Low-Cost Breathalyser Ignition Interlock

By

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08288

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the Information & Communication Technology Programme Universiti Teknologi PETRONAS
In partial fulfilment of the requirements for the
Bachelor of Technology (HONS)
(Information & Communication Technology)

Approved by,

____
(Dr. Low Tang Jung)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
May 2015

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

(Then Yik Lung)

ABSTRACT

Driving under the Influence (DUI) is the act of driving a motor vehicle with blood levels of alcohol (BAC) in excess of a legal limit and is one of major risk factors for road traffic accident causing an average of 120, 000 accidents annually in Malaysia. There hasn't been any substantial device or system in Malaysia that is designed to monitor and prevent driving under the influence of alcohol (DUI) and methods to curb the offenders from driving while intoxicated are still limited. The author's proposed solution to this problem is a breathalyser ignition interlock device, an electronic device installed to a vehicle's ignition system used to measure and test the blood alcohol content in a person's blood stream before allowing for a vehicle's ignition system to be started up. This project involves the design, development and fabrication of a breathalyser ignition interlock device which controls an ignition switch. Upon assembly, the system is able to detect the alcohol concentration in a person's breath sample and displays the detected amount in terms of BAC (Blood Alcohol Concentration) percentage. According to the amount, the system decides whether to enable or disable the ignition switch circuitry which is pre-set to the legal limit of 0.08 g/dl in Malaysia for this project. We will limit the scope of this project by building an electronic circuit which will simulate a vehicle's ignition system instead of actually installing the breathalyser ignition interlock to a vehicle's actual ignition system due to time and financial constraints. The hardware module includes microcontroller board Arduino Uno, MQ3 alcohol sensor, LCD panel and ignition switch circuitry. The software component includes the programming and source code which is implemented via the microcontroller. Prototyping is selected as the methodology to develop the prototype. The main factor is because an electronic prototype device is hard to visualize before fabrication thus allowing for an incremental viewing, testing and observing the progress of the project which also allows for testing of each module of the individual function of the device thus ensuring that it is working as intended. The major findings from these project are the adverse effect of alcohol on driving capabilities, the risk factor of Driving under Influence (DUI), brief history on breathalyser and breathalyser ignition interlock and its effectiveness and finally key anti-cheat and anti-tampering features and functionalities in modern breathalyser ignition interlock.

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I would like to thank my mother, Nancy Ho Guek Moi for her continual moral and financial support especially through the tough periods of my life these past few years. Finally, I would like to especially dedicate this project to my father, Alan Then Kuet Khiong who is no longer with us today.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Driving under the Influence (DUI) or drunken driving is the act of driving a motor vehicle with blood levels of alcohol (BAC) in excess of a legal limit. Driving under the influence of drugs or alcohol (DUI) is one of the well-documented risk factors for road traffic accident (WHO, 2004). This is a public safety issue as it not only poses a risk to the driver's themselves but also to the passengers and other road users in general. For the general driving population, the risk of being involved in a crash starts to rise significantly at a blood alcohol concentration level (BAC) of 0.04 g/dl (Compton *et al.,* 2002). Policies, laws and regulations has been implemented and enforced in most country globally regarding Driving under the Influence (DUI).

According the law of Malaysia in Road Transport Act 1987 under section 45G, the legal limit is 35 micrograms of alcohol in 100 millilitres of breath, 107 milligrams of alcohol in 100 millilitres of urine or 80 milligrams of alcohol in 100 millilitres of blood or 0.08 g/dl (Road Transport Act, 1987). For the purpose of this project, we will only focus on the amount of alcohol in the blood (BAC). The current penalty as set by the law of Malaysia if a driver is found to have exceed the legal limit is a fine of between RM1, 000 to RM 6, 000 and imprisonment of not more than 12 months for first time offenders and a fine of RM 2, 000 to RM 10, 000 and imprisonment of not more than 24 months for repeat offenders (Road Transport Act, 1987). As we can observe, methods to curb the offenders from Driving under the Influence (DUI) are still limited and non-extensive, apart from imposing hefty traffic summons, barring of driving licenses and detention of those who are subjected to violation at numerous accounts.

Therefore, the proposed solution to this problem is the breathalyser ignition interlock device. A breathalyser ignition interlock device is essentially a breathalyser installed into a motor vehicle's ignition system which acts as a Driving under the Influence (DUI) prevention device. A driver must breathe into the breathalyser ignition interlock before they can start a motor vehicle. The breathalyser ignition interlock device will then measure the blood alcohol content (BAC) after which it will compare the measured blood alcohol content (BAC) to the pre-set limit, usually this will be the legal limit of the country the vehicle is operating in (0.08 g/dl or 80 milligrams of alcohol in 100 millilitres of blood in Malaysia). If the blood alcohol content registers over the pre-set limit, the motor vehicle's ignition system cannot be started for a short duration of time (few minutes) until a clean breath sample has been provided.

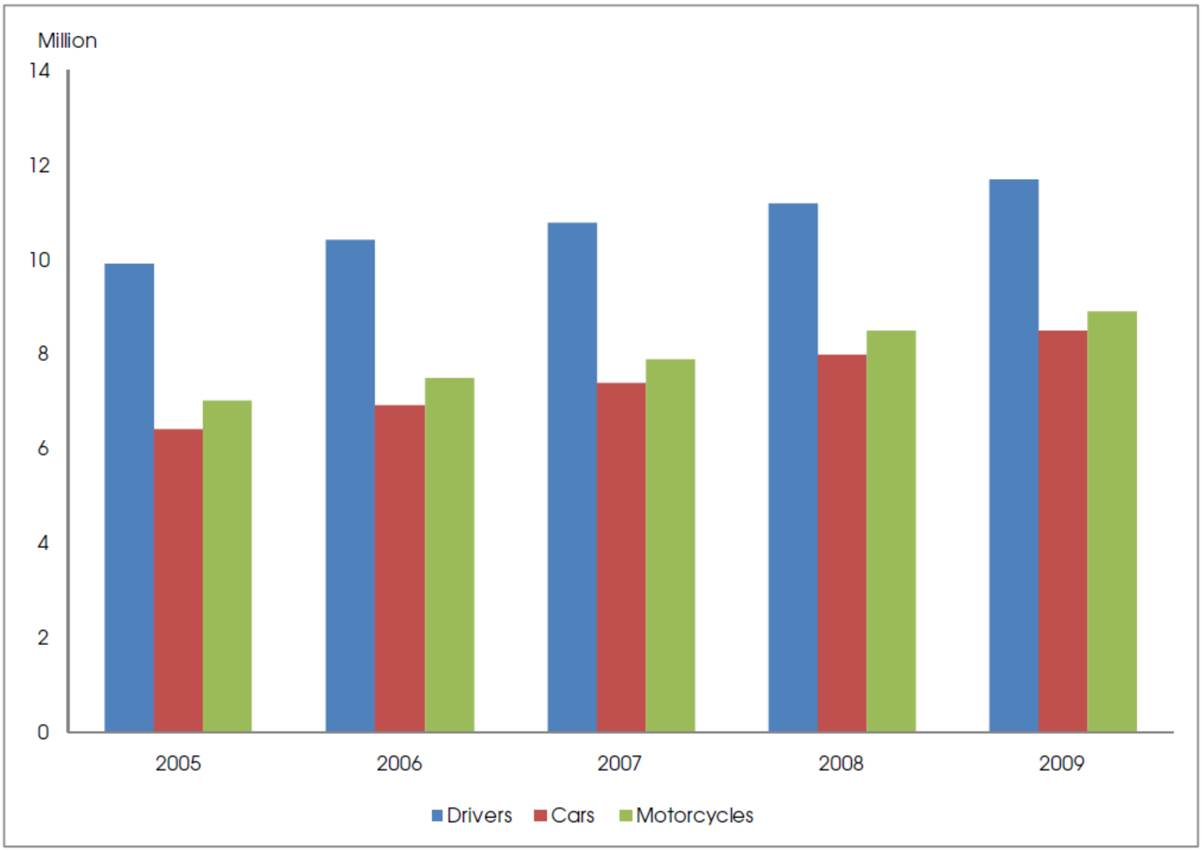
Breathalyser ignition interlock has been widely used and implemented in the United States since the early 1990s and is currently being enforced upon in all 50 states in the United States as a sentencing alternative by law. It has since spread and is currently being implemented widely in Canada and Europe. As of July, 1 2012, France became the first country in the world to decree mandatory breathalyser ignition interlock to be installed in all motor vehicles registered in France (Nelson Ire, 2012). Judging from the results from the implementation there, it has brought about a tremendous amount of success in curbing repeat offenders of Driving under the Influence (DUI) and reducing the amount of motor vehicle accidents caused by Driving under the Influence (DUI).

1.2 Problem Statement

Out of the total world population, 55 percent of the world's population consumes alcohol (WHO, 2011). Considering the total world population of 2011 of more than 6 billion, the number of people drinking is quite astounding. Out of a total of 196 countries in the world, only 9 countries impose nationwide ban of alcohol and 2 partial bans in parts of region in the country (Wikipedia, 2010). All these set for a precedence for a potential of a large number of accidents that are caused by Driving under the Influence (DUI).

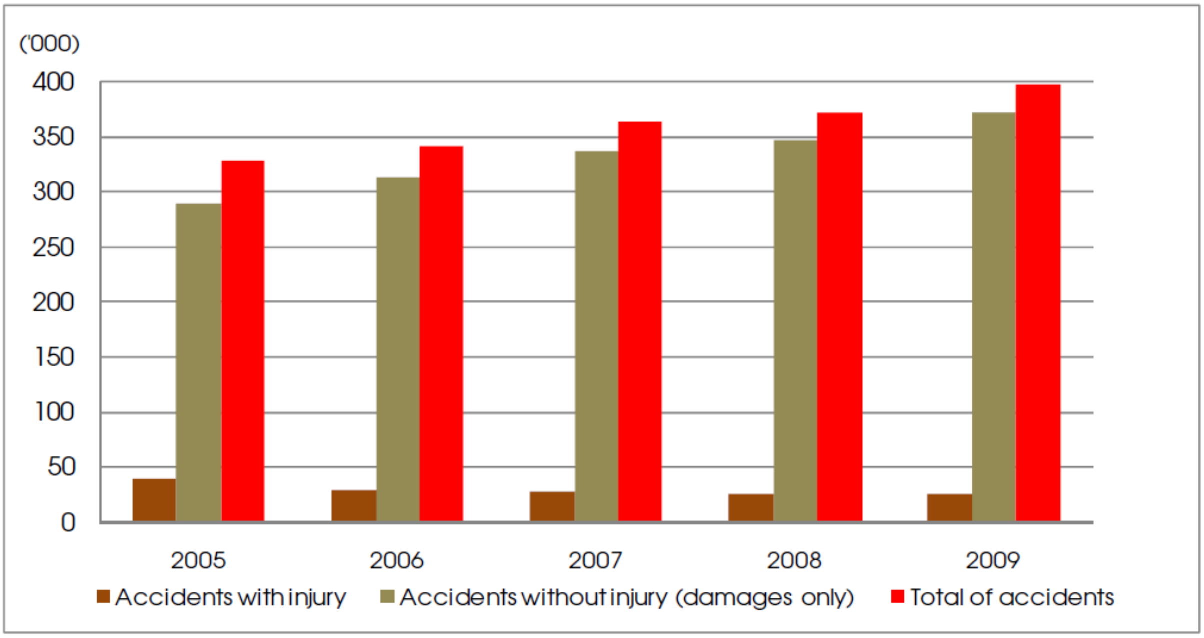
In Malaysia, for all types of drivers, the legal blood alcohol limit is set at 0.08 g/100 ml (Road Transport Act, 1987). Malaysia has a population of 28.3 million people of which 91.8% are citizens. 40% of the population are non-Muslim which comprises of Chinese (24.6%), Indian (7.3%) and the remaining are the, other indigenous population in Sabah and Sarawak (Malaysia Department of Statistics, 2010a). This equates to 40% of the population in Malaysia which consumes alcohol.

According to a census data by the Malaysian Ministry of Transportation, there is an average of 21.25 million vehicles on the road and this number is increasing annually as shown in the Figure 1 (Malaysia Department of Statistics, 2010b). Approximately 400,000 total accidents happen on the road annually in Malaysia by the same census data by the Malaysian Ministry of Transportation and again this number is on an annual rise as demonstrated in Figure 2 (Malaysia Department of Statistics, 2010b). A staggering 30% of the total of all accidents which occurred in Malaysia are caused by Driving under the Influence (DUI) of alcohol (Assunta, 2001). As such, the total number of accidents caused by Driving under Influence (DUI) will only continue to rise due to the increasing number of vehicles and total accidents each year in Malaysia as can be represented by Figure 1 and Figure 2 in the following page.



Source: Department of Road Transport Malaysia

Figure 1 - Cumulative Number of Vehicles in Malaysia (2005-2009)



Source: Department of Road Safety Malaysia

Figure 2 - Number of Accidents in Malaysia (2005-2009)

As serious as the problem is, there hasn’t been any device or system in Malaysia that is designed to monitor and prevent driving under the influence of alcohol (DUI). Methods to curb the offenders from driving while intoxicated are still limited and non-extensive, apart from imposing hefty traffic summons, barring driving licenses and detention of those who are subjected to violation at numerous accounts. A more systematic and effective approach to prevent excessive alcohol consumers from taking the wheel is a definite necessity in this modern age.

The significance of a low-cost breathalyser ignition interlock will allow for implementation of this system in Malaysia, Southeast Asia and subsequently to other developing countries in Asia as an implementation of this system utilizing the device and service from an existing company in the United States, Canada or Europe is not feasible in terms of cost and geography. With the implementation of the breathalyser ignition system, the amount of accidents caused by Driving under Influence (DUI) will be significantly reduced, thus ultimately increasing the safety of the general road population. As this system is targeted at charged Driving under Influence (DUI) offenders, it will also provide a method to monitor these offenders during their probation period and to prevent recidivism or repeat offense which currently is non-existent in our law enforcement of Driving under Influence (DUI).

In this situation, the significant absence of such system will jeopardize the safety of the general public as driving under the influence of alcohol is increasing annually. This brings an increase to the number of material losses, injuries and fatalities from accidents caused by driving under the influence of alcohol (DUI). As such, initiatives must be taken to conduct a research that can produce a reliable and cost effective system that will resolve the aforementioned problems, providing the same key features as the system in United States, Canada and Europe but cheaper to produce, or in other words a low-cost design with all the same features and functionalities.

Furthermore as the economy of Malaysia and Singapore continues to shift towards urbanization, more people will have more disposable income and the modernization will increase more night life activities particularly those involving alcoholic drinking. Today, more and more business deals are conducted in a more casual and modern environment over an alcoholic beverage. As the number of consumption of alcohol by the increases, it poses an increase in the probability of alcohol-impaired driving. This will increase the jeopardy on public safety and increase the number of charged DUI offenders and thus the relevancy and significance of this alcoholic-impaired driving prevention device.

1.3 Scope of Study

The project scope is to create a breathalyser ignition interlock device that is low-cost with comparable features and functionalities to those of its western counterpart. Instead of just indicating and displaying the BAC percentage, the tester is programmed to control the ignition switch, as well as an alarm and a number LEDs. Essentially it is a device that is installed in a vehicle's dashboard which in this project we will simulate as an ignition circuit and the driver must breathe into the device before the vehicle can be started up. If the analysed result is over a programmed predetermined blood alcohol concentration that has been pre-set into the breathalyser ignition interlock, the car would not start which we will represent with a red LED being light up. This device will also keep a record of the activity on the device and is interlocked with the vehicle's electrical system as an anti-tampering, security and monitoring feature.

This project will involve the design and development of a breathalyser ignition interlock device which controls an ignition switch. The hardware modules include MQ-3 alcohol sensor, Arduino Uno microcontroller board, 2x16 characters LCD alphanumeric display and ignition switch circuit. The software component includes programming and source code which is implemented via the Arduino Uno microcontroller. Upon assembly, the system is able to detect the alcohol concentration in a person’s breath sample and displays the detected amount in terms of BAC (Blood Alcohol Concentration) percentage on the 2x16 characters LCD panel. According to the amount, the system decides whether to enable or disable the ignition switch circuitry. The amount for this is usually pre-set to the legal limit of 0.08 g/dl in Malaysia.

For the purposes of this project, we will limit the scope of this project to focusing solely on designing and fabrication of the breathalyser ignition interlock. As such, we will be building an electronic circuit which will simulate a vehicle's ignition system instead of actually installing the breathalyser ignition interlock to a vehicle's actual ignition system. The time and financial constraints it takes to understand the technical intricacies of a vehicle's actual ignition system and for a proper installation to a vehicle's actual ignition system will not be feasible in the time and budget available and as such it will not be covered within this project scope.

As such, the breathalyser ignition interlock device which will be designed and developed in this project will thus be connected to the ignition circuitry which is used to simulate an actual motor vehicle's ignition system. The focus and scope of this project is to design and develop a breathalyser ignition interlock that is low-cost with comparable features and functionalities to those of its western counterpart. The list of features and functions of the proposed breathalyser ignition interlock will be discussed in the following sub-chapter, 1.4 Aims and Objectives.

The flow of the proposed breathalyser ignition interlock is demonstrated in the flow chart in Figure 3 and the block diagram in Figure 4.

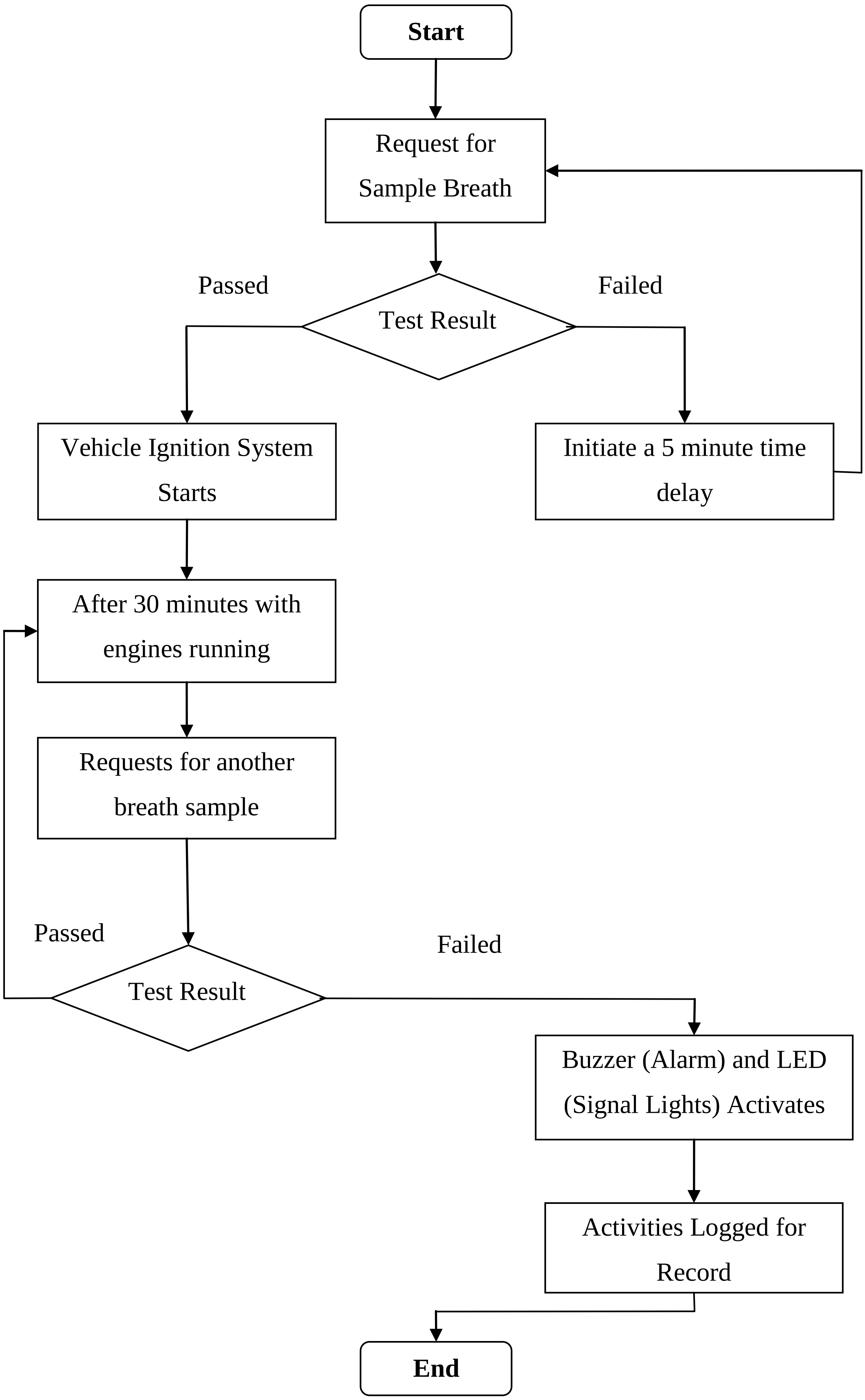


Figure 3 – Flowchart of Process Flow for Breathalyser Ignition Interlock

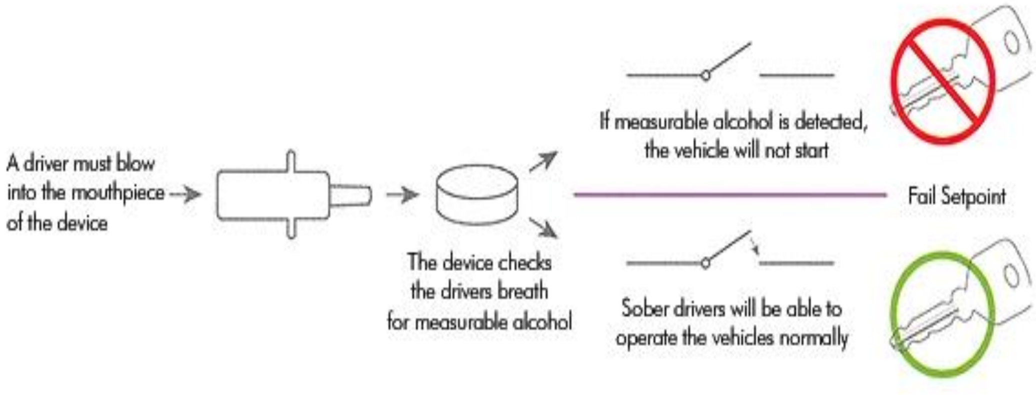


Figure 4 – Block Diagram of Process Flow in Breathalyser Ignition Interlock

1.4 Aims and Objectives

By the end of this project, we shall produce device that is capable of:

- Measure and test for the blood alcohol concentration (BAC) in a person's blood stream.
- Store a pre-programmed blood alcohol concentration (BAC) as a pre-set-limit for tests comparison.
- Compare tested blood alcohol concentration to pre-programmed blood alcohol concentration (BAC).
- Enable vehicle ignition system if measured or tested blood alcohol concentration (BAC) is lower than the pre-programmed blood alcohol concentration (BAC). (vehicle ignition system will be in disabled mode – default settings and will only be enabled if test is passed, therefore if test fails, nothing will happen)
- Randomly request for another test sample after ignition system has been started after a period of time. If another test sample is not provided in given

limit period of time or if tests fail, alarms and headlights/both signal lights will be activated.

- Ability to record activity logs and saves it.

We will also be looking to resolve the identified flaws in the current breathalyser ignition interlock design which are:

- The design of their breathalyser ignition interlock that distracts the driver's attention from the road in order for them to perform the rolling re-tests.
- Passenger providing the clean breath sample for the driver for the rolling re-tests
- Removal of power source will result in log recording function disabled, thus circumventing the supposed "anti-tampering" feature

1.5 Relevancy of Project

As mentioned earlier in sub-chapter 1.2, Problem Statement, in Malaysia alone, 30% of all accidents are caused by Driving under the Influence (DUI) (Assunta, 2001). The total number of accidents in Malaysia annually is approximately 400,000. As such a total of approximately 120,000 accidents are caused by driving under the influence of alcohol (DUI). That is potentially 120,000 accidents which could have been prevented with the breathalyser ignition interlock annually.

Additionally, the numbers of accidents each year is increasing as shown in Figure 2. The number of vehicles owned by the general public in Malaysia is also on the rise yearly as shown in Figure 1. All this statistical data shows that the number of accidents on the road each year will only be rising and as such, new measures and steps must be initiated in order to tackle the problem.

As such, a breathalyser ignition interlock device will definitely be of relevance in tackling the issue of drunken driving which is rampant not only in Malaysia but other countries which does not ban the sales of alcohol. As noted earlier, out of a total of 185 countries permits sales of alcohol and 55 percent of the world's population consumes alcohol. Of that total, a big percentage of the general road population consumes alcohol and drive at the same time. A very good example of another country with this problem will be our neighbour, Singapore where 85% of the population in Singapore are non-Muslim and more than 40% of all accidents in Singapore each year are caused by driving under the influence of alcohol, which is the second most common cause of accident behind speeding.

Also mentioned earlier, the economy of Malaysia continues to thrive and moves towards urbanization, there will be a higher percentage of the general population who will have more disposable income and the modernization of the country will increase the amount of night life activities particularly those involving alcoholic drinking. Furthermore, more and more business deals are conducted in a more casual and modern environment over an alcoholic beverage. Thus, the number of alcoholic-impaired driving is projected to be on a steady rise over the coming years and as such will increase the risks and threats it pose towards the general road population. Therefore, this device will see a bigger and more important role in curbing the problem of Driving under the Influence (DUI).

Therefore, this project will act as a research into ways of designing and developing a low-cost breathalyser ignition interlock device design and fabricate a working prototype.

1.6 Feasibility of Project

In terms of feasibility of realizing the objectives of this project, the author of this document has taken a minor in Digital Electronics in Universiti Teknologi Petronas, specifically Microprocessor, Digital Systems & Design, Digital Electronics, Computer System Architectures and Circuit Theory. In addition, the author has taken Embedded Systems as one of the courses for Software Engineering major. As such, there are no problems regarding the technical assembly and development of a prototype for the proposed project thus making this project technically feasible. Furthermore, as the author majors in Software Engineering, the programming and source code portion of the project is also within technical feasibility.

For this project we will be focusing on designing and delivering a low-cost breathalyser ignition interlock device. The identified fundamental hardware for the device MQ-3 alcohol sensor, Arduino Uno microcontroller unit, 2x16 characters LCD alphanumeric display and the electronic components for the ignition switch circuitry. All this hardware will be within the budget of RM500 allocated by Universiti Teknologi Petronas and will encompass for a huge chunk of this budget and as such makes this project financially feasible.

Due to time and financial constraint, the focus of this project is solely on the design and development of a prototype for the breathalyser ignition interlock device. This means that the connection or installation to an actual ignition system of a vehicle will not be within the scope of this project instead we plan to build an electronic circuit which simulates the vehicle's ignition system and connecting the prototype breathalyser ignition interlock to this electronic ignition circuitry, which is used to simulate an actual vehicle ignition system, effectively mimicking an installation or connection to an actual ignition system of a vehicle.

As such, we can effectively demonstrate how the prototype breathalyser ignition interlock works. By constructing an electronic circuit to simulate a vehicle's actual ignition system, we effectively simplify the project and make it much more feasible to complete in the 6-7 months and RM500 budget which we are allocated and a huge chunk of the financial budget will go to the actual development of the breathalyser ignition interlock device as the cost of the electronic components of the ignition circuitry will be much cheaper than the utilization of an actual vehicle. We will also not take up time which is limited to understand the intricate nature of installing and connecting the breathalyser ignition interlock to an actual vehicle's ignition system thus making this project feasible to be completed within the time allotted.

In conclusion, all three technical, financial and time limit feasibility of this project has been researched and studied extensively and by limiting the scope of the project, we manage to make this project achievable for all three aspects.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

For this particular project, in order to fully understand the issue at hand and the proposed solution to the problem, we have to review different aspects of literatures, papers, researches, journals and articles, each of which plays an important role in contributing towards the realization, feasibility and existence of this project in the first place. It is therefore, crucial to delve further into all the aspects which this project encompasses.

We will first examine the root cause, alcohol and the impairment effects alcohol has on people and how it will affect their motor and control skills which are directly linked to their driving capabilities. We shall examine the root of this issue, alcohol and its effect on the psychomotor abilities related to driving by reviewing researches and papers from which the authors have conducted a series of empirical method as well as experimental and laboratory research to demonstrate the effects of alcohol on driving.

We will further examine the risks pose by Driving under the Influence (DUI) and review studies of the level of blood alcohol content on the risk of crashing while driving. From this review, we can reinforce the relevancy and significance of this project proposal.

After which, we will look upon a brief history of breathalyser and breathalyser ignition interlock device.

We will also review a few research on the effectiveness of breathalyser ignition interlock device.

Therefore, fundamentally, we will be reviewing on these following aspects:

- Alcohol and its effect on driving
- Risk of crash when Driving under Influence (DUI)
- Brief history of breathalyser and breathalyser ignition interlock
- Anti-cheat and anti-tampering designs
- Effectiveness of breathalyser ignition interlock

2.2 Alcohol and its Effect on Driving

Alcohol which we get in alcoholic beverages is actually ethanol or known by its chemistry molecular formula of C_2H_6O. Ethanol acts as a drug affecting the central nervous system. Its behavioural effects stem from its effects on the brain and not on the muscles or senses themselves. After consumption, alcohol enters the stomach and is then absorbed into the bloodstream through the walls of the stomach and small intestines. Once in the blood, the alcohol reaches the brain in about ten minutes. Alcohol has a numbing effect on the brain resulting in a lowering of inhibitions, a reduction in the ability to concentrate and remember, and an increase of the user's overestimation of his abilities. In this report, we will simply use the conventional norm and refer ethanol as alcohol. In Figure 5 on the following page, we can clearly observe the varying degree of time required for alcohol to be removed from the body according to the amount of alcohol ingested.

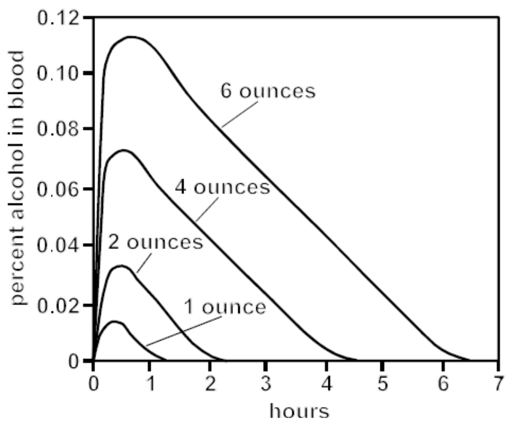


Figure 5 – BAC versus Time after Consumption of 1, 2, 4 & 6 ounces Ethanol

In order to identify the mechanisms by which alcohol affects individual skills related to safe driving, numerous well-controlled laboratory experimentation have been used. These laboratory experiments have examined a wide range of BACs from low to relatively high and have found that numerous driving-related skills are degraded even at low BACs. Alcohol has been shown to adversely affect tasks such as tracking, perception of distance and speed, and reaction times to respond to changes in road conditions. In addition, alcohol causes the dis-inhibition effects on the cerebral cortex of the brain, which can increase aggressive and risk taking behaviour in some individuals (Burke, 2007). Howat *et al.* (1991) had conducted reviews on the findings of experimental and laboratory research in order to identify the effects of alcohol on human behaviour especially on driving skill. Many of the studies reviewed showed statistically significant decrements in driving performance at a BAC of 0.05 or lower. The authors found out that complex tasks such as performed on driving simulators, or tracking with divided attention are adversely affected by BACs of 0.05. A simpler task such as simple reaction time is affected by higher BAC. However, complex tasks have more relevance to the operation of a vehicle compared to the simpler tasks.

Howat *et al.* (1991) also added that, sufficient evidence from the experimental study indicated that BACs of 0.05 or higher can cause impairment of the major components of driving skill for most people. They recommended that the setting of a uniform 0.05 statutory limit should be one measure in a comprehensive approach to reducing impaired driving including other legal, social, behavioural, and environmental strategies to deal with the problem. Chamberlain and Solomon (2002) reviewed findings of laboratory and field studies regarding the potential benefits of creating 0.05 BAC in Canada. The authors found out that the laboratory and field studies showed that important driving related skills are adversely affected by relatively small amount of alcohol. The affected driving related skills are vision, steering, braking, vigilance as well as information processing and divided attention tasks. Since the studies have never been seriously challenged, there is reasonable consensus among experts regarding the adverse effect on driving related skills by small and moderate amounts of alcohol.

The study by Howat *et al.* (1991), Burke (2007) as well as Chamberlain and Solomon (2002) have proven the adverse effect alcohol has on the psychomotor skills directly related to an individual's driving capabilities. Through various empirical method as well as experimental and laboratory research, these studies has proven unequivocally that the activity of consuming alcoholic beverages above a certain quantity overlapping with the activity of operating or driving motor vehicle, poses a huge threat to the safety of the driver and the general road population. This therefore gives evidence to the relevancy of this project.

2.3 Risk of Crash when Driving under Influence (DUI)

Fundamentally, in the previous sub-chapter, Alcohol and its Effect on Driving, we can summarize that the consumption of alcohol also affects driving behaviour. Because the driver cannot steer the car as effectively, he begins to swerve. The driver's reaction time also becomes slower. As drivers under the influence of alcohol become indifferent due to the numbing effect of ingesting alcohol, they will also be less inclined to compensate for their reduced driving skills. In addition, these drivers will overestimate their own abilities and underestimate the risks involved.

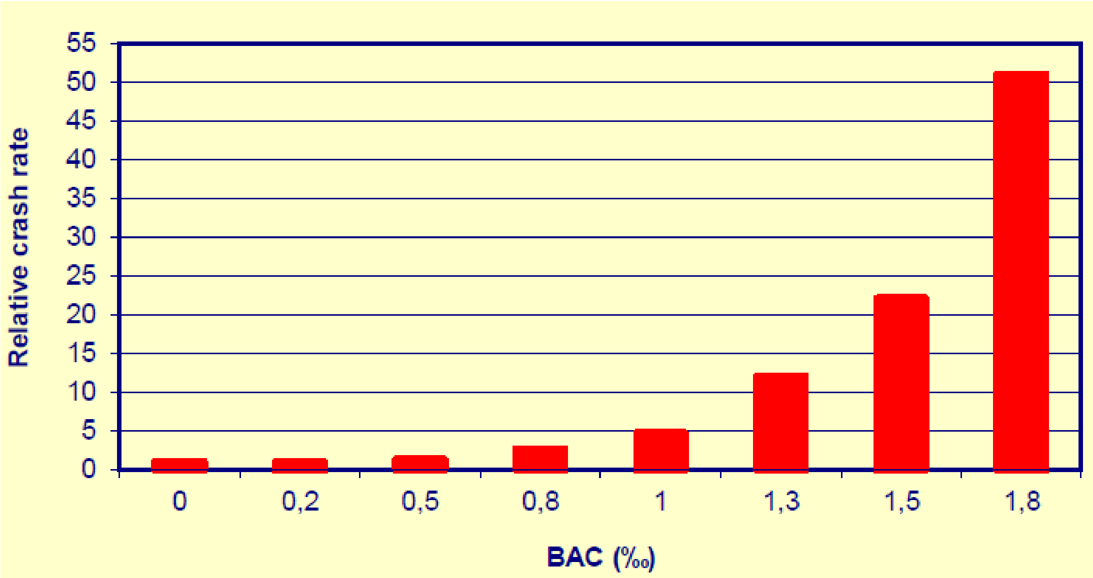


Figure 6 – Crash Rates for Various BAC Levels (Blomberg *et al.*, 2005)

The relative cash rate for a certain BAC level is the crash rate compared to that of a sober driver is shown in Figure 6. The risk increases exponentially as the BAC level increases. Blomberg *et al.* (2005) estimate the risk for drivers with a BAC of 0.5 percent (0.05 g/dl) to be approximately 40 percent higher. At 1.0 percent (0.1 g/dl), the risk is almost 4 times higher and at a BAC of 1.5 percent (0.15 g/dl), it even becomes 20 times higher. For Malaysia, as mentioned earlier the legal limit is 0.8 percent (0.08 g/dl) which means even at a legal limit of 0.5 percent, (0.05 g/dl) the risks of crash when driving is still 40 percent higher than that of a sober driver according to the study by Blomberg *et al.* (2005).

There is another method of which the assessment of the risk of crash involvement by drivers at various BACs has been carried out which is using epidemiological research methods. In these studies, a relative risk function was determined which indicated the likelihood of a driver at specified BAC being involved in a crash compared to a similar driver under the same conditions at 0.00 BAC. These relative risk functions have been widely used as a ground for setting up the legal limits for driving under the influence of alcohol. Perhaps the most widely cited epidemiological study of the crash risk produced by alcohol is the Borkenstein Grand Rapids Study (Compton *et al.*, 2002).

Findings from the Grand Rapid Study, which was done in 1964, showed that drivers who had consumed alcohol had a higher risk of crash involvement in comparison to drivers with a zero BAC. The finding also indicated that the risk of crash involvement increased rapidly as the BAC rose as shown in Figure 7. These results provided the basis for setting up legal blood alcohol limits and breathe content limits in many countries around the world, typically at 0.08 g/dl (WHO, 2004).

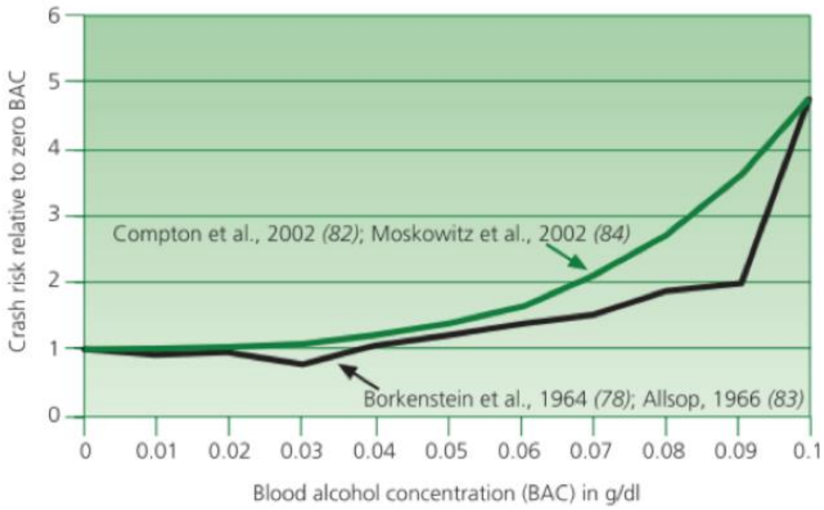


Figure 7 – Relative Risk of Driver Involvement in Police-Reported Crashes (WHO, 2004)

The BAC level not only affects the crash rate, it also has an influence on injury severity. The outcome of crashes involving alcohol use is generally serious. Drivers with more than 1.5 percent (0.15 g/dl) of alcohol in their blood, for example, are about two hundred times more likely to die in a road crash than sober drivers. This must be attributed to both the higher risk of being involved in a crash and the more severe injury in the event of a crash (Simpson & Mayhew, 1991). The more severe injuries in road crashes are mainly due to the fact that drivers under the influence of alcohol often speed and less frequently uses their safety belt. The reduced physical condition of heavier drinkers may be yet another factor (Desapriya *et al.*, 2006).

Thus, as demonstrated by Blomberg *et al.* (2005), the number of crashes increases exponentially as the amount of blood alcohol content (BAC) increases as shown in Figure 6. This claim is further reinforced by Compton *et al.* (2002) whom came up with the same conclusion. Furthermore, the study done by Simpson & Mayhew

(1991) and Desapriya *et al.* (2006) further substantiates the relevancy and significance of this project proposal.

2.4 Brief History of Breathalyser and Breathalyser Ignition Interlock

The study of alcohol as an academic experiment can be traced back to the 1700s when J.J. Plenc proposed the chemical identification of poisons (Center for Studies of Law in Action, 2007). However, the first ever practical roadside breath-testing device, called the drunk-o-meter was pioneered by Professor Rolla H. Harger in 1938 (Center for Studies of Law in Action, 2007). His version collected the driver's breath sample into a balloon in the device. The sample was pumped in an acidified potassium permanganate solution, and if alcohol existed in the sample of breath, the solution changed colour, and the more the colour changed, the more alcohol was in the breath. However, this device invented by Professor Rolla H. Harger was impractical as it requires re-calibration every time it is moved around.

It was not until 1954, when Professor F. Borkenstein invented the breathalyser, a substantial improvement to its predecessor by Professor Rolla H. Harger as this version is highly protable thus making it more practical (Center for Studies of Law in Action, 2007). However, the device was merely a testing device and had no prevention properties towards Driving under the Influence (DUI). All this would change in the 1970s, when an drunk driver killed both Craig D. La Londe's father and 3 year old brother ("What is an interlock device?," 2012). Craig D. La Londe, a self-made businessman pioneered the breathalyser ignition interlock that wouldn't let a motorized vehicle start until the operator took a mandatory breath alcohol test, if failed the vehicle won't start ("What is an interlock device?," 2012). Unfortunately from my research of the subject matter, he made his invention public before securing his copyright and protection of his invention, the idea was not necessarily his and he was not nearly credited with his ideas as others stole his discoveries ("What is an interlock device?," 2012).

The designs by Professor Rolla H. Harger, Professor F. Borkenstein and Craig D. La Londe were not ideal for mass production and implementation as their designs were flawed. The design by Craig D. La Londe was too simple and had no fail-safes to the devices which meant the user or driver of the car simply has to ask another individual to provide a clean breath sample to the device in order to start the ignition of the car. In other words, the system can be cheated. The design by Professor Rolla H. Harger on the other hand was not feasible to be implemented and was more of an academic research instead of targeting towards the feasibility of implementing the device. Although the design by Professor F. Borkenstein sets precedence for modern breathalyser device, it was not attached to a vehicle's ignition system as a control device.

Now there are several important lessons that we can learn from Professor Rolla H. Harger's work. First of all, he disregards the issue of feasibility and treats it more of an academic experiment. We can learn from the scientific inquisitive mind of Professor Rolla H. Harger as he paved the way by demonstrating that it is possible for the detection of content of alcohol in an individual's breath. We also applaud Professor F. Borkenstein who came up with the first working practical prototype of breathalyser and Craig D. La Londe who innovated the idea of a breathalyser device into an ignition interlock control device.

Professor Rolla H. Harger's, Professor F. Borkenstein and Craig D. La Londe gave us a clearer objective regarding scope of study of this project. Now there are some considerations that have to be made to properly conduct the design and development phase of the project.

First, it must be decided on the mechanism of the whole process of testing breath sample and enabling or disabling the ignition system and ways of which an individual can cheat the system. For example "What happens if an individual were to request for a clean breath sample from someone else?" or "What happens if the individual were to leave his car with the engine running and grab a drink of alcoholic beverage and return to his car?".

And lastly, "How effective are the breathalyser ignition interlock in curbing the Driving under Influence (DUI) pandemic?"

To answer those impending questions, we will move on to the next sub-chapters of literature review.

2.5 Anti-Cheat and Anti-Tampering Designs

As mentioned in the previous sub-chapter, there are potentially ways of cheating the design by Craig D. La Londe (1970) as the design was too simple and straightforward in addition to not having any cheat-prevention features. The design by Craig D. La Londe was just an interlock ignition device which acts to request for a one-time breath sample before a vehicle's ignition system can be started up. This provides ample opportunity for the user to cheat, i.e.; requesting a clean breath sample from another individual before starting up the vehicle thereby rendering the device useless.

One method to curb this particular exploit of the device is a feature which requires for users to take rolling re-tests after the engine has been running for a certain period of time (US Department of Transportation, 2010). If the user were not to take the test within a given period of time, or fails the rolling re-tests, the car's alarm will sound and the emergency signal lights will be activated. This will continue on until the driver found a safe spot to pull his car over and shut off the engine. This will therefore mitigate the problem of requesting for a clean breath sample from another individual prior to starting up your car.

The purpose behind the alarm blaring and the emergency signal lights is to alert other nearby drivers to stay away from the potentially drunk driver and the authorities to pull the vehicle over for inspection (US Department of Transportation, 2010). However, the design of their breathalyser ignition interlock is not ideal or optimum in a way that it distracts the driver's attention from the road in order for them to perform the rolling re-tests. This will be one aspect which we look to improve upon in future works. Furthermore, there will also be a problem of a passenger providing the clean breath sample for the driver which we will look to resolve in our research for the ideal low-cost prototype in future works.

One feature that acts as an anti-tampering deterrence is the log recording feature which records all recent activities in a log for reference by the authorities in case of tampering or failed rolling re-tests by the charged DUI offenders (US Department of Transportation, 2010). This feature acts as a hindrance for any potential cheating or tampering of the system or device.

In this project, we will be looking towards integrating these anti-cheat and anti-tampering features in our device and also looking towards resolving some of the flaws of which the breathalyser ignition device still suffers.

2.6 Effectiveness of Breathalyser Ignition Interlock

According to Coben JH and Larkin GL (1999) in their paper “Effectiveness of ignition interlock devices in reducing drunken driving recidivism”, five of the six studies found interlocks were effective in reducing DWI recidivism while the interlock was installed in the car. Recidivism can be defined as repeat offenders. In the five studies demonstrating a significant effect, participants in the interlock programs were 15 percent to 69 percent less likely than controls to be re-arrested for DWI. The only reported randomized, controlled trial demonstrated a 65 percent reduction in re-arrests for DWI in the interlock group, compared with the control group.

The 6 studies which Coben JH and Larkin GL (1999) selected and their outcome are as follows:

Study	Outcome measures	Relative risk	95% Confidence intervals	Prevented fraction	*P* value
The EMT Group (1990)	DUI recidivism	0.71	0.40, 1.24	30%	>.05
Popkin et al. (1992)	DUI recidivism	0.38	0.20, 0.70	64%	<.05
Morse and Elliott (1992)	Re-arrest for DUI	0.33	0.15, 0.72	69%	<.05
Jones (1992)	Re-arrest for DUI	0.85	0.71, 1.00	16%	0.05
Weinrath (1995)	Impaired driving recidivism	0.40	0.25, 0.65	66%	<.05
Beck et al. (1997)	Re-arrest for DUI	0.36	0.20, 0.61	65%	<.05

Table 1 – Summary of Outcome for 6 Studies on Effectiveness of Breathalyser Ignition Interlock Device

They concluded in their paper that alcohol ignition interlock programs appear to be effective in reducing DWI recidivism during the time period when the interlock is installed in the car and that future studies should attempt to control for exposure (i.e., number of miles driven) and determine if certain sub-groups are most benefited by interlock programs.

According to Andrew Fulkerson (2003) in his paper, “The Ignition Interlock System - An Evidentiary Tool Becomes a Sentencing Element”, the device has been proven in empirical studies to reduce recidivism for repeat DUI offenders, young drivers, and persons with very high BAC levels. Andrew Fulkerson (2003) added that those reductions are substantial and statistically significant and the interlock is effective in preventing future violations even when the particular offenders have difficulty in controlling their own behaviour. Andrew Fulkerson (2003) further concludes that the interlock does not rely upon motivation or cooperation by the offender and operates to prevent the offending behaviour by intervening between the offender and the vehicle. According to him in his paper, it only stops the person from drinking and driving in the vehicle equipped with an interlock and thus, controls the “intersecting risk behaviours” of drinking and driving.

Therefore, according to the studies made by Andrew Fulkerson (2003) and Coben JH and Larkin GL (1999), a breathalyser ignition interlock device is indeed an extremely effective tool in combating Driving under the Influence (DUI), thus making this project that much more relevant as it is proven to be an effective tool and mechanism.

CHAPTER 3

METHODOLOGY

3.1 Introduction

Methodology chapter is intended for further explanation of the research and fabrication processes as well as the activities in this project. Fundamentally, the research project can be broken down into three layers of activities of which they are interdependent, timely fashioned, and fairly manageable. They are extracted from the basic prototyping methodology. The basic flow of prototyping can be viewed in Figure 8.

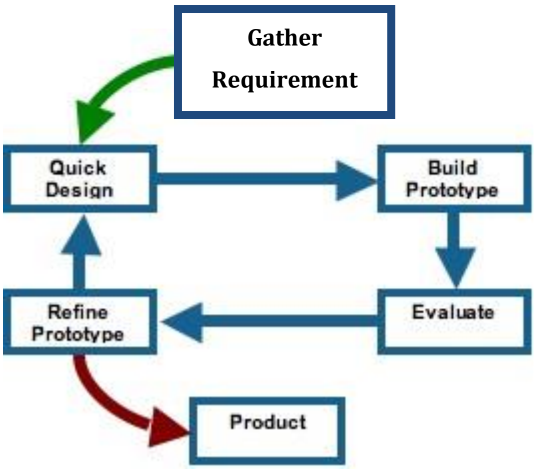


Figure 8 – Prototyping Methodology

Prototyping is generally viewed as one of the best engineering approach to developing an electronic device prototype. The main reason is because an electronic prototype device is hard to visualize over a paper and schematic diagrams might seem confusing to some novice users. Therefore, prototyping allow target users to incrementally view, test and observe the progress of the project. It will also allow for testing of each module of the individual function of the device by the author thus ensuring that it is working as intended.

This methodology is chosen because the author can quickly roll out a prototype on a breadboard circuit (ignition circuitry) and programming on the Arduino Uno microcontroller board, adding in one function at a time and testing each function as each prototype rolls out. It allows for an incremental development of the system and it ensures that each module of the functions works correctly as well as allowing for easy testing and calibration of the device. This eventually leads to a complete system where the integration of all modules can be tested and if an error occurs, we can conclude that it does not derive from the individual modules but the integration which makes troubleshooting a lot easier.

Prototyping is unique as it enforces iteration after each module delivery and if the partial product is rejected by the stakeholders or the particular module failed in the testing procedures. There are some benefits resulting from this approach. First, the author can obtain valuable insight and information in the formative stages of the project. This method also allows the author to gradually check his work against the original requirements. The author can also perform regular assessment on whether the project is able to meet the timeline and budget constrain.

Finally, in prototyping, the prototype will be tested every time one functionality or module is added to it. In this project, the term modules refer to the individual functionalities of the device such as ability to store a pre-programmed blood alcohol content (BAC) data or retrieval of breath sample and comparing it to the pre-programmed blood alcohol content (BAC). As such, prototyping is the best option to be used for a system composed of modules. This is because during the testing period some modules might need to be modified or recalibrated. This way the working module can remain safe while the problematic modules are fixed. With a good and efficient design, the author can develop his device function by function without compromising the integrity of the device as a whole. This is much better than developing the electronic device with all functionalities and rolls it out for testing. If an error occurs, it will be hard to pinpoint which function or module is the one which contributes to the error.

The first of the three layers of activities is acquiring requirements or specification and understanding the nature of the issue at hand by interviewing the targeted users. The author then extracts the core of the requirements to generate an initial prototype that serve the main features or functionality expected from the device. These users are then invited to view and criticize the prototype. The author later gathers feedback from the users to enhance the prototype. This process is done repeatedly until every single original features and relevant and feasible user's feedback is adapted into the final prototype design. The second layer will be the designing of the prototype and all the necessary secondary modules which is required for this project. The third will be the development of the prototype, which involves testing of the prototype to ensure that it is working as intended and finally, the calibration of the device, and adding of functionalities to it in order to finalize the prototype and delivering it.

3.2 Project Activities, Design and System Modeling

There are three essential research questions laid down upon the birth of this project. Different methodologies must be used to cater each question. The first question pertains to the core functionalities and system requirement gathering. The second question is the flow of and element components of the system. The system can be divided into 4 modules, power supply circuitry, alcohol sensor, microprocessor and display and alarm circuitry. For the purpose of this project, we would also have to build an additional module, ignition circuitry to simulate a vehicle's actual ignition system. The third and last question would be the testing and calibration of the system, ensuring that the device is working as intended. All this will be addressed in the following sub-chapters.

After pre-development analysis is conducted, there should be a post-development survey as well. Here we will check whether our prototype is able to satisfy its stakeholder's objectives. The author also double-checks whether this software qualifies its pre-development intentions. In this stage, a mix of qualitative and quantitative analysis shall be conducted. This phase is repeated iteratively until the best fit formula of the prototype is determined.

3.2.1 System requirements gathering

As mentioned in the previous subchapter, the first essential research question to be answered is "What are the core functionalities of the system and how do we identify them?" For this project, there is a precedent system; therefore the author employs the "feasibility studies" technique which basically is a study of existing systems and the possibilities of replacing them, which can then provide an outline of requirements details. This gives the author the initial idea on the core functionalities of the system. This involves examining and analysing the problem identified which, are the accidents caused by Driving under Influence (DUI) and also examining the features and functionalities existing similar system in the United States to design and develop a breathalyser ignition interlock system with improved features and functionalities to those of its western counterpart to be implemented in Malaysia.

From the initial stage of the system requirement gathering where "feasibility studies" technique is employed, we have a guideline of the core functionalities that the system will have. The initial list of core functionalities identified as follows:

- Measure and test for the blood alcohol concentration (BAC) in a person's blood stream.
- Store a pre-programmed blood alcohol concentration (BAC) as a pre-set-limit for tests comparison.
- Compare tested blood alcohol concentration to pre-programmed blood alcohol concentration (BAC).

- Enable vehicle ignition system if measured or tested blood alcohol concentration (BAC) is lower than the pre-programmed blood alcohol concentration (BAC). (vehicle ignition system will be in disabled mode – default settings and will only be enabled if test is passed, therefore if test fails, nothing will happen)

The second stage of system requirement gathering will be the enhancement and refining of these initial features, be it improving existing or adding new functionalities to the breathalyser ignition interlock system. This is where the system development methodology of prototyping plays an important role. After iterations upon iterations of the system are complete, tests are being run in all different kind of scenarios exploring every weakness of the system and possible loopholes which can be exploited. Specifically speaking, this pertains to the way to cheat the system by employing a friend who has not ingested alcohol to perform the tests for another individual whom has ingested alcohol and is above the Blood Alcohol content (BAC) legal limit. After further research and brainstorming, the author added another functionality to combat this system weakness:

- Randomly request for another test sample after ignition system has been started after a period of time. If another test sample is not provided in given limit period of time or if tests fail, alarms and headlights/both signal lights will be activated.

- Ability to record activity logs and saves it.

The author initially intended to add another function of fingerprint scanner to the system which will act as a security feature to the motor vehicle, which works in the manner that any attempt to start the motor vehicle’s ignition system will have to be first unlocked by the breathalyser ignition interlock system. However, after further research into this, the author discovered that a cost of fingerprint scanner alone which in this project would cost RM 339.20 which will nearly double the cost of system to about RM 500 which goes against the concept of the project of being a simple yet effective low cost system with all core functionalities of a breathalyser ignition interlock system. Furthermore, a fingerprint scanning feature is not a core functionality of the system and therefore, decision was made by the author to omit this functionality entirely.

3.2.2 System modeling

The second essential question of this research project is "How does the system flow look like and what are the key element components of the system?" This is demonstrated as a system model in Figure 9 on the following page which shows the interconnection of the hardware of this system. For this project the author uses a USB cable to connect a power bank or a laptop as our power supply. An AC-DC adapter can also be used to supply 12 V to the voltage regulator circuit which will reduce this value to approximately 5 V.

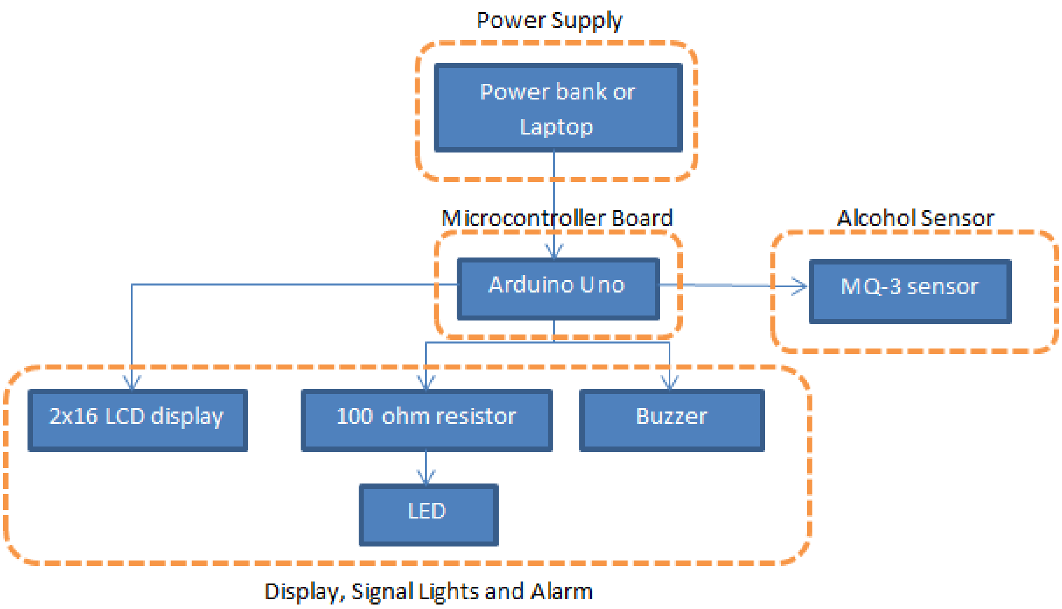


Figure 9 – System Modeling of Proposed System

3.2.3 System testing and calibration

The third essential question of this research project to be answered is "How do we properly test and calibrate the system and ensure that it is working as intended?" First step is the proper testing of the voltage regulator. The circuit of the voltage regulator will be tested using LED as the load and the corresponding output voltage across the LED will be measured using a multimeter.

The input voltage fed into the microcontroller is not entirely linear over all concentrations of ethanol which is the test alcohol used in this project. Details on the preparation of the ethanol as test subject will be further elaborated in Chapter 4, Results and Discussions. Careful attention will have to be placed so that calibration was over the linear, or near-linear, region and care will also have to be taken as the possibility of saturating or even damaging the sensor if too high a concentration is placed on the sensor. Each prepared ethanol concentration will then be placed against the sensor and the voltage level, will be viewed on the multimeter and recorded.

First, the completed circuit without the MQ-3 alcohol sensor will be put through functional testing to ensure each of the modules work. The sensor voltage will be replaced by a variable resistor in this scenario. Once this calibration is done, only then will the sensor connected to the rest of the circuit. The whole device will be tested using the alcohol solutions that were prepared for the calibration of the sensor.

After calibrating the MQ-3 alcohol sensor and connecting it to the Arduino Uno microcontroller board, the output voltage from the sensor at normal room temperature will be measured. This output voltage will be set as the reference voltage for the calibration process. Then, human breath sample will be blown at the MQ-3 alcohol sensor and the subsequent output voltage taken.

Finally, the sensor will then be tested using alcohol substance and its output voltage will be taken as well. The voltages set in the programming will have to be readjusted according to the voltage measured during calibration and the hardware will again have to be tested to verify the BAC percentage produced. The result of this calibration will be further elaborated in Chapter 4, Results and Discussions.

3.3 Key Milestones

There are few key milestones in this project. The first one is the identification of all the components that are required, namely the type of alcohol sensor, type of microprocessor etc. The second is the design phase of the prototype and the circuitry which will simulate an actual vehicle's ignition system. The next one is the development of the ignition circuitry and the first prototype of the device which shall be tested and the finally, after the iterative process is completed, the device will be ready to be delivered.

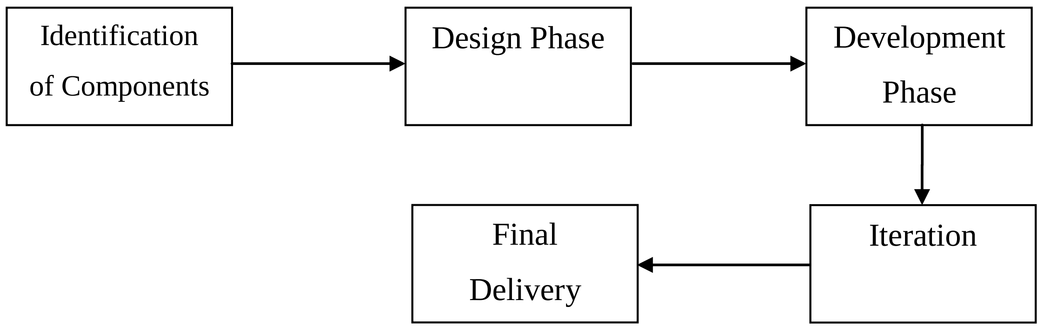


Figure 10 – Key Milestones for the Project

3.4 Gantt Chart

Tasks	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Selection of Project Topic and Project Proposal									
Preliminary Research Work									
Design of Project Outcome									
Interim Report									
Research and Initial Design Concept of Prototype									
Proposal Defense									
Identification and Procurement of Components									
Development of Prototype and Ignition Circuitry									
First Delivery of Prototype									
Pre-SEDEX and Poster Presentation									
Technical Paper									
Testing and Calibration									
Dissertation (soft bound)									
Iteration and Re-modification									
Final Delivery									
Final Oral Presentation									
Dissertation (hard bound)									

Table 2 - Project Gantt Chart

CHAPTER 4

RESULTS & DISCUSSIONS

4.1 Tools Required

In this research project, the author lists the components of the breathalyser ignition interlock system in the following Table 3:

No	Name	Roles
1	Arduino Uno	Microcontroller board
2	SD Shield for Arduino Uno	SD Memory card capacity (Log keeping)
3	MQ-3 – Hanwei Manufac.	Alcohol sensor
4	Buzzer	Display. Signal Light and Alarm Circuitry
5	2 X 16 LCD Display Shield	
6	Red LED	
7	100 ohm resistor	

Table 3 – List of Hardware Required for the Project

The ignition switch circuitry used here is meant to emulate a motor vehicle's ignition system and the power supply is meant to regulate to voltage from an external power supply such as an AC/DC source or battery.

The specifications of the other main hardware components not mentioned will be further elaborated in the subsequent subsections.

4.1.1 MQ-3 alcohol sensor

The model of alcohol sensor identified for use is MQ-3 alcohol sensor which is manufactured by Hanwei Manufacturers. This model is chosen by the author to be used in developing this project because it is highly sensitive to alcohol compound, stable, has fast response time and longer lifespan compared to other alcohol sensors explored in the market (Hanwei Electronics Co. Ltd, 2003).

This sensor operates as potentiometer which essentially is a three-terminal resistor with a sliding or rotating contact that forms an adjustable voltage divider. Fundamentally, it is a voltage divider used to measure voltage. 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 different parts of the MQ-3 alcohol sensor are shown below in Figure 11:

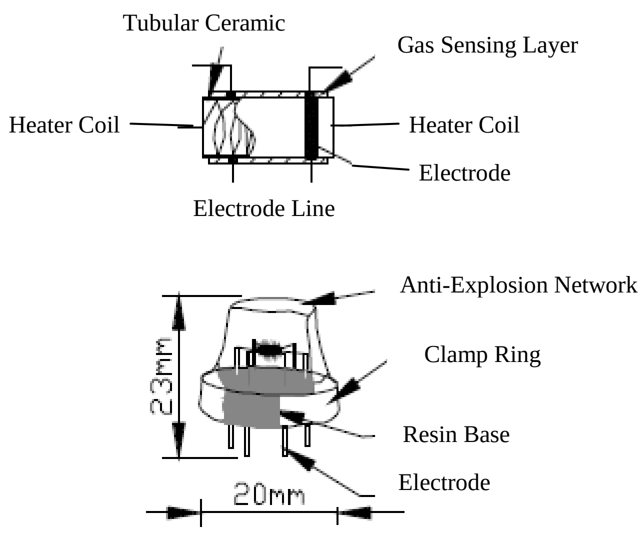


Figure 11 – MQ-3 Alcohol Sensor

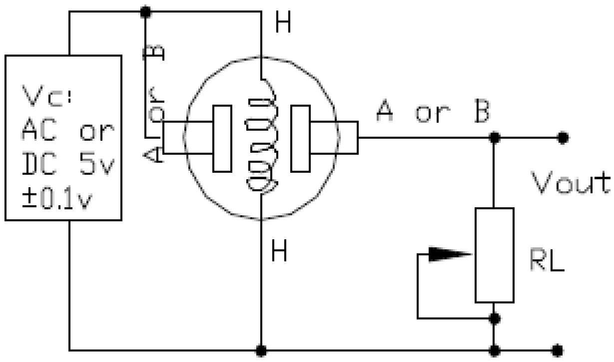


Figure 12 – Circuit Diagram of MQ-3 Alcohol Sensor

The resistance of the MQ-3 varies with different types of gases at different concentration levels. Therefore, when using this component, calibration is a necessity to determine its proper alarm point. The recommended value of the load resistance is about 200 kΩ as experimented. Due to the fact that the sensor is a semiconductor device, it is highly affected by temperature and humidity.

With that being mentioned since the extensive testing of those two variables are beyond the scope of this project, the author will be assumed that the temperature and humidity is nearly constant during any calibration processes. The sensor is also highly time dependent. While the resistance of the sensor reaches a fairly consistent steady-state value when exposed to ethanol gas concentrations, it still takes about a minute, on average, for that value to be attained.

It should also be noted that this sensor is sensitive to other organic compounds. Using pure ethanol and testing in a well-ventilated area therefore will alleviate any error by these detectable substances.

The proposed semiconductor breath alcohol detector is cheaper in cost and is as effective as other types of breath alcohol detector. Furthermore, the MQ-3 alcohol sensor can be easily interfaced to a microcontroller as the output yield is in voltages. Power dissipation does not influence the MQ-3 alcohol sensor as the semiconductor sensor model has very low power dissipation although it works with presence of heat because it only needs low voltage value in the range of 3.3 V to 5 V as its input. The sensitivity of the sensor is also relatively high compared to the other models researched. Although the MQ-3 alcohol sensor is capable of detecting other substances and misinterprets it as alcohol, the sensitivity towards alcohol is much higher and this makes it a very reliable alcohol detecting device.

4.1.2 Arduino Uno microcontroller board

The Arduino Uno is a microcontroller board with the ATmega328 microcontroller which has 32 Kb of Flash memory. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analogue inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header and a reset button (Atmel Co., 2009). The author chose this microcontroller board because it contains everything needed to support the project. There is two way to obtain a power supply for Arduino Uno, first by simply connecting it to a computer with a USB cable or second to power it with a AC-to-DC adapter or battery. The Arduino Uno microcontroller board is shown in Figure 13 below:

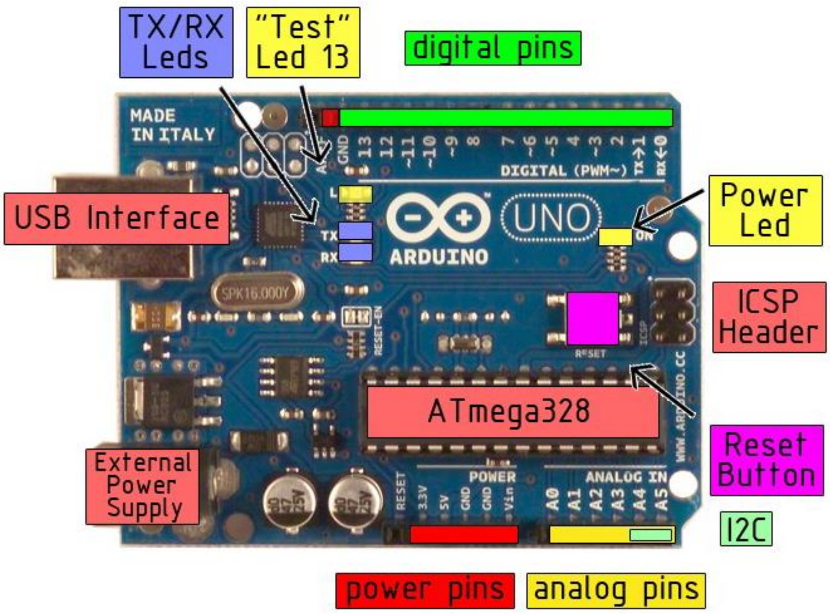


Figure 13 – Arduino Uno Microcontroller Board

There two main reasons as to why Arduino Uno was selected as this projects microcontroller board, the first of which is the capability for Arduino Uno to have an SD memory card shield expansion which is a key feature in allowing for log keeping within the SD memory card. The second being that the flexibility of two different external power supplies namely USD to computer or from AC/DC source or battery is a feature that is extremely useful for demonstration purposes of the project. It also simplifies the hardware portion as it is a board with microcontroller ATmega328 built in.

Programming on the Arduino Uno board will require using the Arduino IDE software. The programming is then done on the Arduino IDE software. To upload the source code onto the Arduino Uno board requires a Universal Serial Bus (USB) connection to the computer containing the Arduino IDE software and the source code intended to be burned to it.

4.1.3 SD Card Shield

For the purpose of log keeping, the author has decided to use an SD Card Shield expansion to the Arduino Uno microcontroller board. This allows for the keeping of logs on each successful or unsuccessful attempt at the breathalyser tests for law enforcement or parental purposes. There are many reasons why the author chose to keep the log data within the SD card. The first being that it is relatively inexpensive and you can choose your own logging format and whether or not you want time stamps. The storage media is easily replaceable when worn out and can be removed quickly and read by any standard computer with a SD Card reader.

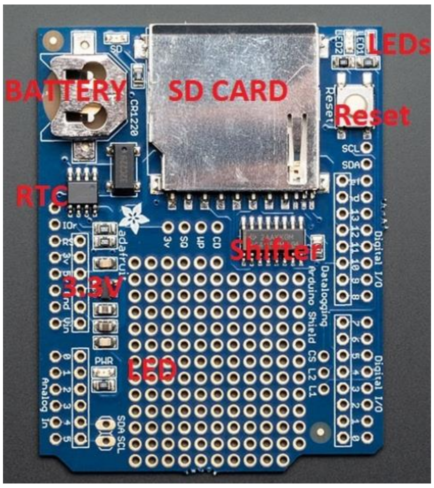


Figure 14- SD Card Shield

For future expansion works, this SD Card Shield will also be keeping logs of any form of tampering to the Breathalyser Ignition Interlock system, example removing of the power supply for the system for law enforcement purposes as the system is used as a probation tool to prevent any repeat Driving under Influence (DUI) offenders.

4.1.4 Display and alarm circuitry

For this project, the display an Arduino 2x16 LCD Shield will be used to display the Blood Alcohol Concentration (BAC) levels and whether or not the ignition switch is ENABLED or DISABLED.

To represent a motor vehicles' alarm in the event of a failed rolling re-test, a buzzer is used in the system and to represent a motor vehicles' signal light, a red LED is used.

4.2 Preparation of Ethanol for Calibration of MQ-3 Alcohol Sensor

This section will explain how ethanol is prepared for the MQ-3 alcohol sensor calibration. Ethanol is used here because all alcohol which is consumed is fundamentally ethanol. The blood alcohol concentration is defined to be the percentage of alcohol, in grams, in 100 mL of blood. Therefore, 0.08% BAC is 80 mg of alcohol within 100 mL of blood. Since the sensor detects the presence of alcohol in air, not blood, the author relies on a constant ratio of 2100:1 which is implemented to create these mock-solutions. This ratio comes from a scientifically agreed upon notion that the Breath Alcohol Concentration is defined as the amount of alcohol, in grams, in 210L of air.

Ethanol has a specific gravity of 0.79 which means that 1mL of ethanol weighs about 0.79g (contrasting it to water, where 1g = 1mL). Calculations to find the amount of ethanol needed in each solution is done for the following concentration levels: 0.02, 0.04, 0.06, 0.08, 0.10, 0.12, and 0.20.

With the quantities of the ethanol corresponding to each of the 7 concentration level derived, it is easy to create these concentrations by putting the amount of ethanol needed via a micropipette into a 1 L flask. These flasks were then labelled and sealed in order to allow them to reach equilibrium. This typically took about an hour since the amount of ethanol was so low. Once they were created and ready, extensive calibration testing was then performed on the MQ-3 alcohol sensor to obtain the equivalent voltage value which will be further elaborated in the following subsection, 4.3, Simulation of Breathalyser Ignition Interlock System.

4.3 Simulation of Breathalyser Ignition Interlock System

A simulation was run on the Breathalyser Ignition Interlock System with the ethanol equivalent Blood Alcohol Concentration (BAC) of 0.00, 0.02, 0.04, 0.06, 0.08, 0.10, 0.12, and 0.20.

The fundamental of the circuitry is divided into 3 sub-circuits which are the voltage regulator circuit, the Arduino Uno microcontroller board which houses the ATmega328 microcontroller and the MQ-3 alcohol sensor. The MQ-3 alcohol sensor is connected to the Arduino Uno microcontroller board which controls the whole system.

The lowest Blood Alcohol Concentration (BAC) is set to be 0.00% BAC whereas the highest possible detected is set to be 0.20% BAC and any higher than 0.20% BAC will be displayed as > 0.20 % BAC.

When the system is switched on, the sensor takes time to stabilize its readings. The specification of the sensor of the system upon calibration as explained how is done in subsection 3.2.3, System testing and calibration, is as in the Table 4 in the following page:

The following two figures show the front and back view of the prototype:

Figure 15 - Back View of Prototype

Figure 16 - Front View of Prototype

Parameter	Values
Time taken for sensor to stabilize	15 to 20 seconds
Operating temperature	29°C (Room temperature)
Heater temperature	45°C to 60°C
Input voltage	5 V
Output voltage range	0 to 4.75 V
Saturated output voltage value	4.75 V
Normal atmosphere detected value	1.85 V to 2.5 V
Human's breath without alcohol detected value	0.50 V to 1.84 V
Detected BAC%	BAC = 0.00% to 0.06% - normal BAC = 0.08% to 0.20% - high
Lowest BAC%	0.00%
Lowest BAC%	0.00%
High BAC% starts from	0.08%
Highest BAC%	0.20%

Table 4 – Specification of MQ-3 Alcohol Sensor after Testing and Calibration

The response of the MQ-3 alcohol sensor for different alcohol concentration and its corresponding voltage value after the testing and calibration of the MQ-3 alcohol sensor with the prepared ethanol as explained in section 4.2, Preparation of Ethanol as Calibration for MQ-3 Alcohol Sensor, and are shown as in the Table 5 below:

Voltage(V)	BAC (%)	Analogue value of Sensor
0	0.00	0
4.02	0.02	804
4.14	0.04	828
4.25	0.06	850
4.32	0.08	864
4.42	0.10	884
4.75	0.20	950

Table 5 – Voltage Values and Corresponding BAC and Analogue Values

Since the MQ-3 alcohol sensor is 5V, and the analogue value of the sensor is from 0 to 1000, 0 analogue value of sensor represents 0 V whereas 1000 analogue value represents 5 V. With the voltage measured with the multimeter, the author can find out which corresponding analogue value of the sensor represents which BAC % as demonstrated in Table 5 in the previous page. With that, the author can manipulate this analogue value within the source code of the device using the formula of:

Voltage * (5V/1000) = Analogue equivalent

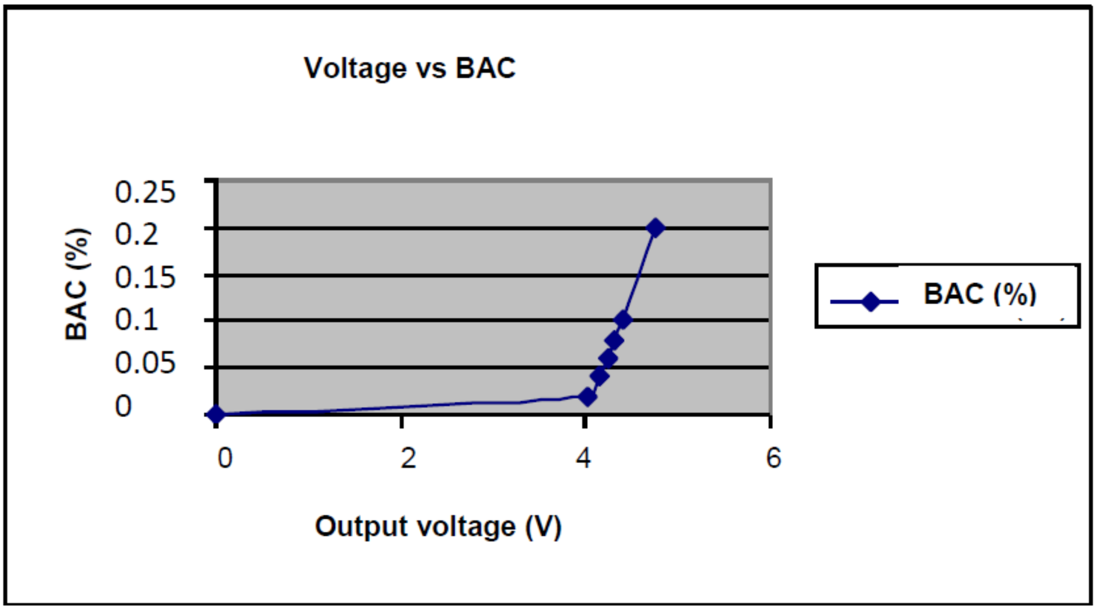


Figure 17 – Response Curve of BAC (%) to Voltage Values

For data analysis, a variable resistor was connected to the Arduino Uno microcontroller board as a replacement of the alcohol sensor. The input was then varied its value accordingly in range of 5 V to match the corresponding BAC value. This value was displayed on the LCD panel. Graph in Figure 17 above demonstrates the relation between the Blood Alcohol Concentration (BAC) to the output voltage.

The analogue input received was quantized into digital signal in the A/D converter. The signal was further processed by microcontroller ATmega328 to yield its corresponding BAC value.

The buzzer and red LED will only switched ‘ON’ only during the rolling re-test. When the sensor detected the BAC from 0.00% until 0.06% during the initial test or the first test, the LCD was displayed CAR ENABLED which means the ignition switch was enabled because the BAC value was under the legal limit range.

When the sensor detected the BAC from 0.08% until 0.20%, the LCD was displayed CAR DISABLED which means the ignition switch was disabled and locked because the BAC value was on the illegal limit range and will require the driver to wait to take another re-test after 30 minutes.

If the driver passes the first initial test, there is an anti-tampering feature which is the rolling re-test which is kick in after 20 minutes of driving which requests for another breath sample. Should this test be failed, then the red LED which signifies the signal light and buzzer which signifies the motor vehicles’ alarm will be turned ON.

This result is summarized in tabular format in the following 4.4 section, Results and Analysis.

4.4 Results and Analysis

From the simulation ran which was demonstrated in the previous subsection 4.3, we can summarize the result as follows in Table 6 and Table 7:

BAC (%)	Ignition Switch
0.00	CAR ENABLED
0.02	CAR ENABLED
0.04	CAR ENABLED
0.06	CAR ENABLED
0.08	CAR DISABLED
0.10	CAR DISABLED
0.20	CAR DISABLED

Table 6 – Summary of Result from Simulation of Initial Test

BAC (%)	Red LED	Buzzer
0.00	OFF	OFF
0.02	OFF	OFF
0.04	OFF	OFF
0.06	OFF	OFF
0.08	ON	ON
0.10	ON	ON
0.20	ON	ON

Table 7 – Summary of Result from Simulation of Rolling Re-Test

From the results obtained, we can analyse that the proposed semiconductor breath alcohol detector MQ-3 alcohol sensor is as effective as other types of breath alcohol detector although it is cheaper in cost. Furthermore, as mentioned before the system can be easily interfaced to a microcontroller as the output yield is in voltages. However, there is a discovery that the value of the concentration becomes saturated for BAC more than 0.20% even though the alcohol concentration used is more than that value which is why the maximum Blood Alcohol Concentration (BAC) is set to the maximum of 0.20%.

With regards to power dissipation, the semiconductor sensor model has very low power dissipation although it works with presence of heat because it only needs low voltage value in the range of 3.3 V to 5 V as its input. The sensitivity of the sensor is also relatively high compared to the other models. Although the sensor is capable of detecting other substances and misinterprets it as alcohol, the sensitivity towards alcohol is much higher and this makes it a very reliable alcohol detecting device. This project has proven within the given project scope of the project the viability of a semiconductor alcohol sensor as a low cost alternative to the more costly fuel-cell alcohol sensor, in the fabrication of a low cost breathalyser ignition interlock system.

CHAPTER 5

CONCLUSIONS & RECOMMENDATIONS

5.1 Conclusion

5.1.1 Relevancy of objective and scope of study

Before the inception of this project, a clear goals and objectives was defined in that a low-cost breathalyser ignition interlock device with comparable features and functionalities from its western counterpart will be designed and developed. Additionally, it will also address a few design issues in the current breathalyser ignition interlock device in the market. Furthermore, the issue of cost prevents western counterpart of the breathalyser ignition system to be implemented, exposed and fully-utilized in Malaysia thus making a low-cost breathalyser ignition interlock with comparable features and functionalities an attractive and relevant option.

Before the author took upon the project, studies were made on what to include in the project itself, in other words the project scope to prevent it from getting too big and thus infeasible. The author took upon the task of focusing solely on designing and developing the breathalyser ignition interlock prototype and by limiting our scope to that; we have made the project feasible technically, financially and within the time line given. The author decided not to delve into the intricacies of understanding a vehicle's ignition system and how to wire and install the breathalyser ignition interlock device to it. Instead, the author limits the scope to the device, by building an ignition circuitry simulating a vehicle's actual ignition system.

The author chose to undertake this project as there has been little to no development on this device in the Asian region and exposure, usage and implementation is next to non-existent and as such it is still a relatively new field to explore for this region with much room for improvement. Furthermore, the issue of Driving under the Influence (DUI) and its constant rise annually will always make this device significant and relevant in combating it.

5.1.2 Relevancy of literature review

As this project is more geared towards researching an ideal low-cost design of a breathalyser ignition interlock with comparable features to those available in the western market, we will thus examine the brief history of the breathalyser and breathalyser ignition interlock device thus understanding the inspiration behind its conception and the initial features available. The author also examined all the key features and functionalities introduced to combat “cheating” the device as well as the anti-tampering features of the system, identifying the key features to be included in our design as well as improving on the design flaws. It is crucial thus to conduct a literature review on the subject, to better educate ourselves on the subject and knowing the available technology and innovation out there, including the relevant ones in the project scope and resolving the design flaws to come up with the ideal low-cost breathalyser ignition interlock.

The author also had to examine the relevancy of such a device therefore; and delved into the literature review proving that alcohol indeed brings an adverse effect on the driving capabilities of an individual. It is also further explored the effects of amount of alcohol in the blood (BAC) affects the risk of crashing while driving. To further explore the relevancy of this project, the author reviewed studies and research on the effectiveness of breathalyser ignition interlock against Driving under Influence (DUI). The conclusions of the authors’ findings are very encouraging and the studies and research concludes that it is indeed a very effective mechanism and as such enforces the relevancy of this project.

5.1.3 Relevancy of methodology

It is important to decide on a methodology of which to develop the project that is efficient and effective. The author of this report chose the prototype methodology because it is one that can allow for the completion of the project within the time and budget allotted.

Prototyping ensures a delivery of core feature gradually and error-free but not sacrificing the extendibility of additional extra features and functionalities in a later date. Simply, the author want to ensure that the initial prototype is able to measure the blood alcohol content (BAC) and measure it with a pre-programmed limit of blood alcohol content (BAC) after which the device will decide to enable or disable the ignition system. Only then, will the author enhance it to be able to perform re-rolling tests, initiate alarm and lights if failed, the ability to save logs and other anti-cheat and anti-tamper features which was discussed in the previous chapters.

After the device able to perform the core features, the author will add on extra functionalities that shall add value to the device making it more useful and reliable.

5.2 Proposed Near Future Features to Resolve Current Design Flaws

As identified in the literature review, there will be some design flaws in the current breathalyser ignition interlock which we will also look to resolve as part of our objective to design and develop the ideal low-cost breathalyser ignition device. The identified flaws in the current design which we look to resolve are:

- A flow control sensor which acts as an anti-cheating measure
- The design of their breathalyser ignition interlock that distracts the driver's attention from the road in order for them to perform the rolling re-tests.

- Passenger providing the clean breath sample for the driver for the rolling re-tests
- Removal of power source will result in log recording function disabled, thus circumventing the supposed “anti-tampering” feature

For the first design flaw of distraction from the road, the proposed design for the breathalyser ignition system is to ensure that it is ergonomic and convenient, within reach and require a minimal effort to retrieve the breathalyser with one hand, put it up to your mouth and breathe into it.

For the second flaw design, we propose a simple physical limitation solution in that, the device is only accessible to the driver and the connector/wire between the device to the vehicle is only long enough for the driver to provide a breath sample, thus limiting access to the passengers.

For the last flaw, we propose to include a backup battery within the system, so as when the main power source is being tampered with, a final log record can still be made and this will result in further review by the law enforcement and actions taken accordingly.

5.3 Recommendations

In regards to the potential expansion and future works of this project, there is a lot of area which we could explore especially in regards towards preventing cheating of the system and preventing tampering of the device.

In regards to anti-cheating, one prevalent way to cheat the device is to request for a clean breath sample from another individual before starting up the car. Proposed future expansion and works to alleviate this issue involve, security facial recognition software to authenticate that it is the registered driver of the vehicle taking the test. Another possible solution will be a fingerprint scan while taking the breathalyser test, to prevent a different individual from the registered driver from operating the vehicle. Another more advance proposal will be a simple DNA test, from the breath sample obtain to authenticate that it is the right person of whom should be taking the breathalyser test.

For problems of anti-tampering, one proposed solution is to make all breathalyser ignition interlock device installed in vehicle’s to be connected to a central headquarter, wirelessly, thus there will be a live monitoring of all devices and any attempts of tampering will be notified to the authorities immediately.

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APPENDICES

Appendix A: Arduino Source Code

```
#include <LiquidCrystal.h>
#include <EEPROM.h>

// initialize the library with the numbers of the interface pins
LiquidCrystal lcd(8, 9, 4, 5, 6, 7);

int led = 10; // backlight pin
int drunk = 0; // innocent until proven guilty
int retest = 40; // resting interval in sec
int val; // variable to store value of sensor reading
int diag = 0; // diagnostic mode
int address = 0; //eeprom address to store threshold value
int l_address = 3; //eeprom address to store logged address
int value; // variable for threshold setting
int menupage = 0; //page menu variable holder
int logged; // number of logged incidences
int decision = 0; // variable to keep the while loop going before a button decision has been made
int drunk_val; //variable to store failed value
int drunk_retest = 30; //seconds elapsed before a retest can be done


void setup() {
 logged = EEPROM.read(l_address); // get number of logged events from eeprom
 pinMode(led, OUTPUT);    // backlight control
 pinMode(13, OUTPUT);    // led and buzzer control

 // set up the LCD's number of columns and rows:
 lcd.begin(16, 2);
 digitalWrite(led, HIGH);   // turn the backlight on

 lcd.print("Get ready...");
 delay(5000);
 if (analogRead(0) < 1000) {
  diag = 1; // enter diagnostic mode if any button is pressed and held during startup
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("Entering");
  lcd.setCursor(0, 1);
  lcd.print("diagnostic mode");
  delay (1000);
  while (true) {  // loop forever
   if (menupage == 0) { // sensor diagnostic page
    val = analogRead(1); //Read Gas value from analog 1
```

```
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("Reset to exit");
  lcd.setCursor(0, 1);
  lcd.print("Sensor val:");
  lcd.print(val, DEC);
  delay (100);
  if (analogRead(0) < 5) { //right button is pressed
    menupage = 1;
    value = (EEPROM.read(address) * 10);
    delay(200);
  }
}

if (menupage == 1) { //threshold setting page
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("Threshold value");
  lcd.setCursor(0, 1);
  lcd.print(value, DEC);
  delay (100);
  if ((analogRead(0) < 160) && (analogRead(0) > 100)) { // up button is pressed
    if (value < 1000) {
      value = value + 10;
    }
  }
  if ((analogRead(0) < 350) && (analogRead(0) > 300)) { // down button is pressed
    if (value > 0) {
      value = value - 10;
    }
  }
  if ((analogRead(0) < 550) && (analogRead(0) > 450)) { // left button is pressed
    menupage = 0;
    delay(500);
  }
  if ((analogRead(0) < 780) && (analogRead(0) > 700)) { // select (save) button is pressed
    lcd.setCursor(0, 1);
    lcd.print("Value Saved");
    EEPROM.write(address, value / 10);
    delay (1000);
  }
  if (analogRead(0) < 5) { //right button is pressed
    menupage = 2;
    delay(200);
  }
}

if (menupage == 2) { //logged events page
  lcd.clear();
  lcd.setCursor(0, 0);
```

```
      lcd.print("Logged counts:");
      lcd.setCursor(0, 1);
      lcd.print(logged, DEC);
      delay (100);
      if ((analogRead(0) < 550) && (analogRead(0) > 450)) { // left button is pressed
        menupage = 1;
        delay(200);
      }
      if ((analogRead(0) < 780) && (analogRead(0) > 700)) { // select (save) button is pressed
        decision = 0;
        lcd.clear();
        lcd.setCursor(0, 0);
        lcd.print("Clear logged?");
        lcd.setCursor(0, 1);
        lcd.print("Select=clear");
        delay(500);
        while (decision == 0) {
          delay(100);
          if ((analogRead(0) < 780) && (analogRead(0) > 700)) { // select (save) button is pressed
            EEPROM.write(l_address, 0);
            lcd.clear();
            lcd.setCursor(0, 0);
            lcd.print("Logs cleared!");
            logged = EEPROM.read(l_address); // get number of logged events from eeprom
            delay (1000);
            decision = 1;
          }
          if ((analogRead(0) < 160) && (analogRead(0) > 100)) { // up button is pressed
            decision = 1;
          }
          if ((analogRead(0) < 350) && (analogRead(0) > 300)) { // down button is pressed
            decision = 1;
          }
          if ((analogRead(0) < 550) && (analogRead(0) > 450)) { // left button is pressed
            decision = 1;
          }
          if (analogRead(0) < 5) { //right button is pressed
            decision = 1;
          }
        }
      }
    }
  }
}

lcd.setCursor(0, 0);
lcd.print("Please provide");
lcd.setCursor(0, 1);
lcd.print("breath sample...");
value = (EEPROM.read(address) * 10);
```

```
  logged = EEPROM.read(l_address); // get number of logged events from eeprom
  // take 50 readings over 5 seconds
  for (int i = 0; i < 50; i++) {
    val = analogRead(1); //Read Gas value from analog 1
    delay(100);
    if (val > value) {
      drunk = 1;
      drunk_val = val;
    }
  }
}

void loop() {

  if (drunk == 1) {
    if (drunk_retest == 0) {
      drunk = 0;
      lcd.clear();
      lcd.print("Get ready...");
      delay(5000);
      lcd.setCursor(0, 0);
      lcd.print("Please provide ");
      lcd.setCursor(0, 1);
      lcd.print("breath sample...");
      value = (EEPROM.read(address) * 10);
      logged = EEPROM.read(l_address); // get number of logged events from eeprom
      // take 50 readings over 5 seconds
      for (int i = 0; i < 50; i++) {
        val = analogRead(1); //Read Gas value from analog 1
        delay(100);
        if (val > value) {
          drunk = 1;
          drunk_val = val;
        }
        drunk_retest = 30;

      }
    } else {
      lcd.clear();
      lcd.setCursor(0, 0);
      lcd.print("Vehicle Disabled");
      lcd.setCursor(0, 1);
      //lcd.print("Sensor val:");
      //lcd.print(drunk_val, DEC);
      lcd.print("Retesting: ");
      lcd.print(drunk_retest, DEC);
      lcd.print("s");
      drunk_retest--;
    }
    delay(1000);
```

```
}

if (drunk == 0) {

  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("Vehicle Enabled");
  lcd.setCursor(0, 1);
  lcd.print("Retesting: ");
  lcd.print(retest, DEC);
  lcd.print("s");
  retest--;
  delay(1000);
  if (retest == 0) {
    lcd.clear();
    lcd.print("Get ready...");
    delay(5000);
    lcd.setCursor(0, 0);
    lcd.print("Please provide");
    lcd.setCursor(0, 1);
    lcd.print("breath sample...");

    // take 50 readings over 5 seconds
    for (int i = 0; i < 50; i++) {
      int val;
      val = analogRead(1); //Read Gas value from analog 1
      delay(100);
      if (val > value) {
        drunk = 1;
        drunk_val = val;
      }
    }
    if (drunk == 1) {

      lcd.clear();
      lcd.setCursor(0, 0);
      lcd.print("Test failed.");
      EEPROM.write(l_address, logged + 1);
      while (drunk == 1) {
        digitalWrite(13, HIGH);   // turn on the led and buzzer
        lcd.setCursor(0, 1);
        lcd.print("                ");
        lcd.setCursor(0, 1);
        //lcd.print("Sensor val:");
        //lcd.print(drunk_val, DEC);
        lcd.print("> 0.08 BAC");
        delay (2000);
        lcd.setCursor(0, 1);
        lcd.print("Incident logged");
        delay (2000);
```

```
        }

      }
      else {
        lcd.clear();
        retest = 40;
      }
    }
  }
}
```