TOUCH BASED BLOOD ALCOHOL CONCENTRATION (BAC)

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BY

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I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

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ABSTRACT

Alcohol consumption can lead to both long term and short term effects. The most prominent impairment of the short term effects and the focus of this project is drunken alcoholic beverage but also on innocent members of the society. Alcohol impaired driving is an immense issue resulting in large amounts of traffic accidents and fatalities each year.

Despite the great efforts of law and enforcement officers to alcohol impaired driving. It's impossible to catch and arrest all alcohol impaired drivers as proven when considering the ratio of police officers patrolling the roads and highways to that of drivers/cars. Furthermore, the main technology used today in roadside testing of the BAC level is the breathalyzer, and althught it's sufficient it doesn't solve the problem at hand. Were the driver has to be spotted & suspected first by the police officers and then pulled over to perform the test. Hence, it doesnot actually prevent alcohol impaired driving at source.

By building A TOUCH BASED BLOOD ALCOHOL CONCENTRATION (BAC) sensor & implementing it in cars, alcohol impaired driving can be conquered at its roots and stopped once and for all. Were the touch based sensor would control the car ignition system and thus control the car start up , all based on the BAC level it detects . such that if the BAC level it detects is higher than the legal limit the car ignition system will be triggered to inhibit the car start up and will send a message for someone to come and pick up the driver, vice versa if the BAC level detected is within or below the legal limit .

Since it's a touch based sensor it provides a non-invasive and non-intrusive BAC detection, hence unlike previous BAC measurement techniques no sample will be required to be drawn from the driver.

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LIST OF ABBREVIATIONS

ACTS: Automotive Coalition for Traffic Safety

ADC: Analogue to Digital Converter

BAC: Blood Alcohol Concentration

BrAC: Breath Alcohol Concentration

DADDS: Driver Alcohol Detection System for Safety

DC: Direct Current

EEPROM: Electrically Erasable Programmable Read-Only Memory

Etg: Ethyl Glucuronide

FDA: Food and Drug Administration

GC: Gas Chromatography

ICSP: In-Circuit Serial Programming

I/O: Input/Output

IR: Infrared Radiation

LCD: Liquid Crystal Display

LED: Light Emitting Diode

NHTSA: National Highway Traffic Safety Administration

NIAAA: National Institute on Alcohol Abuse and Alcoholism

NIR: Near Infrared Radiation

PCB: Printed Circuit Board

PWM: Pulse Width Modulation

SpO2: Oxygen Saturation in the Blood

UAC: Urine Alcohol Concentration

USB: Universal Serial Bus

CHAPTER1

INTRODUCTION

Alcohols are defined as any class of organic compounds that contain a hydroxyl functional group (-OH) bound to a saturated carbon atom. In modern day society the use of the term alcohol in colloquial speech to beverages containing the primary alcohol ethanol. Alcoholic beverages contain a considerable amount of ethanol that varies in concentration from one type to another(McNaught, Wilkinson, 1997).

Ethanol is a prime simple alcohol that contains 2 carbon atoms and has the molecular formula CH3CH2OH (an alternative notation is CH3-CH2-OH) and is widely referred to as ethyl alcohol(PubChem, 2016).

Ethanol is a psychoactive drug. Which means it's a chemical substance that alters brain function and behavior(Nt.gov, 2016).

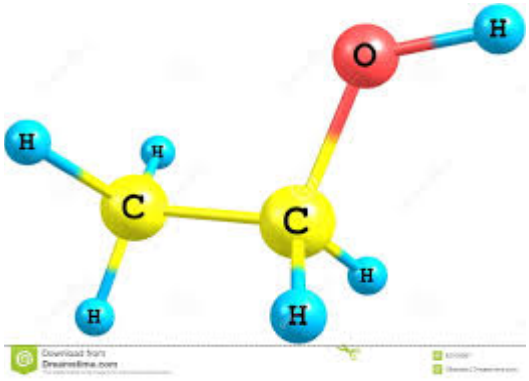


Figure 1.1: Ethanol Molecule Structure.

The normal blood alcohol concentration is 0.00% when no alcoholic beverages are consumed. However in an abnormal biological case ethanol can sometimes be internally produced in the human body without having to drink any beverage, the case is called Auto-Brewery Syndrome. When it occurs, it's then enough to title the individual legally intoxicated. The probability of occurrence of this pathology is very rate. This Syndrome causes the body to produce ethanol of different concentrations that vary from on individual to another (AW, 2016). The justification for the production of different ethanol concentrations is not yet recognized. When the pathology is found ethanol is only produced when the

patient's diet is rich with carbohydrates, and especially after ingesting a carbohydrate-rich meal. This is because the carbohydrates initiate an abnormally rapid reproduction of yeast, which in turn ferments producing the ethanol(Jansson, Meurling, Petrini, Sjolin, 2007).

The effect of alcohol consumption is well known and documented and varies widely based on many factors. It is known that when alcohol is consumed twenty percent of it is rapidly absorbed into the blood stream while the rest is processed through the gastro-intestinal tract. After the alcohol is absorbed into the bloodstream it can then diffuse into almost all tissues and cells due to the high cell permeability to alcohol. This causes both long and short term effects.

There is a variety of long term effects, were prolonged and excessive consumption of alcohol causes great harm to the human biological system. These include neurological impairment, cardiovascular disease, liver disease, psychiatric disorders and brain damage. It is also associated with hypertension, coronary heart disease and can have a negative impact on aging. Furthermore, long term consumption of alcohol increases the risk of many cancers such as liver, breast, ovaries, esophagus, pancreas, mouth, larynx and pharynx. In addition, it causes alcohol dependency, better known as alcoholism which requires specialized treatment in rehabilitation(Cargiulo, 2007).

Short term effects occur when the alcohol consumption rate is much greater than the metabolic rate in metabolizing the alcohol units (ethanol). The effects depend on the Blood Alcohol Concentration (BAC) level, which is defined as the measurement of the amount of alcohol in the blood. The BAC level expresses the percentage of ethanol in the blood in units of mass of alcohol per volume of blood or in units of mass of alcohol per mass of blood. The BAC level is used to define intoxication and provides a rough measure of impairment. However the value of the BAC for two individuals who consumed the same amount of alcohol may differ, since the BAC calculation depends on multiple factors. These include age, weight, body fat composition and gender, body water content, general health, biological rhythm, amount of alcohol consumed, percentage of ethanol in the alcoholic beverage, drinking period, alcohol dependency, the presence of any other drugs or medications and

whether the consumption is on an empty stomach or not. Upon all this depends the degree of impairment (Cederbaum, 2012).

1.1 Why we need this

According to the World Health Organization (WHO) each year more than 2 million people die due to alcohol related basis. In 2012, 3.3 million deaths around the world were related and caused by alcohol intoxication. These attributed to 5.9% of the total global deaths that year. And since the beginning of 2016 till the current time (20^{th}-May -2016 1:00 pm) 962.928 global deaths are caused by alcohol, with this number continuously rising per minute (Worldometers, 2016).

Hence, alcohol consumption plays a large role in premature deaths contributing to large amounts globally. Not to forget the large amounts of traffic fatalities affiliated with alcohol consumption. Whereas according to the National Highway Traffic Safety Administration (NHTSA) 32,675 people died in traffic crashes in 2014 in the United States. Our of which 9,967 people died due to alcohol impaired driving, accounting for almost 31% of all traffic fatalities in that year(US department of Transportation, 2016).

The main disadvantage with the currently available roadside BAC measurement device, the breathalyzer, is that it can only be used if a driver is pulled over and only if suspected to be intoxicated while driving. Hence a sample is required to check for intoxication and it can only be acquired if the suspect is pulled over. And considering the ratio of police officers patrolling the roads and highways to that of cars, many intoxicated drivers can easily pass by unsuspected. Having a device installed into steering wheels, gearshifts or the push to start button of a car that can measure the BAC instantly will help provide safety for the intoxicated drivers as well as the general public, where it controls the engine ignition and prohibits any possibility of alcohol impaired driving. Thus, solving the problem of alcohol impaired driving from its roots.

1.2 Objectives:

1.2.1 General Objective

This project aims to acquire a way to sense blood alcohol concentration, in attempt to prevent driving while intoxicated, then send a message to a taxi company for picking him up.

1.2.2 Specific Objectives

1. To build a non-invasive BAC sensor.
2. To utilize the concept of near infrared tissue spectroscopy to create a touch based BAC sensor.
3. To control car engine ignition in order to prevent alcohol impaired driving.

1.3 Significance of study

Alcohol impaired driving is one of the major causes of car accidents and fatalities. As previously stated in 2014, across all 50 states in the USA, alcohol impaired driving crashes resulted in 9,967 deaths. Resulting in an average of 1 alcohol impaired driving fatality every 53 minutes(US department of Transportation, 2016).

Out of the 9,967 alcohol impaired deaths, 6,391 of them (or 64%) were drivers with BACs of 0.08% or higher. Furthermore 2,752 (or 28%) deaths were car occupants and 824 (or 8%) deaths were non-occupants such as pedestrians, cyclists or others.

However, in contrast to 2013, alcohol impaired fatalities decreased by 1.4%; from 10,110 deaths in 2013 to 9,967 deaths in 2014. Moreover Alcohol impaired driving fatalities has decreased in the past 10 years by 27% from 13,582 in 2005 to 9,967 in 2014 (US department of Transportation, 2015).

This project intends to improve these statistics further, and reduce alcohol impaired driving deaths to the minimum. Whereas an outcome, this issue can be prevented at its roots, such that driving while intoxicated would be prohibited, thus reducing the statistics 0%.

1.4 Thesis layout

Chapter One: Introduction

Chapter Two: Literature Review

Chapter Three: Methodology

Chapter Four: Results

Chapter Five: Discussion, Conclusion and Recommendation

1.5 Key Terms

Blood Alcohol Concentration (BAC)

It's the measurement of the amount of alcohol in the blood. The BAC expresses the percentage of ethanol in the blood in units of mass of alcohol per volume of blood or in units of mass of alcohol per mass of blood.

Breath Alcohol Concentration (BrAC)

It's the measurement of the amount of alcohol in the breath. Were some alcohol is excreted from the body before its metabolized in the breath.

Urine Alcohol Concentration (UAC)

It's the measurement of the amount of alcohol in urine, as some of it excreted unchanged through the urine.

Near Infrared Radiation (NIR)

Is a bandwidth of wavelengths within the infrared region of the electromagnetic spectrum, extending from approximately 0.75Micro m to 2.5Micro m.

Tissue Spectroscopy

It's the study of the interaction between living biological tissue and electromagnetic radiation.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

This chapter examines the pre-existing techniques and initial methods used for BAC measurement. As well as driving into the details of Near Infrared Tissue spectroscopy, which is the method exploited in this project.

2.2 BAC Measurement Techniques

A BAC measurement examines if a person is intoxicated and the degree of intoxication. Such measurements help determine how to treat the intoxicated person and examine if the subject is illegally intoxicated; for instance drinking while on parole that prohibits alcohol consumption or underage or, as this project aims to prohibit, drinking whilst driving.

BAC measurement can be obtained within minutes of the consumption of an alcoholic beverage due to the high permeability of ethanol molecules and their rapid absorbance into the blood. Give that when alcohol is consumed twenty percent of it is rapidly absorbed into the blood surpassing the gastro-intestinal track. However the BAC only peaks about an hour after consumption of an alcoholic beverage because by then all the alcohol passed through the gastro-intestinal track into the blood. However if food has been consumed and was present in the stomach at the time of alcohol consumption it may increase the amount of time it takes for the BAC to peak(Thompson, Tharrat, 2014).

About 90% of the consumed alcohol is metabolized in the liver, thus one of the major long term effects of alcohol consumption is liver damage by cirrhosis, steatosis (fatty liver) and alcohol hepatitis. While the remaining 10% of it is excreted out of the body as alcohol unchanged through urine, sweat, faeces, milk, saliva and breath. It is the latter process of excretion that allows the non-invasive breathalyzer test to be carried out. However there are multiple methods and test for measuring the BAC (Day, 2007)&(Forcon, 2004).

The three main tests are referred to as the chemical tests, which are blood, breath and urine BAC tests, but other non-invasive techniques have come to rise, such as what this project exploits; Near Infrared Tissue Spectroscopy. Furthermore, not to forget the first method of

BAC measurement, Widmark's Micro-method created by the pioneer of the field of alcohol kinetics Erik M.P. Widmark(Anelli, 2015)&(JONES, 2001).

Figure2.1:Erik M.P. Widmark, the pioneer in the field of alcohol kinetics and blood based BAC(Erik Widmark, 1940).

2.2.1 Chemical Tests

Chemical Tests are normally administered after a person suspected to be driving while intoxicated fails the field sobriety tests. In the field sobriety test the police officer examine the driver's balance, coordination and cognitive capabilities by a series of takes. Were he asks the suspected driver to perform activities such as standing on one leg. Walking a specific number of steps in a straight line and back, reciting the alphabet backwards and following a small flashlight/pen move horizontally back and forth. The latter test is known as the horizontal gaze nystagmus test and it allows the police officer to test for any inconsistent eye motion that is also an indication of intoxication. If however the suspected driver passes the field sobriety tests and has proven not to be driving while intoxicated he is then free to go (Brown, 2016).

There are three chemical tests that can be performed; blood, breath and urine. The blood test measures the BAC directly from the blood itself while the breath and urine tests are indirect (Anelli, 2015).

In this project we will focus and compare between the breath tests which has a system was used in the same way of our project in the cars' detection and NIR spectroscopy which we are using and it's not a chemical test.

2.2.1.1 Breath Test – Breathalyzer

The breathalyzer or breath test is a non-invasive method used to calculate the BAC. It is an indirect method that calculates the breath alcohol concentration (BrAC) first then converts it into an estimate of the BAC using a conversion factor(Anelli, 2015).

This conversion factor is the ratio of alcohol in the blood to that in the breath and it is known as the partition coefficient, denoted generally by the latter 'K'. It is calculated from the partition ratio, (BAC: BrAC= 1: 2100) which means that 1 part of blood containing alcohol is equivalent to 2,100 parts of alveolar air containing the same amount of alcohol. And from the partition ratio the partition coefficient is obtained equaling $K_{brAC/BAC}$ = 2100(Washington, 1996).

This relationship between the BrAC and BAC is based on Henry's gas law, which states that: "The quantity of gas that dissolves in a liquid at standard temperature and pressure is directly proportional to the partial pressure of that gas in the gas phase"(Forcon, 2004).

As blood containing alcohol passes through the dense mesh of capillaries in the lungs, the alcohol being highly permeable and volatile, diffuses from the pulmonary capillaries through the alveolar-capillary membrane into the alveoli. Then it's excreted along with waste gases such as carbon dioxide to the external environment, and this is where the detection and measurement of the BrAC takes place(Craig medical, 2016).

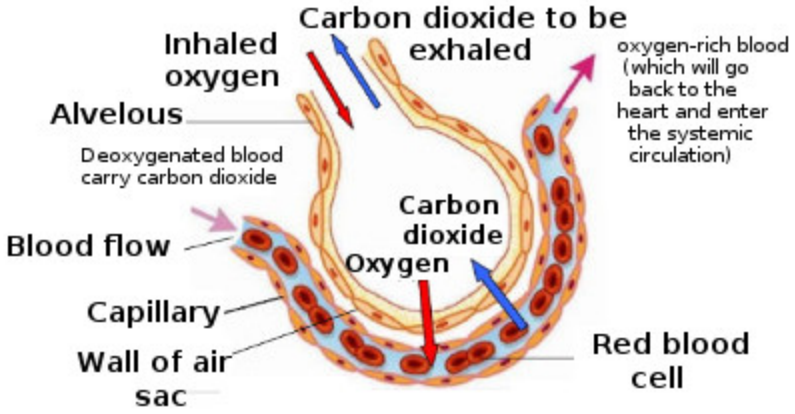


Figure 2.2: Demonstrates the exchange of gases between the blood and alveoli

The very first applications of a blood alcohol detection system based on respiration came to rise in the United Sates between the years 1931-1935, and it was known as the Drunkometer. Compared to the standards and device available today the Drunkometer is rather primitive, but at that time it provided sufficient results. The technology behind the breathalyzer continued to boom over the years until fuel cell testers were invented and they are now the main technology used in breathalyzers(AW, 1996)&(Jones, 2000).

Fuel cell testers depend on the process of electrochemical oxidation, where alcohol in the breath is oxidized and produces an electric current that is used to determine the BrAC and thus the BAC. Its structure consists of two platinum electrodes separated by porous acid-electrolyte material.

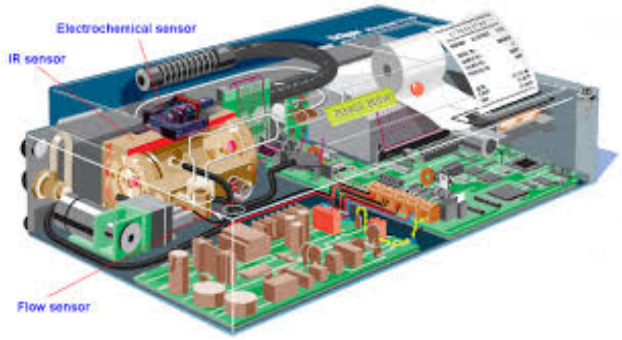


Figure 2.3: The basic structure of a Fuel Cell Breathalyzer Device.

When an intoxicated person exhales into the device, the presence of alcohol in his breath causes a redox reaction that takes place between the two electrodes, resulting in the formation of a current between them. The greater the alcohol in the breath the higher current value, due to the occurrence of a greater electrochemical reaction. A microprocessor is used to measure and process the current produced to give the corresponding BrAC and then convert it to the equivalent BAC estimate. The result is then displayed by the device using an LCD or LEDs or an audible beep alarm depending of the model of the device.

Breathalyzers provide a quick and appropriate method to measure the BAC of a suspected intoxicated driver. When the suspect fails the field sobriety test carried out by the police officer a chemical test is required to confirm intoxication. To ask for urine sample is inappropriate in public and rather intrusive and just like a blood sample analysis will consume time till the results are obtained. Hence the breathalyzer test provides immediate results and is appropriate to use, that's why it's the method exploited by police officers for roadside testing(Dasgupta, Pelarenos, 2016).

Furthermore, the breathalyzer is small in size, light in weight, portable and easy to handle. They are also widely available and relatively cheap, where the price of a unit varies according to model and manufacturer(Craig medical, 2016).

On the other hand, breathalyzer tests are not as accurate as the direct blood test, where the partition coefficient is an average value, that doesn't distinguish between the different traits of different individuals, such as gender, weight, age and so on. In fact this value may even vary for the same individual during different times depending on body temperature, respiration rate, and weather the individual is within or between drinking sessions.

Additionally, environment factors can affect the reading and cause a falsely higher BAC, like the presence of gasoline, thinner, paint, glue and even air cleaners. Moreover the presence of alcohol containing substances in the mouth like cough syrup, mouth wash or breath fresheners can also cause a falsely higher BAC reading, since the amount of ethanol detected will not be purely that exhaled from the lungs. Even smoking, burping or throwing up before the test can increase the BAC falsely. Smokers need to wait a minimum of ten minutes after smoking and before taking the test to insure that any residual smoke has been expelled from the lungs. This is why the officers administrating the test should monitor the suspect before

carrying out the test to insure he doesn't perform any of the previous actions that can skew the test results.

Lastly, breathalyzers need to be frequently calibrated by air with known amounts of ethanol to maintain their accuracy. And a breathalyzer test should be repeated two to three times by the suspect and the results averaged. This is because different readings would usually be obtained due to different test conditions and independent variables that may change between one test and the other, such as amount of air exhaled from the lungs each time (Brown, 2016).

2.2.2 Near Infrared Tissue Spectroscopy

Spectroscopy in general refers to the study of the interaction between matter and electromagnetic radiation. Tissue Spectroscopy hence refers to the interaction of electromagnetic radiation with a tissue, mostly skin. In turn, near Infrared (NIR) Tissue Spectroscopy is the interaction of the Near Infra-Red radiation with tissue, with the NIR being the electromagnetic radiation used.

The concept of tissue spectroscopy is used in many applications such as the pulse Oximeter. The pulse Oximeter is a non-invasive device used to measure the oxygen saturation (SPO2) of a patient's blood. It uses two sources of light (Electromagnetic radiation), one red (approximately 650nm) and one IR (950nm). The red is absorbed more by deoxyhemoglobin than the IR while the IR is absorbed more by the deoxyhemoglobin than the red. The ratio of the deoxyhemoglobin to the total deoxyhemoglobin gives the oxygen saturation in the blood. The device is placed on the patient's finger and readings are taken through the skin, making it a non-invasive device, hence using the concept of tissue spectroscopy with not one but two different wavelengths of electromagnetic radiation (Skoog, Holler, Crouch, 2006).

Another application that exploits the concept of tissue spectroscopy, is the non-invasive touch based alcohol detection system implemented in this project. That uses NIR as its source.

Pre-existing work using NIR tissue spectroscopy for alcohol detection through the skin has been conducted by the TruTouch Technologies. The Driver Alcohol Detection System for

Safety (DADSS) Program is a research partnership between the National Highway Traffic Safety Administration (NHTSA) and the Automotive Coalition for Traffic Safety (ACTS). It seeks ways to improve the alcohol detection technologies currently available, and at the same time supports new development or prototypes of hardware that could be implemented in cars or vehicles as to increase safety with regards to alcohol intoxication.

The DADSS program has selected two concepts to develop and implement in cars for alcohol detection and drunken driving safety and prevention. First, is the Distance Spectroscopy System (breath-based) and secondly, the Tissue Spectroscopy System (tissue-based). Three prototype detection systems were developed, two of which employed alcohol detection through the drivers' breath (breath-based) while the third one employed the detection of alcohol through the drivers' tissue (tissue-based).

For the tissue-based system, TruTouch Technologies was the company chosen to create the prototype of this non-invasive sensor that detects alcohol through the skin. NIR tissue spectroscopy was exploited. Near infrared radiation is a bandwidth of wavelengths within the infrared region of the electromagnetic spectrum, extending from

approximately 0.75um to2.5um. However, a bandwidth of 1.25 to 2.5um was determined to be the best range to use by TruTouch Technologies, where it provided the highest alcohol measurement sensitivity and selectivity.

Pigments present in the skin such as melanin (that differs from one person to another due to different ethnicities), as well as the presence of different skin chromospheres such as oxyhemoglobin and deoxyhemoglobin, limit the bandwidth of 0.7-2.5um. Hence using the bandwidth of 1.25-2.5um is alcohol specific resulting in an alcohol detection signal a hundred times stronger than signal produced by the 0.7-2.5um bandwidth (Ferguson, Zauok, Dalal, Strohl, Traube, Strassburger, 2003).

The specific molecular absorption of one molecule differs from another, were the structure of the molecule is what determine the way in which it adsorbs light or electromagnetic radiation. Thus the absorbance spectrum is different for each molecule, which in turn allows discrimination of different molecules in the body by different wavelengths. The 1.25-2.5um

bandwidth is what separates alcohol from other pigments and chromospheres that are abundantly present in the skin such as melanin or oxyhemoglobin or even water.

Also, the beam of NIR used could penetrate up to 5mm deep, up to the dermal layers of the skin. The basic structure of the human skin consists of three main layers with different properties that effect the non-invasive measurement. First, is the epidermal layer, which is the outermost layer that acts as shield and protects the body from external environment. It has a varying thickness throughout the body but is about1.5mm thick in the hands. It has very little extracellular fluid and thus plays a negligible role in the tough based alcohol detection system.

Secondly is the dermal layer that is thickest layer of all three, ranging up to 4mm in thickness. It is also where the capillaries carrying the blood are rich and well embedded, as well as contains a high water content, constituting approximately 65% of the volume of this layer. Hence it is where the alcohol dissolved in water resides and where the detection occurs. Lastly, is the subcutaneous layer which is composed mostly of fats. Which have low water solubility. This in turn results in poor alcohol solubility and thus also results in a negligible role in the touch based alcohol detection system. Thus it's safe to say with the 5mm depth penetration of the NIR beam, the detection would occur suitably in the dermal layer, yielding the best result of all three layers (Ridder, VerSteeg, Laaksonen, 2009).

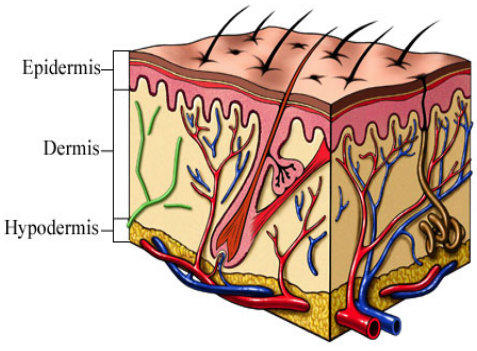


Figure 2.4: Representing the three main skin layers.

Another advantage of using NIR besides alcohol specificity and sensitivity, and depth of penetration is that it is safe. According to the FDA the level of the NIR light used is less than the limits established for non-ionizing radiation.

The prototype by TruTouch Technologies incorporated a small fiber optic touchpad with which the user interface. The test is carried out simply by the user placing the tip of his/her index finger on the touchpad. Spectral data is then collected and calculation is made in order to display the results on the screen. The prototype is a stand-alone unit that carries out testing through the sensor, along with data a processing unit.

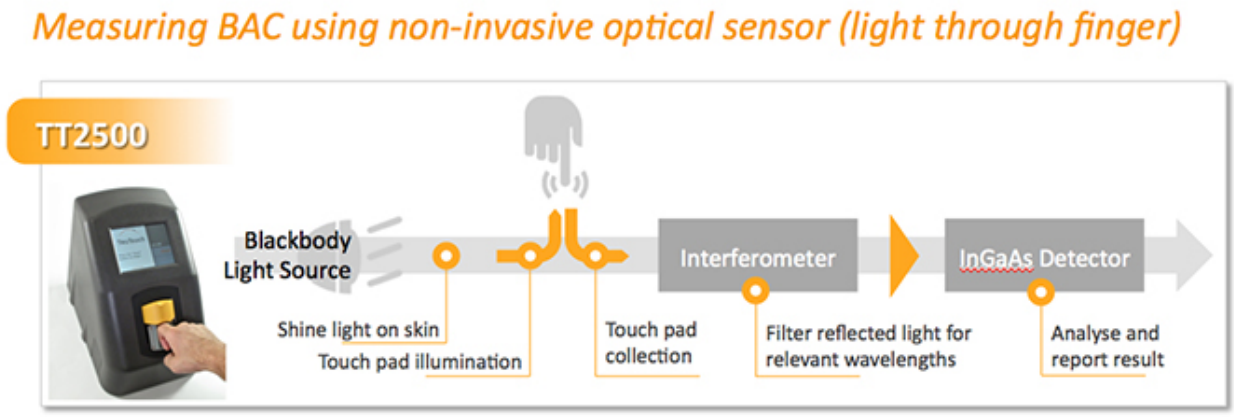


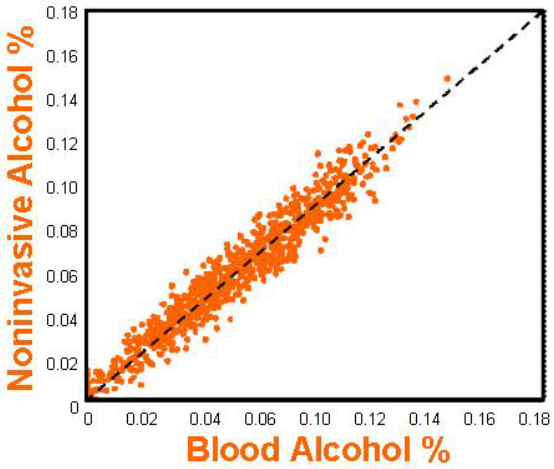
Figure 2.5: Representing one of the prototypes constructed by TruTouch Technologies for a non-invasive touch based BAC measurement System based on NIR tissue spectroscopy

Figure 2.6: Represents another TruTouch touch Based BAC measurement system prototype

In comparison to figure 2.5 figure 2.6 represent a larger prototype that is also a non-invasive touch based BAC measurement system based on NIR tissue spectroscopy. However the different is that in figure 2.5 the prototype is smaller and the measurement is based on the index finger only, while in figure 2.6 the measurement is taken from the entire palm of the hand.

The measurement is based on the reflectance method, where the NIR is transmitted to the skin that is in contact with the prototype's touchpad, and then the light reflected by the skin is collected. The reflected light is then analyzed to determine the concentration of alcohol present in the tissue. Since ethanol molecules have a specific molecular absorption for the bandwidth of NIR wavelength from 1.25-2.5um, they would absorb those waves strongly. This means that the higher the concentration of alcohol in the blood, the more the absorption of the NIR light, the less the reflected light. This in turn would result in a low output from the sensor indicating a high BAC level.

The prototype developed by TruTouch Technologies returned very high accuracy levels. Were the system has less than 0.01% BAC error. The accuracy of the TruTouch Technologies' prototype was determined by measuring the BAC of 70 volunteer subjects to whom controlled alcohol does were administered. At every 15-minute-interval, blood alcohol measurements were taken to monitor the concentration of alcohol. Once the alcohol was completely absorbed in to the blood and the BAC began to decline due to excretion and metabolism, cycles of blood, breath and touch based alcohol measurements were taken repeatedly from the 70 volunteers. The figures below demonstrate the accuracy of TurTouch Technologies touch based method. Where they compare the blood BAC measurement with that of breath BAC and touch based BAC. Hence both methods (touch based and breath based) are each compared to blood based measurement of the BAC, which is rendered the most accurate test.



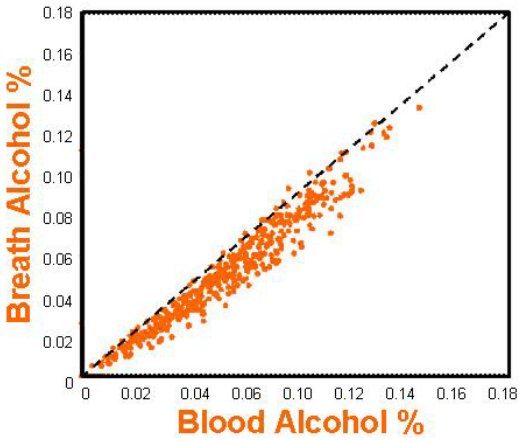


Figure 2.7: Non-invasive BAC Measurement compared to blood BAC measurement

figure 2.8: Breath BAC measurement compared to blood BAC measurement

From the figure above it can be interpreted that the touch based, non-invasive TruTouch technologies prototype is highly accurate, and almost equivalent to the blood based BAC measurement. At the same time it can be concluded that it's more accurate than the breath test. The data points for the touch based test are highly lumped around the diagonal, which indicates equality in the values of both measurement techniques. While for the breath tests the data points are slightly skewed below the diagonal, especially at higher readings.

Furthermore the high accuracy attained by the touch based, non-invasive TurTouch technologies prototype is only one of many advantages it presents.

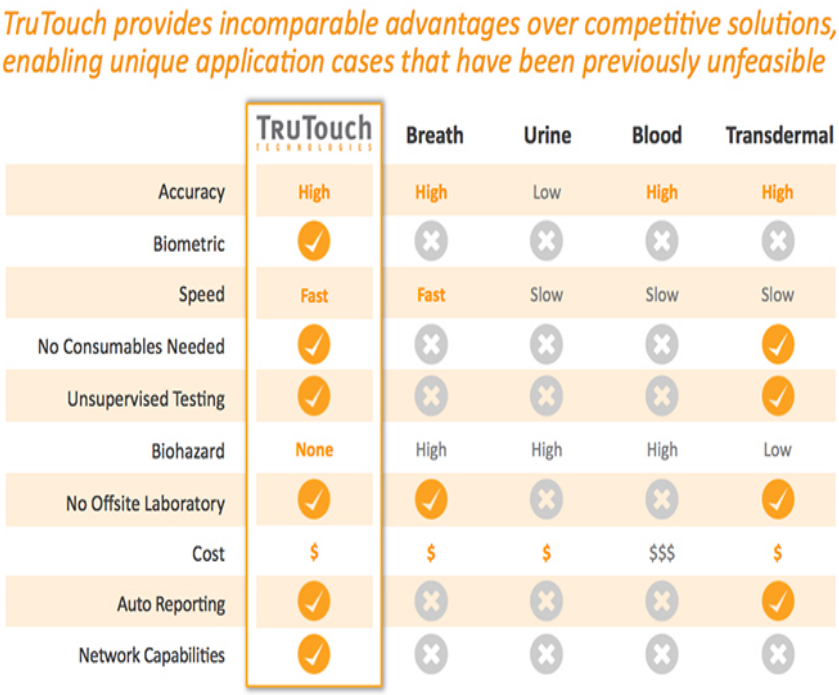


Figure 2.9: Displays and compares the benefits of the TruTouch technologies Touch based system with the other BAC measurement techniques.

This project exploits the same concept used by TruTouch Technologies, which is the NIR tissue spectroscopy, but with a couple of modifications. Firstly, the project aims to overcome the problem of alcohol intoxicated driving from its roots. Hence, it aims to reconstruct a touch based; non-invasive blood alcohol detection sensor that can be implemented in cars. Along with a control circuit it would inhibit the car ignition system in case of detection of a BAC level above the legal limit. The design of the sensor can be implemented in the push to start button of the car, or for older car models in the steering wheel or gear shifts(Ridder, VerSteeg, Laaksonen, 2009).

CHAPTER 3

THEORETICAL FRAMEWORK

3.1 Introduction

This chapter provides details concerning the components used and the procedure performed throughout the different phases of the project development.

3.2 Material Used:

3.2.1 Arduino UNO Board

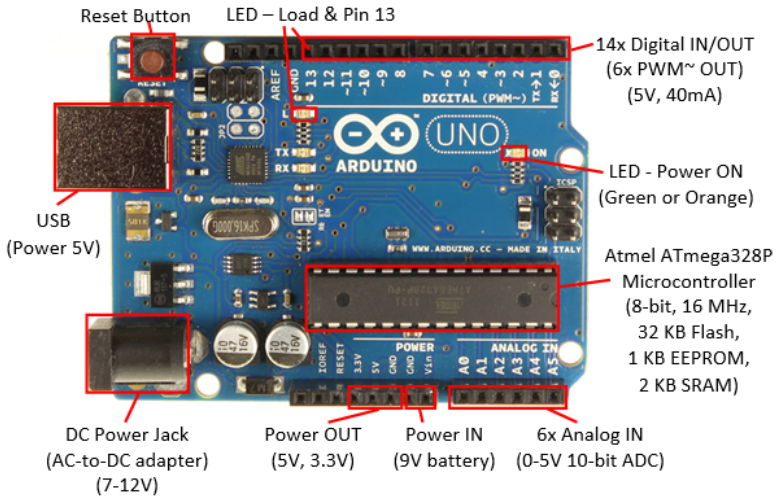


Figure3.1: Arduino UNO Board

An arduino UNO is a complete microcontroller printed circuit board (PCB) that is based on ATmega328P microcontroller chip. It has a total of 32 pin terminals, excluding the USB connection, the power jack, a reset button and an ICSP header.

Table 3.1: Specifications of the Arduino UNO microcontroller.

Microcontroller	ATmega328P
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limit)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
PWM Digital I/O Pins	6
Analogue Input Pins	6
DC Current per I/O Pin	20 mA
DC Current for 3.3V Pin	50mA
Flash Memory	32 KB (ATmega328P) Of which 0.5 KB used by boot loader
SRAM	2 KB (ATmega328P)
EEPROM	1 KB (ATmega328P)
Clock Speed	16 MHz
Length	68.6 mm
Width	53.4 mm
Weight	25 g

The pin-outs include 14 digital I/O pins (inspect in figure 3.1 above), 6of which

Can be used as 8-bit Pulse Width Modulation (PWM) outputs [3, 5, 6, 9, 10. And 11], 2 of which are external interrupts [2 & 3] and another two that are used for serial communication [0 & 1, with 0=RX –the receiver & 1=TX –the transmitter]. Each of these 14 pins provides an output of 5 volts, and can emit or receive 20mA of current.

It's recommended not to exceed a maximum of 40mA of current input or output at these pins, or it would cause permanent damage to the microcontroller chip.

The pin-outs also include 6 analogue inputs (A0-A5), each with a 10 bit word width and a default reference voltage of 5V for the built in analogue to digital converter (ADC).

The board is powered by connecting it to a computer via the USB connection or by connecting it an AC-to-DC adapter via power jack, or even by connecting it to a battery via its ground (GND) and voltage input (Vin) pin-outs in the ‘power’ section. The board operates with a 5V power supply that is provided to it when connected by the USB connection. However when supplied externally by a battery or an adapter it can withstand a supply voltage of 6-20V, yet it’s recommended to limit the voltage supplied between 7-12V. The GND and Vin pins can also be used to access the power supplied to the board as to distribute it to other adjacent components.

Also in the ‘power’ pins section there is a 5V pin as well as a 3V3 pin. They both supply a regulated output voltage generated by the on board regulator, with values of 5V and 3.3V respectively. Hence, they can also be used to distribute power to other adjacent components used with the Arduino microcontroller. This concept was exploited in this project to supply the other components on the sensor system such as the IR module, LCD and output LEDs.

The Arduino UNO microcontroller board was employed in this project due to the great properties it provided. For instance it has a quartz crystal of 16MHz, providing an excellent clock rate and performance. Furthermore, it has built in circuits such as an ADC, which eliminates the need for excessive hardware. Not to forget its appropriate size and light weight, with a length of 68.6mm, a width of 53.4mm and a weight of 25g. Moreover, it overrides the need of an external hardware programmer or driver, whereas the USB connection provides the required interface with the computer as to upload programs into the chip. Lastly it’s commonly available and easily found in the market in Turkey, and has a cost effective price allowing students with a limited budget to purchase and experiment on it (Arduino.cc, 2016).

3.2.2 IR Module

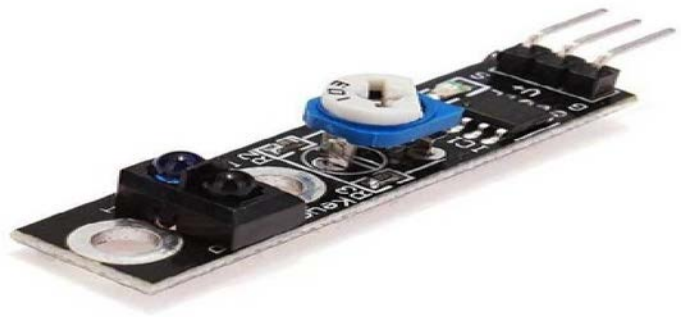


Figure 3.2: IR Module

The IR Module used is a Line Tracking Sensor, also known as the Arduino KY -033 Hunting sensor. The module consists of an infrared light transmitter and receiver as well as a potentiometer to adjust the detection distance.

It also has a small red LED that lights up when an object is detected. It does so as an indicator of the reflection of the transmitted IR light, because human vision is limited to the visible light band of the electromagnetic spectrum and thus can't detect or see the IR light being transmitted reflected back and received.

How far the detected object is will depend on the detection distance set by the potentiometer, where it ranges from 2-40cm. it has 3 pins, one for ground (G), one for the required 5V power supply (V+) (the middle pin) and the last one for the output signal (S).

Its specifications include a working voltage that can range between 3.3V-5V, 5V being the ideal, also a working current that is less than or equal to 20mA, 18mA-20mA being the ideal range corresponding to a 5V power supply. The range of the operating temperature is -10˚C - +50˚C and its dimensions are 28mm×33mm.

This IR module was employed in this project because it complies with the requirements of the project, which is the need of an IR transmitter and a receiver as well as an appropriate size.

3.2.3 Neo-6MV2 GPS Module:

Figure 3.3: Neo-6M GPS Module

A neo-6M GPS (global positioning system) is a GPS module that designed for location positioning even in the most challenging environments and it'suses an IC designed for this purpose which is takes the same of this name but the module helps us to make the connection with the main microcontroller easier.

Its specifications include a working voltage that can range between 3.3V-5V, 5V being the ideal, also a working current that is less than or equal to 20mA, 18mA-20mA being the ideal range corresponding to a 5V power supply.

The range of the operating temperature is -40˚C - +85˚C and its dimensions are16 x 12.2 x 2.4 mm.

This GPS module was employed in this project according to its ability in exactly locating the not working car place even in the hard conditions.

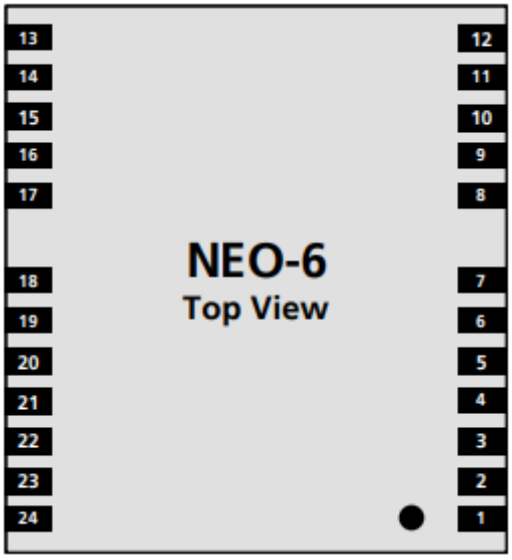


Figure3.4: NEO-6 Top View

Table3.2: PIN Definition for the IC of Neo-6MV2 module.

PIN	Name	I/O	Description
1	Reserved	I	Reserved
2	SS_N	I	SPI slave select
3	TIMEPULSE	O	Timepulse
4	EXTINT0	I	External interrupt PIN
5	USB_DM	I/O	USB data
6	USB_DP	I/O	USB data
7	VDDUSB	I	USB supply
8	RESERVED		See hardware integration manual PIN8 & 9 must be connected together
9	VCC_RF	O	O/P Voltage RF section
10	GND	I	Ground

11	RF_IN	I	GPS signal input
12	GND	I	Ground
13	GND	I	Ground
14	MOSI/CFG_COM0	O/I	SPI MOSI/configuration PIN
15	MISO/CFG_COM1	I	SPI MOSI/configuration PIN
16	CFG_GPS0/SCK	I	Power mode configuration
17	RESERVED	I	Reserved
18	SDA2	I/O	DDC Data
19	SCL2	I/O	DDC clock
20	TxD1	O	Serial port 1
21	RxD1	I	Serial port 1
22	V_BCKP	I	Backup voltage supply
23	VCC	I	Supply voltage
24	GND	I	Ground

3.2.4 GSM GPRS A6 Module:

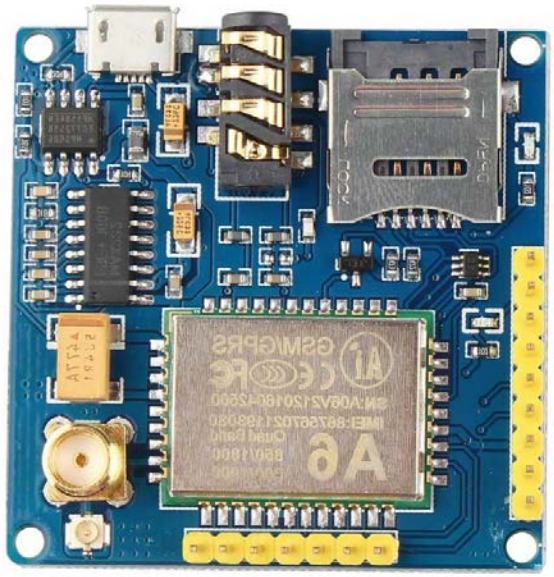


Figure3.5: A6 GSM module

It is a module designed to be compatible while using with the arduino board to activate a valid SIM card by it, to make calls or send messages or even receive calls like a normal phone while there are a microphone and speaker connected to it.

Its specifications are :

Supply voltage from 3.3 to 4.4V and the typical is 4V.

Operating temperature from -30C˚ to +80C˚.

Dimensions 22.8x16.8x2.5mm.

SIM application tool package.

This GSM module employed in this project in order to send message when the BAC is more than the legal limits, it’s sends the location of the car which located by the GPS module.

3.2.5 LEDs:

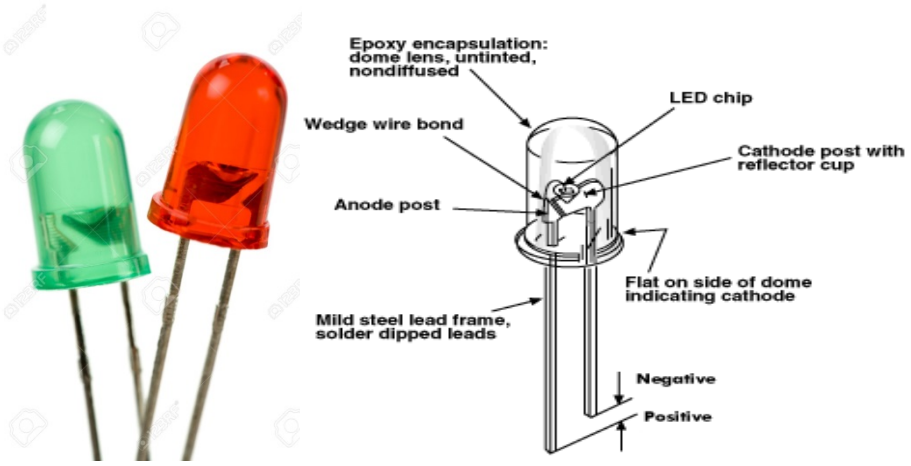


Figure 3.6: LEDs

LED stands for 'Light Emitting Diode'. A LED is a light source has 2 pins one is cathode and the other one is anode. The anode is the longer pin and the cathode is the shorter. Each LED can display one color according to the input signal; it's programmable to display light as needed in the experiment.

Its specifications include a forward current of If=20mA for the anode as well as a reverse current of 10µA again for the anode, while forward voltage of Vf=2.5V ±0.1V as a tolerance for the anode. Moreover it has an operating temperature of -25˚C to 85˚C.

The LEDs was employed in this project as a display unit, to output different colors under different circumstances.

3.2.6 Limiting Resistor

Figure 3.7: Limiting Resistor

In this project a 220 Ohms, 5% tolerance resistor was employed to the LED from burning out and acts as a limiting resistor.

3.3 Block Diagram

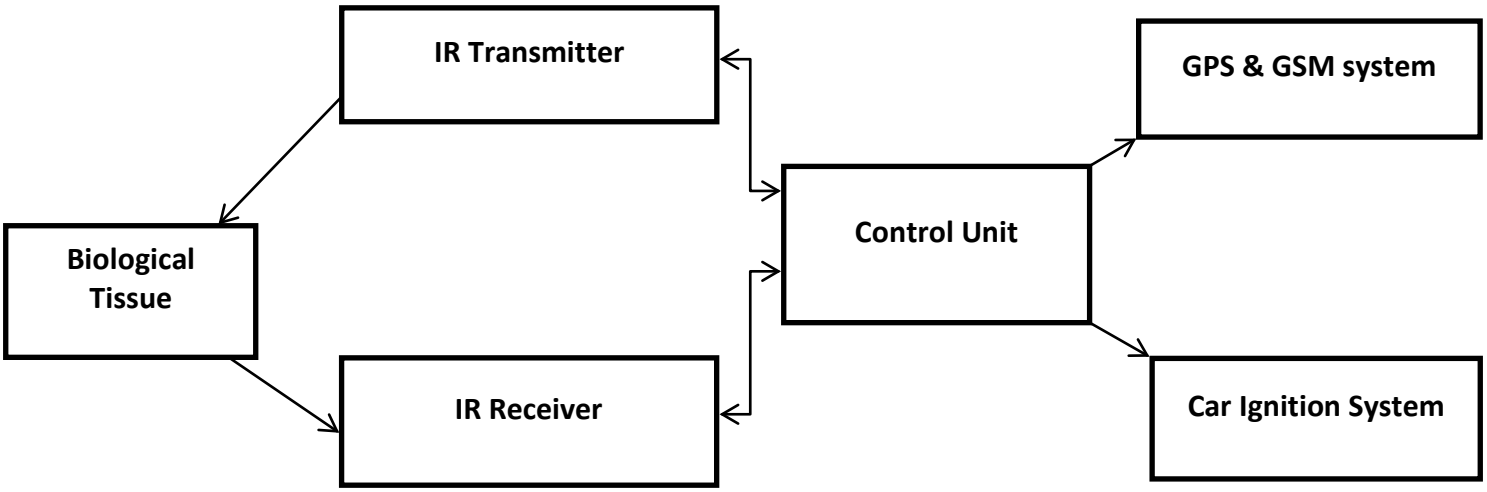


Figure 3.8: Block Diagram representing the Touch-Based BAC sensor

3.3.1 Biological Tissue

The Biological tissue here represents the skin on the tip of a finger. It is placed on the sensor for detection, to check if the biological tissue is ethanol-free or not.

3.3.2 IR Transmitter

The IR transmitter is the source of the infrared light such that it transmits a beam of IR to the biological tissue, for it to interact with the tissue.

3.3.3 IR Receiver

Ethanol molecules in general interact with IR by absorbing it. This project operates on the reflectance method, which means it detects the reflected IR beam from the biological tissue, which is in turn detected by the IR receiver. The more the absorbance by the ethanol molecules, the less the reflected IR beam.

3.3.4 Control Unit

The control unit is the brain of the sensor. It is used to decide whether the car is allowed to start up or not according to reflected IR beam intensity, which in turn depends on the BAC level. It also provides the power supply to the different components of the sensor and controls the display and car ignition system.

3.3.5 GPS & GSM System

This system is to locate the car position when the car was not allowed to start up its ignition system then sends the location to the desirable company or person to control this situation.

3.3.6Car Ignition System

This block is used to represent the car ignition system. Based on the commands from the control unit, it either starts up or not, which in turn determine the startup of the car engine.

3.4 Operational Block Diagram

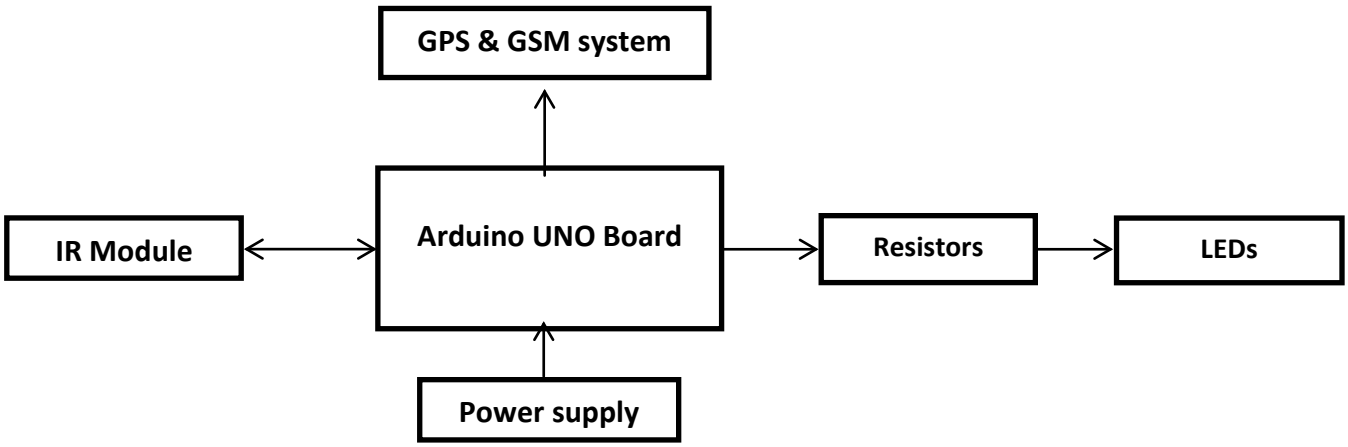


Figure 3.9: Block Diagram representing the Circuit Implementation

3.5 Experimental Circuit

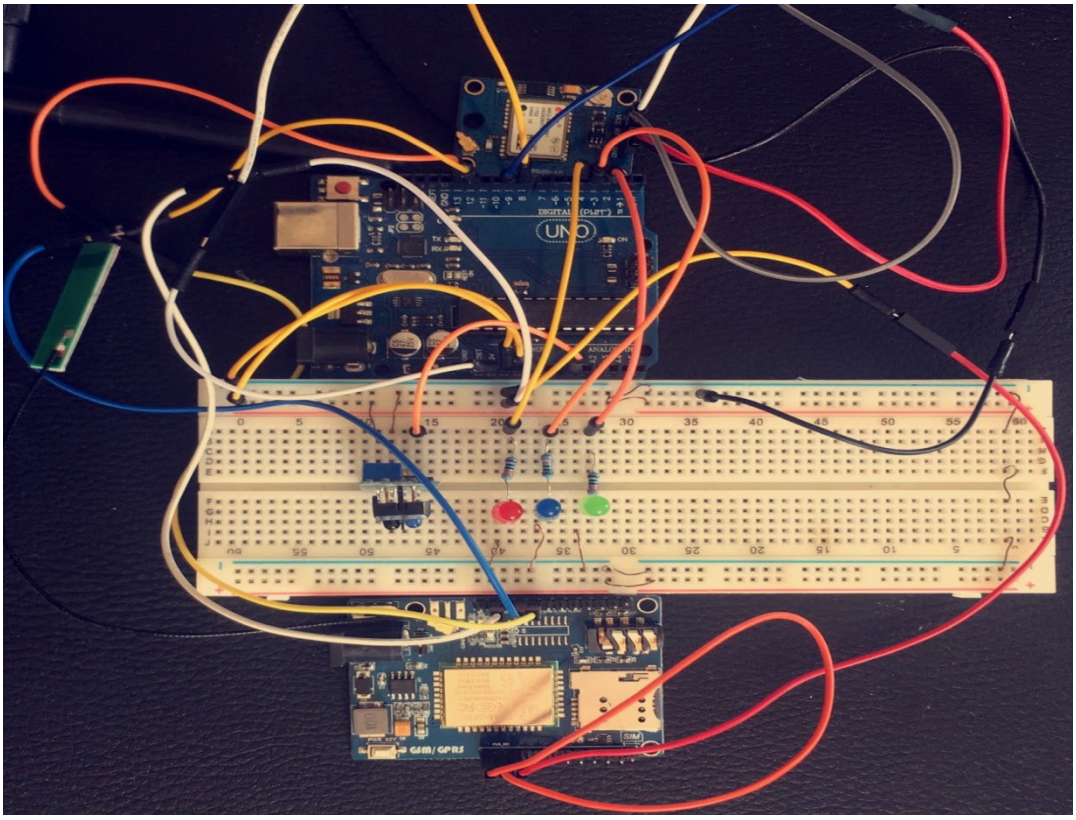


Figure3.10: Experimental Circuit

3.6 Procedure

The project is a touch-based BAC sensor that sense if the person is intoxicated (BAC>0.06%) or not and at the same time inhibits the ignition of the car engine in case of intoxication and vice versa. The implementation of the sensor's block diagram is shown in the experiment circuit above, where the biological tissue is the tip of a person's finger (skin), the IR Transmitter and Receiver are mounted on a complete IR module. The control unit used is the Arduino UNO microcontroller, while the results display consists of two parts, an LED and an LCD.

At first, the device is calibrated to ensure that difference skin thickness, skin type, skin colour (melanin) and other chromophores will not affect the detection process. This was done by asking 16 people to place their fingers onto the sensor in order to obtain the lowest possible reflected intensity, upon which a threshold value was chosen. The threshold value is a value just below the lowest possible reflectance obtained. The 16 subjects chosen were of different gender, age, diverse skin colour, thickness and type in order to select a suitable threshold that could be used universally. If the reflected intensity was below the threshold, this indicates the presence of a foreign parameter that absorbed more IR radiation, hence the presence of ethanol molecules. And since the IR module used is of a broad bandwidth rather than the specific 1.25 to 2.5μm, the calibration ensured that any factors (such as skin colour, type, thickness, biological chromophores) that could absorb and attenuate the IR radiation and reduce the reflected intensity are eliminated, thus any further reduction in the reflected intensity corresponds to the presence of ethanol molecules. Furthermore the IR module detection distance is set to the minimum value of 2cm by turning the potentiometer knob. This is done as to perform the measurement from close range proximity, as to increase the accuracy and obtain a direct contact touch based sensor.

Next a subject is asked to place his/her finger on the sensor. The expected results are as follows:

1. At the first when we running the program, the blue LED will turn on which means the device is ready to be used and the person which examine the device must put his finger on the sensor. After a short period the green LED turns on which means there is no alcohol detected.
2. Because it’s not possible to come for the University drunk so instead of that we will make the same person (as part’1’) dip his/her finger into ethanol samples of different concentrations and quickly place it on the sensor again, since ethanol is extremely volatile. This time, the opposite is expected. After a short delay the red LED will be turns on showing the presence of alcohol (or in genuine situations that the person is intoxicated). The GSM will send a message contains the location of the person with the sentence “The guy in this location cannot drive right now please give him some help”.

3.6.1 Phase 1: Simulation

A simulation of the circuit was carried out on the TinkerCard.com website before the actual hardware was implemented. Errors that seemed to make the simulation fail to run were fixed. This ensured that the actual components used were suitable for the project and were protected from being damaged. This input stimulus provided representing the presence or lack of alcohol was a simple logic 0 or 1. Zero represented lack of ethanol while 1 represented presence of ethanol. Simulation carried out was used to observe the output in the LEDs with different colours.

3.6.2 Phase 2: Breadboard Test

In this phase the components were bought and connected on the breadboard. The same simulation carried out on the tinkercard was carried out here except the biological tissue replaced the input stimulus that was logic 0 and 1.

3.6.3 Phase 3: Testing & Evaluation

Lastly, once the breadboard circuit was completed, the hardware was tested. Calibration took place to obtain the threshold value and a few changes and alternations were carried out in the software.

CHAPTER 4

RESULTS

4.1 Introduction

This chapter presents the results obtained after testing the touch based BAC sensor on the Chosen subjects.

4.2 Results:

4.2.1 Subjects Selected

Table 4.1: The individual traits of the tested subjects.

Subject	Gender	Age	Skin colour
1	Male	19	Chestnut
2	Male	21	Almond
3	Male	22	Sand
4	Male	20	Honey
5	Male	23	Almond
6	Male	18	Chestnut
7	Male	23	Porcelain
8	Male	24	Espresso
9	Female	17	Natural
10	Female	19	Espresso
11	Female	21	Ivory
12	Female	22	Porcelain
13	Female	22	Golden
14	Female	23	Almond
15	Female	24	Warm Ivory
16	Female	28	Chestnut

(see Appendix '3')

4.2.2 Results Based on Subject "8":

Table 4.2: The test results of the experimental as carried out on subject "8".

Alcohol percent used in (%)	LED state after detection	LCD Message
0	Green	ON
1	Green	ON
2	Red	OFF
3	Red	OFF

5	Red	OFF
10	Red	OFF
15	Red	OFF
20	Red	OFF
25	Red	OFF
30	Red	OFF
40	Red	OFF
45	Red	OFF
50	Red	OFF
55	Red	OFF
65	Red	OFF
75	Red	OFF
80	Red	OFF
85	Red	OFF
90	Red	OFF
100	Red	OFF

CHAPTER 5

DISCUSSION, CONCLUSION& RECOMMENDATIONS

5.1 Introduction

This chapter discuss the results obtained from testing the touch based BAC sensor as displayed in the previous chapter. It also continues to conclude the project and provide recommendations for futuristic purposes.

5.2 Discussion

With reference to table 4.1, 16 subjects were selected, 8 of which were males and 8 females. Subjects selected were of an age group of 17-28 years and had a variety of skin colours, skin types and thickness, hence a diverse group of individuals. The sample size of 16 subjects was selected for this project because it was sufficient and provided ease of evaluating each and every one of them within a time given. A diverse group of people was chosen in order to be able to apply this device universally.

With reference to table 4.2, subject “8” who is a 24-year-old male with skin colour “espresso” was tested. The entire table of results is based subject “8”. Multiple tests were carried out for the same subject to get a fair test using different concentrations of sensor. Subject 8 was selected because of multiple reasons:

1. Firstly, the subject had the darkest skin colour of the 8 males,
2. Secondly and most important, subject “8” had the lowest reflected intensity of the IR beam, amongst the 16 subjects. Hence the threshold value acquired at the calibration was derived from results obtained from subject 8’s test and evaluation phase.

5.3 Recommendations

For future references to anyone who wishes to apply this concept, it is highly recommended to:

1. Use as many diverse test subjects as possible and a larger sample size.
2. Expand the age group of the test subjects.

3. This project is based on TRNC where alcohol consumption in general is prohibited if the BAC was above 0.06%, it is recommended to exploit an IR bandwidth of the range of 1.25µm to 2.5µm as to be able to accurately detect the BAC level.
4. Place the touch based BAC sensor in locations other than the push to start button, such as the steering wheel or gear shift. So that periodic measurements would take place at given time intervals to ensure that no alcohol is consumed whilst driving.

CHAPTER 6

CONCLUSION

According to the results, when subject 8's finger was dipped in alcohol concentration of 2% and above, the sensor detected the presence of alcohol and inhibited the ignition system. It

did so successfully based on the non-invasive method of tissue spectroscopy; hence no sample was required, and the detection is simply based on the touch of a finger.

When the sensor detected the presence of alcohol it turned the red LED, displayed the message “Ethanol Present Engine OFF!” on the LCD so inhibited the car ignition system.

On the other hand, when the alcohol concentration was less than 2% (0% and 1%), the green LED turned, the LCD displayed “No Ethanol Engine ON!”. This indicates that the sensor has the ability to sense ethanol concentration as low as 2% on the surface of the skin.

6.1 Future Work

1. May the addition of a database system that also connected to the GPS module will be better; it will have a database deciding the alcohol limits according to the car’s location to make the device be globally.

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APPENDICES

Appendix ‘1’:

Figure 7.1: Volume of different alcohols equivalent to a Standard Drink according to the NIAAA

Appendix '2':

Table 7.1: displaying the effect of different BAC levels on a subjects' behaviour and the resulting impartment.

Progressive Effects Of Alcohol		
BAC (% by vol)	**Behaviour**	**Impairment**
0.001-0.029	• Average individuals appears normal	• Subtle effects that can be detects with special tests
0.03-0.059	• Mild euphoria • Relaxation • Joyousness • Talkativeness • Decreased inhibition	• Concentration
0.06-0.099	• Blunted feelings • Reduced sensitivity to pain • Euphoria • Disinhibition • Extroversion	• Reasoning • Depth perception • Peripheral vision • Glare recovery
0.1-0.199	• Over-expression • Boisterousness • Possibility of nausea and vomiting	• Reflexes • Reaction time • Gross motor control • Staggering • Slurred speech • Erectile dysfunction
0.2-0.299	• Nausea • Vomiting • Emotional swings • Anger or sadness • Partial loss of understanding • Impaired sensations • Decreased libido • Possibility of stupor	• Severe motor impairment • Loss of consciousness • Memory blackout
	• Stupor • CNS depression	• Bladder function • Breathing

0.3-0.399	• Loss of understanding • Lapses in and out of consciousness • Low possibility of death	• Disequilibrium • Heart rate
0.40-0.50	• Several CNS depression • Coma • Possibility of death	• Breathing • Heart rate • Positional alcohol nystagmus
>0.50	• High risk of poisoning • High possibility of death	• Life

Table 7. 2: Displaying the effect of different BAC levels on a subject with respect to the driving impairment.

BAC	**Typical Effects**	**Predictable Effects on Driving**
.02% About 2 alcoholic drinks	• Some loss of judgment • Relaxation • Slight body warmth • Altered mood	• Decline in visual functions (rapid tracking of a moving target) • Decline in ability to perform two tasks at the same time (divided attention)
.05% About 3 alcoholic drinks	• Exaggerated behavior • May have loss of small-muscle control (e.g., focusing your eyes) • Impaired judgment • Usually good feeling • Lowered alertness • Release of inhibition	• Reduced coordination • Reduced ability to track moving objects • Difficulty steering • Reduced response to emergency driving situations
.08% About 4 alcoholic drinks	• Muscle coordination becomes poor (e.g., balance, speech, vision, reaction time, and hearing) • Harder to detect danger • Judgment, self-control, reasoning, and memory are impaired	• Concentration • Short-term memory loss • Speed control • Reduced information processing capability (e.g., signal detection, visual search) • Impaired perception

.10% About 5 alcoholic drinks	• Clear deterioration of reaction time and control • Slurred speech, poor coordination, and slowed thinking	• Reduced ability to maintain lane position and brake appropriately
.15% About 7 alcoholic drinks	• Far less muscle control than normal • Vomiting may occur (unless this level is reached slowly or a person has developed a tolerance for alcohol) • Major loss of balance	• Substantial impairment in vehicle control, attention to driving task, and in necessary visual and auditory information processing

Appendix ‘3’

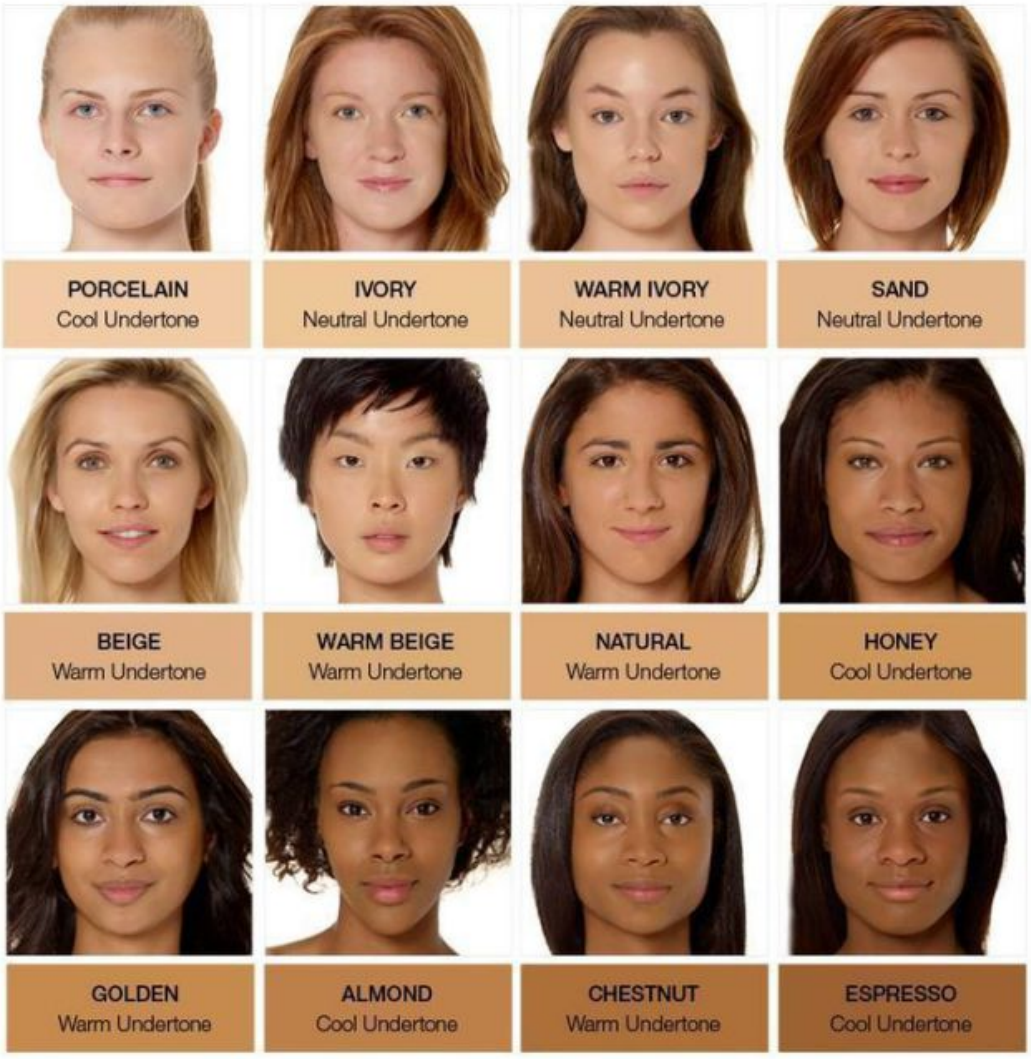

Figure 7.2: Displaying the colour Chart against which the subjects selected for testing had their skin colour evaluated.