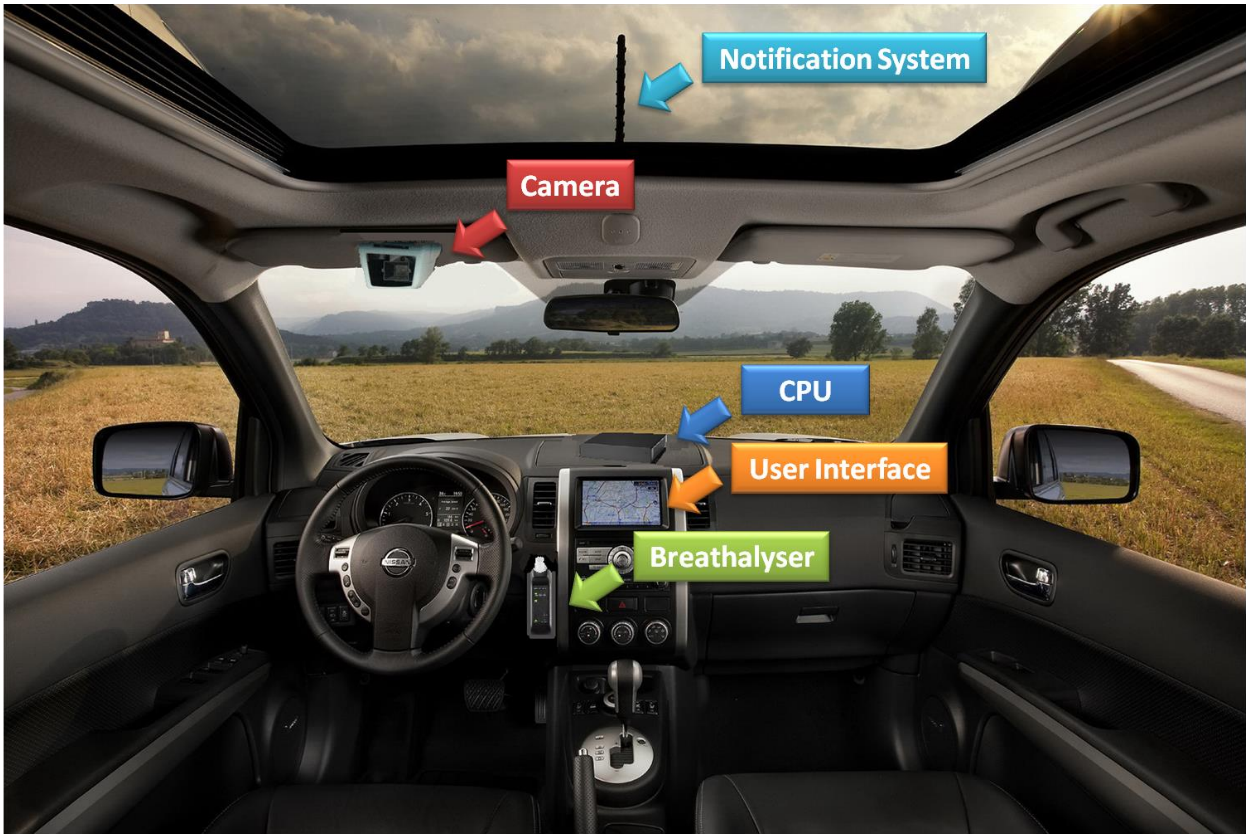


Figure 5: Envision of the final product integrated into the vehicle design

2.4 Design Limitations

As mentioned earlier, the key limitation of the original system was that a sober driver may be replaced by a drunk driver during the driving cycle. This action can now be caught due to periodic image comparisons throughout operation of the vehicle. Another more serious concern is when the driver is sober upon initiating the drive but begins drinking over time while operating the vehicle. Periodic image comparison will all yield positive matches and be unsuccessful in detecting this violation. A thorough solution would entail requiring another breath sample which is a feature that would render the system more disruptive and annoying than bearable. For this reason, we mutually agree to categorize this case to be a calculated limitation of the system and disregard it in the current design.

3.Breathalyzer design specification

As it stated in the previous sections and documents we are using a Breathalyzer from a third party in market. Breathalyzer plays the initiative role in our product and therefore it has to be implemented properly. Breathalyzer consists of few components which the role of each component will be explained in this section.

Figure 6: Breathalyzer

Figure 7: Gas Sensor and 7 Segment LED Display

Components	Role
Gas Sensor	detect the Alcohol level
7 segment LED	Display the alcohol level
PCB	To place and route all the components on it
Electrical Components	MCU, Resistors, Capacitors and etc

Table 1: Breathalyzers parts and components

This Breathalyzer and its parts will be discuss below further in details but the whole use of this Breathalyzer for our project is the signals we have to retrieve data from them. The three signals are has to be detected each at a specific time.

We use the MCP3008 chip from Microchip. Since the RBPi does not have a built-in Analog to Digital Converter (ADC), we propose that you give it an external one with the MCP3008. Teaming up the MCP3008 with the RBPi enables simultaneous measurement of eight analog channels while using up only four digital pins of the RBPi. Figure 7 and figure 8 below shows the propose connections to the built in analoge signal convertor and also the connections we need for the MPC3008 convertor using a breadboard correspondingly.

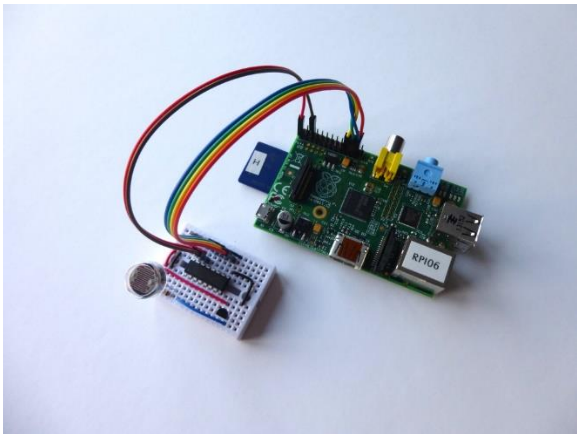


Figure 8: Connection between Raspberry Pi Module and MCP3008

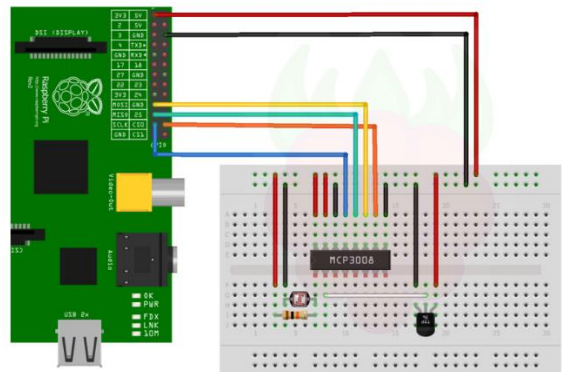


Figure 9: Breadboard Connections between Raspberry Pi and MCP3008

The signals below are shown in the figures throughout this section

1) **VDD:** it's a Breathalyzer power, which we can retrieve it either from the microcontroller chip MCU (Holtek-HT45R065B) pin #15 or the gas sensor in order to realize when the user is turning on the Breathalyzer. As soon as our MCU detects the high signal from VDD, it turns on the camera.
2) **Gas Sensors output voltage:** this signal is been reading continuously from MCU after the user turn on the Breathalyzer. It takes 15 second for the Breathalyzer to be ready to operate and when user starts to blow in the Breathalyzer the output voltage from the gas sensor it will start varying. And as soon as the MCU detects this change in the output voltage, it will command the camera to start taking pictures.
3) **Gas Sensors Output voltage:** we use this signal for detecting the Breath Alcohol Concentration level as well. Since this is a third party device and we don't have an access to the calibration file we have to do some manual test in order to find out at what alcohol concentration level what voltage level is gas sensor outputting. Basically we are going to have a threshold for the voltage level from gas sensor output. Our MCU will continuously retrieve the output voltage level from gas sensor for some period of time. If the voltage level passed the threshold the MCU won't let the car to turn on but of the level is below the threshold and MCU doesn't detect the out of range voltage level, it will allow the car to turn on.

3.1 Gas Sensor

An Alcohol Gas Detector or "Breathalyzer," is a device used to determine the Blood Alcohol Content, or BAC, of an individual ("Blood Alcohol Levels"). A person's BAC must be below a certain level in order to operate a motor vehicle legally. When a user exhales into a Breathalyzer, an alcoholic sensor detects the ethanol vapors present. Through a chemical reaction, the ethanol is oxidized into an acetic acid (“Oxidation/Reduction Reactions”).

This sensor provides an analog resistive output based on the alcohol concentration on the breath. The sensitive material in the gas sensor is SnO2, which with lower conductivity in the air. How it work is when it detects the alcohol, the sensors conductivity increase along with the gas concentration rising. The electro circuit converts the change of conductivity to correspond output signal of gas concentration.

The drive circuit is very simple as all it needs is one resistor. A simple interface could be a 0-3.3V ADC.

Figure 10: Gas Sensor Pinouts

The sensor consists of a tin dioxide sensitive layer inside aluminum oxide micro tubes, measuring electrode and a heating element inside a tubular aluminum casing. The front end of the sensor is covered using a stainless steel net and the rear side holds the connection terminals. The Sensor has a sensing range of 0.05 mg/L to 10 mg/L. The legal BAC in Canada is 0.08 grams per 210 litres, or 0.38 mg/L (“Blood Alcohol Levels”). The sensor is very sensitive to alcoholic content present and has an appropriate range of detection.

This sensor operates as potentiometer. The higher alcohol substance is detected on its sensing layer, the higher to output voltage will be. Its input voltage is approximately 5 V. This sensor requires driver circuit in order to function.

The resistance of the gas sensor varies with different types of gases at different concentration levels. Therefore, when using this component, calibration is necessary to determine its proper alarm point. The recommended value of the load resistance is about 10kΩ Due to the fact that the sensor is a semiconductor device; it is highly affected by temperature and humidity.

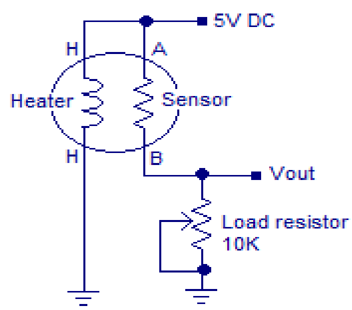


Figure 11: Gas Sensor Schematic

3.2 7-segment LED

The 7 segment LED n the Breathalyzer is basically there to show the alcohol concentration in the air in percentage. Basically how it works is that gas sensor converts the alcohol concentration into analog voltage and sends it to the Breathalyzer MCU (Holtek-HT46R065B) and then MCU send signal to the 7-segment display which is based on the voltage to show the percentage.

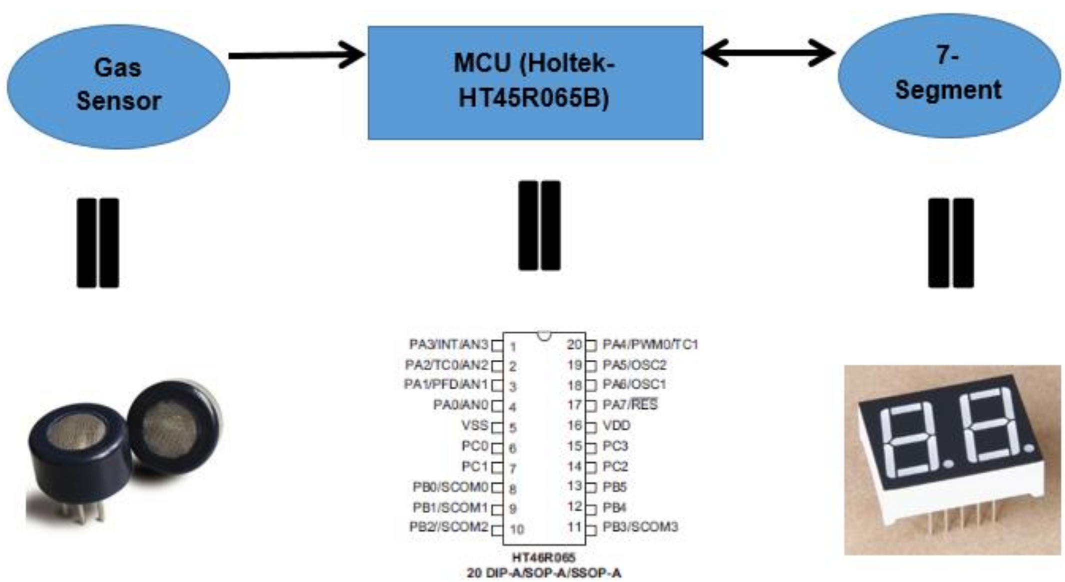


Figure 12: Communication between Gas Sensor and LED Display

3.3 Holtek-HT45R065B Chip

This microcontroller is an enhanced Analog/Digital type 8-Bit high performance, RISC architecture. This microcontroller features low power consumption, Input/output flexibility, timer function and low voltage reset which are the main parts for the Breathalyzer we are using. All the computation and signal processing for the Breathalyzer happens through this chip.

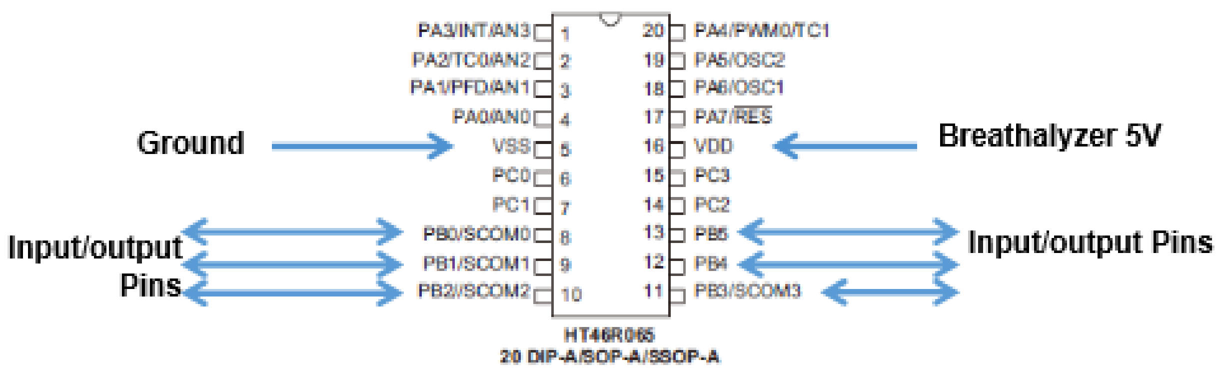


Figure13: Holtek-HT45R065B chip pinout

The following block diagram illustrates the main functional blocks for the Holtek-HT45R065B chip.

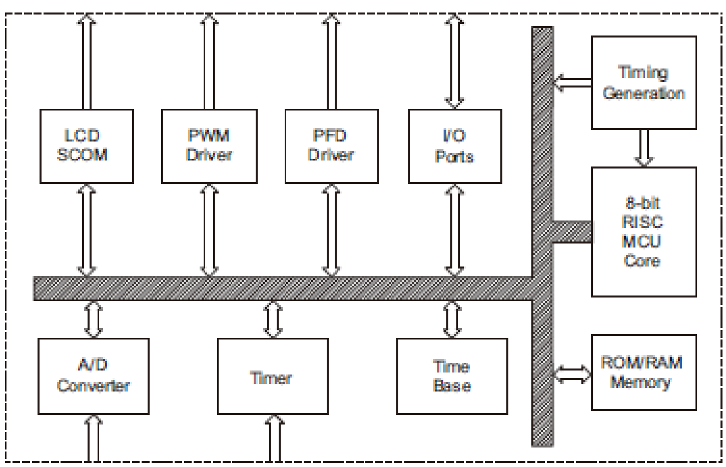


Figure14: Functional Block Diagram of Holtek-HTK45R065B

4. Camera

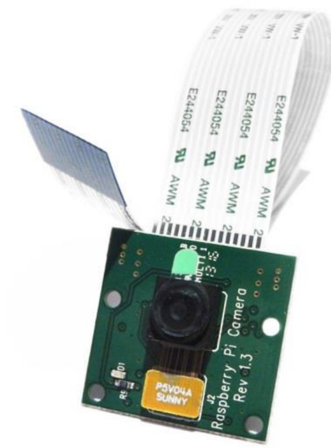


Figure 15: Raspberry Pi camera

Figure 16: Raspberry Pi camera connected to the board

4.1 Scope

The camera is the main component in the face detection and recognition system. It provides visual data needed for initial and random checks of the driver's identity. The camera captures a certain number of the driver's pictures as references for later identity checks. The output result is fed to the Processing unit to generate data actuation signals. The following section outlines the technical specifications of camera [2].

4.2 The Raspberry Pi Camera Board Features

The Raspberry Pi Camera board is attached to the raspberry Pi through a 15 Pin Ribbon Cable, to the dedicated 15-pin MIPI Camera Serial Interface (CSI). It delivers a 5MP (2592X1944) onmivision 5647 sensor. The CSI bus carries very high data rates and it fully transmits pixel data to the BCM2835 processor [5].

The Raspberry Pi Camera board features the following:

- Fully Compatible with Both the Model A and Model B Raspberry Pi
- 5MP Omnivision 5647 Camera Module
- Still Picture Resolution: 2592 x 1944
- Video: Supports 1080p @ 30fps, 720p @ 60fps and 640x480p 60/90 Recording
- 15-pin MIPI Camera Serial Interface - Plugs Directly into the Raspberry Pi Board
- Size: 20 x 25 x 9mm
- Weight 3g

The camera board itself is considerably small. It is at around 25mm x 20mm x 9mm, and it weighs a little bit over 3 g. In addition to the above specifications, our team choose the Raspberry Pi camera because it is perfect for our product since the size and weight does not cause distraction to the driver [6].

4.3 The Raspberry Pi Camera Board control options

One more advantage to using a Raspberry Pi camera in this project is that it allows us to adapt to different lighting condition through the control option mentioned below:

- Sharpness, -sh

The sharpness setting range is from -100 to 100; 0 is the default.

- Contrast, -co

The contrast setting range is from -100 to 100; 0 is the default.

- Brightness, -br

The brightness setting range is from -100 to 100; 50 is the default. 0 is black, 100 is white.

- Saturation, -sa

The image saturation range is from -100 to 100. 0 is the default. This feature set the color saturation of the image.

- ISO, -ISO

This feature sets the so that it can be used for captures. The range is from 100 to 800.

5. Relay

We are using a Relay for the communication between Raspberry Pi and the ignition system. Basically how the system works is after the system detects that blood alcohol concentration is below the limit and facial authentication is passed the CPU generates a signal to turn on the relay. The signal from Raspberry Pi module is somewhere between 2-5V (logic Signal) which will cause the relay to short and let the user turn on the car.

We are placing the relay between the car's ignition system and the car battery. We control this interconnect by sending signals from CPU in order to short the connection and let the user to start the car.

We decided to use Solid-state relays which consist of an input circuit, a control circuit and an output circuit. The Input Circuit is the portion of a relays frame to which the control component is connected. The input circuit performs the same function as the coil of electromechanical relays. The circuit is activated when a voltage higher than the relays specified Pickup Voltage is applied to the relays input. The input circuit is deactivated when the voltage applied is less than the specified minimum Dropout voltage of the relay. The voltage range of 3 VDC to 32 VDC, commonly used with most solid-state relays, makes it useful for most electronic circuits. The Control Circuit is the part of the relay that determines when the output component is energized or de-energized. The control circuit functions as the coupling between the input and output circuits. Simple schematic of a solid state relay is shown below.

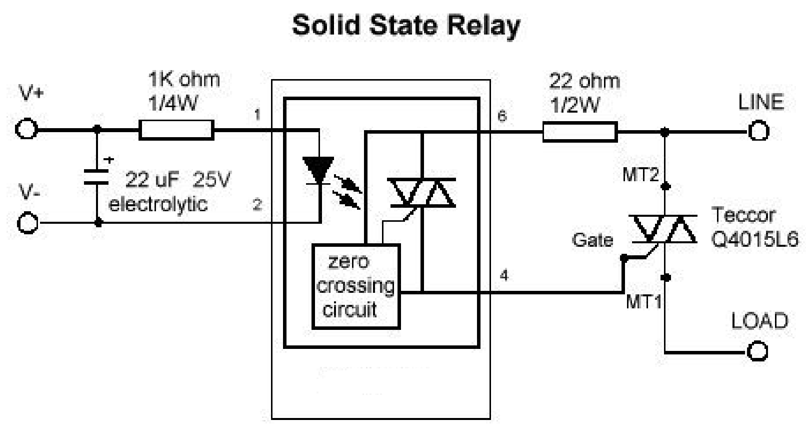


Figure17: Solid-state Relay Schematic

6. Processing Unit

6.1 Hardware Design

6.1.1 Raspberry Pi Model B Rev 2.0

The Soberjack computation system involves frequent image processing and hence requires relatively heavy computations. We were looking for an affordable platform that is fast enough to process certain number of images while performing other operation like writing and reading data to and from other components based on requirement R62-I. Also, to satisfy requirement R67-II**,** the processing unit had to power up using no more than 12V. The Raspberry Pi single board computer technical features fit most of our specified requirements. It operates using 5V and performs at 700MHz. The board is in the size of a credit card, it weighs 45 grams and could be easily enclosed in a small case which satisfies the physical requirements. Table 2 presents full details about the technical specs of the Raspberry Pi we have chosen to process our project modules.

CPU	ARM 1176JZF-S – 1 core
Process speed	700 MHz
System RAM	512 MB
Operating system	Linux, Raspbian
Graphics	Broadcom VideoCore IV
Storage	SD card
Power	3.5W 3V
Dimensions/weight	3.37 inches (h), 2.13 inches (w), 0.67 inches (d) / 45 g
Ports	1x HDMI, 2x USB2.0, Ethernet, CSI connector camera, RCA video,

Table 2: Raspberry Pi Model B Rev 2.0 technical specs

For our project, the main on-board components are the camera connector and the GPIO (general purpose input output) header. Figure 16 illustrates a diagram of the Raspberry Pi model B with the relevant components highlighted [9].

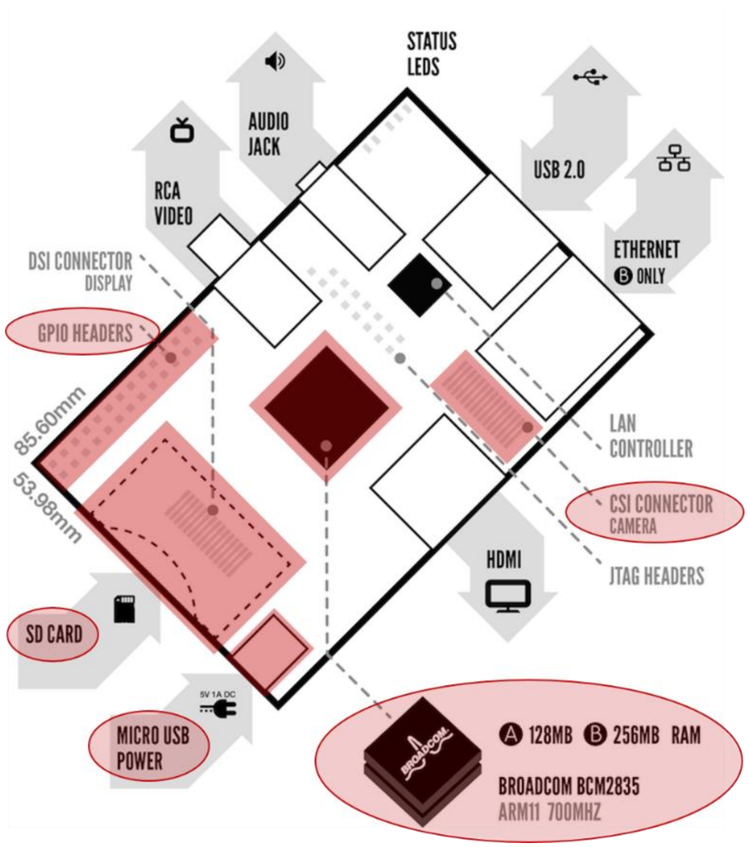
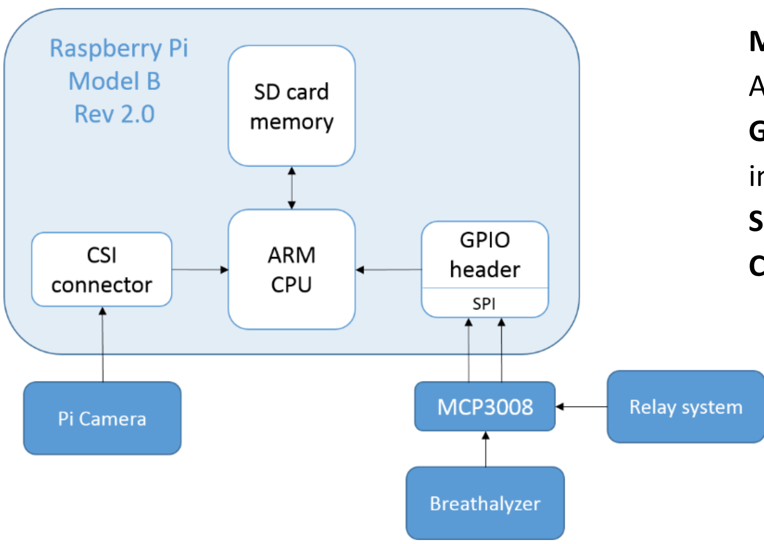


Figure 18: Raspberry Pi with relevant components highlighted

6.1.2 High level Hardware System design

This section highlights the hardware high level design of the processing unit system. All the parts are on-board components and are controlled through the operating system software shell. Figure 17 depicts the block diagram of the hardware structure including the external components (i.e. camera, Breathalyzer, relay and ADC).



MCP3008 - 10bit 8-channel Analogue to Digital Convertor
GPIO - General-purpose input/output
SPI - Serial Peripheral Interface
CSI - Camera Serial Interface

Figure 19: Processing unit high level hardware system block diagram

6.1.3 Input/output Pins Header

In order to be able to write and read signals to and from external providers, the board provides a 2x13 grid of pins referred to as expansion header. The expansion header includes 8 GPIOS, a UART, SPI, and I2C [8].

Figure 20: GPIO header simplified diagram

6.1.5 Memory

The processing unit uses an 8GB SDHC card as a storage unit. Part of the storage memory is used for the operating system.

6.2 Software Design

6.2.1 High level Hardware System design

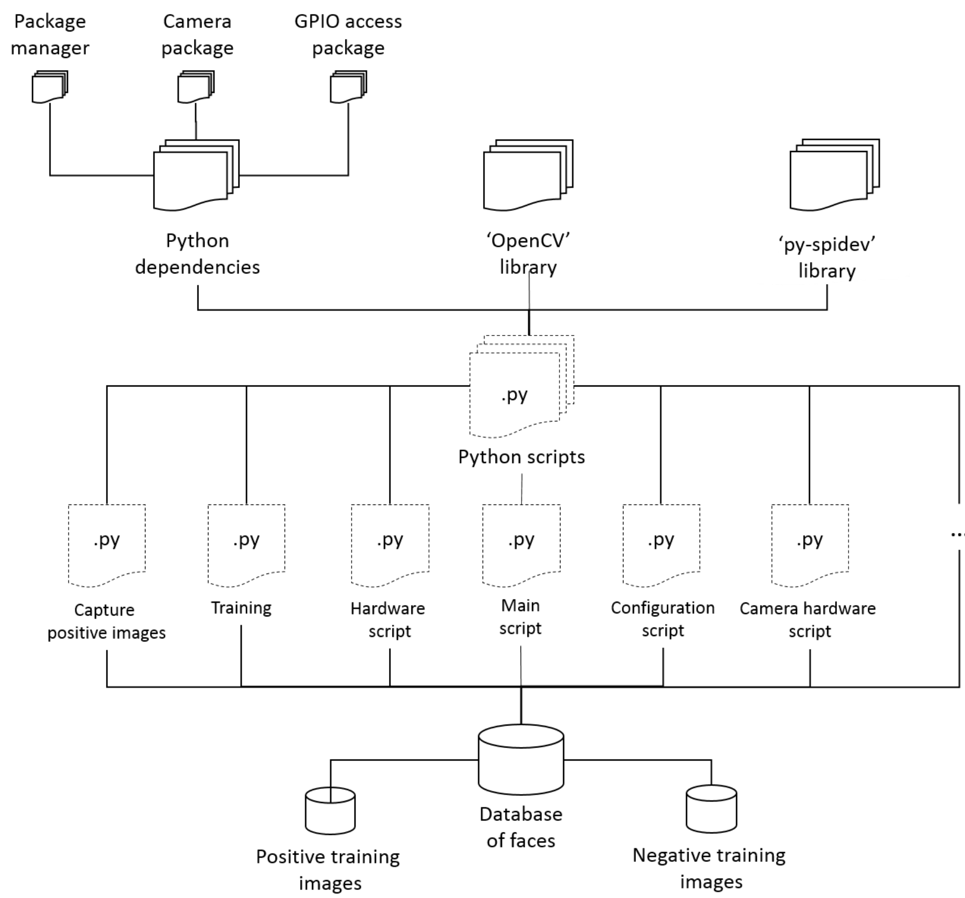


Figure 21: Processing unit high level software system block diagram

6.2.2 Python script modules

The python script modules comprises of the camera module and the SPI connection module

7.Test Scenarios for the Prototype Version

To evaluate the complete system, the following test cases will be performed. The first case illustrates the devices capability to detect a drunk individual. The second case demonstrates when all inputs to the system are positive and no restrictive action is taken. The third scenario illustrates a violation of the system.

TEST 1

Actions to be performed

1. The individual will present them self in the front of the camera and hold their position stationary for a period of 10 seconds.
2. The individual will then turn on the Breathalyzer and provide a drunk breath sample while ensuring they remain within the camera capturing frame.

Expected Result

The Breathalyzer will detect the breath sample to have exceeded the allowable BAC level and consequently the electromechanical relay will be actuated open. A failure indication would be present on the respective LED on the user interface. In a real world scenario this implies the user is not permitted to operate the vehicle.

TEST 2

Actions to be performed

1. The individual will present them self in the front of the camera and hold their position stationary for a period of 10 seconds.
2. The individual will then turn on the Breathalyzer and provide a sober breath sample while ensuring they remain within the camera capturing frame.
3. The individual will remain within the capture frame of the camera for the next 2 minutes in which successive verification images will be taken.

Expected Result

Upon detecting a BAC level below the legislated limit, the electromechanical relay will be actuated closed. This mimics the real life case in which the user is allowed to operate their vehicle. Within the next 2 minutes, additional processes will ensure that the individual in the image frame was indeed the individual who performed the Breathalyzer test. No further actions will be taken.

TEST 3

Actions to be performed

1. The individual will present them self in the front of the camera and hold their position stationary for a period of 10 seconds.
2. The individual will then turn on the Breathalyzer and provide a sober breath sample while ensuring they remain within the camera capturing frame.
3. The individual will then leave the camera capture frame and a new individual will present themselves. They will remain within the capture frame of the camera for the next 2 minutes in which successive verification images will be taken.

Expected Result

Upon detecting a BAC level below the legislated limit, the electromechanical relay will be actuated closed. This mimics the real life case in which the user is allowed to operate their vehicle. Within the next 2 minutes, additional processes will ensure that the individual in the image frame was indeed the individual who performed the Breathalyzer test. Since a mismatch will be detected, the user interface will display a violation.

Conclusion

The SoberJack product as designed by the team at AlcoShield is intended to keep the streets safer and sober by preventing impaired driving. Prior to operation of the vehicle, the driver must first perform a breathalyser test to ensure their BAC is below the legislated limits. In addition, a driver authentication system is also designed to ensure no violations of the system are possible.

To implement such a system, the design specifications detailed in this document closely capture the functional requirements originally outlined. The overview of the system clearly illustrates the purpose of the impaired driving prevention system and mentions both its positive implications along with its current limitations. The proof-of-concept prototype is intended to demonstrate the driver authentication system while the commercialized product will feature enhanced capabilities such as an authority notification system. Current constraints on implementing a complete product are primarily minimal time resources. Beyond this, the document also highlights the selection process of each component justifies its use through its capabilities and financial convenience.

The company aims to present a functioning product applying to the proof-of-concept model by April 11, 2014. The attached test plan will be a assessment tool to verify the operation of the system.

References

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