DESIGN AND IMPLEMENTATION OF MICROCONTROLLER BASED MOTOR VEHICLE SPEED GOVERNOR USING A MAGNETOSTRICTIVE AMORPHOUS WIRE SPEED SENSOR

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Design and Implementation of Microcontroller Based Motor Vehicle Speed Governor using a Magnetostrictive Amorphous Wire Speed Sensor

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other University

Signature………………………………… Date……………………. ……………..

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This thesis has been submitted for examination with our approval as university supervisors

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DEDICATION

I dedicate this work to my dear husband Richard, daughters Joy and Alisa, siblings (Felistas, Peter and Denis) and parents (Mr. and Mrs. Raymond Kiio) for their love, support and encouragement during the entire time of my studies.

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First and foremost I would like to thank God, for giving me good health during the entire period of this research. I wish to acknowledge the efforts of my supervisors, Prof. John N. Nderu and Prof. Stanley I. Kamau for their ideas, support and contributions in various stages of this research. I would also wish to acknowledge the financial support of Jomo Kenyatta University of Agriculture and Technology for my studies. I also wish to thank my friends and colleagues for their support all through the entire period.

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LIST OF ABBREVIATIONS

AC	Alternating current
ECU	Electronic control unit
ISA	Intelligent Speed Adaptation
LBJ	Large Barkhausen Jump
LCD	Liquid Crystal Display
MAW	Magnetostrictive Amorphous Wire
PCB	Printed Circuit Board
PDM	Pulse Duration Modulation
PWM	Pulse width modulation
RPM	Revolutions Per Minute
VR	Variable Reluctance

ABSTRACT

Kenya is ranked among countries with highest rate of road accidents globally by world health organization. The government has put in place several systems to curb accidents and among them is a vehicle speed governor. This is a device which limits top speed of a vehicle. This research focused on an electronic vehicle speed governor which consists of three key elements namely: vehicle speed sensor, controller unit and actuator.

There are various systems to prevent excessive speeding in roads and highways. These include use of Intelligent Speed Adaptation (ISA) system and speed governors. Most developing countries like Kenya adopt use of speed governors since ISA requires immense infrastructural investment. Design and performance of a vehicle speed governor depends highly on the speed sensing mechanism. Some conventional vehicle speed sensor such as variable reluctance sensor whose output signal is of a low magnitude and voltage pulse magnitude depends on shaft speed and requires complex circuitry for signal processing. Another problem experienced with current speed governors is vehicle jerking when top speed limit is attained. This is due to sudden fuel cut to the engine at top speed limit. To address this problem, this research focused on design of a vehicle speed governor prototype using Magnetostrictive Amorphous Wire (MAW) as speed sensor which has various advantages over variable reluctance sensor such as stable voltage pulses, voltage pulse output with appreciable high magnitude and also digital signal that is easy to interface with digital devices. It also involved design of control algorithm based on Pulse Width Modulation (PWM) technique to enable gradual fuel control when top vehicle speed is attained.

This thesis presents design and implementation of the vehicle speed sensor using MAW sensor in a vehicle, circuits for signal processing and speed governor control unit. A microcontroller based algorithm for the speed governor based on PWM duty cycle was also developed and experiments conducted through simulation and actual experiments.

For the speed sensor, results obtained show that it is a good choice for vehicle speed sensing and its unique features provide an excellent platform for interfacing with the control unit developed. With the control unit developed using atmega 32 microcontroller, speed processing and display was achieved.

From the results obtained, it was concluded that the MAW sensor and use of PWM algorithm could be a suitable choice for application in automotive industry for vehicle electronic speed governor development.

CHAPTER ONE

INTRODUCTION

1.1 Background

Road accidents are an increasing phenomenon due to reckless driving on the road. Most of the roads lack speed cameras and appropriate monitoring system for identifying over-speeding vehicles. Although many systems have been developed to minimize the accidents, further work is still necessary to improve the current situation.

Nowadays, huge research and development efforts are invested in curbing negative effects like traffic accidents and fatalities [1]. Vehicle safety is a critical issue in the automobile industry and there are two existing types of vehicle safety systems: active safety and passive safety systems. Active safety prevents accidents from happening and passive systems are built in the car to protect the occupants or users after the accident has happened. Active safety systems contribute substantially to reduction of severe injuries and fatalities in traffic and as the degree of active safety technology in vehicles is increased, the numbers of accidents decrease. Vehicle speed governor is one of the most important devices in the active safety system. It is a device in vehicles that limits the top speed of a vehicle.

This thesis focused on design and development of an electronic vehicle speed governor which comprises of three elements namely; speed sensor, control unit and solenoid valve actuator. With the electronic inclusion in the automotive field, electronic solutions have provided reliable solutions over time. The use of embedded systems into vehicle systems has increased over the years to make the systems more efficient and to control and monitor many of the functions that a few years ago were totally mechanical [2]. This has resulted to the advancement from the mechanical vehicle speed governors to their electronic counterparts.

Speed sensors have broad application in vehicles which include speed governors, anti-lock braking system and traction control system among others. The growing need for safety makes it impossible to work without intelligent systems and hence the increase in invention of intelligent devices consisting of sensors and microprocessors among other devices. Vehicle electronics today play a key role in all comfort and safety features. The advent of electronically controlled actuators has contributed to growth of automotive sensors [3]. Vehicle speed sensor is key for design of speed governors, thus choice of speed sensors contributes a lot in the circuitry required for the signal processing. Consequently, this thesis employed a magnetostrictive amorphous wire sensor as a vehicle speed sensor.

The choice of control algorithm also determines performance of a vehicle speed governor and hence use of PWM control technique. Consequently, the improvement of speed governor systems is crucial in order to reduce the number of accidents and to increase safety and comfort for both drivers and passengers.

1.2 Problem Statement

With the fatal crashes experienced all over the world, various improvements in traffic and vehicle safety have been put in place to curb them. One of the ways to reduce such vehicle crashes is to prevent excessive speeding in roads and highways. Some of the devices put in place to curb excessive speeding include Intelligent Speed Adaptation (ISA) devices [4] and the speed governors. The ISA device monitors the speed of the vehicle and makes adjustments to keep the vehicle within legal and safe speed limits.

The ISA devices are implemented using global positioning system receivers, radio frequency receivers or optical recognition systems which requires considerable infrastructural investment [5]. Such infrastructure is not available in most of the developing countries and it’s challenging to implement them in Kenya, hence the use of vehicle speed governors is mostly adopted in such countries.

Several vehicle speed governor systems have been developed for use inside the vehicle for speed monitoring and control purposes. Some of the main components of an electronic vehicle speed governor that have significant impact on its overall performance are the speed sensors, control algorithm and controller unit. Conventional vehicle speed sensor currently in use include Variable Reluctance (VR) sensor. The output of VR sensor is an analog signal whose frequency and amplitude are proportional to vehicle speed. Such sensors require complex circuitry for signal processing, thus the adoption of MAW sensor to reduce on circuit complexity and adopt its special features. Another problem with the existing electronic vehicle speed governors is that fuel supply to the engine is suddenly cut when vehicle top speed is attained due to the on/off control technique which results to vehicle jerking. A PWM based control technique has been adopted in this research to alleviate vehicle jerking.

1.3 Justification

Road accidents are an increasing phenomenon due to reckless driving on the road. Most of the roads lack speed cameras and appropriate monitoring system for identifying over-speeding vehicles. Although many systems have been developed to minimize the accidents, further work is still necessary to improve the current situation.

Embedded systems find application in many control systems currently in use. Such systems are often based on microcontrollers where the key characteristic is to handle a particular task within a larger mechanical or electrical system. The design and development of such embedded system is considered in this research with the idea of vehicle speed sensing and control.

The use of magnetostrictive amorphous wire sensor for speed control offers various advantages such as stable output signal, a signal with appreciable high magnitude that does not vary with vehicle speed, high signal to noise ratio, insensitivity to mechanical vibrations, small size (wire diameter in the order of micrometers), high reliability and minimal degradation over time [6]. Speed sensors provide critical information especially in vehicle black box system needed for better accident analysis [7]. Today's industry is experiencing a continuous positive change from obsolete technologies of measurement to the most advanced techniques that make use of the advances in microprocessor technology.

The automobile is also one of the main means of transportation, and people make extensive use of it throughout their lives. This reason, among others, justifies the necessity of application of the advances in sensors, instrumentation and control in vehicles with the objective of improving road safety. The use of PWM control technique presents an effective method used to adjust the amount of power delivered to a load.

1.4 Objectives

1.4.1 Main Objective

To design and implement a prototype motor vehicle speed governor that employs a magnetostrictive amorphous wire speed sensor.

1.4.2 Specific Objectives

- To design a robust vehicle speed sensor using magnetostrictive amorphous wire
- To design a microcontroller based control circuit and develop an algorithm based on PWM for the vehicle speed governor
- To develop, test and evaluate a prototype motor vehicle speed governor through simulations and experiments

1.5 Scope of the study

This research is limited to design of a vehicle electronic speed governor that limits the vehicle speed to a specified top speed. The work is limited to electronic vehicle speed governor which includes performance testing of MAW speed sensor in vehicle, design and development of control circuit using atmega 32 microcontroller with algorithm based on PWM technique.

1.6 Outline of the Thesis

This thesis is structured in five main chapters with their corresponding sections and subsections.

Chapter one provides an introduction to the research work and sets out the aims and objectives of the research.

Chapter two deals with literature review describing the overview of vehicle speed governors. It also describes various sensing mechanisms and also by comparing the various mechanisms, magnetostrictive amorphous wire sensors is chosen to implement the system.

Chapter three describes the methodology i.e. vehicle speed measurement experimental set-ups, simulations and details of the magnetostrictive amorphous wire, procedures and data generation from the speed sensor. It also covers the various methods employed in achieving the research objectives.

Chapter four covers the results, analysis and discussions. This gives the results of the vehicle speed sensor and the control circuit.

Chapter five gives conclusions and recommendations.

1.7 Contribution of the Thesis

Based on the technical characteristics of variable reluctance sensor used in vehicle speed sensing systems, one of the main contributions was to develop a vehicle speed sensor using magnetostrictive amorphous wire that utilized the sensor simplicity and other features. From the results obtained, it is shown that use of MAW sensor produces a stable and digital signal which addresses challenges posed by VR sensors and it also requires simple circuitry for signal processing. Developing a control unit based on Atmega 32 microcontroller presents a robust controller which by utilizing its special features offers an efficient method for vehicle speed limiting and speed control based on PWM to alleviate vehicle jerking as per the results obtained.

CHAPTER TWO

LITERATURE REVIEW

2.1 Background

Safety is one of the major concerns in transportation in Kenya. With increased engine power, attainable speeds are much higher than the speed limits on the highways and other roads. Some of the methods to manage vehicle speed include cruise control and speed limiter systems [8]. Cruise control system is capable of maintaining speed defined by the driver and the advanced version adaptive cruise control system that keeps the vehicle at safer distance from the preceding vehicle. Speed limiter systems limit the vehicle speed up to a predefined desired speed and they are mostly adopted in most of the public transport sectors. There are two techniques involved in vehicle speed limiting: manual and automatic techniques. Manual speed regulation technique relies on actions of driver which could act as bottleneck in vehicle speed limiting process [9]. An effective solution is to equip vehicles with automatic speed governors. Speed limiting is essential functionality of vehicles which enable prevention of speeding for vehicles. However, the degree of speed control depends heavily on the performance of the speed governor. The performance depends ultimately on the underlying technology and design of each specific speed governor. Modern vehicle speed governors are as a result of successive improvements on the previous ones with much improvement attributed to technology and materials. Even though a speed governor is not part of the fuel system, it is directly related to this system since it functions to regulate speed by control of fuel or air-fuel mixture, depending on the type of engine. In diesel engines, governors are connected in the linkage between the throttle and the fuel injectors. They act through the fuel injection equipment to regulate amount of fuel delivered to the cylinders.

2.2 Types of Vehicle Speed Governors

As stated earlier, the main function of a vehicle speed governor or road speed limiter is to ensure that the speed of the vehicle does not exceed a prescribed limit. Vehicle speed governors may be classified according to either the technique of applying the speed control or the functionality of the speed governor [10]. Based on the control technique, speed governors may be classified as accelerator control also known as cable type, direct fuel control (solenoid valve type) and electronic pedal control for electronic accelerators. Based on functionality, speed governors may be classified as;

1. Top speed limiting - These speed governors prevent the vehicle from exceeding a maximum set speed. This is most suitable for public service vehicles.
2. Top speed or speed limit set by the driver – They prevent the vehicle from exceeding the pre-selected speed. They are also referred to as 'Adjustable Speed Limiters'.
3. Intelligent speed limiter - These speed governors limit vehicle speed based on specific road section speed limits.

Several speed governors which require the driver to manually set the speed have several limitations because they assume that the driver knows the speed limit or can decide a safe speed which brings out possibility of human error. Secondly, setting the speed may be tedious and also distracting and hence such systems may not be used on a regular basis.

2.3 Electronic Speed Governors

The major difference between a mechanical and an electronic governor is that in electronic governor, electrical signals (current and voltage) are used together instead of mechanical weights and spring forces. This is possible through the use of magnetic pick up sensor which is, in effect, a permanent magnet single-pole device. This magnetic pick-up concept is being used on all existing electronic systems and its operation can be considered common to all of them. The sensors are vital communication link between the engine crankshaft speed and the on board computer i.e electronic control module. The magnetic pick-up sensor is installed next to a drive shaft gear made of material that reacts to a magnetic field. As each gear tooth passes the sensor, the gear interrupts the sensors magnetic field. This, in turn, produces an AC (Alternating Current) signal, which corresponds to the speed of the shaft. The signal is sent to the electronic control module to establish the amount of fuel that should be injected to the combustion chambers of the engine. The major advantage of the electronic governor over the mechanical governor lies in its ability to modify speed reference easily through the algorithm. It is also more compact and cheaper compared to mechanical counterparts.

2.4 Basic vehicle speed measurement system

The basic measurement system consist mainly of three blocks: Sensing element, signal conditioning element and signal processing element as shown in Figure 2.1.

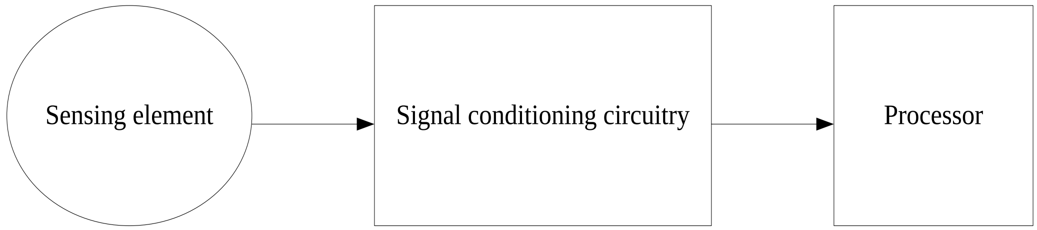

Figure 2.1: Basic measurement system

An electronic speed limiter/governor comprises of three key elements namely the vehicle speed sensor, Electronic Control Unit (ECU) and a fuel flow control valve. The speed sensor generates electronic pulses in relation to the vehicle speed and transmits the same to the ECU. In this experiment, the sensing element converts the non-electrical signal (mechanical rotational motion) into electrical signal (voltage pulses). The purpose of the signal conditioning element is to convert the variation of electrical signal into a voltage level suitable for further processing. This is achieved using amplifier circuit and digital Logic circuit. The next stage is the signal processing element which is a microcontroller which takes the output of the signal conditioning element and converts it into a form suitable for presentation and other uses (display, recording and feedback control). Based on the installed algorithm, the electronic control unit computes the speed of the vehicle and continuously monitors the same. Whenever the vehicle attains the maximum set speed, the electronic control unit activates the actuator which regulates the fuel flow and hence the vehicle speed is limited. The basic elements for an electronic speed governor are explained in depth in the subsequent sections. Vehicle speed measurement in this research is based on wheel speed measuring principle. The vehicle speed is determined through the use of timers/counters in atmega 32 microcontroller. The data obtained from the speed sensor is thus used to calculate the vehicle speed taking into consideration some parameters of the vehicle such as wheel diameter.

2.5 Vehicle Speed Sensors

A sensor is a device that converts a physical phenomenon or quantity into an electrical signal which can be further used to indicate or control the measured variable. Sensors can be classified according to the type of information they collect. Various types of sensors include rotational motion sensors, angular and linear position sensors, temperature sensors and pressure sensors. The most commonly used types of sensor for the vehicle speed detection are the rotational speed sensors as they detect rotational motion. Magnetic sensors are mostly used as rotational motion sensors and they differ from most other detectors in that they do not directly measure the physical property of interest. Devices that monitor properties such as temperature, pressure, strain or flow provide an output that directly reports the desired parameter as shown in Figure 2.2.

Magnetic sensors on the other hand, detect changes, or disturbances in magnetic fields that have been created or modified and from them derive information on properties such as direction, rotation presence or angle as shown in Figure 2.3.

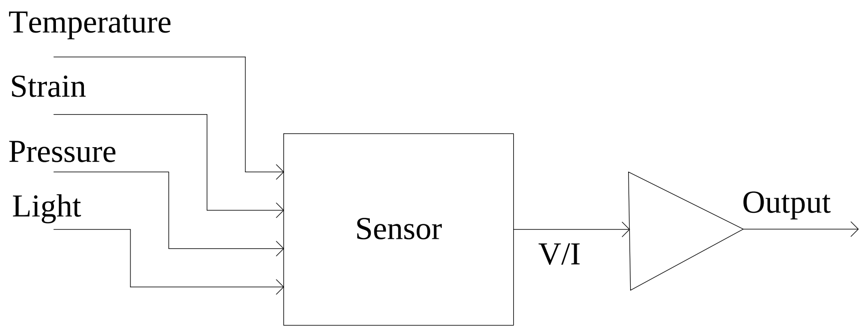

Figure 2.2: Conventional sensor arrangement

The output signal of these sensors requires some signal processing for translation to the desired parameter. Although magnetic sensors are somewhat more difficult to use, they do provide accurate and reliable data without physical contact. Rotational motion sensors measure shaft rotational motion and can be built using various technological approaches each having its own advantages and disadvantages as discussed in the next sections [11].

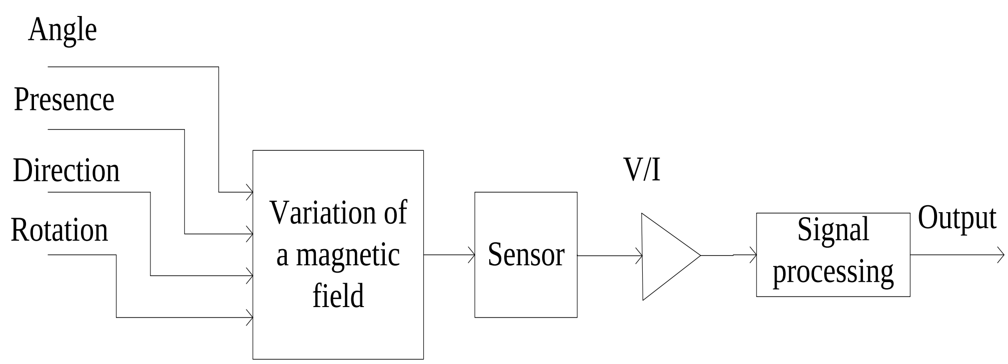

Figure 2.3: Magnetic sensor arrangement

2.5.1 Variable Reluctance Sensor

Variable reluctance sensors are electromagnetic devices which produce a pulse-train-like voltage output signal governed by the time varying fluctuations of magnetic flux created by rotating motion of mechanical parts. A sensor generates voltage variations in its sensing coil which correspond to the magnetic flux when a magnetized pole on rotating shaft passes by the sensor [11] **.** Advantages of such sensors include low cost, small to moderate size and stable performance in varying temperature. Disadvantages include loss of signal at zero speed and moreover the voltage pulse magnitude depends on shaft speed and requires sophisticated electronics to evaluate the large signal voltage range, especially in applications requiring low jitters.

2.5.2 Hall Effect Sensor

The basic Hall sensor is a small sheet of a semiconductor material as shown in Figure 2.4.

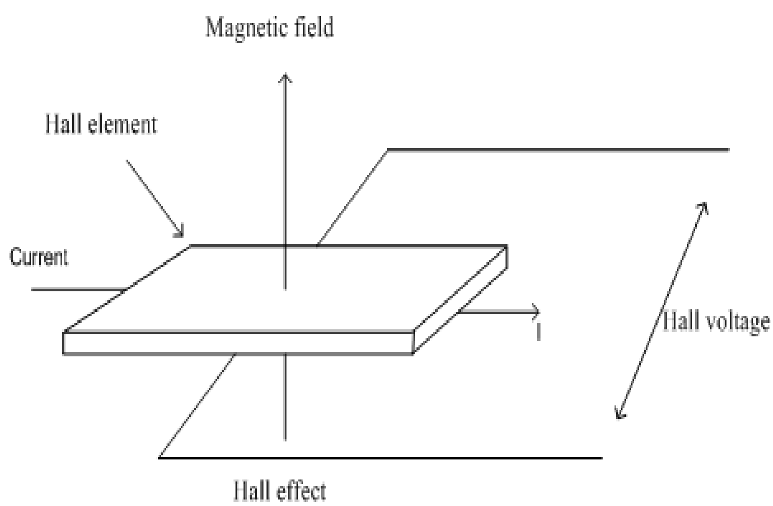

Figure 2.4: Hall Effect Principle

They generate a voltage signal that corresponds one-to-one with fluctuations of magnetic flux created by rotation motion of mechanical parts. As a tone-wheel gear tooth rotates past a Hall sensor, magnetic flux variations are generated [11]. Since Hall effect sensors are semiconductor devices, they require a bias current. Advantages of Hall effect sensors are low cost, small size and operation to zero speed; disadvantages include sensitivity to interference from other magnetic flux.

2.5.3 Magnetoresistive Sensor

Magnetoresistive devices exhibit a change of resistance based on Lorentz force, proportional to magnetic flux density. Similar in principle of operation to Hall effect sensors, magnetoresistive sensors have the advantage of relatively low cost as they can be produced using integrated circuits on a chip. Other advantages include collecting reliable information even at zero speeds and in conditions of varying temperature. Their disadvantage is their size which is relatively large.

2.5.4 Magnetostriction

The magnetostrictive effect was first described in the 19th century by an English physicist James Joule. Magnetostriction is the change in shape of materials under the influence of an external magnetic field. All ferromagnetic materials exhibit the magnetostrictive effect which is basically changed in outer dimensions of the material when subjected to an external magnetic field. In the absence of an external field the magnetic domains (elementary dipoles) are randomly oriented. When a magnetic field is applied, these domains tend to line up with the field, up to the point of saturation [12].

2.6 Magnetostrictive Amorphous Wire Sensor

Magnetostrictive amorphous wires with diameters ranging between 80 and 160 μm are prepared by rapid quenching from the melt. This is referred to as "in-rotating -water quenching -method" Using this method, the molten metal is loaded into a quartz nozzle, and then ejected under pressure through the orifice of quartz nozzle into a rotating water layer [13]. Due to the rapid quenching rate; the crystallization of the material is inhibited, thus resulting in an amorphous wire. The process employs forced cooling and hence the material resulting from such a process is in unstable state.

Amorphous magnetic wire present outstanding interest for researchers and also for various applications like, magnetic field sensors, tensile stresses sensors, torque sensors, pulse generator elements, security fences and current sensors [14]. The MAWs are very attractive in construction of a new generation of sensors spread in large area of application such as robot industries, power motor drives, electric power drives, automobiles and laboratory instrumentation [15]**.** Magnetostrictive amorphous wires also have features that render them attractive for construction of various sensors [16]**.** Such features include Large Barkhausen Jump, Matteucci effect, magneto-elastic effect and magneto-impedance effect. Large Barkhausen Jump is important in sensor applications since almost all sensors connect to the outside world by providing a voltage. A method of speed sensing using magnetostrictive amorphous wires has been discussed in [6] .

Magnetostrictive amorphous wire has the property that if placed in an eternal magnetic field parallel with the axis of the wire, then when the direction of the external magnetic field is changed, the direction of the internal magnetic flux reverses abruptly. To detect the change in direction of flow of the magnetic flux, a pick up coil is wound around the magnetostrictive amorphous wire. Using the wire as a sensor, the operation is based on large Barkhausen Jump; sudden magnetic flux reversal [17]**,** [18]. Due to the Large Barkhausen jump, very sharp and stable voltage pulses are generated at the ends of a coil wound around the MAW in alternating fields. Figure 2.5 shows the voltage pulses generated; this is due to the mechanism of magnetic reversal into the inner core.

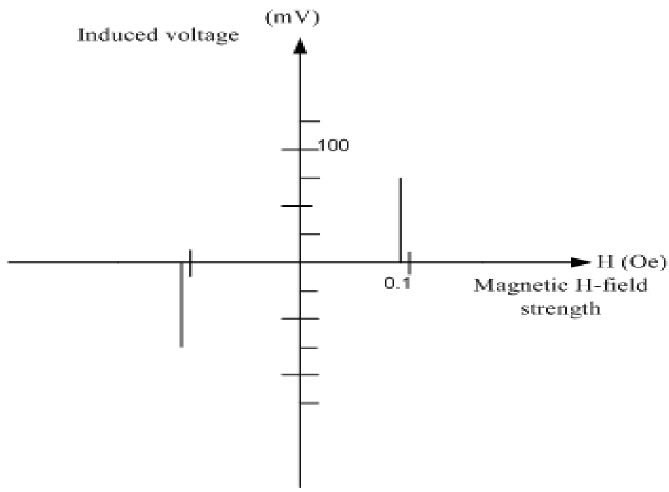

Figure 2.5: Voltage pulse induced in a MAW wire due to LBJ

The unique magnetization (flux) reversal is illustrated by referring to the hysteresis loop shown in Figure 2.6. The loop shows the change in magnetization-magnetic field (M-H) locus as the amplitude of the field is varied.

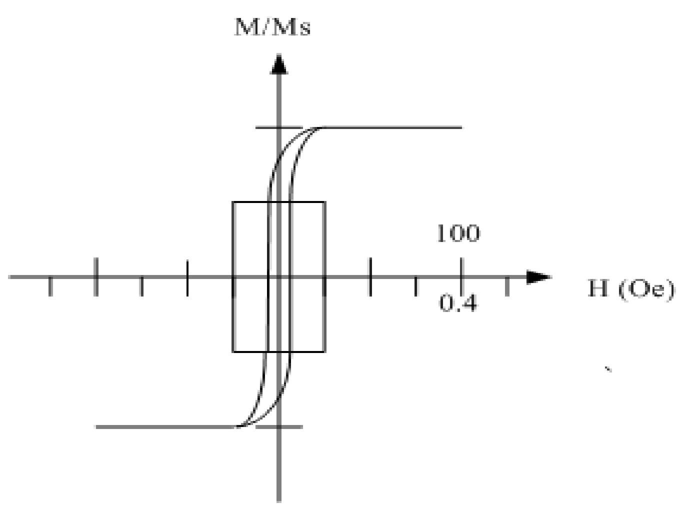

Figure 2.6: Low and High field M-H loops for MAW sensor

Advantages of sensors employing amorphous wires include high signal to noise ratio, quick response with cut-off frequency of more than several kilohertz, insensitivity to mechanical vibrations, small size (wire diameter is in the order of micrometers), high reliability and minimal degradation over time, digital output suitable for interfacing with the microcomputer, good corrosion resistance, outstanding elasticity and excellent electromagnetic properties [16]**.**

By comparing with sensors currently in use, magnetostrictive amorphous wires sensor offer the following advantages as seen in figure 2.7.

a) They give a digital output that can easily be interfaced with electronic devices
b) Requires no power to operate
c) Give relatively high output that requires just a little amplification
d) Not easily affected by other electrical noises

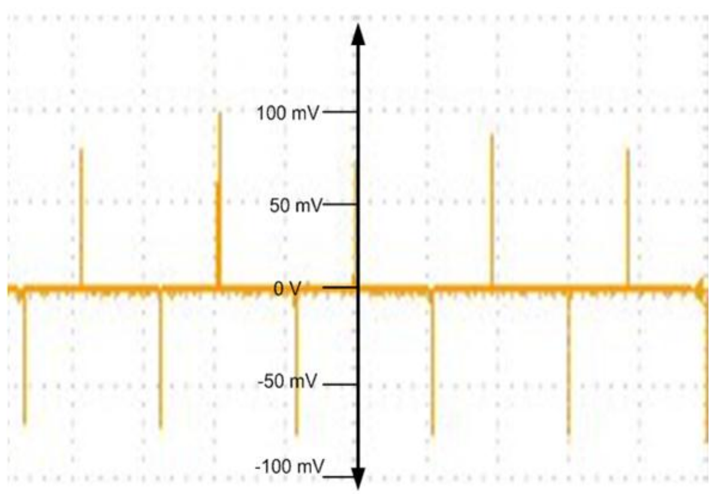

Figure 2.7: MAW sensor output signal

One of the disadvantages of the MAW is that elevated temperatures affect the wire sensing characteristics, though Nderu et al [17] devised a remedy to that problem. Several researchers have also carried out related studies on application of MAW wire in various sensor applications. Sensor development using the unique feature of the amorphous wire has found applications in several fields. Han [19] in his paper, the unusual properties of the amorphous wire have been discussed. Such properties discussed include giant magneto-impedance (GMI) effect, Giant stress-induced impedance effect, Large Barkhausen effect and magnetostriction effect. Several sensor operating principles and applications exploiting these unusual properties have also been discussed. Such sensors include magnetic field sensors, position sensors, bio sensors, non-destructive testing sensors and stress sensors.

2.7 Signal Conditioning

Signal conditioning is an important component of data acquisition system for the user to rely on the accuracy of the measurement. Many applications involve environmental or structural measurement from sensors. These sensors, in turn require signal conditioning before data acquisition device can effectively and accurately measure the signal [20]. Signal conditioning needs vary widely in functionality depending on specific sensor. Some of very low-voltage signals may require linearization, amplification and filtering while other sensor signals may need none of these. The key to a successful signal conditioning system is to understand the circuitry you need to ensure an accurate measurement whatever the channel mix.

2.7.1 Signal conditioning fundamentals

Most signals require some form of preparation before they can be digitized or interfaced with digital devices. The preparation technologies involved are forms of signal conditioning. Some of the signals conditioning types, their functionalities and examples have been listed below.

Amplification

Amplifiers increase voltage level to better match the analog-digital converter range, thus increase in the measurement resolution and sensitivity. In addition, locating external signal conditioners closer to the sensor or transducer, improves the measurement signal-to-noise ratio by magnifying the voltage level before it is affected by environmental noise.

Attenuation

Attenuation is necessary when voltages to be digitized are beyond the analog-digital converter range. This form of signal conditioning decreases the input signal amplitude. Attenuation is typically necessary when measuring voltages that are more than 10 V.

Filtering

Filters reject unwanted noise within a certain frequency range. Often, low-pass filters are used to block out noise in electrical measurements such as 50/60 Hz power. Another common use for filtering is to prevent aliasing from high-frequency signals.

Isolation

Voltage signals well outside the range of a digital device can damage the measurement system and harm the operator. For that reason, isolation is usually required in conjunction with attenuation to protect the system and the user from dangerous voltages or voltage spikes.

Linearization

Linearization is necessary when sensors produce voltage signals that are not linearly related to the physical measurement. This is the process of interpreting the signal from the sensor, or can be implemented either with signal conditioning or through software.

2.7.2 Key aspects of signal conditioning

When designing any new conditioned measurement system, some of the variables that contribute to its success are directly related to the conditioning circuitry while others are more practical and relate to the implementation, system integration and maintenance of the design.

Integration

The ability of the signal conditioning system to integrate easily with the rest of the system is important. Understanding the interaction between different components of the measurement system chain helps characterize expected results and troubleshoot unexpected ones.

Connectivity

Connecting signals to a signal conditioning system can be a major issue if not considered carefully beforehand. A best signal conditioning system should offer a wide range of connectivity options.

Expandability

By designing a system in a modular way gives more flexibility to change and expand channel count and signal mix.

Isolation

When the measured signal is either a high voltage or a voltage subject to spikes, these signals should be isolated from the rest of the system. In adequate isolation compromises the safety of the operator as well as the integrity of the entire data acquisition system.

2.8 Control Unit

An Electronic Control Unit (ECU) is an electronic device that reads sensors and uses the information to control systems. Modern ECU's use microprocessors which can process the inputs from the sensors in real time. An electronic control unit contains the hardware and software (firmware). The hardware consists of electronic components on a printed circuit board (PCB). The main component on the PCB is a microcontroller chip. The software is stored in the microcontroller, typically in the EPROMs or Flash memory so that it can be re-programmed by uploading the updated code.

Microcontroller

Microcontrollers have only been in existence for a few decades but their impact (direct or indirect) on our lives is profound. With the advancement in technology, intelligent systems are produced every day. Everything is getting more sophisticated and intelligent [21]**,** [22]. Microcontrollers play a very important role in the development of smart systems as brain is given to such systems. Microcontrollers form the heart of modern technologies that are being introduced daily. They are used nowadays as single chip microprocessors dedicated for control and automation of machines and processes. With their accuracy, they are being used in many disciplines of life for carrying out automated tasks [23] . A microcontroller is a highly integrated self-contained chip with memory processor and peripherals needed for a controller. The microcontroller typically includes a Central Processing Unit (CPU), Random Access Memory (RAM), Read Only Memory (ROM), Electrically Erasable Programmable Read Only Memory (EEPROM), Input / Output (I/O) - serial and parallel, timers and interrupts. Why use microcontroller? It provides inexpensive, programmable logic control and interfacing to external devices. It has the ability to store and run unique programs which makes it highly versatile.

The small size of microcontrollers, the minimal support circuitry required and the relative ease of programming microcontrollers compared to other programmable devices have led to the widespread embedding of microcontrollers in many products and machinery. Microcontrollers find application in control applications such as home monitoring system, and in embedded applications, automotive applications, appliances (microwave oven, refrigerators, television and stereos, automobiles (engine control, diagnostics, climate control), environmental control (green house, factory, home), instrumentation, aerospace and thousands of other uses.

2.9 Use of microcontrollers in electronic speed governors

Automation is fundamentally changing the role of people in many systems and hence driving is no exception. An increasing number of vehicles are being equipped with speed control systems e.g. limiting the distance between two vehicles. An example of embedded controller use in vehicles is described in [24] for a variable vehicle speed governor and vehicle black box system in [7]**.** An electronic vehicle speed governor requires a fuel control valve for fuel control. In most cases a solenoid valve is used. A solenoid valve is an electromechanical valve where its dynamic behavior has influence on fluids. Conventionally, an on/off solenoid valve is used in most of the vehicle speed limiters. It has a simple built-in electrical solenoid and armature actuator, to open and close the valve passage. The drawback presented by such a valve is that it does not have a variable flow and causes jerking while limiting top vehicle speed. To alleviate this problem, a fast switching valve method is adopted in this research. This is also known as rapid on-off solenoid valve [25]. It modulates flow by rapidly opening and closing the valve passage. The variation in length of on-time versus off-time establishes an average flow of any amount desired. This valve is well preferred to as a Pulse width Modulation (PWM) valve.

PWM is an effective method for adjusting the amount of power delivered to a load. It is a technique in which the width of the output pulse is varied by varying a DC voltage reference which is given as one of the inputs to a comparator. The other input is a saw-tooth voltage waveform. A PWM signal consists of two main components that define its behavior. A duty cycle which describes the amount of time the signal is in a high (ON) state as a percentage of the total time of it takes to complete one cycle and a frequency which determines how fast the PWM completes a cycle. By cycling a digital signal off and on at a fast enough rate, and with a certain duty cycle, the output will appear to behave like a constant voltage analog signal when providing power to devices. PWM signals are used for a wide variety of control applications. Their main use is for controlling DC motors but it can also be used to control valves, pumps hydraulics, and other mechanical parts. The frequency that the PWM signal needs to be set at will be dependent on the application and the response time of the system that is being powered. Nowadays PWM control method is mostly used in power converter applications e.g. DC/AC conversion and also as a means of powering AC devices [26]. These PWM signals can be generated using analog circuits as well as digital circuits. PWM generation using analog circuits requires large number of discrete circuits. Also the response of analog circuit may get affected by environmental conditions, noise, changes in voltages and currents in the circuit and so on. Thus analog method is critical and increases complexity and cost of the circuit. Digital method of PWM generation requires only microcontroller and its minimum configuration and with technology advancement, many microcontrollers have in-built features of PWM generation.

2.9.1 Digital PWM generation

Different methods for digital PWM generation have been outlined in [27]. The paper describes PWM generation based on microcontroller's register architecture and applications depending on the type of control required.

Digital PWM generation is prevalent in the automotive industry for controlling solenoid valves. This is because digital based PWM generation technology is more stable than analog based techniques. Analog based techniques which use passive components adjustment circuitry is subject to frequency and duty cycle value drift and hysteresis due to tolerances and variances in component value due to temperature. Furthermore, digital techniques allow for instantaneous changes in duty cycle value from one value to another with no interim values. This aids in obtaining fast control system response.

PWM is a comparatively recent technique which has been made practical by modern electronic power switches. It is an efficient method of providing intermediate amounts of electrical power between fully on and fully off. The average value of voltage and current fed to the load is controlled by turning switch between the supply and load on and off at a faster rate. If the switch is on for a longer period as compared to the off period, the total power supplied to the load is higher. Duty cycle describes the proportion of 'on' time to the regular 'period' of time. Consequently, a low duty cycle corresponds to low power because power is off most of the time. Duty cycle is usually expressed in percent, with 100% being fully on.

Basically, the on/off valves can either be open or closed, but with use of PWM as input signal, it is possible to switch between the on and off position for one single PWM period resulting in limited fuel flow through the valve.

2.9.2 PWM Applications

Use of PWM technique in speed control has been widely applied in DC motor speed control as illustrated in [28], in this paper, the digital PWM generation using microcontroller has been adopted in DC motor speed control. The use of PWM has also been adopted in a battery charging control system by [29] . In this paper, the digital generation of PWM using microcontrollers has been adopted. In automotive industry, design of a microcontroller based electronic speed governor for an engine as detailed by [30], with the speed governor developed using PWM to control the position of throttle actuator and generation of PWM using PIC microcontroller. The use of PWM has also been applied in Fuzzy based wireless speed limiter in [31].

2.10 Summary of research novelty

The design of electronic vehicle speed governor in this research adopts the use of magnetostrictive amorphous wire sensor as the speed sensor. This sensor is yet to be adopted in the automobile industry, specifically on speed measurement yet it's currently finding applications in various industrial based systems. Based on its unique magnetic properties, the speed sensor requires only a few simple components to produce sharply defined voltage pulses in response to change in applied magnetic field as compared to the conventional speed sensors currently in use.

The use of PWM control technique is also applied in the design of the control algorithm to eliminate the conventional on/off control which results to vehicle jerking during speed limiting process. The two aspects thus contribute towards improving the general performance of electronic based vehicle speed governors.

CHAPTER THREE

METHODOLOGY

3.1 Overview

This chapter describes the design of a novel electronic vehicle speed governor system using the magnetostrictive amorphous wire as speed sensor. It also covers the design specification and implementation of a vehicle electronic control unit using atmega 32 microcontroller and circuit simulations on Proteus software.

The design of the electronic vehicle speed governor prototype follows as closely as possible standard designs of existing electronic vehicle speed governors. Nevertheless, changes have been made to the design and implementation of various components namely the speed sensor and control circuit. The block diagram for the novel speed governor is shown in Figure 3.1.

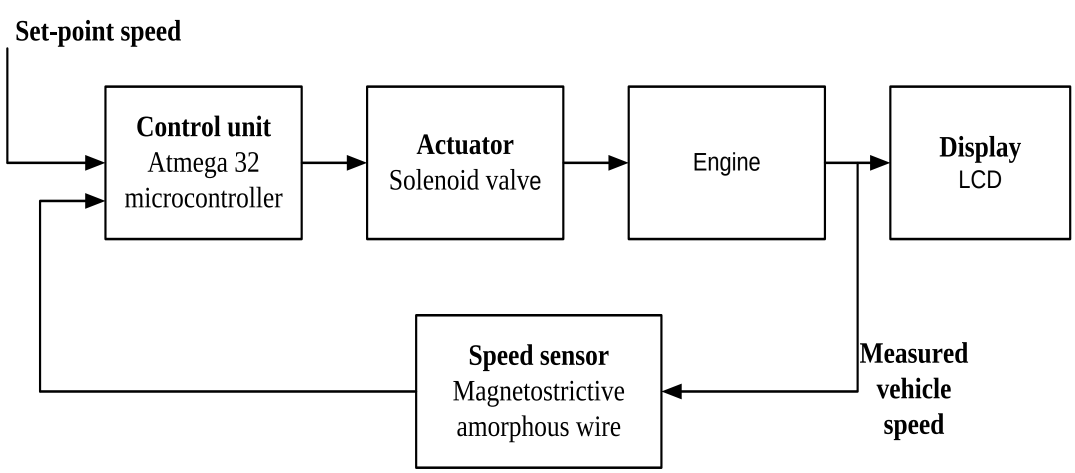

Figure 3.1: Design particulars for vehicle speed governor

3.2 Design of vehicle speed sensor

Design of the electronic vehicle speed sensor comprised of three units namely;

- Sensing element
- Signal conditioning circuit
- Signal processing unit

3.2.1 Sensing element

The sensing element comprised of two permanent magnets attached on a vehicle rotating shaft and magnetostrictive amorphous wire as shown in sensing element circuit in Figure 3.2. The MAW sensor was chosen over variable reluctance sensor currently in use because of advantages previously discussed. The amorphous wire used has a composition

$(Fe_{50}Co_{50})_{78}Si_9B_{13}$, 7cm long and 125 µm diameter. Since the wire is iron based, the length used is approximately 7cm [32]. This is the critical length for a wire of 125 µm diameter for which the large Barkhausen jump occurs and the point at which the signal generated is optimum. Using wires of other lengths affects the signal strength of the generated voltage pulses.

With the magnetostrictive amorphous wire placed inside a stationary pick-up coil of 3000 turns, it was placed 7 cm from the rotating shaft as shown in Figure 3.2. 7 cm is the air gap between the pickup sensor and the magnet, which depends on the magnet strength.

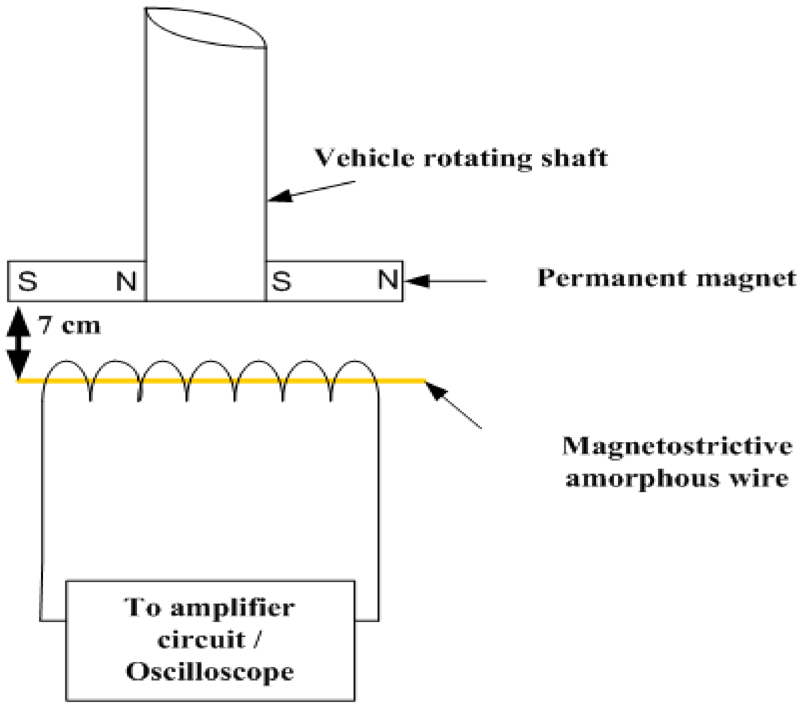

Figure 3.2: Sensing element circuit

Ends of the coil were connected to a digital oscilloscope for frequency measurement of the output pulses. Depending on which magnetic pole (north or south) triggers the sensor, positive or negative voltage pulses are generated. The output of the sensor is a series of voltage pulses whose frequencies are proportional to vehicle's speed. The voltage pulses are induced in the MAW sensor each time a magnetic pole comes close to the wire. As the vehicle speed increases, the rotation speed of the shaft increases and consequently the measured pulse frequency increases. The frequency obtained is directly proportional to the vehicle's speed and hence is used for vehicle speed calculation. The experimental set up for the sensing element is shown in Figure 3.3.

Figure 3.3: Experimental set up for the sensing element

Frequency measurements were taken in two scenarios, first with vehicle's one wheel stationary and second with both wheels spinning freely. The rotational frequency of the shaft is directly proportional to the vehicle speed and thus with the wheel's specifications it is possible to compute vehicle's speed in km/h. The known variable is the diameter of the wheel. The wheel's specifications for the vehicle used are, 15 inch rim and 195/65 tires. The wheel diameter D was determined using Equation 3.1

$$D = (R \times 25.4) + \left(\frac{A}{100} \times w \times 2\right) \quad \textbf{(3.1)}$$

Where;

D= wheel diameter (mm)

R = Rim diameter (inches)

A = Ratio of the height of the tires cross-section to its width

w = Tire width (mm)

With the frequency obtained from the MAW speed sensor, the vehicle speed V was thus computed using Equation 3.2

$$V = 3.6\pi Df \qquad \textbf{(3.2)}$$

Where;

3.6 is used for conversion of speed from m/s to km/h

V =Vehicle speed in kilo meters per hour

D =Wheel diameter (m)

f = Rotational frequency in Hertz (Hz)

For laboratory prototype development, the experimental set-up was as shown in Figure 3.4. A Direct current (DC) motor was used to simulate a vehicle rotating shaft. The choice of DC motor was based on the fact that an increase in supply voltage results to increase in the motor shaft speed.

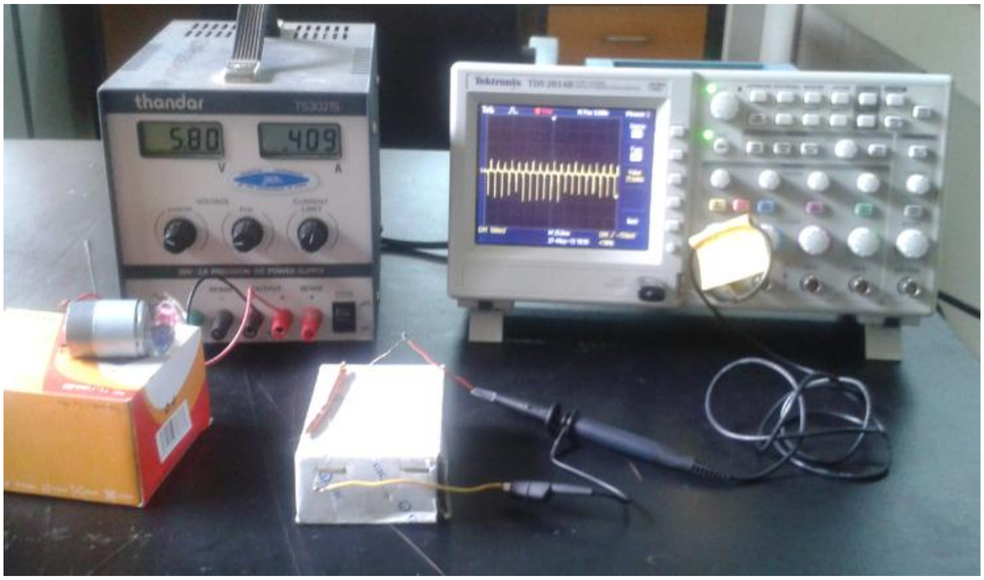

Figure 3.4: Laboratory motor set up for speed measurement

3.2.2 Design of signal conditioning circuit

The speed sensor output is voltage pulses whose magnitude varies between 80 mV and 200 mV peak value. The frequency of these voltage pulses is determined by the use of a microcontroller and thus amplification and conditioning of the signal is suitable before feeding it to microcontroller. The voltage pulses need to be amplified to a voltage high enough to drive a transistor for purposes of regulating the pulse voltage to digital logic levels (LOW-0 V and HIGH-3.5 V). An amplified voltage of at least 3.5 V to attain logic HIGH Voltage is required. Thus the gain required is based on the minimum voltage pulse value as shown in Equation 3.3

$$Gain = \frac{Output}{Input} \quad (3.3)$$

Where;

Output=3.5 V

Input= 0.08 V

Thus a gain of around 44 is required to convert the sensor signal to Logic HIGH. Consequently, the amplified signal peak value varies between 3.5 V to 8.8 V. These voltage levels need to be regulated within digital logic levels (0 V or 5 V) before interfacing to a microcontroller. Figure 3.5 shows the signal conditioning circuit.

The first stage consists of inverting operational amplifier which amplifies the signal by a gain of around 47 as given by Equation 3.4, with $R_{1=}$ 1 kΩ and R_2=47 k Ω.

$$G = \frac{R_2}{R_1} \quad (3.4)$$

The output at this level is inverted and thus to restore it to its initial form another inverting operational amplifier with unity gain is used at the second stage. With the gain used, some of the amplified voltage pulses are greater than 5 V which is not suitable for interfacing with microcontrollers. Thus, a digital logic conversion circuit is used to regulate the voltage pulses to 5V as shown in the digital logic stage. A snapshot of the experimental set up for the signal conditioning circuit is shown in Figure 3.6.

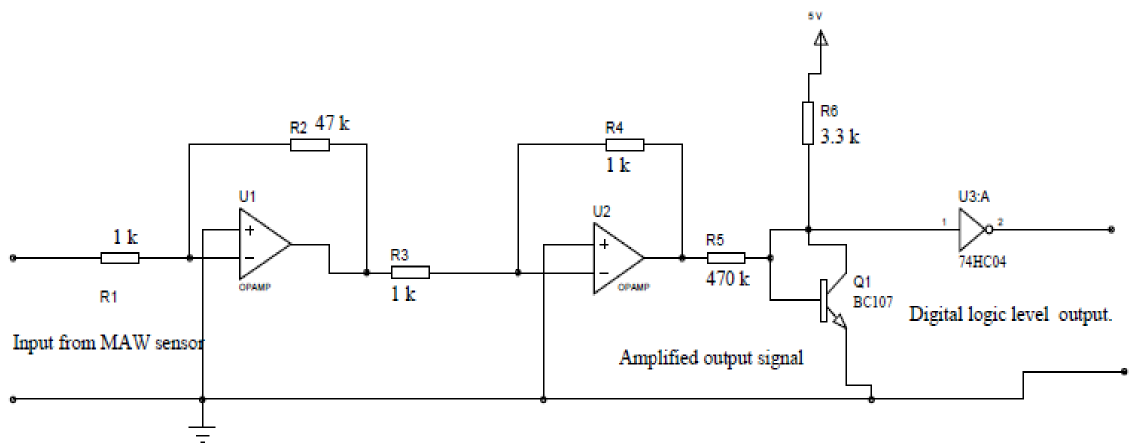

Figure 3.5: Signal conditioning circuit

The output pulses from the amplifier act as digital input to the transistor circuit. The digital HIGH from the sensor circuit is level shifted to suit a TTL input. When the digital input (pulse) is HIGH, the transistor is turned on and this results to a direct path to ground, hence the input to the inverter is 0 V or a logic LOW.

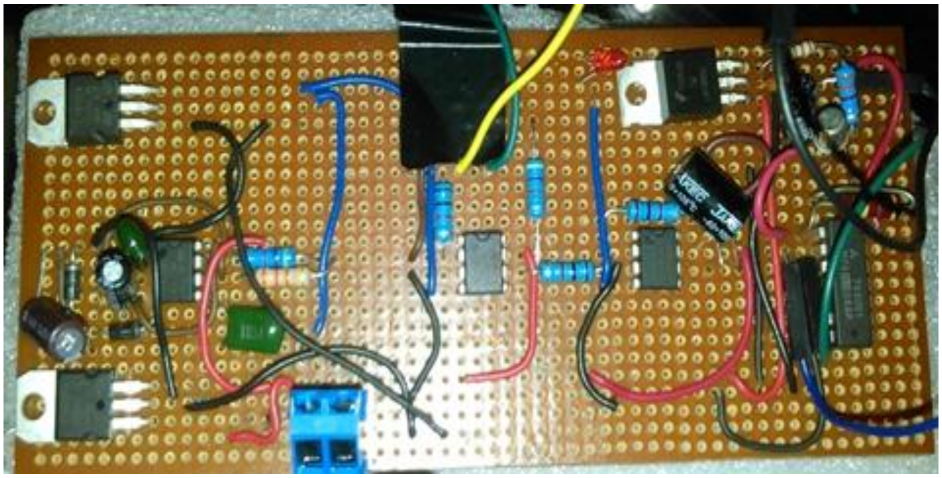

Figure 3.6: A snapshot of signal conditioning circuit

Thus the input to microcontroller is a Logic HIGH. When the digital input (Pulse) is LOW, the transistor is off which means there is no path for current from the collector to the emitter, therefore the input to inverter is logic 5 V or logic HIGH and input to microcontroller is a logic LOW. The circuit also eliminates the negative voltage pulses per cycle. Hence the inverter restores it to its initial position and to a regular pulse waveform that can be interfaced to a microcontroller.

3.2.3 Signal processing /frequency measurement

The signal fed to microcontroller is shown in Figure 3.7 with HIGH (5 V) and LOW (0 V) voltage pulses. The signal is processed to obtain values of frequency for various vehicle speeds.

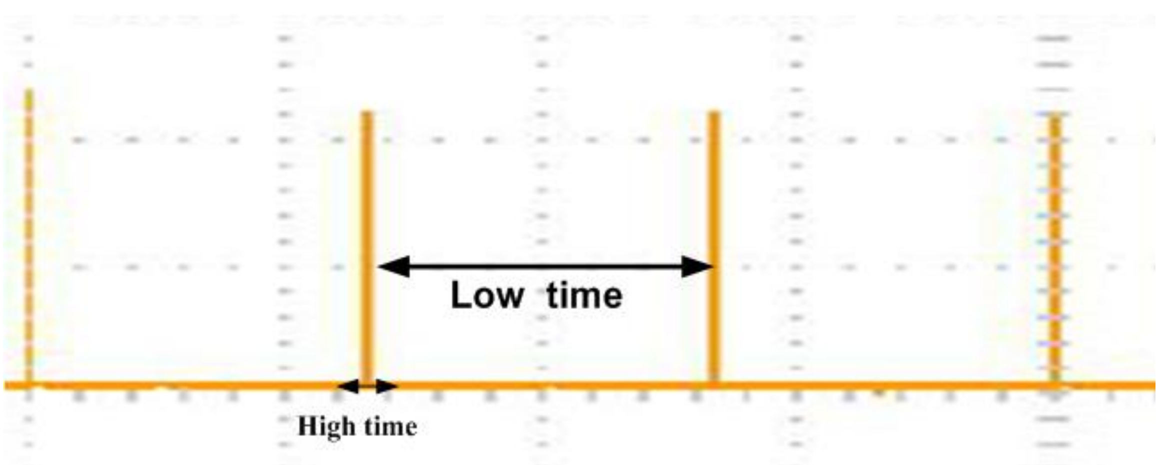

Figure 3.7: Input signal to microcontroller

In developing the vehicle speed limiter, frequency measurement of the speed sensor signal is important. One of the basic requirements is for the signal to have amplitude that is within the input pin threshold for the microcontroller. The other requirement is for the microcontroller to have at least two timers, and that one of them can be used with an external clock source. The other timer can be created by a software delay loop. This is mainly to feed the signal to be measured into one timer's clock input and then use the other as a time reference. From the earlier experiments, it can be deduced that the vehicle speed signal is a relatively low frequency signal and thus frequency was measured by

Circuit board (PCB) and reduced costs. Hence, ATMEGA 32 microcontroller built on a development board was used. It was thus chosen because it is rich with features like onboard 32 Kbytes of in- system self-programmable determining the period between two successive pulses as shown in Equation 3.5

$$\text{Frequency} = \frac{1}{Period} \qquad \textbf{(3.5)}$$

Where;

Period= High time +Low time

3.3 Design of control unit

The controller unit consists of hardware and software development, with the interface between the hardware and software being a microcontroller

3.3.1 Hardware design

With the advancement in technology, microcontroller plays an important role in development of smart systems. For this prototype, a microcontroller is used as the controller unit or the speed limiter controller which allows the circuit to be realized with minimum number of circuits resulting to minimization of the occupied space on a printed flash program memory, 1024 Bytes EEPROM, 2 Kbytes internal SRAM, 10bit ADC (8 channel) and SPI bus interface and other features as illustrated in its data sheet. The

schematic and layout of the atmega 32 microcontroller development board were prepared using Easily Applicable Graphical Layout Editor (EAGLE) PCB design software. The software is suitable for drawing schematics and creating a printed circuit board (PCB). Figure 3.8 shows the schematic design of the AVR development board. The circuit comprises the following functional blocks; Microcontroller, Clock circuit, Power supply circuit, Reset circuit, ISP interface, Output buffers and LCD circuit. An LCD display module contains all necessary control circuitry to drive a dot matrix LCD so that it can be interfaced to the atmega 32 microcontroller using 8 data lines and 3 control lines. In this design, the speed sensor frequency, speed and duty cycle are displayed on the LCD.

The microcontroller receives the inputs and processes them based on the program fed onto it. The pulse signal (digital logic) obtained from the sensing unit is the main input to the controller unit. After the program logic has processed the speed input, i.e vehicle speed conversion to km/h based on the signal frequency obtained from the magnetostrictive amorphous wire sensor. The frequency and speed obtained are displayed on the LCD.

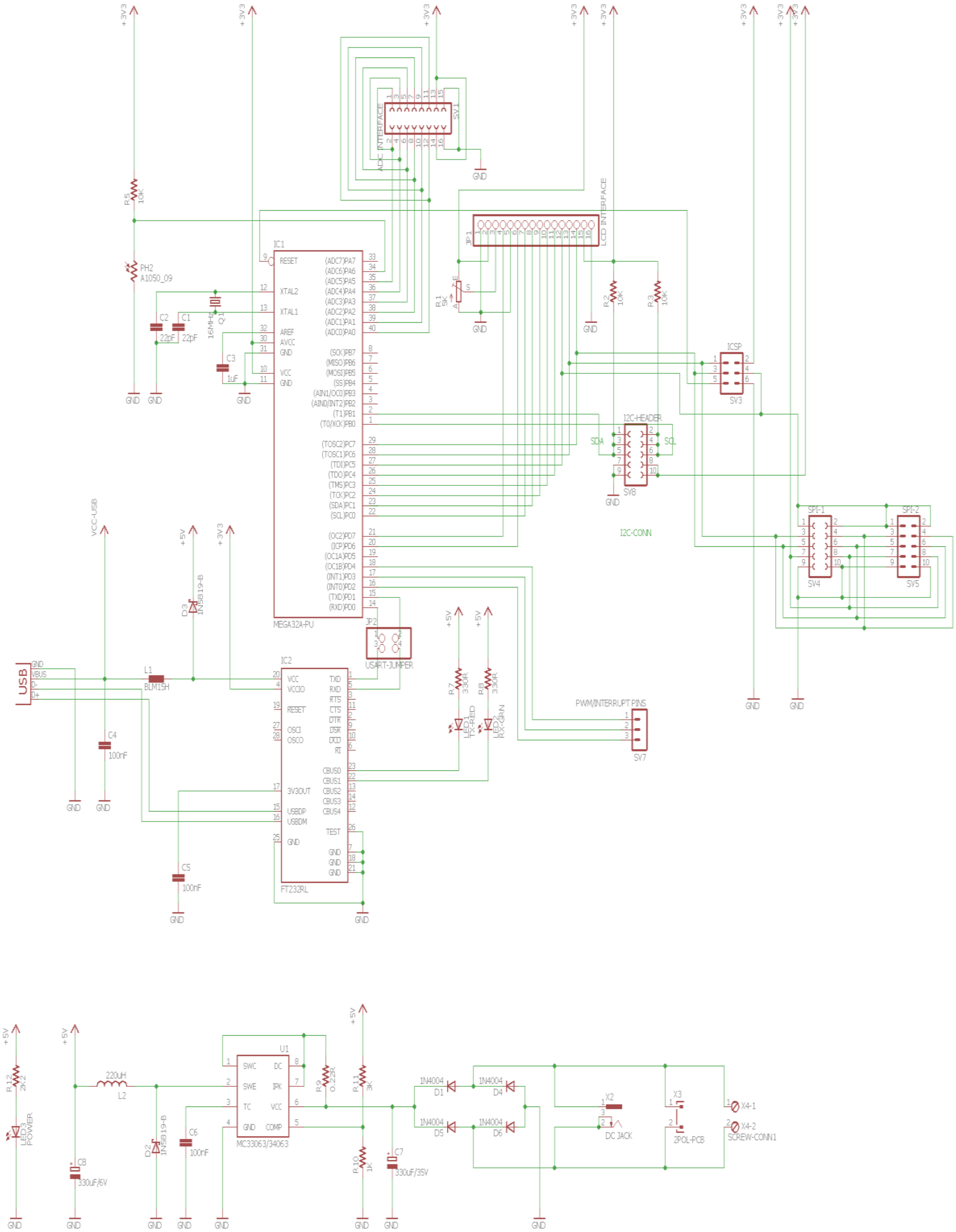

Figure 3.8: Schematic circuit design

3.3.2 Software/Algorithm Design

Based on the algorithm, the vehicle speed is compared with the desired speed and pulse width modulated signals with different duty cycles generated which controls the current flowing through solenoid valve hence controlling the fuel supply and limiting vehicle speed to the limit speed.

Microcontroller acts as the brain of the speed limiting system. It receives the desired top speed from the user through the algorithm which is compared with the vehicle actual speed as measured by the speed sensor. The correction is done by the microcontroller to always limit the vehicle top speed. An algorithm has to be developed to enable the microcontroller to respond to inputs and outputs accordingly.

One of the major contributions of this research was to minimize jerking during the speed limiting process caused by on/off control techniques. Thus, to gradually limit the vehicle's top speed, the use of PWM fuel regulation was employed. This method ensures that fuel supply is not instantaneously cut-off but decreases gradually as the vehicle's top speed is approached. The design of the algorithm enables the speed governor to limit vehicle speed within ±5% of the desired speed limit. This is based on vehicle speed governor regulations, that the vehicle speed shall not exceed 5% of the desired top speed limit. The PWM technique is applied to gradually limit the fuel supply to the vehicle engine within that range hence minimizing vehicle jerking. This is achieved by varying duty cycle based on the vehicle speed as shown in table 3.1. The top vehicle speed was chosen to be 80 km/h and the speed governor is engaged at ±5% which is 76 km/h to 84km/h range. The algorithm was developed using Atmel AVR studio Integrated Development Environment (IDE) for programming Atmega 32 microcontroller in embedded C programming. Atmel AVR studio is the integrated development environment for developing and debugging embedded Atmel AVR applications. Atmel Corporation offers AVR studio as a free programming and debugging tool to support AVRs. AVR studio gives a seamless and easy to use environment to write, build and debug C code. The algorithm developed was based on pulse width modulation generation for various speeds as shown in Table 3.1. The logical representation of the algorithm is presented in the flowchart form as shown in Figure 3.9.

Table 3.1: Duty cycle and speed tabulations

S/No	Vehicle speed	Duty cycle
1	Less than or equal to 75 km/h	100%
2	Less than 75 km/h and less than or equal to 78 km/h	75%
3	Less than 78 km/h and less than or equal to 81 km/h	50%
4	Less than 81 km/h and less than or equal to 84 km/h	25%
5	Greater than 84 km/h	0%

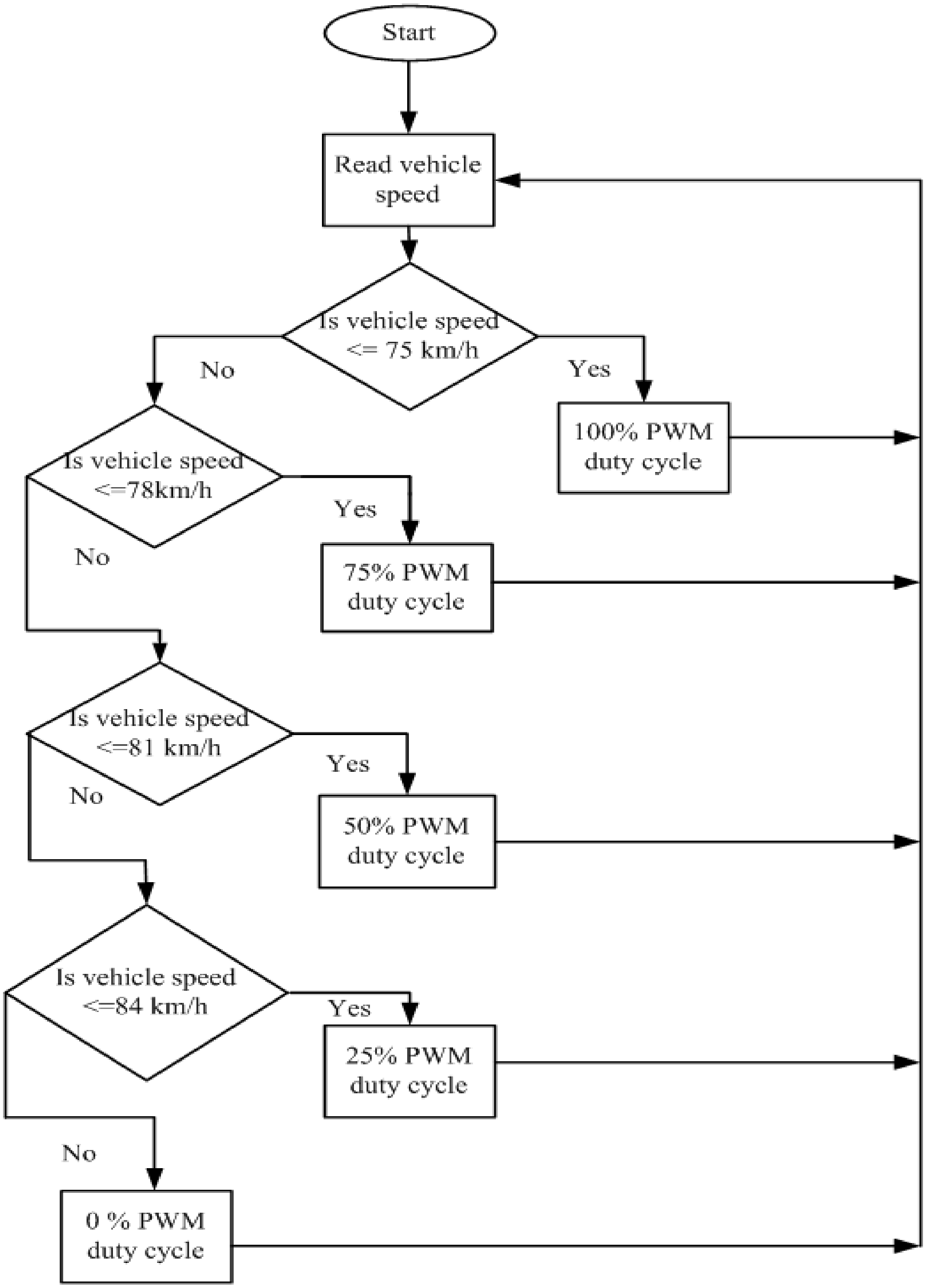

Figure 3.9: Speed limit flow chart

3.3.3 Generation of PWM signals using AVR timers

Microcontrollers have a wide range of features, one of which is the PWM function on one or more digital pins. It is possible to vary the characteristics of a PWM signal by accessing the special PWM registers e.g. the timer registers, timer counter/control registers and output compare register. In this research, the timers interact with the CPU using compare match interrupt. A compare match interrupt is issued by a timer whenever the value of the timer becomes equal to a certain predefined value which is stored in a register known as the outputs compare register.

In this work, a PWM output with a duty cycle varying between 0% and 100% is generated based on the flow chart shown in Figure 3.9. In AVR microcontrollers, PWM signals are generated by timers. Atmega 32 microcontroller has 3 timers/counters. Timer0 was configured for Fast PWM mode which provides a PWM waveform generation with high frequency suitable for connection of coils such as the solenoid valve. Whenever the value of timer0 matches the value in the output compare register zero (OCR0) register, output pin is pulled low and when counting sequence begins again from zero, it is reset. Pin PB3 of the atmega 32 was used as the output pin. A snapshot of the controller PCB hardware is shown in Figure 3.10.

3.4 Prototype development and testing

Prototype developed comprised of sensing element based on magnetostrictive amorphous wire sensor, control circuit unit based on atmega 32 microcontroller, control algorithm based on pulse width modulation technique and a solenoid valve as its actuator.

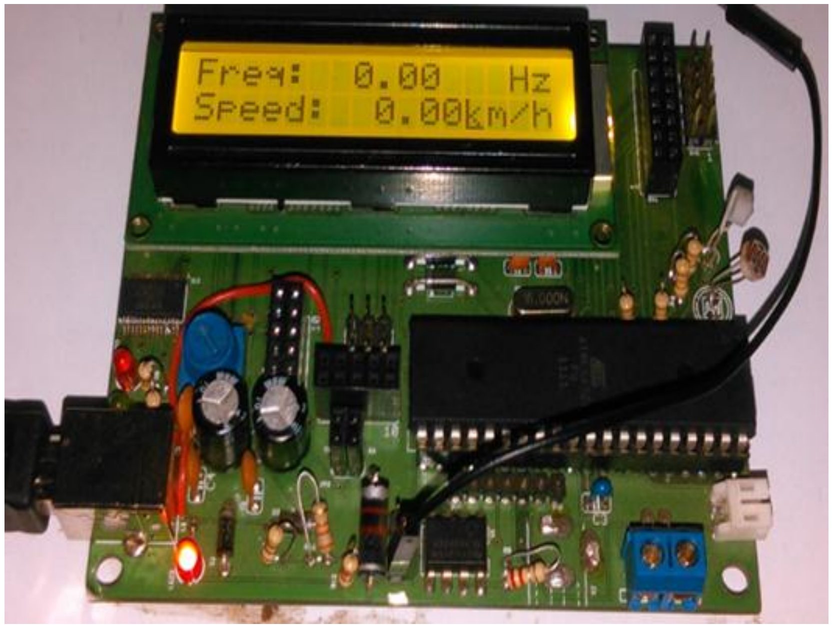

Figure 3.10: A snapshot of the implemented control circuit

3.4.1 Speed sensor

First the use of MAW sensor was carried out in the vehicle as explained earlier and results are shown in Chapter Four. In the laboratory environment, the voltage pulses generated by the MAW sensor were interfaced to the microcontroller. Using the LCD, the frequency of the pulses was observed. Based on the algorithm and calculations explained earlier in the methodology, the speed in km/h was also observed on the LCD as shown in Chapter Four.

3.4.2 Control unit

The functioning of the control unit based on the microcontroller was evidently through its ability to process the voltage pulses thus displaying the frequency in Hz and corresponding speed in km/h. The control unit was the main host for the algorithm developed which also determined the performance and operation of the entire system.

3.4.3 Actuator

The fuel control valve employed was the standard on/off solenoid valve. A solenoid valve is used to open or close flow path using electrical inputs and it works on the principle of electromagnetism. The solenoid valve should be placed right before the fuel injector pump as shown in Figure 3.11.

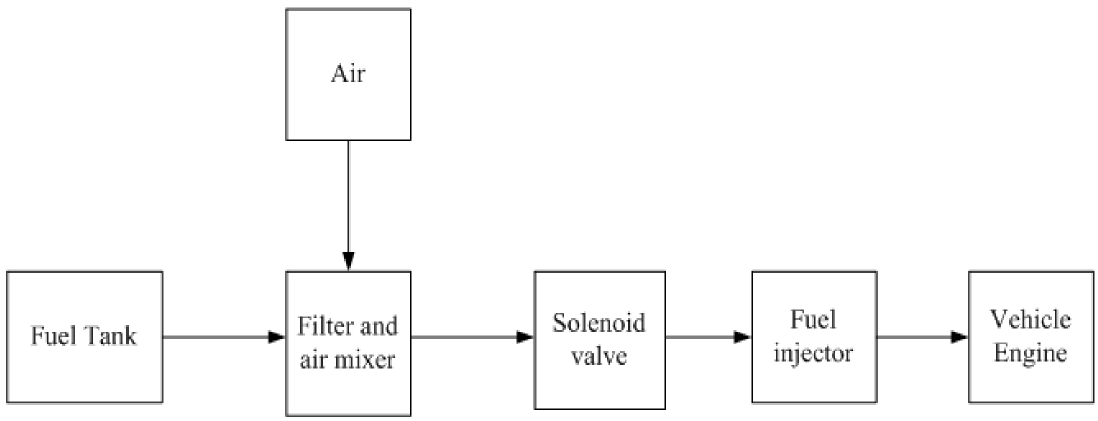

Figure 3.11: Solenoid valve placement

The valve opening was controlled by the signal based on PWM duty cycle. The main objective at this stage was to restrict fuel flow during the speed limiting process. Based on the vehicle speed and duty cycle as per the control algorithm, the terminal voltage at the solenoid valve was measured at different vehicle speed while observing water flow (representing fuel flow in vehicle).

The testing of the electronic vehicle speed governor was carried out in a laboratory environment. As the controller was not operating in a vehicle, the testing and validation of the speed governor was based on the rotational speed of a dc motor. The choice of dc motor was due to linear relationship exhibited by its supply voltage verses output speed.

Thus there was a need to carry out a calibration procedure to relate the rotational speed of the motor to the speedometer readings in km/h. The calibration was based on the frequency readings obtained earlier using MAW speed sensor in the vehicle. E.g. a frequency of 3.15 Hz corresponds to vehicle speed 22.6 km/h. Using DC Motor, voltage at which the motor rotates at 3.15 Hz was calibrated as 22.6 km/h vehicle speed. The testing involved both simulation and experimental procedures.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Overview

The results and analysis have been presented for the vehicle speed governor three key units;

a) Design of vehicle speed sensor based on MAW sensor

b) Design of controller unit

c) Prototype development and testing

4.2 Results for vehicle speed sensor design

The proposed vehicle speed sensing element using magnetostrictive amorphous wire sensor was tested in a vehicle and whose details have been described in Chapter three. Signal conditioning and signal processing circuits testing were tested using prototype developed and results presented I subsequent sections.

4.2.1 Sensing element unit results

The results for the experimental set up using a vehicle rotating shaft, two permanent magnets, amorphous wire sensor, pickup coil and digital oscilloscope to read the frequency were observed in two scenarios to determine if there was any speed variation between the two cases. Case 1, one wheel stationary and the other spinning freely and case 2, both wheels spinning freely. Using the speed measuring principle described in the methodology, the results are as shown in Table 4.1. In both cases, frequency is observed between vehicle speeds of 20 km/h and 80 km/h. The various pulse signals and corresponding frequencies were also obtained for the various vehicle speeds.

Table 4.1: Speedometer speed versus calculated speed

Speedometer reading	Both wheels spinning		One wheel stationary	
km/h	Frequency (Hz)	Calculated speed (km/h)	Frequency (Hz)	Calculated speed (km/h)
20	3.15	22.6	6.45	46.2
30	4.12	30	8.87	63.7
40	5.74	41.2	12.02	86.3
50	7.26	52.1	14.86	106.6
60	8.55	61.4	17.29	124.1
70	10.38	74.5	21.41	153.7
80	11.73	84.2	23.24	166.8

Case 1: One drive wheel rotating freely

Figure 4.1 show the MAW sensor output voltage pulses frequency for various vehicle speed with only one wheel free to rotate. In some cases the pulse amplitude varies based on the strength of the excitation field and not the speed of rotation. The frequency obtained is proportional to the vehicle speed as evident from the graph of speed versus frequency as shown in Figure 4.2.

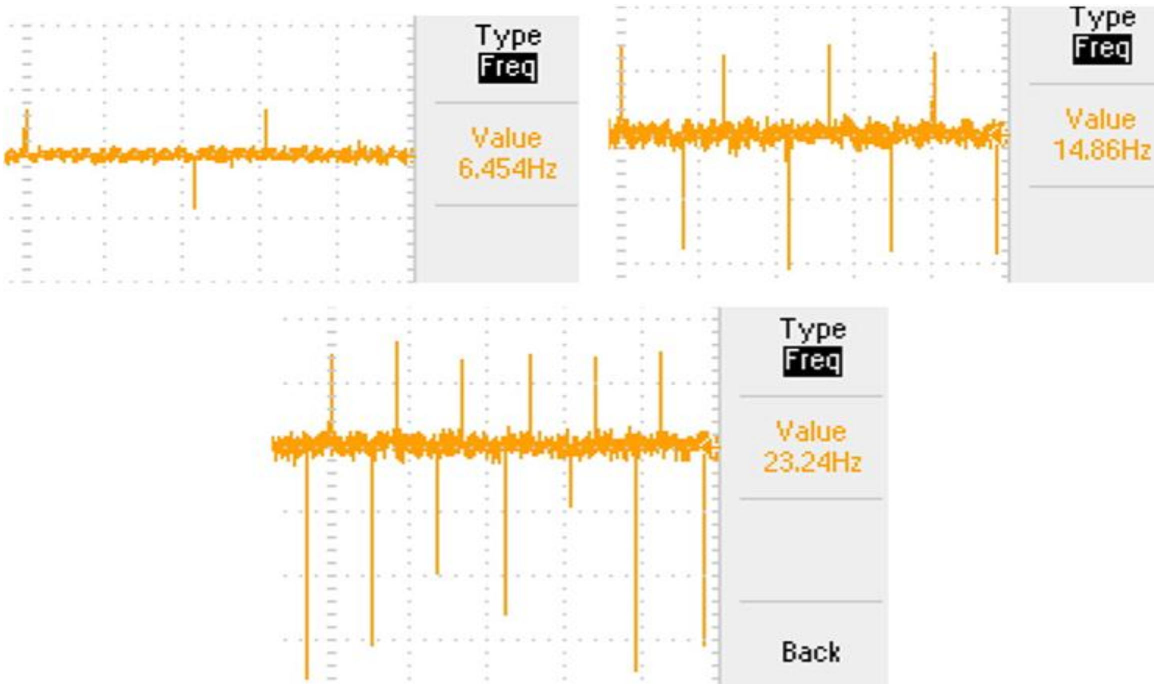

Figure 4.1 Case1: MAW sensor output signal for 20km/h, 50 km/h and 80 km/h

It was also observed that, by holding one wheel stationary, the vehicle speed recorded by the speed sensor based on the calculations is almost twice the vehicle speed indicated by the speedometer. This is attributed to non-locked automotive differential system which transfers all power to the rotating wheel. Hence the difference between actual and calculated speed since speedometer only indicates half the speed at which the wheel rotates.

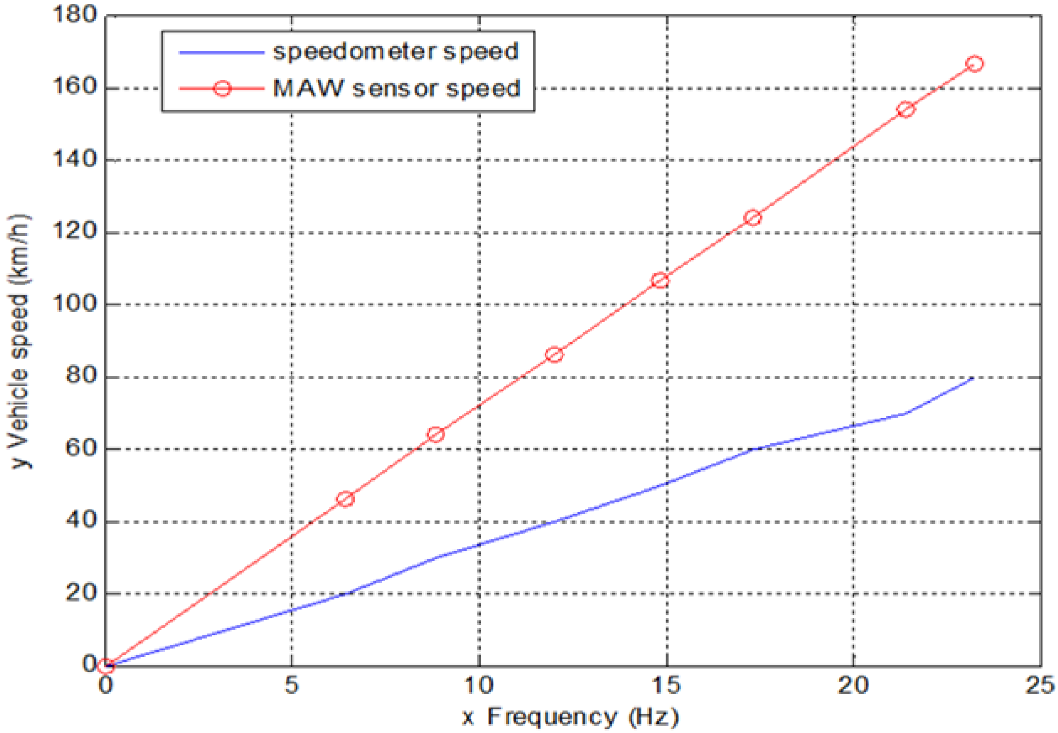

Figure 4.2: A graph of speed versus frequency with one drive wheel held stationary

Case 2: Two drive wheels rotating freely

Figure 4.3 show the MAW sensor output voltage pulses frequency for various vehicle speed with both drive wheels free to rotate. This corresponds to the graph in figure 4.4 that shows the speed calculated using measured frequency compares well with the speedometer speed. The signal obtained using the magnetostrictive amorphous wire sensor is in the form of pulses and it is easier to interface with a microcontroller since it a digital signal.

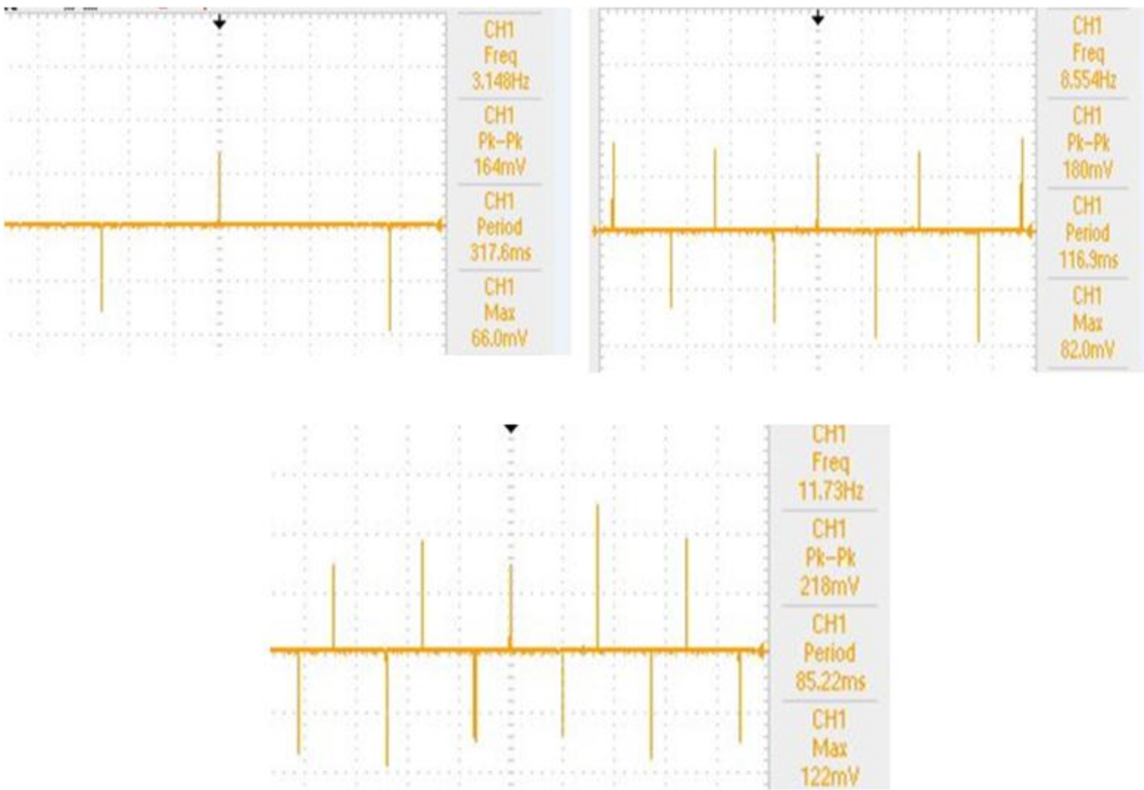

Figure 4.3: Case 2: MAW sensor output signal for 20 km/h, 60 km/h and 80 km/h

The results show that the sensor offers good and reliable signal output whose amplitude is independent of the speed of the vehicle. This reveals the robustness of the sensor based on signal quality and its stability with varying vehicle speed. The frequency obtained is directly proportional to the vehicle speed. Duration between the pulses decreases with vehicle speed. With low speeds, duration between the pulses is big as compared to high speeds when the duration is small due to increase in frequency. A conclusion can be made that Magnetostrictive amorphous wire sensor can be successfully implemented as a vehicle speed sensor which offers advantages such as;

a) They give a digital output that can easily be interfaced with electronic devices.

b) Requires no power to operate.

c) Give relatively high output that requires just a little amplification

d) Not easily affected by other electrical noises.

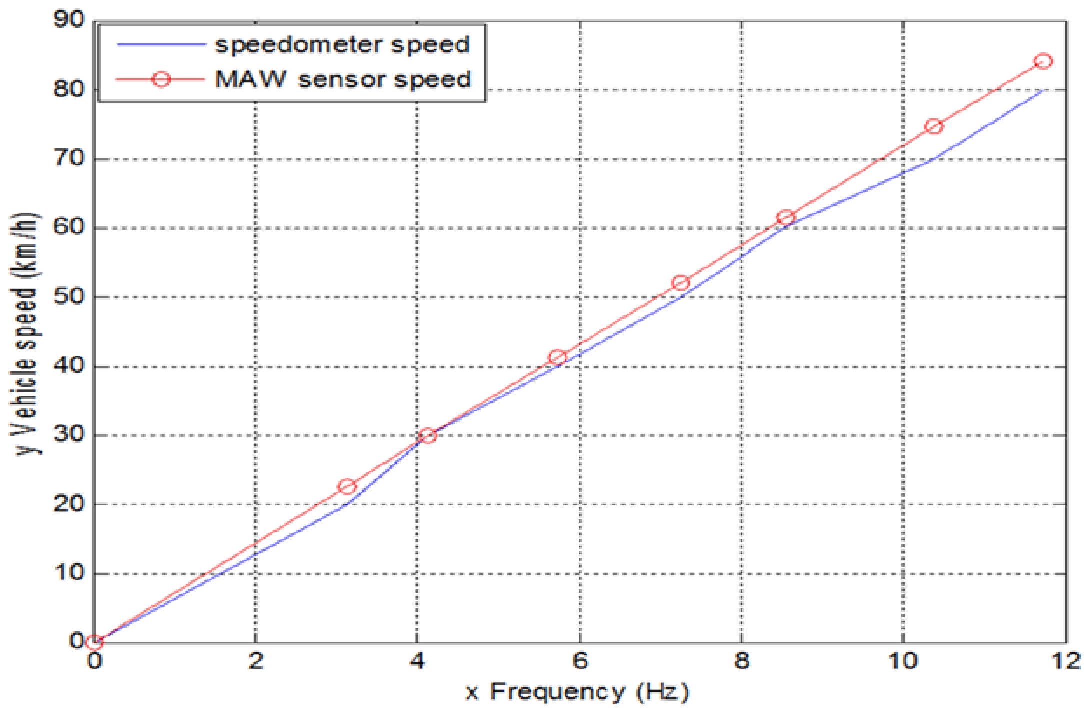

Figure 4.4: A graph of speed versus frequency with both drive wheels rotating freely

Laboratory prototype speed simulation

Since the prototype was being developed in a laboratory environment, it was important to establish a signal which relates well with the vehicle speed signal obtained earlier using the vehicle. As noted earlier, increase in vehicle speed resulted to increase in signal frequency. Consequently, a DC motor was chosen since increase in the supply voltage results to increase in the shaft rotational speed. The signal obtained in laboratory set up using the DC motor is shown in Figure 4.6. By comparing the two signals in Figures 4.5 and 4.6, they are very closely related and possess the same characteristics of the Large

Barkhausen jump. Hence the DC motor was established as more suitable to use in laboratory environment for the implementation of the prototype as compared to using a signal generator.

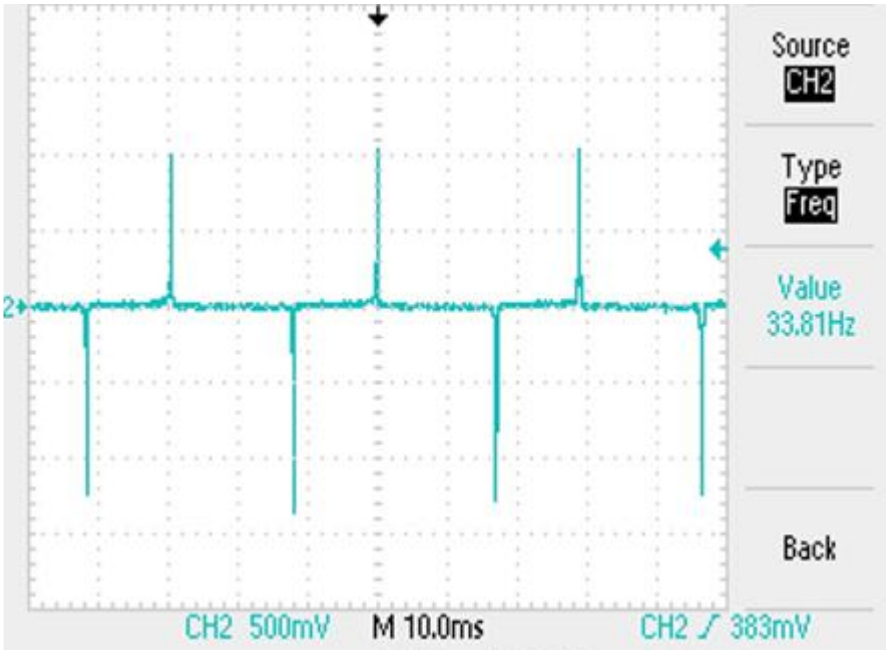

Figure 4.5: Pulse signal obtained using DC motor in the Lab

The results show that the sensor offers good and reliable signal output whose amplitude is independent of the speed of the vehicle. This reveals the robustness of the sensor based on signal quality and its stability with varying vehicle speed.

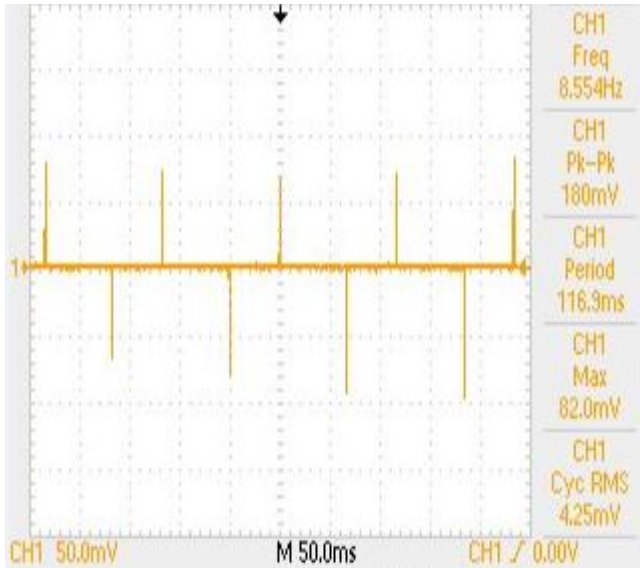

Figure 4.6: Pulse signal obtained from the vehicle rotating shaft using MAW

4.2.2 Signal conditioning circuit results

For validating various sections, Proteus simulation software was chosen for testing various parts of the entire system. Simulation environment offered a convenient way of simulating the design and ensuring signal integrity and electrical connectivity throughout. This also aided in the implementation of the prototype afterwards. This is because it offers the complete set of tools necessary for the design process and also aids in observing how the circuit behaves. Proteus is also a complete simulation platform of embedded software and hardware. It can simulate quite a large number of single-chip microcontroller peripheral circuits. By using Proteus software, it is thus easy to obtain a full-featured easy to use microcontroller laboratory.

(a) Simulation of MAW signal conditioning circuit

The main aim of simulation for this stage was to ensure that the signal from the magnetostrictive amorphous wire is properly collected, processed and successfully interfaced to the microcontroller. Consequently, the simulation circuit shown in Figure 4.7 was designed and carried out. To simulate the sensor's activity, an input signal generator is used, providing peak to peak voltage of 0.2 V sine wave as shown in Figure 4.8. An oscilloscope was used to observe different waveforms at different points of the circuit. The first waveform to check is the amplification of the input signal which is at the range of millivolts to higher voltage levels. This signal is amplified through an inverting amplifier of a gain of 47 as described in the methodology. Using the two inverting operational amplifiers, the signal waveform is observed after the second inverting operational amplifier and comparison between the two signals done. The second stage regulates the amplified signal voltage to digital logic levels. The signal waveform is observed before and after feeding to not gate.

(b) Analysis of signal processing simulation results

Signal processing simulation using Proteus and the circuit shown in Figure 4.8 generated the results presented in the oscilloscope as shown in Figure 4.8. The simulation results show an input signal before amplification stage and the amplified signal as it can be seen on the oscilloscope. A sine wave input signal waveform of 200mV peak -to-peak is shown as the yellow waveform of Figure 4.8. This signal is amplified through an inverting amplifier of a gain of 47 and then inverted back using a second inverting amplifier of unity gain.

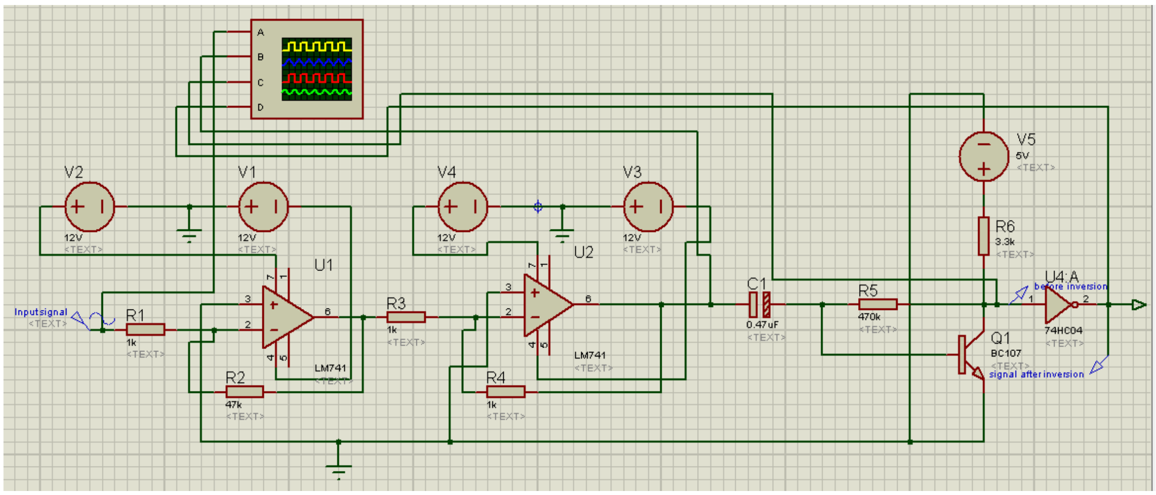

Figure 4.7: Sensor signal processing simulation circuit

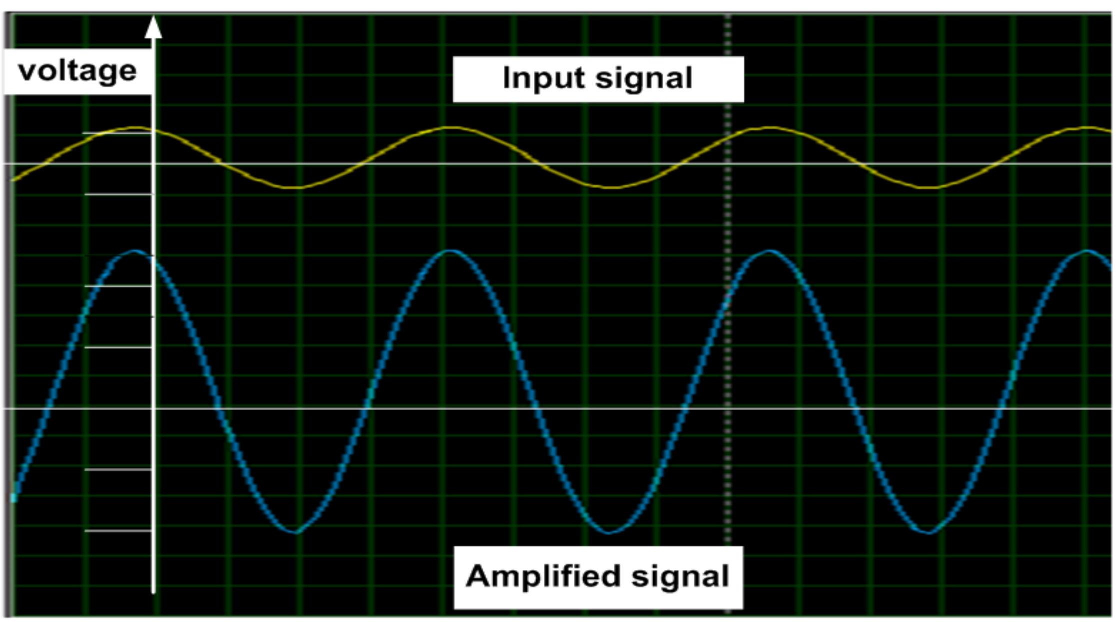

Figure 4.8: Input and amplified signal

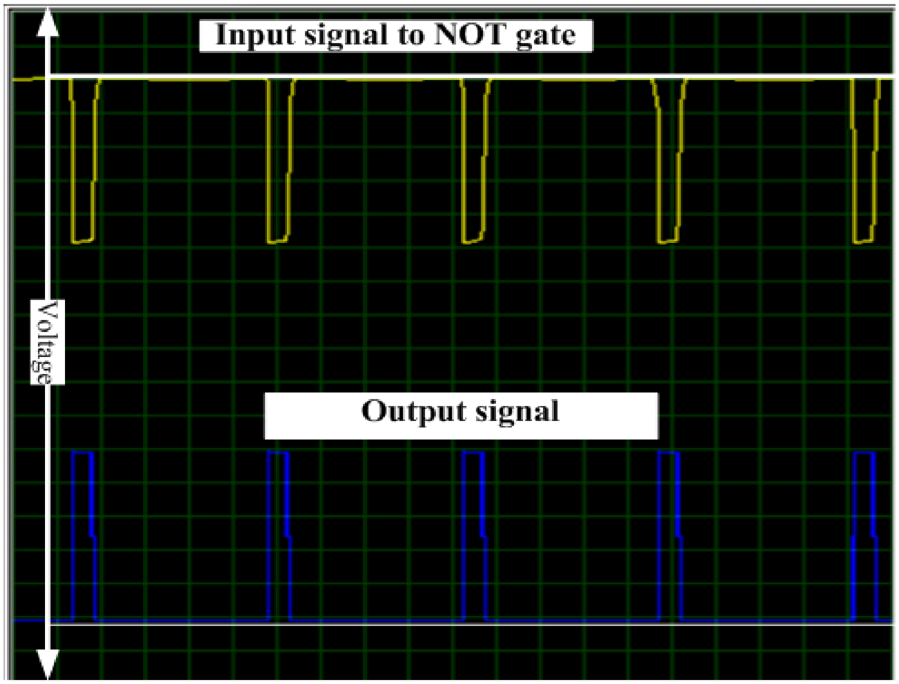

Figure 4.9: Digital logic signal before and after inversion

The amplified signal is shown in Figure 4.9 as the blue waveform of 9.4 V peak-to-peak. Hence the input signal has been amplified with a gain of 47, obtaining a signal which is strong enough to drive a transistor. The amplified signal is passed through a Bipolar Junction Transistor (BJT) and an inverter to regulate the amplified signal to 5 V.

The signal observed after the transistor circuit is shown in Figure 4.9. This indicates that using the transistor circuit inverts the signal waveform and an inverter is necessary to restore the signal to its initial form. This results to the blue waveform on the oscilloscope. It can be seen that the inverter does not affect the signal voltage. The signal obtained is thus suitable as an input signal to the microcontroller. With the validation of the circuit through the simulation results, the circuit was implemented as per the simulation circuit design.

(c) Signal conditioning experimental results

The raw signal obtained from MAW sensor is shown in Figure 4.10 together with the amplified signal. The raw signal has a peak to peak voltage of 200 mV and the amplified signal has an amplified voltage of 9.4 V

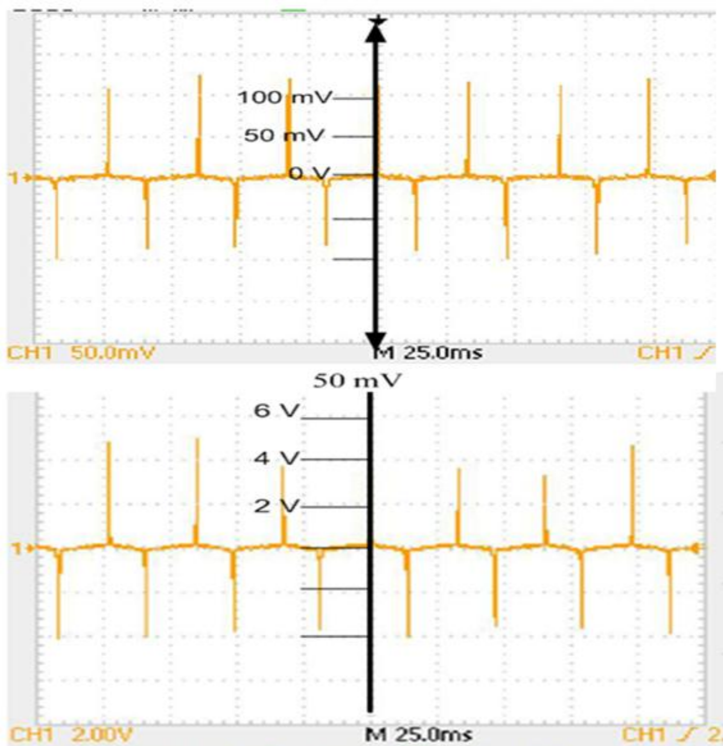

Figure 4.10: MAW sensor output and amplified signal

The regulated signal interfaced with the microcontroller is shown in Figure 4.11 with a voltage of 4.2 V. This is the signal fed to microcontroller for processing of signal frequency.

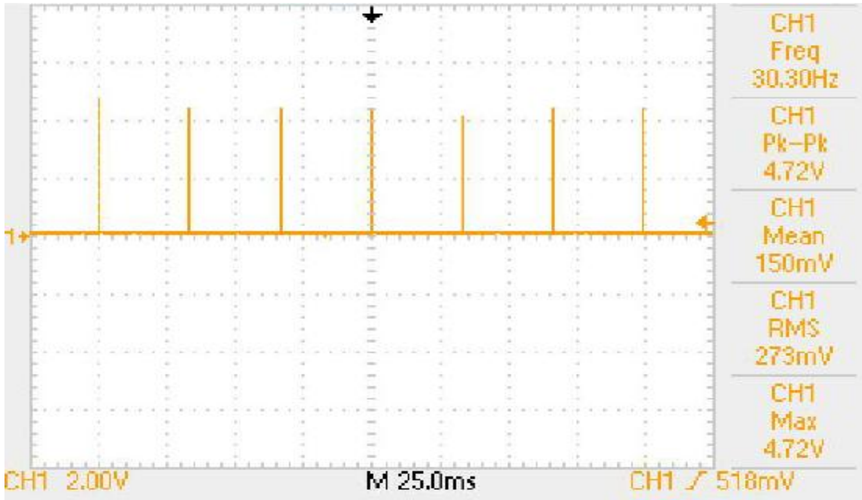

Figure 4.11: Signal fed to microcontroller for frequency processing

4.2.3 Signal processing results

The output of signal processing is display of the pulse frequency in HZ as shown in Figure 4.12.

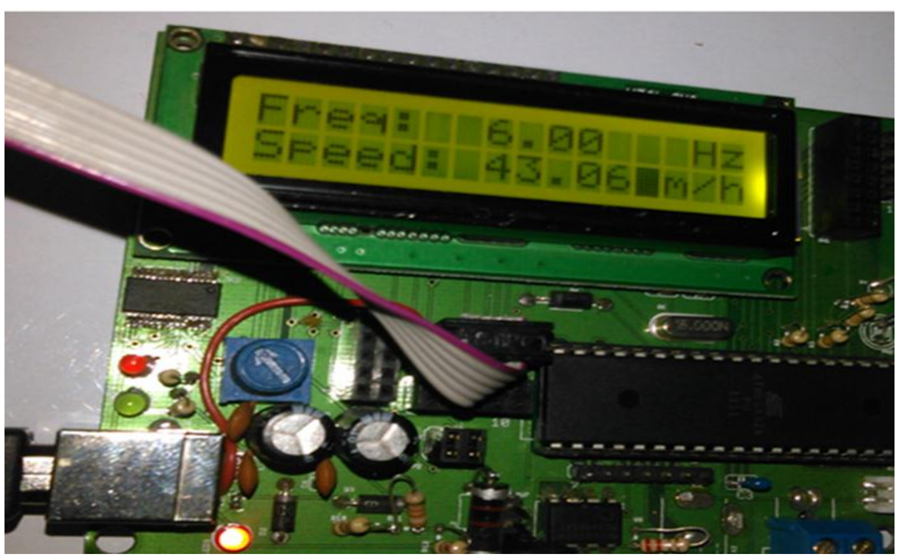

Figure 4.12: Frequency display in HZ

4.3 Design of controller unit results

The processed signal was interfaced with the controller. The main aim at this stage was to properly collect the vehicle speed signal frequency as measured by the magnetostrictive amorphous wire. Since the sensor offers pulse signal, this made it easier to interface with the microcontroller. Using an algorithm developed in AVR studio. The frequency of the voltage pulses from the speed sensor is displayed on the LCD in Hertz. Using the pulse frequency as the input, the microcontroller calculates the vehicle speed in km/h as displayed on the LCD in Figure 4.12 and a full PCB implementation in Figure 4.13. Both frequency and vehicle speed were displayed for experimental purposes but for commercial use, only vehicle speed would be necessary for display.

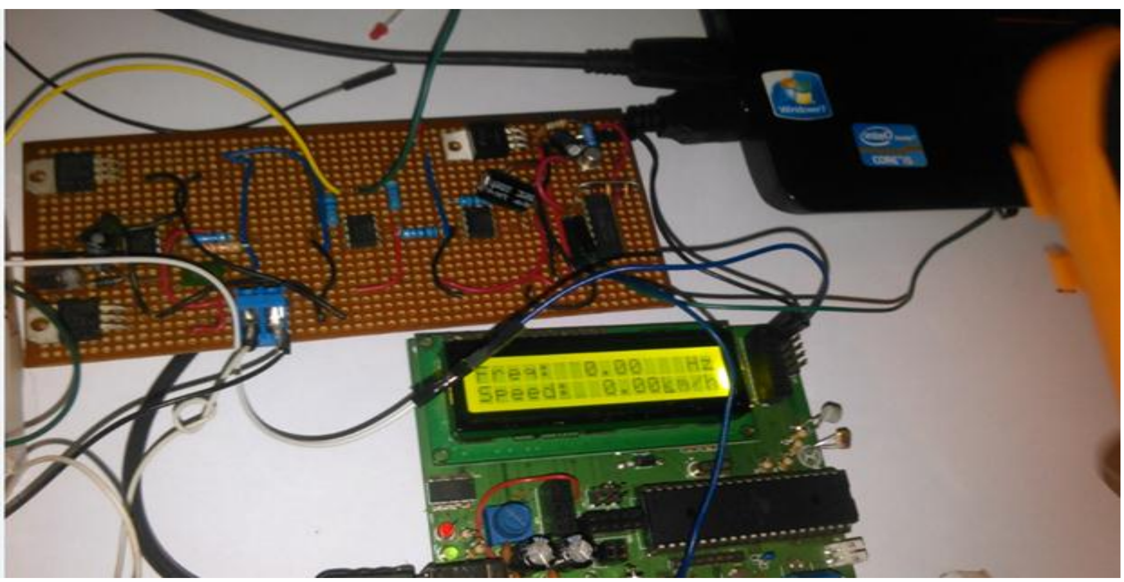

Figure 4.13: Prototype implementation

The speed displayed is calculated based on Equation 4.1. E.g. for a frequency of 6 Hz and rim diameter of 0.6345 m the vehicle speed is calculated as 43.06 Km/h

$$V = \pi D f \times 3.6 \qquad (4.1)$$

Circuit simulation

The controller circuit design system simulation was done on Proteus Professional software and coding of the system done in embedded C language. Using atmega 32 microcontroller, the LCD display was connected to PORT C. The simulation of the circuit is shown in Figure 4.14.

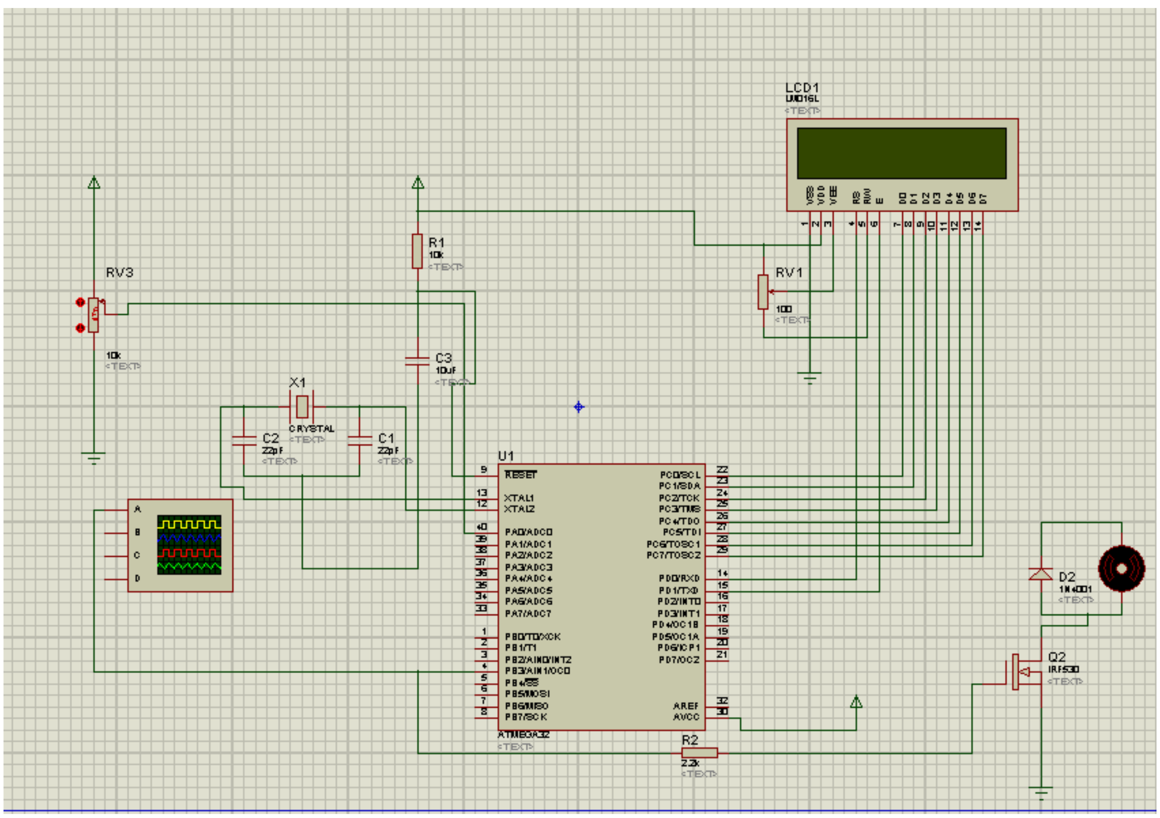

Figure 4.14: Circuit simulation using Proteus software

Based on the signal obtained from the magnetostrictive amorphous wire sensor described earlier, the vehicle speed is calculated and displayed on the LCD. The speed of the vehicle is controlled by using PWM technique. This is achieved by varying the duty cycle based on the vehicle speed as presented in section 3.6.

4.3.1 Algorithm results

To achieve gradual vehicle speed limiting process, the PWM technique adopted in Chapter Three was tested and simulation results are shown in Figure 4.15.

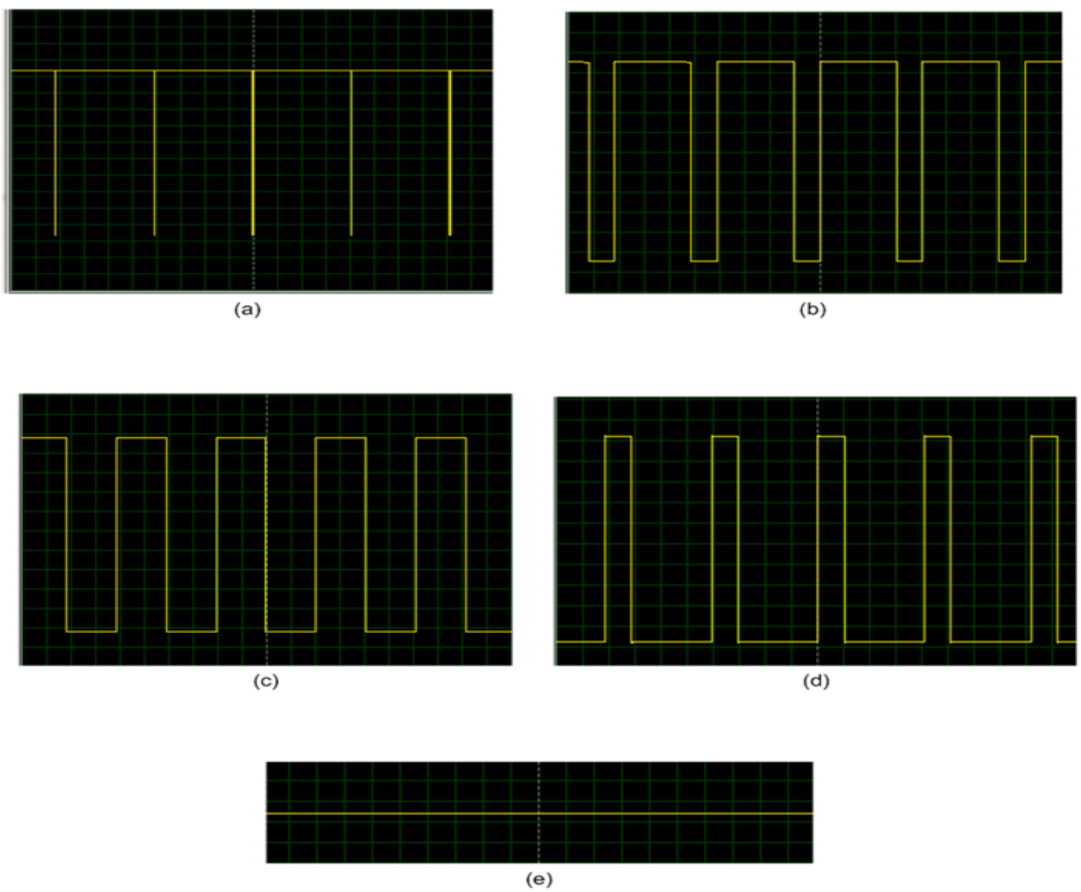

Figure 4.15: Duty cycle simulation results between 100% and 0%

4.3.2 Experimental results

Using the prototype developed, the pulse width modulated signal sent to the solenoid valve at various vehicle speeds were captured using a digital oscilloscope and results are shown in Figure 4.16.

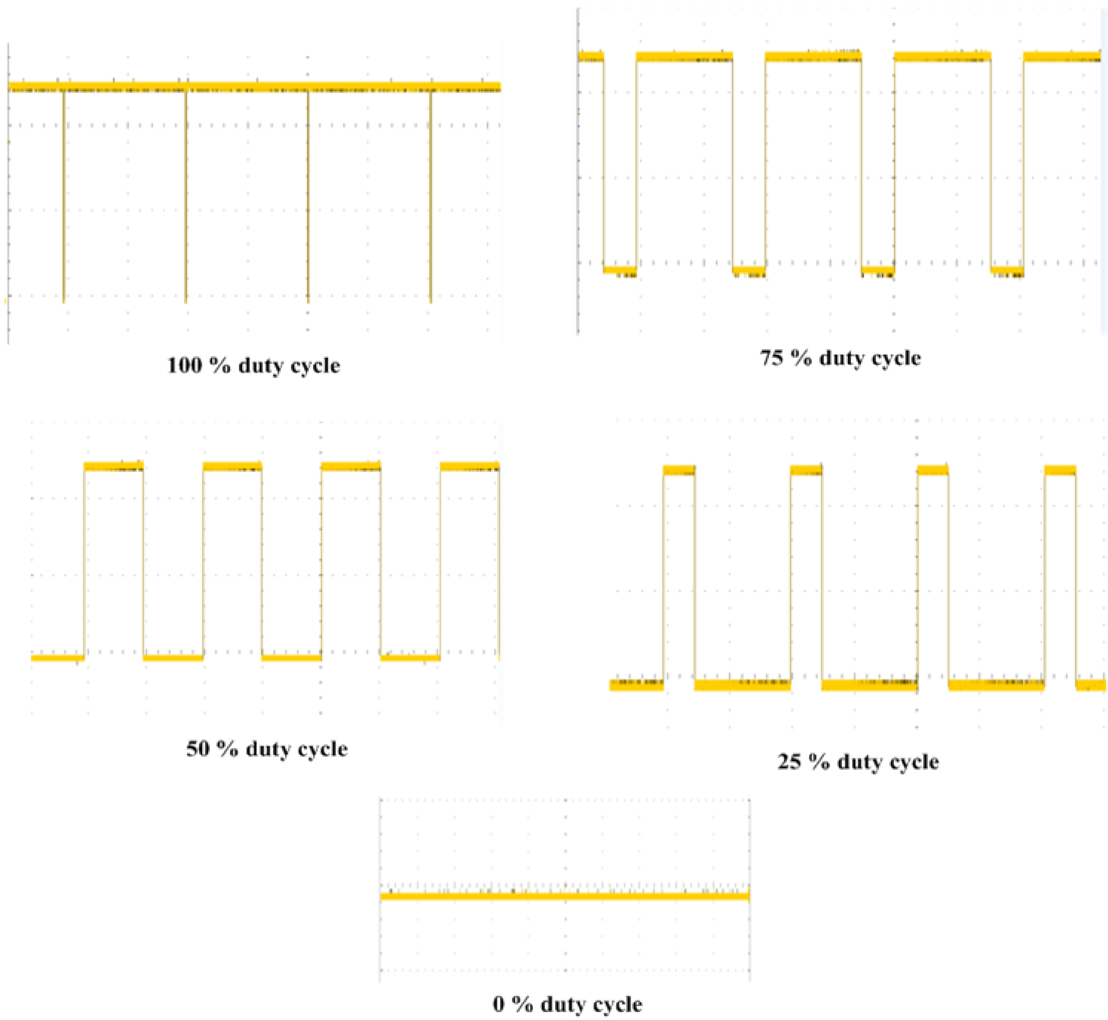

Figure 4.16: Duty cycle experimental results

With 100% duty cycle, there is no fuel restriction and the vehicle can freely accelerate. As the vehicle speed reaches within $\pm 5\%$ of the desired speed limit, the PWM technique is then applied leading to reduction in duty cycle thus gradually reducing the valve's terminal voltage and hence fuel flow.

4.4 Prototype development and testing results

The prototype developed is shown in Figure 4.17

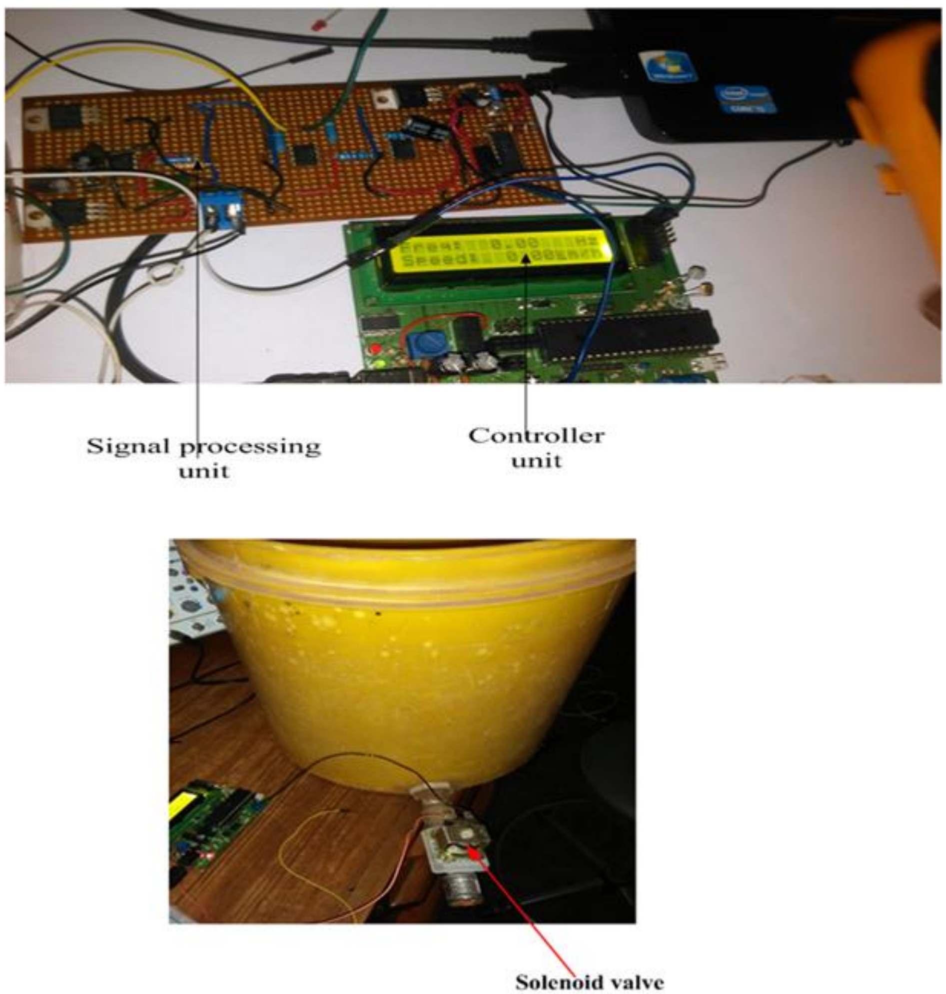

Figure 4.17: Electronic vehicle speed governor prototype

Various sections which include speed sensor, signal conditioning, signal processing, and controller results have been presented. The controller signal is thus sent to a solenoid valve for fuel regulation to the engine.

Actuator results

A solenoid valve operating at 12 V was used as actuator. With the signal fed from the microcontroller, various terminal voltages were observed. The expected voltage was calculated based on solenoid valve maximum operating voltage as shown in Equation 4.2

$$V = x \times 12 \qquad \textbf{(4.2)}$$

Where x is the duty cycle per given vehicle speed and 12 is solenoid valve operating voltage. From Table 4.2, it was observed that the pulse width modulation duty cycle and the valve terminal voltage are proportional to each other. Gradual Change in the PWM duty cycle as shown in figure 4.16 resulted to change in valves terminal average voltage and hence change in fuel flow to the vehicle's engine resulting to change in vehicle's speed.

Table 4.2: Solenoid valve terminal voltages at various duty cycles

Vehicle speed km/h	Duty cycle	Expected voltage	Measured voltage
75	100%	12 V	11.6 V
78	75%	9 V	8.8 V
80	50%	6 V	6.5 V
82	25%	3 V	3 V
86	0%	0 V	0.6 V

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This work mainly focused on an electronic based vehicle speed governor. Microcontroller based vehicle speed governor using magnetostrictive amorphous wire sensor was successfully designed and tested. This includes its key units namely; speed sensor, controller circuit unit and solenoid valve actuator.

Speed measurement based on magnetostrictive amorphous wire was successfully designed and implemented. The results obtained show that magnetostrictive amorphous wire is a potential vehicle speed sensor and could be applied in the automotive industry for speed sensor development. Based on the results obtained, deployment of the wire in vehicle speed measurement presents its unique features and simple components to developing a vehicle speed sensor. The MAW sensor output was utilized for electronic vehicle speed governor development, thus the need for signal processing to obtain a quality signal for digital processing. Design and development of the signal processing circuitry was successful, hence presenting a signal suitable for interfacing with a digital controller.

The development of electronic vehicle speed controller was based on design and implementation of the controller hardware. This comprised of atmega 32 microcontroller and its development board hosting the supporting circuitry. The use of the microcontroller provided a good environment for the speed processing, display and algorithm development.

The algorithm developed based on PWM provided unique control aspect for the speed governor. Use of PWM control has been widely adopted in many fields especially in motor speed control and based on this research, its application in vehicle speed limiting goes a long way in improving the performance of electronic vehicle speed governors. A digital controller such as the microcontrollers offers flexibility in developing various control aspects in automobile applications. Thus, the integration of the MAW speed sensor and the PWM based algorithm in electronic vehicle speed governor offers suitable measurement and control improvement features.

5.2 Recommendation

Further work can be carried out on the encasing of the magnetostrictive amorphous wire speed sensor components to make it a single unit and eliminate some of the challenges encountered while taking measurements. The speed measurement process involved in this research is for digital speed display. Further modification can be done on the signal processing for analogue vehicle speed display.

Various features can be adopted in improvement of electronic vehicle speed governors based on the algorithm development. Most of vehicle based controller testing such as the vehicle speed governors requires tools that emulate the external application environment. Such tools allow different design iterations to be carried out and modifications can be done before the final product is made. The only drawback is that such tools are expensive.

Further work can be carried out using such tools as hardware in the loop for testing the performance of the developed electronic vehicle speed governor.

Further modification may be done on signal processing for digital speed display with a scale and pointer. The speed controller algorithm developed for the speed governor was based on Pulse width modulation technique, other control techniques such as fuzzy logic may also be adopted based on control objectives.

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APPENDICES

APPENDIX 1: List of Journal Publications & Conference papers

1. M. N. Kiio, J. N. Nderu and S. I. Kamau: **Automobile Speed Measurement System based on Microcontroller and Magnetostrictive Amorphous Wire Sensor**, European International Journal of Science and Technology, Vol 3 No 8. Pp 21-28, October 2014. ISSN 204-9693.

2. M. N. Kiio, J. N. Nderu and S. I. Kamau: **Vehicle Speed Measurement System based on Microcontroller and Magnetostrictive Amorphous Wire Sensor,** Proceedings of KSEEE- JSAEM international engineering conference. pp. 23-26, Sept 2014.

3. M. N. Kiio, J. N. Nderu , S. I. Kamau and A. M. Muhia: **Motor Vehicle Speed Measurement using Magnetostrictive Amorphous wire sensor,** Proceedings of KSEEE- JSAEM international engineering conference. pp. 14-17, Sept 2013.