ASHESI UNIVERSITY

A LOW COST ANTI-THEFT TRACKING SYSTEM FOR ELECTRIC VEHICLES

CAPSTONE PROJECT

BSc. Electrical and Electronic Engineering

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CAPSTONE PROJECT

Capstone Project submitted to the Department of Engineering, Ashesi University, in partial fulfilment of the requirements for the award of Bachelor of Science degree in Electrical and Electronic Engineering.

Michael Dzine

2020

DECLARATION

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

Candidate's Signature:

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Candidate's Name:

Michael Tafadzwa Dzine……………………………………………………………………...

Date:

29 May 2020…………………………………………………………………………………...

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

Supervisor's Signature:

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ABSTRACT

A vehicle tracking system is any technology that can be used to access the location of a vehicle; either in real time or offline. However, for many car owners, especially on the continent of Africa, vehicle tracking is a luxury which only a few people can afford. Many people are struggling to get a car in the first place. Analysis of vehicle theft data done in South Africa showed that most of the vehicle theft in the Southern African country are as a result of poor security systems. Furthermore, the vehicles stolen do not have any tracking systems. Therefore, to reduce the number of vehicle theft on the continent, this project is aimed at developing a low cost, flexible vehicle tracking system. The tracking system uses Ublox's GPS module, NEO-6M, to obtain the coordinates of the vehicle. These coordinates can then be sent to the owner of the vehicle using a cellular network. The network chosen for this project is MTN. To reduce the cost of operating by sending too many SMS messages, the device makes use of the concept of geofencing. Geofencing allows the device to only send a text message to the owner if the vehicle is going to unfamiliar territory. The device also allows the owner of the vehicle to lock the vehicle in the event of, or suspected, theft. A statistical analysis was performed to test the accuracy of the coordinates obtained from the device. It was observed that the device would give accurate coordinates 95% percent of the time.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Chapter 1: General Introduction

1.1 Background

According to Almomani et. al, a Vehicle Tracking System (VTS) is a collection of components including an electronic device, a monitoring server, and a user interface mainly used by huge fleet operators to follow the movements of their vehicles [1]. VTS systems use technologies such as the Global Positioning System (GPS), the Global Navigation Satellite System (GLONASS) and the Geographic Information System (GIS) receivers to connect to satellites, in space in order to accurately determine the latitudes and longitudes of any location on earth, with exact UTC (Universal Time Coordinated), of the vehicle [1] [2] [3]. Figure 1.1 shows an image, by NASA, of the satellites used in global navigation systems. The receivers receive coordinates of the location of the vehicle every second, with time and date, as Radio Frequency (RF) signals from space. The information received by the receivers can also be used to mathematically determine distance travelled on a trip, vehicle mileage and the speed of the vehicle [4]. The vehicle's location can be viewed using electronic maps or specialized softwares. Among the many applications of vehicle tracking, VTS can also be used as an anti-theft system.

Ibraheem and Hadi [2] suggested; there are basically two types of vehicle tracking; passive tracking and active tracking. The classification is based on whether the tracking information in transmitted in real time or not [2]. In active tracking, the location of the vehicle is transmitted to a server or the user immediately as it is received. On the other hand, in passive tracking, the tracking information is stored in a memory device and manually transferred to a computer at predetermined locations. Due to the unreliability of network services in some areas, it is almost impossible to fully implement an active tracking system, therefore, modern VTSs use a combination of both passive and active tracking.

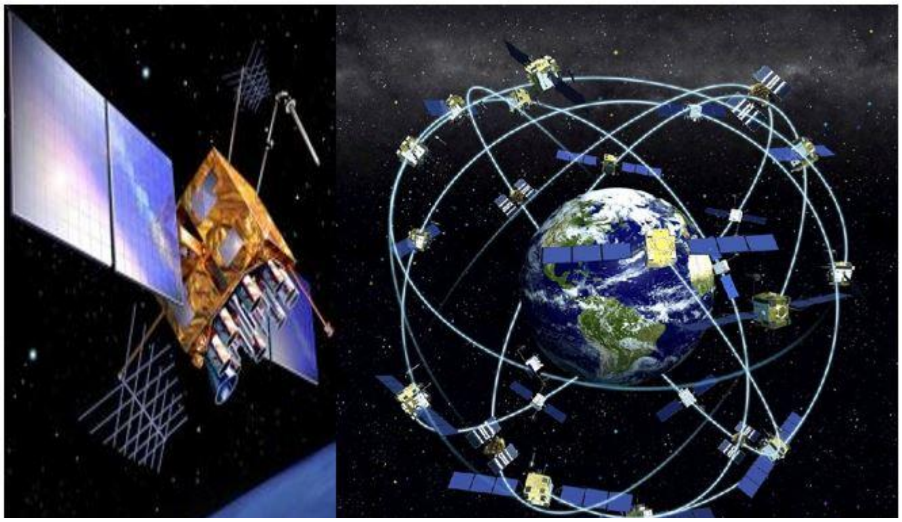

Figure 1.1: satellites used in global navigation systems

Currently, most vehicle tracking systems available use internet as a form of connectivity which makes the tracking systems more expensive and inaccessible in areas that do not have internet connection [5]. Apart from the cost, these types of tracking systems pose significant limitation because of the difficulties in implementing internet-based vehicle tracking systems. In wireless communication, there is need for gateway nodes which require high levels of investments to be implemented. This further increases the cost of implementing vehicle tracking systems [5]. According to Brown [6], Navigation information and vehicle tracking is currently limited to luxurious cars and rental fleets. Figure 1.2 shows cases of vehicle theft, in South Africa, of various car models [7]. The figure is further evidence for the need for more affordable vehicle tracking systems such that in the event of vehicle theft, the owner of the vehicle can track his/her vehicle. The graph shows that the more expensive brands such as Volvo, Chrysler and Porsche have far less cases of theft than the cheaper brands such as Toyota, Volkswagen and Nissan. It can be argued that, in terms of numbers, the less expensive cars are way more than the more expensive cars hence the higher occurrences of theft. However, the aim is to reduce the high occurrences of theft in lower end cars by deploying an anti-theft vehicle tracking system in cars that do not already have the systems.

Furthermore, Parvez and Ahmed et. al [5], revealed that property losses amounting to $6.4 billions of dollars were recorded in the United States as a result of vehicle theft. This shows the high demand for affordable vehicle tracking systems which can be mounted on any vehicles. Behzad et. al [4], also argues that the costs of the tracking technologies on the market are too high as compared to their performance and the facilities they offer. The authors in [4] argue that the cost of available tracking devices on the market is increased because one needs to purchase

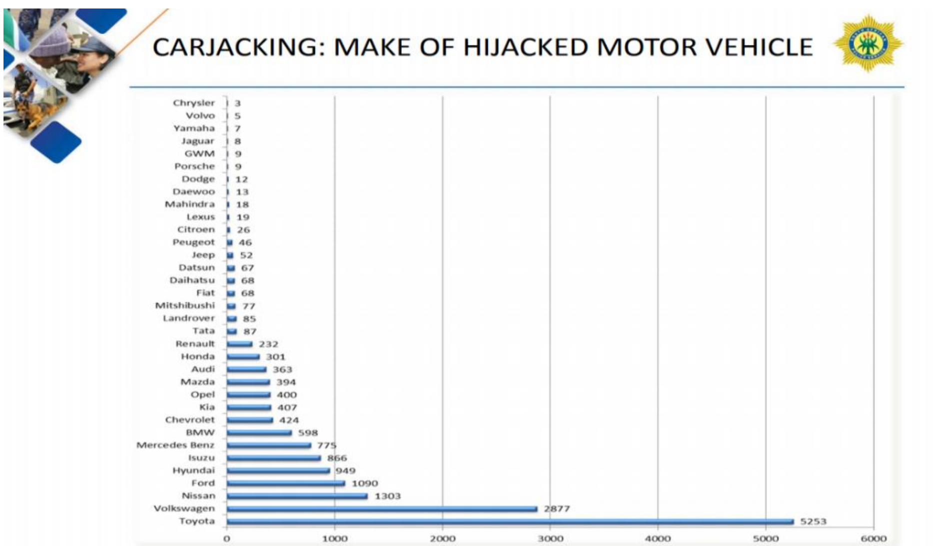

Figure 1.2: Shows the cases of car hijacking in South Africa.

another device in order to view the location of the vehicle. Furthermore, the owners of the vehicles do not have full access or control over the tracking of their own vehicles. They must go to a third-party company in order to access the tracking information of the vehicle. This introduces a delay in the tracking process. In the event of theft, the car hijackers will be afforded ample time to escape with the vehicle. Henceforth, the need to give the car owner remote control of the vehicle's engine.

With the world moving towards green cars at a fast pace, it is important that any vehicle security and tracking systems be applicable to electric vehicles (EV). Electric vehicles mainly use five different types of electric motors: the brushless direct current motor (BLDC), permanent magnet synchronous motor (PMSM), alternating current induction motor (ACIM), interior permanent magnet motor (IPMM), and permanent magnet switched reluctance motor (PMSRM). However, according to Hashemnia and Asaei [8], BLDC motors have much more benefits when it comes to EV applications. Some of the benefits include less pollution, less fuel consumption and high power to volume ratio [8]. Ghosh et. al [9] defined a brushless motor as a permanent magnet synchronous electrical machine driven by direct current. According to Gao and Liu [10], in conventional DC motors, commutation is achieved using electro-brushes, while Brushless DC motors use electronic commutation as to replace the electro-brushes in normal DC motors. The absence of the brushes means the motor requires lesser maintenance as compared to the brushed DC motor. According to Priya et. al [11], other benefits of using a BLDC motor also include; high torque-current ratio, good dynamic response and reduced noise levels. Moreover, when it comes to EVs, the emphasis is on reducing pollution while maintaining high levels of efficiency, which the BLDC motors can do. In this project, emphasis is put on how the BLDC motor can be controlled remotely hence controlling the state of the engine remotely.

1.2 Problem Definition

The increase in the number of vehicles in many African countries has come at a cost of more vehicle theft cases. One of the main reasons why this is so is that most cars on the continent are lower end cars which means they are less likely to have any tracking or advanced security systems such as remote control of the car's engine. Furthermore, Wi-Fi connectivity is not as widespread on the continent of Africa as it is in other continents which makes most tracking systems inapplicable to the African context. The goal of this project is to design and implement a low cost anti-theft vehicle tracking system. The system should be able to track the vehicle and prevent car hijackers from escaping with the car, in the event of theft, by locking the engine.

1.3 Motivation

The motivation of the project is to reduce the occurrences of vehicle theft and make vehicle tracking accessible and affordable to an average African car owner, taking into consideration the future of automobiles.

1.4 Project Objectives

1. Design a GPS-GSM/GPRS based vehicle tracking system.
2. Design an anti-theft system to add to the tracking device.
3. Minimize the cost of operating the system.
4. Reduce cases of vehicle theft.

1.5 Scope of Work

This project is limited to GPS-GSM system interfaced with a microcontroller, and an anti-theft mechanism that locks a vehicle's engine remotely. The systems also have connection to a remote server connected to a MySQL database.

1.6 Project Organization

This project consists of five chapters. The first chapter gives the general overview of the project through discussing the background of vehicle tracking systems, vehicle security systems as well as electric motors used in electric vehicles. The first chapter also discusses the motivation for carrying out the project, project scope, and the objectives of the project. The second chapter explores related work on vehicle tracking systems as well as anti-theft mechanisms used in vehicles. The chapter discusses the different technologies used in tracking vehicles as well as the advantages and disadvantages of each. Chapter 3 details the step-by-step process of designing the proposed system. At the end of chapter 3, the subsystems are integrated into one large system containing all the subsystems discussed in prior sub chapters. Chapter 4 deals with results obtained from carrying out the project. Lastly, chapter five concludes the work as well as discussing limitations of the project and future works.

Chapter 2: Literature Review

2.1 Vehicle Tracking Systems Related Works

Due to the increase in the number of vehicles stolen [12], a lot of work has been done in order to help companies and individuals track their vehicles. From the literature, the basic architecture of tracking systems comprises a coordinates receiver, a microcontroller to process the coordinates and a wireless communication protocol that transmits data received from the receiver to a remote server or user. However, the technologies used in each of the works differs and they all have advantages and disadvantages. Furthermore, not much work has been done on integrating security systems on the vehicle tracking systems. The following are some of the most popular tracking technologies found in literature.

2.1.1 GPS-GSM/GPRS Vehicle Tracking Systems

A system for fleet management and monitoring drivers was proposed in [1]. The GPS sensor obtains the coordinates of the location of the vehicle and sends it to a mobile and a web application via GPRS. The system in [1] also monitors the speed of the vehicle and sends an SMS to the owner of the vehicle in the event that the speed limit is exceeded. The advantage of this system over the other systems in literature, is that the SMS is only sent when necessary which significantly reduces the cost taken by the SMS subsystem, however, the use of GPRS to continuously update the location of the vehicle significantly increases the cost of operating the whole system. The major drawback of the system, with respect to the problem being tackled in this project, is the lack of a security mechanism. The system only allows the location of the vehicle to be accessed but nothing else can be done if the vehicle is stolen except knowing where it is. Contrary to sending messages only when necessary, Rashed et. al [13] opted for a continuous real time tracking, together with a mechanism to lock the vehicle's location and alert the owner if it has been moved. Aside from the huge cost incurred in sending SMSs continuously, the system also lacks a robust security system. Just like in [1], the system in [13] does not allow the user to lock the vehicle in the event of theft; it only alerts the owner that his car has been moved from its parked space. Similar designs were implemented in [5] [14] [15]. The major drawbacks with the GPS-GSM/GPRS systems found in literature are the high cost of operation, and a lack of a security system that allows the vehicle owner freedom to independently track and remotely control his car. The goal of this project is to fill that gap with a robust, but flexible anti-theft low cost vehicle tracking system.

2.1.2 GPS-Zigbee Vehicle Tracking Systems

Ibraheem and Hadi [2], proposed a low-cost tracking system that utilizes GPS to receive coordinates from the satellites in space. The authors used the wireless technology, Zigbee, to relay information from the main tracking device to a remote server. The reasons for choosing

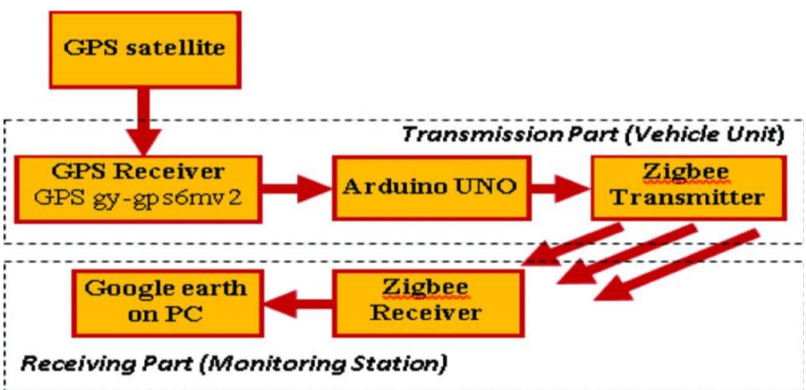

Figure 2.1: block diagram of a GPS-Zigbee tracking system

Zigbee include high level security, penetration avoidance and the cost of the technology in sending and receiving information [2]. Zigbee is also advantageous because of its mesh topology, which provides a higher reliability. An Arduino was used as a microcontroller. According to Sudharsan and Katta [16], The challenges associated with the Zigbee technology are the low data rate (20 kbps to 250 kbps) and the short range (300 Ft to 400 Miles) of communication. Figure 2.1 shows the block diagram of the vehicle tracking system proposed in [2]. Other key features of the Zigbee wireless technology are operating frequency flexibility (2.4 GHz, 915 MHz or 868 MHz) and topology flexibility: it can operate in the star, mesh or tree topology [2].

2.1.3 RFID Based Tracking System

Pandit, Talreja et. al [17], presented a novel vehicle tracking system using Radio Frequency Identification (RFID). The aim of the authors was to address the problems of traffic signals timings, traffic congestion and theft of vehicles. Solutions to all these problems were presented. All car owners are registered into a central database which stores the track log of the users' vehicles. Each vehicle is mounted with an RFID tag and the there are several RFID readers across the road network. Figure 2.2 shows the architecture of an RFID based vehicle

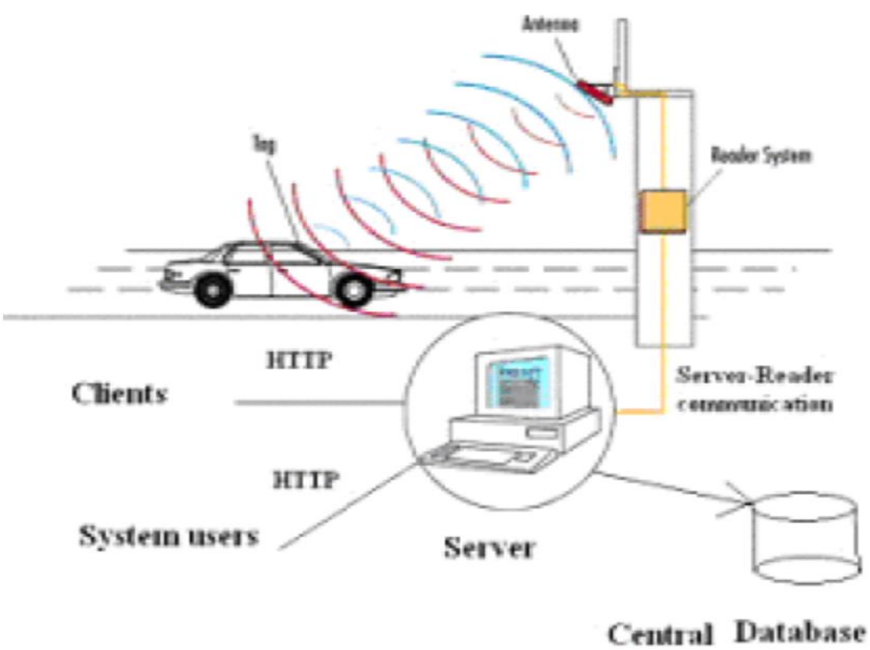

Figure 2.2: RFID based tracking architecture

tracking system as suggested by Pandit, Talreja et. al [17]. The vehicle's location is based on the location of the latest RFID reader that was used to scan the RFID tag on the vehicle. Although the system suggested by Pandit, Talreja et. al [17], is novel, it has some limitations. One of the limitations is the range of the RFID communication protocol which is only up to a few kilometers. Consequently, the number of the readers that would be required to implement the tracking system would be large which would make the whole system expensive, at least for the tracking functionality. However, because the RFID readers are preinstalled with an accurate location, it means the system is accurate in terms of determining the position of the vehicle, if the vehicle is close to the reader. But another problem also arises from this because once the vehicle is not close to the reader then there is no way to determine its position unless it approaches another reader. The system is meant to track the location of the vehicle in real time, however, some of the times the vehicle's location is not known.

2.2 GSM/GPRS Working Principle

2.2.1 GSM Network Operation

GSM is the acronym for Global System for Mobile Communication. GPRS stands for General Packet Radio Service. GSM is a wireless communication standard for mobile telephone systems [18]. GSM is often referred to as 2nd Generation (2G) because it was first deployed as a replacement to the 1ST Generation Analog Network. The GPRS is an extension of the GSM network. It provides an efficient way to transfer data with the same resources as the GSM network [12]. According to Parvez et. al [5], in GSM topology, there are many base stations called Base Transceiver Stations (BTS). Each BTS serves a specific area. The areas are divided into honeycomb like structures, each of them is called a cell and it is hexagonal in shape. Each BTS serves three of the hexagonal cells. Each is designed to use one or more radio frequencies which means the BTS can handle more than one frequency. To control the frequencies being used by the numerous transceivers, a BSC is used. The purpose of the BSC is to provide physical

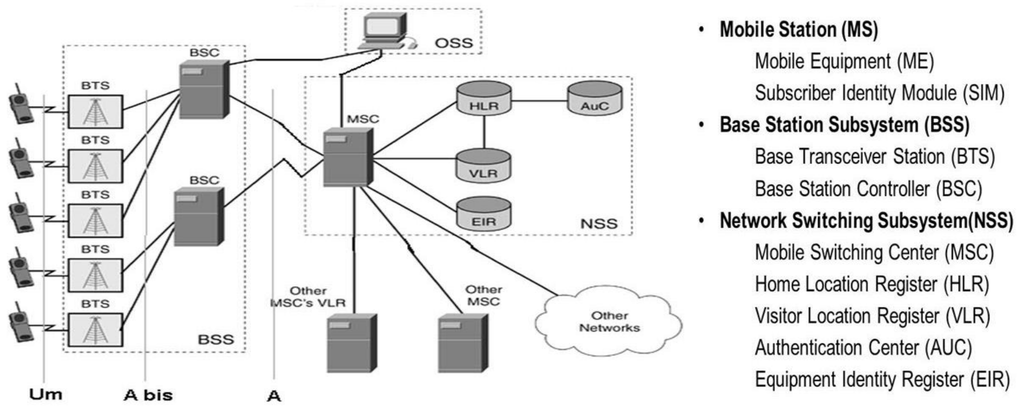

Figure 2.3: GSM Basic Architecture

links between the MSSC (Mobile Services Switching Center) and the BTS. Figure 2.3 shows the basic architecture and topology of a GSM system. Parvez et. al [5] also explained how GSM uses radio transmission. The GSM system uses up to 25MHz frequency bands (890-915MHz and 935-960MHz). These two bands are divided into 124 pairs of duplex channels with 200kHz carrier spacing using Frequency Division Multiple Access (FDMA). The transmission bit rate is 271 kbps and the data bursts are transmitted using Time Division Multiple Access (TDMA). There are numerous BTS systems in Ghana and Africa covering huge square meters which makes it possible for cellular networks to be used in various applications such as vehicle tracking. Cellular networks offer flexible connectivity and go far and wide that is why they were chosen for this project.

2.3 GPS System Working Principle

According to Wahab et. al [19], the Global Positioning System (GPS) is a satellite defense navigation system initiated and developed by the U.S department of Defense. The GPS system is made up of 24 satellites. 21 of the satellites are in active use all the time and three are used as spare satellites to replace a damaged satellite. The GPS receiver can track up to 10 satellites. Once the receiver is connected to satellite it locks it. If the locked onto satellite goes out of range, the GPS receiver quickly switches to a different satellite. As explained by Wahab et. al [19], The GPS receiver uses a principle known as trilateration to determine the location on earth. Figure 2.4 illustrates the process used to determine the position of a receiver (P) by three satellites (A, B and C). The transmitter A sends a radio signal which is picked by the receiver anywhere around satellite's A radius. Then satellite B detects the same receiver which

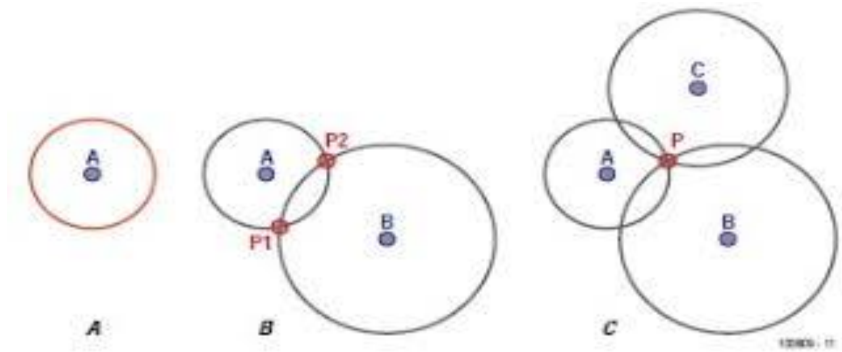

Figure 2.4: GPS trilateration

can be anywhere around B. However, it is the same receiver detected by A which narrows the possibilities to two positions (P1 and P2). If another transmitter C detects the receiver then the position of the receiver can only be P which is the accurate position of the receiver with respect to the three satellites. The distance between the receiver and each of the satellites can be obtained using equation 2.1, where the time lapse is the time between transmitting a signal from a satellite to the receiver. Since the wave being transmitted is an electromagnet wave, the speed of the wave is the same as the speed of light.

$$s = c.t \tag{2.1}$$

Where:

s = distance

c = speed of light

t = time lapse

2.3.1 Geofencing

According to Reclus and Drouard [20],geofencing is a technology used to virtually fence a specific area using geographic coordinates obtained from, in most cases, GPS sensor. The virtual boundary is known as a geofence. This geofence is used to monitor specific objects when they enter or leave the predetermined boundary. Figure 2.5 shows a geofencing example as illustrated by Reclus and Drouard [20]. The dotted line shows the geofence while the circles show the radius of the vehicle that is violating (entering/leaving) the geofence. Applications of geofencing include Transport and Logistics, defense and security, and fleet management. According to Jawade and Goyal [21] there are two main algorithms used in geofencing: Nearest Geofence; which is based on calculating the distance between the object being tracked and the nearest geofence. The second algorithm involves any good functional searching algorithm, for examples the binary search algorithm. Geofencing is important in this project because it helps

Figure 2.5: geofencing example

in reducing the operation costs of the device. Geofencing allows the system to only contact the vehicle owner if his vehicle is leaving the geofence.

Chapter 3: System Design and Methodology

3.1 System Overview

The system is divided mainly into two parts, namely; hardware and software. The hardware comprises the GPS subsystem, the GSM subsystem and the motor control subsystem. The software part comprises a web application which is hosted on the Ashesi Engineering Server, and a microcontroller program. Figure 3.1 shows the overall block diagram of the

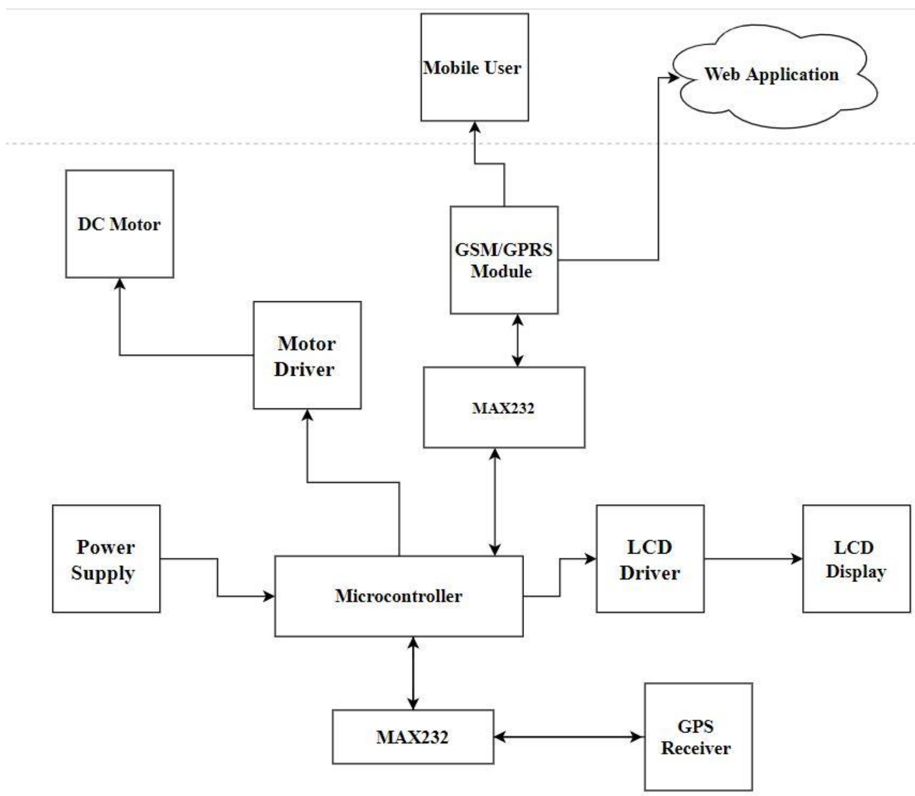

Figure 3.1: Block diagram of the overall system

system. The GPS receiver receives the location of the vehicle and sends the information to a MAX232 which converts the information into TTL logic which the microcontroller can understand. The microcontroller then sends the information to the GSM/GPRS module which processes the data to be send to the owner of the car or to the database to display the location of the vehicle on an electronic map. The user can also control the motor using a text message.

The information of the vehicle is displayed on an LCD which is also controlled by the microcontroller. The rest of the chapter explains in detail the design process.

3.1.1 Design Specifications

1. The tracking device should accurately determine the location of the vehicle using geo-satellites.
2. The tracking device should be able to communicate with the user wirelessly.
3. When a cellular network is available, the system should transmit the location data to the user.
4. The tracking device should get power from the vehicle.
5. The owner of the vehicle must be able to lock the vehicle's engine remotely.
6. Tracking of the vehicle should only be done if necessary.

3.1.2 Design Requirements

- The tracking device should communicate with the user using SMS.
- The system should have some internal memory, which allows it to store some data if the network is not available.
- The system should also be able to fetch information from the internal memory and then sent it to the server using an SMS
- The system should have a GPS sensor that accurately determines the location of the vehicle.

3.2 Boot Loading the Microcontroller

The first thing done in this project was to boot load the microcontroller (Atmega328P). The Atmega328P was selected because of its relatively high memory (32kb) at a small cost. According to the Atmega328P datasheet [22], some of these microcontrollers come boot loaded already, especially the ones that have a P in the name like the one used in this project. To test whether the microcontroller being used was boot loaded, an Arduino program (blink) was uploaded to the microcontroller. An LED was connected to pin number 19 of the microcontroller, which is wired to pin number 13 of the Arduino, the LED, however, did not blink. This result showed that the microcontroller which was procured for the purpose of this project was not boot loaded therefore it needed to be boot loaded in order to be used for this project. Figure 3.2 shows the pin layout of the microcontroller used in this project. Once it was

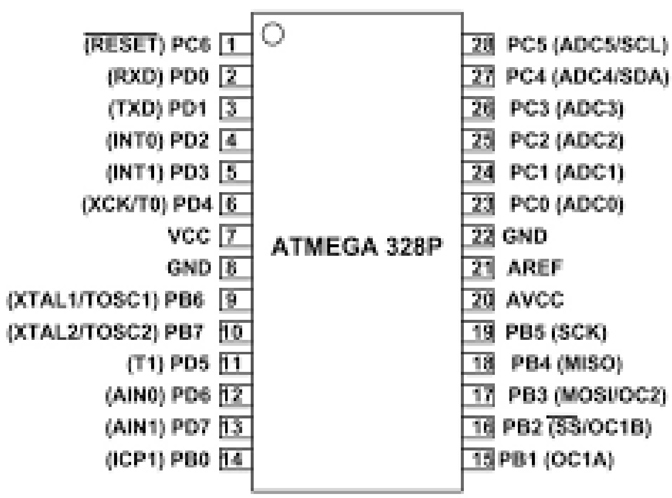

Figure 3.2: Atmega328P pin layout

established that the microcontroller was not boot loaded, the first step to the whole project was to boot load the microcontroller. First an Arduino was connected to a PC, it was then configured to work as an ISP. To make the Arduino work as an ISP, the ArduinoISP program was uploaded to the Arduino Uno. To make sure that the Arduino was working as an ISP successfully, an LED was connected to pin number 9 of the Arduino. If the Arduino, is working as an ISP, the

LED connected to pin number 9 would blink slowly showing the Arduino is working correctly as an ISP. The next step now is to boot load the microcontroller using Arduino Uno as an ISP. Pin 7 (VCC) of the microcontroller is connected to 5V and the pin 8 is connected to the ground. As shown in Figure 3.3, pin 7 of the microcontroller is the VCC pin and the pin 8 is the GND pin. AVCC of the microcontroller is connected to the 5V. then another ground pin (pin 22) is connected to ground. Now a 10k resistor is connected to the RESET pin. The other leg of the resistor is connected to the ground. An oscillator was then connected to XTAL1 and XTAL2. An external oscillator was connected to this microcontroller because the microcontroller does not have an internal oscillator, according to the datasheet [22]. Also, two 22 pF capacitors were connected to ground from the two oscillator pins (9 and 10). From Arduino pin 10 was then

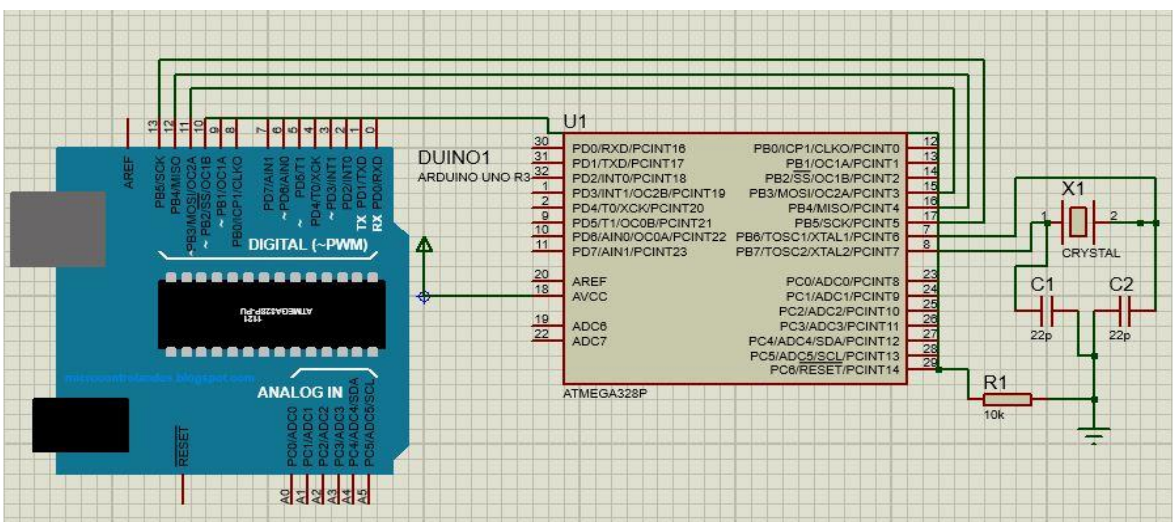

Figure 3.3: Atmega328P boot loading circuit

connected to pin1 of the microcontroller. Pin11 of the Arduino Uno was connected to MOSI pin of the microcontroller. Pin12 of the Arduino was connected to MISO pin of the microcontroller. Lastly pin13 of the Arduino Uno was connected to SCK pin of the microcontroller. When all the connections were made, the Arduino board was connected to the

PC. The last step is to burn the bootloader program in Arduino. Figure 3.3 shows the circuit schematics used to boot load the ATmega328P. After the boot loader has been burned, it means the microcontroller is ready for use. Before proceeding to the next stage of the project, the microcontroller must be tested if the boot loading process was successful. To test if the boot loading was successful, the Arduino blink code should be uploaded to the microcontroller. However, some of the pins connected during the boot loading process should be disconnected otherwise the microcontroller would be damaged. From the microcontroller, pin 1, 17,18, and 19 will be disconnected. These pins were connected to pin 10-13 of the Arduino which were also removed. The next step is to upload the blink code onto the microcontroller. However, before this step is achieved, the microcontroller on the Arduino Uno is removed. The pin1 of the boot loaded microcontroller (Atmega328) is connected to the reset pin of the Arduino board. The VCC pins of the Atmega328 are connected to the VCC pin of the Arduino board. Same with the ground pins. Pin3 of the Atmega328 is connected to pin1 of the Arduino board. Pin0 of the Arduino Uno is connected to pin2 of Atmega328. After these connections, the Atmega328 (boot loaded) now acts as the microcontroller to Arduino board. The anode of the LED is then connected to pin19 of the Atmega328. After the connections were made, the LED was observed to blink, confirming that the boot loading process was successful. The microcontroller is now ready to be used in this project.

3.3 GPS Subsystem Design

The high-level view of the subsystem is shown in Figure 3.5. The GPS receiver (Ublox NEO-6M) receives coordinates in the form of RF waves from outer space then sends the coordinates to the MAX232 for logic level conversion. For this project, GPS receiver with 1Hz position update rate and a start time of, at most, one minute is required so that the module can quickly update the position as soon it is turned on. The GPS is also supposed to be able to sense the position indoors. Furthermore, the GPS receiver should have a configurable baud rate for easy configuration with the microcontroller. The Ublox NEO-6M meets all the requirements at a low cost. The microcontroller (Atmega328P) processes information from the receiver and sends to the LCD to be displayed.

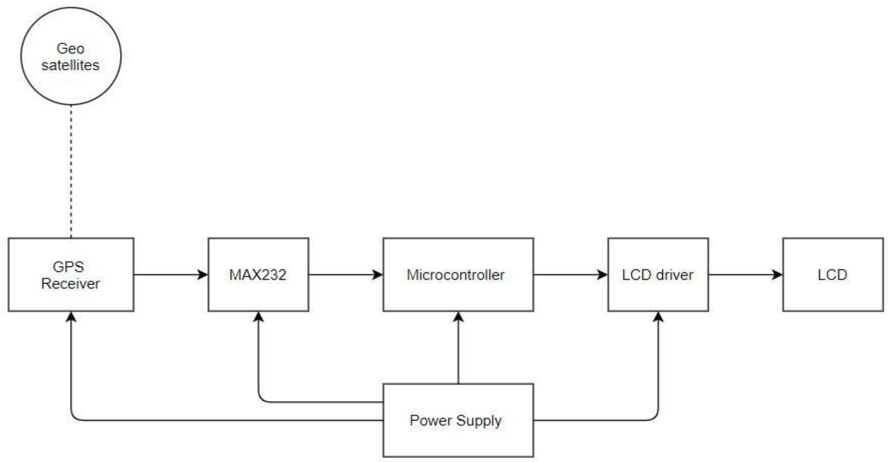

Figure 3.4: GPS system block diagram

3.3.1 The GPS Circuit

As explained earlier, the GPS system is made up of four major elements; the GPS receiver, the microcontroller, the power supply and an LCD that displays the coordinates. To establish connection between the microcontroller and the GPS module, the transmitting pin (TXD) of the GPS module is connected to the receiving pin (RXD) of the microcontroller. In older microcontrollers, pull up resistors would be required to avoid a phenomenon known as floating. Floating is a phenomenon whereby one of the pins on the microcontroller is configured as an input; when nothing is connected to the pin, the microcontroller will have difficulties determining the state of the pin. However, in this circuit, no pull up resistors are required, as the microcontroller has in-built pull-up pins.

The microcontroller, the LCD, and the GPS module all require power, therefore, there is need to provide power to all the components. The LCD and the microcontroller will be connected to the 5v supply represented by an arrow facing up in Figure 3.6. The GPS system used in the circuit diagram does not show all the pins that are found on the actual GPS module. There is a VCC pin and a GND pin. The VCC pin will be connected to 3.3V according to the datasheet of the GPS module used in this project [23]. In order to reset the whole system, a reset button is connected to pin 9 of the microcontroller. The data lines (D4-D7) of the LCD screen are connected to PC4-PC7 pins in port C of the microcontroller. R/W, RS and enable (E) of the LCD are connected to PD6 PC2 and PC3 of IC2. **Error! Reference source not found.** shows the full design of the GPS system without the power supply. A potentiometer is connected to the VSS pin of the LCD to adjust the contrast of the display. When the GPS receiver begins to

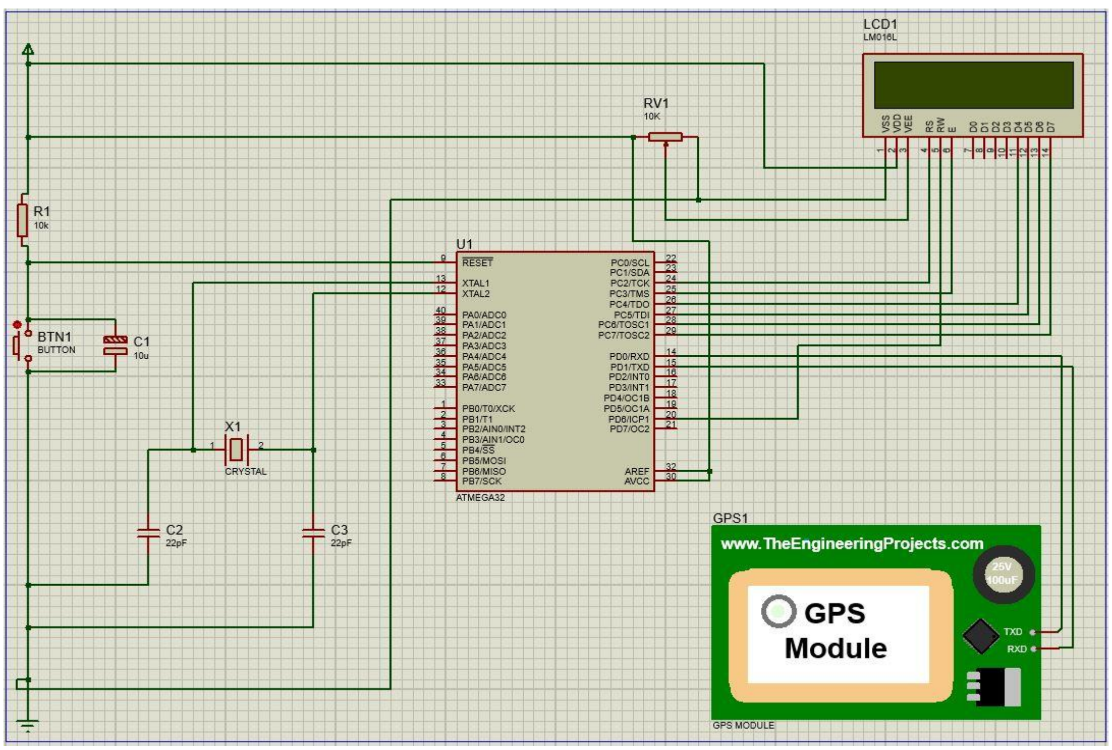

Figure 3.6: GPS circuit design

receive coordinates, a red LED built on the module blinks every second, which means the coordinates are ready to be processed. In this project, the MAX232 is not discussed because it is inbuilt in the Ublox NEO-6M.

3.4 GSM System Design

3.4.1 The GSM System Block Diagram

The GSM system mainly consist of GSM modem and a microcontroller. The GSM module used in this project (SIM800L) has an inbuilt logic converter hence there is no need to discuss the connections with the MAX232. The GSM module receives SMSs from the mobile

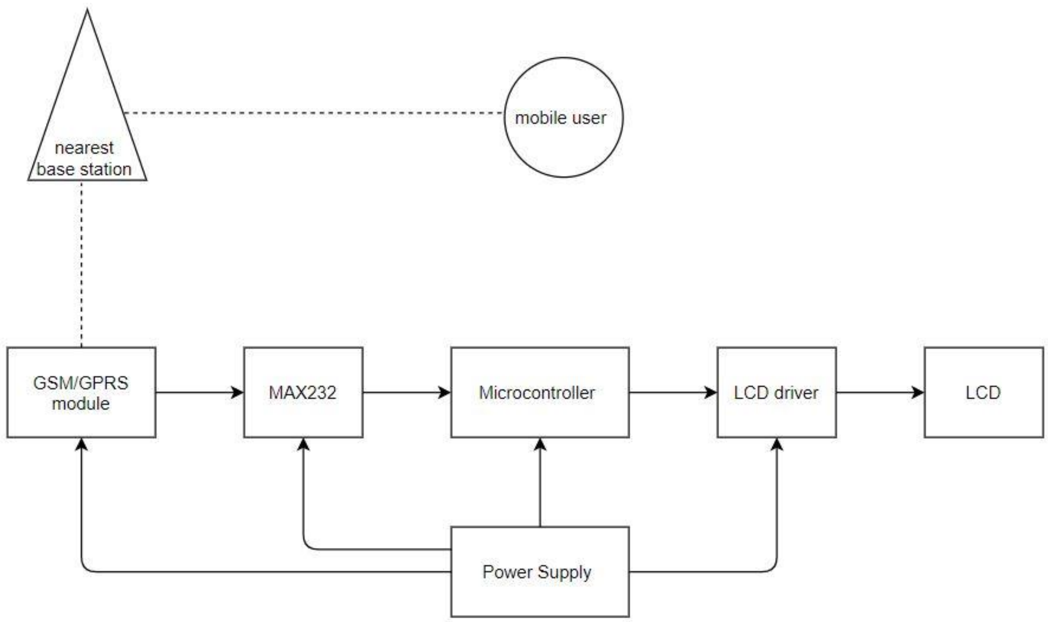

Figure 3.7: GSM design block diagram

user via the nearest base station. The information is then serially sent to the microcontroller, which processes the information. If there is need, a message is processed and sent back to the user, for example, when the user requests the location of the vehicle; the system sends back coordinates to the user via the nearest base station. Figure 3.7 shows the block diagram of the GSM subsystem.

3.4.2 The GSM Subsystem Circuit Diagram

Error! Reference source not found. below shows the circuit schematics for the GSM system of the project. The GSM module used in the circuit is the SIM900D as the software does not have the module used in this project; neither its external modules nor the inbuilt library. However, the two modules function in the same way. The VCC pin of the GSM module is connected to the 4.4V from the power supply. The GND pin is connected to the GND pin of

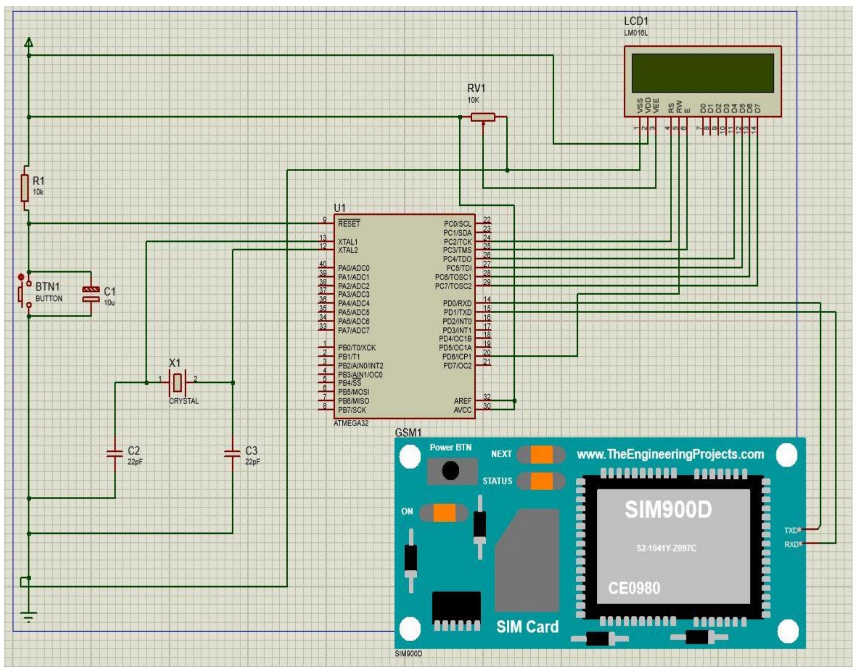

Figure 3.8: GSM circuit design

the power supply. The TXD pin is connected to pin16 (PB2) of the microcontroller and the RXD to pin17 (PB3). When all the connections are done, and the GSM module is connected to a base station, it should blink once every three seconds. If it blinks faster, it means it is still trying to establish connection.

3.5 Power Supply

The different parts of the system require a DC power supply. However, the power available is AC therefore, the power needs to be regulated to supply the small DC voltages required by the different components. The GSM (SIM800L) module used in this project requires 4.4V, both the microcontroller and the LCD require 5V, and the GPS receiver requires a 3.3V. Also, the BLDC motor used in this project requires 12V. A power supply that caters for all these constraints is designed in this section of the paper .The power supply is shown in Figure 3.9.

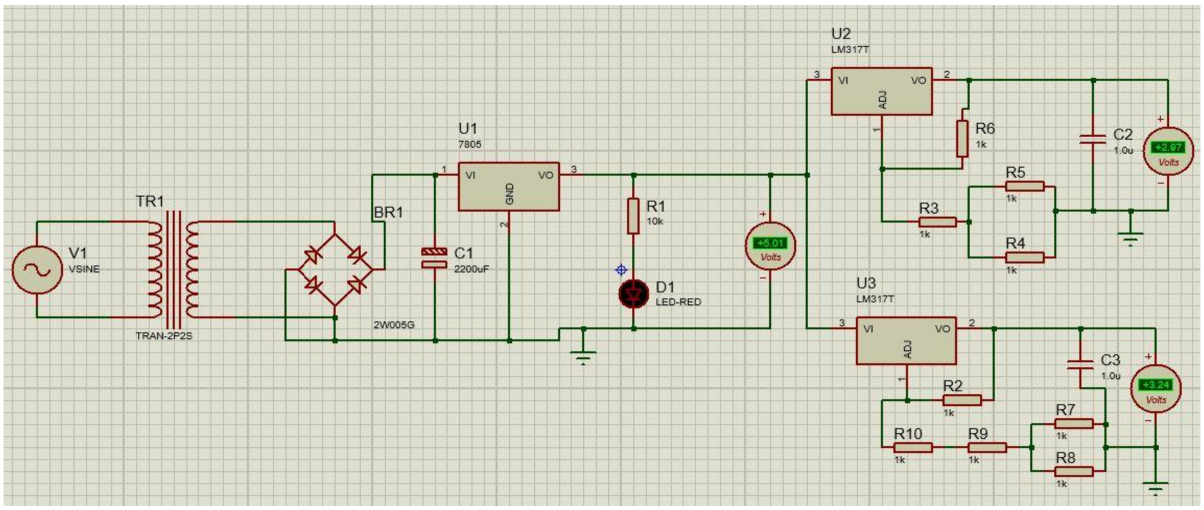

Figure 3.9: 5v power supply

The power input is 230V at 50 Hz. First, this power input must be stepped down to a lower voltage. In this project, 230/12V step down transformer will be used. The 12V obtained from the step-down transformer is then sent to a full wave bridge rectifier. However, the voltage that is obtained from the rectifier is still not smooth. A capacitor is added to smoothen the output voltage. After smoothening, the output voltage is a constant 12v DC. Then a 5v voltage regulator is added to make sure there is a constant supply of 5v. Equation (3.1) was used to calculate the size of the capacitor required to smoothen the voltage. The goal is to minimize V_r thus smoothening the output voltage. R_L is the resistance of the load.

$$C = \frac{V_{in}}{V_r R_L} \times \Delta t \qquad (3.1)$$

Where:

V_{in} = is the input voltage (12V).

V_r = is the ripple voltage (0.05V).

R_L = is the resistance of the load (10kΩ).

$C =$ is the capacitor size, in Farads.

$\Delta t =$ time-lapse between two successive peaks.

To obtain the 3.3V and the 4.4V required by the GPS receiver and the GSM module respectively Equation (3.2) was used. R_2 is the value to be selected in order to obtain the right V_{out}.

$$R_2 = R_1(\frac{V_{out}}{1.25} - 1) \tag{3.2}$$

Where:

$R_1 =$ is constant resistance value (220Ω).

V_{out} = the output voltage (3.3V or 4.4V).

$R_2 =$ value of resistance to be obtained.

3.6 The BLDC Motor Control System

3.6.1 The Block Diagram

A DC motor cannot be connected directly to the microcontroller because of the following reasons:

1. The microcontroller cannot supply the right amount of current required to run the motor.
2. The back EMF generated in the motor may cause some damage to the microcontroller.
3. In applications where the direction of the motor must be reversed, the microcontroller cannot switch the polarity of the power doing to the motor.

4. The microcontroller does not provide enough voltage to the motor.

To cater for all these constraints, a motor driver is used as an interface between the microcontroller and the motor. In this project, the L293D motor driver as the interface between

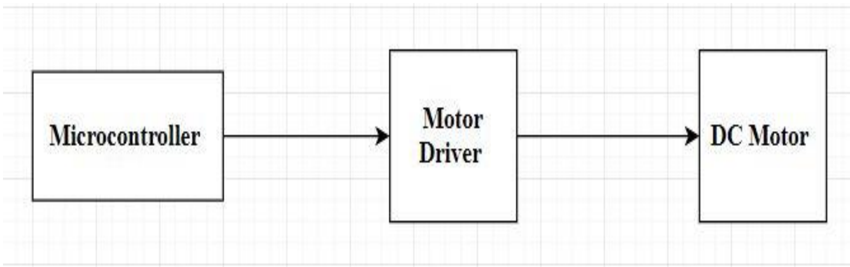

Figure 3.10: motor control block diagram

the microcontroller and the dc motor. The L293D does not need any extra components like transistor, resistors or freewheeling diodes.

3.6.2 The Circuit.

The L293D contains four half H Bridge drivers and are enabled in pairs. The EN1 is used to enable the pair (IN1-OUT1), EN2 used the other pair. In this project, the focus is only

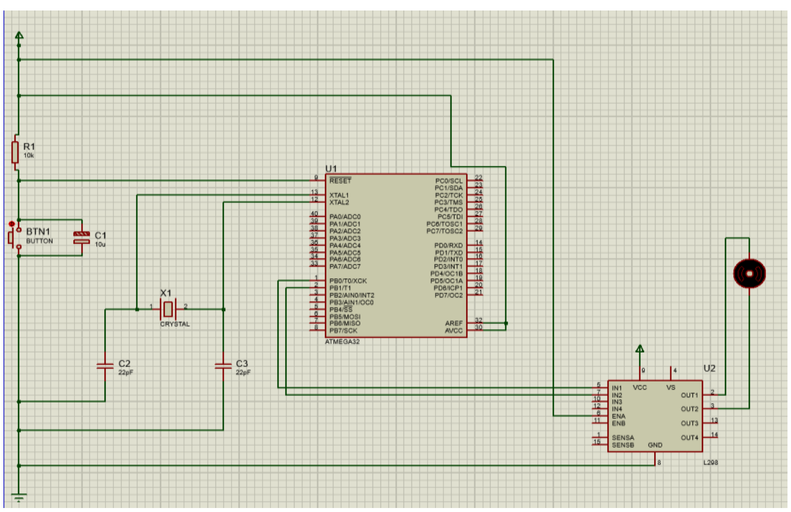

Figure 3.11: motor control circuit

on one pair since the project deals with only one motor. The PWM pins (both forward and reverse) are always at 255 since the speed of the motor is not being controlled. In this project, the focus is on turning the motor ON/OFF, which is achieved by activating/deactivating EN1. The EN1 is connected to the pin PB1 and IN1 and IN2 are connected to PD5 and PD6 respectively, both PWM pins set to 255 for maximum power when the motor is enabled. The microcontroller is connected to the 5v supply and the 12v of the motor driver is connected 12v power supply. Figure 3.11 shows the full circuit design of the motor control system circuit.

3.7 Overall Circuit

Figure 3.12 shows the full circuit schematics of the project. The LCD and the microcontroller get the power from the 5v output of the power supply. The DC motor is

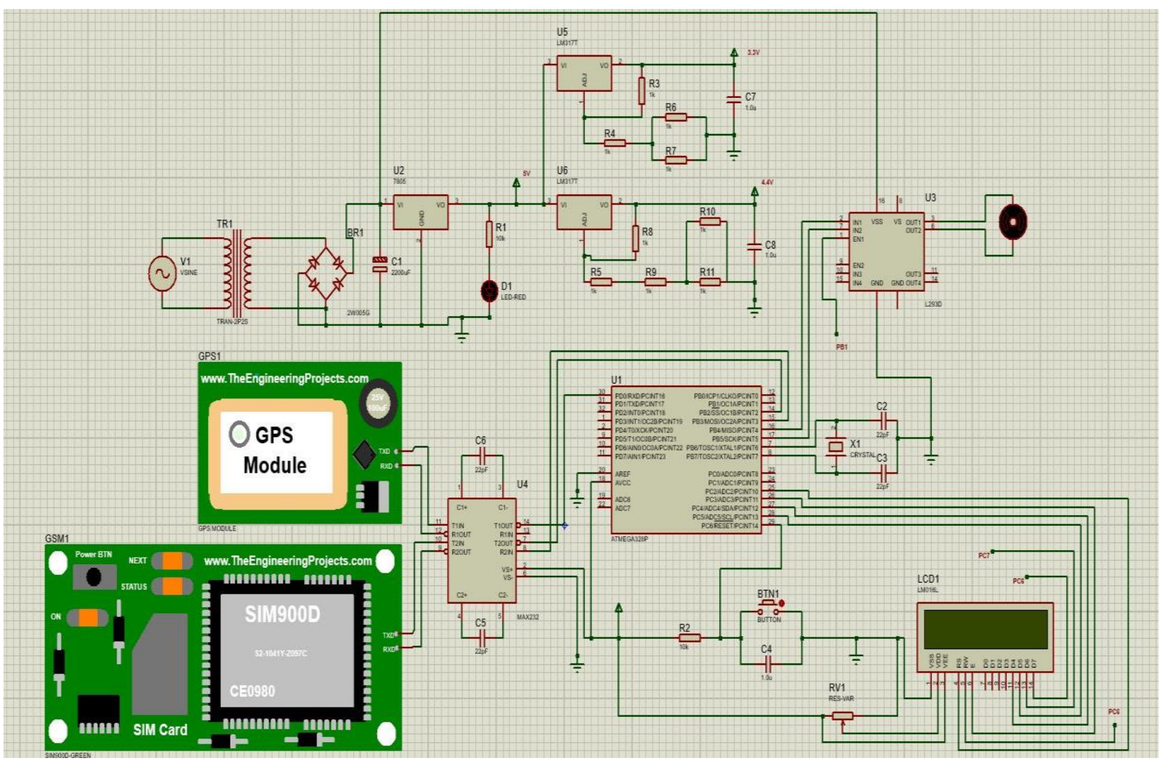

Figure 3.12: full project circuit

connected to the 12v supply output. The capacitor connected across the 12v output of the main power supply just before the 7805-voltage regulator makes sure that the power supplied to the

DC motor is constant. Not all pins could be joined because of the complexity of the circuit and unavailability of some pin on the modules. Multiple GND were also introduced to avoid wires tangling up, but they all represent the same ground connection. Other connections are shown with a dot and a label showing where the wire should have been connected. Arrows pointing upwards were used to show a connection to 5V, 3.3V and 4.4V. Theses arrows are labeled showing which power supply each arrow is pointing to.

3.8 The Software Design

3.8.1 Overview

The software design for this project was divided into microcontroller program and web application. The microcontroller program was the Arduino code that was loaded onto the microcontroller and the web application is the site that was used to display the position of the car using an electronic map. The Arduino idle was used to boot load the microcontroller. The web application was be programmed using PHP, HTML and CSS. The database used for this project is a MySQL database. The web application was hosted on the Ashesi Engineering Server.

3.8.2 Microcontroller Program

When the engine is started, the system is powered and the program on the microcontroller starts. When the device is powered, both the GPS sensor and the GSM module are initialized. If the GPS system is initialized, the system checks the GPS serial port, to read the information sent by the GPS receiver. The GPS sensor sends data to the microcontroller at a rate of 5Hz in the form of sentences. If the sentence contains the coordinates, the system then checks if the coordinates are within the geofence setup in the software. To set up the geofence, the GPS sensor is used to obtain the coordinates at the user's home or work. These coordinates are then used to create a virtual boundary which is around the home/workplace of a radius of 10km. If the coordinates obtained from the GPS sensor are outside the geofence, the coordinates are packaged into a URL which will be sent as a text message to the owner of the vehicle. The owner of the vehicles can then click on the URL to view the location of the vehicle on the web application.

After the GSM module is initialized the AT command, “AT + CSQ” to check the signal strength. The signal strength ranges from 0-31 [24]. However, a signal strength of above 10 is

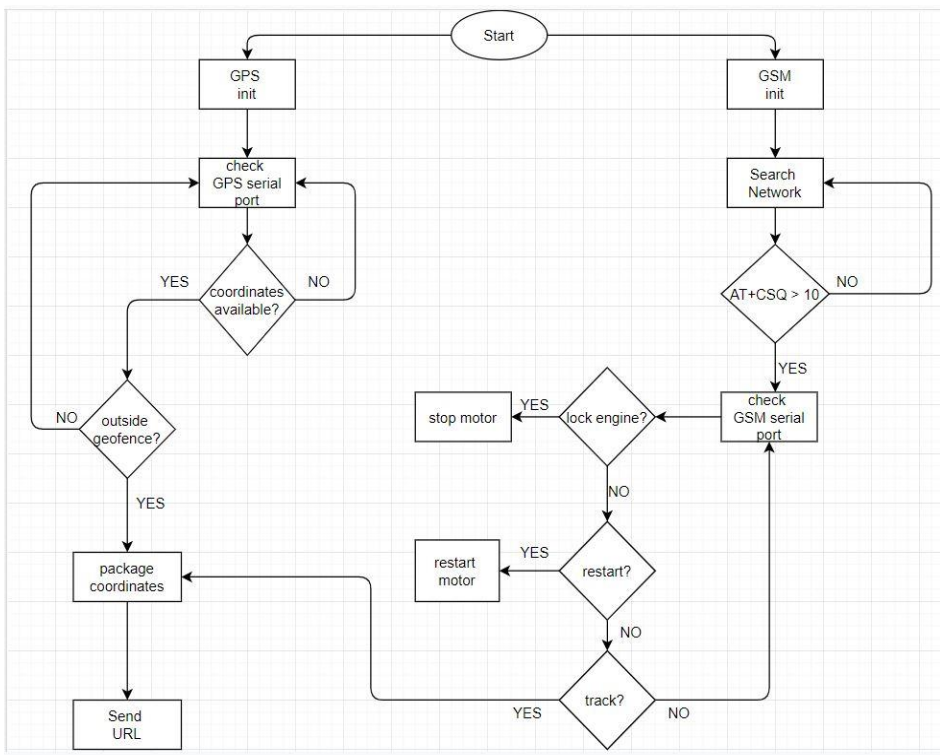

Figure 3.13: Atmega328P program

enough to send a text message, just that it draws more power [24]. If the signal strength is above 10, the system checks for a message in the SIM800L serial port. If the message is lock engine, the system sends a signal to turn of the vehicle’s engine. The vehicle’s engine is turned on by an AND logic, if there is no message to turn off the engine the signal from the microcontroller is always high so that when the ignition key is turned on the car can start. On the other hand, if the message to lock the engine is received one of the input for the AND logic becomes low which implies that even if the ignition key is turned on the car will not start. In such a case the car can only be turned on by a restart text message from the user. The restart message switches the microcontroller input of the AND logic ON, which means; when the ignition key is turned on the car can restart. Figure 3.13 shows the flow chart for the program described above for the microcontroller.

3.8.3 Web Application

An SQL database to keep the coordinates was designed and hosted on the engineering server. The database has four columns: Data ID for uniquely identifying each of the entries to the database. The second column is for the latitude, longitude will be stored in the third column. The last column is for the timestamp that will record the time for each database entry. A google Maps API is added to the web application to display the location of the vehicle on to the map. The web application also has PHP files. The first file is an index page, which can also be referred to as login page. When this page is accessed using an HTTP request, the page displayed shows a form for the user to input his login details. If the login details are correct, the next page (*last_position.php*) displays the last recorded location of the vehicle by making a database query to get the latest recorded latitude and longitude and display these on an electronic map. In the event that system sends the user a URL via SMS, the URL is an HTTP GET request which displays the current position of the vehicle on the electronic map.

Chapter 4: Results and Discussion

4.1 Chapter Overview

This chapter discusses the results of testing the subsystems designed in the previous chapter. At the end of the chapter, the integrated system is tested as one whole system.

4.2 GPS System

In this project, the RX of the GPS module is connected to nothing since this module is only used as a receiver of the geographic location, rather the TX pin is connected to the RX pin of the microcontroller. When the module receives the coordinates, they are sent to the microcontroller through the TX pin of the module which is connected to the RX pin of the

Figure 4.1: empty sketch uploaded.

microcontroller. An empty Arduino program was uploaded onto the Arduino board in order to access the serial monitor. Figure 4.1 shows the Arduino sketch uploaded on to the board in order to access the serial monitor of the software. It was also observed that the Arduino program could not be uploaded onto the program unless the RX pin was not connected to anything. This is because when the code is being loaded onto the Arduino, the RX pin is used by the serial communication, therefore the code cannot be uploaded unless the RX pin is not connected to anything. After disconnecting the TX pin of the module, which was connected to the RX pin,

```
COM9

$GPGSV,4,1,13,08,03,288,,10,52,124,21,11,08,251,19,14,17,191,17*7F
$GPGSV,4,2,13,16,28,342,38,18,04,033,,20,44,074,26,21,22,026,30*72
$GPGSV,4,3,13,25,14,125,20,26,54,003,33,27,18,314,28,31,57,216,26*7D
$GPGSV,4,4,13,32,15,166,07*48
$GPGLL,0539.10362,N,00001.31852,W,173144.00,A,A*7A
$GPRMC,173145.00,A,0539.10377,N,00001.31845,W,0.583,,260320,,,A*6B
$GPVTG,,T,,M,0.583,N,1.080,K,A*24
$GPGGA,173145.00,0539.10377,N,00001.31845,W,1,11,0.77,19.7,M,20.4,M,,*75
$GPGSA,A,3,21,27,26,16,20,14,25,32,11,31,10,,1.52,0.77,1.31*00
$GPGSV,4,1,13,08,03,288,,10,52,124,20,11,08,251,18,14,17,191,18*70
$GPGSV,4,2,13,16,28,342,38,18,04,033,,20,44,074,27,21,22,026,29*7B
$GPGSV,4,3,13,25,14,125,21,26,54,003,33,27,18,314,28,31,57,216,27*7D
$GPGSV,4,4,13,32,15,166,07*48
```

Figure 4.2: NMEA sentences obtained from the GPS receiver

the code was finally successfully uploaded to the Arduino board. When the module was powered, and the TX pin of the module was connected to the RX pin of the Arduino, the module immediately began to transmit information to the Arduino which was then displayed on the Arduino serial monitor.

The information received from the GPS receiver comes in the form of NMEA sentences. Each of the sentences represents some information obtained from the satellites. The meaning of each sentence is explained in Table 4.1. For the purpose of this project, the required information is contained in the GPGLL. The GPGLL sentence contains the latitudes and the longitudes which are required to track the vehicle. Also, it was noted that when the GPS receiver is in doors, it takes longer to connect to the satellites. The module comes with an inbuilt red-light emitting diode (LED) that blinks when the module has connected to at least three satellites as explained in 2.2.1. Once the red LED starts blinking, it indicates that the module is receiving information from 3 or more satellites. The program to extract the coordinates was also designed as part of the microcontroller program.

4.3 Statistical Analysis

In order to validate the coordinates obtained from the GPS module, the data from the GPS is compared to the GPS coordinates obtained from a mobile phone. In this project the mobile phone used is the iPhone 6S. The GPS module in the iPhone has been certified to give the accurate coordinates. Therefore, the objective was to develop a hypothesis that there is no statistical difference between the coordinates obtained from the mobile phone and the mean of the coordinates obtained from the GPS module used in this project. To test this hypothesis a one-sample t-test was conducted. Table 4.2 shows the setup of the hypothesis to be tested. The confidence level for this hypothesis testing was 95% which means the P value to be used is 0.05. Higher confidence levels did not pass the test. Firstly, data had to be obtained before the

Table 4.1: NMEA sentence explanation.

Code	Interpretation
GPGSV	Shows the satellites accessible to the receiver (NEO-6M)
GPGLL	Geographic position, latitude/longitude
GPRMC	Recommended minimum specific GPS/Transit data
GPVTG	Track made good and ground speed
GPGGA	Fix data
GPGSA	GPS DOP and active satellites

test could be conducted. The set of coordinates from the mobile phone was collected. The location of the phone was marked so that the GPS module could be placed in the exact location

Table 4.2: hypotheses table

H	Hypotheses
H_0	There is no difference between the mean of the GPS module (UBLOX NEO-6M) coordinates and coordinates obtained from the mobile phone (iPhone 6S)
H_a	There is difference between the two means

for the fairness and reliability of the test. Data from the GPS module was loaded into an excel file. A program to collect the data was written in Arduino, another software was used to connect the computer serial communication to the Arduino. In this project, the open source Tera Term was used to establish serial connection between the PC and Arduino. Figure 4.3 shows the Tera Term software logging coordinates data into Microsoft Excel. The mean and standard deviation was obtained for both the latitude and the longitude. The t-test was performed for both the latitude and longitude.

$$\mu_{lat/lon} = \sum_{i}^{n} x_i \tag{4.1}$$

$$\sigma_{lat/lon} = \sqrt{\frac{\sum_i^n (x_i - \mu_{lat/lon})^2}{n-1}} \tag{4.2}$$

Where:

$\mu_{lat/lon}$ = average of the latitude (*lat*) or longitude (*lon*) coordinates

$\sigma_{lat/lon}$ = standard deviation for the latitude or longitude

n = sample size of the coordinates

i = index of the coordinate

x = coordinate

Table 4.3: summary of data collected and processed

Parameter	**Value**
n	30
μ_{lat}	539.10330
μ_{lon}	1.31807
σ_{lat}	0.29110
σ_{lon}	0.50078
Mobile phone latitude	539.18368
Mobile longitude	1.13437

The operations were done in Microsoft Excel. Table 4.3 shows a summary of the data that was collected and analyzed. Equations (4.1) and (4.2) were used to calculate the two (latitude and longitude) means and standard deviations of the data collected. Now all the data is sufficient to perform a one-sample t-test. Equation (4.3) was used to calculate the t-value.

$$t = \frac{\mu - \mu_0}{\frac{\sigma}{\sqrt{n-1}}} \tag{4.3}$$

Where:

μ = mean of the latitude or longitude from the GPS module.

μ_0 = the latitude or longitude obtained from the mobile phone.

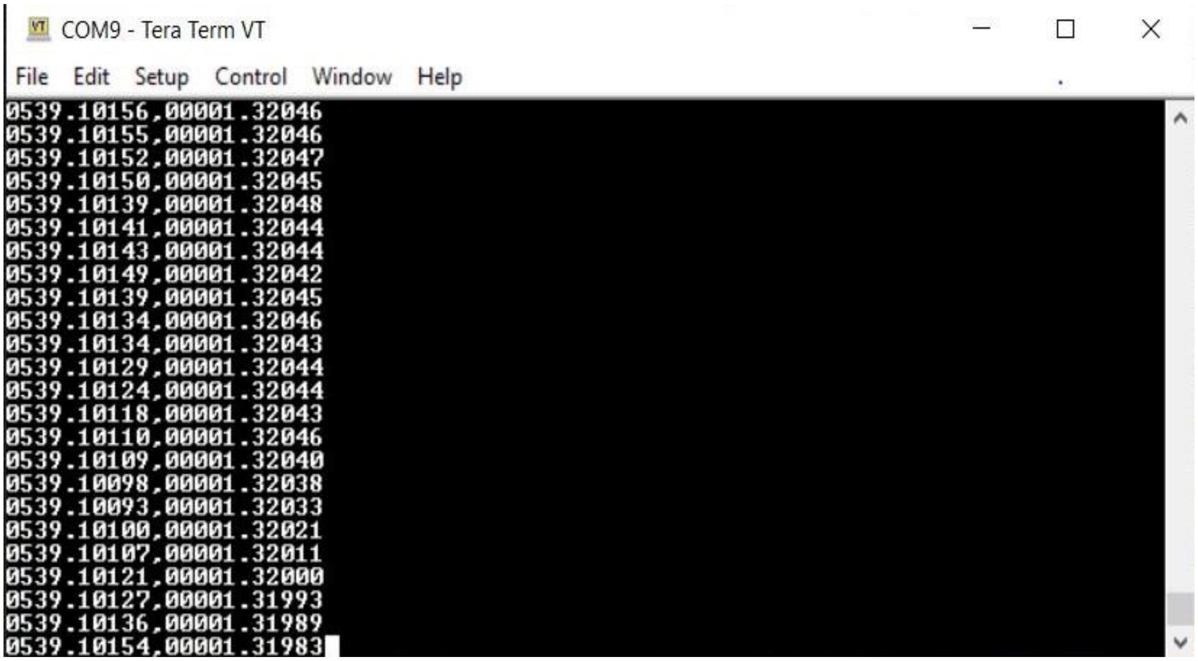

Figure 4.3: Tera Term software connecting to Microsoft excel

σ = standard deviation.

The results of the t-test are summarized in Table 4.4. For the hypothesis to be accepted, the t-value much be less than or equal to 2.05, or greater than or equal to -2.05 ($-2.05 \leq t \leq +2.05$). According to the values in the table, the null hypothesis was accepted that there is no significant difference between the coordinates obtained by the GPS module and the those from the certified

Table 4.4: t-test summary

Parameter	Latitude	Longitude
t-value	-1.49	1.98
Critical value	± 2.05	± 2.05

mobile device, on a 95% confidence level. This means the device gives accurate results 95% of the times it is used.

4.4 GSM System

The GSM module used in this project is the SIM800L. Firstly the connections were made according to Figure 3.6. It was observed that; when the GSM module is transmitting it draws up to 2 Amps. Therefore, to make sure the current is high enough, resistance caused by

Table 4.5: AT commands for the GSM module

AT Command	Explanation
AT	Returns OK if the GSM module has established connection with the nearest base station.
AT + CMGF=1	Sets the GSM module into text mode. Returns OK if the module is set.
AT+CMGR=1	Reads the first sim card in the sim memory
+CMTI: “SM”,1	SMS has arrived and it’s placed in memory position 1
AT+CMGD=1	Deletes the message in memory number 1

the wires had to be eliminated, therefore the 4.4 power output was put as close to the GSM module as possible. When a sim card is installed in the module, it was observed that a red LED blinks every second. When this happens, the GSM module is still initializing. Once the GSM module has established connection with the nearest base station, the LED starts to blink once every 3 seconds. This signifies that the module is ready to send and receive messages. There are AT commands that can be used to test the different functionalities of the GSM module [24]. For this project, the AT commands used are shown in Table 4.5. After the setup was finished, a test text message, “track”, was sent to the system and the system responded by sending back a message, “test successful”, confirming the successful reception and sending of the text messages by the system.

4.5 The Integrated System

Because of the COVID-19 pandemic, the BLDC motor could not be obtained in time as well as the transistors required to make the AND logic. An LED was used to represent the BLDC motor and the AND logic was designed in the microcontroller program. Also, the power supply could not be built, therefore, an alternative power supply (9V battery) was used. After the integration, the GSM module could not send or receive messages. This was caused by the resistance introduced by longer wires. Figure 4.4 shows the final physical circuit of the

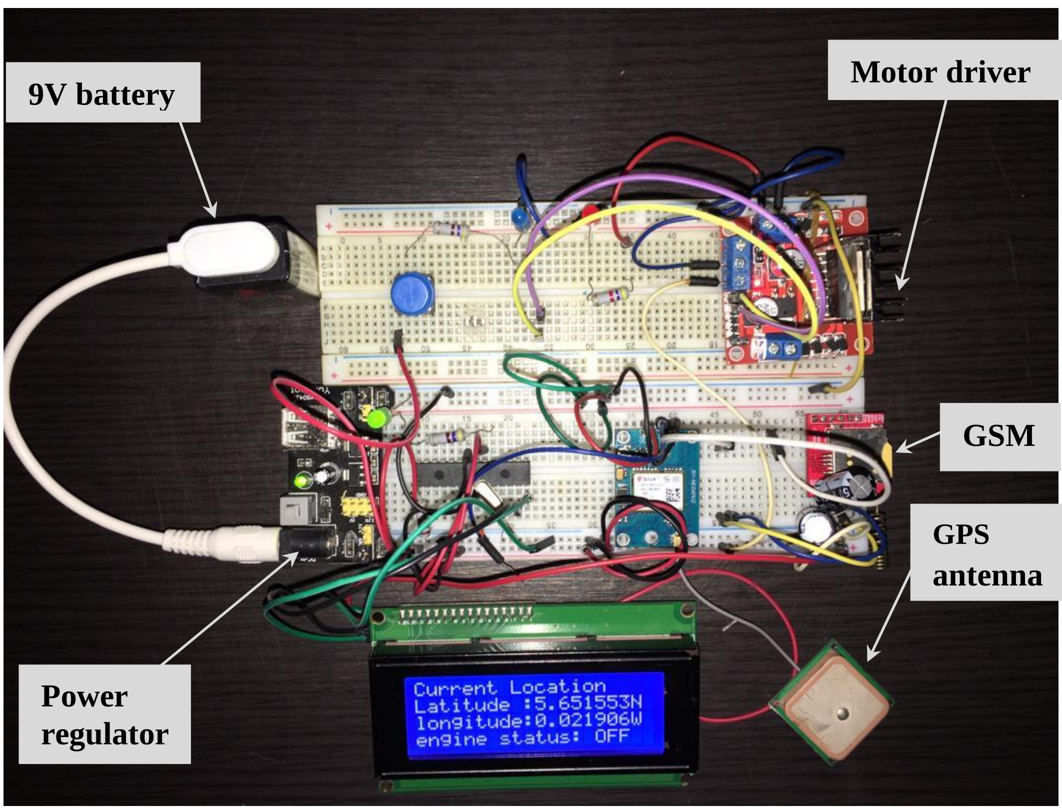

Figure 4.4: breadboarded tracking device

whole system. After removing the extra jumper wires, the system responded as expected. The GPS module took more time to initialize when the device was placed inside the house. However, when the device was placed inside a car, it took less than 1 minute to initialize. After the GSM system had established (the LED blinking every three seconds) the text message, “lock vehicle," was sent to the device and the device sent back a text message confirming that the engine was locked after the LED which represented that the BLDC motor went off. A push button was used to represent the ignition key. Even if the push button was pressed, the LED

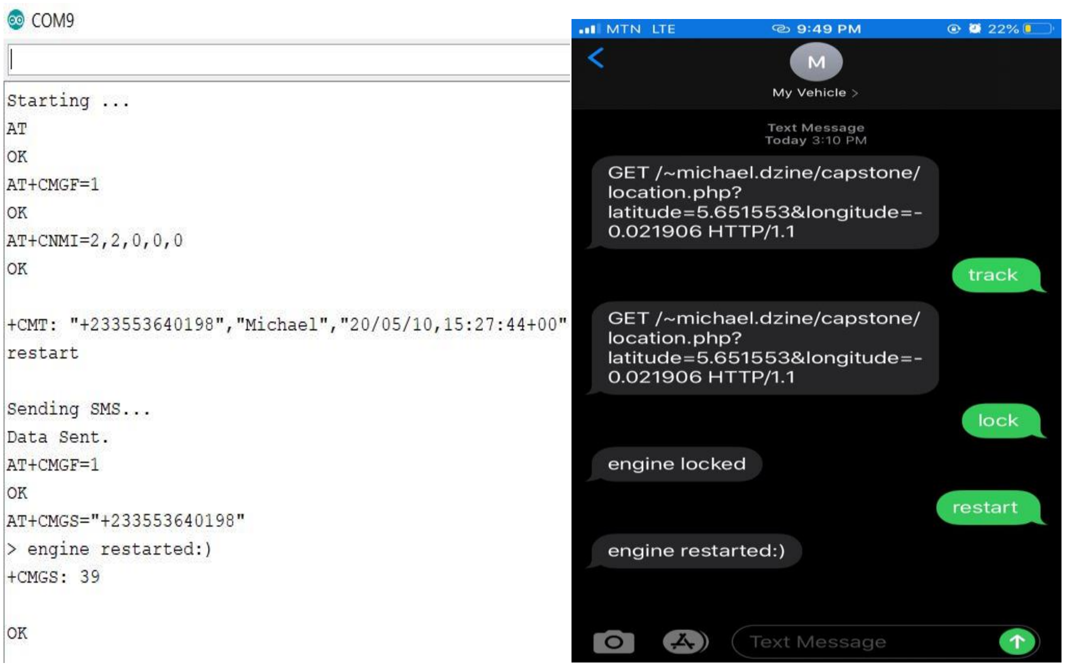

Figure 4.5: testing the SMS system

could not turn ON. Another text message was sent to the car: "restart." After the LED was turned ON, the system texted back confirming that the vehicle had started moving again. Figure 4.5 shows the Arduino serial (on the left) and the screenshot taken from owner's mobile phone (on the right) after sending the three text messages. Lastly the device was taken out of the 10km radius geofence and it sent a message to the owner's mobile phone alerting the owner that the vehicle had moved out of the geofence. In order to access the current location of the vehicle, a text message, "track" was sent to the device and the device responded by sending back a text message with the location of the vehicle packaged into a URL.

Chapter 5: Conclusions, Limitations and Future Works

5.1 Conclusions

An anti-theft vehicle tracking system was successfully designed, implemented and tested in this project. The tracking devices was made up of different subsystems. In the first subsystem, the main component was the GPS module (UBLOX NEO-6M), which was used to connect the satellites in outer space. The GPS module connected to at least three satellites in order to use trilateration to determine the position of the receiver which is the position of the vehicle being tracked. When the module was connected to at least three satellites, a red LED blinks to indicate that the module has locked the necessary number of satellites required to determine the position of the vehicle. A statistical analysis was performed to compare the coordinates from the module to the coordinates obtained from a mobile phone's GPS system. It was observed that there is no statistical difference between the two sets of coordinates, on a 95% confidence level.

After this was established, a GSM system was added to the system in order to relay the coordinates to the owner of the vehicle. The system employed the geofencing concept in order to cut costs of communication. When the vehicle is out of "normal" territory, then the module would call the user and begin to send coordinates to the user. The coordinates are put in a URL that directs the user to google maps which shows the location of the vehicle on a map. Geofencing improves the security of the system.

Lastly, the device was capable of turning off the vehicle's engine upon the request of the user. Due to the ongoing pandemic, this system could not be properly implemented on an actual vehicle, but a prototype was designed to mimic the functioning of the device.

5.2 Limitations

Firstly, the Module used in this project does not give accurate result all the time because it is 95% accurate which means it gives the accurate results 95% of the time. The GSM module used in this project also works if there is cellular network, if that it is not the case, then the device cannot communicate with the user. The device is also not a standalone device as it relies on power from the vehicle's engine, therefore, the vehicle cannot be tracked in the event that the engine is turned off. In that case, the user has to rely on the most recent coordinates to track the vehicle. Furthermore, for the location of the vehicle to be viewed, the user requires internet which adds to the cost of the tracking system. Last but not least, the software used to design circuits did not have enough modules, therefore external libraries had to be used. Furthermore, the software left out pins that would otherwise have been on the physical device, for example, the microcontroller from the software (Proteus) did not have all the pins that are on the physical microcontroller.

5.3 Future works

Firstly, the GPS module is not yet giving accurate results 100% of the time. However, there are other GPS modules available on the market which could be used as a substitute for virtually the same cost as the UBLOX NEO-6M. Before the module is purchased, a statistical analysis would be done in order to make sure the next module to be used gives 100% accurate results. Also, the device should be able to power itself in the event that the car engine has been turned off. This would help the owner track the position of the car in real time even when the engine's turned off. The system should also be implemented on a PCB or perforated board. This could not be done because of the ongoing pandemic.

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