Design and Development of Fuel Cut Off Mechanism for Unintended Pressing of Accelerator Pedal

Pikolo Ali Hussen

A Thesis Submitted to

The Department of Mechanical System and Vehicle Engineering

School of Mechanical, Chemical and Materials Engineering

A Thesis submitted in Partial Fulfillment of the Requirement for the Award of the Degree of Master of Science in Automotive Engineering

Program: M.Sc. in Automotive Engineering

Office of Graduate Studies

Adama Science and Technology University

Adama, Ethiopia

January 2021

Design and Development of Fuel Cut Off Mechanism for Unintended Pressing of Accelerator Pedal

By

Pikolo Ali Hussen

Advisor: Dr. Ramesh Babu Nallamothu

A Thesis Submitted to

The Department of Mechanical System and Vehicle Engineering

School of Mechanical, Chemical and Materials Engineering

A Thesis submitted in Partial Fulfillment of the Requirement for the Award of the Degree of Master of Science in Automotive Engineering

Program: M.Sc. in Automotive Engineering

Office of Graduate Studies

Adama Science and Technology University

Adama, Ethiopia

January 2021

APPROVAL OF BOARD OF EXAMINERS

We, the undersigned, members of the Board of Examiners of the final open defense by Pikolo Ali Hussen have read and evaluated his thesis entitled “Design and Development of Fuel Cut Off Mechanism for Unintended Pressing of Accelerator Pedal” and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirement of the Degree of Master of Science in Automotive Engineering.

______________________	______________	____________
Advisor	Signature	Date
______________________	______________	____________
Chairperson	Signature	Date
______________________	______________	____________
Internal Examiner	Signature	Date
______________________	______________	____________
External Examiner	Signature	Date
______________________	______________	____________
Head of the Department	Signature	Date
______________________	______________	____________
School Dean	Signature	Date
______________________	______________	____________
Dean, Graduate Studies	Signature	Date

CANDIDATE'S DECLARATION

I hereby declare that this MSc Thesis "Design and Development of Fuel Cut Off Mechanism for Unintended Pressing of Accelerator Pedal" is my original work and has not been presented for a degree in any other university, and all sources of material used for this thesis have been duly acknowledged.

Name: Pikolo Ali Hussen

Signature: ___________

This MSc Thesis has been submitted for examination with my approval as a thesis Advisor.

Name: Dr. Ramesh Babu Nallamothu

Signature: ___________

Date of submission: _________________

ADVISOR’S APPROVAL SHEET

To: SoMCM Engineering Automotive Engineering Department

Subject: Thesis Submission

This is to certify that the thesis entitled “**Design and Development of Fuel Cut Off Mechanism for Unintended Pressing of Accelerator Pedal**” submitted in partial fulfillment of the requirements for the degree of Master’s in Automotive Engineering, the graduate program of the department of Automotive Engineering, and has been carried out by Pikolo Ali Hussen Id.No. A/PR15347/10 under my supervision. Therefore, I recommend that the student has fulfilled the requirements and hence hereby he can submit the thesis to the department.

________________________	__________________	_______________
Advisor	Signature	Date

ACKNOWLEDGEMENT

I thank all who in one way or another contributed in the completion of this thesis. First, I give thanks to God for protection and ability to do work. I would like to express my special appreciation and thanks to my advisor Dr. Ramesh Babu you have been a tremendous mentor for me. I would like to thank you for encouraging my research and for allowing me to finish this work. I would like to thank Natnael, Minilik, Melaku, Engeda and those of you didn't mention your name without whom I would not have been able to complete this thesis. I would like to thank my work friend and boss specially Mr. Admasu Asefa and Daneal Seyifu.

Nobody has been more important to me in the pursuit of this project than the members of my family. I would like to thank my parents, whose love and guidance are with me in whatever I pursue. They are the ultimate role models. Most importantly, I wish to thank my loving and supportive wife, Enat, and my three wonderful Etyael, Nebeyu, and Mia, who provide unending inspiration.

TABLE OF CONTENTS

CONTENTS PAGE

ACRONYMS AND ABBREVIATIONS

CAS	Collision Avoidance System
FCWS	Frontal Collision Warning System
GDP	Gross Domestic Product
GMC	General Motor Corporation
IDE	Integrated Development Environment
LED	Light Emitting Diode
MPC	Model Predictive Control
OLS	Ordinary Least Square
SUA	Sudden Unintended Acceleration
VCA	Vehicle Collision Avoidance
ADC	Analog to Digital Converter
PWM	pulse width modulation
NTSB	National Transportation Safety Board
DRS	Driver Rehabilitation Specialist

LIST OF FIGURES

FIGURES **PAGE**

LIST OF TABLES

TABLES **PAGE**

ABSTRACT

Worldwide, the number of people killed in road traffic crashes each year is estimated at almost 1.2 million, while the number injured could be as high as 50 million- which amounts to a combined population of five of the world's large cities. Sudden unintended acceleration (SUA) is unintentional and unexpected rapid acceleration of the vehicle i.e. where drivers depress the accelerator pedal when they intend to depress the brake pedal. It has been reported several times that unintended pedal misapplication when a driver panic contributes to numerous traffic accidents. This calls for an automated solution implemented on the car to prevent pedals from working when applied unintentionally. Usually when drivers panic and misapply a force on a pedal, they do it in a forceful and quick manner different from the normal way of applying force on a pedal which is steady and constant. Considering this important factor an electro-mechanical system to lock fuel supply system to the combustion chamber while the driver pressed the gas pedal suddenly with instant of time was developed in this work. The system consists of electrical and mechanical components. The electrical part consists of potentiometer and a control logic which senses when the accelerator pedal is pressed accidentally by sensing gas pedal pressing time. Using this information the control logic blocks the force applied on the accelerator pedal from increasing the speed of the car. Also, the mechanical system was involved in preventing the force from increasing the speed. Unintended acceleration test was performed in different driving conditions in order to identify panic condition. The test result show that the maximum deviation occur in sudden acceleration pedal pressing from ideal to full load, sudden acceleration pressing in the middle of normal driving and sudden acceleration pedal pressing while drive at high speed with the slope deviation of 20.6m/s, 15.9m/s and 9.95m/s respectively. If the slope of potentiometer reading to time is above 9.95m/s the system locks the fuel supply system to the combustion chamber while the driver pressed the gas pedal suddenly with instant of time. Unintended acceleration locking mechanism is one possible way of improving safety of passengers in order to reduce property damage, injuries, and fatalities caused by these errors.

Keywords: Collision, Panic, Pedal misapplication, potentiometer, unintended acceleration

1. INTRODUCTION

1.1. Background of the Study

Road safety is a multi-sectorial and multi-dimensional subject. It includes orderly development and management of roads, provision of safer vehicles, and a comprehensive response to accidents. It relies on modern traffic management systems and practices, improved safety standards in design, construction, operation and maintenance of roads, and production and maintenance of safer vehicles.

Road traffic accident can be of collision between vehicles, between vehicles and different environment geography or any obstacles, between animals and vehicles, or between pedestrians and vehicles. Increasing fatalities rate require more attention to be controlled. Various investigations are carried out by other countries to find the accident data.

In order to increase safety and reducing road accidents, people are spending lots of money, knowledge and time for the advancement in the driving techniques which ensures the safety. The technology makes people think more to improve the safety of to save the lives. The automobiles are more conscious of providing safety feathers like seat belts, air bags and strong body structures which provide the passive safety that may reduce the effects of an accident and also there is lots of active safety features like ABS, traction control, hill assist cruise control, and this automatic accelerator pedal locking system.

A vehicle or car accident is a road traffic incident which usually involves one road vehicle being in collision with, either another vehicle, or another road user, or a stationary road side object, and this may result in death, injury and/or property damage. Some of the major reasons found for accidents are fault of driver, driver of other vehicle, pedestrian, passenger, cyclist, road condition, motor vehicle, weather condition and poor light etc.; but sometimes barrier of roads are also being responsible for accidents such as median, road side barriers etc. Everyone would agree an accident is unplanned and unwanted, but the idea that accident is controllable is new concept. Various safety measures such as speed barkers and crash cushions are made to make traffic calm and reduce their speeds.

The industry strategy for automotive safety systems has been evolving over the last 20 years. Initially, individual passive devices and features such as seatbelts, airbags, knee bolsters, crush zones, etc. was developed for saving lives and minimizing injuries when an accident occurs. Later, preventive measure such as improving visibility, headlights, windshield wipers, tire traction, etc. were deployed to reduce the probability of getting into an accident. Now we are at the stage of actively avoiding accidents as well as providing maximum protection to the vehicle occupants and even pedestrians. The systems that are under intense development include collision avoidance systems/warning/intervention systems, lane departure warning, drowsy driver detection, and advanced safety interiors.

A Vehicle Collision Avoidance System in an automobile system has the objective to develop safety features in automobiles so that there is avoidance of collision with vehicles or an obstacle in the way. In bad weather conditions these systems are especially useful. While driving the main objective of these systems is to prevent collision of car due to their carelessness, mistake or blind spot (Mir Insha et al., 2016).

Road traffic accidents are a significant but neglected global public health problem requiring a coordinated effort for effective and sustainable prevention. There are many different kinds of drivers in traffic. Not all drivers are always carful to prevent pedal operation mistake not are they all skilled enough to be prepared to correct such unexpected driver mistakes.

1.2. Statement of the Problem

Now day's vehicle traffic accident is becoming the major cause of death in Ethiopia. Besides being cause of death, it is affecting the GDP and demography of our country. It is a well-known fact that vehicle accident causes socio-economic, physical and psychological crisis which needs to be dealt seriously.

From the reasons causing vehicle accident driver mistake and driving without experience are among the many. The driver can mistakenly press the acceleration pedal when his intention was to step on the brake, which sprints the vehicle making it highly vulnerable to accident. And some people drive a certain vehicle without having good driving skill which most probably ends with accident. It should be underlined that the slightest chance of having/causing accident affects life seriously and efforts have to be made to make the streets safe for movement.

1.3. Objectives

1.3.1. General Objective

The main objective of this thesis work is to design and develop fuel cut off mechanism to avoid vehicle collision caused by panic pressing of the pedal by the driver.

1.3.2. Specific Objectives

The specific objectives of this thesis work are as follows:

- To study the normal pressing and panic pressing of accelerator pedal.
- To design and development an electrical sensor setup to detect when the accelerator pedal is pressed during panic time.
- To design a fuel cut off mechanism to prevent the car from accelerating when controller gets a panic signal from potentiometer.
- To demonstrate the overall system by testing the system under several scenarios.

1.4. Significance of the Study

The outcomes of this thesis help in minimizing traffic accident as well as to improve safe transportation. The result of this paper can be useful as a reference for individuals, researchers and manufacturers who are engaged in minimizing traffic accident.

1.5. Beneficiaries of the Study

Vehicle owners, society and country as a whole benefitted with this work because traffic accident may harm individuals, community, and country.

1.6. Scope of the Study

This work includes the development of a modern system to reduce the vehicle collisions caused by panic depression of acceleration pedal. Only some accident studies are made and programming of the modern system is done. The construction of the prototype for the demonstration of the functionality is also included in this work. This an automatic accelerator pedals locking mechanism for unintended pressing system can be installed on any type of gasoline and diesel engine vehicles.

1.7. Limitation of the Study

Safety is the eternal themes of automotive technology development. To perform unintended acceleration test it's necessary to use linear potentiometer to obtain more accurate results. Moreover, linear type of potentiometer doesn't easily available on the market, due to this it's mandatory to use rotary type potentiometer. But, rotary type potentiometer needs additional components such as rack and pinion gear in order to change the linear motion into rotary motion. Also for an accurate and realistic result it's better to use a simulator test. These are the main limitations on this work.

1.8. Organization of the Thesis

This Thesis consists of five chapters. The first chapter is an introduction to the study. It includes the background of the study, statement of the problem, objectives, significant of the study, beneficiaries of the study, scopes, limitation, and structure of the thesis. The second chapter focuses on different kinds of literature that emphasize on previous investigation, literatures on pedal misapplication and research gap. Chapter three contains materials used with their explanation, mechanical modeling and electrical modeling. Fourth chapter presented the result and discussion of the experimental tests. The final chapter of this thesis consists of summary, conclusions and recommendations.

2. LITERATURE REVIEW

A number of researchers have reported on road traffic accidents worldwide. Some studies are carried out in accident analysis caused by pedal misapplication, accident investigation; active and passive safety systems have been conducted in order to improve passenger's safety. Unfortunately, there is nothing in the literature which pertains directly to this issue. Therefore the following literature review will take a boarder approach. At the end of this chapter, the research gap is pointed out.

2.1. Previous Investigations

Asaye and Mossa (2015) state that road traffic accidents are a major global socio-economic problem, affecting all people of the world regardless of age, sex, wealth etc. The study has the major objective of assessing the causes of road traffic accident in Bahir Dar city. Both primary and secondary data sources were used. Cross-sectional survey with utilization of both qualitative and quantitative approaches was used. It was shown on the study that unless immediate actions to revert the problem are taken, it will worsen in the coming future as motorization and population of the city is growing altogether.

Kumar and Devi (2014) studied on road traffic accidents which are serious health concerns at present as far as public health and prevention are concerned. Increase in number of vehicles on road, urbanization, shift in rural areas to urban centers, Unplanned urban growth, poor driving conditions due to improper road maintenance, unplanned intersections and insufficient provision for pedestrian have led to traffic congestion on roads and subsequently to accidents on roads. Road traffic injuries are one of the leading causes of death across the world with severe socio-economic costs.

Prince et al., (2016) studied on road related fatalities which are high in South Africa compared to other African nations. The purpose of the study was to analyses the determinants of road accident fatalities in South Africa's transport sector. The determinants were examined using the ordinary least squares (OLS) method. The results suggest that drunken driving, paved roads and use of seatbelts are some of the determinants in the number of road related fatalities. The study recommends that the South African government put strict measures in dealing with drunk driving that has contributed to the unnecessary loss of life, especially during holiday periods.

Rifaat Shoukrallah (2004) mention worldwide, about 1.2 million people are killed and 50 million people are injured in road crashes each year. Developing countries are experiencing high rates of increase in car owner ship, population and in demands for enhanced mobility. The resultant increase in the number of people killed or injured in road crash espouses great challenge for those responsible for the road transport system in the developing world.

Pooja et al., (2017) highlighted hypothetical data on road accidents of various parts of India. Analysis for factors affecting road accidents is the most importance to reduce frequency of occurrence. Preventive measures were been justified to reduce the frequency of road accidents. Research paper included hypothesis and study of relationship between types of lanes, total no. of injuries, accidents, persons killed, types of vehicles, awareness of drivers and accidents, types of highways (National highway, State highway and other roads) and number of accidents, persons killed or injured. The test is also applied to check the relationship between no. of accidents in National highway and State highway with other roads.

Oluwagbemi et al., (2010) describe the mortality rate in the West African sub-region of the world was undoubtedly very high. In Africa for example, the prevalent incidences of road-traffic accidents had been responsible for the untimely death of many innocent citizens. Also, particularly disturbing was the high number of sudden deaths scenarios that are recorded yearly among patients on an emergency transfer held up with in terrible road-traffic congestions. Although this particular road-accident phenomenon was not just limited to West African Countries, it was particularly disturbing that Africa seems to be among the few remaining regions of the world where a permanent antidote or a solution approach was yet to be found and adequately implemented for the full benefits of the victims of such unpleasant circumstances. In the research work, a simulated programming approach was applied to reduce road-traffic accidents on West African high ways.

Haddon (1970) works stand out as one of the most valuable contribution in road safety management. The Haddon matrix is popularly used as a tool to assist in developing ideas to preventing injuries. Four columns and three rows are combined to identify factors contribute to injury.

Table 2.1: Illustrates the Haddon matrix.

Phase		Human factor	Vehicle and equipment factor	Environmental factor
Pre-crash	Crash prevention	Training and education/ attitudes/ behaviour	Road worthiness system (lights, brakes etc)	Road designs, markings maintenance
Crash	Injury prevention	Use of restraint impairment	Crash worthiness maintenance	Protection, pedestrian crossing
Post – crash	Life sustaining	First aid skill/ access to medics	Ease of access/ fire risk	Rescue facilities/ congestion

The matrix demonstrates that there are phases in road safety and the likely solutions to preventing such accidents. For instance, in the pre-crash phase, human factors such as training and education on road users prevent crash.

Umar Zakir et al., (2018) propose a vehicle collision avoidance strategy based on the usage of Geometrical Based Steering Controller. In this work, GMC is proposed for the Vehicle Collision Avoidance algorithm. It acts as the replanned trajectory follower controller and the maneuver is done by manipulating the model variables, i.e. the steering input to allow the vehicle to avoid the potential collisions and eventually return to its original path, which in the work is the straight-line path. Also shown is the inclusion of safe-distance Threat Assessment strategy for VCA.

Xiao et al., (2012) proposed approach assumes progressive V2V market penetration. With V2V, the information of the first vehicle can be immediately passed to the followers thus the delays can be effectively avoided. With the objective function chosen as the total relative kinetic energy, multiple vehicle collision avoidance and impact mitigation can be achieved. The paper mainly focused on the MPC (Model Predictive Control) implementation and alternative relationship with respect to the further front and rear external vehicles (without V2V).

Athira M. et al., (2018) designed a modern vehicle security system for any type of vehicles. When a vehicle collides with another, the vibration sensor detects and the details of the vehicles are transferred to each other automatically via zigbee communication. It will help to find the vehicle easily which met with the accident. Another feature implemented here is the ultrasonic sensor-based collision prevention system.

Jonas et al., (2002) stated that Driver error causes a majority of all car accidents. They focused on forward collision by braking, and present a general method for calculating the risk for collision. Forward collision avoidance systems aim at avoiding, or at least mitigating, host vehicle frontal collisions, of which rear-end collisions are one of the most common. This is done by either warning the driver or braking or steering away, respectively, where each action requires its own considerations and design.

Umar Zakir et al., (2018) developed a multi-actuators collision avoidance system research platform for the autonomous vehicle (iDrive). The platform acts by providing multi actuation collision avoidance maneuver (steering and braking interventions) during the emergence of an obstacle. To validate the performance, a real-time experiment is done where iDrive produced the desired emergency navigation, thus allowing for the collision to be avoided.

Anil Kumar et al., (2018) investigated different collision detection sensors available and gave a better approach to prevent collision of vehicles through multiple sensors approach, which means combination of two or more different collision avoidance sensors. Collision avoidance sensors detect the surrounding vehicle distance, if vehicle is too near to the system then sensors senses give Alert to the driver. In this working of different sensors as collision detection sensors are studied and compared to give a better approach. In this project raspberry-pi is preferred as the control unit, for faster operation of system and easier interface with different collision detection sensors. The objective being to reduce the cost of the system and efficient working of collision avoidance system (CAS) in vehicles.

Xiao et al., (2012) developed level control to avoid or to minimize the impact of multiple-vehicle longitudinal collision has been considered in this paper. The objective was to generate desired deceleration for each vehicle in the coupled group. The relationship between the coupled group and further front and rear vehicles have been taken into account. A kinetic vehicle following model with additive uncertainties were used in the simulation. The impact (objective function) is defined as the total relative kinetic energy between pairs of vehicles.

Evangelos Skodras et al., (2012) studied an automated algorithm for detection of preceding vehicles is proposed, based on the detection of rear vehicle lights. Unlike many systems which make use of static threshold boundaries for the red color segmentation of rear lights, this method combined color and radial symmetry cues while the threshold is dynamically adapted.

Yimin Wei et al., (2007) work in vehicle Frontal Collision Warning System (FCWS) based on improved target tracking and threat assessment for collision avoidance was described. The system acquires longitudinal and lateral position of objects from radar and Lidar. Together with host's speed and angular velocity, the system tracks all the targets in front. The threat assessment, based on the knowledge of current state, provides a warning signal to the driver when a potential collision is detected.

Douglas (2015) studied a safety shutdown system for a vehicle has a device for detecting a panic-level force applied to a vehicle control with a first state indicative of no detected panic-level forces, and a second state indicative of detected panic-level force. This device is coupled to disable a power plant of the vehicle when in the second state. In particular embodiments the apparatus for detecting has a hydraulic cylinder coupled to a brake line and detects panic-level force on a brake pedal of the vehicle: and in embodiments the apparatus for detecting is adjustable. In other particular embodiments, a second device disables the power plant of the vehicle upon detecting panic-level force on an accelerator pedal of the vehicle.

Sonar installed in the front and rear bumpers detect walls, vehicles, and other obstacles around the vehicle in the direction of travel. If the accelerator pedal is depressed strongly while an obstacle is detected, the system warns the driver with a display alert and warning sound, and suppresses the vehicle from accelerating. If the system judges that there is the risk of a collision, it warns the driver with a screen display and warning sound, and automatically applies the brakes in order to help prevent a collision. In addition to the above function, some models such as LEAF use the front camera to detect vehicles and pedestrians in front of the vehicle. When there is an object detected, the system activates in the same way as pedal misapplication in traveling at speeds of up to 25km/h.(Nissan motor corporation, 2020).

Morrison et. al., (1986) obtained foot movement times while systematically varying the vertical and lateral separations between the pedals. These authors found a statistically significant effect for changes in vertical separation; with coplanar and "lower" brake arrangements (the brake located 5.08 cm below the accelerator) resulting in faster movement times than for those obtained with the brake located 5.08 cm above the accelerator. No differences were found, however, between the coplanar and lower brake arrangements. As in the Snyder (1976) study, changing the lateral separation (in this instance, from 5.08 to 13.34 cm) did not significantly affect movement time. Although the above studies demonstrate the importance of' the_ horizontal and vertical. positioning of' the accelerator and brake in determining movement time, a more quantitative description of the effects of amplitude on movement time is desirable. For this, it is necessary to turn once again to yet another description of the speed accuracy tradeoff in movement behavior.

Davies and Watts (1969) using male subjects, recorded the movement time (the time required to move the foot from the accelerator to the brake pedal) for two different pedal configurations. The brake pedal in these configurations was located either a) coplanar with the accelerator or b) six inches higher than the accelerator. The two pedals in each configuration were separated by a horizontal distance of four inches and were inclined at an angle of 40° with the baseboard. Subjects were told that the lighting of a red light stimulus in front of them represented an "emergency" situation and that they were to brake as soon as possible upon seeing the light. Davies and Watts found that the mean movement time was significantly less for the coplanar arrangement than for the configuration. ‘with the ‘vertical separation between the pedals (0.149 and 0.309 second, respectively). Although the difference in mean movement time was only 0.16 second, the investigators point out that this difference could mean substantial savings in stopping distance at high speeds (Davies and Watts, 1969). In a · subsequent study, Davies and Watts (1970) investigated the possibility of generalizing these results to female subjects. In- addition to using the same pedal configurations and procedures as in their earlier study (Davies and Watts, 1969) two different seat heights were included (seat height was either 12 or 17 inches). Again, a significant difference in movement time was found for the two configurations. The mean movement time for the coplanar pedals was 0.194 second while that for the "higher brake" arrangement was 0.309 second (Davies and Watts, 1970). Thus it appears that the results obtained for males, i.e. faster coplanar movement times (Davies and Watts, 1969) also apply to the movement times of female subjects. Seat height, however, did not significantly affect movement time (Davies and Watts, 1970).

Jeremy Blum (2020), proved steps and strategies on how to use Arduino in technological projects. Arduino became a popular solution that extends computing and robotics to individuals outside technology field. Hobbyists can do these projects at home while gaining all the advantages this product offers teach all about Arduino and the working components behind its functions. Also explained the concepts, important Arduino parts, basic coding fundamentals and many more. Finally Jeremy discussed several tips and tricks, as well as beginner-level project ideas that will help to master Arduino.

2.2. Pedal Misapplication

In recent years as the term "sudden unintended acceleration" has been popularized, there has been a trend toward using it in complaints about any incident involving an unexpected change in vehicle speed, including throttle sticking, excess idle speed, engine surging, unintended acceleration occurring when the vehicle was already travelling at considerable speed, etc. To differentiate them from other types of problems with unwanted engine power, "sudden unintended acceleration" (SUA) are defined for the purposes of this thesis as unintended, unexpected, high-power accelerations from a stationary position or a very low initial speed accompanied by an apparent loss of braking effectiveness (Douglas, 2015).

SUA is the occurrence of any degree of acceleration that a vehicle driver did not purposely cause to occur. The majority of these crashes have been linked to pedal misapplications, with some associated with floor mats or sticky accelerator pedals. While pedal misapplication is most frequently cited as the cause of such crashes, not much is known about how and why they occur. Each year, many preventable crashes occur due to the US Department of Transportation, National Highway Traffic Safety Administration (NHTSA) definition of “pedal errors,” in which drivers mistake the accelerator for the brake. The majority of reported pedal misapplication crashes occur during the day, in clear weather, with good road conditions and in commercial parking lots. Other common situations include when a driver is parking or backing (Lococo et al., 2012). The prevalence of crashes due to pedal application errors (PAEs), also referred to as pedal error or pedal misapplication, where drivers depress the accelerator pedal when they intend to depress the brake pedal.

Road traffic accidents are being the critical public health problem that causes disabilities and death in Ethiopia which could need due investigations Table 2.3 showes that summerized accident occerance in Ethiopia from 2013 upto 2019.

Table 2.3: Ethiopian accident occurance data from 2013 upto 2019 (Ethiopian Federal Transport Authority)

	NUMBER OF TRAFFIC ACCIDENT					VICTIMS OF MOTOR VEHICLE TRAFFIC ACCIDENT						ALL CASES			
year	Death	Serious Injury	Slight Injury	Property Damage	General Total	Death		Serious Injury		Slight Injury		Total Male Female		General Total	Total Property Damage Estimate In Birr
						Male	Female	Male	Female	Male	Female	Male	Female		
2013/14	2,664	3,558	3,474	18,743	28,439	2,451	880	4,400	1,639	4,180	1,708	11,031	4,227	15,258	1,001,604,811.95
2014/15	3,172	4,046	3,561	21,241	32,020	3,815	1,068	4,920	1,564	4,666	1,842	11,540	4,733	16,273	668,322,806.75
2015/16	3,475	4,095	2,819	23,158	33,547	3,376	976	5,282	1,604	5,135	1,936	13,793	4,516	18,309	874,611,141.58
2016/17	3,606	4,449	2,803	27,879	38,737	3,418	1,061	5,593	1,893	5,140	2,295	14,151	5,249	19,400	1,187,486,802.88
2017/18	3,820	4,740	3,073	29,365	40,998	3,905	1,213	5,860	1,894	5,363	2,412	15,128	5,519	20,647	920,771,314.78
2018/19	3,738	4,324	2,587	30,222	40,871	3,532	1,065	5,567	1,840	4,319	1,630	13,418	4,535	17,953	872,884,881

Rogers and Wierwille (1988) studied the relationship between different types of PAEs and pedal configurations at different vehicle speeds using a driving simulator. The study was conducted using four pedal configurations (to represent a sport sedan, a full-size sedan and those pedal configurations that have smaller pedal vertical separation) at two speeds (to represent highway and suburban driving conditions). The foot movement tasks consisted of the foot moving (a) from the accelerator pedal to the brake pedal, (b) from the brake pedal to the accelerator pedal, (c) from the floor to the brake pedal, and (d) from the floor to the accelerator pedal. The PAE was categorized into four groups by severity: serious (driver mistakes one pedal for the other or depresses both pedals), catch (pedal interferes with foot movements), scuff (similar to catch but the interference is minimal) and instructional errors (failure to perform instructed tasks).

Sudden unintended acceleration (SUA) events are rare but very dangerous, often leading to prolonged periods of high, uncontrolled acceleration lasting several seconds. The National Highway Traffic Safety Administration (NHTSA, 2015) estimates 16,000 crashes occur annual due to unintended acceleration events. In many of the cases where SUA leads to a crash, driver often express confusion and insist they pressed the brake instead of the accelerator, despite evidence to suggest that driver error (i.e., pedal misapplication) is responsible for many of these events (Lococo et al., 2012).

Kunihiro et. al. (2020), demonstrated that pedal misapplication occurred more frequently after the pedal application was interrupted for a longer period of time, especially in older adults. Thus, the length of interruption period may be a critical factor in determining the occurrence of pedal misapplications in real traffic situations. The main findings were pedal misapplications occurred more frequently when the duration of the interruption task was longer (about 120 s) compared to shorter (about 30 s). Also, the interruption effect on pedal misapplication was larger in older adults than younger adults.

Xi Yubin (2015) studied driver-pedal interaction with tracing the pedal evolution and collecting existing pedal design guidelines. Then older drivers' characteristics and existing research on PAEs were presented. Based on the research gaps identified from a literature review of past works and statistics on PAEs, 10 research questions were developed. The first research gap identified a need for establishing the baseline driver-pedal interaction characteristics. The other four research gaps established the need to examine three driving scenarios representative of higher PAE risk and to investigate the role of fatigue in foot movement performance of older drivers. The study was carried out by having older adults drive a 27-mile road of various conditions that exist in a neighborhood, urban streets, interstates and parking lots. The participants were involved in PAE-related driving tasks such as forward parking, startle braking and reaching out to swipe card. During the course of driving, variables including participants' foot movements and force applied on the pedals were collected and analyzed. The contributions provided by this research include extending the understanding of an older driver's foot movement method in different driving scenarios, exploring lateral foot placement as an indication of PAE, investigating the relationship between reaching out and foot placement change, as well as pointing out the potential direction for future research.

2.3. Situational Factors that may contribute to Pedal Misapplications

2.3.1. Driving a New or Different Vehicle

The DRS (Driver Rehabilitation Specialist), particularly those who conduct CarFit evaluations, indicated that when drivers purchase new vehicles there typically is only a superficial orientation to the car by salespeople. There are features in new cars that operate differently from older cars, or were not even present in their older vehicles. For example, many drivers of small stature do not realize they have power seats in their new vehicles that can move forward and move higher.

People often do not understand how certain features in their cars work. Automation to increase fuel efficiency may make the car act strangely. It may not accelerate as expected going uphill with the air conditioner on, or the engine may rev for no apparent reason, and people think something is wrong with the car. Car dealers do not explain to customers that the car will normally rev in some situations and at other times may not speed up immediately when the accelerator is pressed, because the computer program that controls the vehicle enhances fuel efficiency and prevents over-torqueing the engine. It confuses drivers when the car does not respond as they expect, and this could contribute to a pedal application error.

Drivers in unfamiliar vehicles may be more likely to make a pedal application error. One DRS evaluated and trained a driver in a sedan, where the driver's legs were positioned out in front of him, and then took him on-road in a van, where he had to pick up his foot to brake, instead of pivoting, because the leg positioning was different. The combination of a different seating posture and leg position resulted in a pedal misapplication (pressing the gas pedal on an approach to a stop sign) requiring DRS intervention. The DRS indicated that it was all could do to keep the car from running into a house and concluded that it cannot always make a valid judgment of someone's capabilities in one type of vehicle based on their performance in another type.

Other DRSs discovered that the pedal application errors that NTSB investigated involved school bus drivers who have a lot of experience as drivers, but (1) the pedal configurations in buses are different than they are in cars, and (2) some of the drivers had recently switched buses. So, even between similar vehicles, the pedal configuration could differ. Drivers who do not adjust the seats, mirrors, etc., to suit them when they drive vehicles shared with other drivers also may be more at risk of making a pedal misapplication.

2.3.2. Driver Seating Position

Small-statured drivers sit with their hips stretched forward and may need to stretch with their toes to reach the pedals. This causes leg cramps and may cause their feet to fall asleep. It is stressful for people when they cannot position themselves comfortably in their vehicle. Someone especially, sit too far away from the steering wheel, sit too low, and need to reach (with their arms and their legs) for everything. Many do not know how to adjust their side mirrors and have no idea that they have a power seat that adjusts seating position in multiple ways.

Cars with bench seats allow people to be “out of position” with respect to foot placement. People who do not wear seat belts may also sit out of position. Some people sit off- center because their seatbelt catches them; they shift it to keep it off their neck, which may move them out of position.

Using cruise control can also cause someone to be “out of position.” A DRS explained that the normal foot positioning on the highway without using cruise control is on the gas, so that’s the point of reference when it is time to move your foot to brake. In cruise control mode, a driver’s foot could be anywhere, so is out of position. The DRSs reported that older people or drivers with multiple sclerosis who have difficulty moving between the gas and brake pedal use cruise control like a hand control to drive in city environments.

2.3.3. Distracted Drivers and Unexpected Events

Distractions inside or outside of the vehicle can contribute to pedal application errors. Something unexpected happening in the driving environment can trigger a pedal application error. An event may be unexpected because a driver is distracted, perhaps by engaging in some kind of non-driving activity. Then the traffic light changes or a car pulls out of a driveway, or another aspect of the traffic situation surprises them, and the result is a pedal misapplication.

2.4. Research Gap

It is found that lots of works had done to reduce traffic accidents by different mechanisms but there is nothing in the literature which related directly to unintended acceleration pedal locking mechanism during panic pressing of acceleration pedal. This study aims to fill this gap by exploring the effect of Acceleration pedal locking mechanism on vehicle collision. Also, here in Ethiopia many accidents are occurred caused by many factors. As other countries pedal misapplication will be one factor for vehicle accident. There is no recorded data for accidents here in Ethiopia directly related to pedal miss application.

3. MATERIALS AND METHODS

This chapter focused mainly on unintended acceleration locking system, which was done using some mechanical and electrical components and the methodologies employed. The materials required for this work and methodology to be followed are given below.

3.1. Materials

Tools used in this study are:

a) Proteus simulation software: used to model an electrical system which involves sensors, controller, and an actuator. With the help of this simulation software schematically connect all electrical components and check the effect of potentiometer movement on the DC motor.

b) PuTTY software: The test performed using PuTTY software, which provides a network linkage between controller of prototype and the computer.

c) Microsoft Excel: Used to draw the analysis result calibration corresponding to the input value.

d) AutoCAD: used to construct the rack and pinion CAD model.

Tablez3.1: Materials used for prototype

No	Items
1	Potentiometer (Rotary type)
2	Board (Frame)
3	Pedal (Toyota Hiace)
4	Motor Drive (L298N)
5	Rack and Pinion Gear
6	Arduino microcontroller
8	Jumper Wire
9	DC to DC Booster
10	Dc motor

3.1.1. Accelerator Pedal

The accelerator pedal is also known as gas pedal. It is the pedal located on the floor on the far-right. This pedal controls the amount of gas being fed into the engine and thereby controls the speed of the vehicle. Figure 3.1 most common type of Toyota hiace Accelerator pedal. When the driver pushes the accelerator pedal with right foot with his heel resting on the ground.

Figure 3.2: Toyota Hiace Accelerator pedal

Accelerator pedal has a spring, which returns it to the idle position when not depressed by the driver. Normally the throttle and brake are operated by the right foot, while the clutch is operated by the left foot. However, drivers sometimes mistake the accelerator for the brake, leading to sudden unintended acceleration.

3.2. Mechanical System Modeling

The CAD models of rack and pinion were prepared using the AutoCAD Figure 3.5. The details of the models are given as follows;

3.2.1. Rack and Pinion Gear

A rack and pinion gears system is composed of two gears. The normal round gear is the pinion gear and the straight or flat gear is the rack. The rack has teeth cut into it and they mesh with the teeth of the pinion gear.

A gear rack has straight teeth cut into one surface of a square or round section of rod and operates with a pinion, which is a small cylindrical gear meshing with the gear rack. Gear racks are utilized to convert rotating movement into linear motion. Rack and pinion can convert from rotary to linear or from linear to rotary. The diameter of the gear determines the speed that the rack moves as the pinion turns.

For spur gear design, pinion and rack both have straight teeth or spur geometry of teeth. Consider the design of pinion as a spur gear.

Force on a Spur gear

Spur gears, have teeth parallel to the axis of rotation and are used to transmit motion from one shaft to another, parallel, shaft of all types, the spur gear is the simplest.

The terminology of spur gear teeth is illustrated in Figure 3.2. The pitch circle is a theoretical circle upon which all calculations are usually based; its diameter is the pitch diameter. The pitch circles of a pair of mating gears are tangent to each other. The circular pitch p is the distance, measured on the pitch circle, from a point on one tooth to a corresponding point on an adjacent tooth. Thus the circular pitch is equal to the sum of the tooth thickness and the width of space.

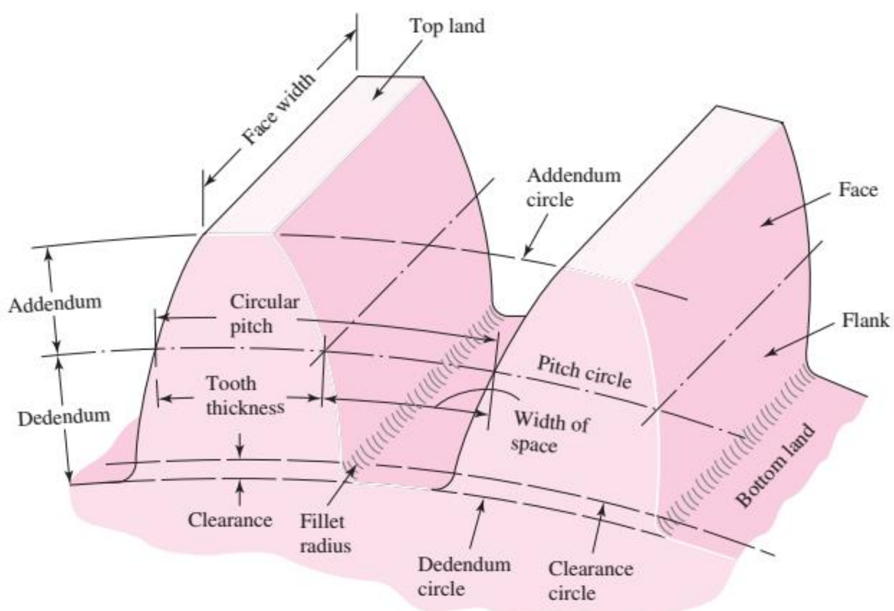

Figure 3.3: Nomenclature of spur-gear teeth (Budynas-Nisbett, 2008)

The module “m” is the ratio of the pitch diameter to the number of teeth. The customary unit of length used is the millimeter. The module is the index of tooth size in SI.

The diametric pitch “P” is the ratio of the number of teeth on the gear to the pitch diameter. Thus, it is the reciprocal of the module. Since diametric pitch is used only with U.S. units, it is expressed as teeth per inch.

The addendum is the radial distance between the top land and the pitch circle. The dedendum b is the radial distance from the bottom land to the pitch circle. The whole depth is the sum of the addendum and the dedendum.

The clearance circle is a circle that is tangent to the addendum circle of the mating gear. The clearance c is the amount by which the dedendum in a given gear exceeds the addendum of its mating gear. The backlash is the amount by which the width of a tooth space exceeds the thickness of the engaging tooth measured on the pitch circles. Where P is diametric pitch, teeth per inch, N is number of teeth, d is pitch diameter, in, m is module, mm, d is pitch diameter, mm and p is circular pitch.

$$P = \frac{N}{d} \quad (3.1)$$

$$m = \frac{d}{N} \quad (3.2)$$

$$p = \frac{\pi d}{N} = \pi m \quad (3.3)$$

$$pP = \pi \quad (3.4)$$

Figure 3.3 shows an involute rack in mesh with a pinion. Corresponding sides on involute teeth are parallel curves; the base pitch is the constant and fundamental distance between them along a common normal as shown in Figure 3.3. The base pitch is related to the circular pitch by the equation where P_b, is the base pitch (Moya et al., 2009).

$$Pb = Pc \cos\varphi \quad (3.5)$$

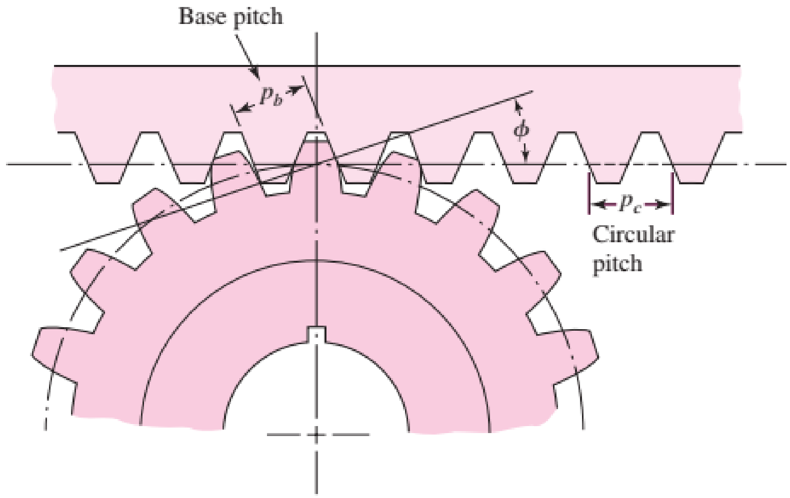

Figure 3.4: Involute-toothed pinion and rack (Budynas-Nisbett, 2008)

When two spur gears are meshed shown in Figure 3.5, the rack is the driver, the contact point moves along a line as the gears rotate. The force on a spur gear has two components: radial (F_r), tangential (F_t) forces and their resultant force (F_r) as shown in Figure 3.4.

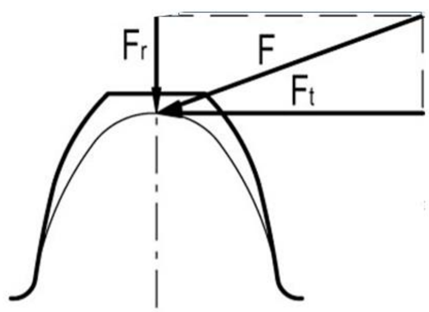

Figure 3. 5: Forces on the tooth

$$\text{Power, } P = \frac{T\,n}{63{,}000} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{ (3.6)}$$

$$\text{Torque, } T = \text{Ft r} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{ (3.7)}$$

Combining equations 3.6 and 3.7;

$$Ft = \frac{2T}{Dp} \qquad (3.8)$$

Lewis form factor method;

$$Fs = \frac{Sn\ Y\ b}{Pd} \qquad (3.9)$$

Where S_n is the allowable stress, Y is Lewis form factor, b face width; D_p is diametral pitch, and F_s allowable dynamic bending force (Moya et al., 2009).

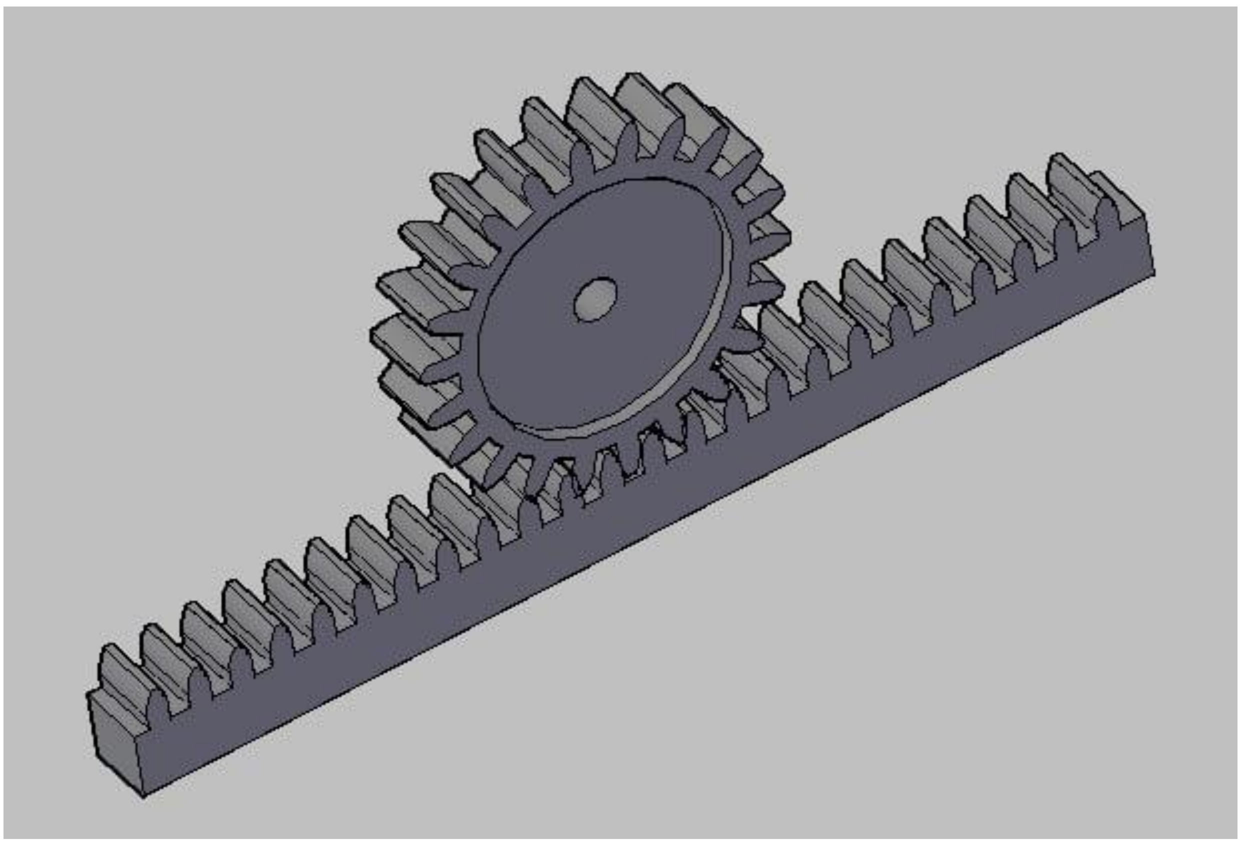

Figure 3.6: Rack and pinion gear

For changing linear motion of the accelerator pedal to rotary motion of potentiometer a rack and pinion type gear mechanism necessary. A rack and pinion type gear of linear actuator that comprises a circular gear (the pinion) engaging a linear gear (the rack), which operate to translate rotational motion into linear motion or vice versa. Driving the pinion into rotation causes the rack to be driven linearly. Driving the rack linearly will cause the pinion to be driven into a rotation.

3.3. Electrical System Modeling

The control logic which involves sensors, a microcontroller, and an actuator driver is modeled using Proteus simulation software. During panic time the driver makes driving error and may press acceleration pedal instead of the brake pedal, if the driver presses very fast, the accelerator pedal, the control module senses this speed and compares with the normal or default accelerator pedal pressing speed and if the accelerator pedal is faster than the normal speed control unit apply cut off signal to fuel pump.

This system involves sensors (potentiometer), a microcontroller (arduino uno), and an actuator (DC motor) in order to sense when the driver presses the accelerator pedal very fast, microcontroller compares this instant pressing time with normal or default accelerator pedal pressing time and if the accelerator pedal is faster than the threshold speed the control unit will command to cutoff fuel pump in order to avoid unintended acceleration.

While analysing the accelerator pedal to identify whether it is panic or normal an experiment was conducted using PuTTY software. The pedal movement response task was controlled by a program loaded desktop computer with putty stimuli were presented on a display screen. The C++ program for an unintended automatic accelerator pedal locking system depicted in Appendix A. In this work Toyota haice 5L pedal was used, which is the most common and easily available from retired vehicles. Cheea p

When conducting the experiment the driver presses accelerator pedal in different conditions i.e suddenly from zero to full load, during smooth driving, sudden accelerator pedal pressing in the middle of normal driving, and sudden acceleration while driving at high speed. These conditions are the most common conditions on the driving road.

In each trial, acceleration performed the pedal choice response task proceed by the pressing and monitoring it. In every experiment task there were raw data and its graph of the trials and its corresponding values, and these values saved in Microsoft Excel format. The accelerator pedal was started from initial (zero) position to its full load position according to its case study situation.

Flow chart of system modeling and design

This Flowchart shows how to create a line follower application and run it on Arduino program. The whole process is repeated over and over many times per millisecond and forms a feedback loop which makes the program follow the line. The sensitivity of the output can be adjusted by changing the value in the threshold variable. Play around with these values until you get the program to follow the line successfully.

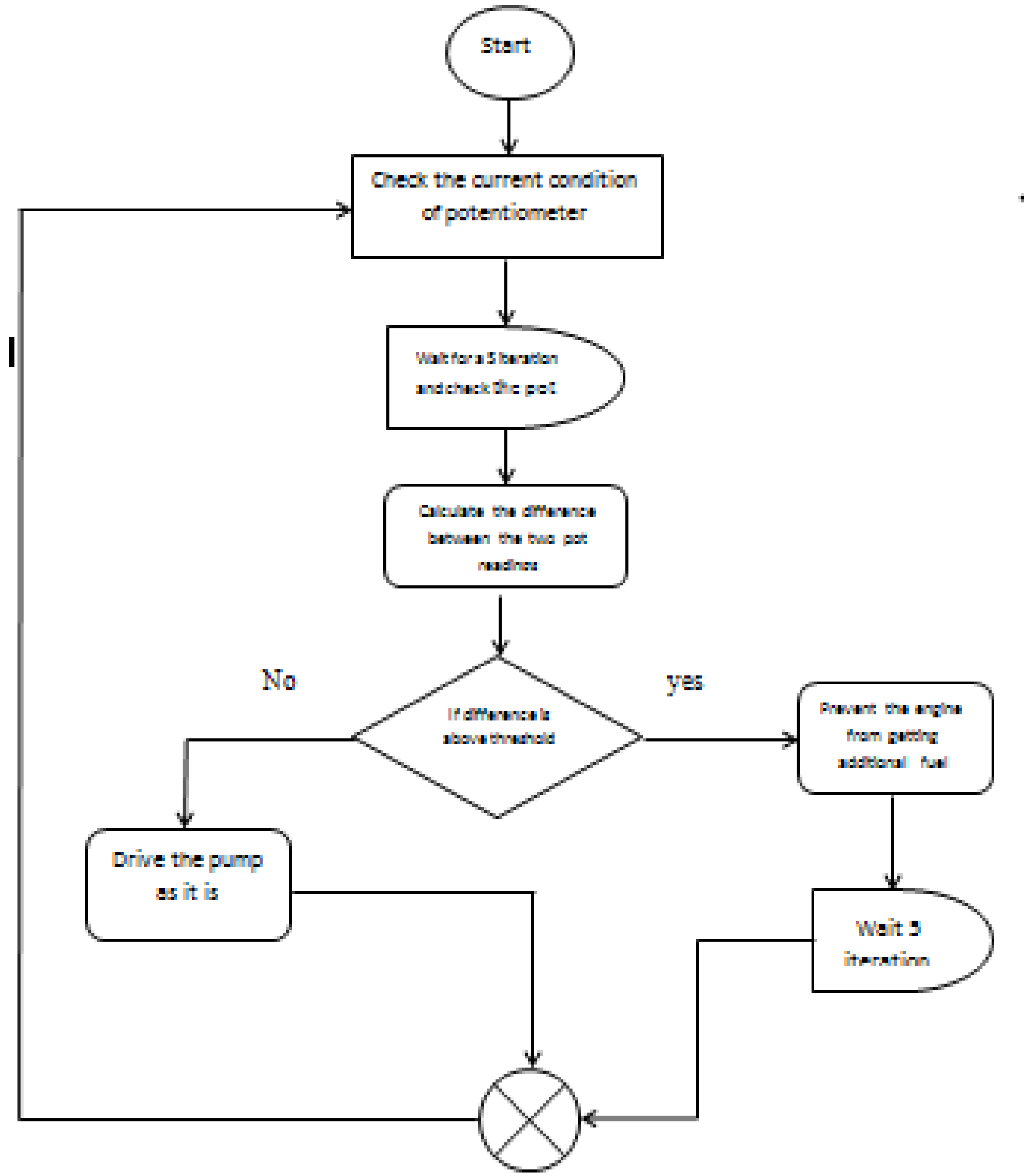

Figure 3.7: Flow chart of control logic

Proteus software simulation

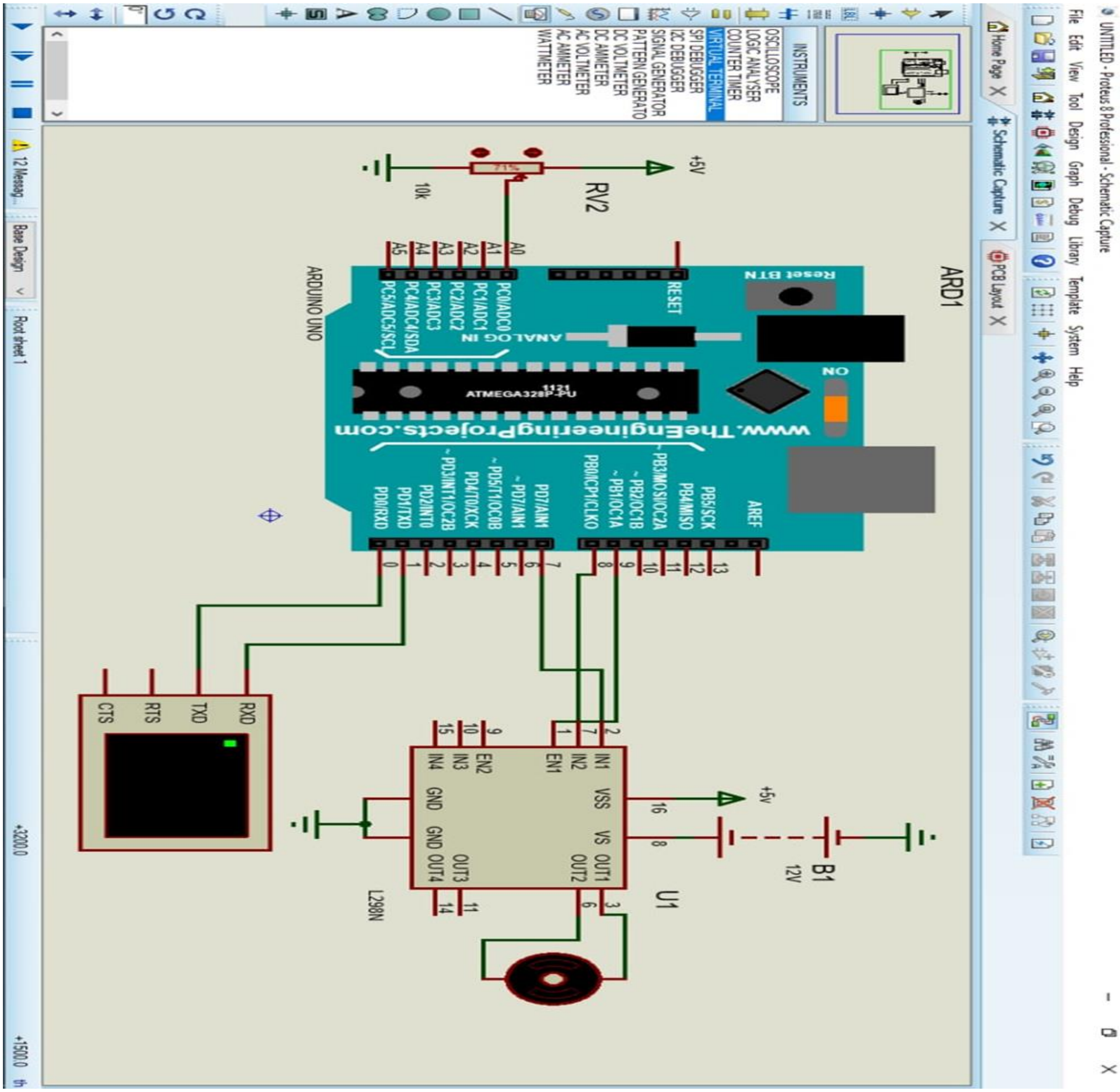

Figure 3.8: Schematic diagram of Electrical system

The potentiometer has three terminals this three terminals connect three pins of the Arduino board using jumper wires. The first goes to ground from one of the outer pins of the potentiometer. The second goes from 5 volts to the other outer pin of the potentiometer. The third goes from analog input

A0 to the middle pin of the potentiometer. A0 terminal reads the analog value that comes from potentiometer and change to the digital value to microcontroller. IN1 and IN2 of the L298N module connected respectively with pin 7 and 8 of the digital part of the Arduino, with this connection fuel pump get power from motor drive module, EN1 pin of drive module and pin 9 of arduino are inter connected, which is used to control the speed of motor. OUT1 attached with the motor positive terminal and OUT2 of L298N connected with negative terminal of the motor. For the power source the L298n drive directly 12 volt from battery. Figure 3.7 shows the schematic diagram of electrical systems, which consists of different components. Such components are presented below.

3.3.1. Arduino

Arduino is an open-source electronic platform used for building electronics projects based on easy-to use hardware and software. Arduino consists of both a physical programmable circuit board (often referred to as a microcontroller) and a piece of software, or IDE (Integrated Development Environment) that runs on computer, used to write and upload computer code to the physical board. All Arduino boards are completely open-source, empowering users to build them independently and eventually adapt them to their particular needs. The software, is open-source, and it is growing through the contributions of users worldwide.

The Arduino platform has become quite popular with people just starting out with electronics, and for good reason. Unlike most previous programmable circuit boards, the Arduino simply used a USB cable, it doesn’t need a separate piece of hardware (called a programmer) in order to load new code onto the board. Additionally, the Arduino IDE uses a simplified version of C++, making it easier to learn to program. Finally, Arduino provides a standard form factor that breaks out the functions of the micro-controller into a more accessible package.

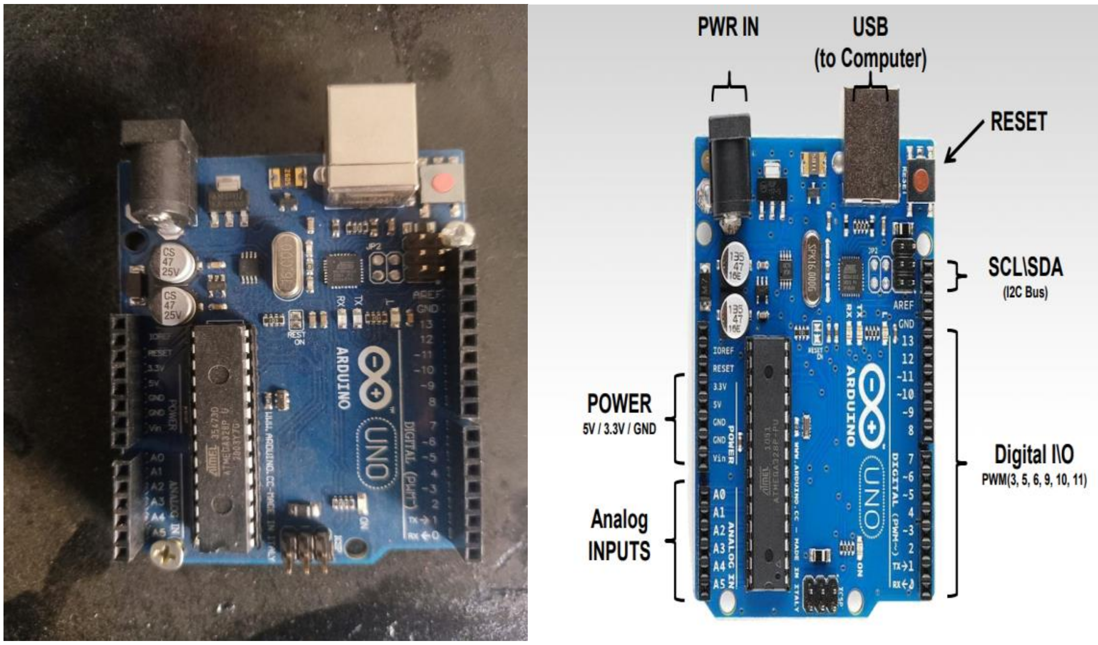

Figure 3. 9: Major components of Arduino

Figure 3.8 shows that arduinos have some major components in common such as,

Power Supply: The Arduino Uno can be powered via the USB connection or with an external power supply. The power source is selected automatically. The external power supplies mainly include AC to DC adapter otherwise a battery. The adapter can be connected to the Arduino Uno by plugging into the power jack of the Arduino board connected by plugging a 2.1mm center-positive plug into the board's power jack. The suggested voltage range will be 7 volts to 12 volts.

Pins: The pins on Arduino used to connect wires to construct a circuit probably in conjunction with a breadboard and some wire. They usually have black plastic 'headers' that allow plugging a wire right into the board. The Arduino has several different kinds of pins, each of which is labeled on the board and used for different functions.

VIN: The input voltage to the Arduino board when it's using an external power source (as opposed to 5 volts from the USB connection or other regulated power source). Voltage can be supplied through this pin, or, if supplying voltage via the power jack, access it through this pin.

GND: Short for 'Ground'. There are several GND pins on the Arduino, any of which can be used to ground the circuit.

5V: This pin outputs a regulated 5V from the regulator on the board. The board can be supplied with power either from the DC power jack (7 - 12V), the USB connector (5V), or the VIN pin of the board (7-12V). Supplying voltage via the 5V or 3.3V pins bypasses the regulator, and can damage the board.

3V3: A 3.3 volt supply generated by the on-board regulator. Maximum current draw is 50mA.

Analog: The area of pins under the 'Analog In' label (A0 through A5 on the UNO) are Analog in pins. These pins can read the signal from an analog sensor and convert it into a digital value.

Digital: Across from the analog pins are the digital pins (0 through 13 on the UNO). These pins can be used for both digital input (like telling if a button is pushed) and digital output (like powering an LED).

PWM: Some of these digital pins (3, 5, 6, 9, 10, and 11 on the UNO). These pins act as normal digital pins, but can also be used for something called Pulse-Width Modulation (PWM).

AREF: Stands for Analog Reference, used to set an external reference voltage (between 0 and 5 Volts) as the upper limit for the analog input pins.

Reset Button: The Arduino has a reset button. Pushing it will temporarily connect the reset pin to ground and restart any code that is loaded on the Arduino. This can be very useful if the loaded code doesn't repeat, but possible to test it multiple times.

Power LED Indicator: Just beneath and to the right of the word "UNO" on the circuit board, there's a tiny LED next to the word 'ON'. This LED should light up whenever the Arduino pluged into a power source. If this light doesn't turn on, there's a good chance something is wrong. Time to re-check the circuit.

TX RX LEDs: TX is short for transmit, RX is short for receive. These markings appear quite a bit in electronics to indicate the pins responsible for serial communication. In this case, there are two places on the Arduino UNO where TX and RX appear -once by digital pins 0 and 1, and a second time next to the TX and RX indicator LEDs. These LEDs gives some nice visual indications whenever Arduino is receiving or transmitting data (like when loading a new program onto the board).

Voltage Regulator: The voltage regulator does it controls the amount of voltage that is let into the Arduino board. It's like a kind of gatekeeper; it will turn away an extra voltage that might harm the circuit. It has limits, so don't hook up Arduino to anything greater than 20 volts.

Microcontroller

The black thing with all the metal legs is an IC, or Integrated Circuit. It's like the brains of Arduino. The main IC on the Arduino is slightly different from board type to board type, but is usually from the ATmega line of IC's from the ATMEL company. This can be important to know the IC type (board type) before loading up a new program from the Arduino software. This information can usually be found in writing on the top side of the IC.

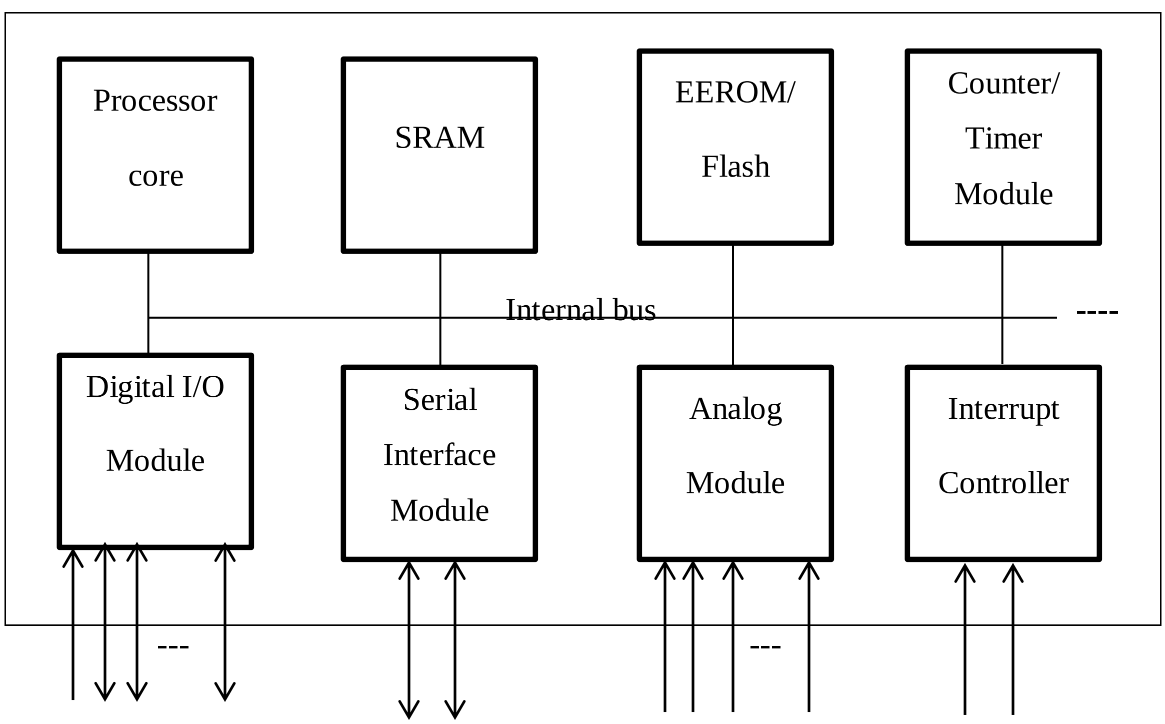

Figure 3.10: Buses of Microcontroller

Figure 3.9 shows that major components typically found in a microcontroller.

Processor Core: The CPU of the controller. It contains the arithmetic logic unit, the control unit, and the registers (stack pointer, program counter, accumulator register, register file).

Memory: The memory is sometimes split into program memory and data memory. In larger controllers, a DMA controller handles data transfers between peripheral components and the memory.

Interrupt Controller: Interrupts are useful for interrupting the normal program flow in case of (important) external or internal events. In conjunction with sleep modes, they help to conserve power.

Timer/Counter: Most controllers have at least one and more likely 2-3 Timer/Counters, which can be used to timestamp events, measure intervals, or count events. Many controllers also contain PWM (pulse width modulation) outputs, which can be used to drive motors or for safe breaking (antilock brake system, ABS). Furthermore the PWM output can, in conjunction with an external filter, be used to realize a cheap digital/analog converter.

Digital I/O: Parallel digital I/O ports are one of the main features of microcontrollers. The number of I/O pins varies from 3-4 to over 90, depending on the controller family and the controller type.

Analog I/O: Apart from a few small controllers, most microcontrollers have integrated analog/digital converters, which differ in the number of channels (2-16) and their resolution (8-12 bits). The analog module also generally features an analog comparator. In some cases, the microcontroller includes digital/analog converters.

Interfaces: Controllers generally have at least one serial interface which can be used to download the program and for communication with the development PC in general. Since serial interfaces can also be used to communicate with external peripheral devices, most controllers offer several and varied interfaces like SPI and SCI. Many microcontrollers also contain integrated bus controllers for the most common (field) busses. IIC and CAN controllers lead the field here. Larger microcontrollers may also contain PCI, USB, or Ethernet interfaces.

Watchdog Timer: Since safety-critical systems form a major application area of microcontrollers, it is important to guard against errors in the program and/or the hardware. The watchdog timer is used to reset the controller in case of software “crashes”.

Debugging Unit: Some controllers are equipped with additional hardware to allow remote debugging of the chip from the PC. So there is no need to download special debugging software, which has the distinct advantage that erroneous application code cannot overwrite the debugger.

3.3.2. Potentiometer (POT)

The instrument designs for measuring the unknown voltage by comparing it with the known voltage, such type of instrument is known as the potentiometer. In other words, the potentiometer is the three terminal devices as shown in Figure 3.10, used for measuring the potential differences by manually varying the resistances. The known voltage is drawn by the cell or any other supply sources.

Figure 3.11: Potentiometer

The potentiometer uses the comparative method which is more accurate than the deflection method. So, it is mostly used in the places where higher accuracy is required or where no current flows from the source under test. The potentiometer is used in the electronic circuit, especially for controlling the volume.

The following are the important characteristics of the potentiometer:

- The potentiometer is very accurate because its works on the comparing method rather than the deflection pointer method for determining the unknown voltages.
- It measures the null or balance point which does not require power for the measurement.
- The working of the potentiometer is free from the source resistance because no current flows through the potentiometer when it is balanced.

The potentiometer has three terminals, the two terminals are connected to the resistor, and the third terminal is connected to the wiper which is movable with the wire. Because of this moving wire, the variable potential is tapped off. The third terminal is used for controlling the variable resistor. The potential of the third terminal is controlled by changing the applying potential at the end of the resistor. The body of the potentiometer is made up of resistive material, and the wire is wound on it.

3.3.2.1. Potentiometer Types

There are three main types of potentiometers:

a) Rotary potentiometer
b) Linear potentiometer
c) Digital Potentiometer

Although the basically rotary and linear potentiometer constructional features of these potentiometers vary, the working principle of both of these types of potentiometers is the same. These are types of DC potentiometers while the types of AC potentiometers are slightly different.

a) Rotary Potentiometer

The rotary type potentiometers (Figure 3.11) are used mainly for obtaining adjustable supply voltage to a part of electronic circuits and electrical circuits. The volume controller of a radio transistor is a popular example of a rotary potentiometer where the rotary knob of the potentiometer controls the supply to the amplifier. By turning the shaft of the potentiometer, it changes the amount of resistance on either side of the wiper which is connected to the center pin of the potentiometer. This changes the relative "closeness" of that pin to 5 volts and ground, giving us a different analog input. When the shaft is turned all the way in one direction, there are 0 volts going to the pin, and read 0. When the shaft is turned all the way in the other direction, there are 5 volts going to the pin and it read 1023. In between, analogRead(POT) returns a number between 0 and 1023 that is proportional to the amount of voltage being applied to the pin.

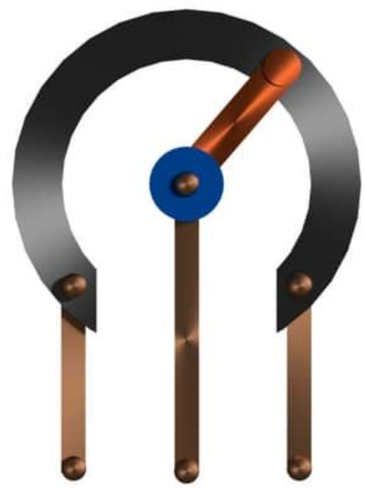

Figure 3.12: Rotary potentiometer

This type of potentiometer has two terminal contacts between which a uniform resistance is placed in a semi-circular pattern. The device also has a middle terminal which is connected to the resistance through a sliding contact attached with a rotary knob. By rotating the knob one can move the sliding contact on the semi-circular resistance. The voltage is taken between a resistance end contact and the sliding contact. The potentiometer is also named as the POT in short. POT is also used in substation battery chargers to adjust the charging voltage of a battery. There are many more uses of rotary type potentiometer where smooth voltage control is required. In this work rotary potentiometer used because it's easily available on the market, have lowest cost and compatible on accelerator pedal arrangement with a slight modification. Also it's installed on accelerator pedal without difficulty.

b) Linear Potentiometer

The linear potentiometer shown in Figure 3.12, is basically the same but the only difference is that here instead of rotary movement the sliding contact gets moved on the resistor linearly. Here two ends of a straight resistor are connected across the source voltage. A sliding contact can be slide on the resistor through a track attached along with the resistor. The terminal connected to the sliding is connected to one end of the output circuit and one of the terminals of the resistor is connected to the other end of the output circuit.

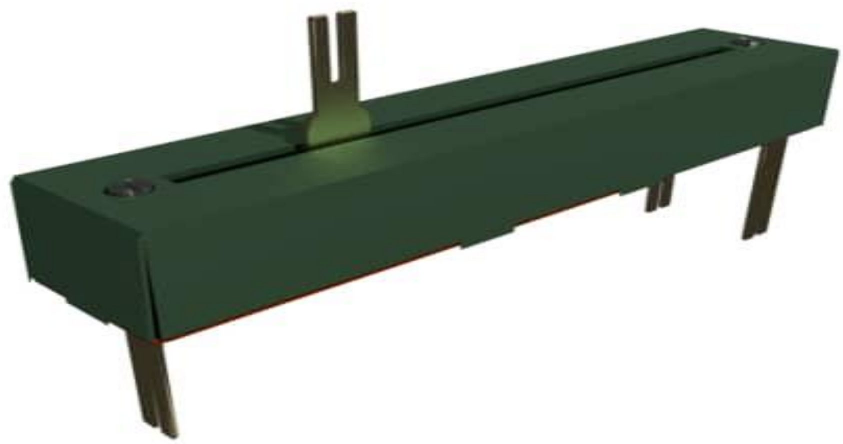

Figure 3.13: Linear potentiometer

This type of potentiometer is mainly used to measure the voltage across a branch of a circuit, for measuring the internal resistance of a battery cell, for comparing a battery cell with a standard cell and in our daily life; it is commonly used in the equalizer of music and sound mixing systems.

c) Digital Potentiometer

Digital potentiometers are three-terminal devices, two fixed end terminals and one wiper terminal which is used to vary the output voltage. Digital potentiometers have various applications, including calibrating a system, adjusting offset voltage, tuning filters, controlling screen brightness, and controlling sound volume.

However mechanical potentiometers suffer from some serious disadvantages which make it unsuitable for applications where precision is required. Size, wiper contamination, mechanical wear, resistance drift, sensitivity to vibration, humidity, etc. are some of the main disadvantages of a mechanical potentiometer. Hence to overcome these drawbacks, digital potentiometers are more common in applications since it provides higher accuracy.

3.3.3. Motor Driver (L298N)

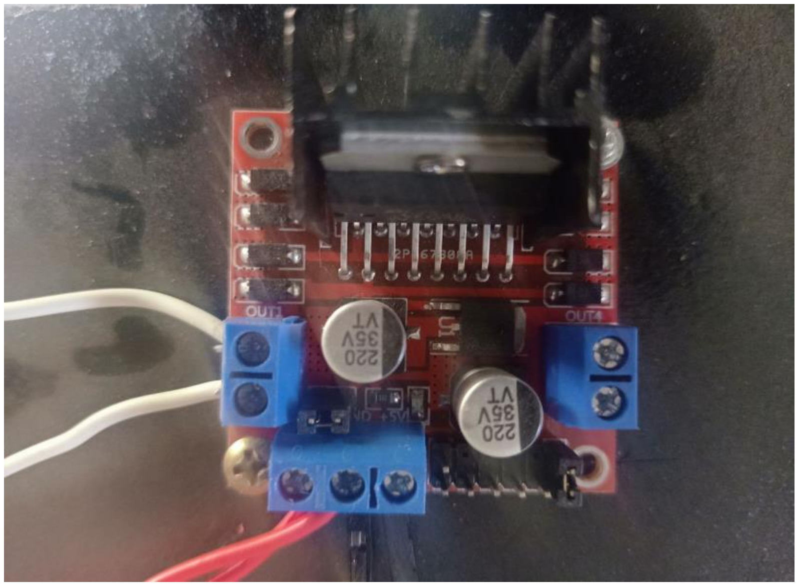

Figure 3.14: L298N Motor Control Module

Arduino board or a microcontroller IO pins don’t have enough current/voltage driving capability to drive a motor (Figure 3.13). L298N control the speed of the motor using PWM technique, Pulse Width Modulation is a technique which allows us to adjust the average value of the voltage that’s going to the electronic device by turning on and off the power at a fast rate. The average voltage depends on the duty cycle, or the amount of time the signal is ON versus the amount of time the signal is OFF in a single period of time and for driving the motor in both directions (clockwise and anti-clockwise) it need to use an H-Bridge. L298N is an integrated monolithic circuit with dual H-Bridge.

For the installation and integrate with the program first define the pins and some variables needed for the program. In the setup section it need to set the pin modes and the initial rotation direction of the motor. The loop section start by reading the potentiometer value and then map the value that we get from it which is from 0 to 1023, to a value from 0 to 255 for the PWM signal, or that’s 0 to 100% duty cycle of the PWM signal. Then using the analogWrite()(analogWrite(ENA, m_speed2) function is send the PWM signal to the Enable pin of the L298N board, which actually drives the motor

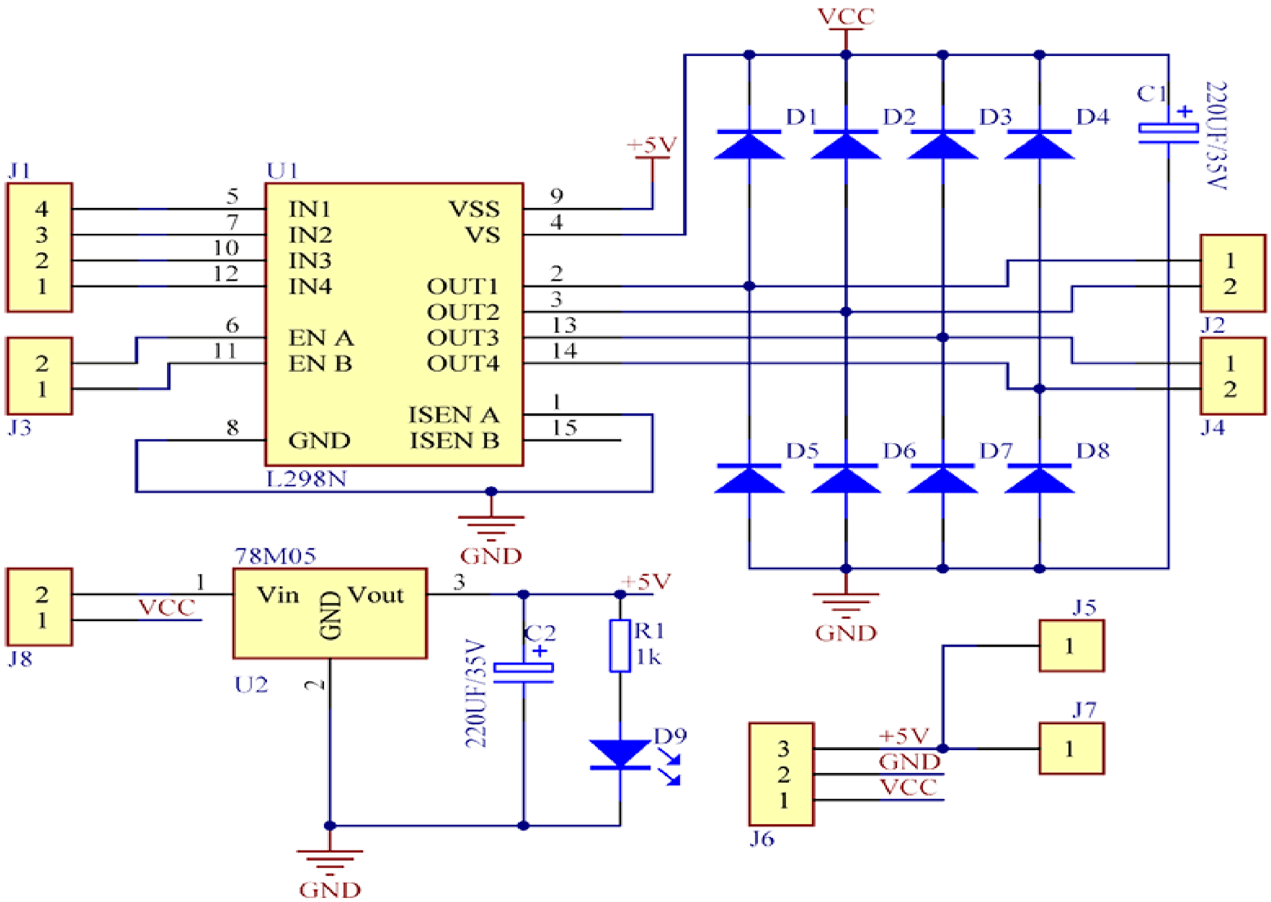

Figure 3.15: Schematic diagram for motor drive module

This L298N Motor Driver Module is a high power motor driver module for driving DC and Stepper Motors. Figure 3.14 shows schematic diagram for motor drive module, which consists of an L298 motor driver IC and a 78M05 5V regulator. 78M05 5V Regulator has an on-board 78M05 5V Voltage regulator. This Voltage regulator will be performed only when the 5V enable jumper is placed. When the power supply is less than or equal to 12V, then the internal circuitry will be powered by the voltage regulator, and the 5V pin can be used as an output pin to power the microcontroller or other circuitry (sensor). The jumper should not be placed when the power supply is greater than 12V and separate 5V should be given through 5V terminal to power the internal circuitry.

L298N Module can control up to 4 DC motors, or 2 DC motors with directional and speed control. This dual bidirectional motor driver is based on the very popular L298 Dual H-Bridge Motor Driver Integrated Circuit. The circuit allows easily and independently controls two motors of up to 2A each in both directions. It is ideal for robotic applications and well suited for connection to a microcontroller requiring just a couple of control lines per motor. It can also be interfaced with simple manual switches, TTL logic gates, relays, etc. This board equipped with power LED indicators, on-board +5V regulator and protection diodes. Table 3.2 shows that the description of L298N Module Pins.

Table 3.2: L298N Module Pins Description

Pin No.	Pin Name	Description
Power Supply Pins		
1	VCC	VCC pin is used to supply power to the motor. Its input voltage is between 5 to 35V.
2	GND	GND is a ground pin. It needs to be connected to the power supply ground(negative).
3	+5V	+5V pin supplies power for the switching logic circuitry inside the L298N IC. If the 5V-EN jumper is in place, this pin acts as output and can be used to power up a microcontroller or other circuitry (sensor). If the 5V-EN jumper is removed, it need to connect it to the 5V power supply of the microcontroller.
Control Pins		
1	IN1	These pins are input pins of Motor A. These are used to control the rotating direction of Motor A. When one of them is HIGH and the other is LOW, Motor A will start rotating in a particular direction. If both the inputs are either HIGH or LOW the Motor A will stop.
2	IN2	
3	IN3	These pins are input pins of Motor B. These are used to control the rotating direction of Motor A. When one of them is HIGH and the other is LOW, Motor A will start rotating in a particular direction. If both the inputs are either HIGH or LOW the Motor A will stop.
4	IN4	

Speed Control Pins		
1	ENA	ENA pin is used to control the speed of Motor A. If a jumper is present on this pin, so the pin connected to +5 V and the motor will be enabled, then the Motor A rotates maximum speed. If jumper removed it need to connect ENA pin to a PWM input of the microcontroller. In that way, it controls the speed of Motor A. If it is connected ENA to Ground the Motor A will be disabled.
2	ENB	ENB pin is used to control the speed of Motor B. If a jumper is present on this pin, so the pin connected to +5 V and the motor will be enabled, then the Motor B rotates maximum speed. If jumper removed it need to connect ENB pin to a PWM input of the microcontroller. In that way, it controls the speed of Motor B. If it is connected ENB to Ground the Motor B will be disabled.
Output Pins		
1	OUT1 & OUT2	This terminal block will provide the output for Motor A.
2	OUT3 & OUT4	This terminal block will provide the output for Motor B.

3.3.4 Jumper Wires

Jumper wires are simply wires that have connector pins at each end, allowing them to be used to connect two points to each other without soldering. Jumper wires (Figure 3.15) are typically used with breadboards and prototyping tools in order to make it easy to change a circuit as needed. Usually jumper wires come in three versions: male-to-male, male-to-female and female-to-female. The difference between each is in the end point of the wire. Male ends have a pin protruding and can plug into things, while female ends do not and are used to plug things into.

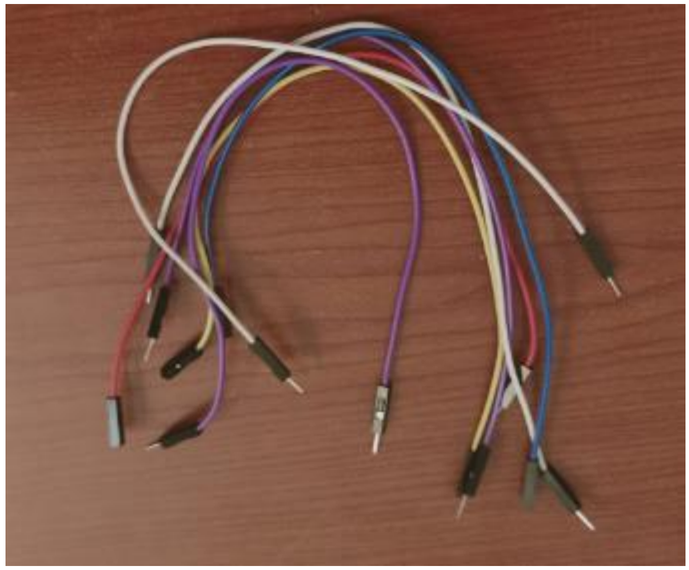

Figure 3.16 Jumper Wire

3.3.5 DC to DC Booster

Boost converters (Figure 3.16) are essentially a step-up power converter that take in a low voltage input and provide an output at a much higher voltage. The converter input voltage range determined as 5V-12V DC and output voltage of boost converter is created as 35V DC. This converter has potential uses 35V compatible applications for operating prototype DC motor. The input terminal of booster connect with the 12V output terminal of drive module and the output terminal connect with motor.

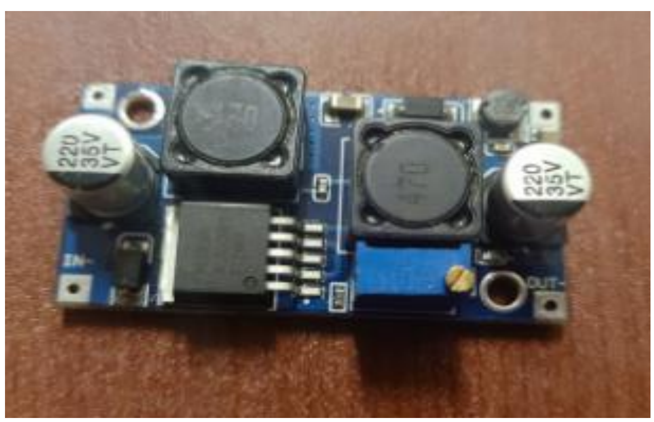

Figure 3.17 DC-to-DC Booster

3.4. PuTTY

PuTTY is a free and open-source terminal emulator, serial console and network file transfer application. It supports several network protocols, including SCP, SSH, Telnet, rlogin, and raw socket connection. It can also connect to a serial port. The name "PuTTY" has no official meaning.

PuTTY was originally written for Microsoft Windows, but it has been ported to various other operating systems. Official ports are available for some Unix-like platforms, with work-in-progress ports to Classic Mac OS and macOS, and unofficial ports have been contributed to platforms such as Symbian, Windows Mobile and Windows Phone.

PuTTY supports many variations on the secure remote terminal, and provides user control over the SSH encryption key and protocol version, alternate ciphers such as AES, 3DES, RC4, Blowfish, DES, and Public-key authentication. PuTTY uses own format of key files – PPK (protected by Message Authentication Code) it supports SSO through GSSAPI, including user provided GSSAPI DLLs. It also can emulate control sequences from xterm, VT220, VT102 or ECMA-48 terminal emulation, and allows local, remote, or dynamic port forwarding with SSH (including X11 forwarding). The network communication layer supports IPv6, and the SSH protocol supports. It can also be used with local serial port connections.

PuTTY comes bundled with command-line SCP and SFTP clients, called "pscp" and "psftp" respectively, and plink, a command-line connection tool, used for non-interactive sessions. Figure 3.17 shows that how to install all prototype components and conducting of the experiment setup.

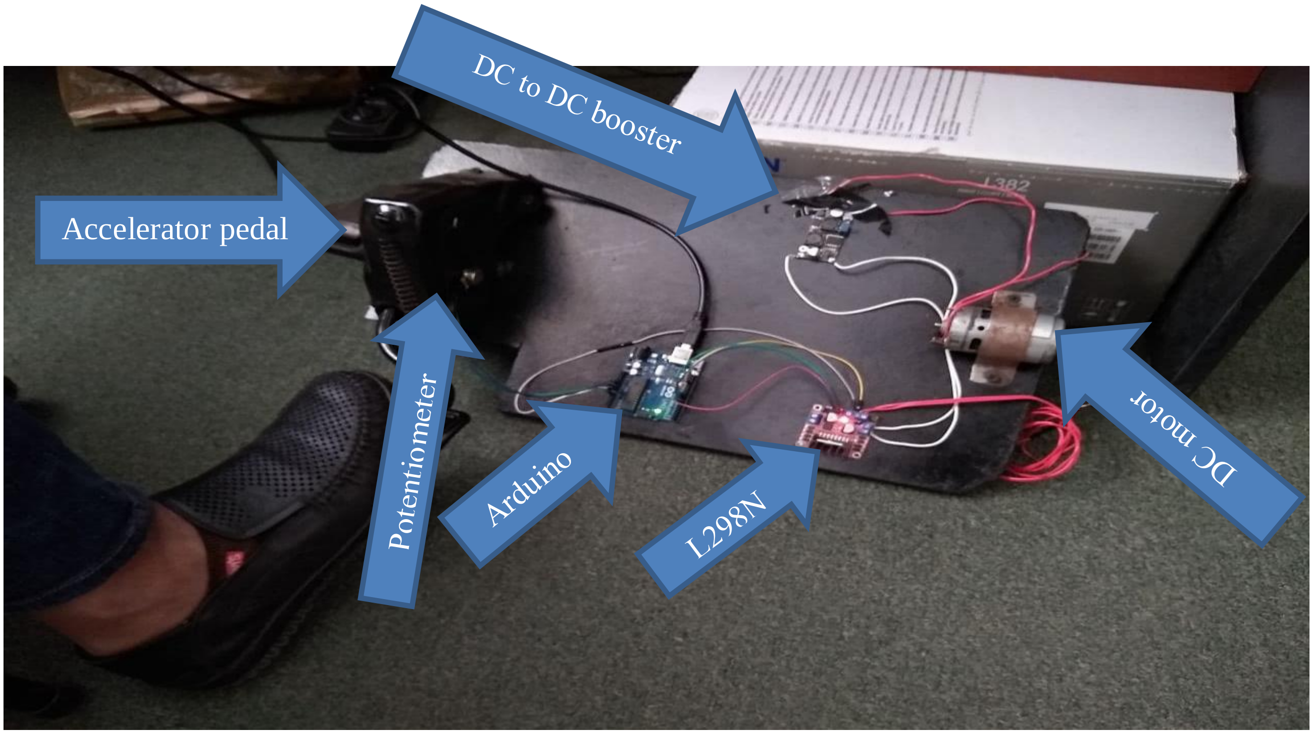

Figure 3.18: Installation of Automatic Accelerator Pedal Lock Prototype

3.5 Working Principle

While a driver driving a vehicle, he pressed and released the accelerator pedal to control the amount of fuel that inject into the car engine these action of pressing and releasing movement of the gas pedal control (monitor) by the sensor element(potentiometer) and give voltage signal to the microcontroller (arduino uno) through jumper wire. According to the program, arduino check the potentiometer difference in every 5(five) millisecond and compare with the threshold value that is 9.95m/s of pedal travel and give command for fuel pump control module. If the vale is more than this vale the control model shutoff the fuel pump, and if the accelerator pedal travel vale is less than 9.95m/s the system run as usual. The main drawback of this system is when the vehicle is at high speed or on the slop road the effect is not that much due to the inertia force.

4. RESULTS AND DISCUSSIONS

This chapter includes the results of unintended acceleration test and discussion based on these results. The test was performed using PuTTY software, which provides a network linkage between controller of prototype and the computer. The results of different cases presented below.

ADC (Analog to Digital Converter) is an electronic circuit used to convert analog signals into digital signals. This digital representation of analog signals allows the processor (which is a digital device) to measure the analog signal and uses it through its operation. Arduino Pins A0-A5, are capable of reading analog voltages. On Arduino the ADC has 10-bit resolution, meaning it can represent analog voltage by 1,024 digital levels. In an unintended acceleration test the results explained which condition of driving is panic. In Figure 4.1, 4.3 and 4.4 the maximum potentiometer reading was 1,023, which is the maximum level reading of Arduino it indicate the maximum voltage (5000mV). This maximum voltage reading (5000mV) indicates the maximum accelerator pedal travel distance from idle to full load position (120mm). Detail result of the experiments i.e. case 1, case 2, case 3and case 4 presented in Appendix C.

4.1. Result of Case One

Case 1*: Pressing accelerator pedal suddenly from zero to full load*

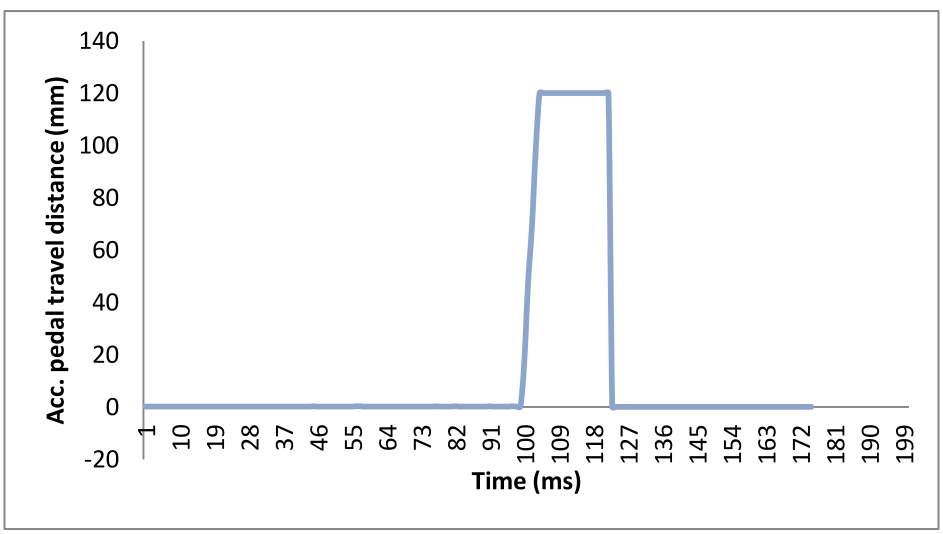

Figure 4.1: Pressing accelerator pedal suddenly from zero to full load

In order to understand whether the acceleration is unintended or not this test was carried out on the prepared prototype using PuTTY software. When the driver drives a vehicle he presses the gas pedal, which controls the speed of the vehicle. The driver should press the gas pedal smoothly in order to have a smooth acceleration otherwise it is difficult to control the vehicle even may cause an accident. This test identified which gas pedal action is smooth and which one is panic.

In this case initially the accelerator pedal is in its initial position then the driver suddenly presses pedal till its reaches maximum accelerator pedal position. This was evident in that the test vehicles' engines did not race to a high RPM level and the vehicles decelerated or gradually accelerated depending on the initial test speed. The vehicle behaved as operating in a normal idle condition. The vehicles remained easily controllable in terms of being free of any abrupt acceleration. The potentiometer reading was zero up to the time 0.99ms this indicated the acceleration pedal was in idle position (120mm), which indicates the driver doesn't apply any force on the accelerator pedal as shown in Figure 4.1. This pedal controls the amount of gas being fed into the engine and thereby controls the speed of the vehicle. The driver pushes the accelerator with his right foot with his heel resting on the ground. After 99ms, the driver suddenly presses the accelerator pedal till the maximum accelerator pedal position (120mm) which steps up the potentiometer reading. The graph deviation from range of 100 to 104ms was 20.6m/s. At the range of this time the accelerator pedal travel from 17mm to 120mm (maximum accelerator pedal position). This brings that the potentiometer reads its maximum value with a fraction of seconds, then the deviation evaluated as,

$Deviation = \frac{\text{Potentiometer difference}}{\text{Time difference}}$ (Take the time difference 5ms)……………………………….(4.1)

4.2. Result of Case Two

***Case 2**: Smooth driving condition*

There are many conditions which influence driving speed such as light, weather condition, road, traffic, and vehicle. The second test was examined at a smooth driving condition i.e. the driver presses and releases the accelerated pedal smoothly in order to accelerate or decelerate (slowing down). Smooth driving condition means when the driver accelerate or decelerate smoothly. Smooth acceleration is achieved by maintaining just enough pressure on the gas pedal to keep the speedometer moving steadily upward, until the desired speed is reached. Sometimes this means holding the accelerator down partially without adding more pressure and at other times, it will demand a gradual increase in pressure. The latter is usually true when accelerating up a slope.

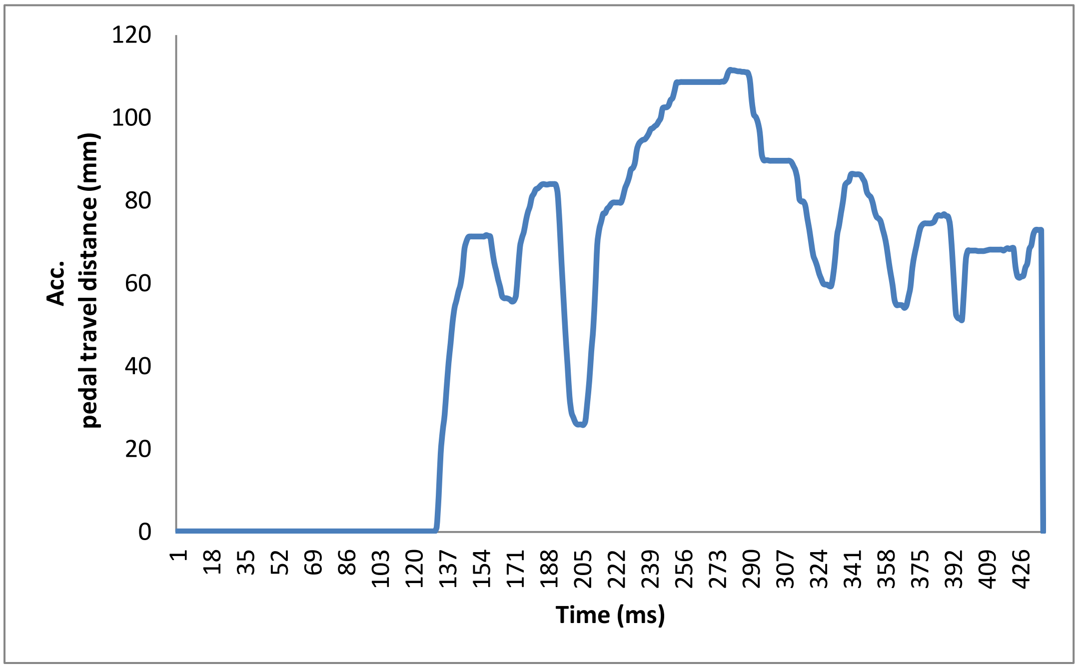

Figure 4.2: Smooth driving condition

The test result indicated that the potentiometer reading was zero while the accelerator pedal was in idle. After 131ms the graph oscillates smoothly as a result of the acceleration pedal movement i.e. pressing and releasing smoothly. At 191ms, the driver smoothly released the accelerator pedal as shown in Figure 4.2 the graph decreased smoothly i.e. the potentiometer reading decreased. From 208 to 213ms the driver pressed the accelerator pedal then the potentiometer reading increased smoothly with a slope of 7.6m/s. Also in this graph the deviation slope of 8.2m/s was a maximum from 395 to 400ms. The above two slopes were the highest slopes in this test. The graph doesn't step up or down like Figure 4.1. In this test the vehicle have a smooth acceleration and deceleration.

4.3 Result of Case Three

***Case 3**: Sudden accelerator pedal pressing in the middle of normal driving*

In this case initially accelerator pedal was in idle position (up to 66milisecond) then the driver smoothly presses the accelerator pedal after 66ms. After this time the driver drive a certain seconds with in smooth acceleration without decelerating, the graph increasing smoothly until the driver pressed the pedal to its maximum pedal position suddenly at 133ms. From 133 to 138ms the graph jumps to highest potentiometer reading with a maximum gradient of 15.93m/s as shown in Figure 4.3. At this range of 133 to 138ms the accelerator pedal traveled to its maximum position (120mm) from 40mm. Sudden acceleration can occur when clutter on the floor or loose floor mats interfere with the driver's operation of the gas pedal. The gas pedal is mistaken for the brakes. When this happens, the driver may push the gas pedal down even harder because he firmly believes he is using the brakes.

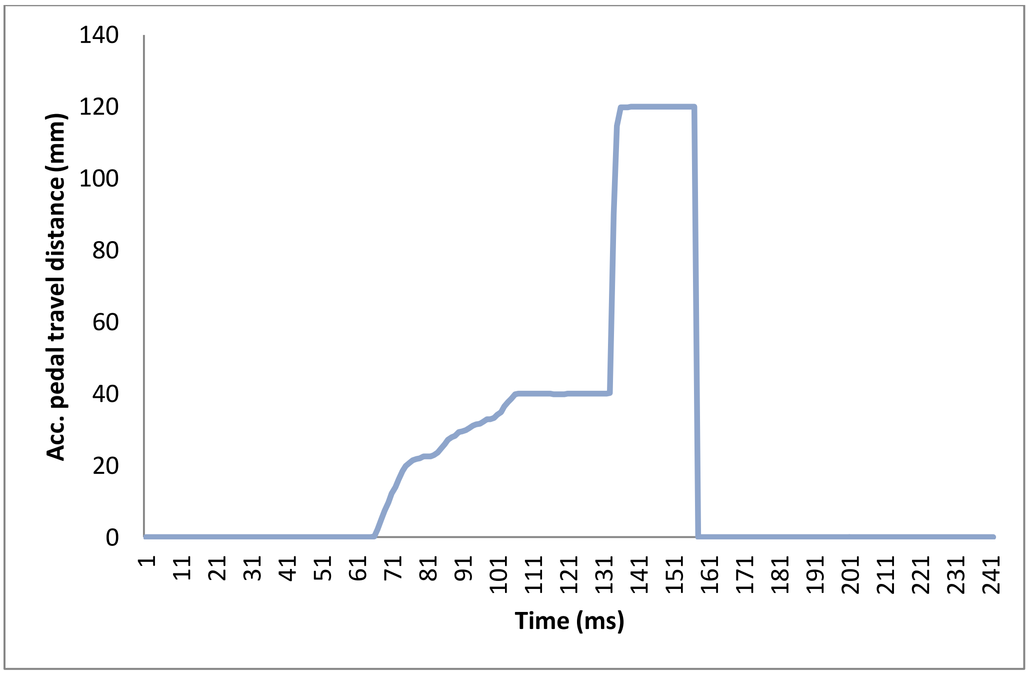

Figure 4.3: Sudden accelerator pedal pressing in the middle of normal driving

4.4 Result of Case Four

***Case 4**: Sudden acceleration while driving at high speed*

In this case the accelerator pedal was in initial position i.e. the driver didn’t apply any load up to 119ms. After this time the driver smoothly applied a load then the vehicle moves at highest speed than the previous three cases. The graph increases smoothly from zero potentiometer reading which indicated that the driver drive with smooth acceleration, until the driver pressed the gas pedal to its final position suddenly at 219ms. After this time the accelerator pedal position traveled to full load position

(120mm). In other words at 220ms the graph steps up to the highest potentiometer reading with a maximum slope of 9.95m/s.

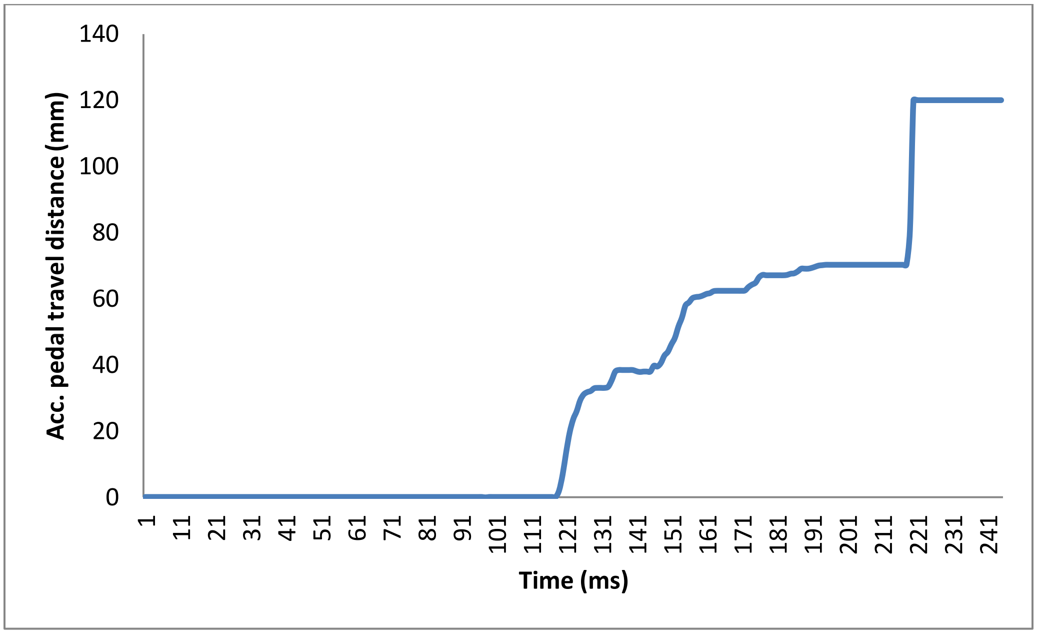

Figure 4.4: Sudden acceleration while driving at high speed

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Summary

Pedal operation mistakes caused by drivers accidentally pressing the accelerator pedal tend to result in accidents when the drivers mistake the pedal for a brake pedal. In a pedal operation mistake, the driver presses on the pedal with extreme force. When the driver thought he has pressed on the brake pedal, but the car continues to accelerate, the driver instinctively presses harder on the pedal with a distinctive amount of force that is different from normal acceleration force. This unusually strong pedal force is a phenomenon that can be used to detect operation mistakes with the accelerator pedal. Based on a gas pedal force investigation within instant time of a driver, this instant time was found to be a practical index for preventing unintended acceleration.

When the car is controlled by a sudden acceleration prevention system triggered by gas pedal pressing time detection, which reduces unwanted acceleration, this decreases car accident or damage occurred. This method can be one possible solution that allows every car driver to prevent accidents caused by operation mistakes with the accelerator pedal.

5.2. Conclusions

Avoiding accidents and saving lives are one of great interest that all researchers and automotive companies work on. Something unexpected happening in the driving environment can trigger a pedal application error. Movement of the foot from one pedal to another is a blind positioning movement. Drivers perform this movement without looking at their feet. When controls are not visible to operators, and it happen in panic condition the driver create mistake and instead of pressing brake pedal it press accelerator pedal in this situation the programmed logic unit(microcontroller) take the position of control.

The main findings are;

- ❖ The results show that Unintended acceleration locking mechanism is one possible way of improving safety of passengers in order to reduce property damage, injuries, and fatalities caused by these errors.
- ❖ According to the tests the maximum deviations occur in case 1, 3 and 4 with the slope deviation of 20.6m/s, 15.9m/s and 9.95m/s respectively. Below the lowest value of deviation i.e. 9.95m/s the program doesn’t consider as a mistake or unintended acceleration. If the potentiometer

reading to time gradient is above 9.95m/s the system locks the fuel supply system to the combustion chamber while the driver pressed the gas pedal suddenly with instant of time.

5.3. Recommendations

- ❖ Many Vehicle manufacturer companies have to improve the safety systems of their vehicles and give more emphasis on safety of passengers to save human precious life.
- ❖ To obtain more accurate results it's recommended that to use a linear type potentiometer in order to reduce the errors occurred by additional components (Rack and pinion gear).
- ❖ Driver training institutions vehicles here in Ethiopia have some modification in accelerator pedal system to monitor trainee. Hence, also this application used to reduce the occurrence of accidents.

5.4. Recommendations for Future Work

Future research would potentially extend the perspectives gained from this study and allow more insight into pedal operation characteristics associated with risks of unintended acceleration.
The following recommendations can be taken into consideration as future work:

- ❖ Unintended acceleration locking mechanism locks the fuel supply system to the combustion chamber while the driver pressed the gas pedal suddenly with instant of time. This system can be more advanced by integrate with brake system.
- ❖ By using different mechanisms of active safety system to improve passenger's safety. Also for an accurate and realistic result it's better to use a simulator test.
- ❖ To obtain more accurate results it's recommended that to use a linear type potentiometer.

REFERENCES

Akihiro Hirakawa, (2019), Characteristics and Measures Against Accelerator and Brake Pedal Misapplication Accidents, research section1, research division.

Asaye Yismaw and Mossa Endris Ahmed, (2015), The Causes of Road Traffic Accidents in Bahir Dar City, Ethiopia, International Journal of African and Asian Studies, ISSN 2409-6938, Vol.11, 2015.

Athira, Maithrik, Aiswarya, Akshay Sivadas, and Ashilly, (2018), Automotive Collision Avoidance System, International Research Journal of Engineering and Technology (IRJET), Volume: 05 Issue: 04,

Bishnu Deo Kumar, Anil Kumar Gupta, and Alok Ranjan, (2018), Object Detection and Collision Avoidance with Train Using GSM, IJETSR, ISSN 2394 – 3386, Volume 5, Issue 5

Daniel Hamrle, (2014), Transport Safety Assessment of Road Adaptive Lighting Implementation, Czech Technical University in Prague Faculty of Transportation Sciences,.

Davies, B.T. and Watts, J.M., Jr. (1970), Further Investigations of Movement Time Between Brake and Accelerator Pedal in Automobiles. Eactors, 12, 559-561.

Douglas Fraser (2015), Sudden Acceleration Shut Down Device Using Hydraulic Brake Pressure Detector to Disable Vehicle on Driver Panic, United States Patent Application Publication, Pub. No.: US 2015/0100218 A1.

Evangelos Skodras, George Siogkas, Evangelos Dermatas, and Nikolaos Fakotakis, (2012),. Rear Lights Vehicle Detection for Collision Avoidance, Researchgate, Conference Paper.

Haddon W Jr., (1970), On the Escape of Tigers: an Ecologic Note,   Public Health Nations Health 60 (12): 2229–34.

Hae-Seung Lee, (1993), Vehicle Safety System for Driver Pedal Misapplication, United States Patent, Patent Number: 5,193,640.

Jake S. Schwartz, (2017), Design of an automobile accelerator/brake pedal robot for advanced driver assistance systems, Purdue University Indianapolis, Indiana.

Jeremy Blum, (2020), Exploring Arduino: Tools and Techniques for Engineering Wizardry, published by Jone Wily and Sons,Inc, Canada.

Jonas Jansson, Jonas Johansson, and Fredrik Gustafsson, (2002), Decision Making for Collision Avoidance Systems, Researchgate.

K. H., Staplin, L., Martell, C. A., and Sifrit, K. J., (2012), Pedal Application Errors. (Report No. DOT HS 811 597). Washington, DC: National Highway Traffic Safety Administration.

Katsuya Matsunaga, Masuyuki Naruse, Fumikazu Muto, and Fumiaki Kitamura, (1996), New Brake Pedal and Accelerator Bar System to Prevent the Mistake of Pressing Down the Accelerator Instead of the Brake in Emergency Situations, Paper presented at the International Conference on Traffic and Transportation Psychology, Valencia, Spain.

Kunihiro Hasegawa , Motohiro Kimura, and Yuji Takeda,(2020), Pedal Misapplication: Interruption Effects and Age-Related Differences, National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba,.

Lococo, K. H., Staplin, L., Martell, C.A.,& Sifrit, K.J. (2012), Pedal Application Errors. Washington DC: National Highway Traffic Safety Administration, U.S. DOT.

Moya, A.S. Machado A.M. Becerra (2003), Determining the Lewis Factor for Plastic Spur Gears with Asymmetric Teeth, IMECE 2009−10172.

Morrison, R. W., Swope, J. G., and Halcomb, C.G.(1986), Movement Tme and Brake Pedal Placement. Human Factors, 28 (2), 241-246

Nissan Motor Corporation, Emergency Assist for Pedal Misapplication, (2020), Nissan technological development activities.

Olugbenga Oluseun, (2010), Reducing Road-Traffic Accidents on African Roads through a Computer Simulation Programming Approach, Australian Journal of Basic and Applied Sciences, ISSN 1991-8178, 4(8): 3016-3024.

Pooja Sikdar, Ahsan Rabbani, and N.K. Dhapekar, (2017), Hypothesis of Data of Road Accidents in India Review, International Journal of Civil Engineering and Technology (IJCIET), Volume 8, Issue 6, pp. 141–146.

Prince Z. Ncube, Priviledge Cheteni, Kholeka P. Sindiyandiya, (2016), Road Accidents Fatalities Trends and Safety Management in South Africa, Researchgate, Volume 14, Issue 3,.

Rogers, S. B., & Wierwille, W. W. (1988), The Occurrence of Accelerator and Brake Pedal Actuation Error During Simulated Driving. Human Factors: The Journal of the Human Factors and Ergonomics Society, 30(1), 71-81.

Tomokazu Suzuki, (2018), Method for Detecting Operation Mistakes with Accelerator Pedal, International journal of automotive engineering, vol 9.

Umar Zakir Abdul Hamid1, Yuichi Saito, Hairi Zamzuri, and Pongsathorn Raksincharoensak, (2018), Collision Avoidance Performance Analysis of A Varied Loads Autonomous Vehicle Using Integrated Nonlinear Controller, PERINTIS eJournal, Vol. 8, No. 1, pp. 17-43.

Xi, Yubin, (2015), Understanding the Automotive Pedal Usage and Foot Movement Characteristics of Older Drivers, All Dissertations. 1804.

Xiao-Yun Lu, Dongyan Su, and Steven E. (2012), Shladover, Impacts of Cooperative Adaptive Cruise Control on Freeway Traffic Flow, Transportation Research Record Journal of the Transportation Research Board, January.

Yimin Wei, Huadong Meng, Hao Zhang, and Xiqin Wang, (2007), Vehicle Frontal Collision Warning System based on Improved Target Tracking and Threat Assessment, Researchgate, September.

APPENDIX

Appendix A: Arduino Programming for Automatic Accelerator Pedal Lock

```
//L298N Motor pin setup
const int IN1 = 7;
const int IN2 = 8;
const int ENA = 9;
//Variable resistor pin setsup
const int POT = A0;
//Variable resistor & motor speed setup
int POT_read1, POT_read2, POT_change;
int m_speed1, m_speed2, m_change;
int threshold = 500; //Threshold to detect
int k = 3;

void setup() {
  //Intialize pins connected to L298N as OUTPUT
  pinMode(ENA, OUTPUT);
  pinMode(IN1, OUTPUT);
  pinMode(IN1, OUTPUT);
  //Set motor rotation direction as clockwise
  digitalWrite(IN1, HIGH);
  digitalWrite(IN2, LOW);
  //Initialize serial port for serial monitor
  Serial.begin(9600);
}

void loop() {
  //Get variable resistor reading and covert to speed level
  POT_read1 = analogRead(POT);
  POT_read1 = 1023 - POT_read1;
```

```
//m_speed1 = map(POT_read, 0, 1023, 0, 255);
delay(500);
POT_read2 = analogRead(POT);
POT_read2 = 1023 - POT_read2;
POT_change = POT_read2 - POT_read1;
if (POT_change > threshold){
  analogWrite(ENA, 0);
  delay(1000);
  //POT_read1 = analogRead(POT);
  //m_speed1 = map(POT_read, 0, 1023, 0, 255);
 // delay(100);
  POT_read2 = analogRead(POT);
  POT_read2 = 1023 - POT_read2;
  //m_speed2 = map(POT_read, 0, 1023, 0, 255);
  POT_change = POT_read2 - POT_read1;
  while (POT_change < 3) {
    //POT_read = analogRead(POT);
    //m_speed1 = map(POT_read, 0, 1023, 0, 255);
    //delay(100);
    POT_read2 = analogRead(POT);
    POT_read2 = 1023 - POT_read2;
    POT_change = POT_read2 - POT_read1;
    //m_speed2 = map(POT_read, 0, 1023, 0, 255);
    //m_change = m_speed2 - m_speed1;
    delay(100);
  }
}
m_speed2 = map(POT_read2, 0, 1023, 0, 255);
m_speed2 = m_speed2;
m_speed2 = m_speed2 * k;
if (m_speed2 > 255){
```

```
    m_speed2 = 255;
  }
  Serial.println(POT_read2);
  //Serial.println(m_speed2);
  analogWrite(ENA, m_speed2);
  delay(100);
}
```

Implementation of Arduino programming for potentiometer reading

```
const int POT = A0;
const int ENA = 9;
const int IN1 = 7;
const int IN2 = 8;
int POT_read;
int original, motor_speed;
int k1 = 10, k2 = 4, k3 = 1.5;// (0-30) -> [10]; (30, 60) -> [4]; (60, 250) -> [1.5]
int k = 1;

void setup() {
  // put your setup code here, to run once:
  Serial.begin(9600);
  pinMode(ENA, OUTPUT);
  pinMode(IN1, OUTPUT);
  pinMode(IN2, OUTPUT);
  digitalWrite(IN1, HIGH);
  digitalWrite(IN2, LOW);
}

void loop() {
  // put your main code here, to run repeatedly:
  POT_read = analogRead(POT);
  original = map(POT_read, 0, 1023, 0, 255);
```

```
  original = 255 - original;
  /*
  if (original >= 0 && original <= 30){
    k = k1;
  }
  else if(original > 30  && original <= 60){
    k = k2;
  }
  else if(original > 60){
    k = k3;
  }
  */
  motor_speed = k * original;
  if (motor_speed > 255){
    motor_speed = 255;
  }
  Serial.println(motor_speed);
  analogWrite(ENA, motor_speed);
  delay(100);
}
```

Appendix B: Cost Analysis

Table B- 1: Total cost for Installation of Automatic Accelerator Pedal Lock System

Item	Unit Price (birr)
Parts and materials	2500
Manufacturing board house	200
Software and Program	500
Man power	220
Total cost	3420

Appendix C: Conducting of the experiment

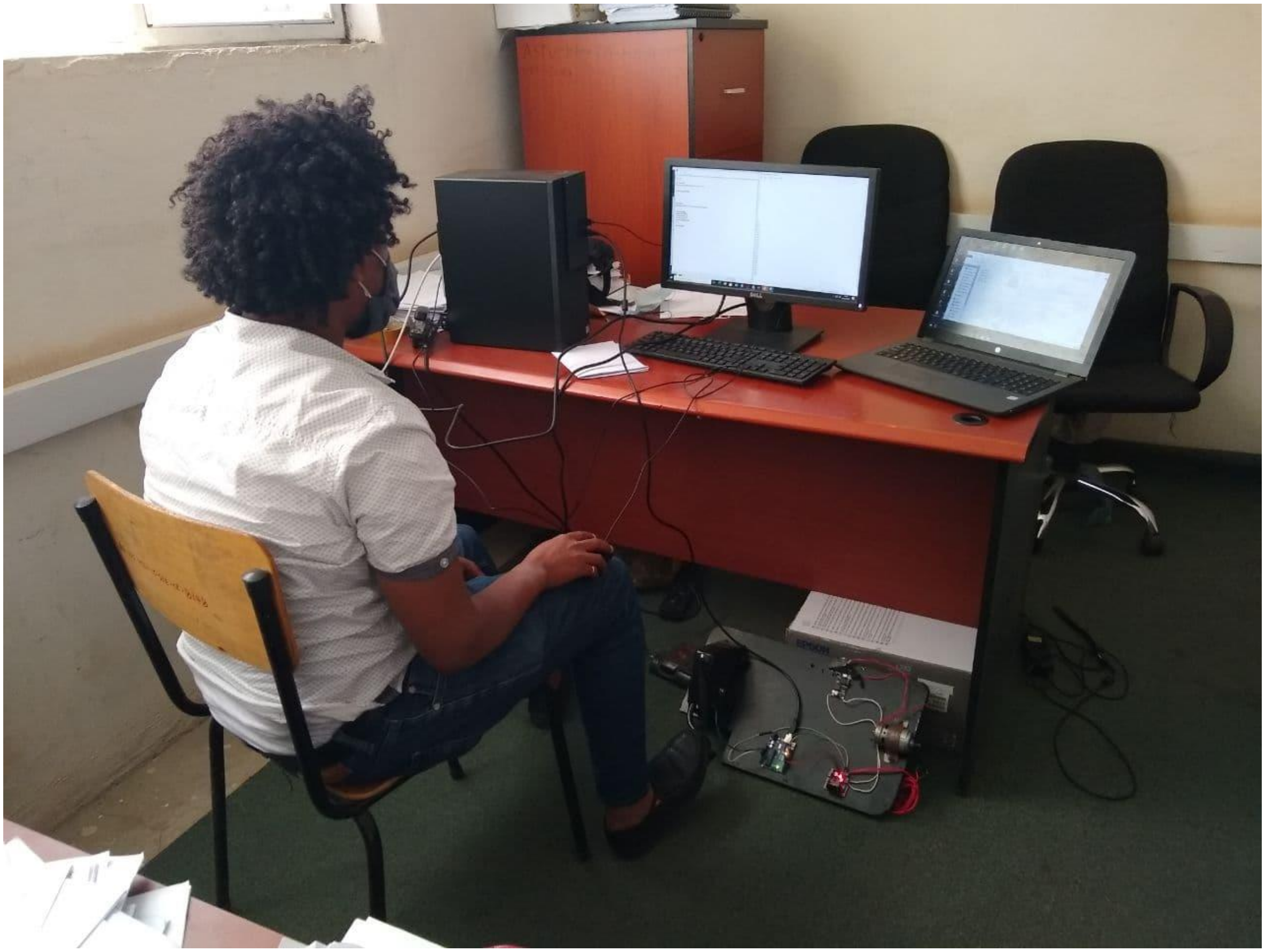

Figure C- 2: Conducting of the Experiment

Appendix D: Experimental Values

Table D- 1: accelerator pedal travel test data

Time (ms)	Case1		Case2		Case3		Case4	
	Potentiometer reading (mV)	pedal travel (mm)	Potentiometer reading (mV)	pedal travel (mm)	Potentiometer reading (mV)	pedal travel (mm)	Potentiometer reading (mV)	pedal travel (mm)
1	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
2	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
3	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
4	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
5	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
6	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
7	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
8	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
9	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
10	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
11	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
12	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
13	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
14	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
15	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
16	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
17	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
18	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
19	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
20	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
21	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
22	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
23	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
24	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
25	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
26	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
27	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
28	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
29	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
30	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
31	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
32	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12

33	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
34	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
35	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
36	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
37	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
38	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
39	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
40	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
41	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
42	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
43	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
44	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
45	9.8	0.23	4.9	0.12	4.9	0.12	4.9	0.12
46	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
47	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
48	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
49	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
50	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
51	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
52	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
53	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
54	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
55	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
56	9.8	0.23	4.9	0.12	4.9	0.12	4.9	0.12
57	9.8	0.23	4.9	0.12	4.9	0.12	4.9	0.12
58	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
59	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
60	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
61	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
62	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
63	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
64	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
65	4.9	0.12	4.9	0.12	4.9	0.12	4.9	0.12
66	4.9	0.12	4.9	0.12	9.8	0.23	4.9	0.12
67	4.9	0.12	4.9	0.12	92.9	2.23	4.9	0.12
68	4.9	0.12	4.9	0.12	215.1	5.16	4.9	0.12
69	4.9	0.12	4.9	0.12	307.9	7.39	4.9	0.12
70	4.9	0.12	4.9	0.12	405.7	9.74	4.9	0.12
71	4.9	0.12	4.9	0.12	508.3	12.20	4.9	0.12

72	4.9	0.12	4.9	0.12	581.6	13.96	4.9	0.12
73	4.9	0.12	4.9	0.12	674.5	16.19	4.9	0.12
74	4.9	0.12	4.9	0.12	767.4	18.42	4.9	0.12
75	4.9	0.12	4.9	0.12	830.9	19.94	4.9	0.12
76	4.9	0.12	4.9	0.12	865.1	20.76	4.9	0.12
77	9.8	0.23	4.9	0.12	899.3	21.58	4.9	0.12
78	4.9	0.12	4.9	0.12	914.0	21.94	4.9	0.12
79	4.9	0.12	4.9	0.12	918.9	22.05	4.9	0.12
80	4.9	0.12	4.9	0.12	938.4	22.52	4.9	0.12
81	4.9	0.12	4.9	0.12	938.4	22.52	4.9	0.12
82	9.8	0.23	4.9	0.12	938.4	22.52	4.9	0.12
83	4.9	0.12	4.9	0.12	958.0	22.99	4.9	0.12
84	4.9	0.12	4.9	0.12	987.3	23.70	4.9	0.12
85	4.9	0.12	4.9	0.12	1026.4	24.63	4.9	0.12
86	4.9	0.12	4.9	0.12	1080.2	25.92	4.9	0.12
87	4.9	0.12	4.9	0.12	1133.9	27.21	4.9	0.12
88	4.9	0.12	4.9	0.12	1163.2	27.92	4.9	0.12
89	4.9	0.12	4.9	0.12	1177.9	28.27	4.9	0.12
90	4.9	0.12	4.9	0.12	1221.9	29.33	4.9	0.12
91	9.8	0.23	4.9	0.12	1226.8	29.44	4.9	0.12
92	4.9	0.12	4.9	0.12	1241.4	29.79	4.9	0.12
93	4.9	0.12	4.9	0.12	1270.8	30.50	4.9	0.12
94	4.9	0.12	4.9	0.12	1300.1	31.20	4.9	0.12
95	4.9	0.12	4.9	0.12	1314.8	31.55	4.9	0.12
96	4.9	0.12	4.9	0.12	1319.6	31.67	4.9	0.12
97	9.8	0.23	4.9	0.12	1339.2	32.14	4.9	0.12
98	4.9	0.12	4.9	0.12	1368.5	32.84	0.0	0.00
99	4.9	0.12	4.9	0.12	1373.4	32.96	4.9	0.12
100	708.7	17.01	4.9	0.12	1383.2	33.20	4.9	0.12
101	1979.5	47.51	4.9	0.12	1422.3	34.13	4.9	0.12
102	2869.0	68.86	4.9	0.12	1456.5	34.96	4.9	0.12
103	4100.7	98.42	4.9	0.12	1520.0	36.48	4.9	0.12
104	5000.0	120.00	4.9	0.12	1573.8	37.77	4.9	0.12
105	5000.0	120.00	4.9	0.12	1612.9	38.71	4.9	0.12
106	5000.0	120.00	4.9	0.12	1661.8	39.88	4.9	0.12
107	5000.0	120.00	4.9	0.12	1671.6	40.12	4.9	0.12
108	5000.0	120.00	4.9	0.12	1671.6	40.12	4.9	0.12
109	5000.0	120.00	4.9	0.12	1671.6	40.12	4.9	0.12
110	5000.0	120.00	4.9	0.12	1671.6	40.12	4.9	0.12

111	5000.0	120.00	4.9	0.12	1671.6	40.12	4.9	0.12
112	5000.0	120.00	4.9	0.12	1671.6	40.12	4.9	0.12
113	5000.0	120.00	4.9	0.12	1671.6	40.12	4.9	0.12
114	5000.0	120.00	4.9	0.12	1671.6	40.12	4.9	0.12
115	5000.0	120.00	4.9	0.12	1671.6	40.12	4.9	0.12
116	5000.0	120.00	4.9	0.12	1671.6	40.12	4.9	0.12
117	5000.0	120.00	4.9	0.12	1661.8	39.88	4.9	0.12
118	5000.0	120.00	4.9	0.12	1661.8	39.88	4.9	0.12
119	5000.0	120.00	4.9	0.12	1661.8	39.88	88.0	2.11
120	5000.0	120.00	4.9	0.12	1661.8	39.88	288.4	6.92
121	5000.0	120.00	4.9	0.12	1666.7	40.00	567.0	13.61
122	5000.0	120.00	4.9	0.12	1666.7	40.00	816.2	19.59
123	4.9	0.12	4.9	0.12	1666.7	40.00	982.4	23.58
124			4.9	0.12	1671.6	40.12	1085.0	26.04
125			4.9	0.12	1666.7	40.00	1221.9	29.33
126			4.9	0.12	1671.6	40.12	1295.2	31.09
127			4.9	0.12	1671.6	40.12	1324.5	31.79
128			4.9	0.12	1671.6	40.12	1339.2	32.14
129			4.9	0.12	1671.6	40.12	1373.4	32.96
130			4.9	0.12	1671.6	40.12	1378.3	33.08
131			48.9	0.12	1671.6	40.12	1378.3	33.08
132			361.7	1.17	1671.6	40.12	1378.3	33.08
133			786.9	8.68	1676.4	40.23	1393.0	33.43
134			1011.7	18.89	3753.7	90.09	1476.1	35.43
135			1177.9	24.28	4775.2	114.60	1583.6	38.01
136			1446.7	28.27	4995.1	119.88	1603.1	38.48
137			1700.9	34.72	4995.1	119.88	1603.1	38.48
138			1896.4	40.82	4995.1	119.88	1603.1	38.48
139			2106.5	45.51	5000.0	120.00	1603.1	38.48
140			2253.2	50.56	5000.0	120.00	1603.1	38.48
141			2331.4	54.08	5000.0	120.00	1588.5	38.12
142			2419.4	55.95	5000.0	120.00	1578.7	37.89
143			2487.8	58.06	5000.0	120.00	1583.6	38.01
144			2624.6	59.71	5000.0	120.00	1583.6	38.01
145			2844.6	62.99	5000.0	120.00	1583.6	38.01
146			2922.8	68.27	5000.0	120.00	1656.9	39.77
147			2966.8	70.15	5000.0	120.00	1647.1	39.53
148			2971.7	71.20	5000.0	120.00	1691.1	40.59
149			2971.7	71.32	5000.0	120.00	1784.0	42.82

150			2971.7	71.32	5000.0	120.00	1832.8	43.99
151			2971.7	71.32	5000.0	120.00	1925.7	46.22
152			2971.7	71.32	5000.0	120.00	2008.8	48.21
153			2971.7	71.32	5000.0	120.00	2150.5	51.61
154			2971.7	71.32	5000.0	120.00	2263.0	54.31
155			2971.7	71.32	5000.0	120.00	2414.5	57.95
156			2986.3	71.32	5000.0	120.00	2453.6	58.89
157			2976.5	71.67	5000.0	120.00	2507.3	60.18
158			2971.7	71.44	4.9	0.12	2522.0	60.53
159			2839.7	71.32	4.9	0.12	2526.9	60.65
160			2712.6	68.15			2541.5	61.00
161			2629.5	65.10			2561.1	61.47
162			2536.7	63.11			2570.9	61.70
163			2463.3	60.88			2595.3	62.29
164			2370.5	59.12			2600.2	62.40
165			2350.9	56.89			2600.2	62.40
166			2350.9	56.42			2600.2	62.40
167			2346.0	56.42			2600.2	62.40
168			2336.3	56.30			2600.2	62.40
169			2316.7	56.07			2600.2	62.40
170			2326.5	55.60			2600.2	62.40
171			2380.3	55.84			2600.2	62.40
172			2619.7	57.13			2605.1	62.52
173			2864.1	62.87			2649.1	63.58
174			2957.0	68.74			2678.4	64.28
175			3020.5	70.97			2702.8	64.87
176			3128.1	72.49			2771.3	66.51
177			3216.0	75.07			2800.6	67.21
178			3274.7	77.18			2795.7	67.10
179			3367.5	78.59			2795.7	67.10
180			3401.8	80.82			2795.7	67.10
181			3445.7	81.64			2795.7	67.10
182			3455.5	82.70			2795.7	67.10
183			3475.1	82.93			2795.7	67.10
184			3494.6	83.40			2800.6	67.21
185			3499.5	83.87			2815.2	67.57
186			3494.6	83.99			2820.1	67.68
187			3494.6	83.87			2844.6	68.27
188			3499.5	83.87			2878.8	69.09

189			3499.5	83.99			2878.8	69.09
190			3499.5	83.99			2878.8	69.09
191			3494.6	83.99			2888.6	69.33
192			3406.6	83.87			2903.2	69.68
193			3098.7	81.76			2917.9	70.03
194			2697.9	74.37			2922.8	70.15
195			2341.2	64.75			2927.7	70.26
196			1984.4	56.19			2927.7	70.26
197			1681.3	47.62			2927.7	70.26
198			1363.6	40.35			2927.7	70.26
199			1202.3	32.73			2927.7	70.26
200			1148.6	28.86			2927.7	70.26
201			1099.7	27.57			2927.7	70.26
202			1080.2	26.39			2927.7	70.26
203			1080.2	25.92			2927.7	70.26
204			1080.2	25.92			2927.7	70.26
205			1075.3	25.92			2927.7	70.26
206			1114.4	25.81			2927.7	70.26
207			1305.0	26.74			2927.7	70.26
208			1520.0	31.32			2927.7	70.26
209			1813.3	36.48			2927.7	70.26
210			2052.8	43.52			2927.7	70.26
211			2434.0	49.27			2927.7	70.26
212			2888.6	58.42			2927.7	70.26
213			3045.0	69.33			2927.7	70.26
214			3123.2	73.08			2927.7	70.26
215			3201.4	74.96			2927.7	70.26
216			3206.3	76.83			2927.7	70.26
217			3250.2	76.95			2927.7	70.26
218			3269.8	78.01			2927.7	70.26
219			3299.1	78.48			3367.5	80.82
220			3313.8	79.18			5000.0	120.00
221			3313.8	79.53			5000.0	120.00
222			3313.8	79.53			5000.0	120.00
223			3313.8	79.53			5000.0	120.00
224			3313.8	79.53			5000.0	120.00
225			3372.4	79.53			5000.0	120.00
226			3455.5	80.94			5000.0	120.00
227			3504.4	82.93			5000.0	120.00

228			3563.0	84.11			5000.0	120.00
229			3646.1	85.51			5000.0	120.00
230			3660.8	87.51			5000.0	120.00
231			3714.6	87.86			5000.0	120.00
232			3846.5	89.15			5000.0	120.00
233			3905.2	92.32			5000.0	120.00
234			3929.6	93.72			5000.0	120.00
235			3944.3	94.31			5000.0	120.00
236			3949.2	94.66			5000.0	120.00
237			3973.6	94.78			5000.0	120.00
238			4007.8	95.37			5000.0	120.00
239			4051.8	96.19			5000.0	120.00
240			4061.6	97.24			5000.0	120.00
241			4081.1	97.48			5000.0	120.00
242			4095.8	97.95			5000.0	120.00
243			4130.0	98.30			5000.0	120.00
244			4164.2	99.12			5000.0	120.00
245			4262.0	99.94			5000.0	120.00
246			4271.7	102.29			5000.0	120.00
247			4271.7	102.52			4.9	0.12
248			4291.3	102.52			4.9	0.12
249			4345.1	102.99				
250			4364.6	104.28				
251			4437.9	104.75				
252			4521.0	106.51				
253			4521.0	108.50				
254			4525.9	108.50				
255			4525.9	108.62				
256			4525.9	108.62				
257			4525.9	108.62				
258			4525.9	108.62				
259			4525.9	108.62				
260			4525.9	108.62				
261			4525.9	108.62				
262			4525.9	108.62				
263			4525.9	108.62				
264			4525.9	108.62				
265			4525.9	108.62				
266			4525.9	108.62				

267			4525.9	108.62					
268			4525.9	108.62					
269			4525.9	108.62					
270			4525.9	108.62					
271			4525.9	108.62					
272			4525.9	108.62					
273			4525.9	108.62					
274			4525.9	108.62					
275			4530.8	108.62					
276			4530.8	108.74					
277			4560.1	108.74					
278			4618.8	109.44					
279			4648.1	110.85					
280			4643.2	111.55					
281			4643.2	111.44					
282			4638.3	111.44					
283			4633.4	111.32					
284			4633.4	111.20					
285			4628.5	111.20					
286			4628.5	111.09					
287			4623.7	111.09					
288			4618.8	110.97					
289			4545.5	110.85					
290			4330.4	109.09					
291			4198.4	103.93					
292			4174.0	100.76					
293			4120.2	100.18					
294			4017.6	98.89					
295			3797.7	96.42					
296			3739.0	91.14					
297			3739.0	89.74					
298			3739.0	89.74					
299			3734.1	89.74					
300			3734.1	89.62					
301			3734.1	89.62					
302			3734.1	89.62					
303			3734.1	89.62					
304			3734.1	89.62					
305			3734.1	89.62					

306			3734.1	89.62				
307			3734.1	89.62				
308			3734.1	89.62				
309			3734.1	89.62				
310			3719.5	89.62				
311			3680.4	89.27				
312			3636.4	88.33				
313			3543.5	87.27				
314			3348.0	85.04				
315			3323.6	80.35				
316			3323.6	79.77				
317			3279.6	79.77				
318			3152.5	78.71				
319			3040.1	75.66				
320			2903.2	72.96				
321			2781.0	69.68				
322			2727.3	66.74				
323			2668.6	65.45				
324			2595.3	64.05				
325			2546.4	62.29				
326			2497.6	61.11				
327			2487.8	59.94				
328			2487.8	59.71				
329			2473.1	59.71				
330			2473.1	59.35				
331			2575.8	59.35				
332			2751.7	61.82				
333			2981.4	66.04				
334			3084.1	71.55				
335			3211.1	74.02				
336			3328.4	77.07				
337			3484.8	79.88				
338			3514.2	83.64				
339			3528.8	84.34				
340			3597.3	84.69				
341			3602.2	86.33				
342			3597.3	86.45				
343			3597.3	86.33				
344			3597.3	86.33				

345			3587.5	86.33				
346			3553.3	86.10				
347			3514.2	85.28				
348			3421.3	84.34				
349			3387.1	82.11				
350			3367.5	81.29				
351			3308.9	80.82				
352			3220.9	79.41				
353			3167.2	77.30				
354			3152.5	76.01				
355			3123.2	75.66				
356			3045.0	74.96				
357			2971.7	73.08				
358			2869.0	71.32				
359			2727.3	68.86				
360			2600.2	65.45				
361			2482.9	62.40				
362			2331.4	59.59				
363			2282.5	55.95				
364			2282.5	54.78				
365			2282.5	54.78				
366			2277.6	54.78				
367			2253.2	54.66				
368			2277.6	54.08				
369			2365.6	54.66				
370			2463.3	56.77				
371			2658.8	59.12				
372			2781.0	63.81				
373			2873.9	66.74				
374			2971.7	68.97				
375			3054.7	71.32				
376			3089.0	73.31				
377			3103.6	74.13				
378			3103.6	74.49				
379			3103.6	74.49				
380			3103.6	74.49				
381			3108.5	74.49				
382			3123.2	74.60				
383			3167.2	74.96				

384			3186.7	76.01					
385			3181.8	76.48					
386			3181.8	76.36					
387			3196.5	76.36					
388			3176.9	76.72					
389			3172.0	76.25					
390			3084.1	76.13					
391			2825.0	74.02					
392			2487.8	67.80					
393			2189.6	59.71					
394			2150.5	52.55					
395			2145.7	51.61					
396			2131.0	51.50					
397			2414.5	51.14					
398			2746.8	57.95					
399			2829.9	65.92					
400			2829.9	67.92					
401			2829.9	67.92					
402			2829.9	67.92					
403			2829.9	67.92					
404			2825.0	67.92					
405			2825.0	67.80					
406			2825.0	67.80					
407			2825.0	67.80					
408			2829.9	67.80					
409			2834.8	67.92					
410			2839.7	68.04					
411			2839.7	68.15					
412			2839.7	68.15					
413			2839.7	68.15					
414			2839.7	68.15					
415			2839.7	68.15					
416			2839.7	68.15					
417			2829.9	68.15					
418			2844.6	67.92					
419			2854.3	68.27					
420			2844.6	68.50					
421			2854.3	68.27					
422			2854.3	68.50					

423			2668.6	68.50					
424			2570.9	64.05					
425			2556.2	61.70					
426			2570.9	61.35					
427			2575.8	61.70					
428			2658.8	61.82					
429			2702.8	63.81					
430			2844.6	64.87					
431			2883.7	68.27					
432			2991.2	69.21					
433			3035.2	71.79					
434			3040.1	72.84					
435			3035.2	72.96					
436			3035.2	72.84					