ASHESI UNIVERSITY

CAPSTONE FINAL REPORT

APPLIED PROJECT

B.Sc. Electrical and Electronic Engineering

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ASHESI UNIVERSITY

A SMART BREATHALYZER SYSTEM FOR GHANA

APPLIED

CAPSTONE PROJECT

DECLARATION

I at this moment declare that this capstone is the result of my original work and that no part of it has been presented for another degree in this university or elsewhere.

Candidate's Signature:

……… ………………………………………………………………………………

Candidate's Name:

………ADWOA ASANTEWAA BREMANG ………………………………

Date:

……………23rd April 2019 …………………………………………………………………

I hereby declare that the preparation and presentation of this capstone were supervised in accordance with the guidelines on supervision of capstone laid down by Ashesi University College.

Supervisor's Signature:

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Supervisor's Name:

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Date:……………………………………………………………………………………………

DEDICATION

I dedicate the paper to God Almighty and my beautiful Family for their support and love.

ACKNOWLEDGMENT

I want to acknowledge Mr. Francis Gasti for his support and feedback on the project. I am also grateful for the assistance Mr. Nicholas Tali provided in designing and printing of my PCD board for the breathalyzer.

I will also like to acknowledge these beautiful people Christopher Anamalia and Barnabas Nomo their time and assisting in the creation the web application.

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ABSTRACT

Imagine a five-year-old boy losing his life by being knocked down by a drunk driver who has been intoxicated with alcohol. The driver's carelessness will cause the family of the little child so much pain, as well as lead to a significant loss of human resources in the country. Road accident according to research has been the second leading cause of death in Ghana. While several countries in the world invest in finding solutions to road accidents [1], little is done by the country to tackle the issue.

This capstone project seeks to help reduce or eliminate road accidents by tackling drunk driving, which is one of the preventable causes of a road accident. The paper focuses on reducing the influence of human activities such as corruption in the enforcement drunk driving laws, by developing a breathalyzer system that leverages on digitization, by incorporating a fingerprint sensor for user authentication, a web server which acts as a repository for all alcohol tests and check number of times users violate drunk driving laws.

The paper discusses extensive research and implemented work to design a smart breathalyzer system that incorporates the internet of things to tackle the issue of road accidents. The paper explores the use of a fuel cell sensor for alcohol detection, fingerprint sensor for configuration of user authentication. It describes how the GPS model provided various test locations, and the procedure the microcontroller communicated to the database through the GSM module. The paper describes a remote database for the Ghanaian police system which serves as a repository for drunk driving law violations and road accidents management. The paper concludes on the complexity of configuring the alcohol fuel cell sensor, since the fuel cell sensor performs accurate measurement of user breath concentration. The paper also

concludes on the importance of internet of things which combines web development and basic electronics in tackling the problem of drunk driving free from the influence of corruption.

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ABBREVIATIONS

API – Application protocol interface

GSM- Global System for Mobile communication

GPS - Global Position System

BAC - Blood to alcohol concentration

CHAPTER 1: Introduction/Background

1.1 Introduction

The human resources of the country Ghana are threatened continuously by Road accidents, the second largest cause of death in the country [1]. Accidents that could be easily prevented are very devastating when they do occur. An example of these accidents are those caused by drunk driving.

The capstone project aims to tackle drunk driving with the use of the Internet of Things. Internet of things (IOT) is an emerging field of technology that over time will completely bridge the gap between objects and human communication. In basic terms, IOT is created from merging integrated Circuit and programming. The existence of IOT has helped simplify a various complex problem and improved and ineffective solutions to problems and has been implemented in various fields of life such as security, healthcare, education and many more [2].

The project aims to design a smart breathalyzer that can combat drunk driving and fit into the context of Ghana. Unlike the conventional breathalyzer which performs only breath test, the project seeks to develop a breathalyzer system that reduce human tempering with enforcing drunk driving laws, by validating the identification of the driver while transmitting the breath data to a central database that can be queried.

Bribery and corruption are major menaces in Ghana. It causes stagnation in the country's development [3]. Therefore, the project aims to ensure effective enforcement of drunk driving regulations as well as preventing police dishonesty. The project takes advantage of the digitization system in Ghana by creating a breathalyzer which adds a fingerprint sensor for user authentication through driver's data from their driving licenses saved by the driver and Vehicle licenses Authority (VLA).

1.2 Background

A breathalyzer is a device that detects the equivalence of a person's blood to alcohol concentration (BAC) within the breath of the person.

Over the years the breathalyzer system has been known as an efficient electronic way of detecting drunk driving which is a cause of road traffic accident. Robert Frank Borkenstein invented the breathalyzer fully recognized as the breath analyzer in the year 1954 [4].

Owing to the fast advancement in technology, the development of the breathalyzer has evolved over the years. Latest inventions focus on ways of making the system smarter, robust and to help reduce road traffic accidents caused by drunk driving drastically.

There have been extensive research and designs on breathalyzer systems. An example is a breathalyzer system that has been coupled with the car ignition system, making it mandatory for drivers to take the test before starting the car. Other designs include wireless communication designed with microcontroller, Global Position System (GPS), Global System for Mobile communication (GSM) module and the alcohol detection sensor to improve the robustness of the system [5], [6]. Moreover, certain countries like the United States, have made it mandatory for drunk driving offenders to install the breathalyzer system in the ignition of their cars [5].

These research and innovation of the breathalyzer in other countries motivated the design of the breathalyzer system customized for Ghana and Africa as a whole. The reason is that the public sector of Ghana is highly bureaucratic and filled with corruption. Corruption is known to be prevalent in the police sector, public sector, among others [3]. Therefore, implementing these projects from well-structured countries will be ineffective. However, Ghana has adopted a digitized way of living, which is reducing the influence of human in various sectors of the country. Hence leveraging on digitization, for user authentication, the problem of drink driving can be tackled effectively with little or no corruption, bureaucracy, favoritism and the unestablished laws.

1.3 Problem Definition.

Road accidents contributed to the excess reduction in human resources, by claiming the lives of many in the country. Research conducted from 2004 to 2013 showed that road accident was the second highest cause of death in Ghana [1]. The primary victims of these accidents ranking from the most affected to the least were pedestrians, commercial passenger, motorist, drivers, cyclist, pillion riders (passengers of bike riders), and bystanders [7]. Moreover, there has been a relative increase in the number of road traffic accident cases over the years, a twelve-year study from the year 1991 to 2012, observed the rise [1]. Research conducted shows various known causes of road accidents categorized into different forms as human causes, vehicle defects, and road different road and environmental occurrences [8]. However, the information provided for road accidents had no statistical records on the various causes of road accidents such as drunk driving, tired drivers, faulty vehicles and many more. Damsere-Derry, Ackaah, and Agyemeng explained in their article that developing countries invested less in ensuring road safety and managing their issues [9].

1.3.1 Problem statement

From the summary of the research finding on road accidents, the problem is that damages caused by road traffic accidents specifically accidents caused by drunk driving (preventable accidents) on human resources are due to poor enforcement of laws on road safety. Moreover, not enough research is conducted on various causes of road accidents in Ghana due to poor record keeping and lack of technology-driven means of ensuring safety and compliance of road safety rules. Therefore, road safety commission is unable to tackle the multiple causes of road accidents.

1.4 Objectives of the Project Work

The objective of the applied capstone project is to design a smart breathalyzer which measures and transmits the alcohol level of the driver to a repository to track drunk driving. The tracking exercise is intended to enforce compliance and safety on the road to save lives while data collected will help in researching the contributions of drunk driving to road accidents.

1.5 Expected Outcomes of the Project Work

1. A significant expectation is to develop a device that reads accurate Blood to alcohol concentration for each test conducted as well as perform alcohol content analysis.
2. Also, the system needs to collect adequate data on the number of drunk drivers to be able to perform a statistical analysis of the various causes of drunk driving.

1.6 Justification/Motivation for Project Topic

The motivation for the project was to use the ideas and concept learned in class, together with other skills hoped to be acquired, to save that a person's life, from being cut short by careless drunk drivers.

1.7 Research Methodology to Be Used

The research method used will be:

1. Experiments: experiments will be conducted to test the efficiency of individual components of the breathalyzer system as well as the holistic functionality of the breath analyzer.
2. Prototyping and testing: a prototype of the breathalyzer will be developed and tested with various alcohol concentration to test its efficiency.

1.8 Facilities/Materials to Be Used for Design and Implementation

Facilities

- Mechanical workshop
- Fabrication Lab

Materials

- A microcontroller
- Lcd screen
- fuel sensor
- Basic electronics (resistors, capacitors)
- GPS
- GSM or wireless communication module

- Software (MEAN (MongoDB, angular, express and node.js) stack, C++, AutoCAD eagle)

Tools

- 3D printers
- Soldering iron

1.9 Scope of Work

The project is a yearlong project, which involves the following deliverables:

1. Development of a prototype of highly efficient breathalyzer which is good enough for adoption by the Ghana Police Service.
2. The system should be able to communicate wirelessly with various police units or stations and have a unique identification code.
3. Also, the system should be applicable in areas where alcohol level of workers is monitored, such as the mining industry.

Chapter 2: Literature Review

2.1 Introduction

Road accidents have been one of the significant causes of death in Ghana. From the year 2002 to 2008, 13166 deaths were recorded [1]. It is believed that the death rate will increase due to government neglect to research into the latest developments that will help curb the problem [1].

The capstone project focuses on tackling drunk driving, a cause of road accident mortality. Breathalyzers have been the closest invention in reducing the accidents caused as a result of drunk driving over the years since 1954 [4]. Efficient utilization of a breathalyzer is equally essential as the functionality of the product. Therefore, developing a smart breathalyzer system will help ensure safety compliance to drunk driving laws by identifying and sanctioning violators of the law, with no influence of corruption and politics it will also help build a data repository for research into drunk driving in Ghana.

2.2 Body

James, Francis, and William in their article shared their findings on a research activity they conducted in the northern part of Ghana to acquire data on drivers under the influence of alcohol. The journal highlighted a significant problem, which was; lack of resources in collecting statistical data on causes of accidents and various ways they could be prevented in Ghana [9]. The focus on the article motivated the design of a breathalyzer system that will keep records of data from tests as well as the various locations the tests were conducted serving. The data collected will serve as a repository of drunk driving violators and related issues concerning road accidents.

A significant feature of the breathalyzer is the alcohol sensor. There have been many developments of alcohol sensors, which consists of the fuel cell sensor, the semiconductor sensor, and an infrared alcohol sensor. Moreover, the review focuses on the fuel and the semiconductor alcohol sensors since they are readily accessible and because of their portability.

The fuel cell sensor for alcohol detection is designed to detect various alcohol concentration. The output of the sensor is a relation between the alcohol concentration injected into the device and the current produced by the device due to the amount of alcohol ingested by the device. Laura [10] in her thesis paper provided extensive research on the fuel sensor. In her article, she highlighted the various categories of fuel cell sensors.

Fuel sensors designed to detect alcohol are categorized in Proton electron Membrane fuel cell (PEMFC).

PEMFCs consists of two electrodes (the anode and the cathode), separated by a hydrogen permeable electrolyte which is electricity resistant. The electrode acts as a catalyst which separates the protons from electrons of the alcohol injected into the system. Equation 1 explains the chemical separation [10].

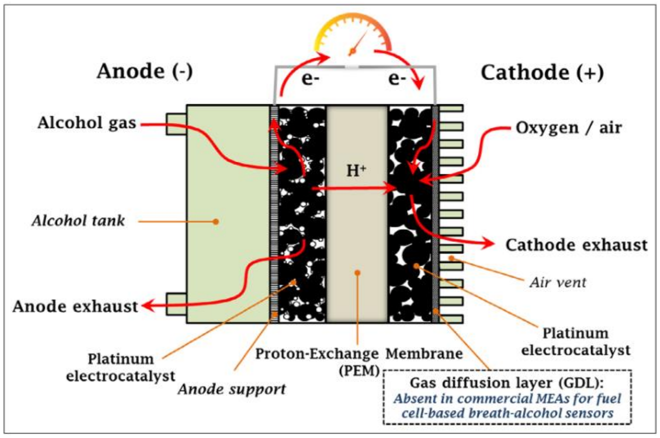

Figure 1: a schematic of the operation of a PEM fuel cell sensor [21]

$$CH_3CH_2OH + H20 \rightarrow CH_3COOH + 4H^+ + 4e^- - - - - - - - - - - - - equation(1)$$

The protons (hydrogen atoms) are transported from the anode to the cathode through the electrolyte, whiles the electrons move through an external circuitry to the cathode. At the cathode, the protons undergo a chemical reaction with oxygen, to form water as shown in equation 2.

$$O_2 + 4e^- + 4H^+ \rightarrow 2H_2O - - - - - - - - -equation(2)$$

An exciting feature of the fuel cell is that it is not powered since the duty of a fuel cell sensor is to transform a chemical into electricity; hence it undergoes electrochemical processes[10].

On the other hand, the semiconductor circuit uses a tin oxide substance to ionize alcohol [11]. These sensors work effectively when there is no presence of volatile substances in the breath of the user. The semiconductor is very sensitive and is designed to determine other gases such as the CH4, LPG, and H2 [12].

The unique feature of the fuel cell sensor to detect alcohol gives it a higher advantage over the semiconductor cell. Also, unlike the fuel cell, the semiconductor sensor needs constant calibration. These benefits of the fuel cell sensor qualify it as the required sensor for the breathalyzer.

Abdul Rahim and Hassan, researchers from the University of Malaysia, developed a breathalyzer system designed to fuse with the ignition system of a car. The motivation for the design was to help the Malaysian government enforce their laws on drunk driving, technically known as driving while intoxicated (DWI) [5]. The system used the semiconductor alcohol detection sensor (MQ-135) to read the blood to alcohol concentration (BAC) of the users [5]. The data read by the sensor was processed using a microcontroller which directly controlled a switch which turns on and off the ignition system based on the response.

Data stored on the device was a significant gap in the product. This system was designed in an effective way of preventing accidents caused by drunk driving. However, the stored data obtained on the device was a very inefficient method of collecting data. This problem is because the system has a high probability of losing data anytime it is misplaced or damaged. However, our system design will read data in real time and store it in a database that could be retrieved remotely.

Similar to Abdul Rahim and Hassan, Baba-Maza and Sanchez-Lopez designed a breathalyzer system that ensured the compliance with the law of driving.

Barba-Maza and Sánchez-López designed a breathalyzer incorporated into the ignition to a car. The design ensures that the driver is unable to start their vehicles while intoxicated. When the sensor detects high intoxication in the vehicle, it stops or disconnects the ignition system of the car, preventing the vehicle from starting. After, a text message is sent from the device to the security system of the vehicle [6]. The design by "Barba-Maza and Sánchez-López" is an excellent way to reduce the number of road accidents caused by drunk driving. However, implementing the system in Ghana will be a major challenge since it will be hard to identify the various car companies of car users in the country. In Ghana, most vehicles owned are used cars imported from outside the country by an individual or a group of people known as "car dealers." Therefore, implementing this system will be ineffective in Ghana.

Leveraging on compliance and user identification, Baba-Maza and Sanchez-Lopez in their design addressed two main critical points of the capstone project. The design for the capstone project takes advantage of the digitization policy being implemented in the country, where corruption is a significant issue. Therefore user identification and compliance to laws are challenging because individuals can easily bribe their way out. On the brighter side, digitization reduces the corruption rate in Ghana [13]. In user registration to systems such as national health insurance, passport system and drivers' licenses, essential details such as fingerprints and eye colour and many more are recorded. The adopted digitization approach by the country Ghana, fueled the birth of the idea to add a unique user identification system to the design of the breathalyzer.

Various companies have developed a reliable way of ensuring the appropriate use of devices to enhance the efficient use of a breathalyzer. A good example is in South Carolina, Spartanburg. In this part of the USA, breathalyzer kiosk has embedded biometrics fingerprint scanner to help store or monitor log in details of persons that use the device installed in rehabilitation centers. Victims charged with alcohol abuse are sent to these rehabilitation centers to help them recover from their addictions. These persons conduct an alcohol test before every meeting. The system also had a face recognition feature, that helps identify person taking the test. The importance of the fingerprint scanner designed by Watson mini was to ensure a useful counseling session, ease officers the duty of conducting the drunk analysis and create a reliable form of data storage as well as help identify the recovery status of victims [14].

The fingerprint feature is an efficient user identification system for the product since it forms a crucial part of digitization in Ghana. However, implementing the face recognition in the breathalyzer system will be ineffective because, in Ghana, the internet service is not very reliable; therefore it will be very costly transferring extensive amounts of data such as information from facial recognition. Also, the data being transferred will require a larger processing space and RAM. Therefore, a larger and more expensive microcontroller like the Raspberry Pi will be needed, leading to an increase in the size of the system.

Identification of drunk drivers by the fingerprint will helps to track the various users. Fingerprint authentication will be the unique user identification component for developing the breathalyzer.

2.3 Conclusion

Finding and analyzing of journals and research paper provided education on the various technology developed in the breathalyzer system development. Also, the literature review helped explain the reasons for different designing a breath analyzer. The study influenced the project,that is developing a breathalyzer that detects alcohol with a fuel cell sensor, has a fingerprint sensor for user authentication and incorporates a digital system that records and creates a repository of alcohol violation cases. The review helped scope the project as well as helped identify realistic and abstract parts of the initial project scope.

Chapter 3: Design

3.1 Review of Existing Design

Section 2.2 and 1.2 provides clear examples of various conventional breathalyzer systems as well as multiple technologies used to innovate the breathalyzer system. The review designs in these sections are more reliable than the traditional breathalyzers used in Ghana, which are only for alcohol detection. These devices are efficient for data collection and enforcing drunk driving laws. However, the concepts behind these designs will be infective in Ghana due to excessive bureaucracy in the government and insufficient funds in the country.

The proposed design combines the technology of existing models that are; Global System for Mobile communication (GSM) for data sending, Global Position System (GPS) for location and a fingerprint scanner, that is a unique model not frequently found in most breathalyzer designs. The unique model will help create a robust system that ensures user identification.

3.2 Project Design

3.2.1 Project Description

The capstone projects birth-out of the internet of things. The project constitutes basic electronics embedded with code. The whole project consists of three main essential subprojects that come together to solve the problem and produce the product.

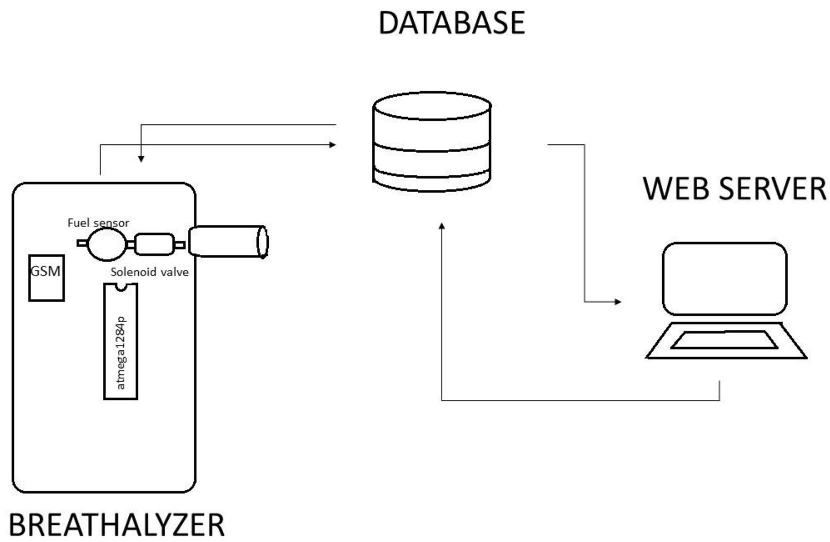

Figure 2: A block diagram of the breathalyzer system

3.2.1.1 Breathalyzer (The Physical Part):

The breathalyzer system is the physical hardware part of the project that tests the alcohol level of the user. This system is made up of a microcontroller (ATMEGA 1284p) which controls four primary sensors, which are; Global Position System (GPS), Global System for Mobile (GSM) module, fingerprint scanner, and fuel cell sensor with a solenoid valve. A liquid crystal display (LCD) displays information specific guidance and results on the device. The fuel cell sensor is the primary device that detects the alcohol level of the user.

How does the device work?

The user first scans his fingerprint on the Adafruit fingerprint sensor. The system then gives the user access to blow air into the inlet (in the form of a tube) of the breathalyzer. The solenoid valve connected to the tube pushes the blown air at a specific speed to the fuel cell sensor.

The fuel sensors provide a specific voltage due to the potential difference between the two electrodes as a result of charges produced by the concentration of alcohol in the air blown. The average ratio of the amount of alcohol in the blood to that of the breath is 2100:1[5]. The output current from the sensor is converted to a readable format by the microcontroller. The microcontroller also processes the input data from the GPS and the converted fuel sensor voltage and stores them in the database through the GSM. The Data from the fingerprint sensor compare with stored fingerprint data in the database to find any relation.

3.2.1.2 Communication:

The communication system involves developing an interface that ensures communication between the device and a police station which will be a web server accessed by authorized personnel. The focus of the communication layer is to create a database system that receives data from the physical layer through the GSM module and updates a web application interface for the police with information.

The database for the project uses MongoDB. MongoDB is a document database and not a relational database like that of MYSQL. MongoDB it eliminates the row and column structure of relational database and consists of documents. These documents define what a row is about and also contains the data in a role. Each document is group under a collection that is similar to tables in relational database. MongoDB helps with data modeling, that is specifying the type of data to store and the format in which the data will be stored. These models are created in a schema (the basic form for modeling)[21].

This part of the project focuses on the transfer of process sensor information to the database for either storage or comparison with already stored data. The GSM is the medium of transmission because it allows wireless communication between the microcontroller and the server for the database.

For the project, the database will have stored information of the biometric fingerprint of drivers from DVLA, as well the number of drunk and non-drunk drivers in the database for statistical references.

3.2.1.3 Police System Interface (Data Collection and Validation):

The section involves creating a backend and front-end interface for the police station to access information in the form of the web application. The backend will compare the fingerprint of proposed drunk drivers with the database of fingerprints of various drivers. The front end will help the review data of records for the day and help with statistical analysis.

The web application will provide the police with data of drunk drivers as well as the data of the ratio of drunk drivers to non-drunk drivers at various regions and cities in the country.

The MEAN stack will be used to build the web application. Mean stack is a full stack development structure where a single programmer studies both the front end and backend of creating an application. The platform used in the project will be node.js. Node.js, unlike PHP, is a software platform that allows one to run a server on the platform locally. Node.js has an in-built HTTP server library, therefore, allowing it run as a server without a separate web server like Apache. Node.js is a single threaded hence helps in the effective management of space and resources [21].

Express.js will act as the backend for the web application. Express.js is a backend web application framework for node.js. Express eases specific complex proceeds of node.js; it helps route various parts of the code, example creating a part for an HTML file in the web application, creating routes or path for an API (application program interface) which receives or send data from the database to the front end or HTML template of the web application.[21]

3.3 Design Decisions and Components for the Project

3.3.1 Component Selection

The Pugh matrix was a tool that helped with the selection of various specific components for the project. Pugh matrix is a tool that serves as a benchmark for the selection of components.

		Baseline	Weight	A	B	C
Criteria						
1	Cost		X			
2	Efficiency		Y			
3	Complexity		Z			
4	Weight		A			
Scores						

The criteria sections consist of vital elements in the project being implemented. For example weight, complexity and efficiency are the main deliverables of a person's project.

The Baseline represents the general component typically used to implement or solving the product. The example most breathalyzer projects are implemented with semiconductor alcohol sensors. The weight prioritizes the various criteria of the project or device. The right component is selected from the Pugh chart by adding the weights to the score given to each component under each criterion. The specified grading of the Pugh chart is between -5 to 5; therefore, the product quality depreciates in a standards as the value decreases and vice versa.

3.3.1.1 Pugh chart table of the various components

		Baseline	Weight	A	B	C
Criteria		(8051)		(ATMEGA1284p)	(ATMEGA328p)	(PIC18F25K50-I/SP)
1	Cost	0	3	0	-1 -3	-2 -6
2	Efficiency	0	5	+1 +5	0	0
3	Complexity	0	4	0 +4	1+ 4	0
4	Weight	0	3	0	1_+3	0
Scores				+5	+4	-6

Table3. 1: Microcontroller selection

		Baseline	Weight	A
Criteria		(mq-135)		Fuel sensor
1	Cost	0	3	-2 -6
2	Efficiency	0	5	+2 +10
3	Complexity	0	4	0
4	Weight	0	3	-1 -3
Score		0		+1

Table3. 2: Alcohol sensor selection

From the Pugh matrix in table 1, the ATMEGA1284p was the desired microcontroller for the project. It is easier to control since it can be boot loaded with the Arduino microcontroller hence preventing extra cost incurred in buying an embedded board specifically for programming it.

Table 2 selected the fuel sensor as the active sensor for the project. Fuel cell sensors accurately detect alcohol in the breath sample as compared to the semiconductor sensor which occasionally mistakes volatile organic compounds in the breath of a person as alcohol [11].

3.3.2 Components /Materials

3.3.2.1 ATMEGA1284p

ATMEGA1284p is a part of the AVR microcontrollers. The microcontroller will be programmed using the Arduino IDE. Arduino will serve as the in-system programmer (ISP) of the microcontroller[22].

3.3.2.2 Adafruit Fingerprint Sensor

The adafruit fingerprint sensor is an optical scanner. An optical scanner works by converting light incident on the photodiode into electric charges. The sensor has various features such as; the ability to store 162 prints. For the project, the sensor will detect and compare fingerprint data of drivers in the project [15].

3.3.2.3 Sim800l Development Board GSM GPRS Module:

SIM800L is a GSM module that has an input voltage of 5V and a maximum current of 2A. It helps devices communicate with the help of code. For the project, the GSM module will be used to send data from the microprocessor to the database [24].

3.3.2.4 I2c LCD:

The I2c LCD is a liquid crystal display with four pins out, unlike the conventional 16 pin LCD. It has a 16X2 screen [16].

3.3.2.5 CH_3CH_2OH (Alcohol) Fuel cell sensor

The fuel cell sensor for the project is a direct alcohol fuel cell sensor (DAFCs). The fuel cell sensor's task is to measure the blood to an alcohol concentration of the user. The sensor is made up of two platinum electrodes separated by an electrolyte. The electrode separates the electrons and protons from the ethanol found in alcohol. The protons are transported through the electrolyte to the other side of the sensor which contains oxygen. However, the electrons flow from one electrode to other producing electric charges which creates a current. The current generated is measured and helps one find the Blood to alcohol concentration in one's breath [10].

3.3.2.6 Neo-6.0.1 GPS Module:

The GPS module measures the latitude and longitude of a specific area. The sensor helps determine the location of the device by producing latitude and longitude data of the specific location the data was recorded [17].

3.3.2.7 Standard Voltage Sensor Module

The standard voltage sensor module is a device that measures the maximum voltage of 24 volts to equivalent analog values interpreted by the microcontroller [18].

3.4 Schematic Diagram Design

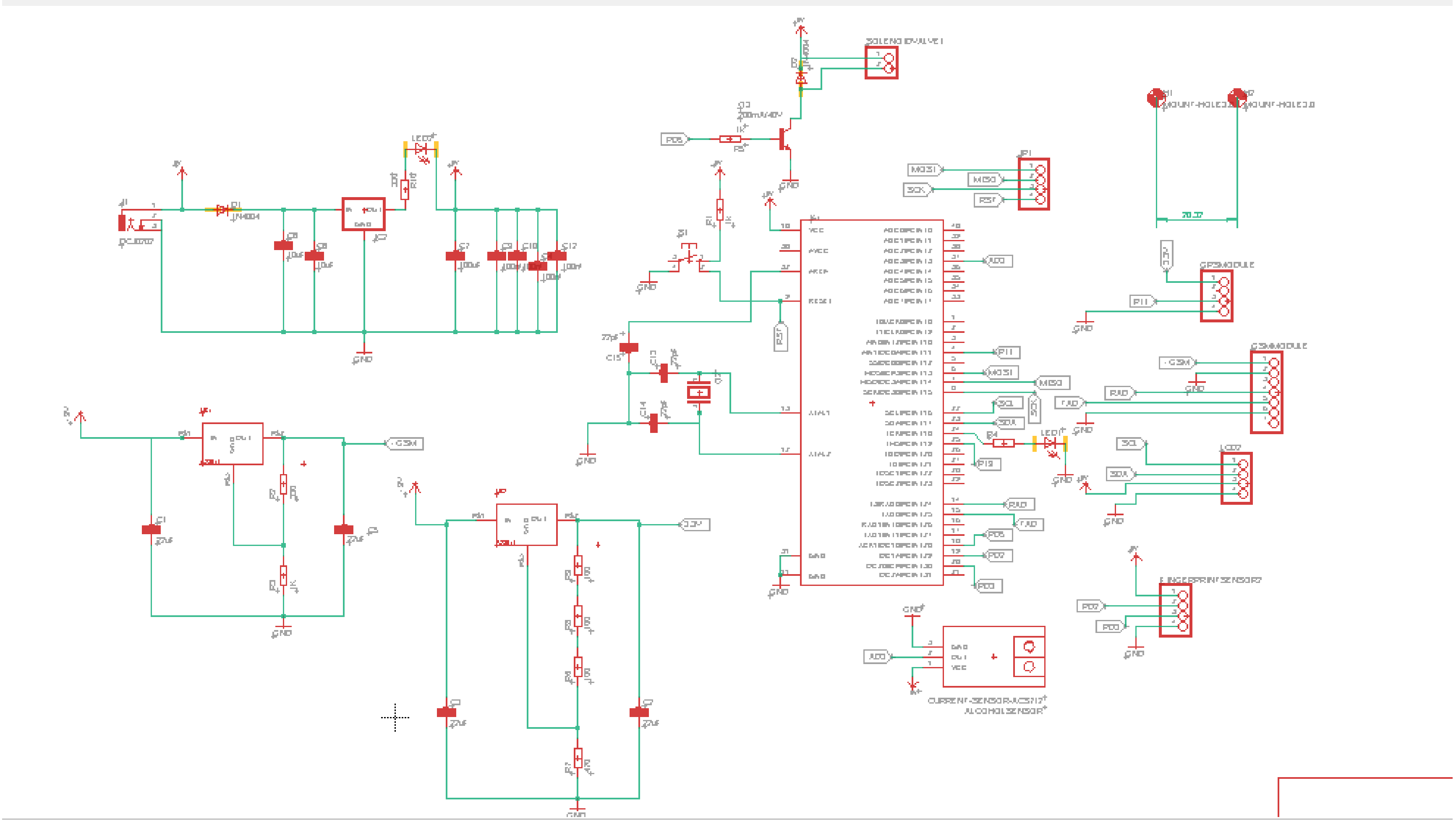

Figure 3: the schematics of the breathalyzer device

The Processor Circuitry Design

A circuitry was developed to help the ATMEGA1284p work independently of the Arduino microcontroller which acted as an ISP (In-System programmer) for the microprocessor.

A 16-clock crystal oscillator was connected to the ***xtal1*** and ***xtal2***, pins of the microcontroller. The crystal oscillator act as clocks of the microcontroller.

3.3.1 Sensor Connections to the Processor

3.3.1.1 Fuel cell sensor

In section 3.3.2.5 of the paper, the fuel sensor was described to produce an output current. Moreover, the output current produced by the sensor can be translated by the microprocessor through a voltage measuring sensor. Therefore a circuitry was created to convert the current produced by the sensor to an amplified voltage.

The output pin of the voltage measuring sensor was connected to an analog pin. The analog pin allows the microcontroller to read the variation in output voltage generated by the output current of the fuel sensor. The circuit designed used an operational amplifier (lm741) to translate the low current produced by the fuel cell sensor to an equivalent voltage value the voltage sensor could measure.

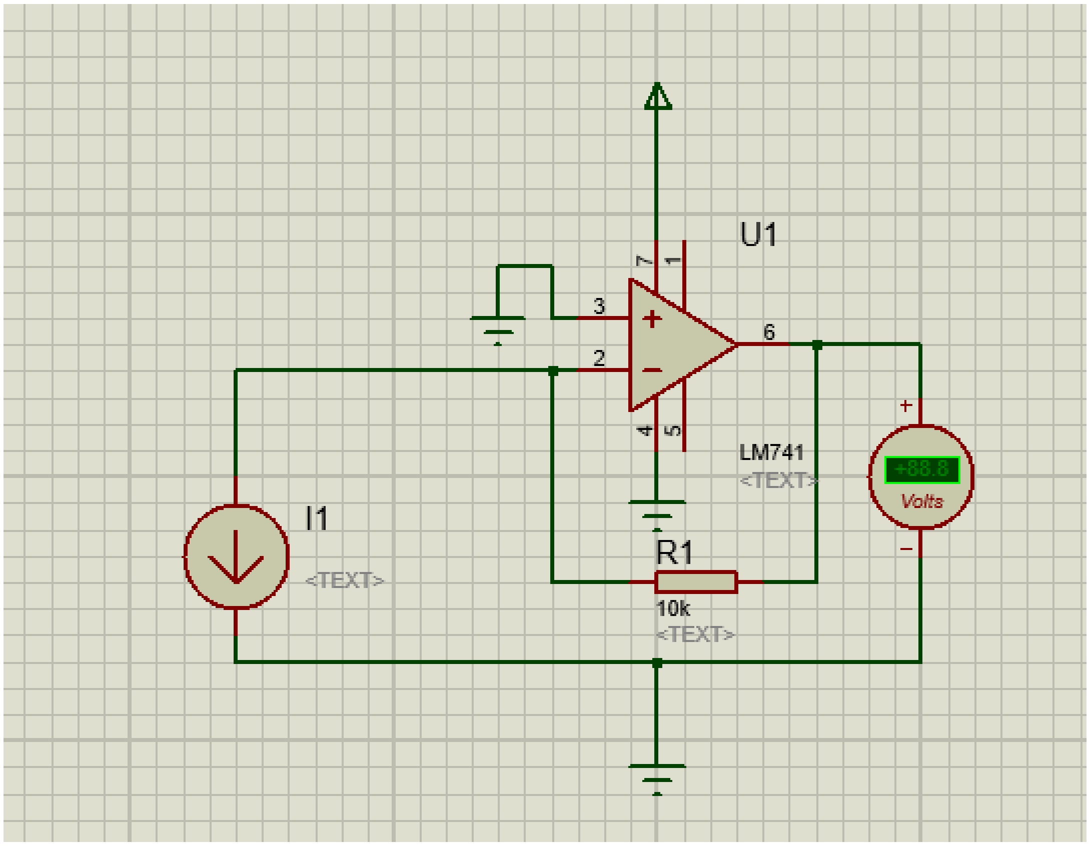

Figure 4:Proteus design of a current to voltage amplifier with an operational amplifier

Figure 4 provides the inverting operational amplifier designed for an equivalent voltage output from the current produced from the fuel cell sensor.

3.3.1.2 Adafruit Fingerprint Sensor

The TX and RX pins of the Adafruit sensor was connected to the corresponding RX ad TX pin on the microcontroller. The design decision was taken to aid full duplex communication between the microcontroller and the fingerprint sensor.

3.3.1.3 LCD

The I2c model of the LCD allows effective functioning of the LCD with fewer pinouts as compared to the previous LCD components. I2C is a communication protocol that communicates through SCL (serial clock) and SDA (data line). In the project design, the SCL and SDA pins on the LCD were connected to equivalent SCL and SDA pins on the microcontroller[16].

3.3.2 power supply design

The design for the project is to power the device with a 9V battery. However, the microprocessor and other sensors need to be powered with a 5V. Therefore, a circuitry with LM7805 voltage regulator was created to step the 9 volts from the battery to 5V.

Also, to ensure stable voltage for the GSM, a circuitry was created using the voltage regulator Az1084 to produce an output voltage of 5 Volts for the GSM module using a 1K ohm resistor and 330 Ohm resistor.

Also, to ensure stable voltage for the GPS, a circuitry was created using the voltage regulator Az1084 to produce an output voltage of 3.3 Volts for the GPS module using a 470-ohm resistor and 300-ohm resistors.

Chapter 4: Implementation

This chapter highlights the various procedures, routines, and steps taken to execute the three main subprojects and their integrate to form the primary component. The chapter explains how engineering concepts and various knowledge learned both in and out of class were implemented.

4.1 PCB Board Design and Printing

A PCD board was created from the schematic diagram designed in section 3.4. However, during the actual implementation, specific changes were made to the original schematic (change schematic is found in figure 8 in appendix). The changes were done to create margins for errors since theoretical design do not always work in real life due to certain uncontrollable situations.

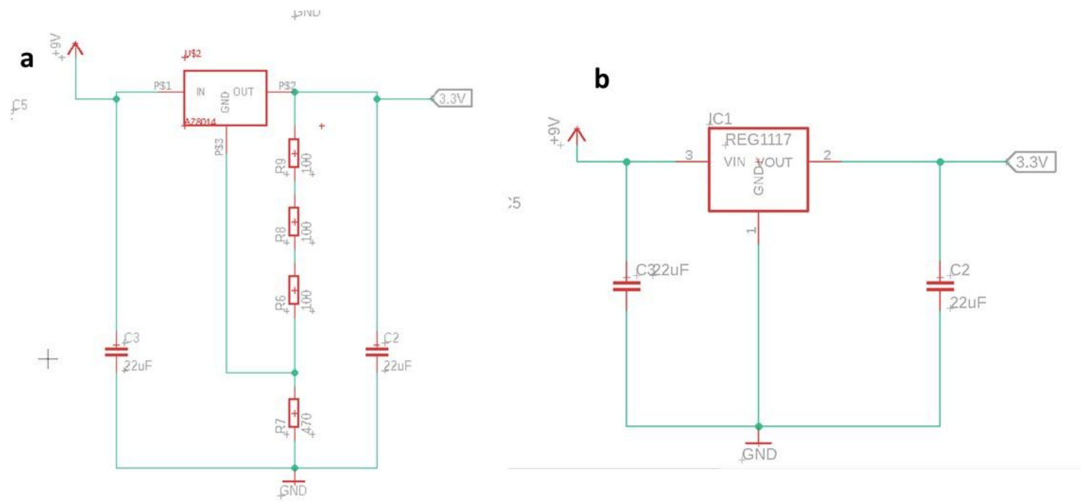

Figure 5: a) designed a schematic for GPS voltage supply b) schematic diagram for implemented GPS power supply

As shown in figure 5, the design of the GPS voltage supply was changed to a 3.3V voltage regulator, which served the same purpose as the adjustable voltage regulator (az1084). The implemented design had fewer components and got rid of the external resistors.

Another feature added to the board was an amplifier circuit designed for the fuel cell sensor. A proteus (A CAD software) circuitry was designed to boost low input voltage to a relative output voltage which could be read by the voltage measuring sensor. An operational amplifier circuit was designed amplifies the output voltage.

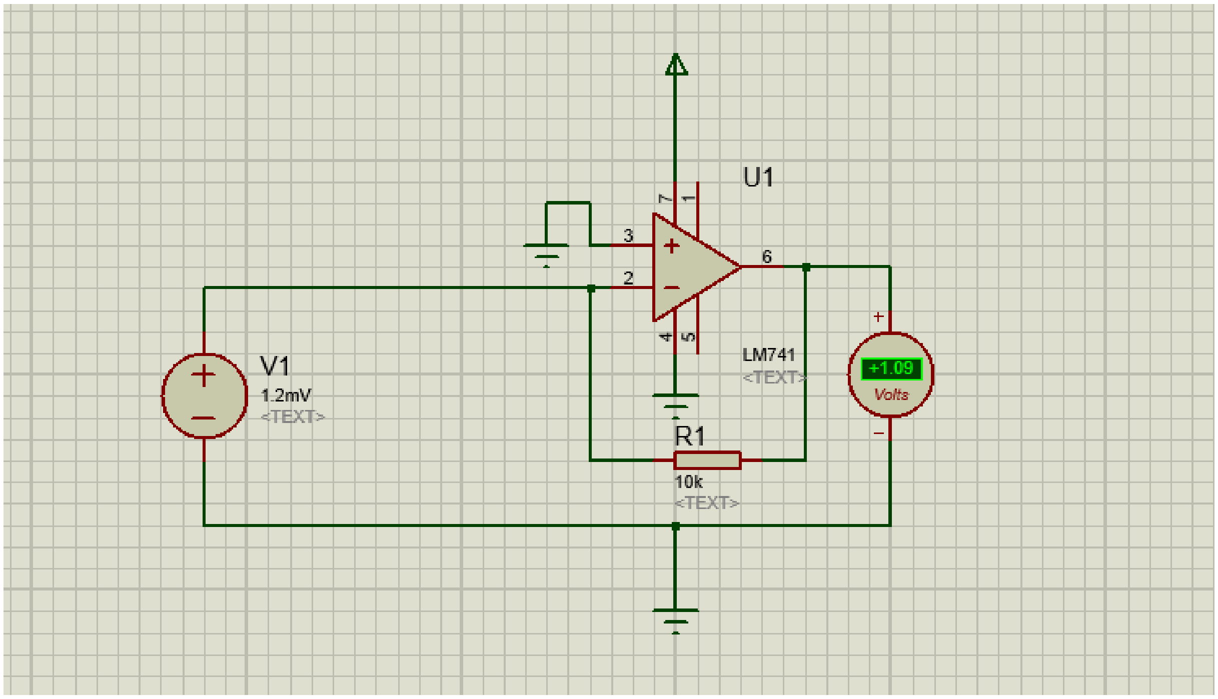

Figure 6: A screenshot of the simulated voltage amplifier for the fuel cell sensor

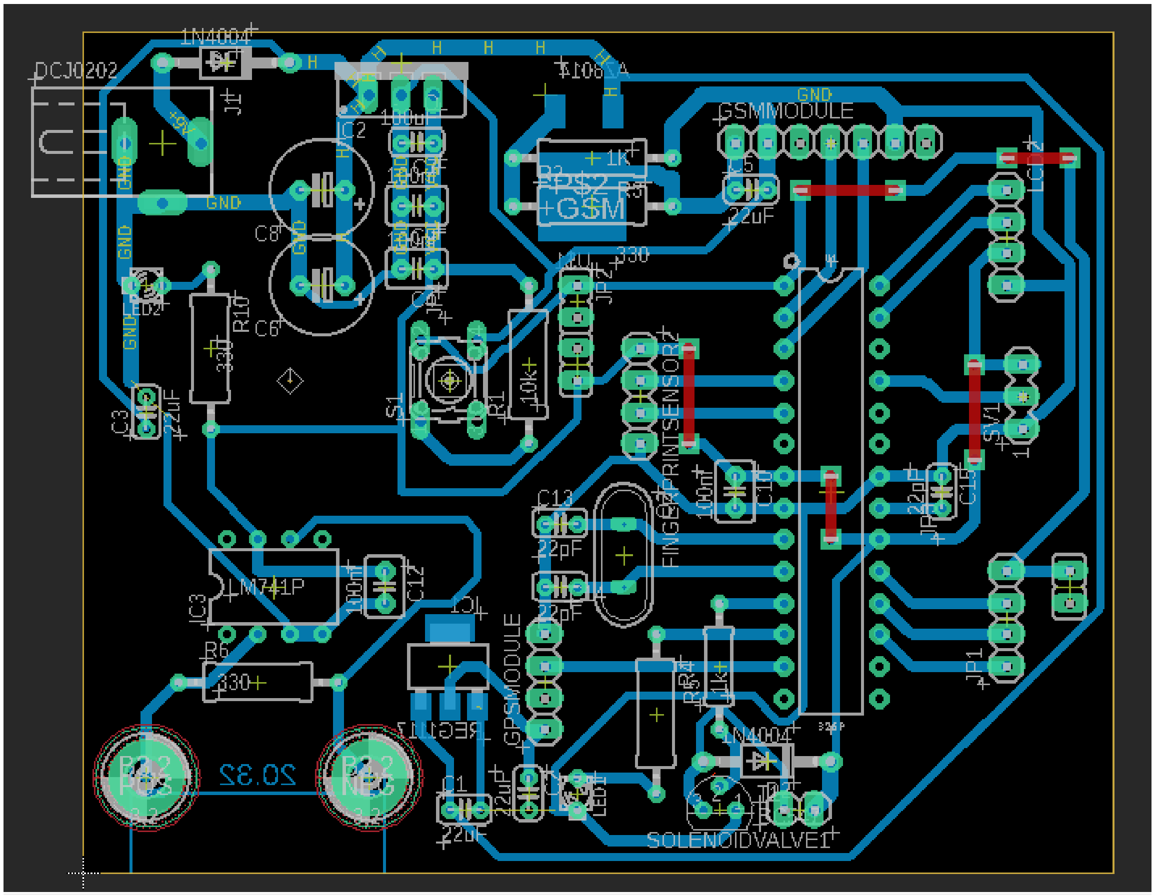

Figure 7: PCB board routing for the physical part of the breathalyzer system

Figure 7 is the routed PCB board created from the updated schematic diagram of the physical components of the Breathalyzer.

4.2 The Physical Breath Analyzer

The goal was to develop a breathalyzer using the ATMEGA1284p as the processor, an embedded fingerprint sensor for driver identification and the fuel cell sensor for alcohol detection.

4.2.1 Microprocessor configuration and bootloader upload.

During implementation, the required microcontroller ATMEGA1284p was changed to ATMEGA328p. The ATMEGA1284p is a low power consumption product [23], as compared to ATMEGA328p. However, the ATMEGA328p has less complexity in programming and can be easily configured.(site)

The bootloader was uploaded to the microcontroller to prepare for programming. A bootloader is a program that allows code to send a run from the software to the microcontroller [18]. Before the bootloader was uploaded, the circuitry in figure 8 was constructed.

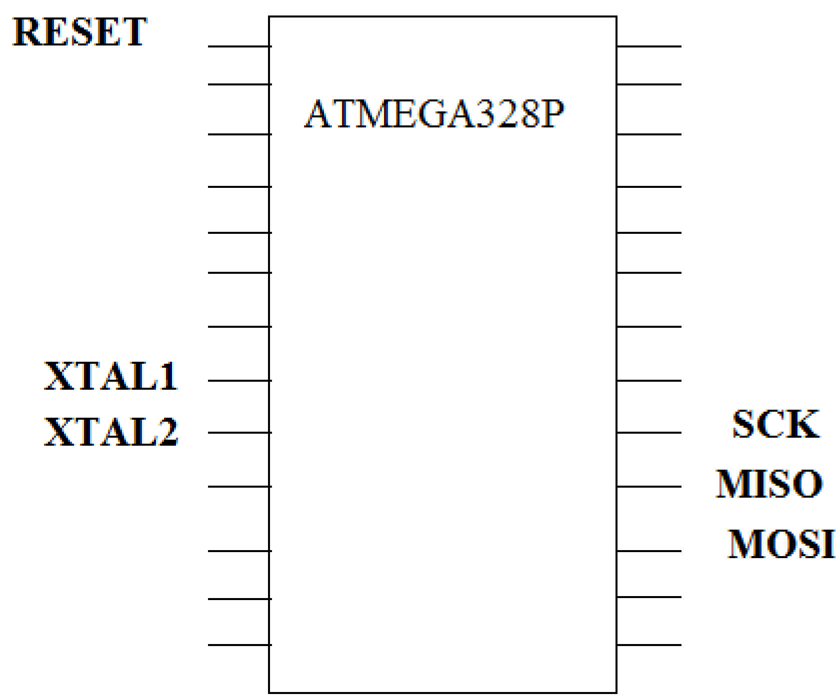

Figure 8: ATMEGA328p, connection with the USBasp

4.2.1.1 Configuring the Bootloader in the Arduino IDE

The library with the various ATMEGA boards were added by inserting the link to the library's URL in preference. The procedure is found in figure 7 in the appendix.

In tools, the board was changed to ATMEGA328p, the programmer chosen was USBasp (mightyCore).

After all the various requirements were met, "burn bootloader" was clicked one.[22]

4.2.2 Fingerprint Sensor Enrollment and Data Retrieving

4.2.2.1 Enrollment

As part of the user authentication session, seven fingerprints were scanned and stored in the fingerprint sensor. The code for enrollment of the fingerprints allowed the user to scan for two to three consecutive times while comparing the scan prints for a match before storing the data.

4.2.3 Alcohol Sensor Calibration

The fuel cell sensor was calibrated with various voltage concentrations, to ensure responsive and accurate measurement of the user's blood to alcohol concentration.

Ethanol of concentration 99.9% was diluted with distilled water to obtain the concentrations three concentrations of alcohol, that is; 0.08%, 0.05%, and 0.2 %.

4.2.3.1 Dilution of the Alcohol and Fuel Cell Sensor Testing

Ethanol with molar mass 47.6 and 99.9% volume concentration of alcohol was diluted to produce three equivalent blood to alcohol concentrations found with the human body which are 0.2%, 0.08% and 0.05%, lower concentrations were not create due to difficulty in measuring alcohol for dilution due to is very low volume.

Calculations for the concentrations

Known values

Molar mass = 46.07g

Volume of alcohol = 99.9ml

Specific gravity= 0.79

Density of water (ρ) $= 1$gml

Finding the concentration

C $=\frac{\rho}{m}$

$$\rho = SG * \rho_{water}$$

$$= 0.79 * 1\frac{g}{ml}$$

Dilution for 0.08% alcohol concentration

$$\left(\frac{m}{v}\right)V_{ethanol} = \left(\frac{m}{v}\right)Voutputconcentration$$

$$\left(\frac{79}{99.9ml}\right)V_{ethanol} = \left(\frac{0.08}{1000ml}\right)100ml$$

$$V_{ethanol} = 0.01ml$$

Dilution for 0.2% alcohol concentration

$$\left(\frac{m}{v}\right)V_{ethanol} = \left(\frac{m}{v}\right)Voutputconcentration$$

$$\left(\frac{79}{99.9ml}\right)V_{ethanol} = \left(\frac{0.237}{1000ml}\right)100ml$$

$$V_{ethanol} = 0.03ml$$

Dilution for 0.05% alcohol concentration

$$\left(\frac{m}{v}\right)V_{ethanol} = \left(\frac{m}{v}\right)Voutputconcentration$$

$$\left(\frac{79}{99.9ml}\right)V_{ethanol} = \left(\frac{0.05}{1000ml}\right)200ml$$

$$V_{ethanol} = 0.0255ml$$

200ml of distilled water was used to dilute the ethanol for a concentration of 0.05%. This was done to prevent errors since 0.01255ml of ethanol was required to produce a concentration of 0.05% with a volume of 100ml. this volume is very small to measure.

4.3 The web application

The web application serves as a digital storage for breathalyzer data in the project. The application was built on the MVC architecture that is; "M" represents a model (database), "V" for View (front end) and "C" for the controller. Building the web application, MongoDB, jade, and express.js were used to construct the various levels of the MVC architecture.

4.3.1 Front end

The view of the web application is made up of the administrative login page, a home page, and the statistical display page. The display for the view was obtained from the "bootswatch bootstrap" template.

Figure 9: login page of the web application

4.3.2 Database

The database used for the project was MongoDB specifically monogolab commonly known as mlab: an online version of MongoDB.

Registered information such as username, email and encrypted password were stored in a collection created called "Users" as shown in figure 10.

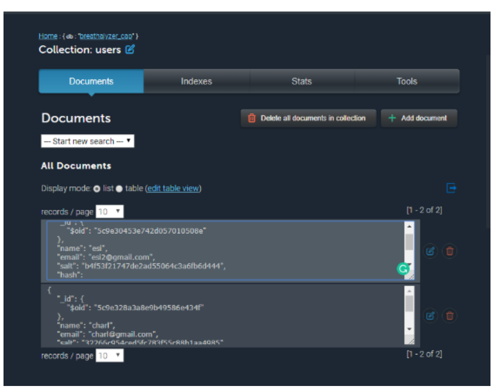

Figure 10: stored user authentication information on mLab

Various models were created to help store data received from the microcontroller in their specified type.

A driver's model was created to store the necessary details of the driver. For the project details of the driver was limited to his name, the drivers model had a reference of the log model in it.

A log's model was created to store specific driver details such as; the location the test was taken, the status of the driver's test, whether it was a pass or a fail.

Figure 2 and figure 3 in the appendix provides a snapshot of the log and driver models.

4.3.3 Back end and API

Express is a JavaScript back end application. In the project, express was used to control the various contents of the view (frontend). Also, it was used to create APIs (application programming interface) for the web application. The API created, helped connect the view (front end) to the database, by providing the view access to the database to retrieve or send data.

A total of three API were created in the web application.

1. API for user authentication and administrative login: The API created for the user authentication required already stored email account and password using the post method of a restful API.
2. API for MQTT subscription: An API was created to subscribe to data published to the MQTT broker from the physical breathalyzer. Database models created for the driver authentication data and log data was linked to the API. As shown in figure 9, the *"var newLog*" code stores data retrieved from the MQTT broker containing driver test data to the log database. Also, the "driver.findOneAndUpdate" identifies user's

identification from data published by the microcontroller and updates the log the test results under a particular user.

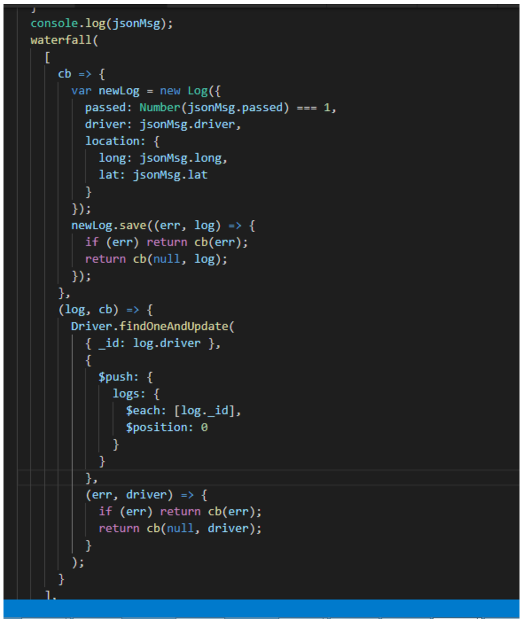

Figure 10: A screenshot of API code for MQTT subscription and database storage

The web application was very keen on security. Therefore the web application was designed for only administrative login. Login details were stored internally to the database through an API post method create for receiver email and password. Password generated were encrypted by the hash and salt, a feature of express.js used for securing password stored in a database.

Figure 11: An example of an encrypted password

4.4 Communication from the Physical Component to the Database and The Web Application

MQTT was the communication protocol used to send data from the microcontroller to the database. MQTT fully known as message queuing telemetry transport is a lightweight, publish and subscribe protocol that sends data wirelessly from one machine to another [19]. MQTT works by a device publishing message to a broker (which can be locally hosted with a reserved port of 1883, or over an online broker frequently CLOUDMQTT) with a specific topic. The data is received by the end user who subscribes to the broker with the same topic published. The project followed the process below for data transferred using MQTT process;

1. Data published from the microcontroller (ATMEGA328p) to an MQTT broker (cloud MQTT).

   A sample Arduino MQTT client code was modified to send the specific data, such as the location of the test, whether the test taken was a pass or a fail.

   A CLOUD MQTT account was created to provide a free cloud MQTT broker service for the data from the microcontroller.

   The username and password of the CLOUD MQTT account were specified in the Arduino code with the specific CLOUD MQTT port of the broker.

   The data published to CLOUD MQTT broker were the longitude and latitude of the GPS model, whether the user passed or failed the test and the user identification.

   The data was sent in the form of a string.

2. Data subscribed from the cloud MQTT to the database (Mongolab)

   Mongoose models were created to specify the form in which data retrieved from the microcontroller will be saved. Section 4.1 describes specified format for the data types.

3. Data in the data containing information on the driver details, the number of drivers who passed the test and those who failed the test, the particular test location and the time the test was taken was queried, and a graph was generated with the data.

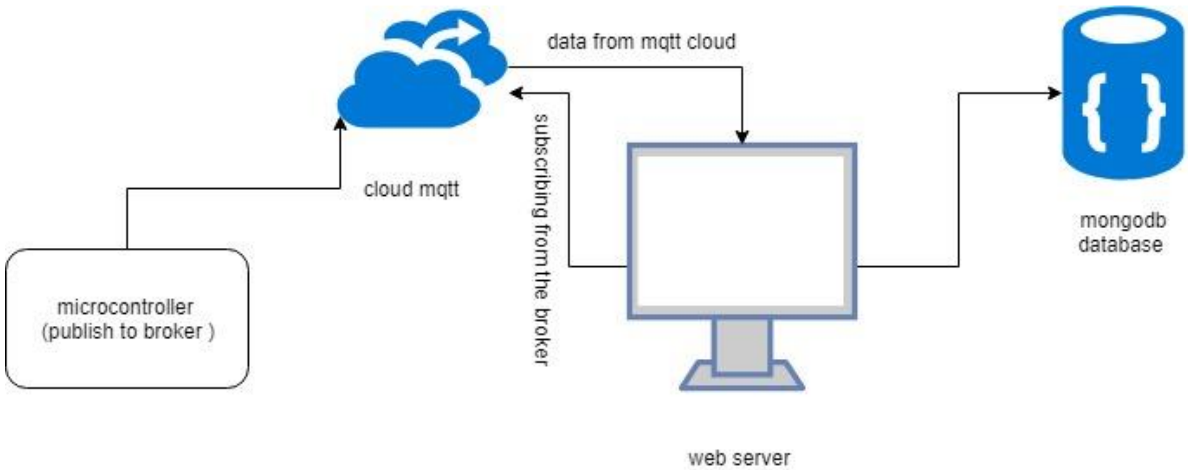

Figure 12: MQTT process for the breathalyzer system

4.5. Breathalyzer system integration

4.5.1 Final code configured on the microcontroller

The final code compiled on the microcontroller performed the various test below;

1. Fingerprint configuration: Sample ID names stored for fingerprint data collected were pushed to the database. Each fingerprint ID represents a user.

   The configured system detects whether the user is registered or not, by comparing scanned fingerprints with stored fingerprint data. The scope of the project pushed only IDs representing the fingerprint data to the database and not the actual fingerprint data. This was done as a proof of concept of the practical implementation of the breathalyzer system in the country. The data was published to CLOUD MQTT, an online MQTT broker. The data published was subscribed by the web application and stored into the database.

2. GPS location tracking: GPS longitude and latitude data were recorded to help specify the location in which the test data was collected.
3. Breathalyzer test (specifying either person passed or failed test):

   Data of user breath samples were simulated and feed as input data to the breathalyzer system. The data was keyed in through the serial monitor of Arduino IDE.
4. Breath test data sampling:

   Each user BAC test was logged into the database using MQTT which was well described in the first point. The data received was queried based on the day the test was taken and whether the user passed or failed the test. Figure 14 provides the outcome from the test data sampled.

Chapter 5: Test and Results

5.1 Results of breathalyzer implementation

5.1.1 Fingerprint enrollment and configuration

The effectiveness and responsiveness of the fingerprint sensor to detect enrolled fingerprint was tested. Figure 11 and figure 10 provide results on how fingerprint values were enrolled and how an enrolled fingerprint sensor is recognized by the sensor.

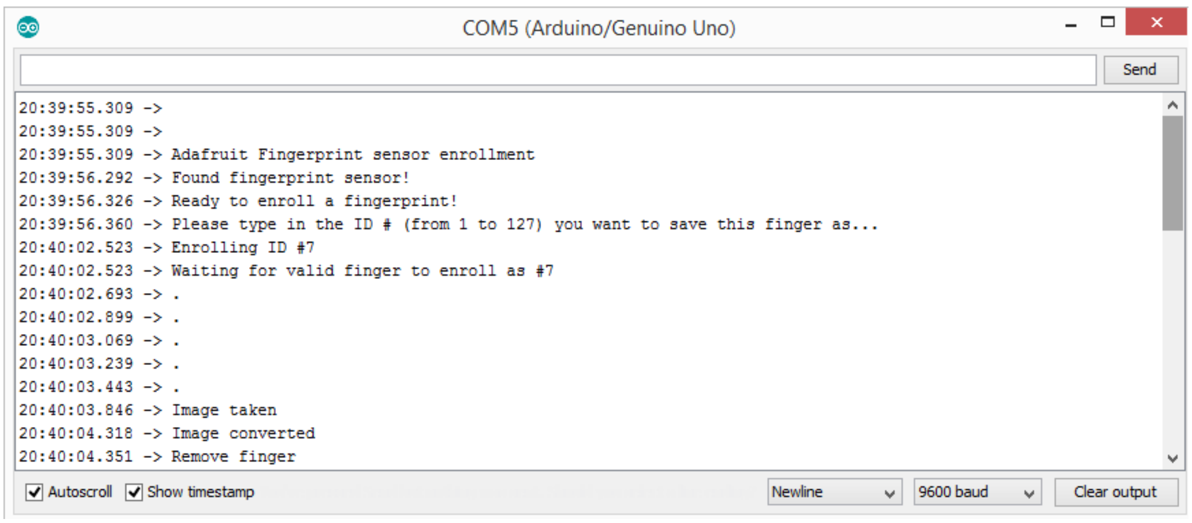

Figure 13: procedure of enrolling a fingerprint

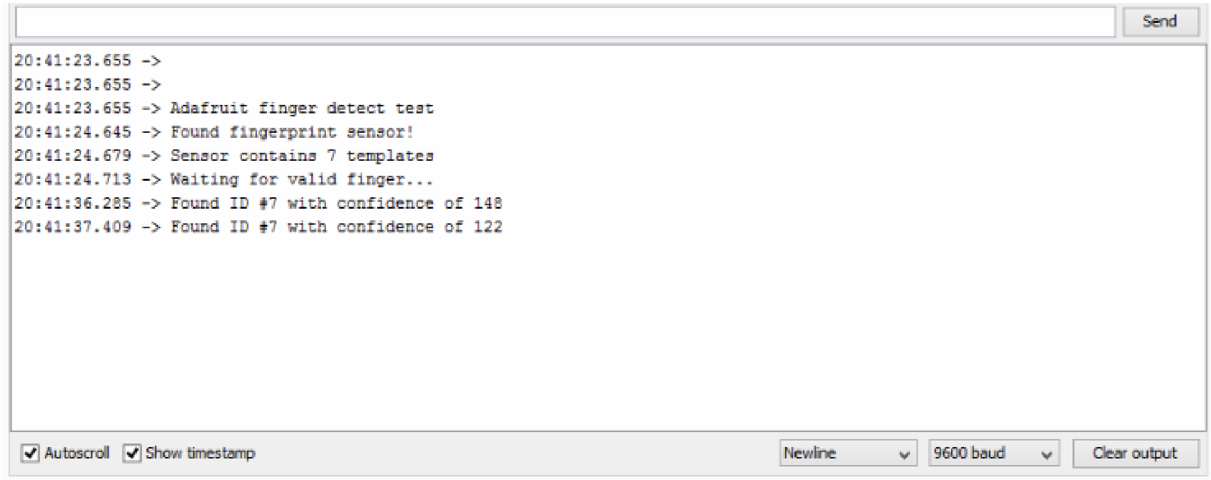

Figure 14: process of recognizing enrolled fingerprint

5.1.2 Output Data of the Fuel Sensor with Respective Alcohol Concentration

5.2 Alcohol sensor calibration

Three sample alcohol tests were taken for each concentration on the fuel cell sensor. The output current and voltage results are shown in table 3 below.

	Alcohol concentration %	0.08g/mL	0.2g/mL	0.05g/mL
Current/uA	Test 1	4.1	4.2	3.0
	Test 2	3.6	3.0	1.8
	Test 3	3.4	4.1	2.7
Voltage/mA	Test 1	0.8	1.2	0.9
	Test 2	0.7	0.5	0.5
	Test 3	0.5	0.9	0.6

Table 5. 1:output voltage and current produced by the fuel cell sensor from various alcohol concentration

5.2.1 Results of amplified voltage values of the fuel cell sensor

Proteus simulation of the design current equivalent voltage amplifier with the non-inverting operational amplifier was tested with the same voltage values recorded from the fuel cell sensor.

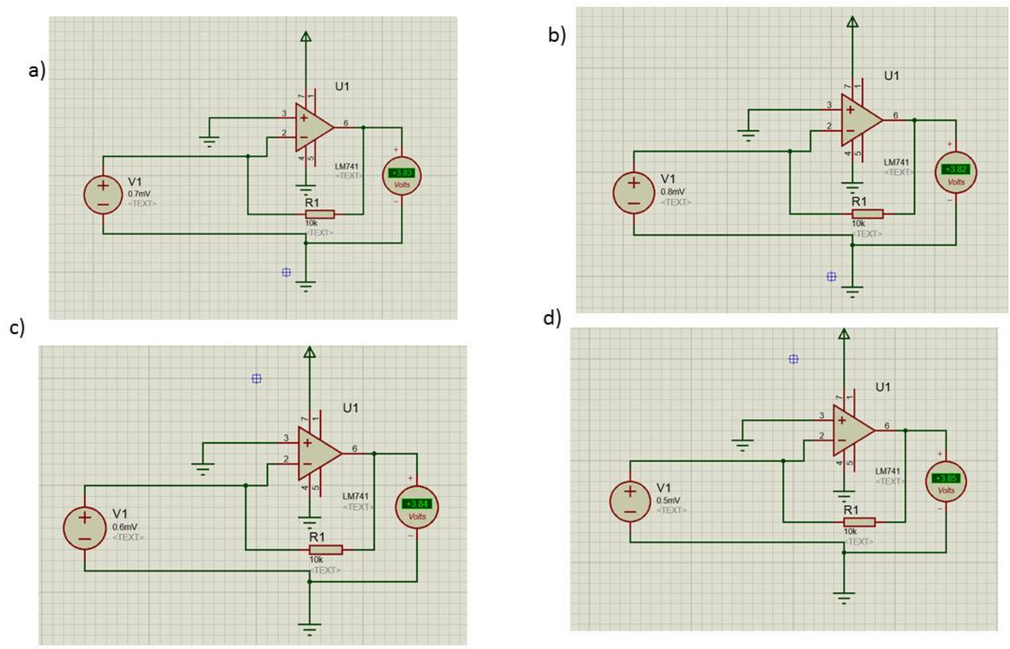

Figure 15: the respective output amplified voltage for sample voltage produced by the fuel sensor

5.3 Statistical data from sample alcohol tests.

A sample test was conducted with the breathalyzer as explained in section **4.5.1** to provide a repository of users who have either passed or failed the breath test and their specific user location. The experiment was conducted over three days in the same place.

The results sent to the database were queried to retrieve the data sent.

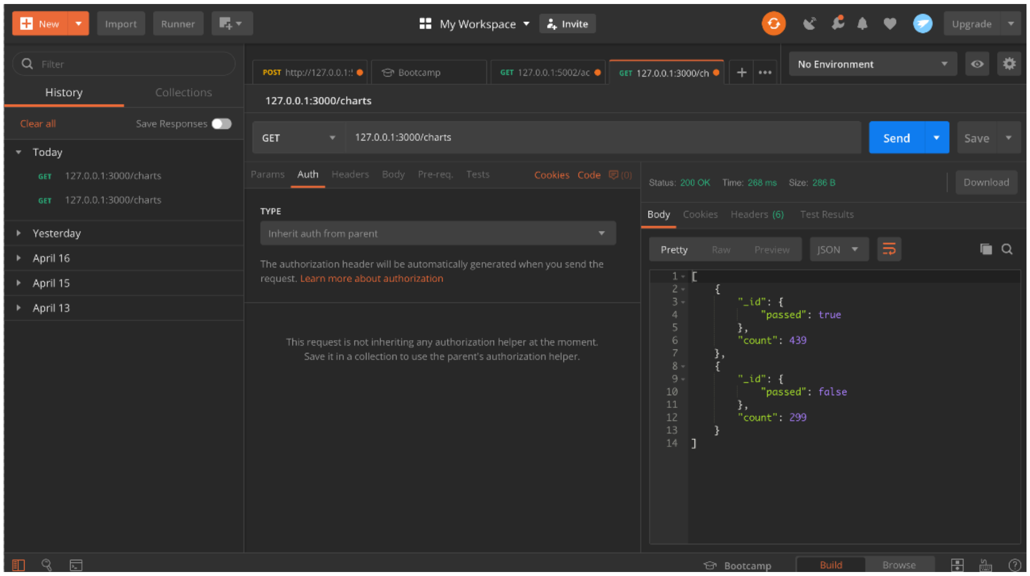

Figure 17: implementation of an API to receive queried data from the database

[{"_id":{"month":4,"day":20,"passed":false},"count":133},{"_id":
{"month":4,"day":22,"passed":false},"count":140},{"_id":
{"month":4,"day":21,"passed":false},"count":26},{"_id":
{"month":4,"day":20,"passed":true},"count":214},{"_id":
{"month":4,"day":22,"passed":true},"count":157},{"_id":
{"month":4,"day":21,"passed":true},"count":68}]

Figure 18: output results of queried data from the database

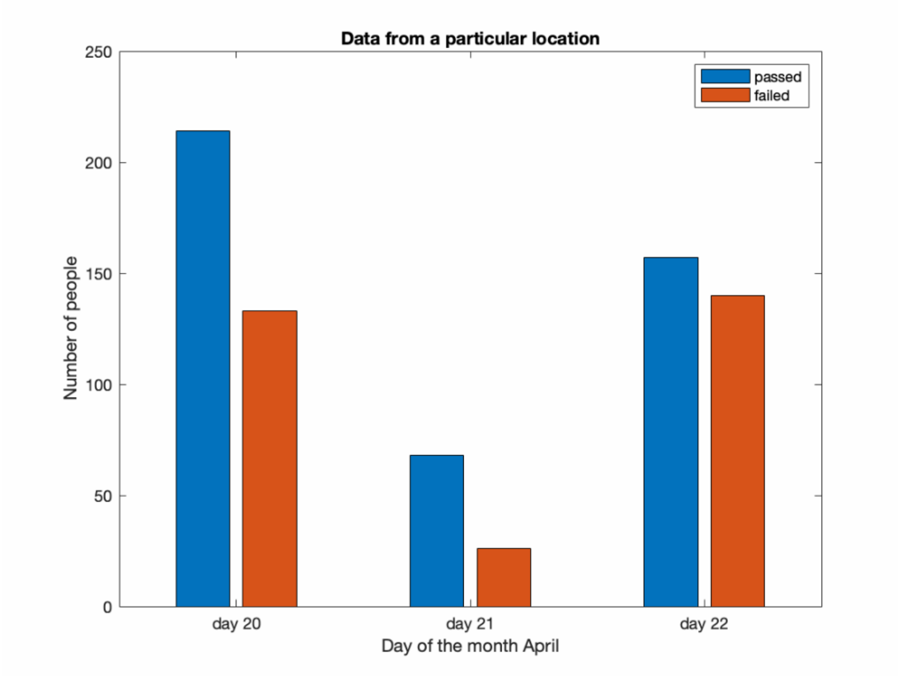

Figure 16: a bar chart of results of the drunk test conducted

Chapter 6: Conclusion

6.1 Discussion

Figure 14 and 15 provides an overview of how the adafruit fingerprint sensor enrolls and retrieve already stored fingerprint data. In figure 10 the user fingerprint data was stored in an ID called 7. The ID is a possible representation of the user identification pin or unique number assigned to the user. This can be compared or related to that for a driver license.

Table 3 provides output voltages and current of alcohol test conducted with the various alcohol concentration. From the table, the output voltage and current produced are of minimal quantity. Very low output voltage and current can be compared to the low concentration of alcohol pumped into the fuel cell.

However, the output values from table 3 are inconsistent for a specific alcohol concentration. The range of values is similar to all other values for other concentration.

The reasons for the variation could be mistakes caused when injecting the alcohol concentration into the fuel cell sensor. Also, incorrect dilution of the alcohol to the desired concentration could have caused the similarities in the output current and voltages of different alcohol concentration.

From the results, it can be concluded that the fuel cell sensor for the breathalyzer was not efficiently calibrated due to similarities in output values for very critical alcohol concentrations and therefore need careful configuration and alcohol concentration testing.

Figure 16 provides equivalent decreasing voltage output for every increase in input voltage. The results can be deduced from the functionality of the inverting operational amplifier (opamp). Figure 6, the positive input of the opamp is connected to ground, while the input voltage from the fuel sensor is connected to the negative input of the opamp. The respective output voltages are as a result of negative values from the difference between the –ve input and the +ve input (which is constantly zero). However, the final output voltage is the reference voltage + the difference between the input voltages.

Hence the respective reduction in reference voltage as input voltage increases.

The uniform reduction in voltage is efficient for fuel cell sensor calibration on the microcontroller.

Figure 17, 18 and 19 provide the output results on a test conducted on the breathalyzer system. Figure 17 displays the results of a get API created to query the number of passes and failed drunk test over a period of three days.

Figure 18, provides a better format of how the queried data was retrieved, displaying various days and the number of counts and a failed test.

Figure 19 provided a bar graph of the data. The bar chart represents a sample statistical format to analyze data retrieve on either weekly, daily or monthly base on the various drunk test results of drivers. The queried data in figure 18 confirms the functionality of the web application to query or retrieve vital data sent from the physical breath analyzer system to the database.

From the results it can be concluded that sending and comparing actual fingerprint data for the project was not achieved, also the fuel cell sensor was not effectively calibrated to produce the required output. Nevertheless the web application works effectively by seamlessly transferring data from the Breathalyzer device to the database for statistical analysis and drunk driving law enforcement.

6.2 Limitations

The breathalyzer system will not work effectively in periods where there is instability in telephone networks since user authentications and statistical data storage leverage on the GSM module for data transmission.

Data generated by the fuel cell sensor may cause inaccuracy in breath results of a user due to sparse data recorded from fuel cell sensor test.

6.3 Challenges

1. Armature skills in computer programming: insufficient skills in programming caused a significant limitation to the project since time was spent learning and understanding programming logic and debugging errors which could have quickly been resolved by a programming expert.
2. There was little access to information on how to use various sensors, such as the alcohol fuel cell sensor. The alcohol fuel cell sensor had less information provided on the sensor purchase, therefore pose a significant challenge trying to configure its use.

6.4 Future Works

Due to time constraint, specific fields of the project were not achieved. For future works;

1. The project will be improved to compare sample driving license fingerprint data with direct fingerprint scanned from the device. The process will be achieved incorporating an algorithm to match two similar prints from both similar and different devices. The milestone will be first achieved by first configuring how to match two similar fingerprints measured with the same fingerprint sensor.

2. Embed angular as the front end of the web application. In future works, angular a front application will be embedded into the web application to ease the server from processing web pages and for receiving and routing requests.
3. A google map API will be incorporated into the web application to provide a pictorial view of the location the data was captured.
4. Further research will be conducted on how to improve the efficiency of the alcohol fuel sensor to respond to slight changes in concentration.

References

[1] N. A. Siaw, E. Duodu, S. K. Sarkodie, Trends in Road Traffic Accidents in Ghana; Implications for Improving Road User Safety. International Journal of Humanities and Social Science Invention. Vol. 2. Iss. 11. pp.31-35, 2013

[2] D. V. Bhuvaneswari and D. R. Porkodi, "The Internet of Things (IoT) Applications and Communication Enabling Technology Standards: An Overview," IEEE, pp. 324-328, 2014.

[3] E. Yeboah-Assiamah, K. Asamoah and A. Osei-Kojo, "Corruption Here, Corruption There, Corruption Everywhere: A Framework for Understanding and Addressing Public Sector Corruption in Developing African Democracies," researchgate, vol. 4, no. 3, pp. 186-201, 2014.

[4] "Robert F. Borkenstein: an appreciation" Society for the Study of Addiction to Alcohol and Other Drugs pp.371–372.

[5] H. A. Rahim, S. D. S Hassan, "Breathalyzer enabled ignition Switch system", 2010 6th International Colloquium on Signal Processing & Its Applications (CSPA), pp.1-4, 2010

[6] C. Sánchez-López, L.M. Barba-Maza, "Development of a breathalyzer for car drivers", 2016 IEEE International Autumn Meeting on Power, Electronics and Computing (ROPEC), pp.1-4, 2016.

[7] Der EM, Naporo S, Damnyag JB and Akosa AB, "Road-traffic related Deaths in Accra Ghana: A 10-year Retrospective Autopsy Study at the Korle-Bu Teaching Hospital, Accra (2004–2013)". Journal of Forensic Pathology. Vol. 1. Iss. 2. Pp.2016

[8] E. Mends–Brew, J. Dadzie, B. A. Dadson, M. O. Amoamah, "Modelling the Trend of Road Traffic Accidents in Accra", Mathematical Modelling and Applications. Pp 1-8, 2018

[9] J. Damsere-Derry, F.K. Afukaar, W. Ackaah, W. Agyemeng, "PREVALENCE OF DRUNK DRIVING IN GHANA", Injury Prevention 18(Supplement 1):A168-A168, pp.1-18, 2012.

[10] L. Prest, "Fundamental Investigation of Fuel Cell-based Breath alcohol Sensors and the Caues of sensor Degration in Low-Humidity Conditions," 2011.

[11] "Fuel cell vs Semiconductor Breathalysers," 17 march 2017. [Online]. Available: https://www.andatech.com.au/resource/fuel-cell-vs-Semiconductor-breathalysers/. [Accessed 31 March 2019].

[12] A. Nayyar, D.-N. Le and V. Puri, "A Comprehensive Review of Semiconductor-Type Gas Sensors for Envronmental monitoring," Researchgate, pp. 55-64, November 2016.

[13] "Digitalisation has reduced corruption in Ghana – GII," Ghana Business News , 23 February 2018. [Online]. Available: https://www.ghanabusinessnews.com/2018/02/23/digitalisation-has-reduced-Corruption-in-ghana-gii/. [Accessed 1 April 2019].

[14] D. Gerulski, "Breathalytics Uses Integrated Biometrics' Watson Mini Biometric Fingerprint Scanner to Revolutionize Correctional Sobriety Testing". Integrated biometrics.2018.

[15] "Fingerprint Scanner (GT-521Fxx) Hookup Guide," [Online]. Available: https://learn.sparkfun.com/tutorials/fingerprint-scanner-gt-521fxx-hookup-guide?_ga=2.165453439.1352266080.1547843366-2134257102.1540289568. [Accessed 18 January 2019].

[16] "Datasheet I2C 1602 Serial LCD Module".

[17] Ublox, "NEO-6 u-blox 6 GPS Modules Data Sheet". [Online]. Available:https:// www.waveshare.com/w/upload/2 /2c/NEO-6-DataSheet.pdf.[Accessed 1 April 2019].

[18] I. Sesi, "invent electronics," 2017. [Online]. Available: https://www.inventelectronics.com/product/standard-voltage-sensor-module/. [Accessed 23 April 2019].

[19] "MQTT.ORG," [Online]. Available: http://mqtt.org/faq. [Accessed 23 April 2019].

[20] S. Holmes, Getting Mean with mongo, express , angular and node, shelter Island: manning Publications Co., 2016.

[21] K. I. Ozoemena, R. Modise, A. K. Ipadeola and S. Peteni, "Fuel cell-Based breath-alcohol sensors: Innovation-hungry old electrochemistry," ResearchGate , vol. 10, pp. 82-87, 2018.

[22] G. P. Vilamil, "Bootload the Arduino Mini," Arduino, [Online]. Available: https://www.arduino.cc/en/Hacking/MiniBootloader. [Accessed 1 April 2019].

[23] Microchip,"ATmega164A/PA/324A/PA/644A/PA/1284/P megaAVR® Data Sheet", 2018.

[24] Simcom, "SIM800L_Hardware_Design_V1.00", 2013.

Appendix

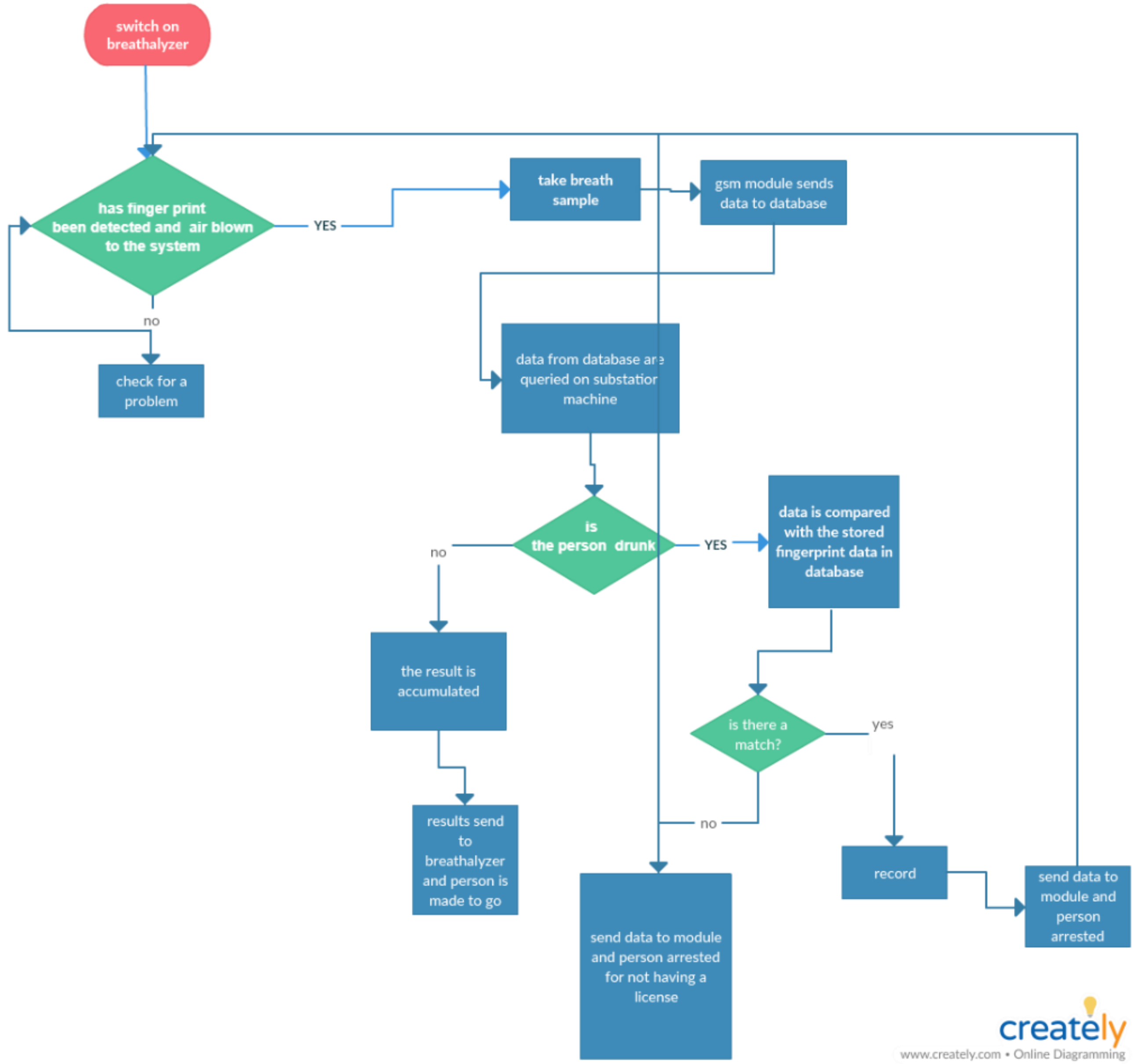

Figure 1: the flow chart of the breathalyzer system

Sample Code for MongoDB Models

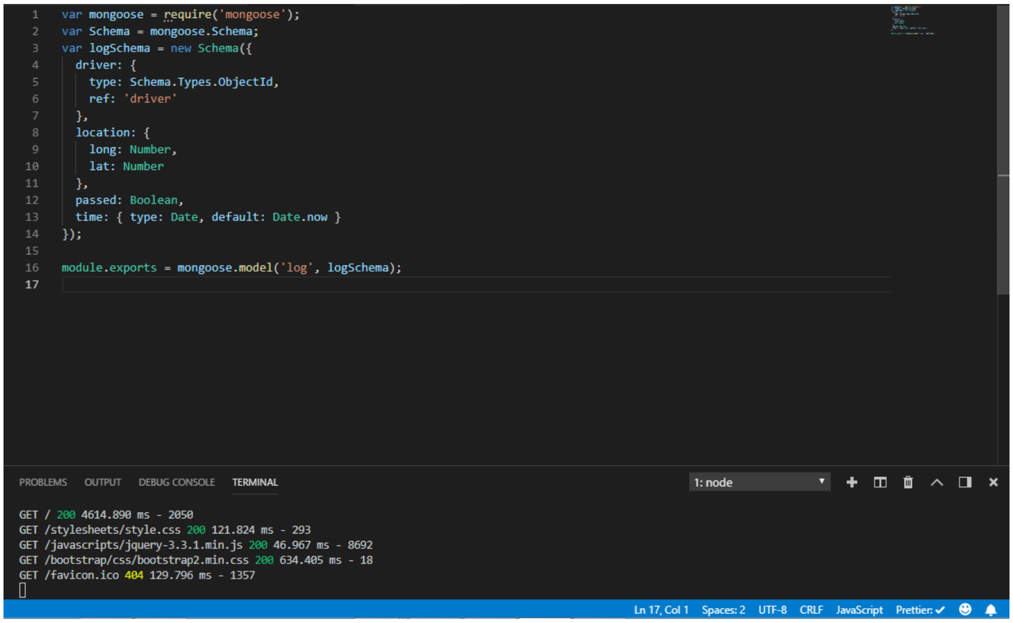

Figure 2: the model code for log database

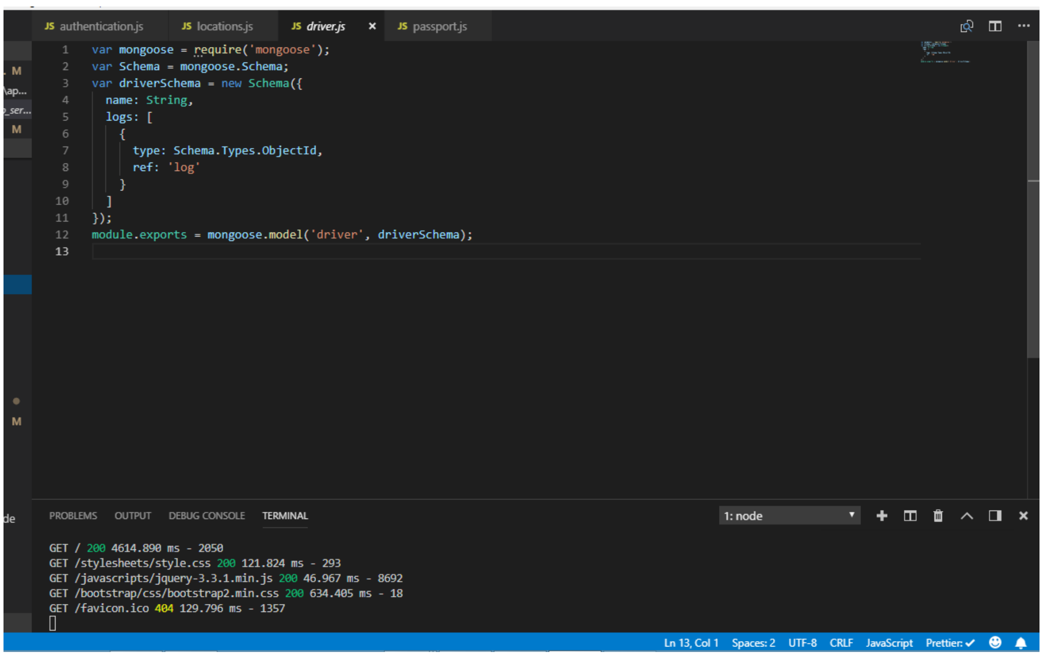

Figure 3: the model code for driver's database

Images of Components for The Project

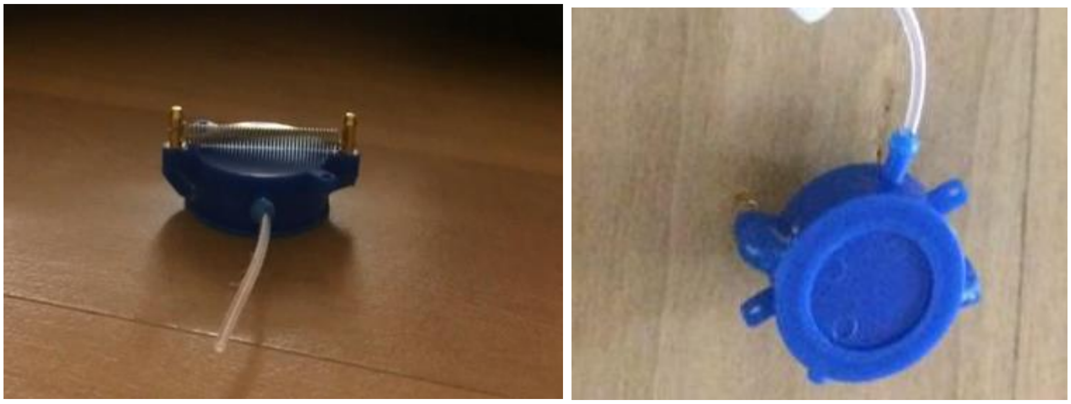

Figure 4: pictures of the fuel sensor

Figure 5: pictures of the fuel sensor

Figure 6: pictures of the solenoid valve

ATMEGA328p configuration

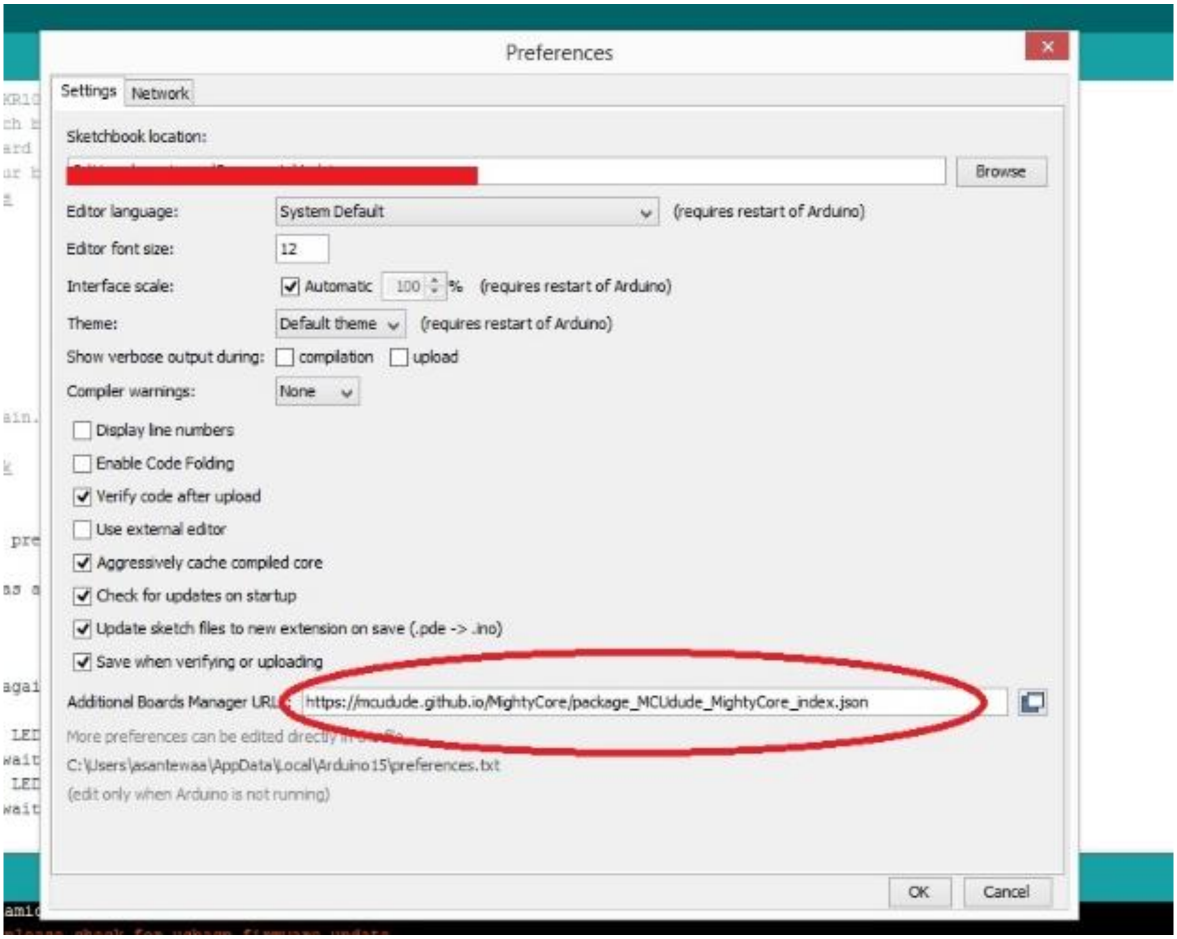

Figure 7: snapshot of ATMEGA328p configuration

Schematic diagram

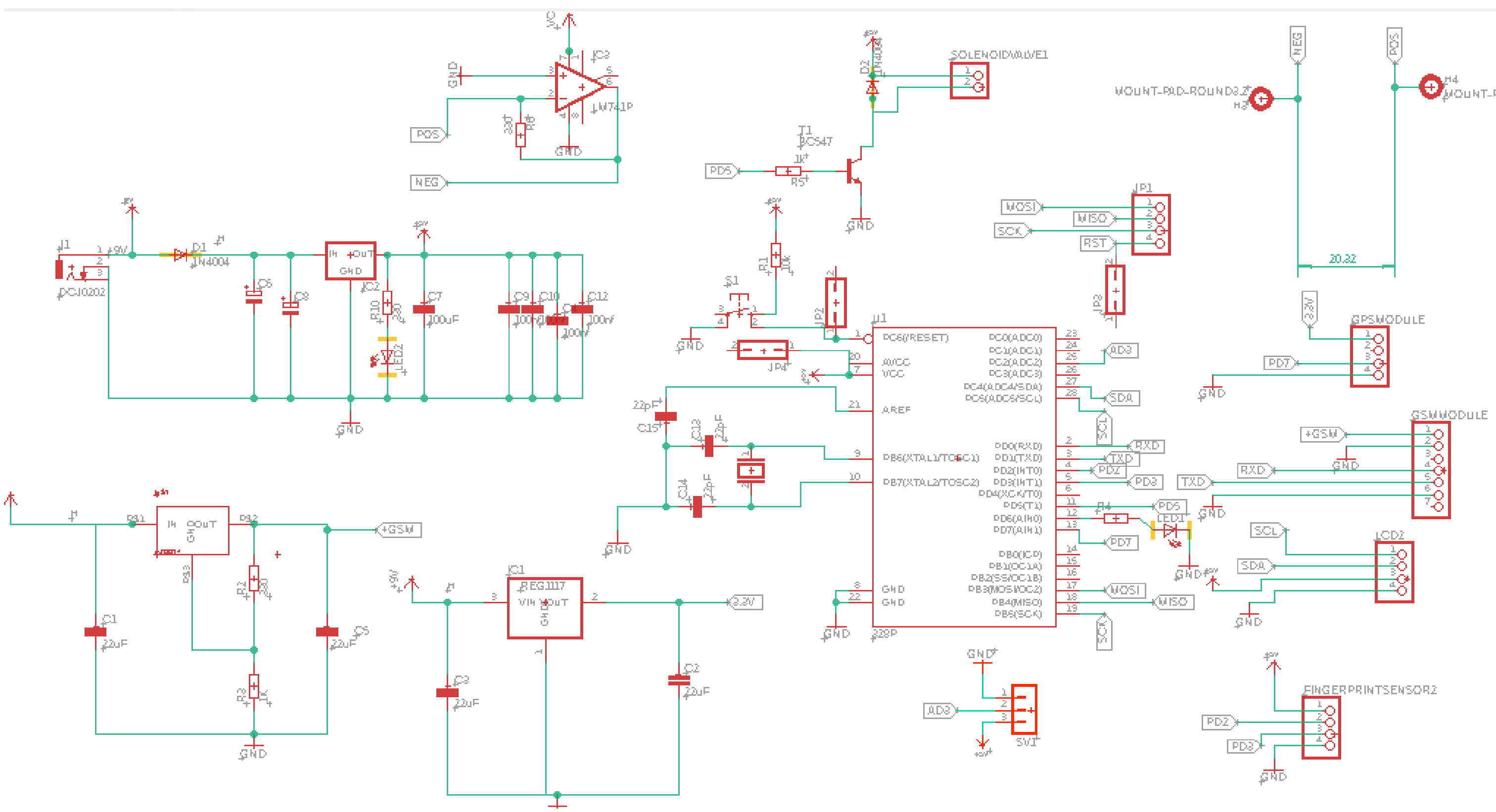

Figure 8: A snapshot of the revised schematic diagram for the physical breathalyzer.